13th Chemical Process Safety Sharing (CPSS)

Addressing LOPC Risks in Brownfield Projects

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  Drivers for Opting Brownfield Modifications
- **Why is Evaluating Risk relevant?**
  for Brownfield Modifications – Need for evaluating Escalation/ Incremental Risk
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  Approach to account for escalation risk

Drivers and Risk Impact from Brownfield Modifications

Drivers

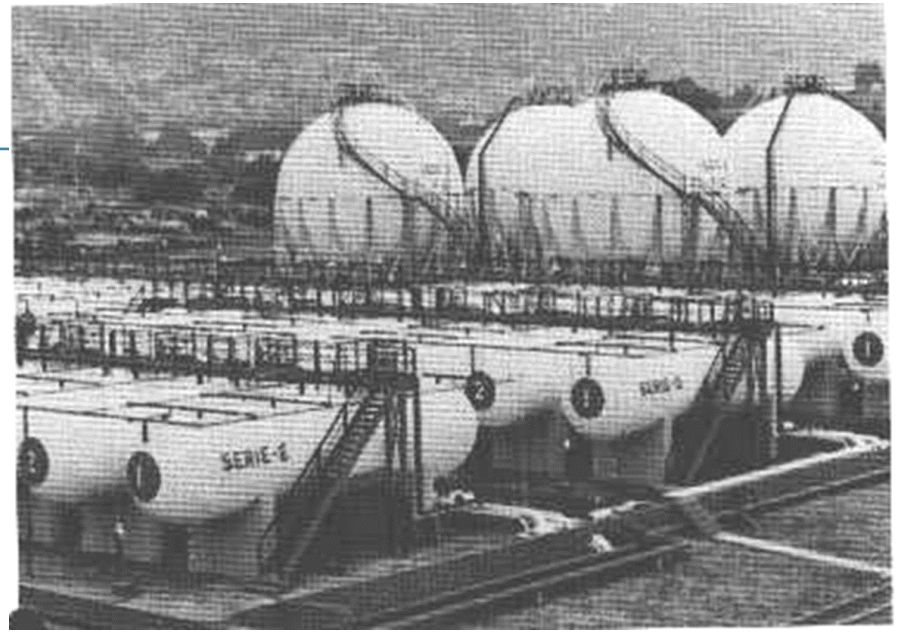
- **Empty plots within the complex can be utilized**
  - Skips the hassle of finding new land
  - Reduces public consultation / permits needed
- **Infrastructures & services are already in place**

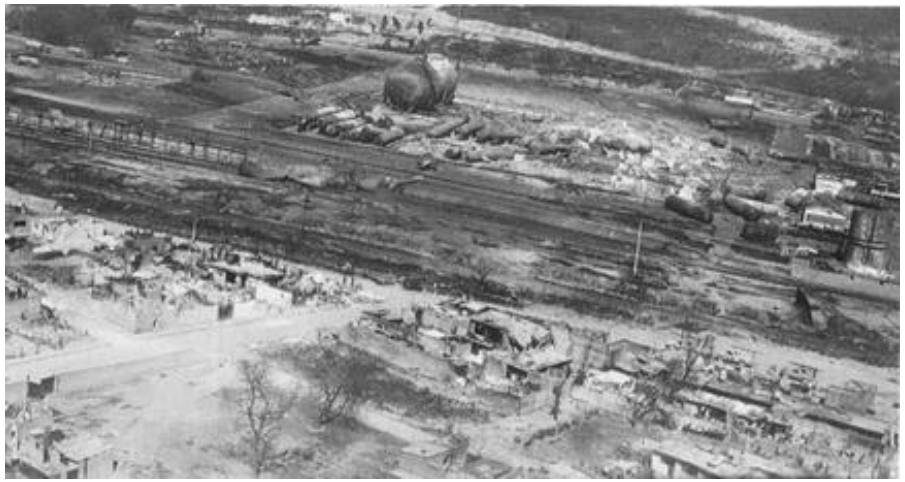
Risk Impact

- Vacant plots are sometimes used even if it is not initially intended for expansion
- Reduced separation distance to adjoining plants/ plant boundary
- Limited plot area may compromise inter-equipment separation distance
- Legacy plants may be operating with inadequate safety features when compared with today's practice
- **Potential increase in risk due to escalation or incremental risk due to the modifications**

San Juanico Disaster

- Rupture of 8” LPG piping causing vapour cloud drift towards ground flare
- Flash fire and flame impingement on one of the sphere causing BLEVE
- Fragments from this sphere and leaked materials damages other equipment/ spheres
- Overall BLEVE of 15 of 48 vessels in domino fashion



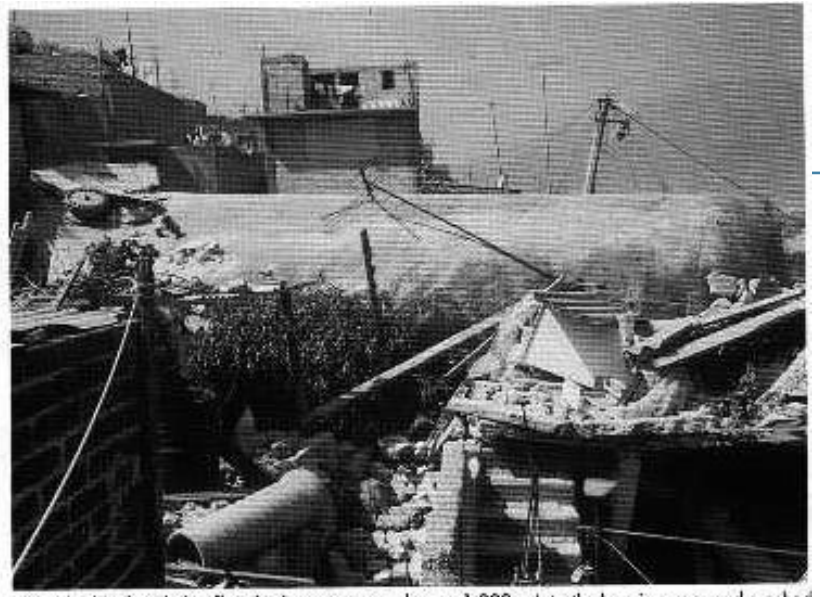


San Juanico Disaster

- 500-600 deaths; 300+ never identified
- 5000-7000 severe injuries
- 10,000-60,000 people made homeless

Adjacent facilities damaged

- Unigas Plant with further LPG Facility
- Gasomatico facility for LPG bottling and dispatch by truck
- Houses destroyed beyond battery limit



The cylindrical tank that flew furthest penetrated some 1,200 m into the housing area and crashed

The desolation of the burnt-out houses recalled a war scene.

What is Escalation Risk and Cumulative Risk

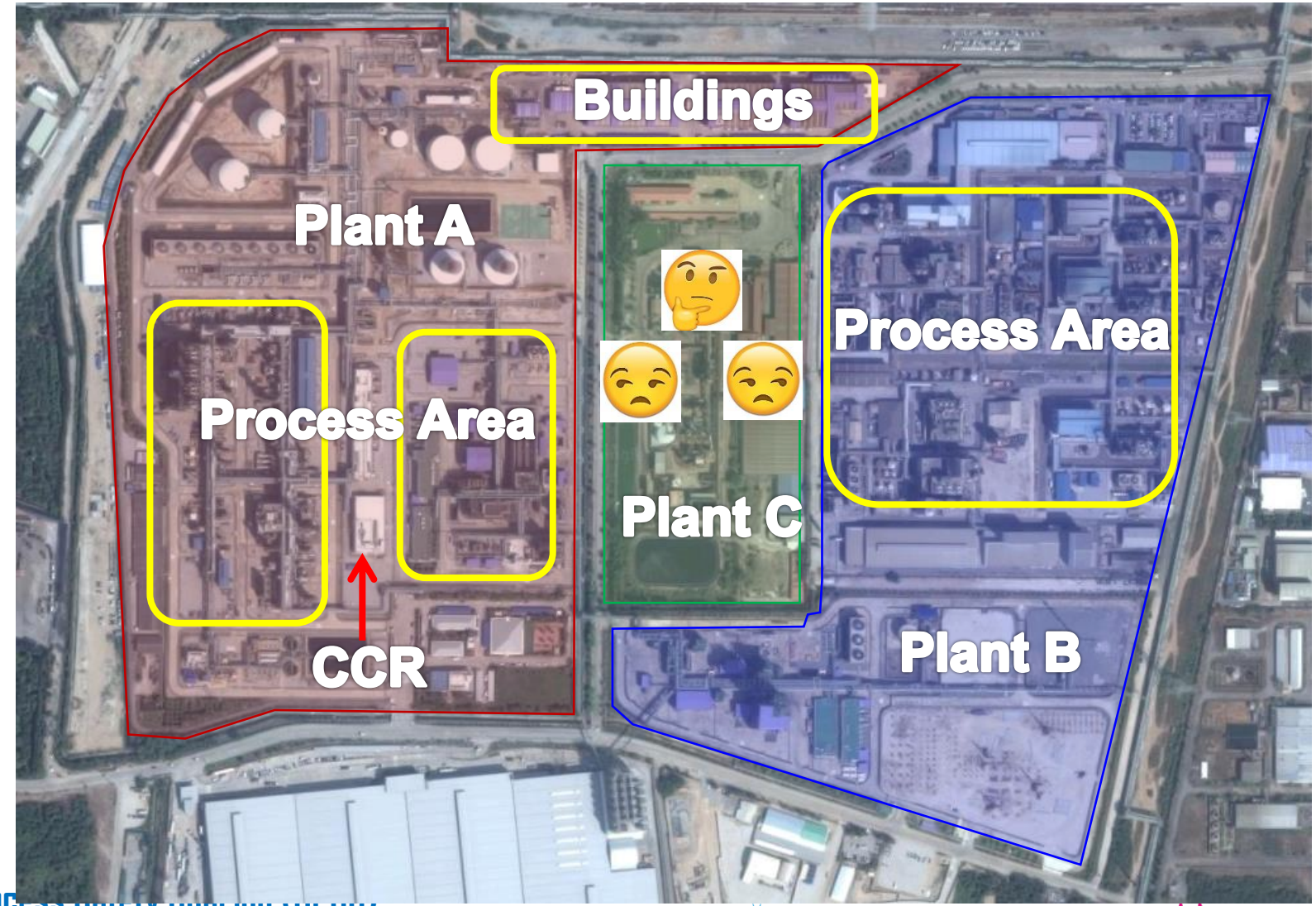
- **Escalation/ Domino effect** refers to the scenario where a small event (e.g. small leak) leads to the failure of adjacent equipment or structures or a more severe consequence

- **Cumulative Risk** refers to the integration of risk from existing Vs new unit to get overall risk perspective. This also applies to integration of risks across facilities.

Sample Industrial Zone

Need for Cumulative QRA accounting Escalation/ Incremental Risks

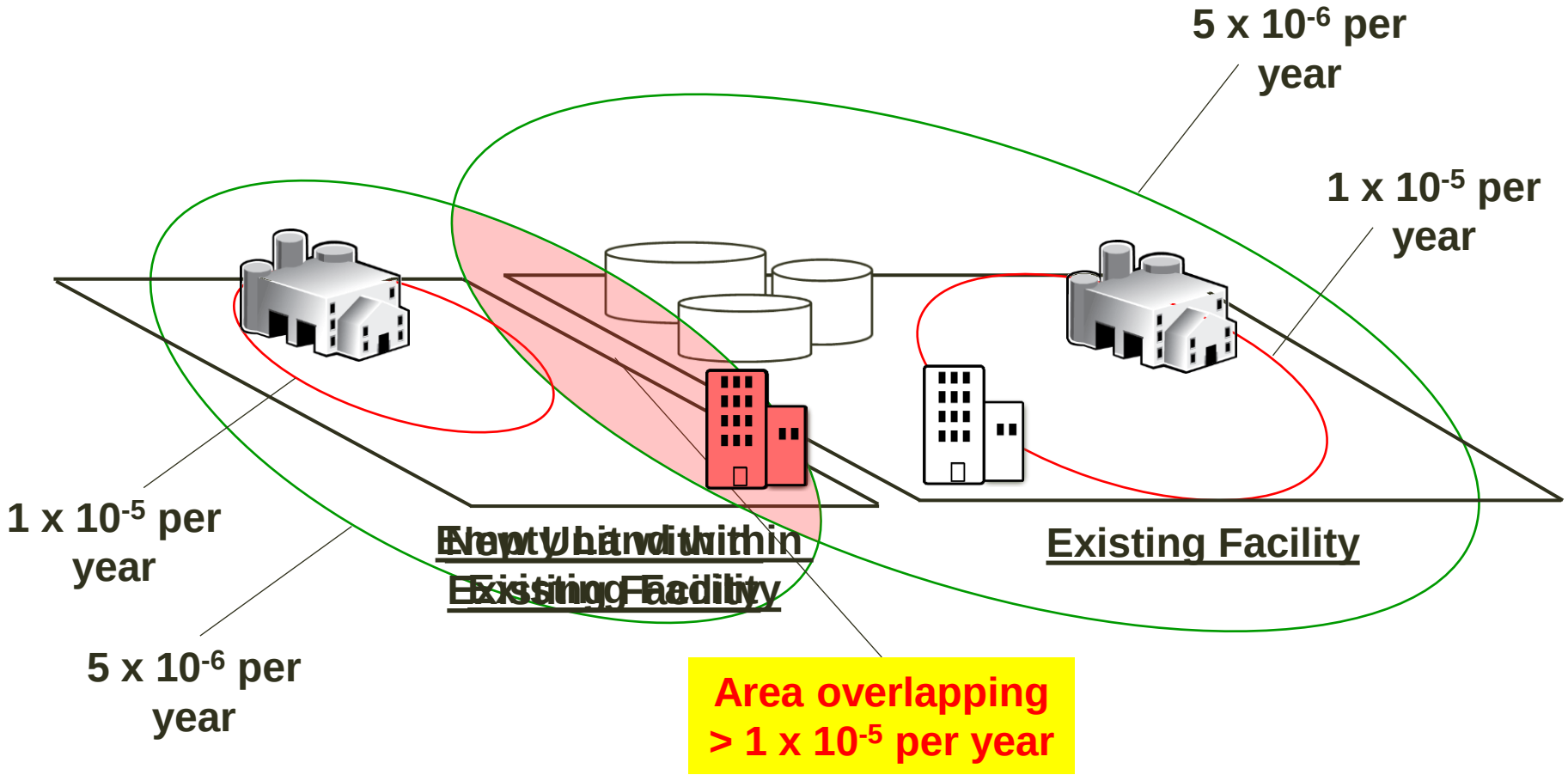
- Why?



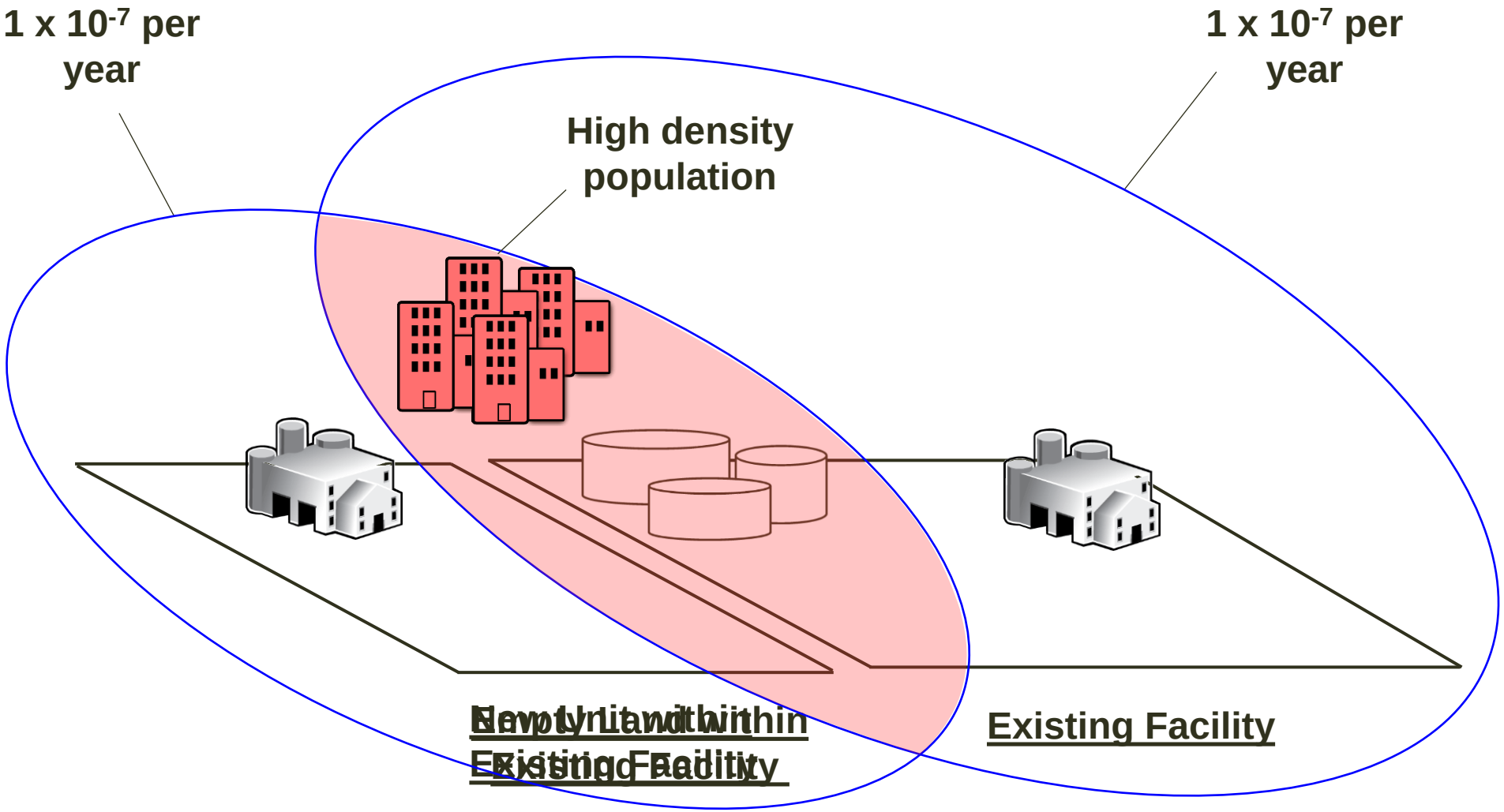
Need for Cumulative QRA – considering escalation risk

- Onsite
- Offsite
- Domino effects/ escalation
- Additional risks during construction phase of brownfield expansion (SIMOPS, higher manning)

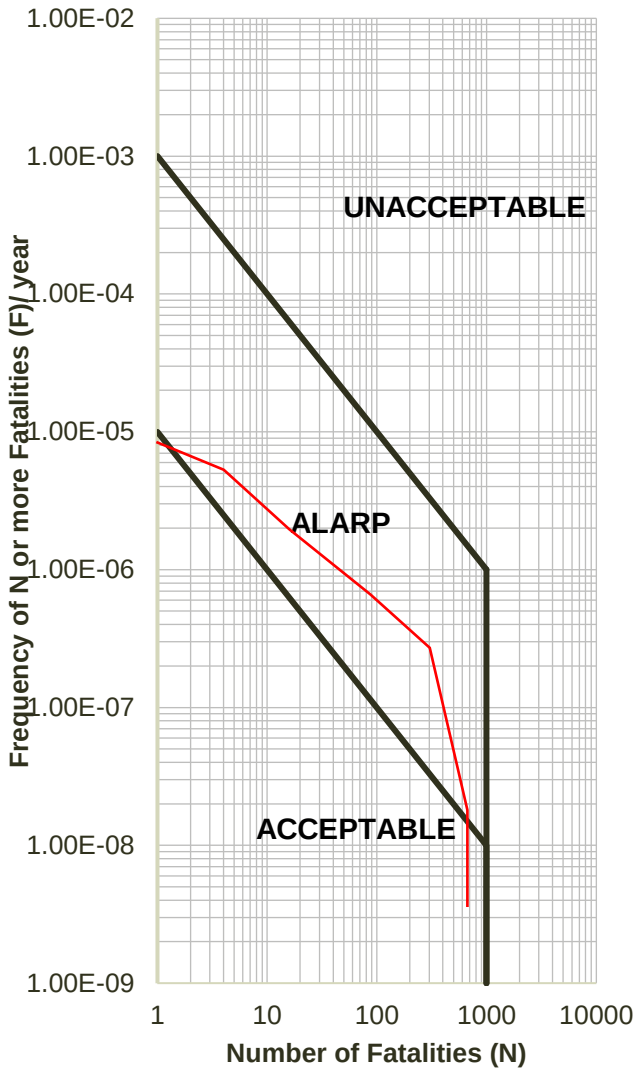
Impact to Onsite

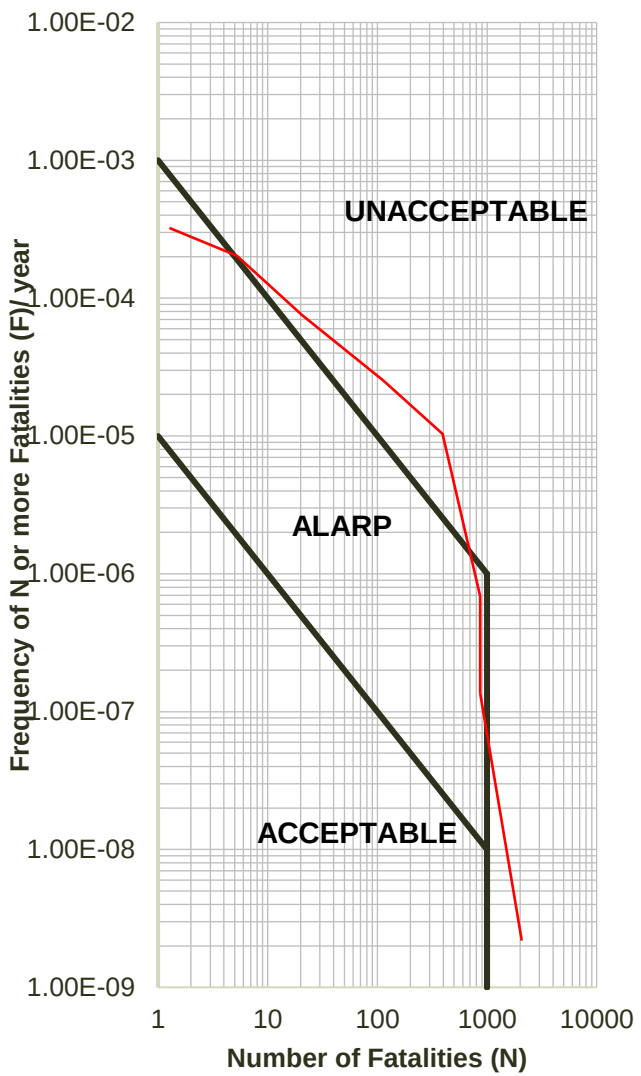


Impact to Offsite

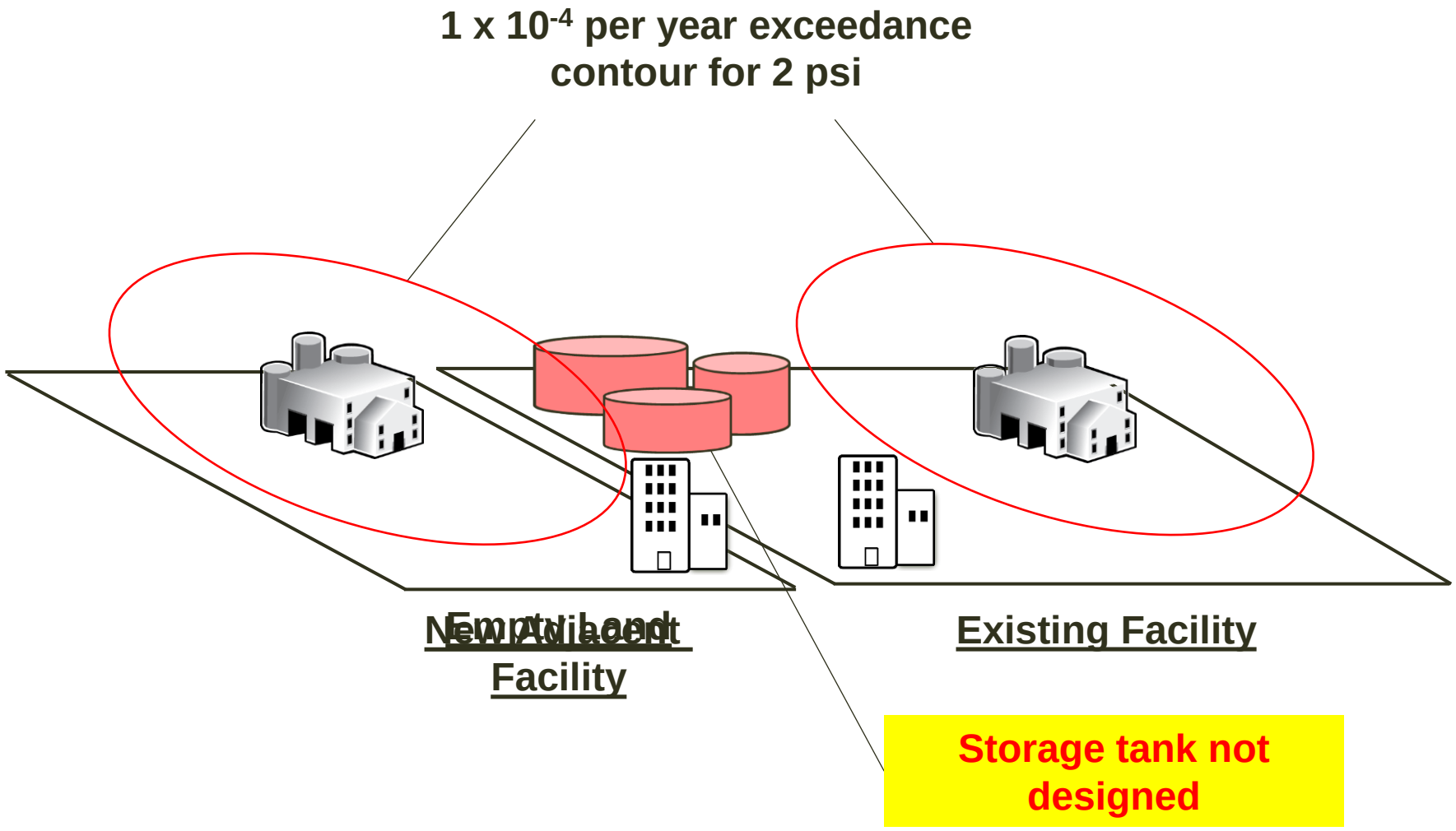


Impact to Offsite





Domino Effects/ Escalation



SIMOPS Risk

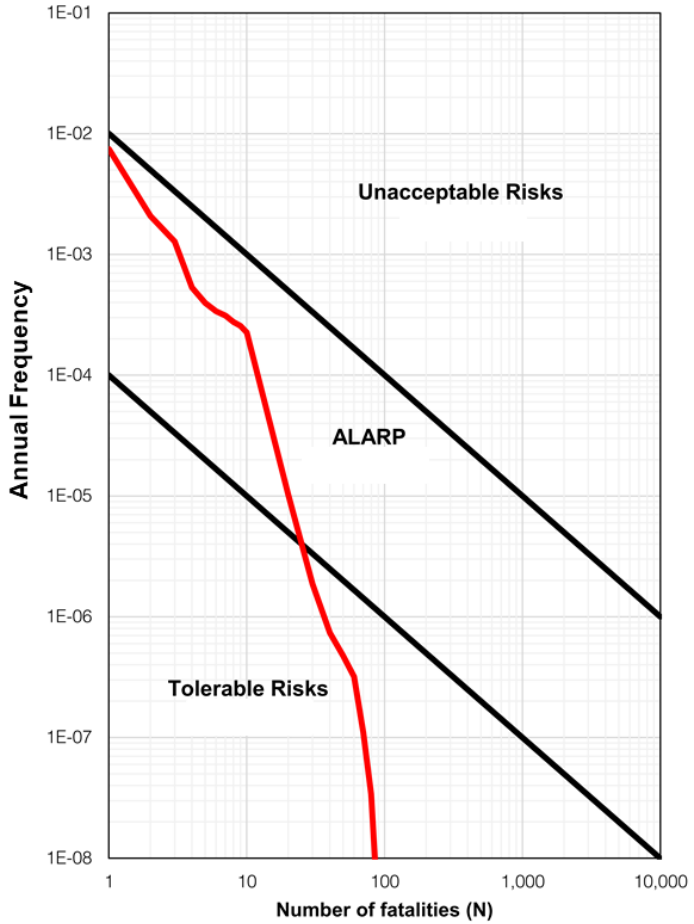
- **Increased manning during construction of brownfield**
  - Construction relating to a revamping/ expansion project running concurrently while existing process facilities are in production mode
  - Lifting, welding (increased ignition risk), excavation, transport activities

- **QRA should account for the additional manning and temporary structures**
  - 200 to 2000 construction personnel for 6 to 36 months
  - Significant impact on group risk / societal risk
  - Temporary structures not constructed to withstand blast and fire

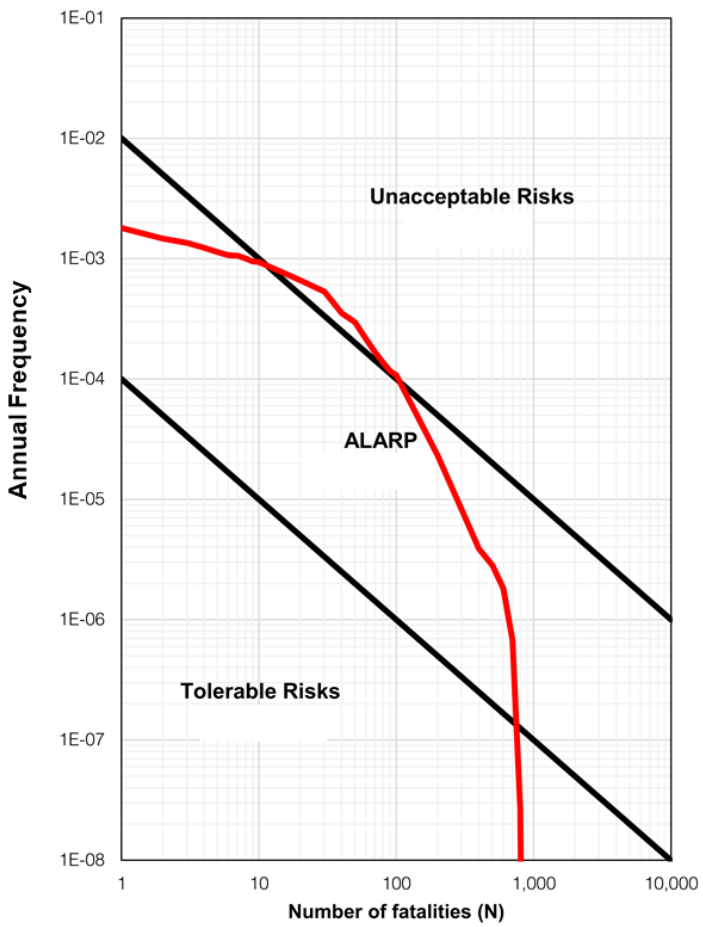
- **Ensure risk criteria is met considering increased manning**

SIMOPS Risk

All trains in operation



SIMOPS with one train operating and one under construction



Why Evaluate Escalation/ Cumulative Risk

Escalation Risk

- To limit escalation beyond the boundary
- To limit impact to adjacent structure or equipment
- To ensure adequate spacing between layout/equipment

Cumulative Risk

- To ensure overall risk within and outside the facility is in ALARP/ Acceptable region due to modifications/ new developments

Challenges

- Lack of legal requirement or Criteria
- Lack of Communication
- Unclear Responsibility - Risk is posed by different facilities and together they should agree on the approach and choose a common consultant who will perform the study
- Major complexes wherein expansion works are done – Effort in estimating cumulative/ overall risks is significant
- Different units within an expansion project handled by different EPC Contractors

Way Forward

- Some Countries have identified this escalation risk issue and criteria to meet

Project / Region	Risk Criteria (per year)	Harm Criteria	Requirement
Singapore guideline – escalation to offsite	1E-04 (for fixed facility)	• 20 kW/m^2 (Fire) • 2 psi (Explosion)	Confined within boundary
New South Wales HIPAP 4 – escalation to boundary	5E-05	• 23 kW/m^2 (Fire) • 14 kPa (Explosion)	Confined within boundary

- Major complexes wherein expansion works done – Risk file of existing facilities to be provided to Safety Consultant who can integrate risk of new facility with existing to get the overall risk perspective

- Voluntary Joint Safety Report or Authorities to coordinate/ commission a region-wide assessment

Approach- Escalation Risk

Now we know **why** Escalation Risk is important

So **how** to calculate Escalation Risk???

Evaluating Escalation Risk – Prescriptive-Based

- Company's established engineering standard
- Industry standards
  - AICHE-CCPS Guideline for Facility Siting and Layout
  - IChemE Process Plant Layout
  - Other relevant standards

Evaluating Escalation Risk – Prescriptive-Based

Table A
TYPICAL SPACING FOR PLANT EQUIPMENT FOR FIRE CONSEQUENCES
Explosion and toxic concerns may require greater spacing
Horizontal Distance (Ft)

	Text References	Boundaries: Process Unit Battery Limits	Boundaries: Property	Emergency: ESD Valves—Manual	Emergency: Fire Pumps	Emergency: Hydrants, Monitors	Emergency: Water Spray and ESD Activation Switches	Process Vessels: Equipment handling nonflammables, noncombustibles, nontoxics	Process Vessels: Reactors and Desalters	Process Vessels: Towers, Drums, Knock Out Pots, On-site Storage Tanks	Heat Transfer Equipment: Air cooled heat exchangers—process	Heat Transfer Equipment: Boilers, Air Compressors, Power Generation (Utility Area)	Heat Transfer Equipment: Cooling Towers	Heat Transfer Equipment: Exchangers (< autoignition or non-self-igniting)	Heat Transfer Equipment: Exchangers (> autoignition or self-igniting)	Heat Transfer Equipment: Fired Heaters	Rotating Equipment: Gas Compressor, Expanders	Rotating Equipment: Pumps handling Flammables > autoignition or self-igniting	Rotating Equipment: Pumps handling Flammables < autoignition or non self-igniting	Transfer Equipment: Loading Racks for Trucks and Rail Cars (except LFG)	Transfer Equipment: Any Liquified Flammable Gas Loading Racks (Trucks and Rail Cars)	Transfer Equipment: Main Piperacks (piping not associated with unit)	Transfer Equipment: Process Piperacks
Boundaries																							
Process Unit Battery Limits	5.7.3 6.8.1	100	Property																				
Property	5.2.5	200	NM																				
Emergency																							
ESD Valves—Manual	6.8.15	50	NM	NM																			
Fire Pumps	5.8.2	200	NM	NM	NM																		
Hydrants, Monitors	6.8.18	NM	NM	NM	NM	NM																	
Water Spray and ESD Activation Switches	6.8.14	50	NM	NM	NM	NM	NM																
Process Vessels																							
Equipment handling nonflammables, noncombustibles, nontoxics	6.8.2	NA	NM	NM	NM	NM	NM	NM															
Reactors and Desalters	6.8.4	NA	200	50	200	50	50	NM	NM														
Towers, Drums, Knock Out Pots, On-site Storage Tanks	6.8.3 6.8.5	NA	200	50	200	50	50	NM	15	15													
Heat Transfer Equipment																							
Air cooled heat exchangers—process	6.8.7	NA	200	50	200	50	50	NM	15	15	NM												
Boilers, Air Compressors, Power Generation (Utility Area)	5.5	100	100	50	200	50	50	NM	100	100	100	NM											
Cooling Towers	5.5.6	100	100	50	100	50	50	NM	100	100	100	100	25										
Exchangers (< autoignition or non-self-igniting)	6.8.6	NA	200	50	200	50	50	NM	15	15	15	100	100	NM									
Exchangers (> autoignition or self-igniting)	6.8.6	NA	200	50	200	50	50	NM	15	15	15	100	100	15	NM								
Fired Heaters	6.8.8	NA	200	50	200	50	50	NM	50	50	50	100	100	50	50	NM							
Rotating Equipment																							
Gas Compressor, Expanders	6.8.10	NA	200	50	200	50	50	NM	15	15	15	100	100	15	15	50	NM						
Pumps handling Flammables > autoignition or self-igniting	5.8.5 6.8.11	NA	200	50	200	50	50	NM	15	15	15	100	100	15	15	50	15	NM					
Pumps handling Flammables < autoignition or non-self-igniting	5.8.5 6.8.11	NA	200	50	200	50	50	NM	15	15	15	100	100	15	15	50	15	NM	NM				
Transfer Equipment																							
Central Loading Racks for Trucks and Rail Cars (except LFG)	5.8.8	200	100	50	200	50	50	NM	200	200	200	200	150	100	200	200	200	200	50	NM			
Any Liquified Flammable Gas Loading Racks (Trucks and Rail Cars)	5.8.8	250	350	50	250	50	50	NM	250	250	250	250	250	250	250	250	250	250	50	150	NM		
Main Pipe Racks (piping not associated with unit)	5.8.6	NM	100	NM	50	NM	NM	NM	50	50	NM	50	50	15	15	50	50	50	50	50	50	NM	
Process Pipe Racks	6.8.19	NM	200	NM	200	NM	NM	NM	15	15	NM	100	100	15	15	50	15	15	15	200	200	NM	NM

Typical Equipment Spacing Table (CCPS, 2003)

Evaluating Escalation Risk

Prescriptive approach

Though prescriptive approach is followed it has to be supplemented by one of the below methods

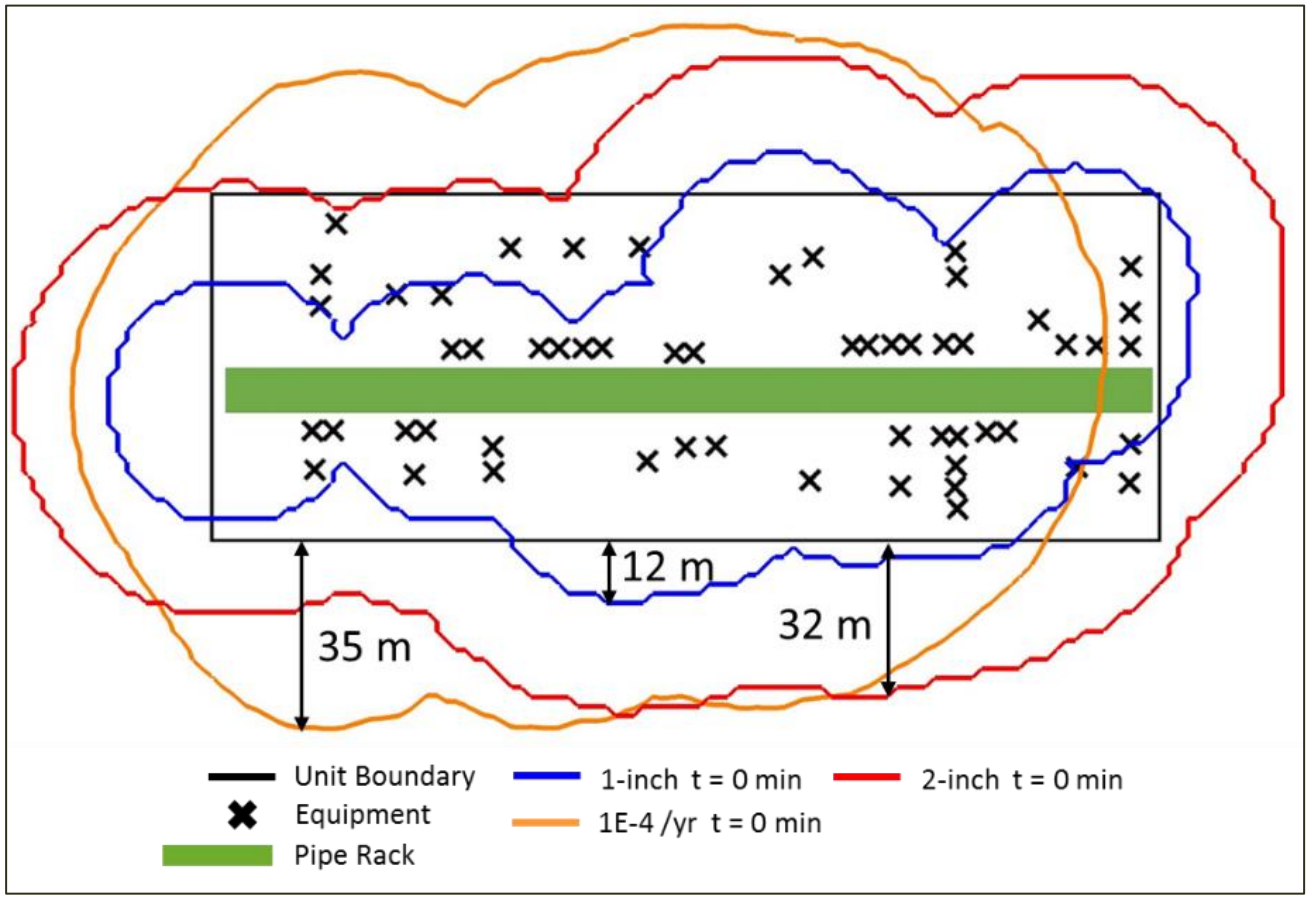
Consequence based approach

Fire events through representative credible leak size (1” or 2”), 37.5 kW/m^2 or 3 psi, reaching sensitive receptor (e.g. building or adjacent process unit)

Risk based approach

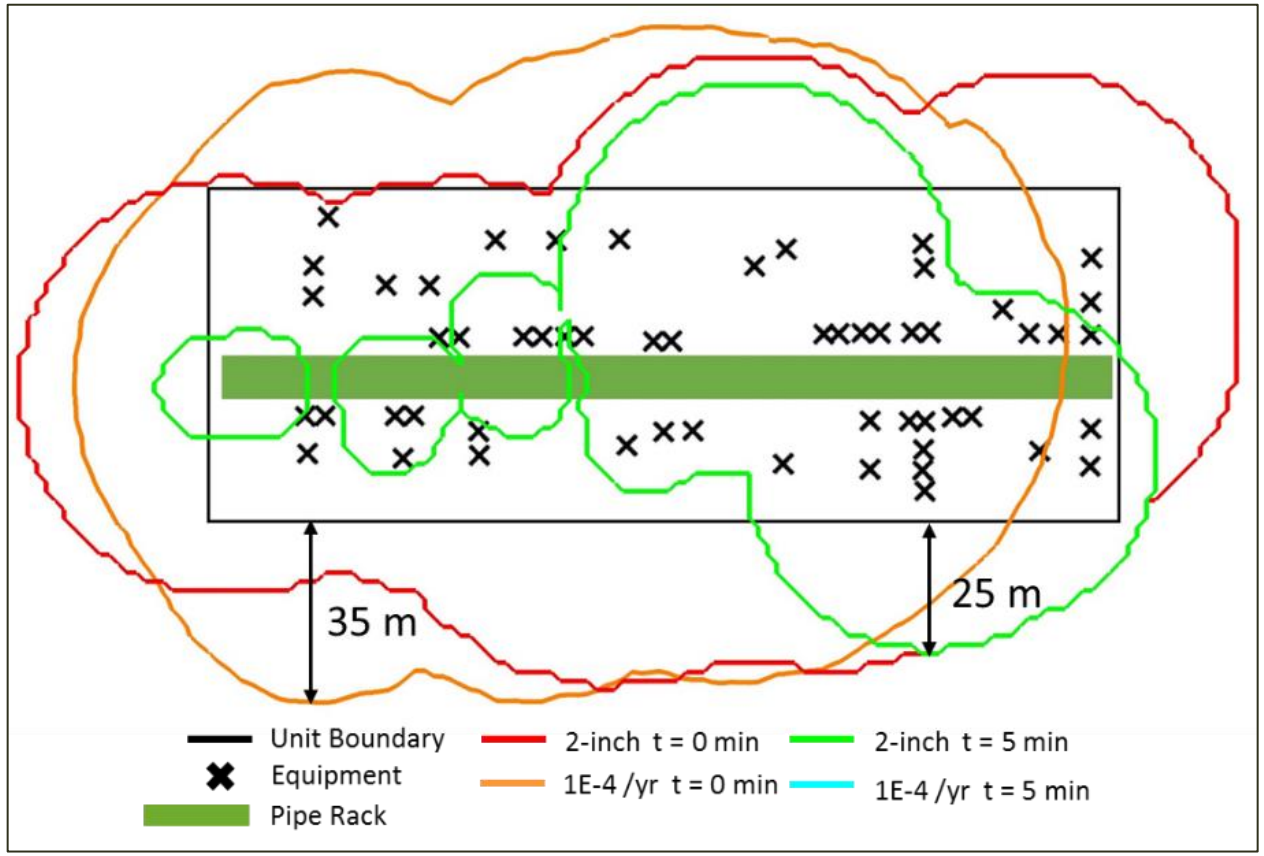
- Harm criteria and risk criteria
- Equipment damage threshold for escalation:
  - Jet Fire Engulfment for 5 minutes
  - Pool Fire Engulfment for 10 minutes
  - 37.5 kW/m^2 Thermal Radiation for 60 minutes

Results for 1”, 2” & Risk-based at t = 0 min



SGP Consequence-based and Risk-based Assessment Result (t = 0 min)

Results for 2” & Risk-based at t = 0 & 5 min



SGP Consequence-based and Risk-based Assessment Result (t = 0 min and t = 5 min)

*** Cumulative frequency at 5 min does not reach 1 x 10^{-4}/yr**

Impact Distances Summary

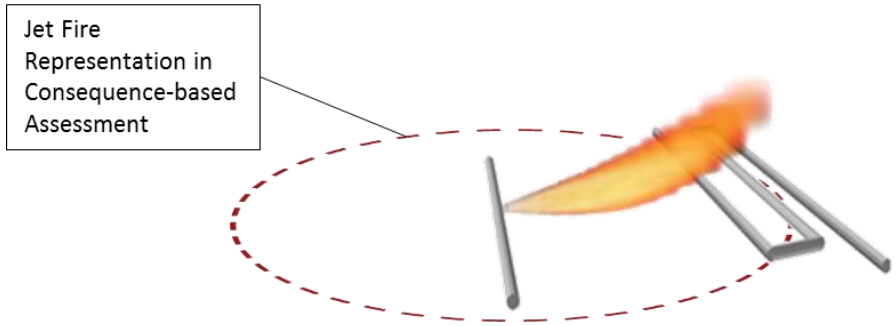
Impact Distances from SGP Unit Boundary		
Methods	Long-side	Short-side
Results based on t = 0min		
Consequence-based (1-inch)	12 m	20 m
Consequence-based (2-inch)	32 m	35 m
Risk-Based (1×10^{-4}/yr)	35 m	25 m
Results based on t = 5 min		
Consequence-based (2-inch)	25 m	10 m
Risk-Based (1×10^{-4}/yr)	-*	-*

- For comparison, the GAPS guidelines recommend 30 m (100 ft) separation for such units
- Impact distance for 2” Consequence-based similar to Risk-based at 1×10^{-4} exceedance /yr
- Impact distances reduced at t = 5 min considering detection, isolation & blowdown
  - can be ignored if such measures are not provided or effectiveness is uncertain

Limitations of Consequence-based Approach

- **Impact distance for 2” release is twice as large as for 1”**
  - Selection of appropriate hole size is critical to the assessment
  - Often based on individual’s judgement rather than a sound justification

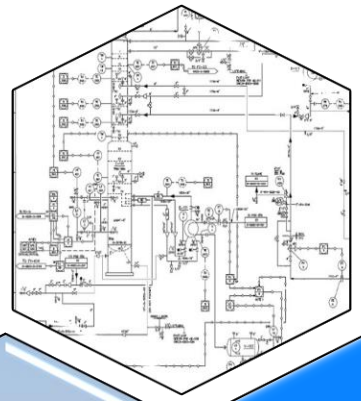
- **Consequence-based approach does not address directional characteristic of a jet fire**



Limitations of Risk-based Approach

- Piping arrangement
- Number of plant component

Require great level of details of the project



Time and resource intensive analysis

- Inventory calculation
- Frequency estimation
- Full range of hole sizes/ scenarios

- Selection of failure database
- Assumptions relating to ignition probability, detection success probability etc.

Uncertainty

Findings From The Case Study

Results by risk-based approach

- Taking into account the uncertainty (e.g. failure data, ignition probability, detection & isolation success probability), distance to 1 x 10^{-4} /yr at t = 0 min is more appropriate
- Gives similar results as the consequence-based approach using 2-inch release
- Gives similar separation distance of 30 m as suggested in GAPS guideline for such refinery units
- Fire protection for equipment and structure within and outside unit to be determined individually using exceedance curves

Further work

- Similar comparative analysis to be conducted for more process units

Summary

- Identifying and Managing escalation risk for brownfield expansion can be challenging and complex
- Joint efforts is required between various stake holders
- Appropriate approach to be selected for escalation risk evaluation

Chemical Process Safety Sharing

Thank you for your attention