Reliability & Risk Division
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Assessment of Oil Leak Containment Strategies in Refineries in Tropical Countries using Quantitative Risk Assessment and ALARP (As Low as Reasonably Practicable)

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Objective

Share design assessment outcomes, learnings, and best practices of two oil containment strategies in refineries located in tropical countries

Outline

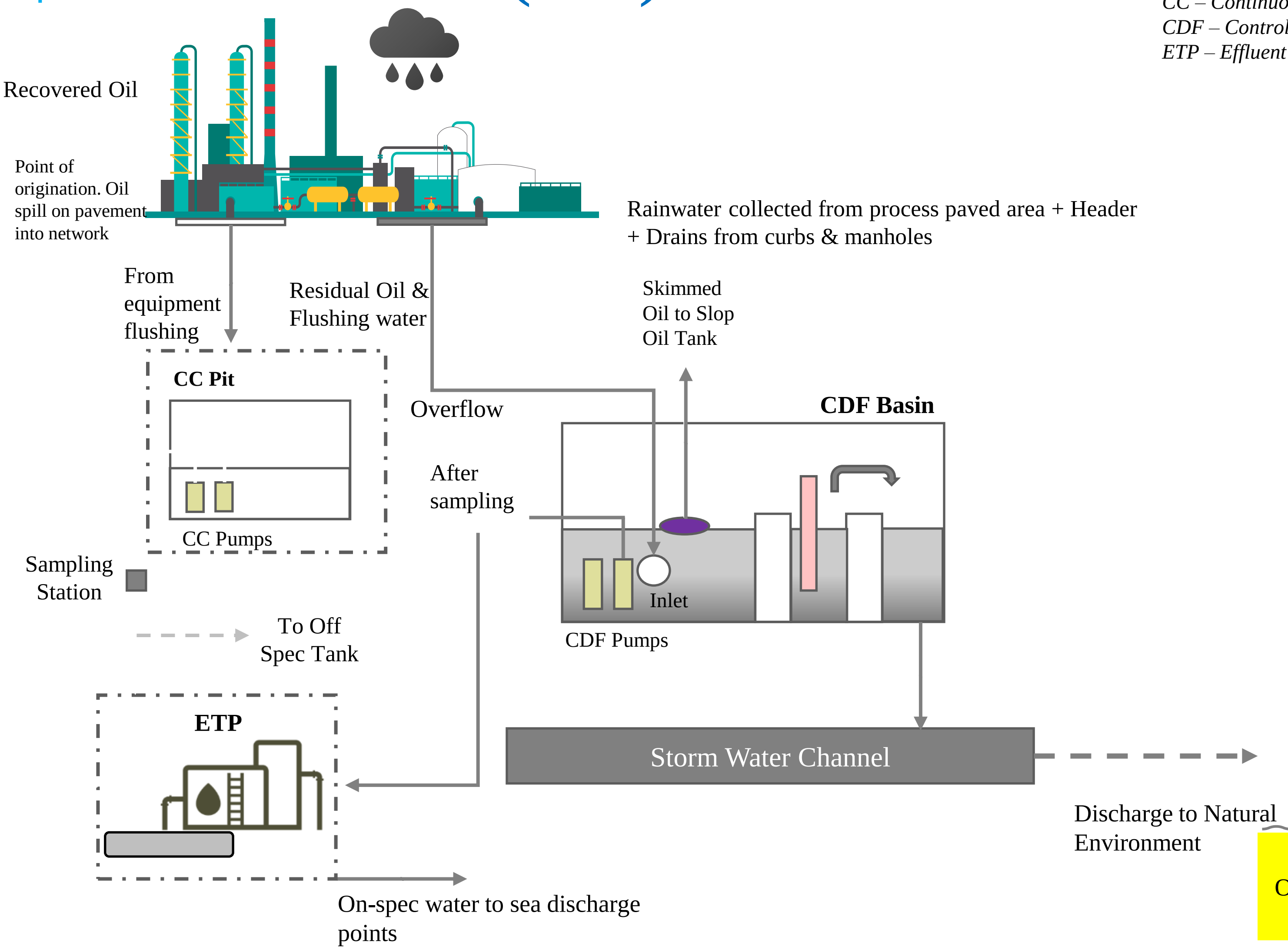
- Introduction
- Methodology
- Data Collection
- Analysis
- Conclusions
- References
- Acknowledgement

Introduction (1/3)

- Refineries and accidental oil spills are to be expected
- In tropical countries, rain can happen in ~50:50 split and as high as ~200mm
- Robust strategy/ies mandatory for protecting environment, especially public waters
- Two setups available. Setup 1: Having a Controlled Discharge Facility (CDF); or Setup 2: Having a large retention pond – or end-of-pipe system

Introduction (2/3)

CC – Continuous Contaminated Service
CDF – Controlled Discharge Facility
ETP – Effluent Treatment Plant



Setup 1

Oil in water quality limit is **5ppm**

Introduction (3/3)

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CDF – Controlled Discharge Facility
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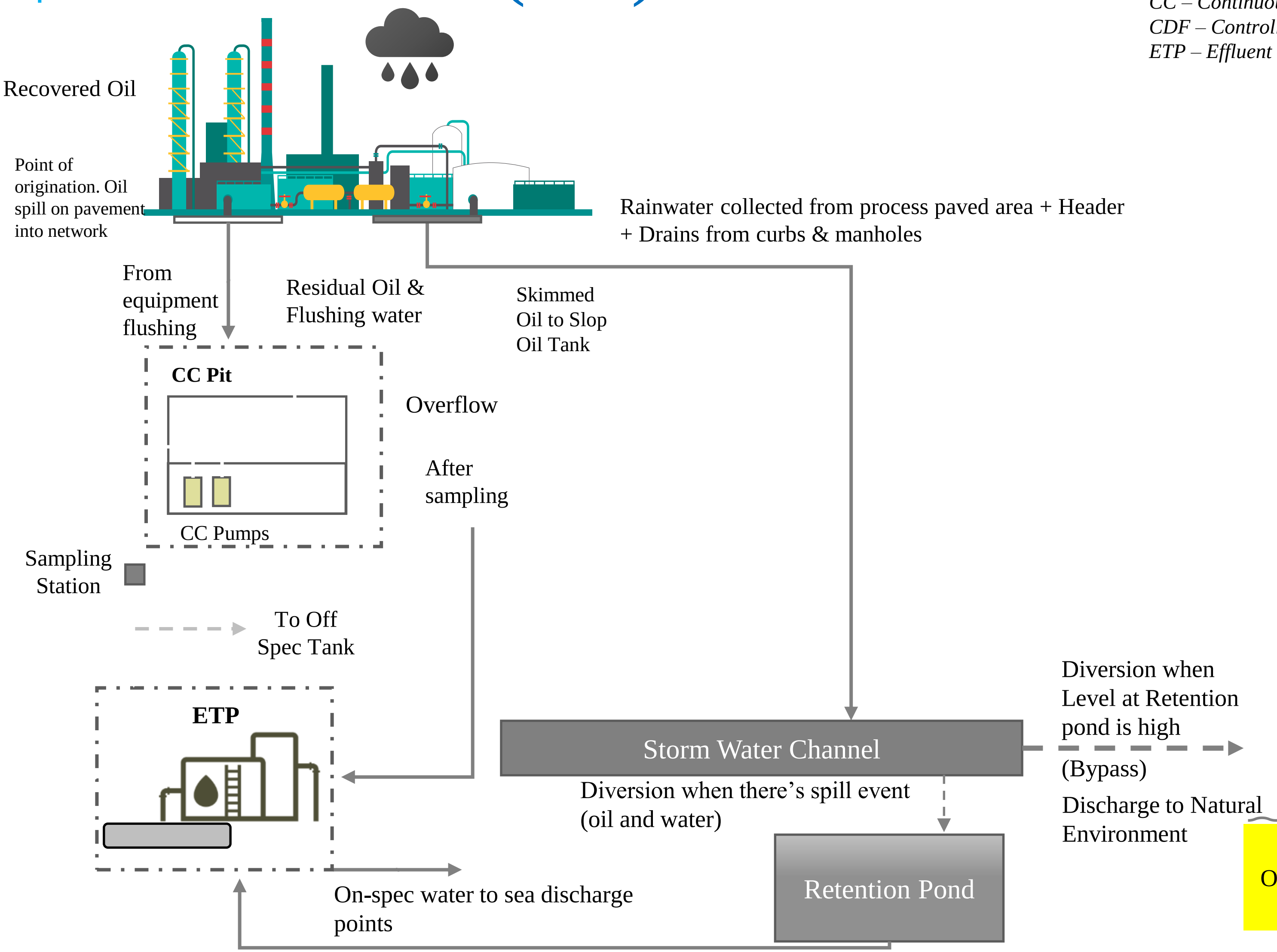


Setup 2

Oil in water quality limit is **5ppm**

Methodology

- Quantitative Risk Assessment (QRA) (including model set-up, parts count, Markov Chain Technique, Monte Carlo simulation [hourly block]) utilizing inputs on the right

- Risk Reduction Factor determination using consequence numbers and event frequencies

- Paved area
- Probability of:
  - rain
  - rain duration
  - rain intensity
- Probability of:
  - spill
  - spill amount
  - spill remnant based on clean-up effectiveness
- Probability of low ullage in retention pond
- Effectiveness of CDF
- Release limits and consequence levels
- Risk Reduction Factor required based on each consequence level

Data Collection (1/5)

- Rain probability and state transition matrix:

	Dry	**Rain**
Dry	3314	2050
Rain	2050	2812
Sum	5364	4862
Proportion	0.52	0.48

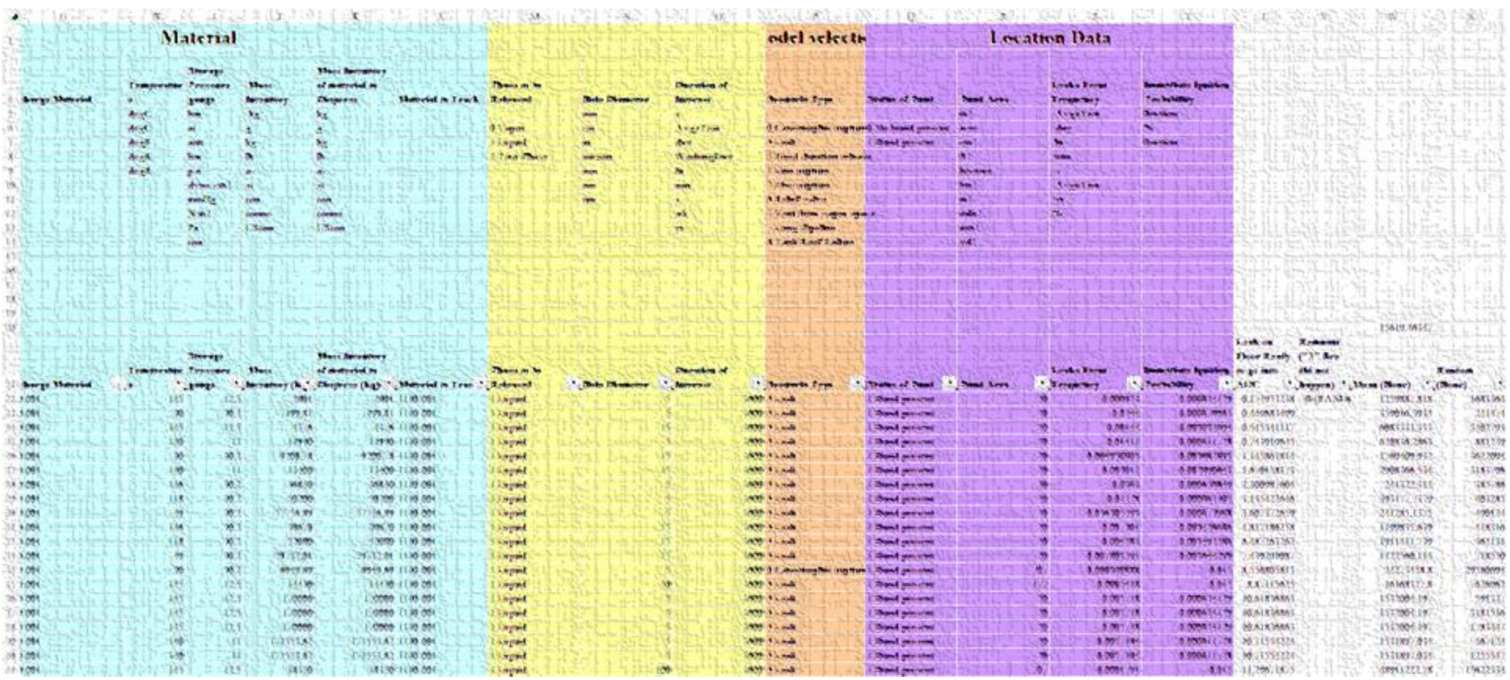
	Dry	**Rain**
Dry	0.62	0.38
Rain	0.42	0.58

- Rain intensity (mm):

Q_a	0.1
Q_b	1
Q_c	5
Q_d	16
Q_e	260

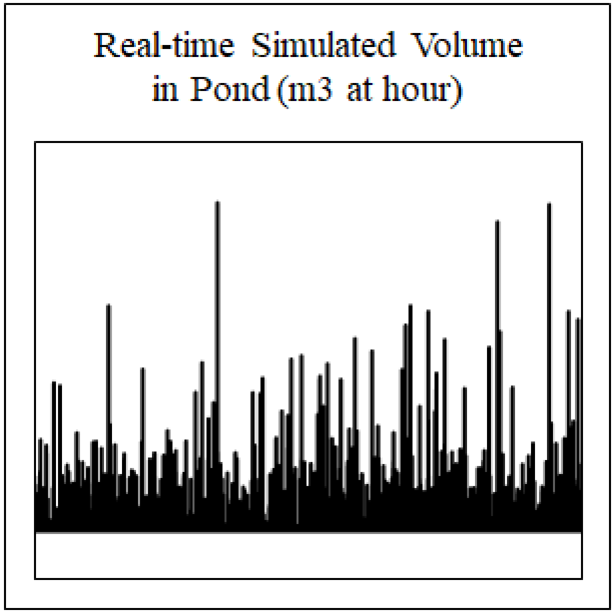
Data Collection (2/5)

Spill probability and spilled amount probability, from parts count.
Note: quickest clean-up estimated at 24 hours, and 30 days for major spills, as an assumption



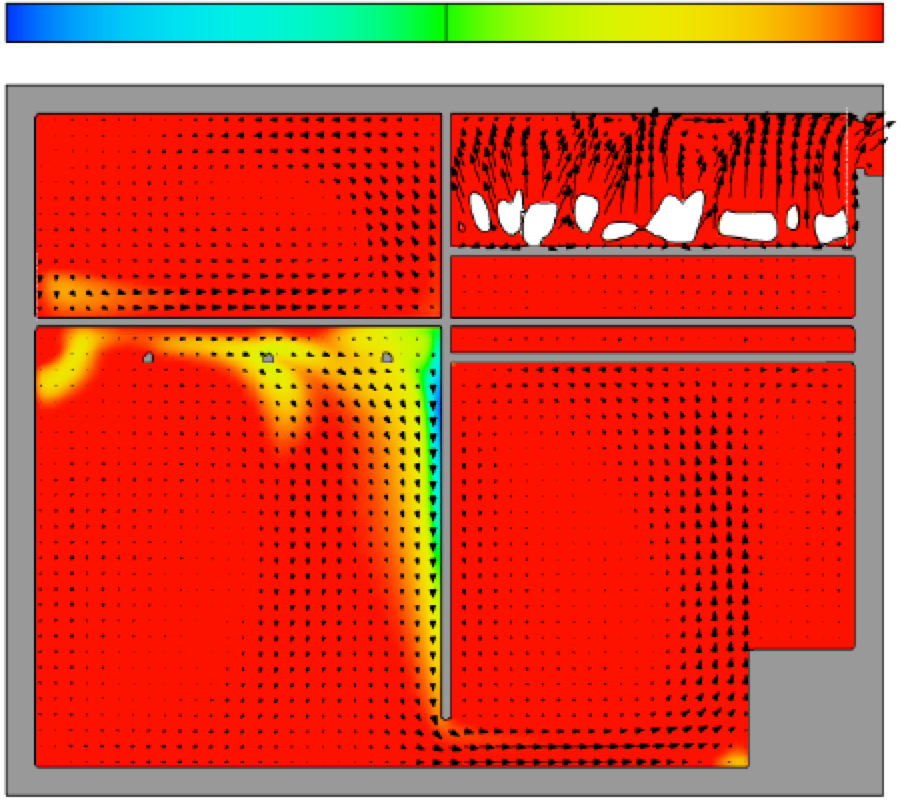
Data Collection (3/5)

Probability of low ullage in pond are simulated based on rain, rain intensity, rain duration, pumping capacity, receiving end capacity, and pond size



Data Collection (4/5)

- Effectiveness of CDF is estimated to be 93%, based on a Computational Fluid Dynamics assessment
- Basis: Oil retention volume against total oil in-flow into CDF



Data Collection (5/5)

Release limits, consequence levels, and required Risk Reduction Factors (RRF)

Consequence	ppm limit	Target events/year	Required RRF
1	0.5	NA	NA
2	5	NA	NA
3	50	0.001	1,000
4	500	0.0001	10,000
5	5000	0.00001	100,000

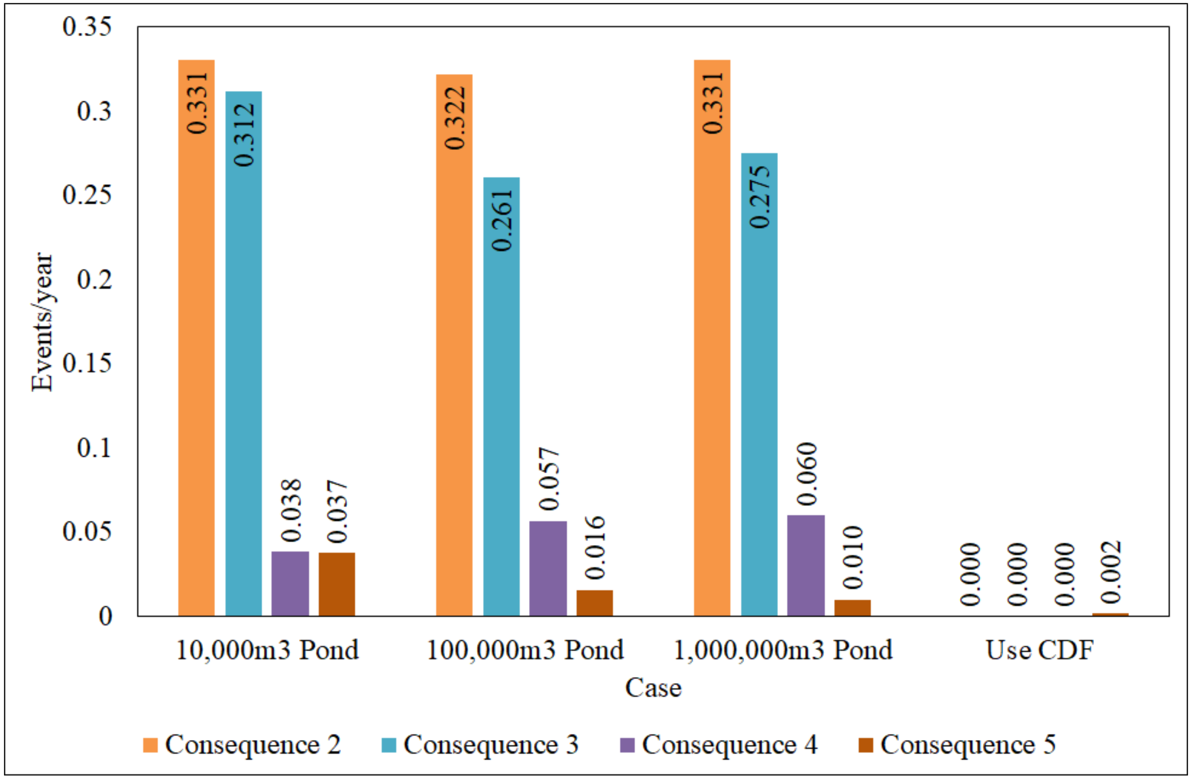
Analysis (1/3)

Minimum simulation required is 36, and actual simulation is 100. Time per simulation is ~2s. Three (3) cases of pond size simulated, and one (1) case of CDF simulated. Total simulation time ~13 minutes using Microsoft® Excel VBA

							Minimum simulation required
							36
Parameter	Low (No)	In-between	High (Yes)	Fixed (*: with sensitivity)	Fixed rate	Dependent variable (Result)	Minimum range of independent variables
Rain	X		X				2
Rain intensity	X	X	X				3
Paved area				X			1
CDF efficiency				X			1
Spill year	X	X	X				3
Spill quantity	X		X				2
Cleaning time					X		1
Oil carried over to pond	X	X	X			X	NA
Pond size				X*			NA
Pond level	X	X	X			X	NA
Oil quantity to public water						X	NA
ppm						X	NA
Appearance						X	NA

Analysis (2/3)

Results (events/year for each consequence and Case):



Analysis (3/3)

Results [required RRF. Note: Number of layer of protection required is ~$log_{10}(RRF)$]. Additional 2 layers of protection required for CDF, for the design studied

		Required risk reduction factor			
Consequence	maximum ppm limit	10,000m^3 Pond	100,000m^3 Pond	1,000,000m^3 Pond	Use CDF
1	0.5	NA	NA	NA	NA
2	5	33	32	33	0
3	50	312	261	275	0
4	500	383	567	600	0
5	5000	3750	1583	1000	167

Conclusions

- Effective control of oil release prevention requires the following key strategies:

Layer of Protection 1: Installation of effective Controlled Discharge Facility (CDF) covering paved area and expected worst case oil spill in the area

Layer of Protection 2: Increasing bund heights to cover for remaining tankage areas

Layer of Protection 3: Establishing emergency response by mechanical and chemical oil spill control and mitigation

- Other administrative barrier that will help and shall be in place are inspection, testing, and maintenance to prevent loss of containment, preparation of oil spill control kits, and emergency drills
- Having end-of pipe setup is not feasible due to limitation of pumps, and ETP for tropical rains, and the ponds may be a source of hydrocarbon vapor release

References

- Company and local government in-house data and standards on Process Safety, HSE, and technical data
- BS EN 752; 2008 Drain and Sewer system Outside Buildings
- IPIECA: Petroleum refining water/wastewater use and management 2010
- IFC 2007. Segregation of liquid effluents principally along industrial, utility, sanitary, and stormwater
- IFC EHS for Petroleum Refining 2016
- DEIA 2016 Chapter 6 EMP 6.5.1.5
- IEC 61165, Application of Markov Techniques, Second Edition, 2006-05
- Paul Barringer's materials on Monte Carlo model setup and simulation

Acknowledgement

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- Masdi Muhammad – Dr