CDOIF

Chemical and Downstream Oil Industries Forum

Supplement to Guideline – ‘Environmental Risk Tolerability for COMAH Establishments’

Complex Site Example

Whilst the CA cannot comment on the accuracy of any site specific data or assumptions, the worked example provided does demonstrate an appropriate interpretation and application of the CDOIF guidance, with a sufficient level of detail to allow the screening process to be complete

Complex Site Case Study

Glossary of Terms used in Case Study

APIS – Air Pollution Information System
BLEVE – Boiling Liquid Expanding Vapour Explosion
CDOIF – Chemical and Downstream Oil Industries Forum
COMAH – Control of Major Accident Hazards
DEM – Digital Elevation Model
EHI - Environmental Harm Index
EA – Environment Agency
EI – Energy Institute
GIS – Geographical Information System
HAZID – Hazard Identification (Study)
HAZOP – Hazard and Operability (Study)
IES - Institute for Environment and Sustainability
LOPA – Layers of Protection Analysis
MAS – Major Accident Scenario
MATTE – Major Accident to the Environment
NRW – Natural Resources Wales
SAC – Special Area of Conservation
SEPA – Scottish Environmental Protection Agency
SIL – Safety Integrity Level
SSSI – Site of Special Scientific Interest
TifALARP – Tolerable if As Low As Reasonably Practicable

Overview of Approach

It is considered appropriate to review how the current CDOIF guidance might be applied to a complex site where there are multiple sources, pathways and receptors which have the potential to combine to enable the generation of a MATTE. Whilst the CDOIF guidance has been used as the basis for the assessment there are some important deviations from the approach which are necessary to make sure that the assessment remains focussed and presents a meaningful and thorough yet concise output in the context of a complex site.

This worked example follows the CDOIF guidance in terms of the degree of assessment required to demonstrate adequate risk controls are in place. Not all major accident scenarios will be assessed to the same extent, rather they are progressed until the frequency associated with the hazard has been reduced to an acceptable level (or to a point that is not a significant contributor to the overall Establishment risk).

The recommended approach of identifying all of the potential pollutant linkages for a complex site which has multiple potential receptors can lead to a lengthy table of results which ultimately provides only limited value in completing either a qualitative or quantitative assessment of risk to the environment. Instead, the CDOIF approach may be worked in reverse by identifying the most significant receptors (based on proximity, magnitude of impact, sensitivity, etc) and then working through the sources to identify which events could plausibly result in an impact at those locations. For example, where there are multiple designations and only subtle differences in the proximity of the sites then the most onerous receptor in terms of impact area/length thresholds should be selected. Consideration of groundwater is a critical element and it may require expertise to assess whether that particular feature should be considered as a receptor within the confines of the site, beyond the site boundary or whether the groundwater simply constitutes a pathway to convey contamination to a different receptor.

The end point of this first stage is therefore to identify receptors (but without looking in detail at the rationale for designation, etc) and associated sources. This results in a manageable set of potential pollutant linkages for assessment.

The sources can then be characterised through review of the available process safety data to identify those major accident scenarios (MAS) which may have already have been documented as having the potential to result in a source of contamination capable of generating a MATTE. This list of sources should then be critically reviewed to remove those unlikely to have a MATTE potential and supplemented by additional scenarios which may not have been considered as part of previous safety assessment work (e.g. tank floor failures).

For each asset there may be a range of plausible sources to the same receptor. To simplify the subsequent calculation steps each asset is assigned to its own compartment. Splitting each part of the site in this way will enable the process of assigning risks to be made transparent and can be effectively managed in a combined spreadsheet and geographic information system (GIS).

Having identified a potential set of sources and receptors the next stage is to identify what types of pathways might join the two – whether that be (for example) via overland flow routes, subsurface migration or via emissions to the atmosphere. Some pathways may be dismissed relatively quickly by completing a high level review of the significance of a release whilst others will inevitably require more detailed assessment of initiating frequencies for the release and assessment of the effectiveness of the barriers separating the source from the receptor.

The pathway assessment for a complex site may therefore be completed in three stages;

1. High level assessment to evaluate whether the link from the source to receptor via the defined pathways could result in a plausible MATTE (e.g. fire associated with a tank producing combustion products and its effect on a SSSI receptor via the air pathway).
2. Unmitigated risks taking into account the initiating frequency (i.e. is this already so low that the impact at the receptor is unlikely to be significant) and existing control measures which would limit the potential for a release from primary containment (e.g. Layers of Protection Analysis (LOPA) for bulk storage tanks).
3. Mitigated risk assessment considering the likely effectiveness of measures which would limit the potential for the source to reach the receptor (e.g. secondary/tertiary containment, emergency response plans, in-ground migration and effectiveness of pathway interruption measures, etc).

At the end of this stage the assessment is nearly complete since we have defined the sources and receptors, considered initiating frequencies, built in the engineering controls and considered the measures in place which could limit the chance of a significant quantity of contamination reaching the receptor. The potential level of risk can be viewed on an asset by asset basis (i.e. compartments), for each MAS and which may then be combined for each receptor.

The last stage is to assess the significance of the potential impact. This is left until last as the assessment process itself may assist in understanding how large of an area could be affected following a release. It is also possible to consider a conservative impact level at the unmitigated stage and a different (likely lower) level of impact following a more detailed review. The potential significance and the acceptability criteria to be used in the summation of the establishment risk follows the guidance outlined by CDOIF. The process is relatively straight forward based on the actual receptor(s) identified. This process results in the tolerability criteria being defined for the establishment and from there the results of the summed risks for the Establishment can be compared to this criteria. One potential area which should be addressed is where a site covers multiple hydraulic or surface flow catchments which may have different receptors.

In order to assist in demonstrating the approach an example process is outlined below for assessing the MATTE risk at a refinery site in South Wales.

Introduction

The case study which follows is based on the need to develop an assessment of the potential environmental risk posed by plausible major accident scenarios at a refinery, building on the existing process safety assessment and is focussed on completing an assessment of MATTE risks under the COMAH regulations taking into account current guidance from CDOIF.

For context the site is located approximately 3km from the coast and is surrounded by numerous small streams which eventually discharge into an ecologically sensitive, and statutorily designated, site (*these are therefore considered as the potential receptors and each was assigned the highest level receptor type based on the ultimate receiving water body which is designated as a SAC*). The geology at the site is a mixture of mudstones, siltstones and sandstones which are folded and dip steeply towards the north and south indicating the presence of a syncline through the northern part of the site. The shallowest bedrock unit is typically mudstone which is overlain by a veneer of made ground comprising gravelly clay. Groundwater beneath the site is classified as being within a Secondary A aquifer with the predominant flow being via fractures and fissures. A groundwater high is located in the north of the site and groundwater flow is generally radial from this point resulting in a range of different receptors for site derived contamination within 5 principal catchments across the main site and a further one at the jetty to the south. **Figure 1** provides background to the site setting.

Figure 1 – Environmental Setting

Receptor Review

The first part of the process is to identify whether there is/are source-pathway-receptor pollutant linkages at the site. This was undertaken in a conservative manner and at a high level. For instance, there are numerous small streams located around the periphery of the site which drain in to a SAC/SSSI (which have marginally different extents). The site is also underlain by groundwater in a Secondary A aquifer and is surrounded, to a large extent, by farmland. A qualitative appraisal of these receptors indicated that the SAC was likely to be the most sensitive and as such was used as the basis for determining the potential for a MATTE to exist based on the potential aerial extent of impact. At this stage no consideration was taken of the length of adjoining water courses (which might remove them from being MATTE receptors) rather it was assumed these formed an integral part of the SAC and they acted as a pathway which itself was not considered to have any mitigation potential at this stage.

Specific details regarding the SAC/SSSI designations are as follows;

- SSSI – The designation is based on a combination of geology and ecology depending on location. Various estimates of the area are provided depending on source information although the formal citation estimates the area to be approximately – 2,190 hectares.

- SAC – The SAC covers a very large area. Review of various designations for the SAC indicate that the key Estuary Habitat covers a similar extent to the SSSI (albeit it includes the full area of the water body. In addition the intertidal mudflats and to some extent the Atlantic salt meadows also cover a similar area as the SSSI. This specific component of the overall SAC was considered as the sensitive receptor when working out potential areas of contamination.

Overall the SAC/SSSI designation aspect is relatively complex so a conservative approach was adopted and simply assumed that the SAC was the most sensitive potential receptor. Further information on these and other receptors are provided in the full submission and in other relevant environmental reports for the site.

A set of CDOIF tables which outlines the process for receptor selection is provided later in the case study – once the plausible sources for each MAS have been identified.

Groundwater is a more challenging receptor class for the site given the aquifer designation. It was, however, discounted as being a receptor in its own right for several reasons relating primarily to existing groundwater quality, extent of site ownership, the low likelihood of it being exploited in the future, etc. Instead groundwater was considered as a potential pathway with the various surface water features located around the periphery of the site being considered the primary receptor and which were classified based on their links to the designated site located to the south of the site. Groundwater outside the site boundary was considered a potential receptor but of lower sensitivity than the surface water receptors (i.e. if there was a MATTE potential for groundwater there would also be a potential for a MATTE relating to the surface waters and adjoining SAC).

If groundwater was considered to be a receptor then it would be classified as severity level 2 as Level 3 would require >1km^2 to be contaminated. Given the nature of flow in the bedrock the actual breadth of contamination is likely to be limited and therefore plumes in excess of 2-3km would be required to exceed this lower level threshold. In addition, the submitted report contains a wide range of reasons why groundwater on-site should not be considered a receptor in its own right (acknowledging that there is a wide range of regulation in place to capture contamination of groundwater on site were it to occur). Notwithstanding this it is acknowledged that this receptor could be at risk and may be affected by different MAS pathways and have different mitigation and this should be considered carefully for sites where groundwater may be a significant receptor. Groundwater pathways to the same receptors which may be affected by overland transport of contamination following a release have been assessed and mitigation measures applied separately based on the pathway analysis. For example, penetration into the ground and migration as a dissolved phase plume towards surface water carries with it the potential to mitigate the level of impact and this would clearly not be applicable for overland routes. Similarly the affect of secondary and tertiary containment is nullified if the contaminants could penetrate into the ground and migrate within groundwater. These are all aspects which will be covered in more detail as part of the Stage 3 assessment as needs dictate.

For this complex site the consideration of receptors was stopped at this stage without the need to consider in more detail the specific rationales for designation, species at risk, etc. A conservative view was taken in terms of the magnitude of potential impact which would subsequently be reviewed once information on the MAS and subsequent environmental risk assessment had been undertaken. For this refinery site it was assumed that the majority of the MAS had the potential to impact between 25 to 50% of the area, designated population or associated linear features (Major/Severity Level 3 in the CDOIF classification scheme). The purpose of the tolerability review is to ensure that appropriate tolerability thresholds are used to screen the site risks against. If this is done conservatively there should be no need to consider each potential receptor in more detail than necessary.

Regarding the SAC/SSSI receptors; in this case study professional judgement was used to select the worst case combination of severity and duration which resulted in the SAC being selected from which to assess the relevant severity and duration criteria.. It will be necessary to look at receptors again, in more detail, if there is an intolerable risk and/or if certain mitigations would only work for one receptor and not another. In this case study the mitigation measures applied are applicable to both.

The next step for this case study was then to produce an assessment of environmental risk taking into account the information contained within the existing Process Safety Report to satisfy applicable environmental aspects of the COMAH regulations.

It should be noted that the CDOIF guidance advocates completing the first stage assessment work in a qualitative manner comprising two steps;

1. to establish first whether there is a pollutant linkage and if there is, using information on volumes of product stored etc, determine the potential degree of impact that a site might have on the identified receptors; and
2. identify the relevant scenarios and associated initiating frequencies and sum these for the Establishment.

The result at Step 2 is then compared against the tolerable thresholds determined from Step 1. Exceedance of acceptability criteria after Stage 1 may require more detailed assessment at Stage 2.

For a complex site this simple breakdown of steps requires some supplementary steps to produce a meaningful output which is transparent and can be reviewed appropriately by the Competent Authority. Given the likely large range of scenarios and number of assets present a methodical approach is required. From experience on working on a range of complex sites completing an ‘unmitigated’ assessment in a qualitative manner is likely to result in an intolerable risk being generated. Whilst Stage 2 of the process outlined by CDOIF incorporates quantitative risk assessment measures there is a wide range of non-quantitative, relatively simple aspects which can be factored in at Step 2 of the Stage 1 process. The following sections of this example outline how the refinery site was broken down into compartments and how the unmitigated and mitigated risks were evaluated at a level commensurate with that outlined as Stage 1, step 2 above.

In the case study, the site was split into 49 main compartments which were then divided into 117 sub-compartments for detailed review and assessment.

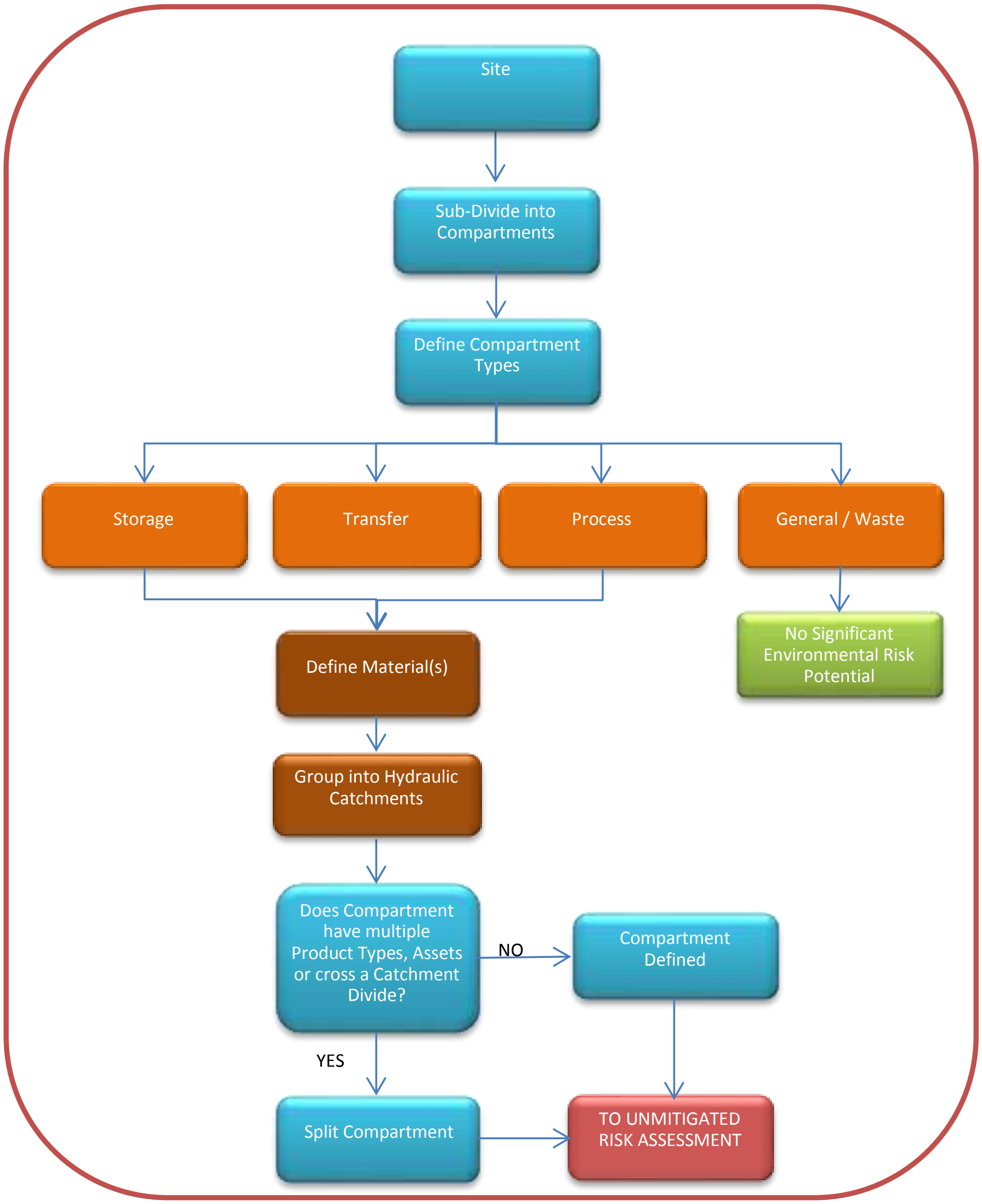
Site Compartments

When dealing with a large site and where there is unlikely to be a ‘simple’ solution by means of a screening process for individual assets, it is necessary to begin by splitting the site into smaller, more manageable pieces. There are many approaches which could be taken depending on site size and complexity. For sites which are both large and complex, compartmentalisation is an approach which provides a high level of flexibility when integrating process safety data and assessing/presenting the overall level of risk. Compartments would typically be defined on the basis of the asset type and location on site. Tanks, pipelines and processing areas would typically be assigned to their own compartment to allow generation of individual risk levels for each piece of plant. These compartments could be further split to differentiate, for example, those tanks which share a common form of secondary containment or where a particular process plant is formed of a number of interconnecting sub-units. Compartments would then also be split based on the environmental setting of the site – particularly where releases via the subsurface pathway or overland could impact upon different environmental receptors as a result of differences in flow direction.

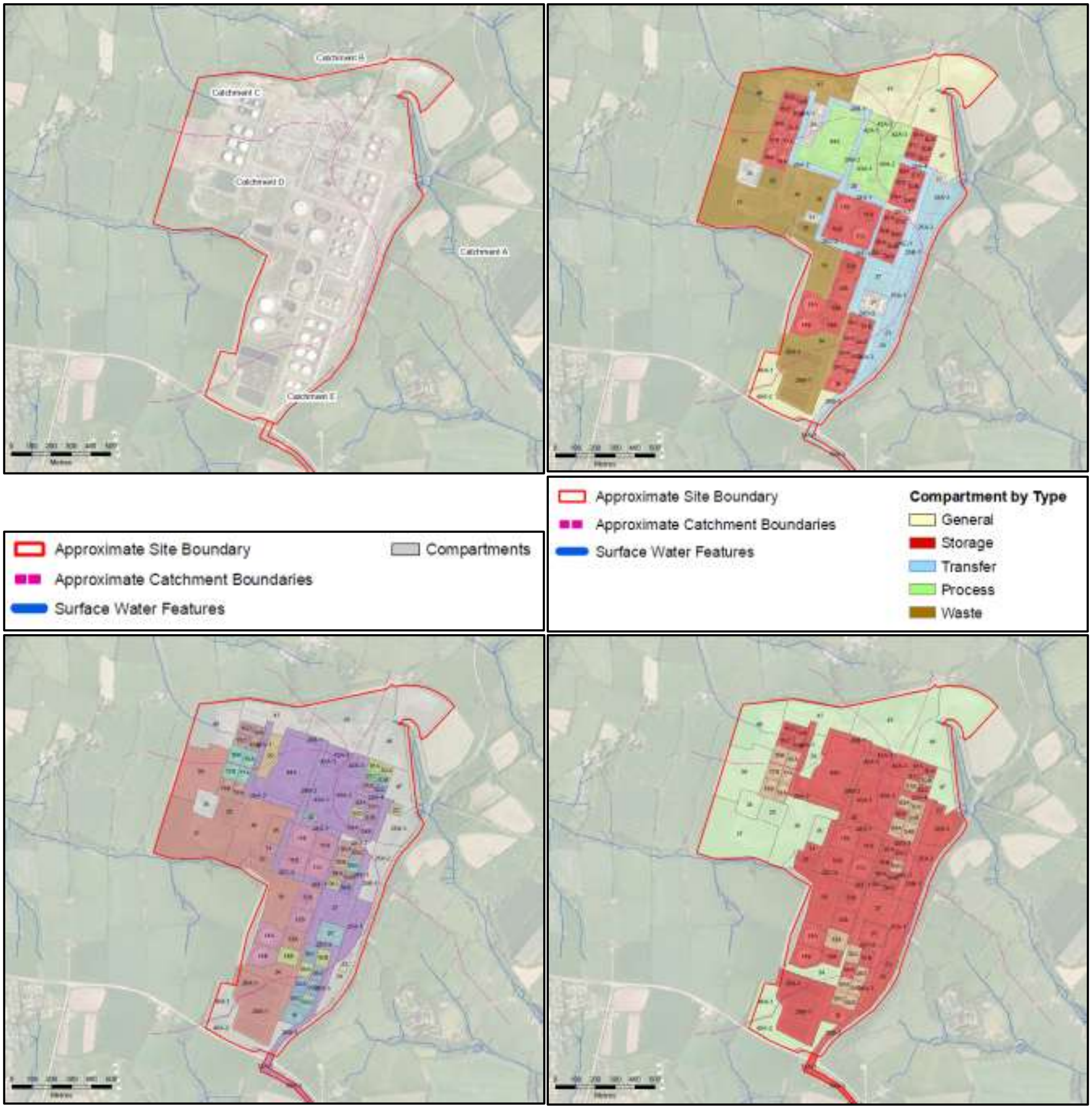
In order to help group risks for different receptors together a series of hydraulic catchments have been defined for the site. These catchments group compartments together based on the specific surface water receptor which is most likely to receive direct run-off or baseflow following a release. The main site catchments are A-E while the jetty itself is catchment F. Catchment definitions are important for a large site since there may be properties associated with the specific which may contribute to development of specific mitigation factors or which may require specific response approaches to deal with a release. In addition the specific distances to receptors within a defined catchment are important when considering mitigation based on in-ground attenuation and when considering the influence of secondary and tertiary containment provisions. For note in the case study catchment B only comprises office buildings and presents no significant MATTE potential.

Figure 2 provides an overview of the process used to split this site into compartments and the type of information which has been be collected on each of the assets to enable commencement of assessing relevant accident scenarios. This figure also illustrates the location of each of the catchments across the main site.

Figure 2 – Site compartmentalisation Process



Following the process outlined above each of the compartments was assigned a 'Type'. For each of these, the material or range of materials was assigned (since different materials will have a different potential environmental impact) and the location on site was reviewed to assess the need to split the compartments. To enable the process to be visually inspected a Geographic Information System (GIS) was used to collate the results from the process. **Figure 3** illustrates the result from the compartment derivation process for the case study site.



Approximate Site Boundary
Compartments
Approximate Catchment Boundaries
Surface Water Features
Approximate Site Boundary
Approximate Catchment Boundaries
Surface Water Features
Compartment by Type
General
Storage
Transfer
Process
Waste

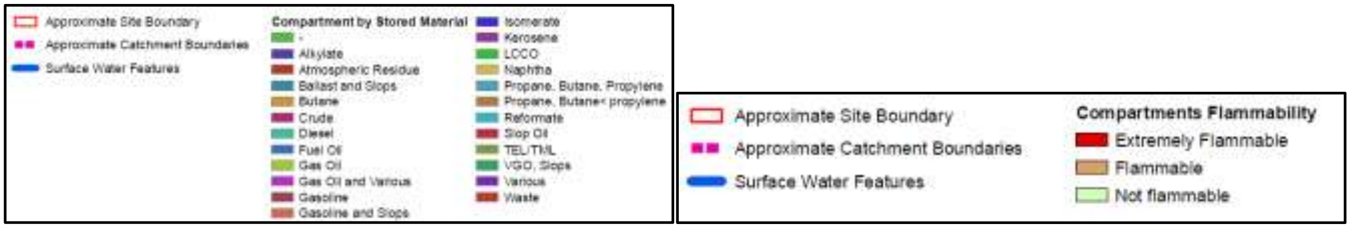


Figure 3 – Site compartments and attributes

Assessing Unmitigated Risks

Having identified that the site contains storage and process equipment that has the potential to generate an environmental impact, the next step was to use the process safety information already generated for the site to begin to assess the level of that risk. As with the compartmentalisation this aspect followed a process to identify the specific assets which could generate a release and to define the initiating events and associated event frequencies in order to assess the significance of each MAS. As part of this process a total of twelve MAS were identified with MATTE potential covering each of the assets. These included groupings of some scenarios within the process area to simplify the approach. For example, more than 3,500 individual release scenarios were identified for process plant at the site. These were screened initially based on product type, release phase (liquid/gas) and potential volume. Once screened the individual scenario initiating frequencies were grouped to enable categorisation into two main MAS; process related release to air and process related release to ground.

The process for assessing the unmitigated risk level at the site is illustrated in **Figure 4**.

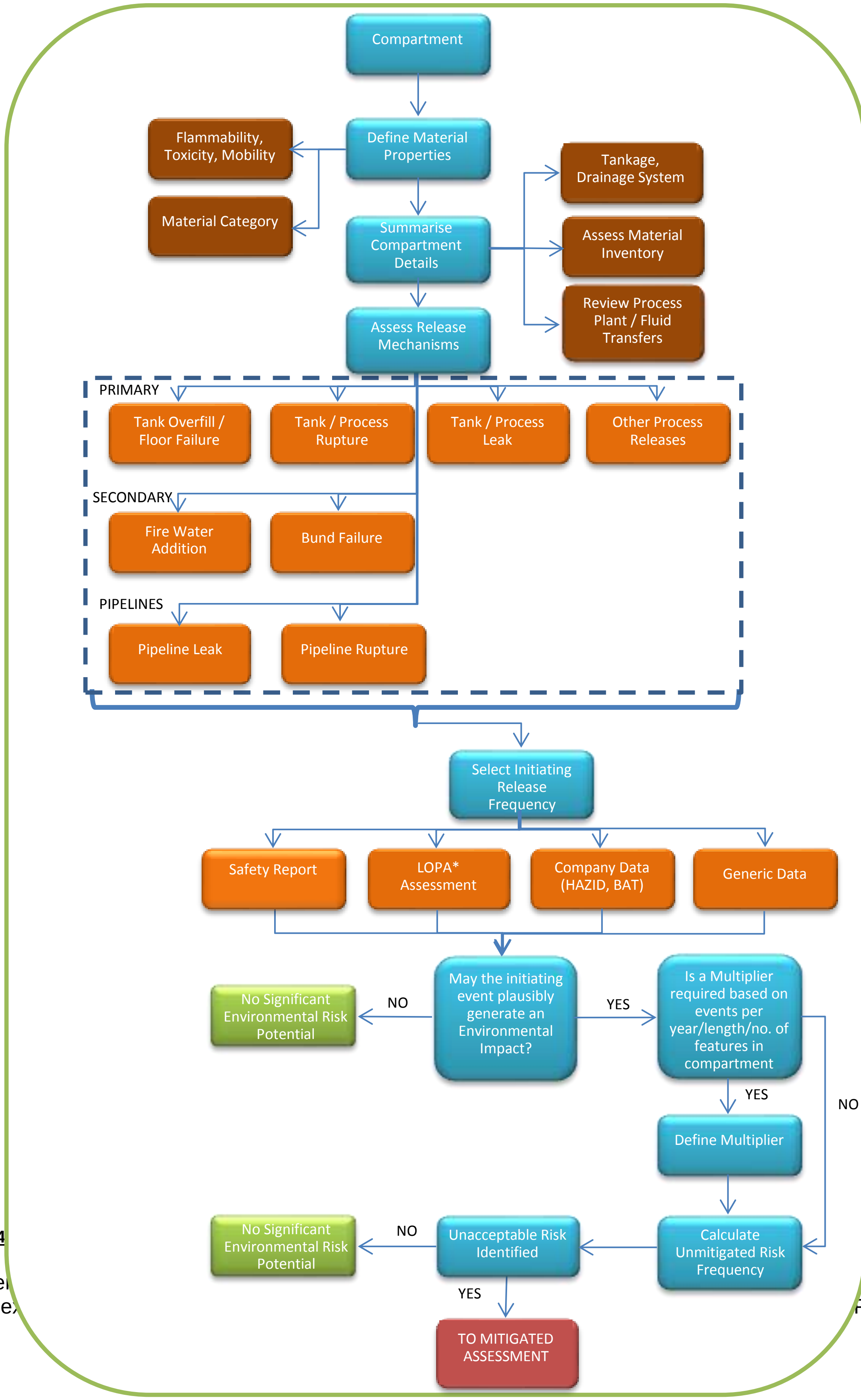
In the case study assessment each individual compartment was then reviewed alongside the identified MAS to identify which plausible scenarios were considered to have the potential to result in a major accident to the environment. Where a credible event was considered unlikely to result in a significant impact it was screened out at this stage of the assessment. The potential for a significant environmental impact was discounted even where there was a potentially significant risk to human health or potential for fatalities under the following scenarios:

- Boiling Liquid Expanding Vapour Explosion (BLEVE) – In this scenario the mechanism for the incident was considered unlikely to result in a significant release of liquid on to or in to the ground. Whilst the explosion has the potential to generate a loss of life and release of combustion products into the atmosphere it was not considered that this presented a significant environmental risk.
- Explosions – As with BLEVEs the most likely pathway for a release into the environment was considered to be via the atmosphere and for the same reasons as a BLEVE was considered unlikely to be significant.
- Small volume releases. In some process release scenarios a relatively small volume release could have a catastrophic effect on the safety of personnel working on the plant (e.g. as a result of a flash fire occurring). The risk to the environment from a small release of liquid hydrocarbons may, however, be negligible – particularly when mitigation through secondary and tertiary containment are considered.

Whilst BLEVE and explosions as initiating events have been discounted with respect to the air pathway, however, if the event was associated with an initial leak of liquid (above the threshold volume considered to be significant) then these scenarios were assessed further and were considered to have potential to result in a major accident to the environment. In addition the Buncefield type scenario of fire/explosion with subsequent addition of fire water was included as a scenario. The source of interest here is the firewater itself and not necessarily the release of liquid associated with the initiating event. The initiating event frequency for a fire was generated from the LOPA assessment. As with the BLEVE and explosions the air pathway related to the fire event was discounted as not having significant MATTE potential.

The threshold volumes for MATTE level events will differ between sites based on the site setting and location of the compartment within the site as well as the product type. With respect to the scale of liquid releases which may or may not be significant to the environment at the case study site a review of toxicity, mobility and flammability was completed in order to classify the material by these parameters. Overall, given the specific site setting, a release of less than $10m^3$ was considered unlikely to have significant potential to generate a major accident to the environment and those release scenarios with a lower liquid release volume were screened out. This volume criteria was selected on the basis of the site setting, location of the main process and storage infrastructure within the site and findings from some initial transport assessments including knowledge of the containment provisions present on site. Such a volume may not be appropriate as a screen in all cases and the ability to screen out may be limited by the availability of existing environmental risk studies at the subject site.

As part of the process of discounting scenarios relating to the air pathway an assessment of the potential significance of a release to the atmosphere was still required to justify its omission. For those scenarios where a gas itself may be released, rather than the combustion products, the toxicity of the gas was reviewed. For natural gas, butane, propane, etc, the gas itself was not considered toxic and unignited releases are ultimately unlikely therefore to present a significant environmental risk. Given the location of the storage vessels for these gases, a release of sufficient magnitude to cause an asphyxiation risk to environmental receptors was also deemed highly unlikely and that dispersion of the gas in the atmosphere would rapidly reduce this risk in any case. In two cases, however, the release was considered to be potentially significant in an environmental context for releases of hydrogen fluoride (HF) and hydrogen sulphide (H_2S) and the release scenarios for the process plant with the potential to generate these emissions were evaluated further.



Compartment
Define Material Properties
Flammability, Toxicity, Mobility
Material Category
Summarise Compartment Details
Tankage, Drainage System
Assess Material Inventory
Review Process Plant / Fluid Transfers
Assess Release Mechanisms
PRIMARY
Tank Overfill / Floor Failure
Tank / Process Rupture
Tank / Process Leak
Other Process Releases
SECONDARY
Fire Water Addition
Bund Failure
PIPELINES
Pipeline Leak
Pipeline Rupture
Select Initiating Release Frequency
Safety Report
LOPA* Assessment
Company Data (HAZID, BAT)
Generic Data
May the initiating event plausibly generate an Environmental Impact?
NO
No Significant Environmental Risk Potential
YES
Is a Multiplier required based on events per year/length/no. of features in compartment
YES
NO
Define Multiplier
Calculate Unmitigated Risk Frequency
Unacceptable Risk Identified
NO
No Significant Environmental Risk Potential
YES
TO MITIGATED ASSESSMENT

Figure 4

For the combustion products from fires, explosions and BLEVE scenarios the risk was reviewed through reference to the Air Pollution Information System (APIS); (http://www.apis.ac.uk). APIS draws upon a very considerable body of evidence and sets out information on releases to air for a large range of pollutants. As the pollutants of interest which may be associated with an explosion or fire are by nature short-term events, the starting point for identification of potential impacts is to consider the sensitivity of receptors to short term, but potentially high dose events resulting from direct exposure to pollutants and through deposition to ground and their subsequent uptake. Where the feature of interest is fauna, then these were considered to be largely dependent upon the maintenance of the health of the underlying floral habitat and general ecosystem.

Fires and explosions have the potential to release to air a number of substances that are potentially polluting both due to direct toxic effects and due to deposition and subsequent uptake. The APIS website sets out evidence relating to the potential impacts of atmospheric pollutants on protected habitats, both flora and fauna. This evidence, gathered from a wide range of sources, was used as the primary source of information to define those pollutants that are of interest and assess the potential for significant impacts on habitats.

On the basis of the evidence set out, emissions of oxides of nitrogen and associated deposition of nutrient nitrogen and acid nitrogen were considered to be potentially significant pollutants from a fire or explosion which might have potential to result in a major accident to the environment. In general terms the generation of these pollutants from a fire or explosion was considered unlikely to generate concentrations which would significantly alter the annual mean criteria as set out by the European Union. This review was considered to be sufficient to eliminate combustion products as having a significant potential to generate a significant accident to the environment.

Similarly the potential for nitrogen derived acid and an increase in nutrients affecting the flora in the area were considered to be negligible from this type of short term emission to the atmosphere.

As part of the review of the potential scenarios it may, in some instances, be necessary to conceptualise each asset and combine this with information generated from existing hazard identification studies (HAZID Studies) to identify those scenarios which need further consideration. By way of example, **Figure 5** illustrates a range of release events which could be generated from a liquid hydrocarbon storage tank. This could be expanded to include initiating event summaries or the information could be populated in a bow-tie diagram.

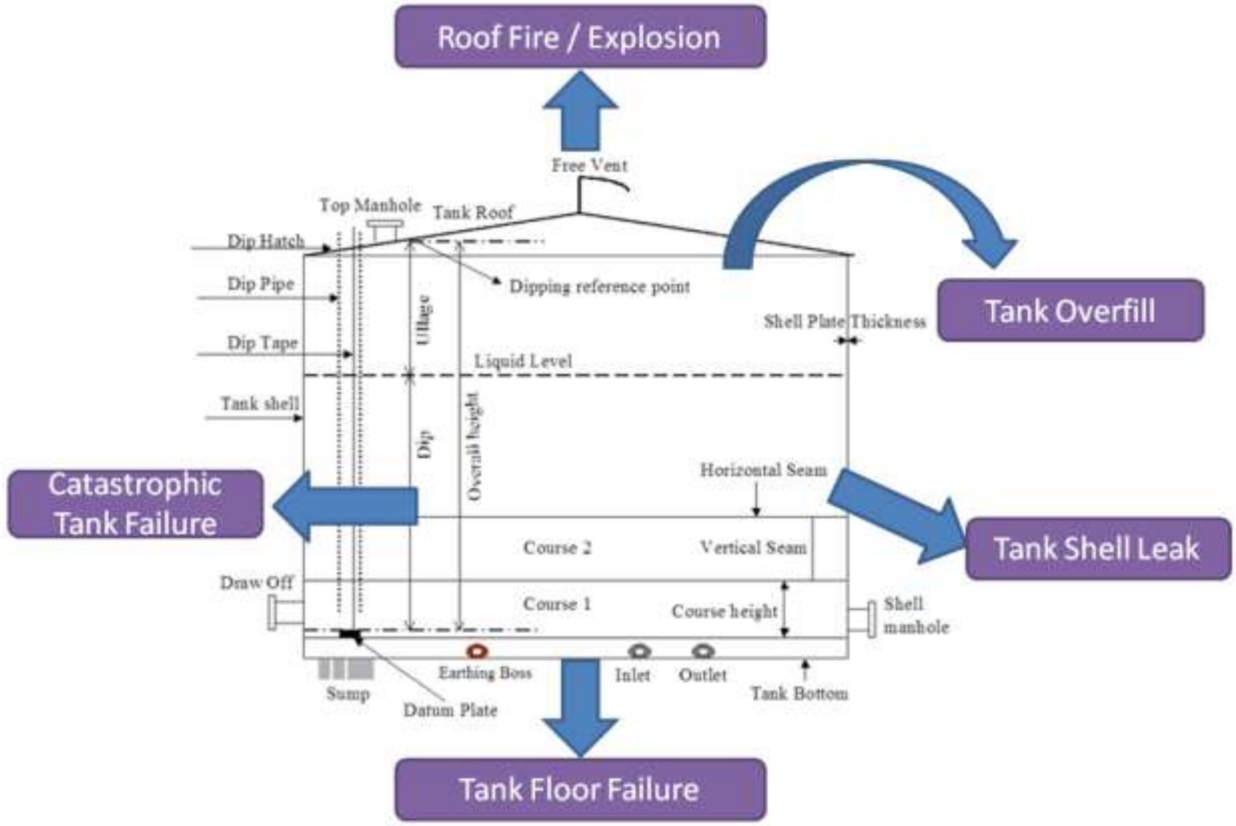


Figure 5 – Illustrative set of sources of potential environmental impact from a bulk storage tank

In the tank compartments event review, the tank floor scenario did not feature in the process safety report as a result of it being low risk in terms of generating potential harm to human health, and the release is also often gradual in effect, not catastrophic. Conversely the potential for a roof fire may not be considered further in the environmental assessment if the emission to atmosphere of hydrocarbon combustion products is not considered significant as outlined above (unless as an initiating event this may result in loss of structural integrity of the tank and a significant volume of stored product being lost to ground).

Typically anywhere between 1 and 6 plausible MAS were identified per compartment based on the review of process safety data. For each event a bow-tie assessment was completed to better illustrate the scenarios and associated potential outcomes. For the site as a whole this resulted in a total of 394 plausible event scenarios which could result in a MATTE (noting that the summed combinations for the 3,500+ process area related release events resulted in 8 MAS for 6 defined process compartments).

During the course of the assessment to this stage a range of information on sources, pathways and receptors has been obtained and as part of the demonstration that the guidance has been followed the CDOIF tables for documenting the process have been populated as outlined in the following section. In order to better understand the result of the unmitigated risk assessment further analysis has been completed within a workbook designed to capture the extensive list of pollutant linkages for each MAS ahead of completing more detailed assessment. Details on this step of the process are provided in subsequent sections of this case study example.

Unmitigated Risk - CDOIF Tables

A summary of the key data collated during the initial stages of the assessment is provided below in order to illustrate how the complex site was assessed and how this meets the data requirements/expectations for the CDOIF tables (Annex 5, CDOIF, 2013). These have been supplemented in the case study work with detailed information for each compartment which includes information on tank construction, storage /operational volumes, construction, etc as well as details on the bunds in which the tanks sit. Detailed information on the MATTE scenarios, receptors, CDOIF tolerability levels, etc have also been provided on a compartment/scenario basis providing a transparent process by which changes to the scenario or site conditions can be rapidly incorporated.

Table 1 – MATTE Potential Summary

The data requirements for this table were summarised by compartments which identified the product type within each which had MATTE potential. In order to complete Table 1 it is necessary to also complete Tables 2 and 3. In the examples provided below the information is limited and for illustration purposes only. In support of subsequent prioritisation further information on why a certain receptor and MATTE severity level have been selected will be required. In order to keep the process relatively simple only the worst case impact has been considered from this point and it is worth noting that this should be continually reviewed through mitigation so that those initially less sensitive receptors are not overlooked in the procedure should some mitigation aspects only provide a risk reduction for certain receptors (e.g. emergency response for surface water receptors, etc).

Transposing the data generated for the site results in the following CDOIF Table 1;

Table 1 - MATTE Potential Sumary Matrix

Row	DETR Table Ref	Receptor Type See table 2	MATTE threshold See Table 3	MATTE Severity Level	Substance / group of substances					
					1	2	3	4	5	6
1	1	Designated Land / Water Sites (Nationally Important)	>0.5ha or 10-50% of site area, associated linear feature or population	2	✓	✓	✓	✓	✓	✓
2	2	Designated Land / Water Sites (Internationally Important)	25-50% of site area, associated linear feature or population	3	✓	✓	✓	✓	✓	✓
3	3	Other designated Land	10 - 100ha or 10-50%	n/a						
4	4	Scarce Hanitat	2-20ha or 10-50%	n/a						
5	5	Widespread Habitat - Non-designated Land	>10ha	n/a						
5	5b	Widespread Habitat - Non designated Land	Contamination of aquatic habitat which prevents fishing or aquaculture or renders is inaccessible to the public.	n/a						
7	6	Groundwater Body - Source Protection Zone (SPZ) for Public Drinking Water Supplies (Note - refer to EA website for SPZ aquifer maps.)	>1ha SPZ or >1000 person-hours interruption	n/a						
8	6	Groundwater Body (non-SPZ)	1-100ha of groundwater body where the WFD status has been lowered*	2 (off site)	✓	✓	✓	✓	✓	✓
9	6	Groundwater (non-groundwater body wrt W ater Framework Directive)	Please indicate if non groundwater body is a pathway to another receptor.	Pathway Only (on site)						
10	7	Soil or sediment (i.e. as receptor rather than purely a pathway)	Contamination of 10-100ha of land etc. as per Widespread Habitat; Contamination sufficient to be deemed environmental damage (Environmental Liability Directive)	2	✓	✓	✓	✓	✓	✓
11	8	Built environment	Damage above a level at which designation of importance would be withdrawn.	n/a						
12	9	Various receptors								
13	10	Particular species	Loss of 1-10% of animal or 5-50% of plant ground cover.	n/a						
14	11	Marine	>2ha littoral or sub-littoral zone, >100ha of open sea benthic community, >100 dead sea birds (>500 gulls), >5 dead/significantly impaired sea mammals	2	✓	✓	✓	✓	✓	✓
15	12	Fresh and estuarine water habitats	WFD Chemical or ecological status lowered by one class for >2km of watercourse or >10% area (estuaries or ponds) or >2 ha of estuaries and >2ha of ponds. Plus interruption of drinking water supplies, as per DETR Table 6	2	✓	✓	✓	✓	✓	✓

* For the purpose ofthis assessment this is only considered to be relevant outside the site boundary for reasons as described in the report text.

Table 2 – Receptor Detail

Rather than try and identify every plausible receptor and threshold exceedance a review of the plausible pathways was undertaken and a conservative selection for the receptor was made given the sites environmental setting. Whilst there are a number of surface water receptors around the periphery of the site it was assumed each wold feed directly into the SAC to the south of the site without any meaningful mitigation and therefore the assessment assumed a worst case threshold for the most sensitive receptor. The receptor for each compartment was identified in the assessment tables generated.

Table 2 - Receptor Detail

Row	DETR Table Ref	Receptor Type	MATTE threshold	Receptor Detail
2	2	Designated Land / Water Sites (Internationally Important)	25-50% of site area, associated linear feature or population	Habitats which contribute to the primary reason for selection of this site as a SAC include the type of Estuary, presence of large shallow inlets and bays and the presence of reefs. Further details may be found here: http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0013116 The species that are a primary reason for selection of this site as a SAC are grey seal and Shore dock. Shore dock may be the most sensitive receptor as; grows on rocky, sandy and raised beaches, shore platforms and the lower slopes of cliffs, and rarely in dune slacks. Plants can be found growing in isolation on the strand-line, through to tall-herb perennial communities at the base of flushed cliffs. However, it occurs only where a constant source of freshwater, running or static, is available. It is most commonly found growing by the side of streams entering beaches, on oozing soft-rock cliffs, and in rock clefts where flushing occurs. Populations of shore dock are known to fluctuate according to the severity of winter storms. Additional species present as a qualifying featuer but which are not a primary reason for the site selection include Sea lamprey, River lamprey, Allis Shad, Twaite shad and Otter. This MATTE threshold was selected on a conservative basis without detailed assessment of the linkage to the primary classification receptors. A linear feature associated with this site is considered to be a single stream (>2km in length fromthe site) and not all of the surface waters which discharge into Milford Haven.

Table 3 – MATTE Scenarios

The MATTE scenarios were tabulated for each compartment but assuming the worst case receptor only. All credible scenarios were considered to have the potential to affect the same most sensitive receptor. Clearly, if through mitigation, this receptor was discounted or inherited receptor specific mitigation measures then an analysis of alternative receptors would need to be undertaken. For simplicity the key objective was seen to be the selection of an appropriate (conservative) tolerability threshold. Where appropriate, as the assessment is progressed certain scenarios may be grouped into lower severity threshold groups which will result in an adjustment in how the overall Establishment Risks are summed.

Table 3- MATTE Scenarios

Row	DETR Table Ref	Receptor Type	MATTE threshold	Credible MATTE Scenarios
2	2	Designated Land / Water Sites (Internationally Important)	25-50% of site area, associated linear feature or population	All Scenarios are considered to have the potential to result in an impact at the SAC by the nature of the presence of surface water features at the site boundaries which drain into the SAC. Of all the individual MAS/Compartment scenarios 34 of them are considered likely to have a lesser effect (MATTE threhsold of 2) at this ultimate receptor. Others have been screened out comepltely. Please see the accompanying MATTE assessment worksheets for a detailed assessment on the scenarios for each compartment, potential receptor that could be affected and the selected MATTE level. By way of a summary the follwing represents a selection of the credible scenarios which could plausibly result in this level of impact from a storage tank compartment; Overfilling of a Storage Tank Fire associated with a Storage Tank Catastrophic Tank Failire Tank Leak Tank Floor Release Bund failure resulting in release of product from secondary containment Addition and release of fire water from secondary containment

Table 4 – Dangerous Substances with Environmental Risk

At the case study site the substances are generally straight forward in terms of categorising the inventory and risk drivers for environmental impact. The table below provides a summary for some of the site's inventory. In addition due consideration has been given to a range of intermediate products, additives and process related chemicals. In particular the potential for H_2S and HF releases was considered as a result of MAS associated with specific process equipment.

Table 4 - Dangerous Substances with Environmental Risk

Subtance Reference	Substance (or group of substances)					Maximum Inventory	Description	Physical State	(Max Tank) Quantity	Ref for info
	Commn Name	IUPAC Name	CAS Number	CHIP Index	Risk Phrases				tonnes	
1	Crude	See appended site MSDS sheets for more detailed information on this substance			R12, R45, R65, R67, R51/53, S53, S9, S16, S35, S36, S39, S45, S61	see Tank Schedule	Raw Material	Liquid	64000	See report annex / COMAH / MSDS
2	Diesel	See appended site MSDS sheets for more detailed information on this substance			R40, R51/53, R52/53, R65, S2, S36/37	see Tank Schedule	Finished Product	Liquid	19800	See report annex / COMAH / MSDS
3	Fuel Oil	See appended site MSDS sheets for more detailed information on this substance			R45, R52/53, R66, S53, S45, S61	see Tank Schedule	Finished Product	Liquid	33000	See report annex / COMAH / MSDS
4	Gasoline	See appended site MSDS sheets for more detailed information on this substance			R11, R53, R38, R45, R48, R63, R65	see Tank Schedule	Finished Product	Liquid	14250	See report annex / COMAH / MSDS
5	Kerosene	See appended site MSDS sheets for more detailed information on this substance			R65, R51/R53	see Tank Schedule	Finished Product	Liquid	11440	See report annex / COMAH / MSDS
6	Naphtha	See appended site MSDS sheets for more detailed information on this substance			R11, R53, R38, R45, R48, R63, R65	see Tank Schedule	Intermediate Product	Liquid	12700	See report annex / COMAH / MSDS

Note furhter products are used at the site but are iether considered to have no MATTE potential based on volume/material or have similar properties to those listed. See MATTE report for more details.

Complex Site – Scenario Analysis

Having identified scenarios the next step in the process at the case study site was to utilise the Safety Report to identify appropriate initiating frequencies for each scenario which could lead to the MAS (central event) occurring.

As noted above, tolerability of environmental impacts is a challenging element within the assessment process. For simplicity in the case study assessment the CDOIF tolerability criteria were adopted. These criteria are based on the likely spatial extent of impact at the sensitive environmental receptor and the duration of that impact. In this process there is limited reference to how harm should be gauged other than through generation of an adverse effect on a receptor or through application of the definition of '*environmental damage'* included in other Regulations. In practice, demonstration (through simulation) of the adverse effects may be highly complex and potentially disproportionate depending on the probability of a risk occurring at the receptor in the first place.

The consequence level is then derived by looking up the severity and duration result in a matrix and converting to a tolerability criteria range as illustrated in Tables 1, 2 and 3 (CDOIF, 2013). The application of the severity criteria is illustrated in the CDOIF summary tables provided for the case study above. The tolerability criteria were then derived following consideration of the longevity of impact. This selection was based on expert opinion relating to the fate of the stored materials in the environment. A medium term impact (1-10 years) was selected for the case study site.

At this stage the other receptors were also reviewed and the potential for different duration/recovery periods was considered in case this elevated a different receptor as being more sensitive (and with a lower resultant tolerability range). No long term or very long term durations were identified for the case study site. Further guidance on environmental recover periods for a range of chemicals is currently in preparation by the Energy Institute and the Institute for Environment and Sustainability (IES) - http://ies.jrc.ec.europa.eu/our-activities/scientific-achievements/the-fate.html.

Initiating event frequencies for each scenario were then adjusted based on appropriate multiplier factors and/or any other inherent mitigation measures. Multipliers take into account the quantity of a particular feature while the inherent mitigation is tasked with considering the in-built engineering controls which would limit the potential for the event to occur (i.e. associated with keeping materials within the primary containment vessel). The inherent mitigation can be illustrated on the left-hand side of a bow-tie in the form of barriers as illustrated in **Figure 6** for **a tank overfill event**. These are typically the elements of process safety which factor directly into the environmental risk assessment.

Multiple bow-ties may be required for each MAS and receptor to fully describe the barriers and mitigation processes considered in the assessment. The use of bow-ties in this case study has been incorporated to aid illustration and their use in actual assessments may not be required depending on the complexity of the barrier and mitigation analysis required.

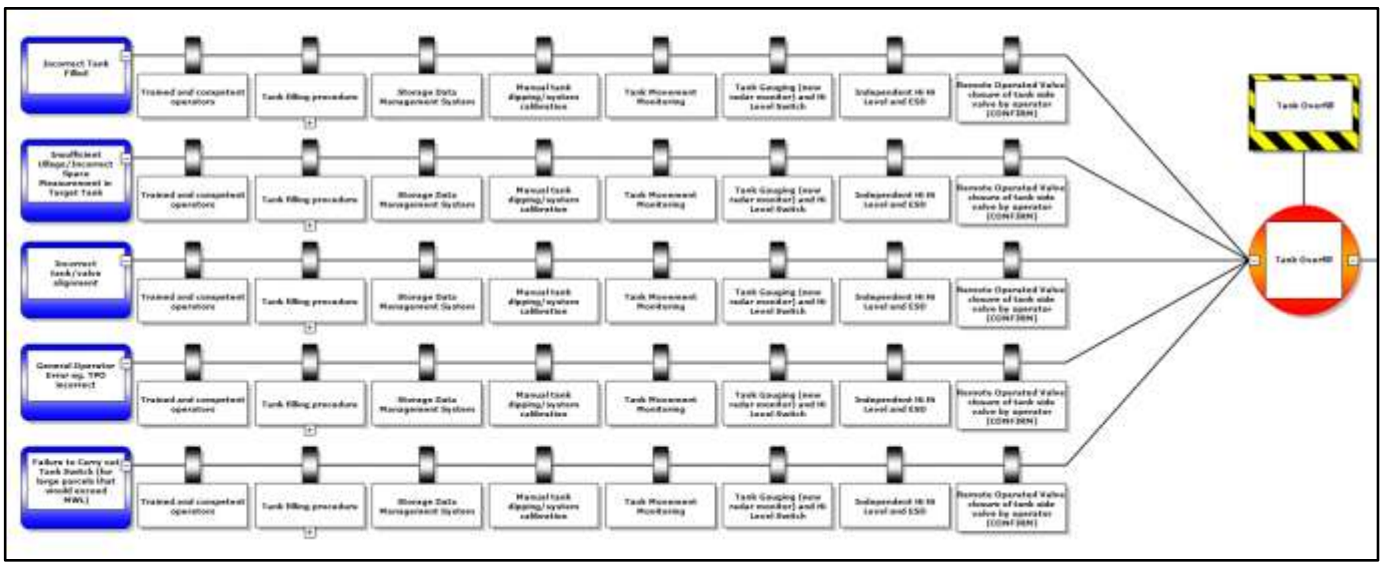


Figure 6 – Illustrative Bow-Tie barrier analysis for Tank Overfill Event

Each of these barriers represents proactive measures to prevent the event from happening and therefore can be considered as part of the unmitigated risk. Measures which could reduce the impact after the event (e.g. secondary and tertiary containment, contaminant fate and transport modelling, etc.) were used in the mitigation assessment stage and appear on the right hand side of the bow-tie.

In process safety, the role of these engineering controls may be assessed as part of a combined layers-of-protection analysis (LOPA) which itself considers the different safety intervention levels which form part of the operation of the asset. The end point of this process is a final unmitigated risk value which represents the probability of the event occurring once all of the aspects on the left hand side of the bow-tie are in place. It may be appropriate to sum the initiating frequencies for each branch on the left hand side of the bow-tie for each central event.

Summation of all scenarios within each individual compartment can then be used to provide an indication of the contribution of the risk from that asset to the combined total for all compartments at the site (or within a particular catchment with the potential to affect the same environmental receptor).

In the case study the contribution from each compartment was summed for each of the scenarios and this was converted to a percentage contribution of the intolerable criteria as defined by the guidance. At the unmitigated stage there is a requirement to qualitatively assess the potential severity of harm on an environmental receptor as outlined above. Based on the site setting and professional judgement considering the mechanisms for release, the volumes involved and the transport routes to the receptors a conservative selection of a potential 'Major' accident to the environment was selected for all events. Based on a medium term duration (greater than 1 but less than 10 years), this equated to a tolerability level of **B** and with a resultant intolerable criteria of 1 x 10^{-3} per year for each potentially affected surface water receptor (*see Tables 1 to 3 for information on criteria*). For some MAS, particularly those with a small potential release volume, the tolerability level was reduced to **A** (41 of the initial 384 scenarios). Examples where the MATTE tolerability criteria were reduced following an initial review of the initiating frequency data included;

- Releases associated with tanker failures at the road loading terminal – primarily due to its position within the site , provision of dedicated containment provisions and presence of hard standing;
- Releases from pipework due to the relatively small volumes involved;
- Releases to ground within the Process Areas due to presence of hardstanding, dedicated tertiary containment and relatively small volume releases.

Severity levels of 0 were effectively assigned to those scenarios not considered to have a MATTE potential. For completeness these MAS were retained within the assessment process for transparency and to enable revisions if required in the future.

The resultant distribution of potential **unmitigated** environmental risks at the site can then be presented in a map as shown in **Figure 7**. A map has been used as the data is geographic and this approach enables visualisation of risk drivers on a single image rather than through generation of multiple tables and/or matrices. With an excel and GIS linked system the contributions from individual MAS across the site or summed total risks by catchment/receptor can be presented.

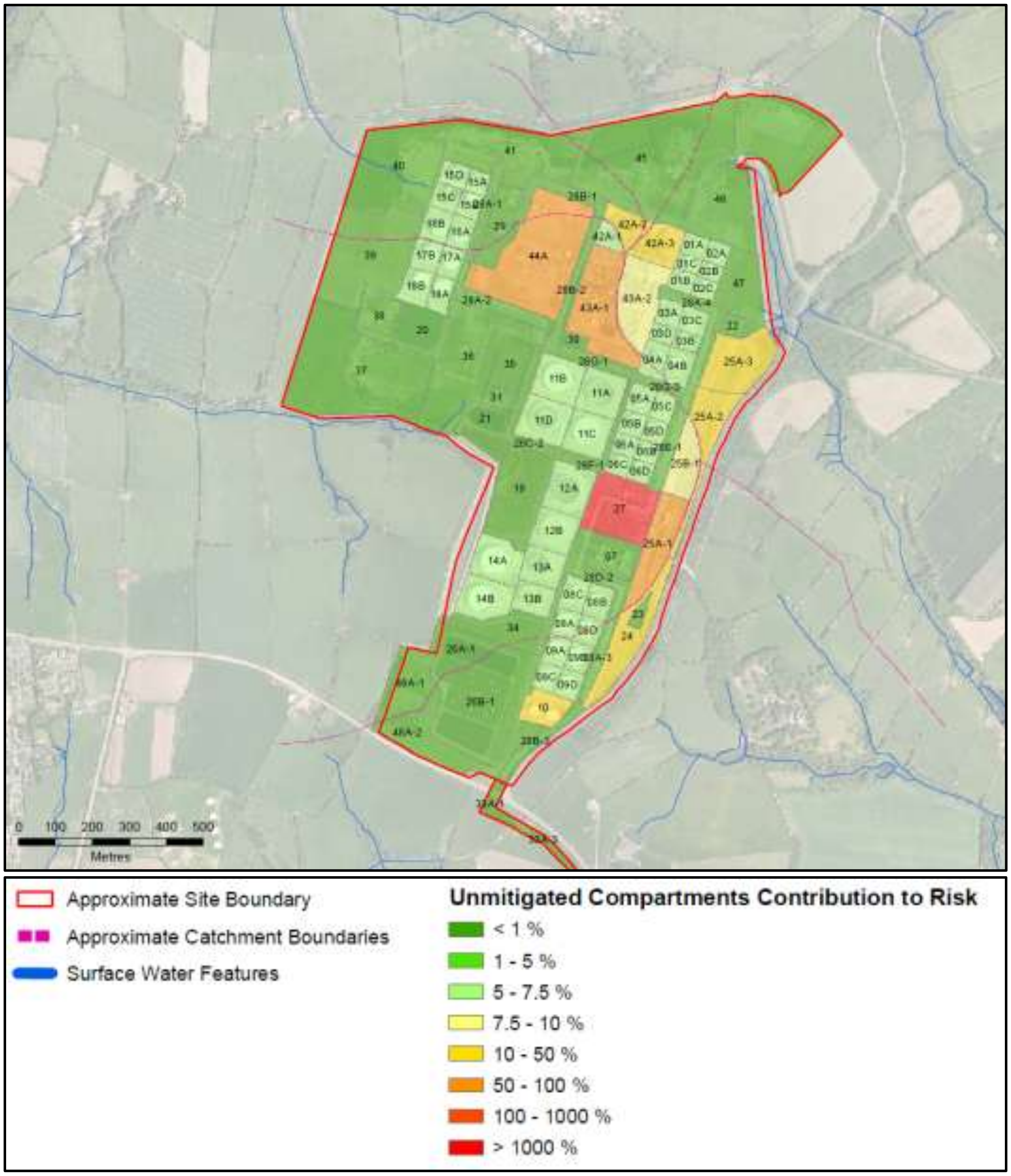


Figure 7 – Unmitigated risk contribution as a proportion of the intolerable risk frequency. Results above 100% indicate that an individual compartment would be capable of presenting an intolerable risk.

In this figure those compartments which are green contribute least to the overall environmental risk for a given receptor whilst those which are orange and red contribute the most. This combined with a ranked list of compartments and events can then be used to focus on those areas where mitigation assessments will make the biggest difference. In addition to the holistic view of risk presented in this figure it is also possible to present site wide data for each individual event type to identify whether it is individual events or individual compartments which contribute the most to the risk.

At the unmitigated stage, and particularly for large and complex sites, the likelihood is that the risk will be intolerable and that further assessment will be required. In the case study site the unmitigated risk was several of orders of magnitude above the intolerable threshold (as illustrated by individual compartments contributing more than 100% of the intolerable threshold level of risk) and more detailed assessment of the potential impact on the environment from a range of MAS was required.

Assessing the Mitigated Risk

The mitigation aspect is concerned with identifying barriers or attenuation processes which could limit the impact following an event. There is a wide range of mitigation elements which could be considered. In the case study these were limited to the following elements:

- Secondary containment;
- Tertiary containment;
- Attenuation of overland flow;
- Assessment of ground penetration rates;
- Saturated zone attenuation; and
- Effectiveness of emergency response.

Each of the mitigation aspects can be illustrated in the bow-tie diagram. The following extract, presented as **Figure 8**, illustrates the wide range of mitigation measures which could be effective in reducing the chance of significant environmental impact following a **tank overfill event**.

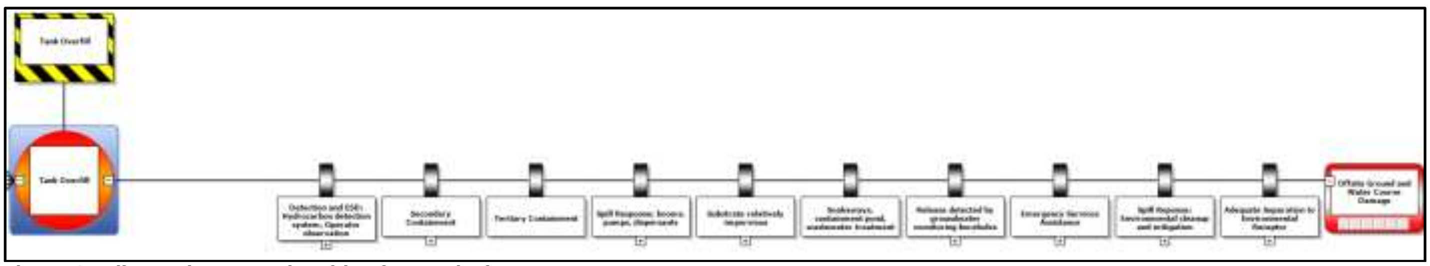


Figure 8 – Illustrative Bow-Tie mitigation analysis

For each mitigation measure there is then a series of assessments which may be completed to better understand the potential effectiveness in reducing the potential environmental impact at the receptor.

Depending on the level of unmitigated risk an assessment of which barriers will produce the most economical (time and cost) way of demonstrating that the Establishment risk is ALARP should be selected. The barriers generally fall into two categories;

- Engineering Controls; and
- Environmental Assessment.

For engineering barriers there is a wide range of published literature data which may be used to determine an appropriate range of mitigation factors for these features based on site specific conditions.

Environmental barriers may require more detailed assessment using site derived data to better estimate the fate and transport of the materials involved in the MATTE scenario but could also include qualitative assessments of a sites preparedness/ability to identify, intercept and/or remediate a release following an incident. Based on the CDOIF guidance the more complex assessments will fall into Stage 2 of the process while credit for existing safety measures which are appropriate for consideration in the event of a release (e.g. bund wall stability, tertiary containment provisions, presence of bund vapour monitors, etc) could and should be included in Stage 1 Step 2.

Taking the example shown in **Figure 9**, a release of product into secondary containment may result in penetration into the ground. In this instance the rate of this penetration and the resultant movement of product away from the tank can be assessed quantitatively using stochastic modelling tools. For this mitigation barrier it then becomes possible to assign a mitigation factor which represents the likelihood of that barrier being successful in limiting the potential impact at the receptor. This process may also identify secondary ‘events’ which will then require a more detailed assessment in their own right; for example the failure of the bund wall as a result of an overfill event.

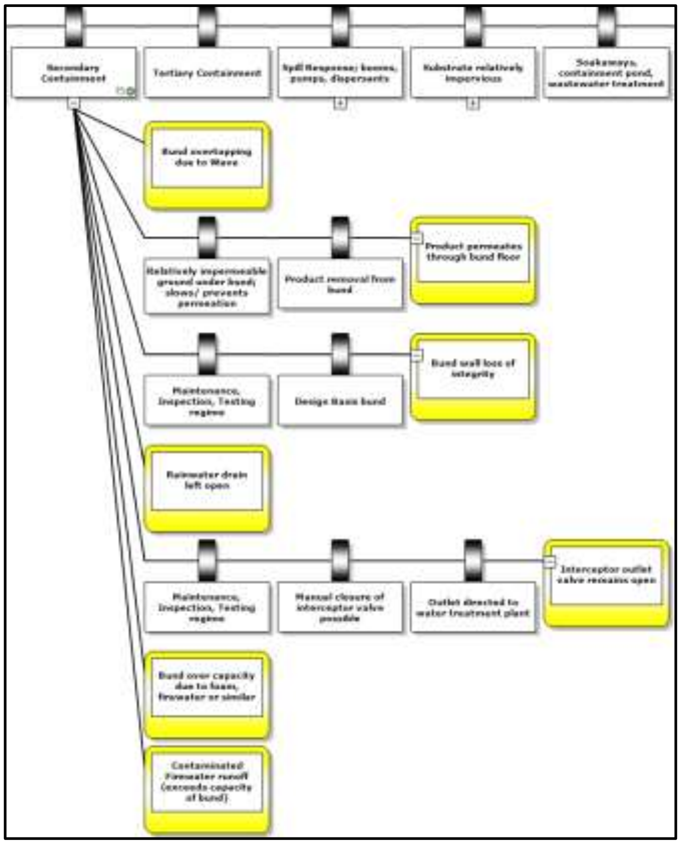


Figure 9 – Illustrative Bow-Tie barrier assessments

The process of assessing mitigation measures for each of the events may be presented in a flow chart as illustrated in **Figure 10**. The intention here is to incorporate a range of mitigation measures for each event in a methodical way and taking into account an increase in complexity as the assessment progresses. At the same time the degree and cost of assessment was kept aligned with the resultant level of risk with only more detailed assessment being undertaken for those scenarios which were identified as driving the risk and to a point at which the risk could be demonstrated to be at least TifALARP. The range of mitigation steps and the order in which those should be assessed will vary between sites.

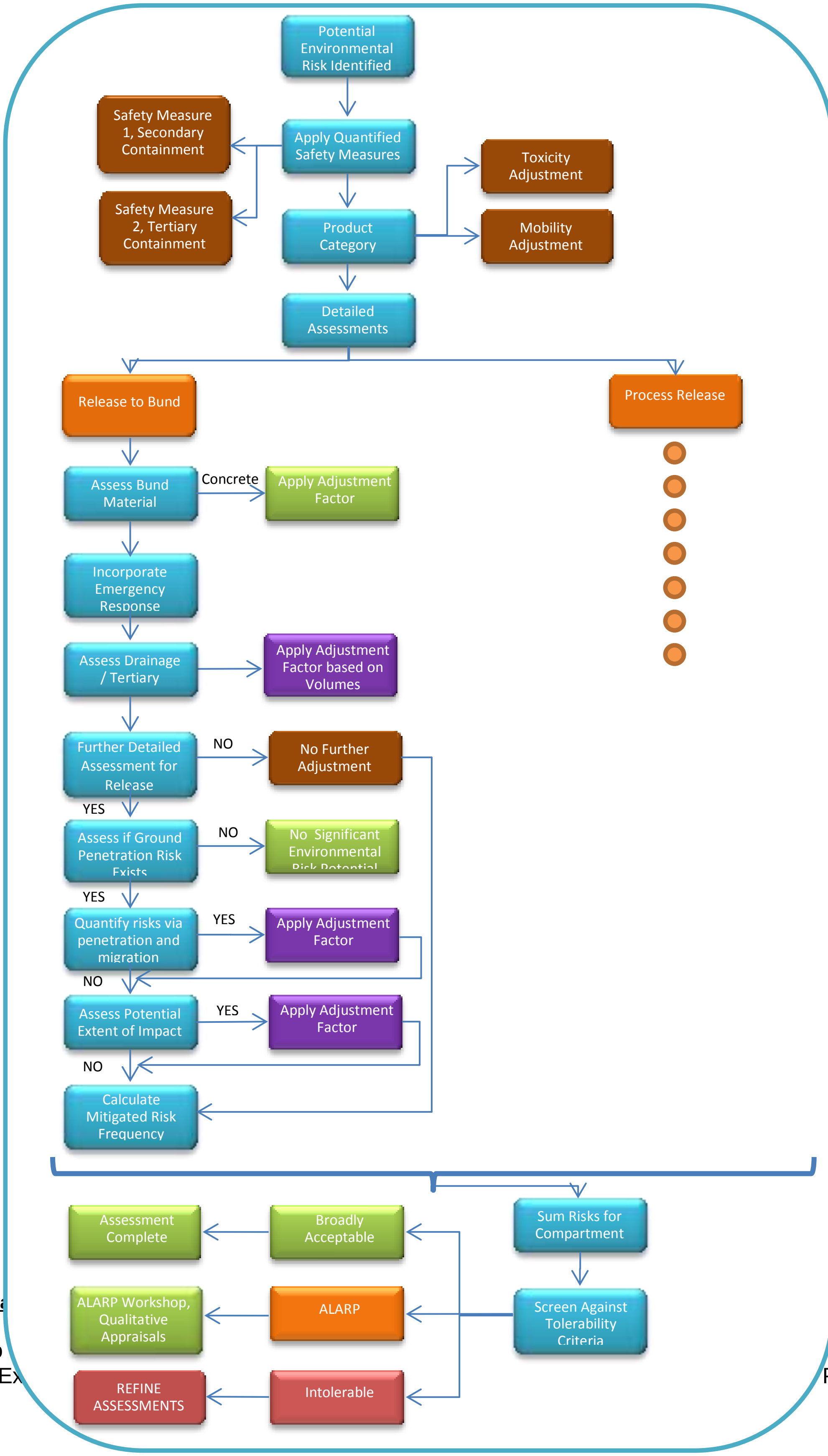


Figure 10 – Mitig

Example Mitigation Assessments

Mitigation would typically incorporate a range of aspects which would have the capability of limiting the potential for a release to reach a sensitive receptor. In essence these aspects consider the effectiveness of interrupting the pathway between the source and the receptor at potential risk. At its most basic, mitigation can take into account the preparedness of a site to respond to an incident both in terms of identifying that a release has occurred and that there is sufficient suitable equipment to contain and recover the released material.

The detection of a leak may be quantified by incorporating engineering controls which will aid the site – for example through inclusion of vapour monitors within bunds which could detect a liquid release from a tank overfill enabling additional controls to be implemented (e.g. drain valve closures, etc). As this example element of mitigation is an engineering control, there are recognised methods and data available to help quantify its likely effectiveness in terms of enabling the site to respond efficiently to the event and as such a numerical adjustment to the unmitigated release frequency may be applied.

For more qualitative elements, such as the ability of a site to respond, this may present more of a challenge to produce a numerical adjustment for. If a site has already demonstrated its practical ability to prevent a significant impact from a particular type of event then an adjustment factor may be generated with the effect of reducing the risk (albeit this is likely to be from a very small data set). Alternatively this aspect could be maintained for consideration in demonstrating that the risk is ALARP – that is that there is a procedure in place which has been assessed as likely to be effective through drills but which has not demonstrated its direct effectiveness and as such has not been quantitatively assessed. The Energy Institute QHRA[1] guidance will also assist sites in making qualitative assessments of human reliability and the role that may have in mitigation associated with procedures which involve human intervention.

Lastly, depending on the type of MAS, site specific parameter information could be assimilated from which the likelihood of a response being effective may be quantified.

In the case study site specific data was used to help assign mitigation factors following an overfill of a tank. The first step in the assessment was undertaken using a stochastic decision tree which considered a weighted range of input parameters from which those combinations which might lead to prevention of a significant release from occurring could be identified.

In this case the decision tree considered the following aspects:

- Potential overfill volumes;
- Area of the bund;
- Head of product which may exist in the bund (calculated from the above);
- Spill duration (i.e. how long might the product be sat in the bund before intervention is possible);
- Hydraulic conductivity of the bund floor; and
- Porosity of the underlying formation.

Values for each parameter were selected based on one or more of: site specific data, engineering drawings, literature sources and/or professional judgement. Where there was a range of possible values for a parameter each one was given a weighting based on an assumed likelihood. For example, the hydraulic conductivity of the bund floor may be variable based on a range of tests conducted at the site and the distribution of these results was used to define the lowest, most likely and upper end

[1] https://www.energyinst.org/technical/human-and-organisational-factors/qhra

estimates for this parameter.

A calculation was then completed at each step of the decision tree to ultimately produce an estimate of the volume of unrecovered product which might then penetrate the ground for each of a range of different spill volumes and durations. Where product had the potential to penetrate beyond a recoverable depth (1 m was used in the case study) a potential risk was considered to exist and the planned response was considered to have the potential to fail to mitigate the potential impact from the release. Given the range of parameter values and the number of calculation steps the decision tree grew into a 5 step process containing a total of 49 branches, each with an associated probability of occurring and a final calculated depth of penetration into the bund floor as a result of a range of plausible overfill events. All those probabilities where the resultant depth was greater than 1m were summed to generate an assessment of the likelihood that the response could fail to prevent a major accident to the environment form occurring. The assessment would then move on to the next mitigation step if required.

Having reduced the assessed risk by an approximate factor of 0.8 (i.e. there was calculated to be an 80% chance that the response to product recovery would effectively mitigate the environmental risk) a review was completed to assess whether further mitigation was required. In this case there were a number of compartments where consideration of additional mitigation measures was considered necessary.

For the tank overfill event the next step was to consider the implication of loss of containment through the bund floor. In this instance a source term could be generated for use in a fate and transport model which evaluated the migration rate of the most toxic and mobile component within the released product. Different assessments, producing different results were generated for each product type within each catchment and taking into consideration the distance from each tank to the nearest down gradient receptor.

When completed stochastically, using a range of model input values for each variable, the output provided a range of potential contaminant concentrations at different probability levels. The assessment was completed using the UK Regulator's adopted approach to assessing risks in groundwater and resulted in two-dimensional plume extents for different probability thresholds. **Figure 11** illustrates the results for the benzene component of the crude oil plumes for one specific compartment for two percentile levels; 50^{th} percentile and 99^{th} percentile. The results from this assessment were then evaluated based on the use of an appropriate acceptable target concentration at the receptor. In this instance a toxicity based threshold for benzene of 300 microgrammes per litre (µg/l) was used assuming crab larvae as the sensitive species at the receptor. It should be noted that for assessment of a MATTE this was considered an appropriate concentration to use rather than the EQS limits of 8-50µg/l (depending on whether an annual average or maximum allowable concentration is selected). No account of dilution was made due to the nature of the surface water courses (small streams with potential for significant baseflow contribution with limited or no upstream flow).

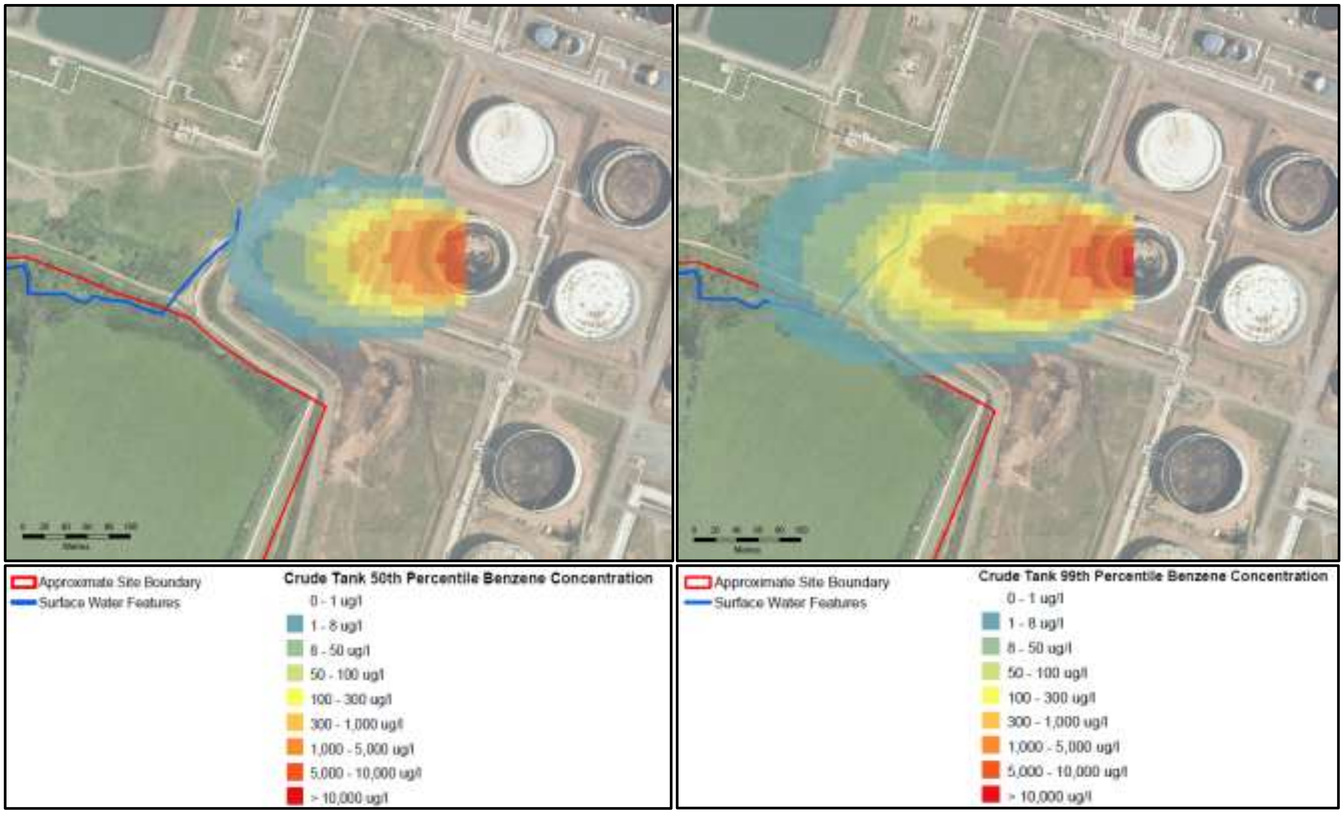


Figure 11 – Simulated dissolved phase concentrations in underlying groundwater from a crude release into secondary containment.

The 50th percentile plume indicated that the toxicity based threshold was not exceeded at the receptor and therefore an adjustment factor greater than 0.5 was likely to be applicable. At the 99th percentile the toxicity threshold was simulated to extend close to the surface water receptor and therefore a maximum adjustment factor of 0.01 was adopted. When applied to the initiating frequency and taking into account the already reduced risk of a significant subsurface source being generated, the overall adjustment along this pathway was reduced by a factor of 200 (i.e. the risk of a significant environmental impact at the surface water receptor from that event within that compartment was estimated to be 200 times lower than indicated by the unmitigated risk frequency).

In addition to the numerical calculations based on contaminant fate and transport, the risks following a release to secondary containment also considered the site setting and likelihood that even if product reached groundwater there would still be time (based on groundwater velocities) to attempt to recover/remediate the resultant plume of product. In this case it was assumed that a remedial approach would have a 50 per cent chance of being effective in minimising the subsequent risk of a major accident to the environment.

Overall reduction factors for this single major accident scenario at the site ranged from just 2 where a tank was close to a receptor and contained a gasoline component which only enabled an emergency response factor to be considered through to more than 1×10^5 for a remote crude tank where the chance of ground penetration and subsequent simulation of migration of dissolved phase constituents was assessed as being unlikely to result in detectable contamination at the sensitive down gradient receptor.

In addition to the numerical assessment there was also consideration of the bunding type, presence of tertiary containment, product toxicity/mobility, etc as part of the mitigation approach. Those bunds which were already constructed to good practice with concrete walls and floors were given further mitigation adjustments whilst those with earth floors were not. Furthermore, bunds with automated valve systems to control rain water discharge were given a mitigation adjustment whilst manually operated valves were not.

For the tank floor release scenario a range of additional calculations were completed to help understand how the failure might evolve and the resultant flux of product which could go undetected through the base of the tank. As with the assessment of release to secondary containment this assessment made use of site specific parameters which could be used to calculate penetration rates through the unsaturated zone which could be compared with tank inspection schedules to assess whether a leak could be identified and remediated prior to the product reaching groundwater. Where the product could reach the groundwater the extent of spreading was assessed and used as a source term for fate and transport modelling in a similar way as the release into secondary containment described above. In some instances where the flux rate was greater than the ground's capacity to absorb the product the calculations indicated that breakthrough at the ground surface might occur – facilitating the chance to apply remedial work much more quickly than where product movement from the tank would potentially go unnoticed for a long period of time. This assessment was only completed in areas of the site where there was unlikely to be short-circuiting pathways, such as faults in the bedrock which could increase the migration rates.

For each of the remaining scenarios a similar approach was adopted – making use of environmental modelling where appropriate to assess the likelihood of a significant concentration of a contaminant reaching the receptors around the site. At this stage in the assessment there was no need to consider the extent of an impact at the receptor (or change the receptor) as the mitigation resulted in sufficient reduction in risk to make this step unnecessary. If required though, it would be possible to use the model outputs to estimate aspects such as time to impact, width of plumes affecting surface waters, mass flux, etc which could then be used to calculate an environmental harm index (EHI). This in turn would assist in generating an evaluation of the level of impact or help support an assessment of area/length of impact in-line with the CDOIF guidance. In many instances at the case study site this may have resulted in the accident scenarios being considered to have an implausible potential to result in a major accident hazard to the environment. This type of receptor focussed assessment was considered to fit better with a demonstration of TifALARP rather than being used to reduce the calculated risk to the lowest possible numerical value and was kept as a negotiating tool during discussions with the regulator.

For scenarios resulting in a release of liquid which could flow over the land surface – for instance following a bund failure – a digital elevation model (DEM) of the site was used together with oil spill modelling tools to estimate the flow direction and ultimate end point of the liquid. Analysis of the flow route was then used to assess whether additional bunds were intersected which could provide further containment, whether the tertiary drainage system was intersected and whether, in any case, the product would end up at a location where product recovery could be effective, thereby reducing the potential for a significant environmental impact. Mitigation adjustment factors were then derived qualitatively based on the information generated.

Fire water addition followed a similar process but took due account of the flammability of the product and therefore the likelihood that fire water/quench water would be added following a release.

Once each scenario had been assessed to an appropriate level the effect of all the mitigation elements were factored in to the unmitigated risk frequencies and a mitigated risk contribution figure was generated as shown in **Figure 12**.

In the case study example the application of a wide range of environmental mitigation assessments resulted in a reduction in assessed risk from intolerable at the site to tifALARP, thus providing the basis for demonstrating a case to the site's regulator that sufficient measures are already in place to manage the risk of a major accident to the environment.

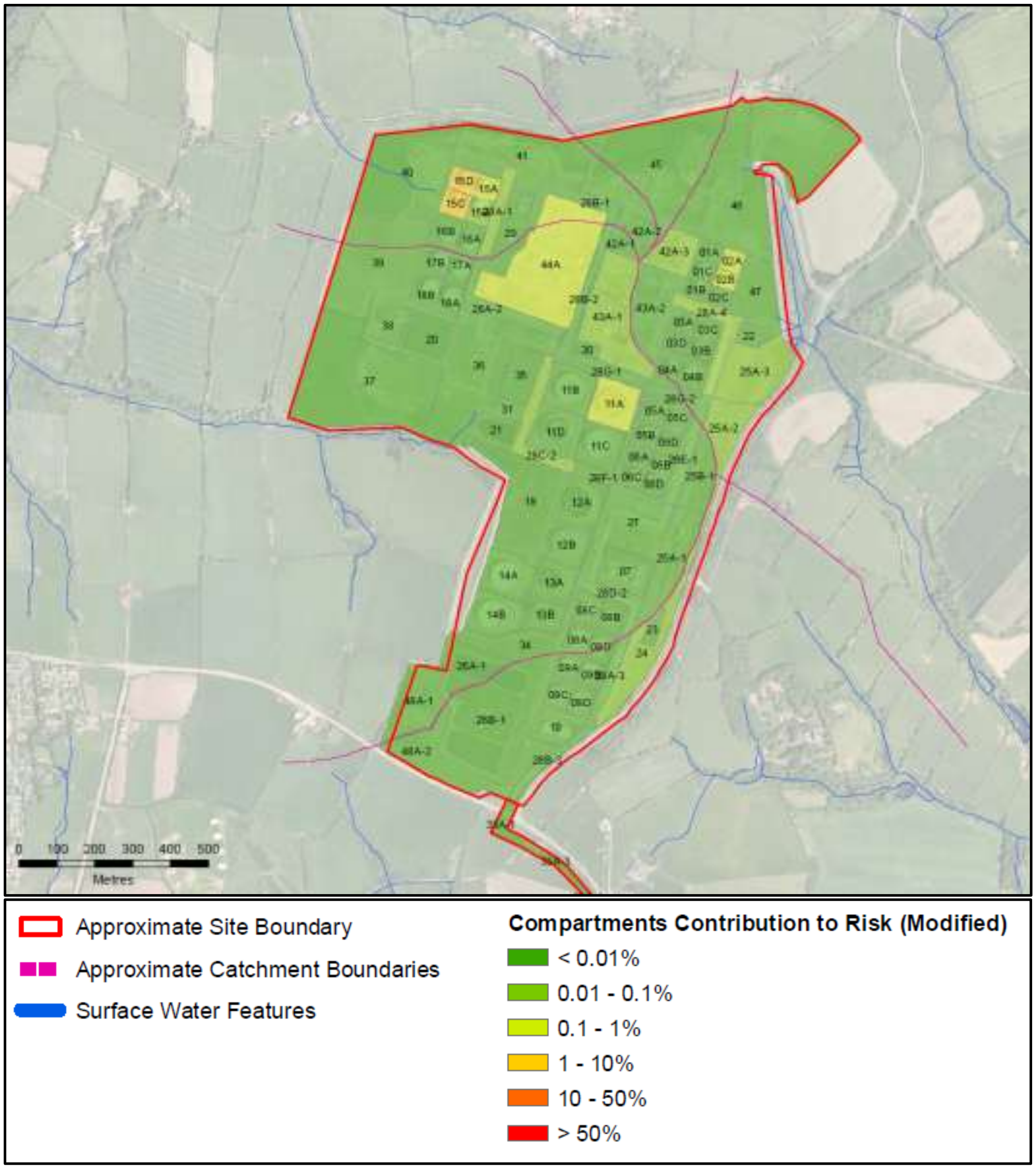


Figure 12 – Mitigated Risk Contribution as a proportion of the intolerable risk frequency.

As well as the graphical representation of the final risk contribution from each compartment a tabular summary of the risk driving scenarios was developed from the accompanying spreadsheet which provided a simple numerical summary of the results for each MAS at both the unmitigated and mitigated assessment stages.

An illustration of this is provided below which assumes all MAS in each of the compartments across all of the catchments could potentially impact the same receptor– a conservative assumption which can be refined further during Stage 2 where necessary.

Table A illustrates the summing of each risk for each consequence level within each Catchment for both unmitigated and mitigated assessment stages. As there is the potential for each of the catchments to drain to the same ultimate receptor these may also be added to provide the overall establishment risk as indicated in the grand total row. The site has been split like this for ease of analysis and to help identify both the highest risk driving catchments at the site and the individual MAS which may need further consideration.

Table A – Summary MAS by Catchment (and overall Establishment) risk levels and assumed unmitigated and mitigated risk levels.

Catchment	Compartment Type	Failure Type	CDOIF MATTE Consequence Level - Unmitigated	CDOIF MATTE Consequence Level - Mitigated	Sum of Event Frequency (per year)	Sum of Mitigated Event Frequency (per year)	Overall Mitigation Factor (summed)
A	Process	Overfill, CTF and PF to Secondary Containment	A	A	3.87E-03	4.02E-06	962
	Storage	Bund Failure	B	A	8.37E-05	1.63E-06	51
	Storage	Fire	B	A	2.08E-06	3.93E-09	527
	Storage	Fire Water resulting in Release to Ground	B	A	8.37E-05	5.77E-07	145
	Storage	Overfill, CTF and PF to Secondary Containment	B	A	8.37E-05	4.97E-08	1684
	Storage	Tank Floor Failure	B	A	6.00E-03	9.02E-05	67
	Transfer	Overfill, CTF and PF to Secondary Containment	A	A	3.61E-03	1.35E-05	266
A Total					1.37E-02	1.10E-04	125
C	Process	Overfill, CTF and PF to Secondary Containment	A	A	4.74E-03	4.93E-08	96154
	Storage	Bund Failure	B	A	4.16E-05	1.38E-06	30
	Storage	Fire	B	A	7.98E-07	2.40E-08	33
	Storage	Fire Water resulting in Release to Ground	B	A	4.16E-05	8.53E-07	49
	Storage	Overfill, CTF and PF to Secondary Containment	B	A	4.16E-05	1.08E-06	38
	Storage	Tank Floor Failure	B	A	3.00E-03	5.27E-04	6
C Total					7.86E-03	5.30E-04	15
D	Process	H2S Release	A	A	2.43E-04	1.22E-06	200
	Process	HF Release	A	A	7.80E-05	3.90E-07	200
	Process	Overfill, CTF and PF to Secondary Containment	A	A	1.65E-02	2.49E-05	661
	Storage	Bund Failure	B	A	1.78E-04	4.61E-07	387
	Storage	Fire	B	A	1.30E-06	7.03E-10	1845
	Storage	Fire Water resulting in Release to Ground	B	A	1.78E-04	6.77E-08	2632
	Storage	Overfill, CTF and PF to Secondary Containment	B	A	1.78E-04	1.83E-07	974
	Storage	Tank Floor Failure	B	A	1.30E-02	1.48E-05	877
	Transfer	Overfill, CTF and PF to Secondary Containment	A	A	1.09E-01	1.03E-05	10534
D Total					1.39E-01	5.24E-05	2654
E	Storage	Bund Failure	B	A	4.10E-05	1.43E-09	28571
	Storage	Fire	B	A	1.50E-07	7.76E-12	19334
	Storage	Fire Water resulting in Release to Ground	B	A	4.10E-05	3.55E-10	115385
	Storage	Overfill, CTF and PF to Secondary Containment	B	A	4.10E-05	2.12E-09	19334
	Storage	Tank Floor Failure	B	A	3.00E-03	3.08E-06	976
	Transfer	Overfill, CTF and PF to Secondary Containment	A	A	2.23E-03	8.03E-06	277
E Total					5.35E-03	1.11E-05	482
F	Transfer	Handarm Failure	B	B	1.22E-02	3.05E-03	4
	Transfer	Overfill, CTF and PF to Secondary Containment	A	A	8.40E-06	4.20E-06	2
F Total					1.22E-02	3.06E-03	4
Grand Total					1.78E-01	3.76E-03	47

Table B below is a summary of the information in the above table and provides summed risk levels for each catchment by consequence level.

Table B – Summary of MAS risk levels by Catchment

Catchment	CDOIF MATTE Consequence Level - Unmitigated	CDOIF MATTE Consequence Level - Mitigated	Sum of Unmitigated Event Frequency (per year)	Sum of Mitigated Event Frequency (per year)
A	A+B	A	1.37E-02	1.10E-04
	B	-	6.25E-03	-
C	A+B	A	7.86E-03	5.30E-04
	B	-	3.13E-03	-
D	A+B	A	1.39E-01	5.24E-05
	B	-	1.35E-02	-
E	A+B	A	5.35E-03	1.11E-05
	B	-	3.12E-03	-
F	A+B	A+B	1.22E-02	3.06E-03
	B	B	1.22E-02	3.06E-03
Grand Total			**1.78E-01**	**3.76E-03**

Note: Catchment B is adminsitration only with no significant MAS with MATTE potential identified

Table C below has then been used to plot the results for each compartment and for the establishment as a whole in line with the CDOIF guidance. These results are also represented graphically in the GIS figures provided earlier. The results in this format clearly indicate those catchments which drive the overall establishment risk and which will require further consideration (i.e. the jetty).

Table C - Results plotted on Unmitigated and Mitigated Matrix for individual Catchments (Grouped by MAS) and Establishment as a whole (X)

	Frequency per establishment per receptor per year (Unmitigated)						
Frequency at which CDOIF Consequence Level is equalled or exceeded	10^{-8} - 10^{-7}	10^{-7} - 10^{-6}	10^{-6} - 10^{-5}	10^{-5} - 10^{-4}	10^{-4} - 10^{-3}	10^{-3} - 10^{-2}	>10^{-2}
D - MATTE							
C - MATTE							
B - MATTE						A, C, E	D, F, **X**
A - MATTE						C, E	A, D, **F, X**
Sub MATTE	Tolerability not considered by CDOIF						

	Frequency per establishment per receptor per year (Mitigated)						
Frequency at which CDOIF Consequence Level is equalled or exceeded	10^{-8} - 10^{-7}	10^{-7} - 10^{-6}	10^{-6} - 10^{-5}	10^{-5} - 10^{-4}	10^{-4} - 10^{-3}	10^{-3} - 10^{-2}	>10^{-2}
D - MATTE							
C - MATTE							
B - MATTE						F, **X**	
A - MATTE				D, E	A, C	F, **X**	
Sub MATTE	Tolerability not considered by CDOIF						

Leters denote risks for catchments

X indicates overall Establishment risk assuming the same ultimate receptor for the Surface Water environment

(green)	Broadly Acceptable
(yellow)	TifALARP
(red)	Intolerable