Comparing QRAs of Facility Siting and Land Use Planning

Prepared for
Canadian Chemical Engineering Conference 2025
Oct 6, 2025

Presented by
Modusser Tufail, P.Eng.,
Fire Protection Engineer
Modusser.Tufail@Strathcona.ca
Strathcona County Emergency Services (SCES)

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About Speaker

- BSc. (Pakistan) and MEng. in Chemical Engineering (UWaterloo)
- 15+ years of experience in process safety and fire protection engineering
- Professional Engineer (Alberta- Canada)
- Certified Fire Protection Specialist (NFPA)
- Certified Process Safety Professional (AIChE-CCPS)
- Member
  - National Model Code Committee Codes Canada (fire and building codes)
  - Technical Committee : CSA PSM Standard Z767
  - Executive of PSM Division CSChE under CIC

Agenda

- About Strathcona County
- Quantitative Risk Analysis (QRA)
  - QRA of Land Use Planning
  - QRA of Facility Siting
- Observations
- Conclusion

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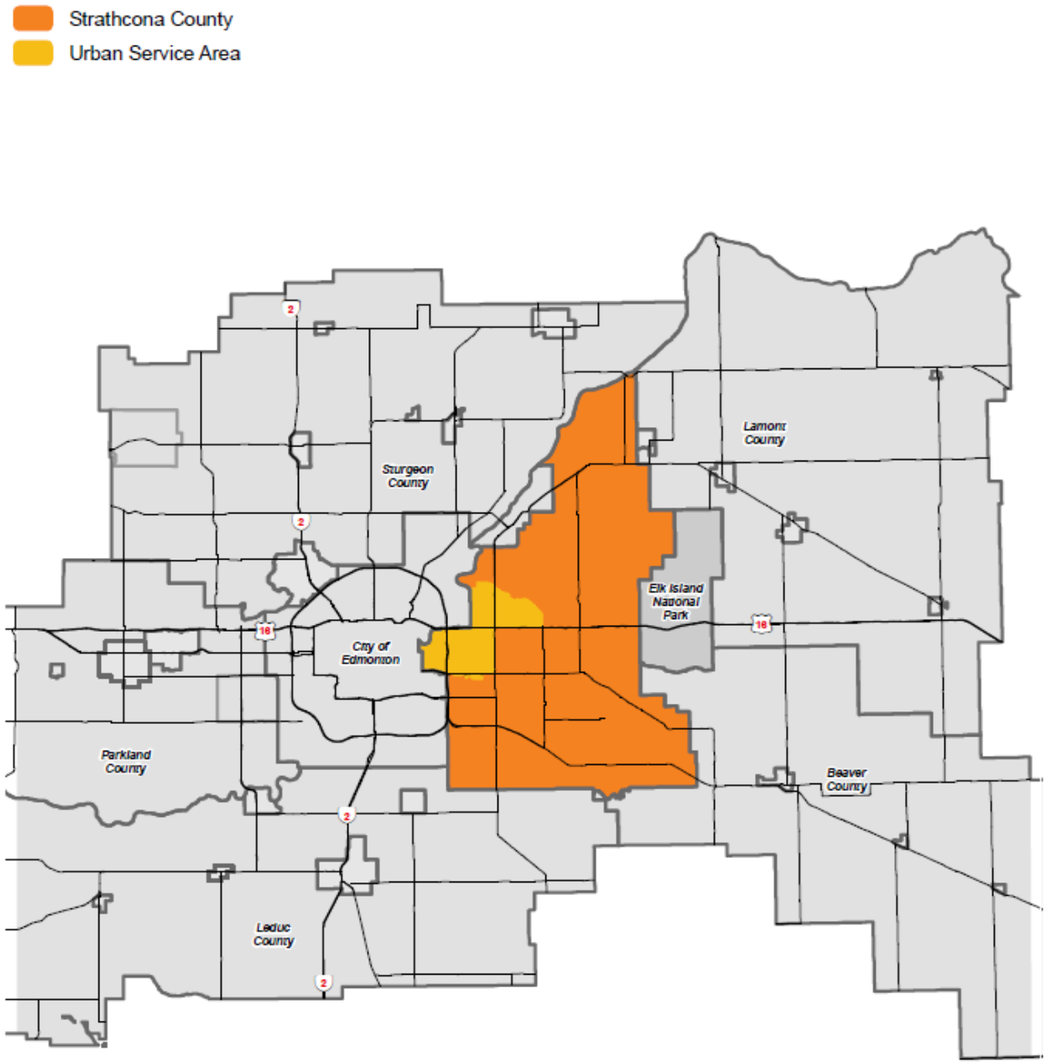
Strathcona County - AB



- Centre of Alberta’s energy and agricultural heartland
- More than 100,362 residents
- Home to 75 per cent of refining in Western Canada.

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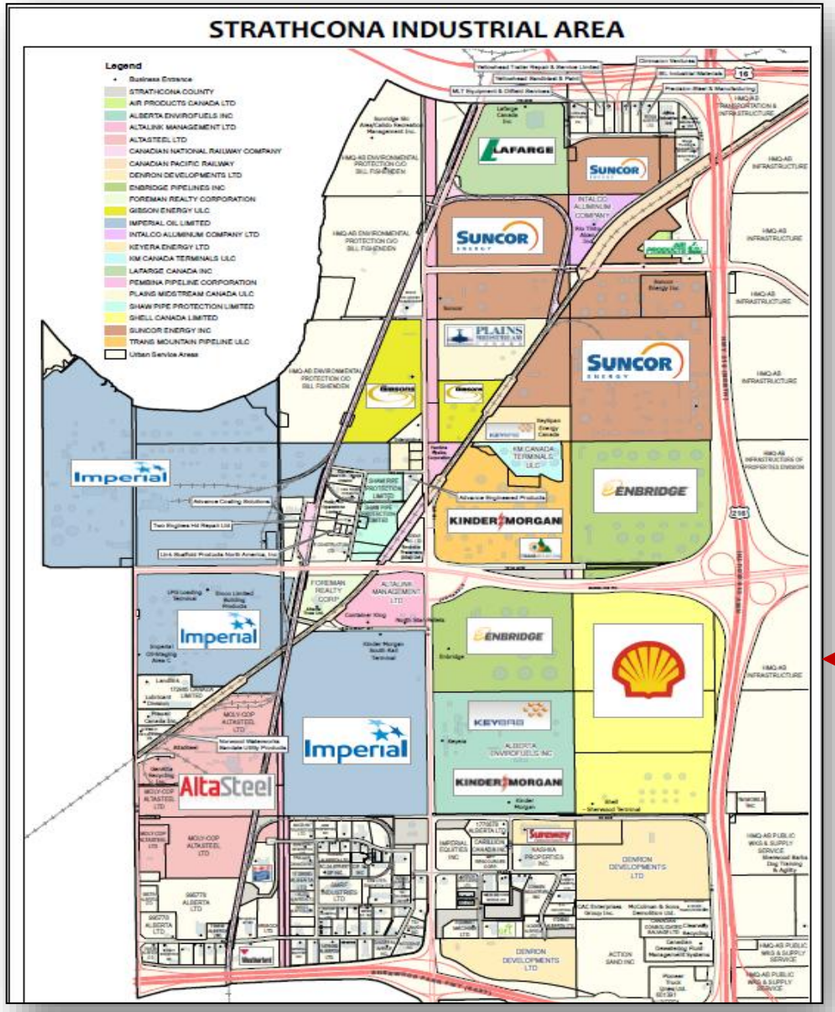
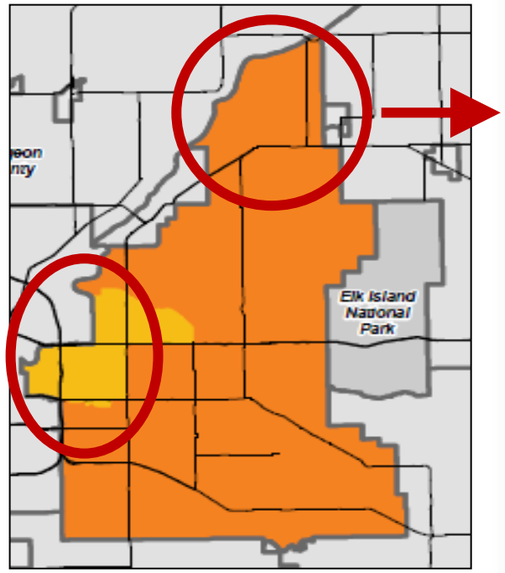
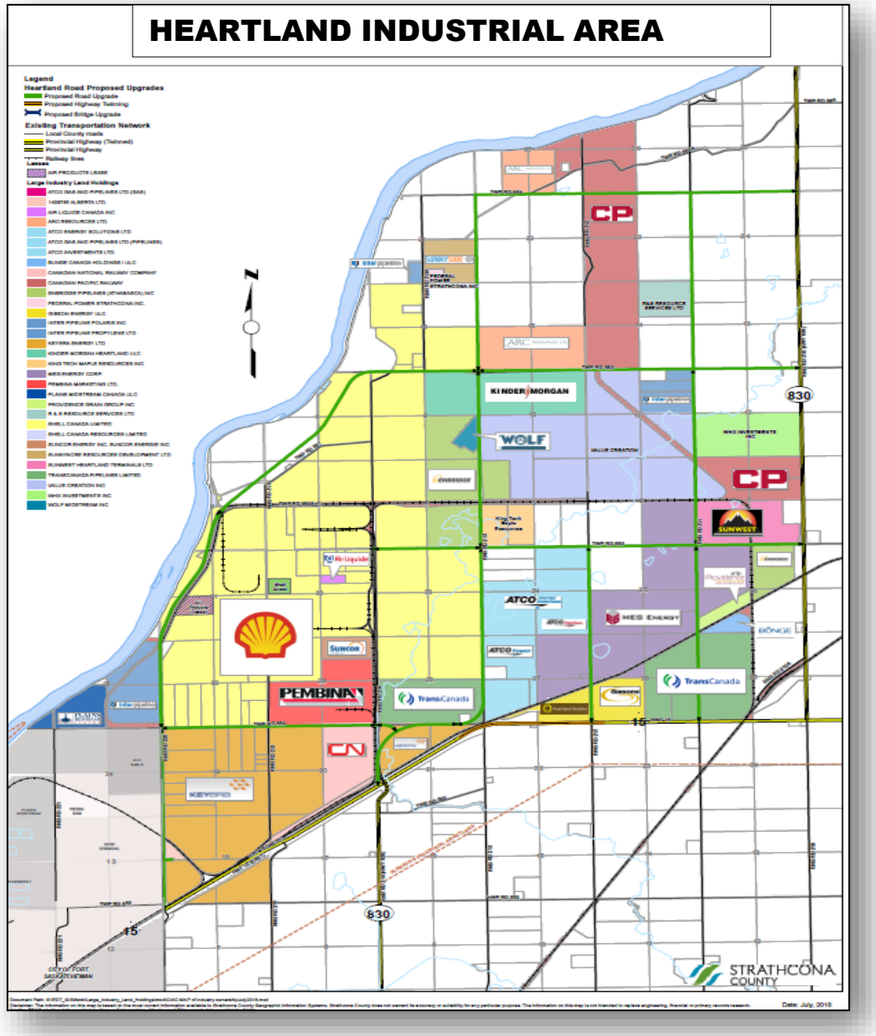
Heavy Industry







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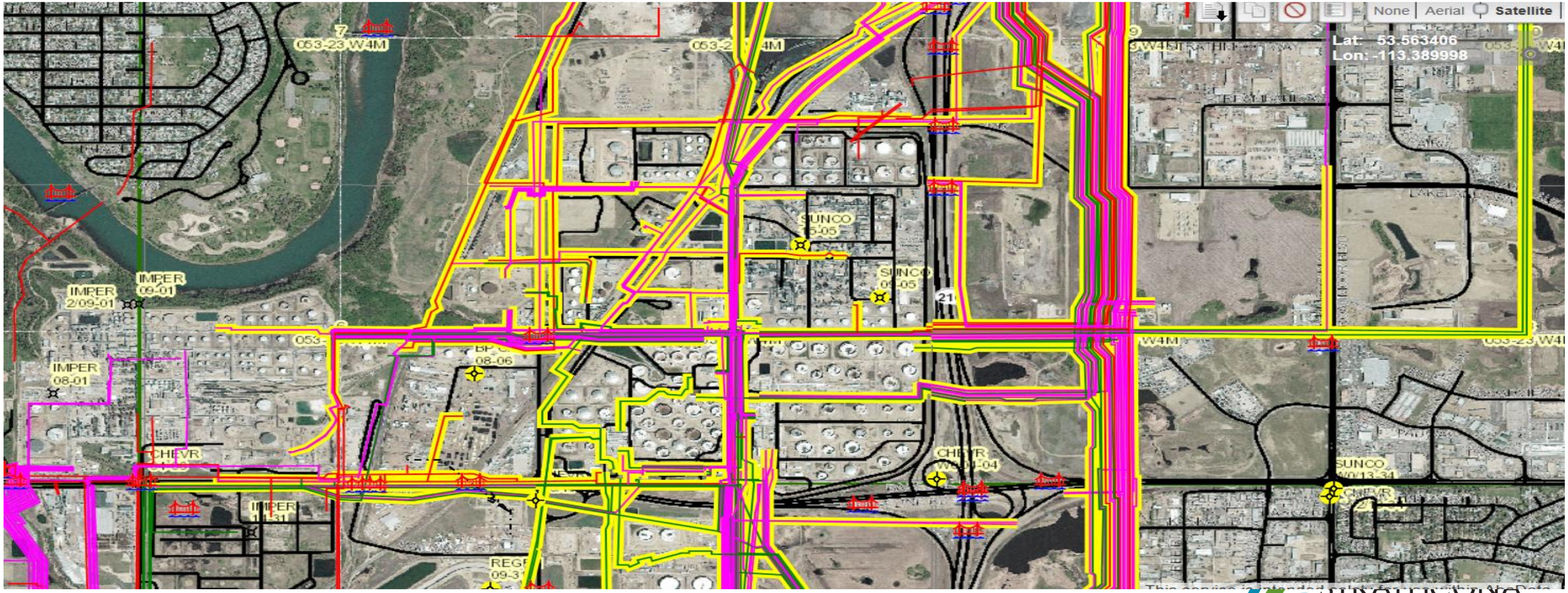
Land Use

- TDG Routes, pipelines, process facilities, tank farms, power lines, commercial & residential developments, wetlands,..



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QRA FOR LAND USE PLANNING

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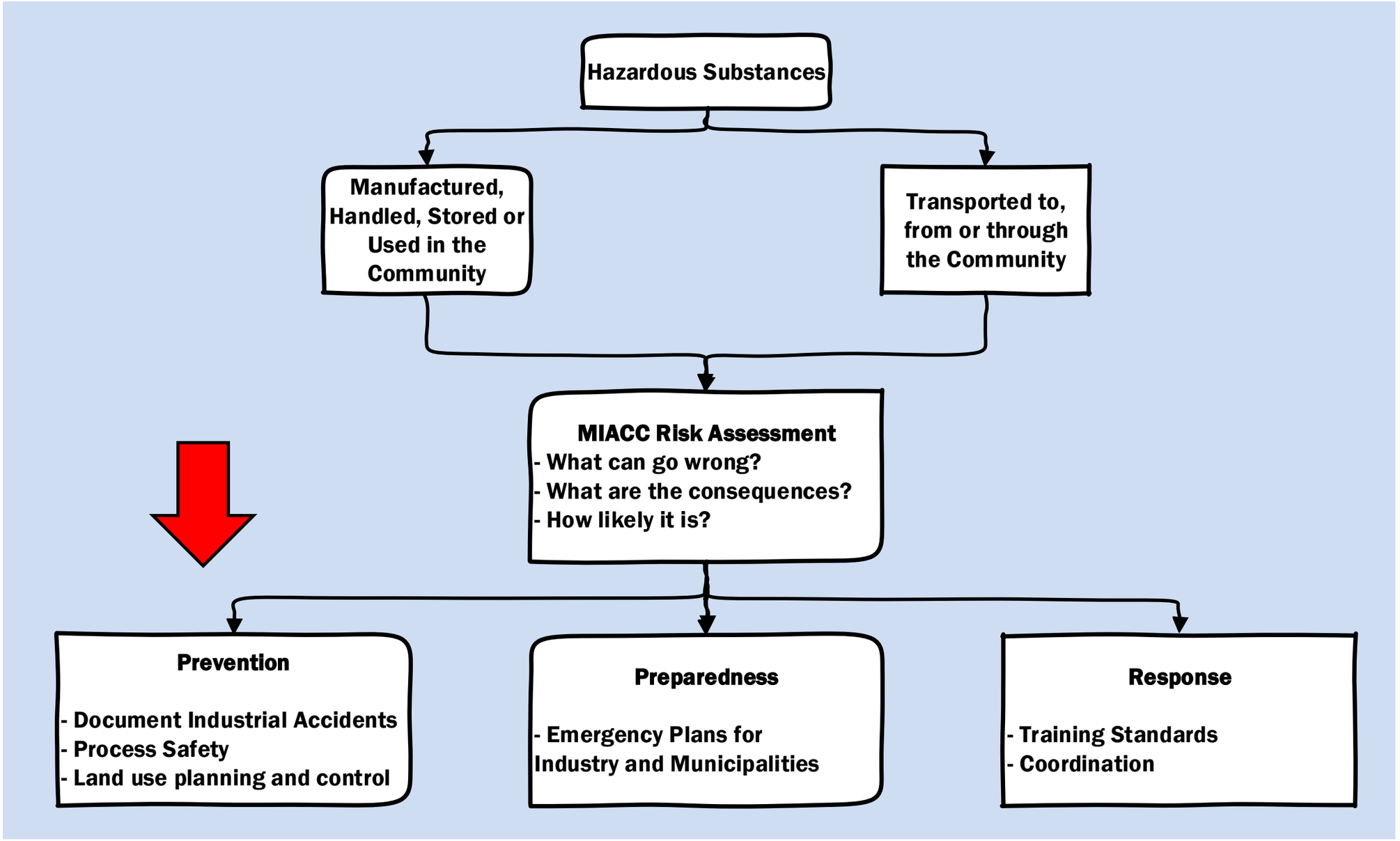
Dealing with Hazardous Substances

Ref: MIACC/ CSChE-PSMD



Ref: MIACC Screening Tool, https://www.cheminst.ca/communities/divisions/psm/psm-publications/

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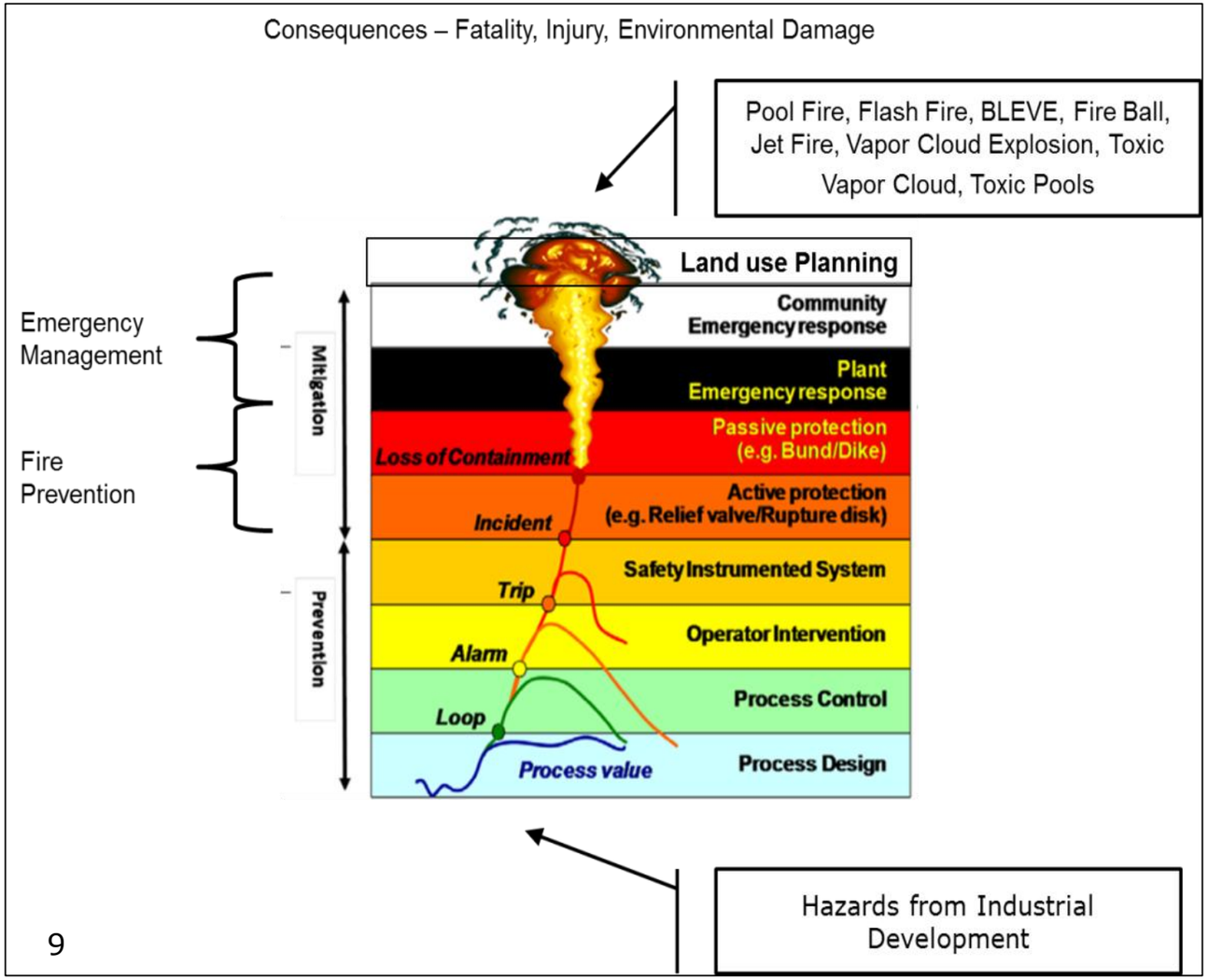
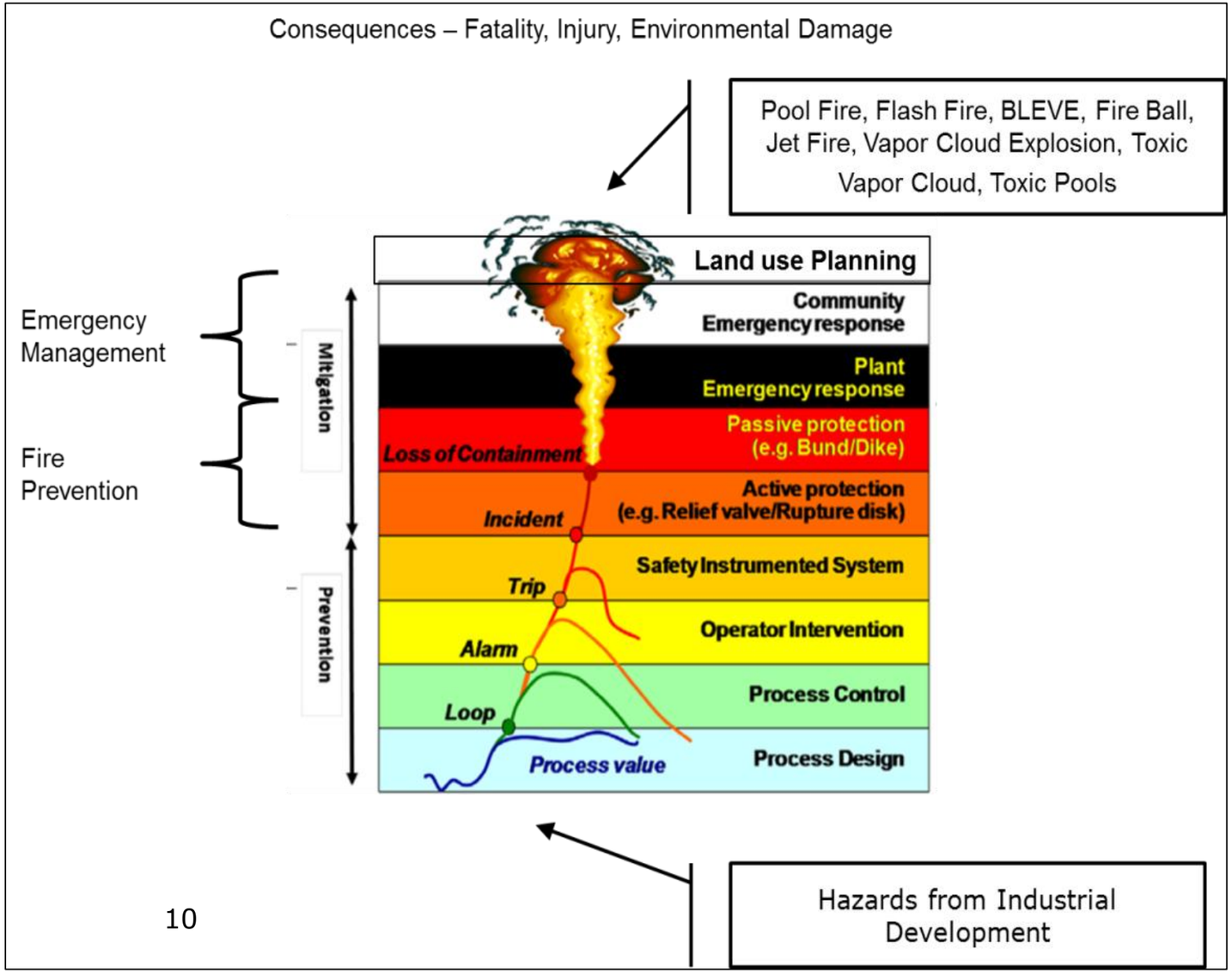
Land Use Planning as Layer of Protection



Site Screening

- Screening through Environmental Emergency Regulations 2019, Schedule 1: list of Substances SOR/2019-51
- more than threshold means offsite impact



MIACC Methodology

Risk = Frequency of occurrence x Estimated consequence

R_d = F X P1 X P2 X P3

Where

R_d = individual risk at distance d
F = frequency of release
P1 = Probability of exposure at d, given the release (1)
P2 = Probability of failure to shelter (0.1)
P3 = Probability of fatality at distance d, given the exposure (1)

Source: Risk Assessment guidelines for municipalities and industries - An Initial Screening Tool (MIACC, 1997)

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MIACC Assumptions

- MIACC approach adopted from “Dutch Guide”
- Consideration of “large” and “small” releases only
- Neglected catastrophic failure scenario
- Little justification for the selected frequencies for large and small releases
  - Large = 100% material release in 30 minutes
  - Small = 10% material release in 30 minutes
- Event individual risk within hazard zone = 0.1 X event frequency
- Event frequencies
  - 1×10^{-2} for small release
  - 1×10^{-4} for large release

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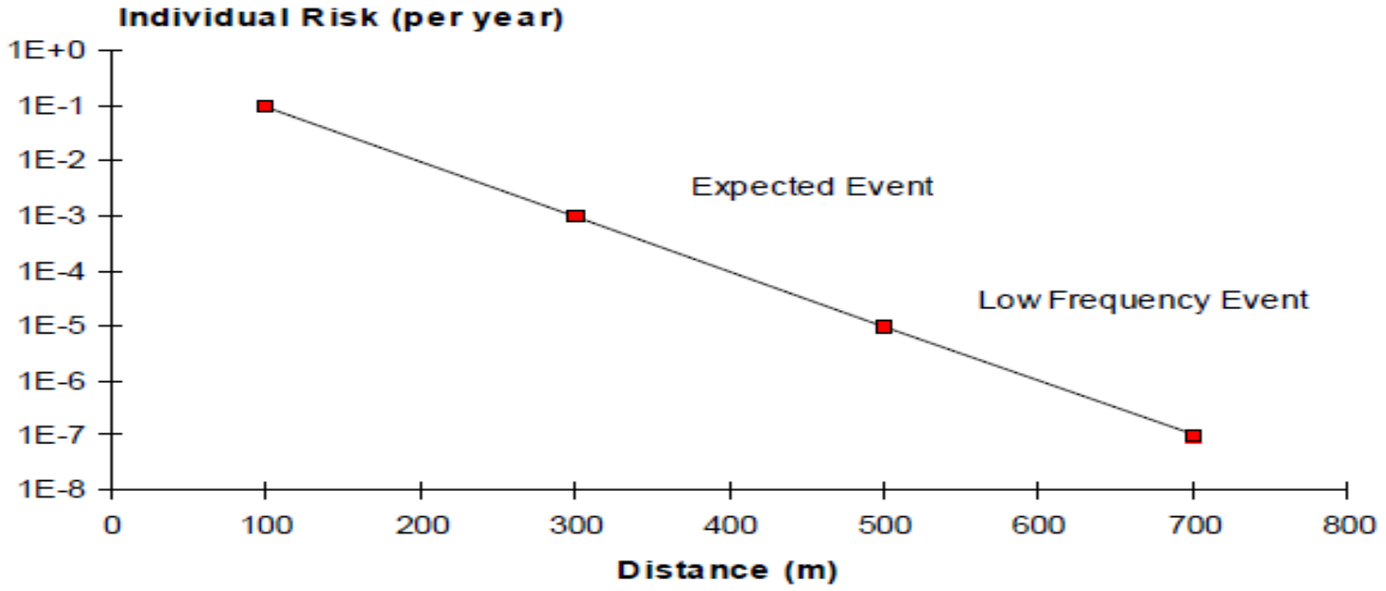
Risk vs Distance

- The subsequent steps in the MIACC approach are to:
  - plot the two (individual risk, hazard distance) pairs on a semi-logarithmic graph (risk on the logarithmic axis), and
  - read off the exclusion zone and unrestricted land-use zone distances as defined by the MIACC risk acceptability criteria of 10-4 and 10-6, respectively



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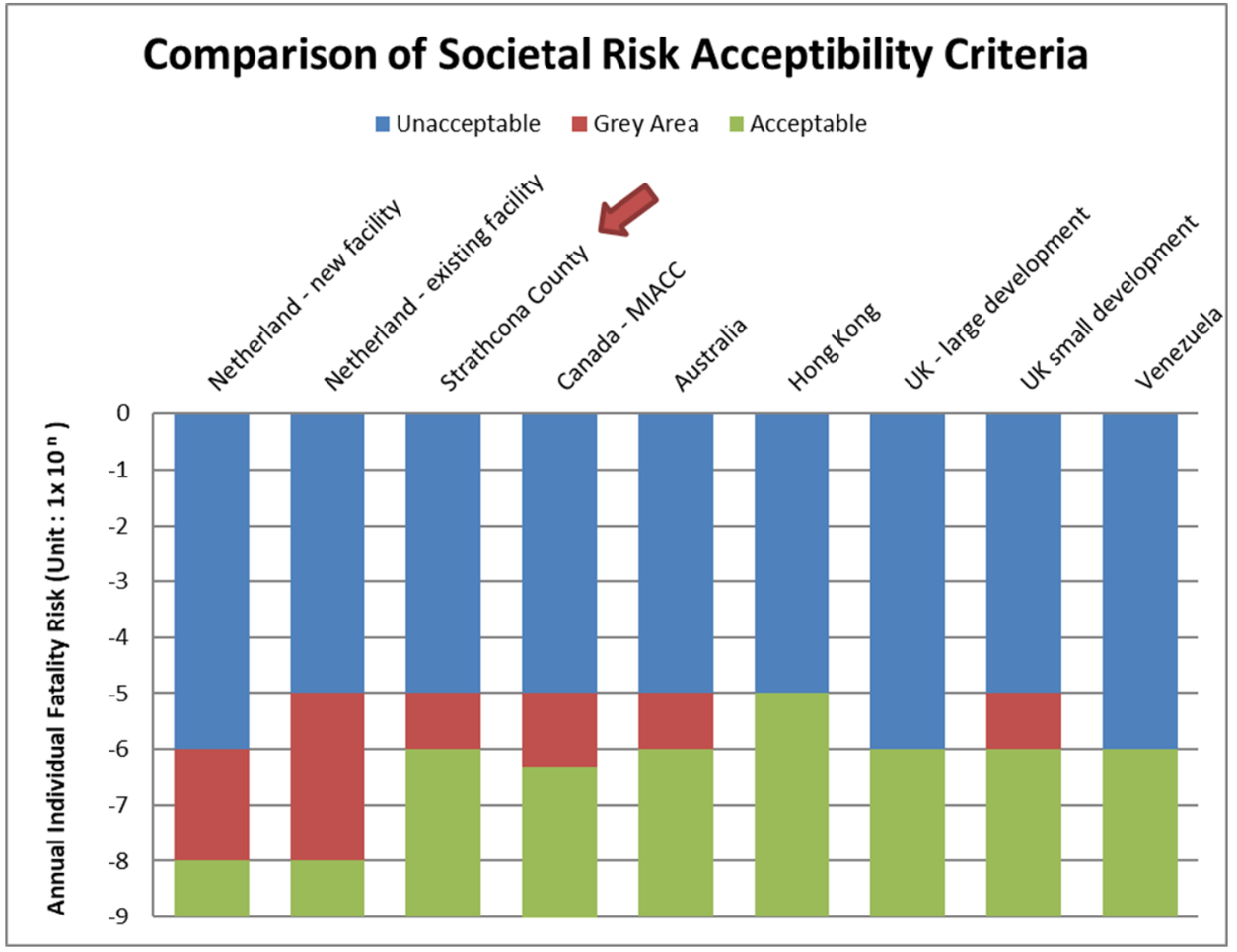
Risk Tolerance



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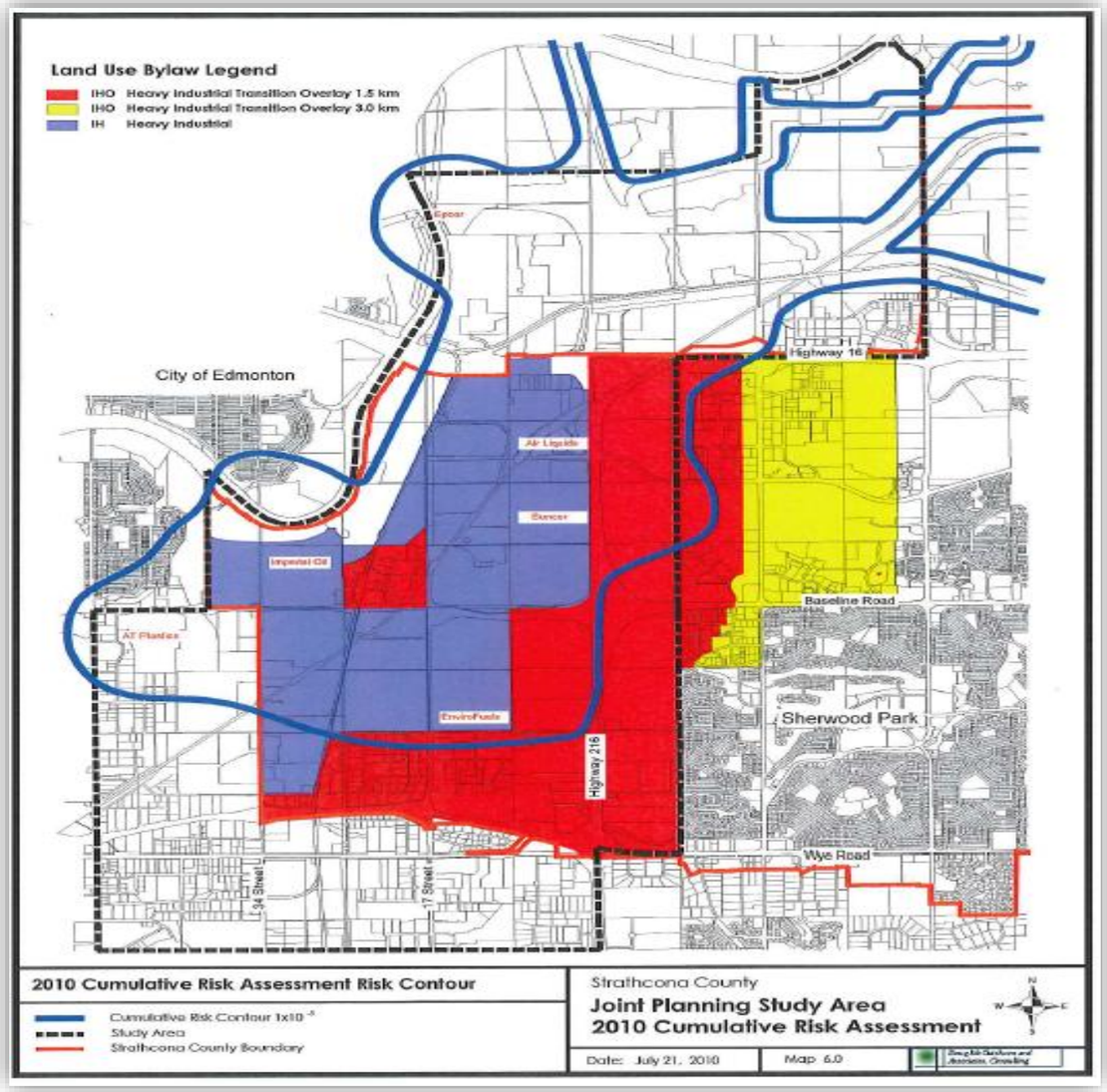
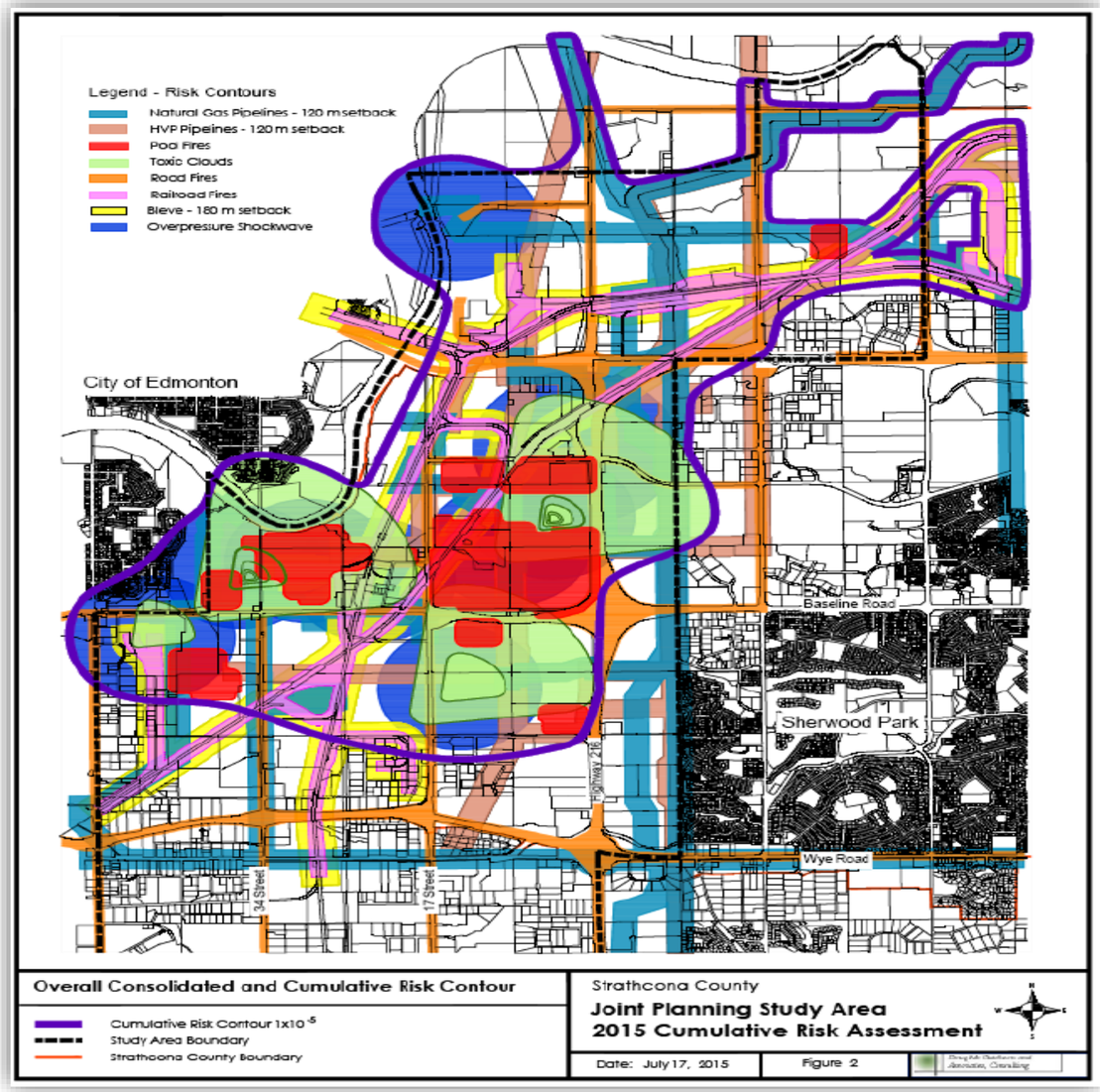
Land Buffers – 1.5 km and 3 km





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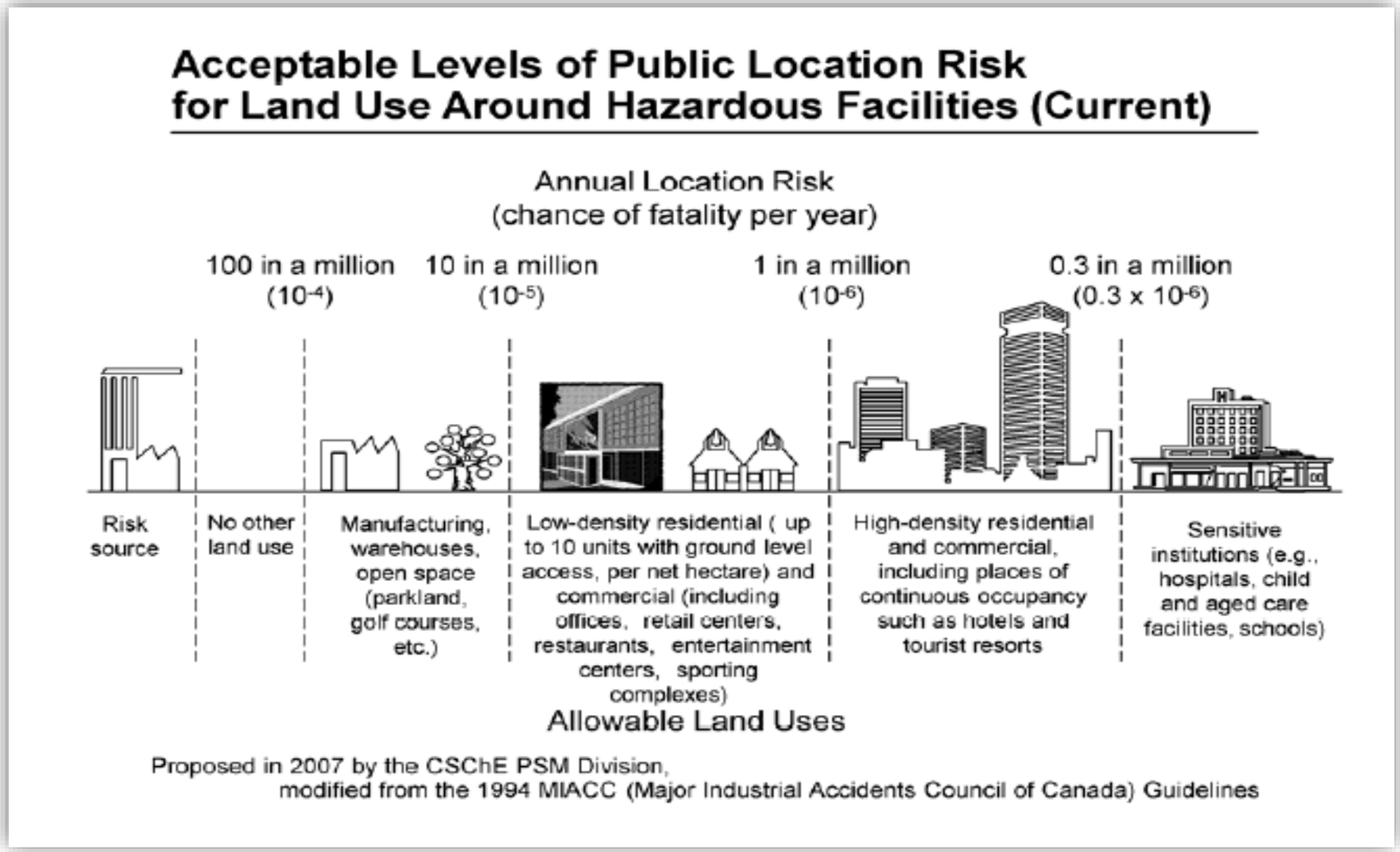
Major Industrial Accident Council of Canada – MIACC / CSChE-PSMD



Zone 1 – up to 1.5 km from industrial land

Prohibited: residential developments, hotels, care centres etc.
Permitted: supportive discretionary uses

Zone 2 – 1.5 to 3.0 km from industrial land

Prohibited: residential developments, heavy industrial uses
Permitted : Hotels, commercial, etc.

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Land Buffering in Canadian Municipalities

Municipality	Refinery Operator	Capacity (bpd)	Buffers
Strathcona County, AB	Imperial Oil Limited	187,000	3 km
Sturgeon County, AB	NWR Sturgeon Refinery	150,000	1.6 km. Can be increased as per risk assessment
Montreal QC	Suncor Energy Incorporated	137,000	Not available, likely there is no separation distance
Levis, QC	Valero	265,000	No information available
Sarnia, ON	Imperial Oil Limited	124,000	No buffer or separation distance
Nanticoke, ON	Imperial Oil Limited	118,000	Industrial influence areas of 3 km
Saint John, NB	Irving Oil Limited	300,000	No minimum distance

Ref: Tufail, Modusser ,“Strathcona County's Industrial Engagement Program: Leading the Way Using the MIACC Model”, Global Congress of Process Safety, New Orleans 2019
https://www.aiche.org/conferences/aiche-spring-meeting-and-global-congress-on-process-safety/2019/proceeding/paper/114b-strathcona-countys-industrial-engagement-program-leading-way-using-miacc-model

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Example of Industrial Emergency

- TPC in Port Neches Texas, had two blasts causing a hazardous material release in the area.

- Three injuries, and close to 50,000 people evacuated within a **4 miles radius of the chemical plant**. (Source link).

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Industrial Emergency - 2

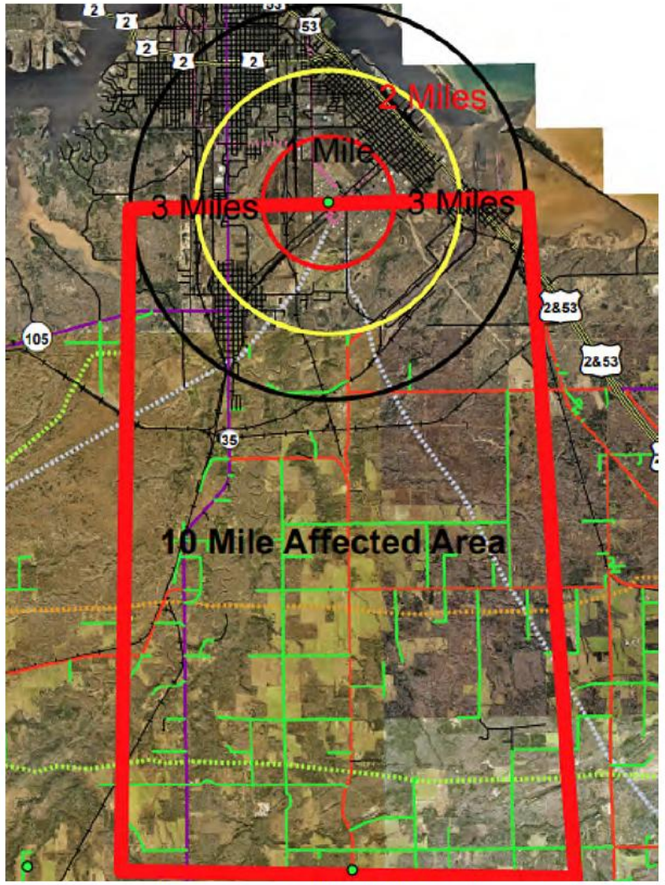

Figure 5. *Evacuation Zone on April 26, 2018. Credit: Douglas County, Wisconsin.*

- April 26, 2018 Husky Superior Refinery Explosion and Fire
- Evacuation 3 miles, and 10 miles
- Reference: CSB Investigation report

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2 – QRA FOR FACILITY SITING

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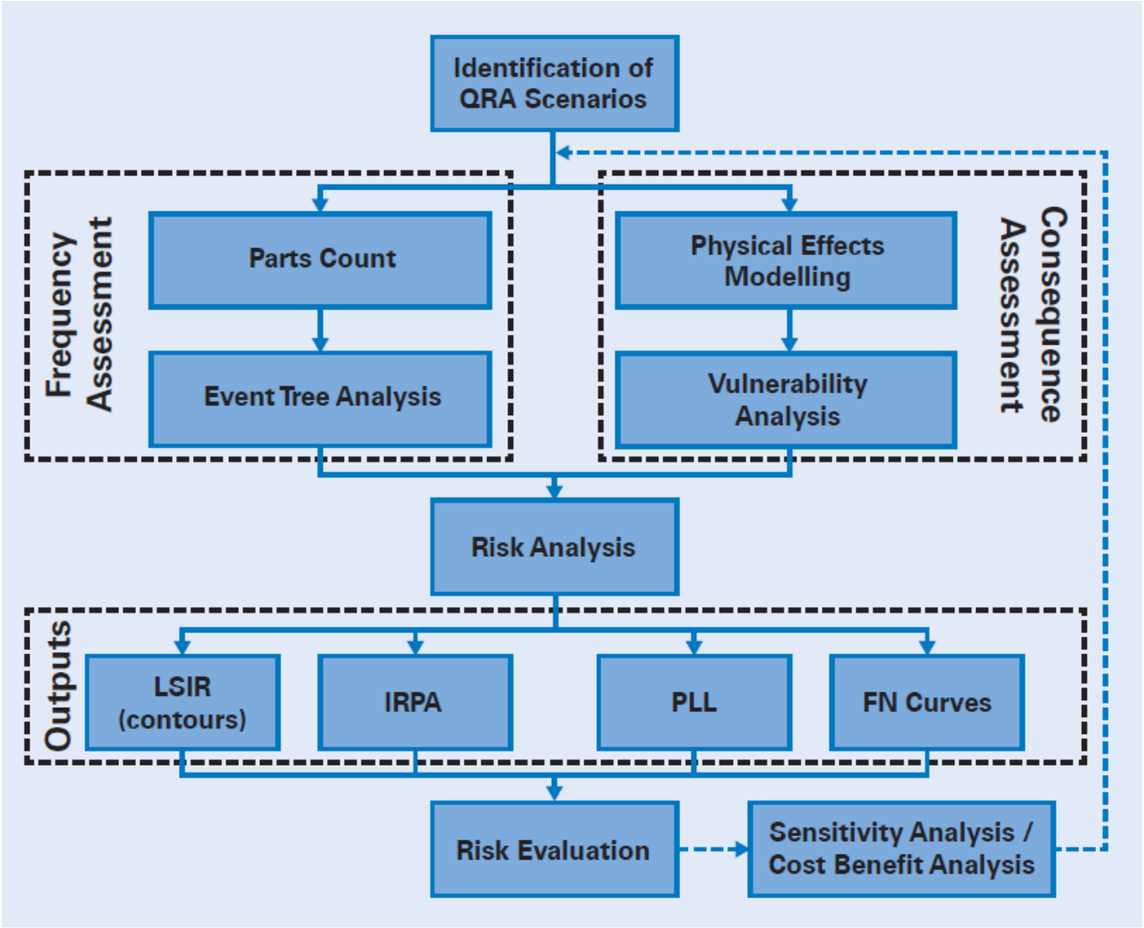
QRA Process

- Identify hazard/scenario
- Frequency of releases
- Consequence Analysis
- Risk analysis
  - LSIR – Location Specific Individual Risk
  - IRPA – Individual Risk Per Annum
  - PLL = Potential Loss of Life
  - FN – Fatality Number
- Sensitivity analysis
  - Variations and affects
- Compare with risk tolerance



Risktec – QRA Publication

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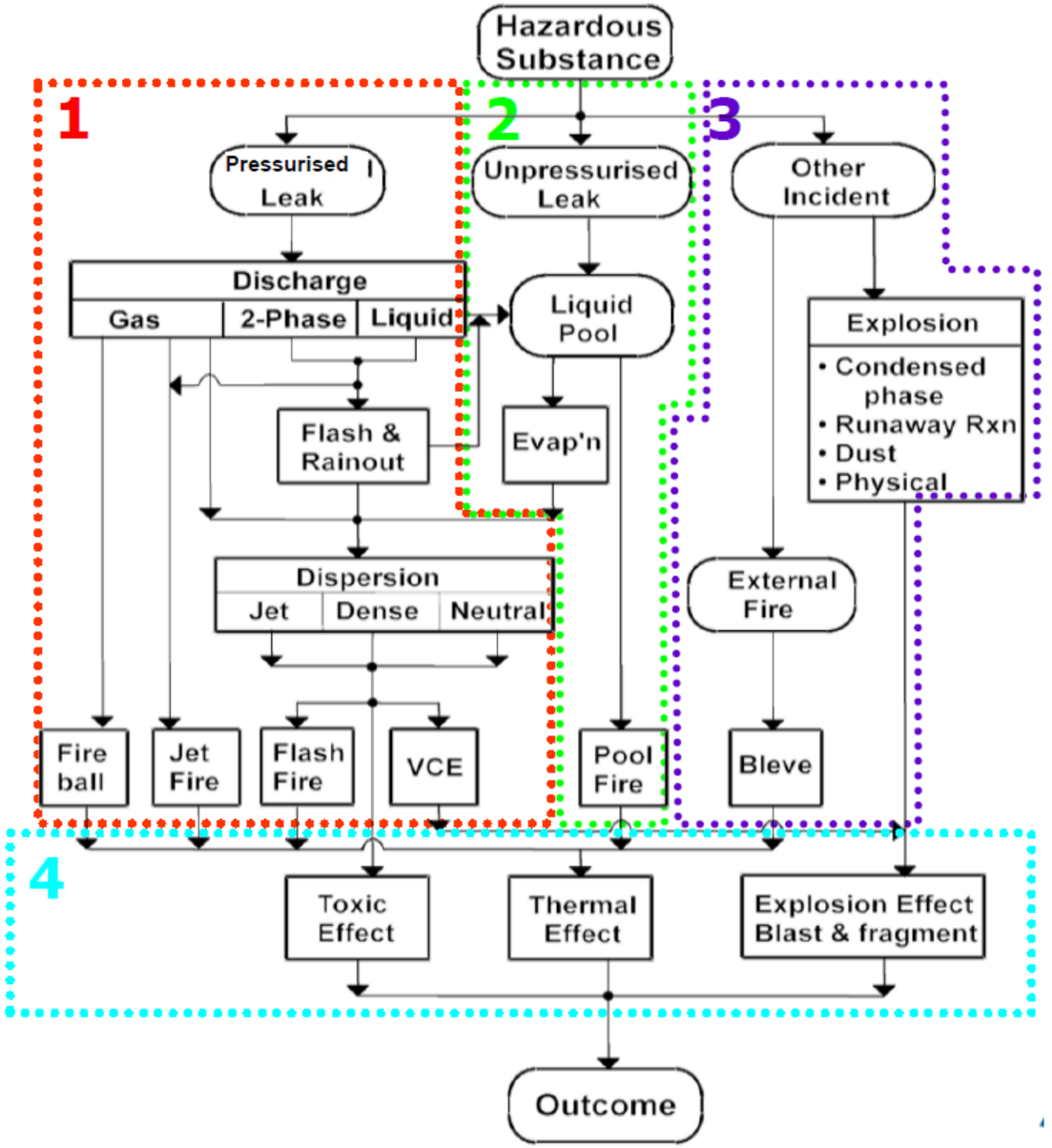
Consequence Analysis

- Fire Ball
- Jet fire
- Flash Fire
- Vapor Cloud Explosion

- Pool Fire
- BLEVE – Boiling liquid expanding vapor explosion

- Toxic Vapor Cloud
- Toxic Pool



International Association of Oil and Gas Producers, Risk Assessment Data Directory: Consequence Modelling, 434-07, March 2010

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Calculating Frequency (IOGP Risk Data Directory)

Table 2.4 Summary of Pressure Vessel Leak Frequencies

Hole Diameter		Leak Frequency (per vessel year)	
Range	Nominal	Storage Vessels	Small Containers
1-3 mm	2 mm	2.3×10^{-5}	4.4×10^{-7}
3-10 mm	5 mm	1.2×10^{-5}	4.6×10^{-7}
10–50 mm	25 mm	7.1×10^{-6}	
50-150 mm	100 mm*	4.3×10^{-6}	
>150 mm	Catastrophic	4.7×10^{-7}	1.0×10^{-7}
TOTAL		4.7×10^{-5}	1.0×10^{-6}

*Or diameter of largest pipe connection if this is smaller

Table 2.1 Atmospheric Storage Tank Leak Frequencies

Type of Tank	Type of Release	Leak Frequency (per tank year)
Floating roof	Liquid spill on roof	1.6×10^{-3}
	Sunken roof	1.1×10^{-3}
Fixed/ floating roof	Liquid spill outside tank	2.8×10^{-3}
	Tank rupture	3.0×10^{-6}

Table 2.2 Atmospheric Storage Tank Fire Frequencies

Type of Fire	Floating Roof Tank (per tank year)	Fixed Roof Tank (per tank year)	Fixed plus Internal Floating Roof Tank (per tank year)
Rim seal fire	1.6×10^{-3}		1.6×10^{-3}
Full surface fire on roof	1.2×10^{-4}		
Internal explosion & full surface fire		9.0×10^{-5}	9.0×10^{-5}
Internal explosion without fire		2.5×10^{-5}	2.5×10^{-5}
Vent fire		9.0×10^{-5}	
Small bund fire	9.0×10^{-5}	9.0×10^{-5}	9.0×10^{-5}
Large bund fire (full bund area)	6.0×10^{-5}	6.0×10^{-5}	6.0×10^{-5}

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Process Leak Frequencies (IOGP Risk Data Directory)

Table 4-2: PLOFAM2 model Parameters From [10]

Equipment type	A_0	m_0	A_D	m_D	B_D	α	$F_{hist,Significant}$	$F_{hist,Marginal}$
Air-cooled heat exchanger	1.00	0	0	0	3.0E-2	0	5.00E-4	0
Atmospheric vessel	1.00	0	0	0	1.0E-1	0	5.00E-4	0
Centrifugal compressor	1.00	0	0	0	6.0E-3	0	1.30E-3	0
Centrifugal pump	1.00	0	0	0	3.0E-5	0	3.00E-3	0
Compact flange	1.00	0	0	0	1.0E-3	0.9	3.00E-6	0
Filter	1.00	0	0	0	8.0E-4	0	2.30E-3	0
Flexible pipe	1.00	0	0	0	4.0E-1	0.75	1.40E-4	0
Gas lift well	1.00	0	0	0	2.5E-2	0	1.00E-4	1.00E-04
Hose	1.00	0	0	0	4.0E-1	0.75	6.00E-5	1.00E-05
Instrument	1.00	0	0	0	1.5E-1	0	1.30E-4	0
Pig trap	1.00	0	0	0	2.0E-2	0	1.70E-3	0
Plate heat exchanger	1.00	0	0	0	1.0E-3	0	3.50E-4	0
Process vessel	1.00	0	0	0	6.0E-4	0	5.00E-4	0
Producing well	1.00	0	0	0	2.0E-2	0	2.00E-5	1.30E-05
Reciprocating compressor	1.00	0	0	0	1.0E-2	0	5.00E-3	-
Reciprocating pump	1.00	0	0	0	3.0E-5	0	3.00E-3	-
Shell and tube heat exchanger exchanger	1.00	0	0	0	7.5E-3	0	3.30E-4	-
Standard flange	1.00	0	18.0	-1.45	5.0E-3	0.5	2.50E-5	5.00E-06
Steel pipe	4.20	-0.30	17.6	-1.75	1.0E-3	0.9	1.40E-5	2.00E-06
Valve	1.11	-0.10	16.0	-1.70	1.0E-3	0.5	2.15E-4	3.50E-05

Values denoted by "-" should be taken as zero.

Calculating Risk

Risk = Frequency of occurrence x Estimated consequence

R_d = F X P1 X P2 X P3

Where

R_d = individual risk at distance d
F = frequency of release
P1 = Probability of exposure at d, given the release
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P3 = Probability of fatality at distance d, given the exposure

Source: Risk Assessment guidelines for municipalities and industries - An Initial Screening Tool (MIACC, 1997)

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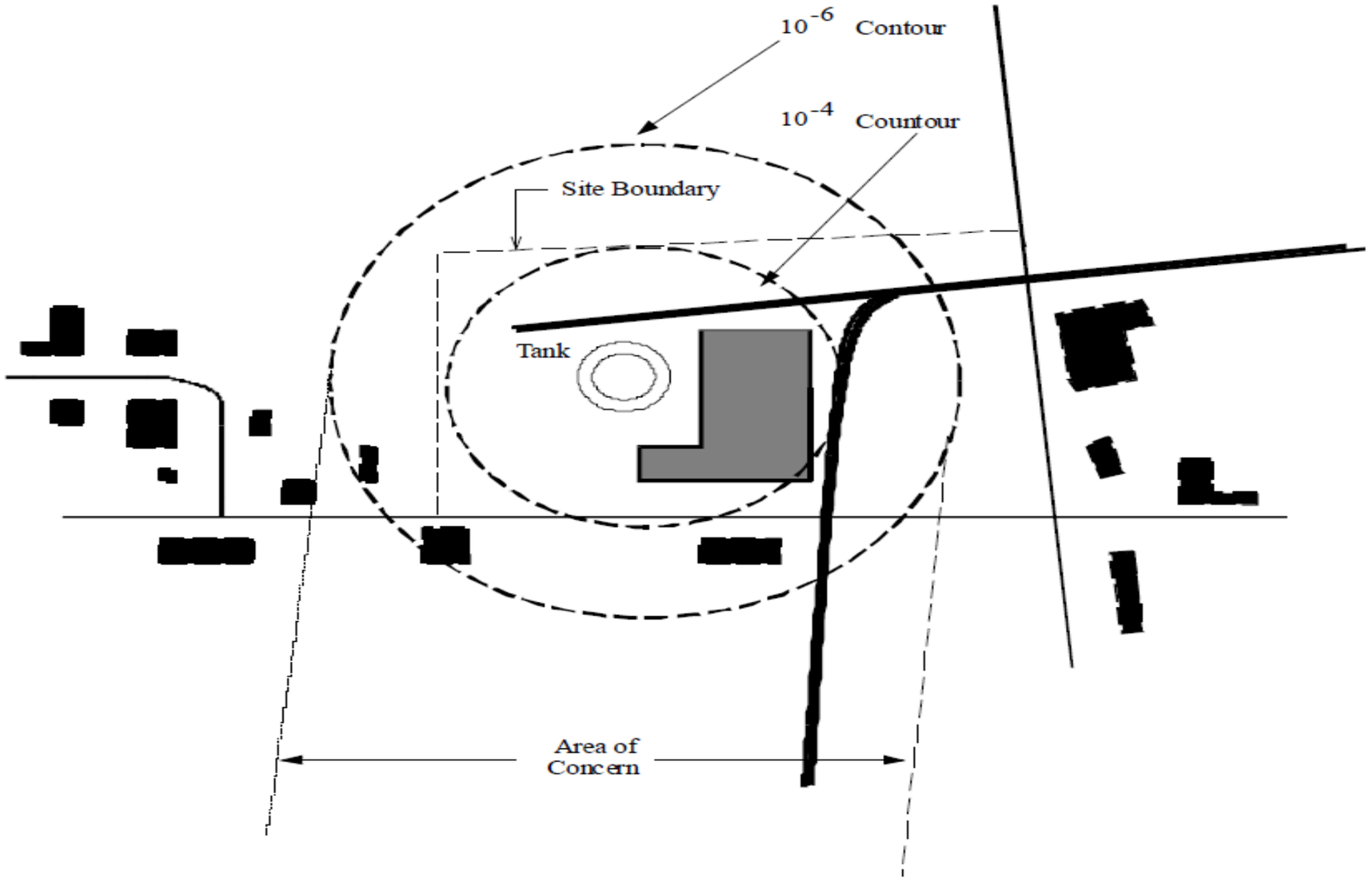
Risk Contours



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Standards

- Standards
  - API RP 752 Management of Hazards Associated with Location of Process Plant Permanent Buildings
  - API RP 753 Management of Hazards Associated with Location of Process Plant Portable Buildings
  - API RP 756 Management of Hazards Associated with Location of Process Plant Tents

Sample Scenarios

- Leak scenarios
  - 0.5”
  - 2”
  - 6” or max line size if less than 6”
- Storage tank failure and overflow
- Pressurized releases

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*Or diameter of largest pipe connection if this is smaller

Comparing Scenarios – High level

Land Use Scenarios

- 10 % volume for Loss of Containment
- 100% volume for Loss of Containments
- Inclusion of toxic clouds
- Use of larger quantities
- Based on credible worst-case scenarios

Remarks: Land buffers vary with varying volumes of hazardous material

Larger buffers e.g. 3 km for 1 x 10E-6

Also suitable for early phase of design

Standards: MIACC Guidelines, CCPS-QRA

Facility Siting Scenarios

- 1 mm hole
- 3 mm hole
- Full bore hole

Remarks: Land buffers might not vary with varying volumes of hazardous material. Contours mostly related to fires and explosions missing toxic events (low frequencies).

Smaller buffers e.g. 200m for 1 x 10E-6

Assumed pipe sizes, not known at early stage of design

Land Buffers

Location Specific Annual Individual Fatality Risk of Facility	Buffer Distance Of Municipality	Buffer Distances of Adjacent Municipality
1×10^{-4}	within property	-
1×10^{-5}	1.5 km	120 m
1×10^{-6}	3.0 km	240 m

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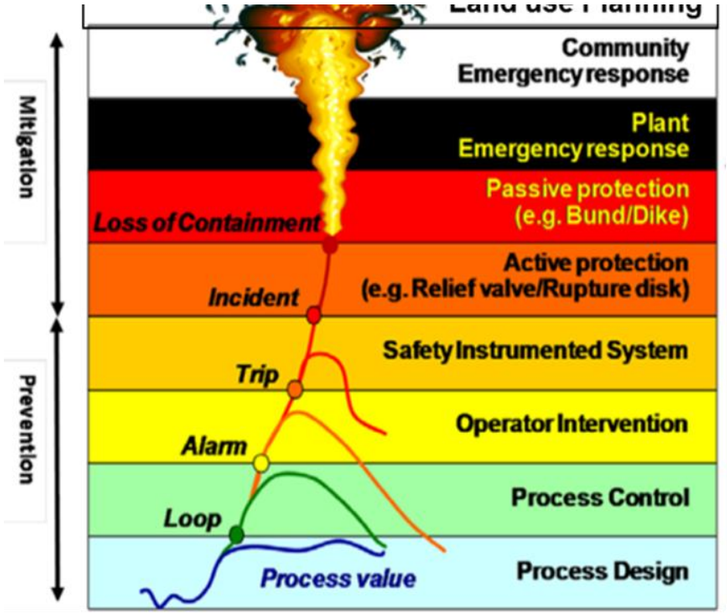
Observations

1. QRAs done with facility siting scenarios only, provide inadequate buffers and are ineffective for community emergency response planning.

2. QRAs done with land use planning scenarios should provide distances comparable to the “community emergency response planning” layer of protection.

3. Updates in MIACC guidelines are required to remove confusions on scenario development, use of data and frequency analysis, and modelling toxic events.

4. Standardization in QRAs of LUP is needed to earn credibility of this engineering assessment.



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Risk-based land use planning – emergency response planning
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https://www.cheminst.ca/communities/divisions/psm/psm-publications/

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Questions?

THANKS

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