Environmental Risk Assessment: Streamlining CDOIF Guideline

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Abstract: The UK COMAH (Control of Major Accident Hazards) 2015 Regulations (implementing the EU Seveso 3 Directive - 2012/18/EU) requires the assessment of Major Accidents to the Environment (MATTE) and a demonstration that the risks to sensitive receptors are reduced ALARP As Low As Reasonably Practicable). The CDOIF (Chemical and Downstream Oil Industries Forum) Guideline 'Environmental Risk Tolerability for COMAH Establishments' describes a method for the assessment which is acceptable to the Competent Authority. The CDOIF Guideline requires consideration of a wide range of receptors over nine different categories covering land, water, air and man-made environments out to a radius of 10km from the site and further where viable pathways exist (e.g. long distance tidal or river movements). Due to the large area under consideration and the wide range of 'environmental' receptors to consider it is likely that most assessments require the evaluation of a large number of receptors combined with a number of scenarios. When completing all the tables specified in the Guideline, the large number of scenarios leads to considerable, repetitive analysis to demonstrate robust screening out of receptors and justification of a short-listed suite of screened in receptors where there is the potential for a MATTE and further analysis is required.

This paper describes an approach to the assessment which uses the benefits of available data and site visits to confirm the environmental baseline, information held within Upper Tier COMAH Safety Reports or the Lower Tier COMAH Major Accident Prevention Policy, the use of GIS (Geographic Information System) technology, Python scripting, and a series of spreadsheets to carry out a semi-autonomous assessment, at least to the stage of screening and scoping specific scenarios for detailed assessment. This is believed to significantly reduce the risk of error from repeated manual data input, increasing processing efficiency. The method has been applied to 8 upper tier COMAH sites and is being rolled out for over 20 lower tier sites. The sites handle similar materials so there is a major advantage in standardising the approach. This approach is seen as being of interest to other operators and the Competent Authority.

Keywords: Seveso, COMAH, CDOIF, MATTE, Environmental Risk Assessment, GIS, Python

Introduction

Regulation and Guidance

The EU Seveso 3 Directive (EU 2012) requires operators of facilities storing or handling quantities of hazardous materials above the specified thresholds to identify potential major accidents and evaluate their consequences on people and the environment (Article 10 – 1 b and Annex II -4). There is a further requirement to demonstrate that "all measures necessary" have been adopted to prevent the occurrence of major accidents and to mitigate the effects of any that might occur (Article 5 – 2). In the UK these aspects of the Directive are implemented by the COMAH Regulations 2015. Specific guidance on the demonstration for Major Accidents to the Environment (MATTE) is provided in CDOIF (Chemical and Downstream Oil Industries Forum) 2016 with a framework on how the CA should undertake its formal review of the safety report and its processes being available within the Safety Report Assessment Manual (SRAM, 2015).

Previous Work

The work involved in following the CDOIF Guidelines can be onerous, CDOIF describes the steps involved but does not give full details of how all potential receptors may be assessed, focusing on only one in the initial screening. (undated example). The CDOIF example proposes a partial reverse of the process 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". There is a problem in establishing which may be "most significant" where receptors may be susceptible to different releases of various materials, transported by different pathways. It is clearly important to establish "Source-Pathway-Receptor" (SPR) trios at an early stage.

Based on CDOIF Guidance and examples of previous studies (Nicholas, et al, 2014; Baker et al, 2015; Manton, et al, 2016; and Graham, 2017), the process is defined as:

1. Identifying Receptors that could be affected by a major accident, normally those in Categories defined in CDOIF (2016) or DETR (1999) within 10 km of the site, or further if there is a pathway such as water (surface streams, groundwater flow or tidal waters);
2. Identify major accident scenarios that could give rise to significant harm to the environment, considering scenarios that are already included in the Safety Report for harm to people and any additional possible releases that have no immediate direct harm to people;
3. Defining the extent and severity of effects for each unmitigated major accident scenario, at threshold of harm, clearly some receptors will be outside the range of some or all scenarios;

4. Check receptors within range for area affected above the threshold, some will be sub-MATTE;
5. Consider duration of effects of harm, in combination with severity, some SPRs will be ruled out if duration is short;
6. Consider frequency of scenarios and sum all those affecting each receptor at each level of MATTE
7. Compare frequency of harm to receptors with Tolerability Criteria with no mitigation in place, some receptors will be below the thresholds of concern and not require further consideration.
8. For receptors and scenarios that have not been ruled out above the steps 2-7 need to be reconsidered with the effects of the mitigation in place which may reduce severity / extent of effects, the frequency of the release, or duration of harm.

Information on receptors is generally available online in GIS format. Scenarios are identified either from the Safety Report (Upper Tier -UT COMAH) or the documents supporting the MAPP (Major Accident Prevention Policy) (Lower Tier -LT COMAH) supplemented with additional scenarios where no direct harm to people arises but have potential to affect environmental receptors. Consequence analysis results are taken from the Safety Report or equivalent, supplemented by additional modelling if required to define the extent and effects levels from a release in at least two representative weather conditions. Data on sources, modelling and receptors is entered on separate worksheets. There are also worksheets for standard information, such as failure frequencies, thresholds of harm etc. The risk assessment is carried out in a series of worksheets corresponding to the tables in CDOIF which are populated automatically from the python scripting and data worksheets. Many source receptor pairs will show “No Pathway” or “Severity Level 1: Significant Harm: Major Accident To The Environment - MATTE WOULD NOT OCCUR.” Others would cause harm for only short duration and not require further consideration. Further worksheets show the frequency of scenarios affecting receptors and the total frequency at which each receptor is affected by all scenarios. CDOIF gives frequency thresholds for different severities of harm and these are used to provide the final screening and conclusions on ALARP (As Low As Reasonably Practicable).

This paper considers how these steps may be automated and streamlined so that any remaining analysis and discussion of potential/likely impacts and improvements can be focussed on the receptors of most concern and the prevention / mitigation of those scenarios impacting them.

Data Requirements

Environmental Receptors and Pathways

Information on the location, character and surface area of environmental receptors and pathways for the UK is freely available from the Spatial Data Catalogue on data.gov.uk, these are held in a format already suitable for use in GIS. Other data may need to be obtained and digitised through review of other internet based sources e.g. aerial imagery using Google Earth Pro, OS Open Data, soil mapping using the Soilscape Viewer from the National Soil Resources Institute as well as published materials on local/regional environmental characteristics such as Environment Agency R&D reports (see Appendix 3 of CDOIF 2016 for an initial list).

Often, some consultation will be required to help provide guidance on less obvious CDOIF environmental receptors and pathways, which can then be digitised on GIS. For example, the routing and destination of surface water and combined sewer drainage from a Site needs to be traced and understood to help define the fate and behaviour of spillages of liquid hazardous materials (e.g. fuels). This is a key consideration to clarify the potential for more remote effects (e.g. presence of storm outfalls and/or pumping stations that could result in a previously undetected riverine receptor needing to be considered e.g. the location and type of water treatment works and how this might be affected, where the spillage discharges to with the potential for untreated sewage also being released).

A site visit is essential to both verify the desk based definition of the environmental receptors and pathways, together with an opportunity to gather information on potential pathways/receptors unavailable from any other source (e.g. the presence of features that could support legally protected species). Such information can then be digitised and added to the GIS.

These sources in combination allow for a comprehensive and robust structure of environmental receptors and their respective pathways to be built and represented in a GIS environment.

Python Scripting

Once both the comprehensive set of environmental data and site scenario modelling have been compiled in GIS, and completed in Excel respectively; it is possible to build an interface between the two using the Python scripting language. This is made possible through ArcGIS integrated Python module: ArcPy (see www.pro.arcgis.com)

The modelling of scenarios for each site identifies a set of possible hazards and their theoretical maximum (unmitigated) area of impact, the on-site mitigation for each of these hazards, and the corresponding effect on the area or extent of each impact. The output of this modelling can be held in a machine-readable format and in turn be read by Python scripts to inform the operation of GIS analytics.

Each individual interaction between the impacts of a particular hazard and environmental receptor can be distilled into an “if-then-else” statement whose complexity varies by the number of alternatives or mitigation scenarios that need to be considered. This allows a series of GIS buffers and extents to be automatically modelled around the site-specific results – bridging the gap between Excel and GIS based models.

Consequence Analysis

There will be different types of major accident consequences that may cause harm to the identified receptors. Typical consequence types are shown in Table 1. Some consequences will not cause harm to certain types of CDOIF receptors, for example fires and explosions will not affect ground water, nor the species living in water.

Table 1 Example Thresholds for Significant Impacts – Consequence Levels

Designation (CDOIF)	Fire	Overpressure	Airborne Toxic	Toxic Liquids
1. Land-National	LFL/1000tdu/12.5kWm^{-2}	100mbar trees	NOEL	NOEL
1. Water-National	None	None	NOEL	NOEL
2. Land-International	LFL/1000tdu/12.5kWm^{-2}	100mbar trees	NOEL	NOEL
2. Water-International	None	None	NOEL	NOEL
3. Land-Other	LFL/1000tdu/12.5kWm^{-2}	100mbar trees	NOEL	NOEL
4. Land-Scarce/Urban	LFL/1000tdu/12.5kWm^{-2}	100mbar trees	NOEL	NOEL
5. Land-Widespread	LFL/1000tdu/12.5kWm^{-2}	100mbar trees	NOEL	NOEL
6. Water-Widespread	None	None	NOEL	NOEL
7. Ground Water Drinking	None	None	NOEL	NOEL
8. Ground Water Not Drinking	None	None	NOEL	NOEL
9. Groundwater Unproductive	None	None	NOEL	NOEL
10. Soil/Sediment (receiver)	None	None	NOEL	NOEL
11. Built Environment	14.7 kW/m^2	100 mbar	None	None
12. NOT USED	-	-		
13. Particular species	LFL/1000tdu/12.5kWm^{-2}	100mbar trees	NOEL	NOEL
14. Marine	None	None	NOEL	NOEL
15. Fresh & estuarine water habitats	None	None	NOEL	NOEL

LFL – Lower Flammable Limit – assumed extent of Flash Fire

tdu – Thermal Dose Units – for fireballs – units (kW/m^2)$^{4/3}$ seconds

kW/m^2 kiloWatts per m^2 – Thermal Radiation Flux – for jet fires, pool fires

mbar – millibar – peak overpressure – overpressure from explosions / VCEs (deflagration)

NOEL – No Observable Effects Level for toxics – ingestion route needs to be specified.

Conventional major accident consequence models are used to calculate the extent of flammable or toxic vapour clouds, and distances to thermal radiation fluxes or doses for various types of fire. Toxic liquid releases may percolate to ground water, flow along artificial or natural surface water channels to affect streams, rivers, fresh water lakes, estuaries and adjacent marine areas.

Failure Frequency Data

Simple loss of containment data are used to define the frequency of scenarios. Wherever possible HSE Frequencies published for use in Land Use Planning assessments are adopted (HSE PCAG chp_6K Version 12 – 28/06/12). Account is taken of the number of items of equipment or length of pipework that could give rise to a release.

Duration of Harm

It is difficult to find comprehensive data on the time taken for the various type of receptor to recover to the pre-accident state. Qualitative estimates have been used based on the life cycle of affected fauna and flora or the ability for populations to migrate into affected areas and the data in CDOIF Appendix 4. For example, mature woodland may take decades to recover in the event of tree deaths due to fire/explosion or toxic effects, but grassland is likely to recover in a matter of months, heathland in a year or two. Populations in water bodies could also be expected to recover rapidly unless the ecosystem is contained, and reproduction is significantly affected, and populations therefore have a long recovery time. The built environment recovery time is the time to rebuild, varying from a few weeks for minor damage to years for major repair to complex structures. The thresholds given in Table 4.2 of CDOIF (2016) reflect these different recovery times.

CDOIF Tables

The CDOIF tables (Appendix 5 in CDOIF) can be completed from the above information and the details in CDOIF Appendix 4 tables.

CDOIF Table 5.1 MATTE Potential Summary

It has been found more useful to use Scenarios as the column headings rather than a single column for each substance as some substances have the potential for harm by various routes due to different hazards that may arise (fire, explosion, toxic release, and more). However, it is necessary to define the threshold hazard consequence level to cause significant harm for each hazardous outcome. A partial list of substances and thresholds of harmful effects for a site is shown in Table 2.

Table 2: Potential Harmful Effect Thresholds

Notes: N - No effects offsite (quantity too small) X - Hazard not present NOEL - No Observable Effects Level

Substance	Fire	Explosion	Air-borne Dispersion	Water Transport	Accumulation
Liquefied Petroleum Gas	14.7 kW/m^2 buildings 1000 tdu fauna & flora 12.5 kW/m^2 vegetation	100 mbar Buildings & Trees	LFL Buildings LFL Vegetation	X	Low Potential
Methanol	N	N	N	NOEL	None known
Paint (includes Xylene)	N	N	N	NOEL	Low Potential
Diesel / Gas Oil	12.5 kW/m^2 vegetation	N	N	NOEL	Possible
Potentially Contaminated Firewater	X	X	N	NOEL	Depends upon contaminants

The table is not implying that fire is not possible for methanol, xylene and diesel but in this case the quantities are small and the geometry of the site such that there are no direct effects. Drainage may take the substances into water courses and soil / groundwater beneath the site.

The thresholds define the end points for the consequence modelling so that the possible areas affected can be compared with the criteria published in CDOIF Appendix 4 Table 4.1.

This process of assigning harmful thresholds relies upon the hazardous properties of the substances present, which is the subject of CDOIF Table 5.4 which appears to be out of sequence. The information on environmental risk for each substance is required to identify whether it has hazardous properties which could harm the receptors above the threshold.

CDOIF Table 5.2 Receptor Detail

This requires listing the receptors that could be within range of any unmitigated releases. The area of interest is typically 10 km and this can be extended if there are pathways such as water courses or tidal waters where any contaminants can be transported large distances without dilution below the NOEL. Equally, in the absence of any liquid releases, it may be possible to reduce this assessment area. In order to automate the assessment of MATTE potential (comparing the potential effects with criteria in CDOIF Table 4.1), the data is collected in GIS format. Table 3 indicates the type of data used.

Table 3 Identification of Receptors (Excerpt from a full table)

DETR 1999	(Locations Defined in GIS files)		
Table 1	**Designated Land/ Water Sites (Nationally Important):**		
		Designation	**Description/GIS Details**
	Water	**MCZ - 1**	**Yarmouth to Cowes**
		SSSI - W 1	**The New Forest**
		SSSI - W 2	**Lee-on-the-Solent to Itchen Estuary**
	Land	**SSSI - L1**	**The New Forest**
		SSSI - L2	**Lee-on-the-Solent to Itchen Estuary**
		NNR - L1	**North Solent**
Table 2	**Designated Land/ Water Sites (Internationally Important):**		
		Designation	**Description**
	Water	**SPA - W1**	**The New Forest**
		SPA - W2	**Solent Maritime**
	Land	**SAC - L1**	**The New Forest**
		SAC - L2	**Solent & Southampton Water**
		RAM – L1	**The New Forest**
		RAM – L2	**Solent & Southampton Water**

Table 3 is an extract from a large amount of data covering the 12 DETR categories (split into 15 for CDOIF) each of which may cover sites with different designations.

CDOIF Table 5.3 MATTE Scenarios

Accidental releases are identified for every major accident substance on the site, but some may be present in small quantities which cannot affect receptors off-site. These may be eliminated from further consideration (‘screened out’) as in Table 2 above. However, some substances may have the potential for releases from different locations, in different quantities or give rise to a range of hazards. Therefore, it may be necessary to specify several scenarios for each substance. For each scenario we have calculated the distance to the specified effect level from Table 1 but in the case of liquids dangerous to the environment the total potential area of water surface or length of channel that could be affected at the NOEL has to be calculated to assess the impact. If the pathway from source to receptor involves flammable or toxic gas cloud dispersion, then both average weather and adverse weather (Poor dispersion) conditions are considered. A partial scenario listing is shown in Table 4:

Through Python scripting it is possible to create an interface between the results of the consequence modelling and ArcGIS – this allows for the comprehensive application of spatial analytics in GIS to be informed by the results of the consequence modelling on a site by site basis. This in turn produces an output that can be used to identify and inform the subsequent stages of the risk assessment. It is then possible to automatically generate a table showing the scenarios with potential for causing a MATTE based on the area affected by consequences above the threshold.

Table 4 Scenarios Representing Potential MATTEs (extract of full list)

Scenario	LPG Fire & Explosion			LFL	0.5 LFL	1000 tdu	$14.7kWm^{-2}$	100mbar
A1	Flash Fire LFL and 0.5 LFL	LPG vessel 100% propane and at 7.6barg and 15 °C respectively.	5D	333m	476m			
			2F	552m	770m			
A2	Fireball 1000 tdu	BLEVE fireball thermal flux and explosion hazards. Fireball mass 87% inventory				145m		
A3	Jet Fire $14.7kW/m^2$ (Horizontal)	Transfer line hose rupture,.					90m	
A4	PRV (Vertical) $14.7kW/m^2$	Single PRV lifting light					60m	
A5	VCE 100 mbar	Strehlow Baker method used to calculate overpressure from ignition of DVC	5D					428m
			2F					607m
B1 -B5	**Bulk Butane**	As for Propane above						
	Diesel			Area Affected				
C1	Pool spread on land - Thermal	1 cm minimum depth Diameter of pool on land		50 m diameter				
C2	Release from surface water drain outfall	Maximum area assuming minimum depth of 1mm		$20000 m^2$				
C3	Release to foul water drain outfall / wwtw	Maximum area assuming minimum depth of 5mm		$4000 m^2$				

Table 5. Area of receptors above threshold of harm (abstract with most lines hidden)

Receptor area affected by hazards - unmitigated									
		LPG Fire & Explosion					Diesel Contamination		
Site Ref	Site Area	A1	A2	A3	A4	A5	C1	C2	C3
Designated Land/ Water Sites (Nationally Important):									
MCZ - 1	1689	0	0	0	0	0	0	0	0
SSSI - 2	591	0	0	0	0	0	0	591	0
SSSI - 9	28924	12.91	1.9	0.2	0	12.91	0	0	0
SSSI - 10	585	0	0	0	0	0	0	424	0
NNR - 1	894	0	0	0	0	0	0	0	0
Designated Land/ Water Sites (Internationally Important):									
SPA - 2	5401	0	0	0	0	0	0	1152	0
SAC - 2	11243	0	0	0	0	0	0	874	0
RAM - 2	5306	0	0	0	0	0	0	1051	0
Other designated land (ESA's, AONB's LNRs, NSA's etc)									
LNR - 1	51	0	0	0	0	0	0	51	0
LNR - 2	13	0	0	0	0	0	0	13	0
LNR - 5	20	0	0	0	0	0	0	20	0
LNR - 8	252	0	0	0	0	0	0	137	0
LNR - 9	144	0	0	0	0	0	0	5	0
Scarce Habitat / Urban LBAP Habitats									
BAP - 1		72.31	10.13	5.1	2.93	61.9	0	0	0
BAP - 2		1.38	0	0	0	1.38	0	0	0
BAP - 3		2.04	0.33	0	0	2.04	0	0	0
BAP - 5		3.65	1.34	0.42	0.11	3.65	0	0	0
BAP - 6		1.71	0	0	0	0	0	10.6	0
BAP - 7		0	0	0	0	0	0	115	0
BAP - 8		0	0	0	0	0	0	216	0
BAP - 9		0	0	0	0	0	0	2.17	0
BAP - 10		0	0	0	0	0	0	863	0
BAP - 11		0	0	0	0	0	0	5.14	0

Results of the Risk Assessment

Using the data held in the GIS, it is straightforward to accurately calculate the area of any receptors that is located above the threshold of harm. This is shown in Table 5 which then feeds into Table 6.

Table 6. Severity of harm for different receptors - unmitigated - before considering duration (extract from analysis)

Severity of harm - unmitigated - before considering duration									
		LPG Fire & Explosion					Diesel Contamination		
Site Ref	Site Area	A1	A2	A3	A4	A5	C1	C2	C3
Designated Land/ Water Sites (Nationally Important):									
MCZ - 1	1689	0	0	0	0	0	0	0	0
SSSI - 2	591	0	0	0	0	0	0	3	0
SSSI - 9	28924	2	2	1	0	2	0	0	0
SSSI - 10	585	0	0	0	0	0	0	3	0
NNR - 1	894	0	0	0	0	0	0	0	0
Designated Land/ Water Sites (Internationally Important):									
SPA - 2	5401	0	0	0	0	0	0	2	0
SAC - 2	11243	0	0	0	0	0	0	2	0
RAM - 2	5306	0	0	0	0	0	0	2	0
Other designated land (ESA's, AONB's LNRs, NSA's etc)									
LNR - 1	51	0	0	0	0	0	0	3	0
LNR - 2	13	0	0	0	0	0	0	3	0
LNR - 5	20	0	0	0	0	0	0	3	0
LNR - 8	252	0	0	0	0	0	0	3	0
LNR - 9	144	0	0	0	0	0	0	1	0
Scarce Habitat / Urban LBAP Habitats									
BAP - 1		3	2	2	2	3	0	0	0
BAP - 2		1	0	0	0	1	0	0	0
BAP - 3		2	1	0	0	2	0	0	0
BAP - 5		2	1	1	1	2	0	0	0
BAP - 6		1	0	0	0	0	0	2	0
BAP - 7		0	0	0	0	0	0	3	0
BAP - 8		0	0	0	0	0	0	3	0
BAP - 9		0	0	0	0	0	0	2	0
BAP - 10		0	0	0	0	0	0	3	0
BAP - 11		0	0	0	0	0	0	2	0

Table 7. Severity of effects considering duration of harm (extract from analysis)

Duration of harm - unmitigated									
		LPG Fire & Explosion					Diesel Contamination		
Site Ref	Site Area	A1	A2	A3	A4	A5	C1	C2	C3
Designated Land/ Water Sites (Nationally Important):									
MCZ - 1	1689								
SSSI - 2	591							2	
SSSI - 9	28924	1	1	1		1			
SSSI - 10	585							2	
NNR - 1	894								
Designated Land/ Water Sites (Internationally Important):									
SPA - 2	5401							2	
SAC - 2	11243							2	
RAM - 2	5306							2	
Other designated land (ESA's, AONB's LNRs, NSA's etc)									
LNR - 1	51							2	
LNR - 2	13							2	
LNR - 5	20							2	
LNR - 8	252							2	
LNR - 9	144							2	
Scarce Habitat / Urban LBAP Habitats									
BAP - 1		1	1	1	1	1			
BAP - 2		1				1			
BAP - 3		1	1			1			
BAP - 5		1	1	1	1	1			
BAP - 6		1						2	
BAP - 7								2	
BAP - 8								2	
BAP - 9								2	
BAP - 10								2	
BAP - 11								2	

Table 5 is used to determine whether the thresholds in CDOIF Table 4.1 are exceeded for each scenario on each receptor to be categorised in the CDOIF levels 0 (No Pathway) to 4 (Catastrophic) depending upon the area of the receptor affected above the threshold of harm in Table 6.

Many receptors will be too far away from the sources or there is no pathway by which harm can arise. However, for those remaining the above Table 6 shows a range of potential severities if the receptor can be damaged for a significant time. CDOIF table 4.2 gives criteria for harm duration categories 1 to 4, which in combination with the Severity Level in Table 6 above are used to define the level of MATTE (sub-MATTE or A to D) according to Table 4.3 in CDOIF. So, the final severity of effects on each receptor for each scenario can be determined as shown in Table 7, calculated in worksheets from the definition of CDOIF Categories A – D in CDOIF Table 4.3 from the calculated severity Table 6 and duration assumptions specify the category of duration of harm or recovery time based on the category thresholds given in CDOIF Table 4.2.

Figure 1 illustrates a GIS output showing the installation being assessed, the location of various receptors and buffers relating to different levels of environmental harm. The GIS accurately calculates the areas of each receptor within each harm threshold and enters this into the assessment database.

Figure 1. GIS Output showing coincidence of receptors and two levels of harm (black dotted lines)

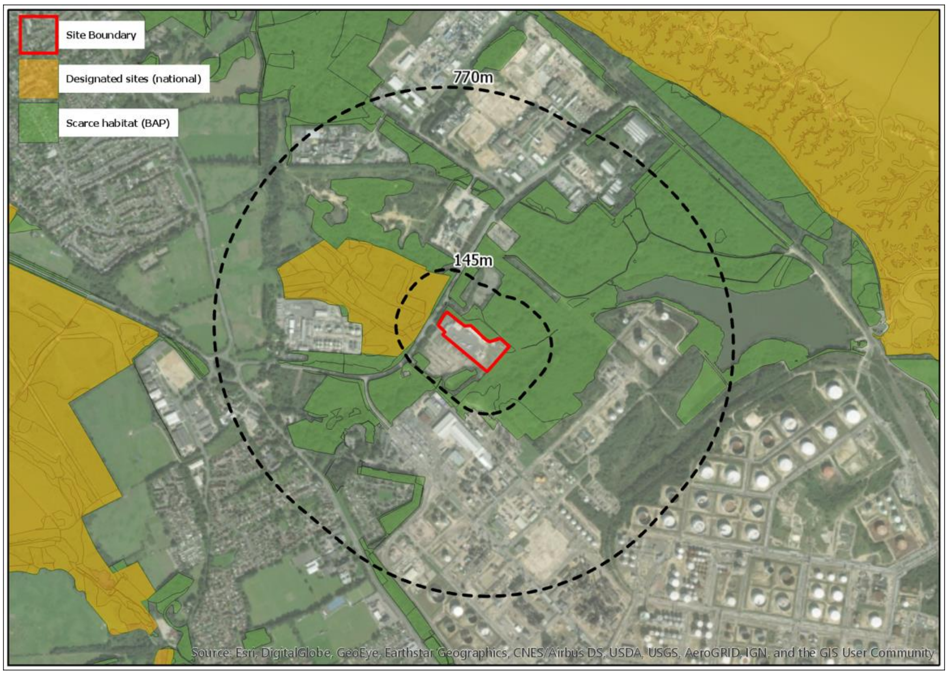

Table 8 illustrates the next stage in the process where receptor tolerability is considered.

Loss of containment frequencies for each of the scenarios in Table 6, have been taken from standard sources (e.g. HSE 2012) or the site Safety Report. Probabilities of ignition are included in the unmitigated calculations to allow the range of outcomes to occur (early ignition jet / pool fire, late ignition flash fire/explosion). The probability of wind direction and weather conditions has not been included in the unmitigated calculation. In some cases, only a single scenario affects a receptor but in others one receptor is affected by several scenarios. The frequency of a particular harm category for each receptor is found by summing the frequency of that harm category for all the scenarios (i.e. across the rows in Table 6). The cumulative frequency of harm (e.g. category or worse is then found).

This can be summarised in a final table for the unmitigated environmental risk assessment in the form of Table 9.

Table 8. Tolerability of harm for different receptors

Receptor tolerability of risk of harm - unmitigated									
		LPG Fire & Explosion					Diesel Contamination		
Site Ref	**Site Area**	**A1**	**A2**	**A3**	**A4**	**A5**	**C1**	**C2**	**C3**
Designated Sites (Nationally Important):									
MCZ - 1	1689								
SSSI - 2	591							B	
SSSI - 9	28924	Sub-MATTE	Sub-MATTE	Sub-MATTE		Sub-MATTE			
SSSI - 10	585							B	
NNR - 1	894								
Designated Sites (Internationally Important):									
SPA - 2	5401							A	
SAC - 2	11243							A	
RAM - 2	5306							A	
Other designated land									
LNR - 1	51							B	
LNR - 2	13							B	
LNR - 5	20							B	
LNR - 8	252							B	
LNR - 9	144							Sub-MATTE	
Scarce Habitat / Urban LBAP Habitats									
BAP - 1		Sub-MATTE	Sub-MATTE	Sub-MATTE	Sub-MATTE	Sub-MATTE			
BAP - 2		Sub-MATTE				Sub-MATTE			
BAP - 3		Sub-MATTE	Sub-MATTE			Sub-MATTE			
BAP - 5		Sub-MATTE	Sub-MATTE	Sub-MATTE	Sub-MATTE	Sub-MATTE			
BAP - 6		Sub-MATTE						A	
BAP - 7								B	
BAP - 8								B	
BAP - 9								A	
BAP - 10								B	
BAP - 11								A	

Table 9 Frequency of unmitigated harm to receptors

		FREQUENCY OF HARM LEVELS				CUMULATIVE FREQUENCIES			
Nationally Designated Sites :		A	B	C	D	≥A	≥B	≥C	≥D
	MCZ-1								
	SSSI- 2			$3.2x10^{-5}$		$3.2x10^{-5}$	$3.2x10^{-5}$	$3.2x10^{-5}$	
	SSSI - 9								
	SSSI - 10		$3.2x10^{-5}$			$3.2x10^{-5}$	$3.2x10^{-5}$		
	NNR - 1								
Internationally Designated Sites:									
	SPA - 2								
	SAC - 2								
	RAM - 2								
Other Designated Land									
	LNR – 1			$3.2x10^{-5}$		$3.2x10^{-5}$	$3.2x10^{-5}$	$3.2x10^{-5}$	
	LNR - 2			$3.2x10^{-5}$		$3.2x10^{-5}$	$3.2x10^{-5}$	$3.2x10^{-5}$	
	LNR - 5			$3.2x10^{-5}$		$3.2x10^{-5}$	$3.2x10^{-5}$	$3.2x10^{-5}$	
	LNR - 9								
Scarce / Urban LBAP Habitats									
	BAP – 1 to 6								
	BAP – 7	$3.2x10^{-5}$	$3.2x10^{-5}$	$3.2x10^{-5}$		$9.6x10^{-5}$	$6.4x10^{-5}$	$3.2x10^{-5}$	
	BAP - 8	$3.2x10^{-5}$	$3.2x10^{-5}$	$3.2x10^{-5}$		$9.6x10^{-5}$	$6.4x10^{-5}$	$3.2x10^{-5}$	
	BAP - 10	$3.2x10^{-5}$	$3.2x10^{-5}$	$3.2x10^{-5}$		$9.6x10^{-5}$	$6.4x10^{-5}$	$3.2x10^{-5}$	

These results are compared with the cumulative frequencies in Table 4.3 of CDOIF, showing that SSSI 2, SSSI 10, LNR 1, LNR 2, LNR 5, BAP 9 and BAP 11 are affected by category B or C MATTEs at a frequency which is only Tolerable if ALARP (As Low As Reasonably Practicable) – TifALARP. The harm to other receptors is low enough to be considered "Broadly Acceptable" even without consideration of mitigation.

Impact of Mitigation

In this example, which is typical of those installations assessed by this method, it is possible to go back and identify the scenarios contributing to the harm for the small number of cases that are not screened out,

- From Table 8 it is clear that only the diesel spills are giving rise to severe MATTEs which require mitigation to be considered.
- It is scenario C2, failure of the bulk diesel storage and release through surface water drainage and outfall to the environment which is the major contributor to environmental risk.
- Scenarios C1, C2 and C3 are reduced in frequency due to the provision of a double skin (total double containment) diesel storage which replaces the two single skin tanks assumed in the unmitigated case), this will reduce the failure frequency by a factor of 20. Further frequency reduction is provided by the provision of bariers to prevent vehicle impact on all sides of the tank. The site includes low points that have the potential to trap and retain a proportion of the spill volume, and is provided with a surface water drainage system with interceptors to collect spills or contaminated water. The combined effect is to reduce the frequency of category B and C events on the receptors at risk down to $1.6x10^{-7}$ and the therefore the cumulative frequency of effects on the receptors are below the Category C "Broadly Acceptable" threshold.
- There is online information available to determine flow paths of surface water runoff and also to define surface topography affecting ponding of liquids

Lessons Learned

CDOIF Method

The CDOIF Method requires the development of a comprehensive environmental baseline across a large spatial area. The availability of an increasing library of opensource data and its management and mapping within a GIS provides a significant advancement that allows georeferencing of information, secure storage, effective manipulation, mapping and analysis and the ability to easily update the database.

The approach is compatible with both CDOIF as well as the SRAM process, providing data transparency and the ability to provide the CA with the data spreadsheets and GIS files if necessary.

Application

It can appear to be a time-consuming approach, disproportionate to the benefits, particularly with respect to evaluating the consequences and risks of unmitigated releases and the consideration of receptors out to a considerable distance. However, streamlining the approach gives a means of being able to document efficiently where no effects are predicted (screening out) as well as highlighting the potential harm from an establishment and the importance of barriers, whether passive or active, and their maintenance.

Using standard data sources in a GIS environment enables accurate interrogation of layers of geolocated data and analysis that also reduces the risk of human errors that otherwise would be taken forward into subsequent stages of the assessment.

The approach set out in this paper also allows the easy calculation of multiple scenarios, including sensitivity analysis without necessarily increasing the project budget.

Through the use of the GIS and spreadsheets, subsequent iterations of the worked database) e.g. as a result of changes in the configuration, or operation of the COMAH installation) can be cost effectively accommodated.

It is important to list and categorise substances early in the process and therefore the first step should be collection of the data in Table 5.4 (Appendix 5 of CDOIF 2016).

Automation of the Assessment

There can be a great deal of data to handle and it involves a repetitive process for completing the tables which is overcome with the system of linked spreadsheets. The proportion of the required data that can be downloaded in GIS format has increased considerably since the start of this work in 2015.

The EA surface water flooding data facilitates the definition of spills and waterborne contaminants' flow path.

The linked spreadsheets reduce the time required for the assessment but enable all the steps to be presented and allow the assumptions and calculations to be followed.

The scale of the assessment process is certainly daunting: the range of hazardous substances, environmental receptors, the identification of relevant pathways, and interaction with corresponding risk thresholds must all be considered in order to provide a comprehensive and robust understanding of risk associated with the storage and handling of hazardous substances.

Through the utilisation of ArcGIS and its integration with the Python scripting language through the ArcPy module it is possible to dramatically reduce the number of steps in this process that require manual user input once the Python scripting has been configured for each site.

Once the scripting has been configured and its results verified subsequent assessments simply require updating the Python script with any relevant changes to the receptors, pathways, or changes in guidance.

In summary, the use of GIS, Python scripting and spreadsheets allows an accurate assessment of the percentage area of a designated site affected below or a above a particular harm threshold without any time-consuming calculations.

Assessment of Mitigation

The scenarios requiring mitigation are readily identified using this approach.

It is straightforward to assess the effects of mitigation, either in terms of reduced consequence distances (Table 4) or reduced likelihood of releases by entering these effects of mitigation into the spreadsheets.

Questions from the Regulator

It is straightforward to test the effects of changing assumptions or making physical modifications so that a sensitivity analysis can be presented very quickly.

The steps in the calculation can be followed by tracing the use of data and intermediate results through the linked worksheets in the work book and the formulae used.

Conclusions

The method presented reduces the time and effort required for the environmental assessment of major accident risk, particularly with regard to unmitigated releases and facilitates the consideration of mitigation where required. Scenarios and receptors screened out are still visible and the reasoning is clear. The method identifies scenarios contributing to risks to each receptor so that, when risks are greater than broadly acceptable, then the areas for improved prevention or mitigation are identified.

The use of a standard approach reinforces the systematic and comprehensive nature of the CDOIF approach and enforces consistency across all the establishments considered. It is particularly useful for organisations with several similar COMAH establishments. The use of GIS and data table as described here also accords with the frame for assessing Safety Reports and their processes as defined by SRAM 2015, with data transparency being demonstrated by sharing the GIS data with the CA if required.

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