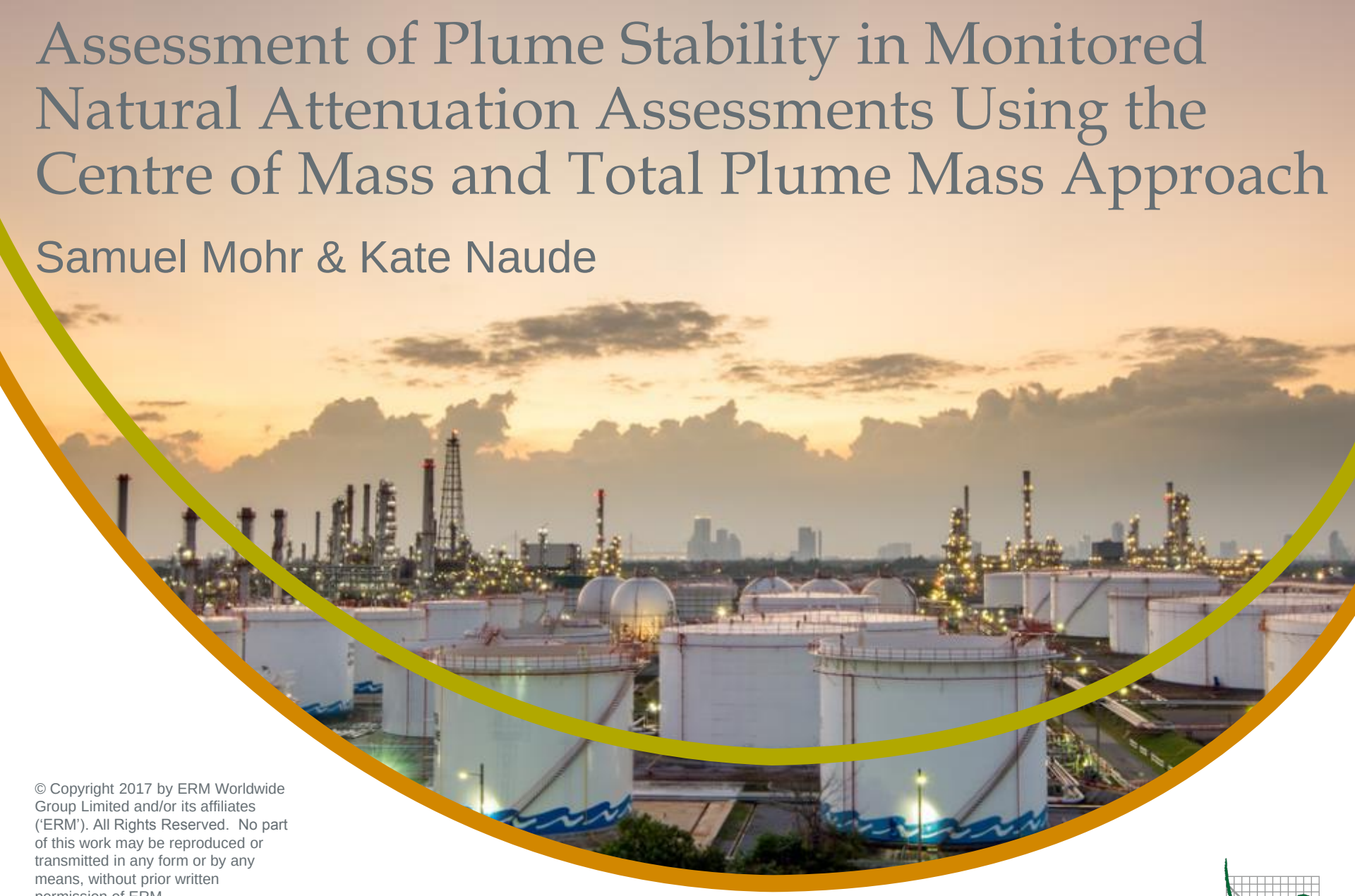
Assessment of Plume Stability in Monitored Natural Attenuation Assessments Using the Centre of Mass and Total Plume Mass Approach

Samuel Mohr & Kate Naude



The business of sustainability

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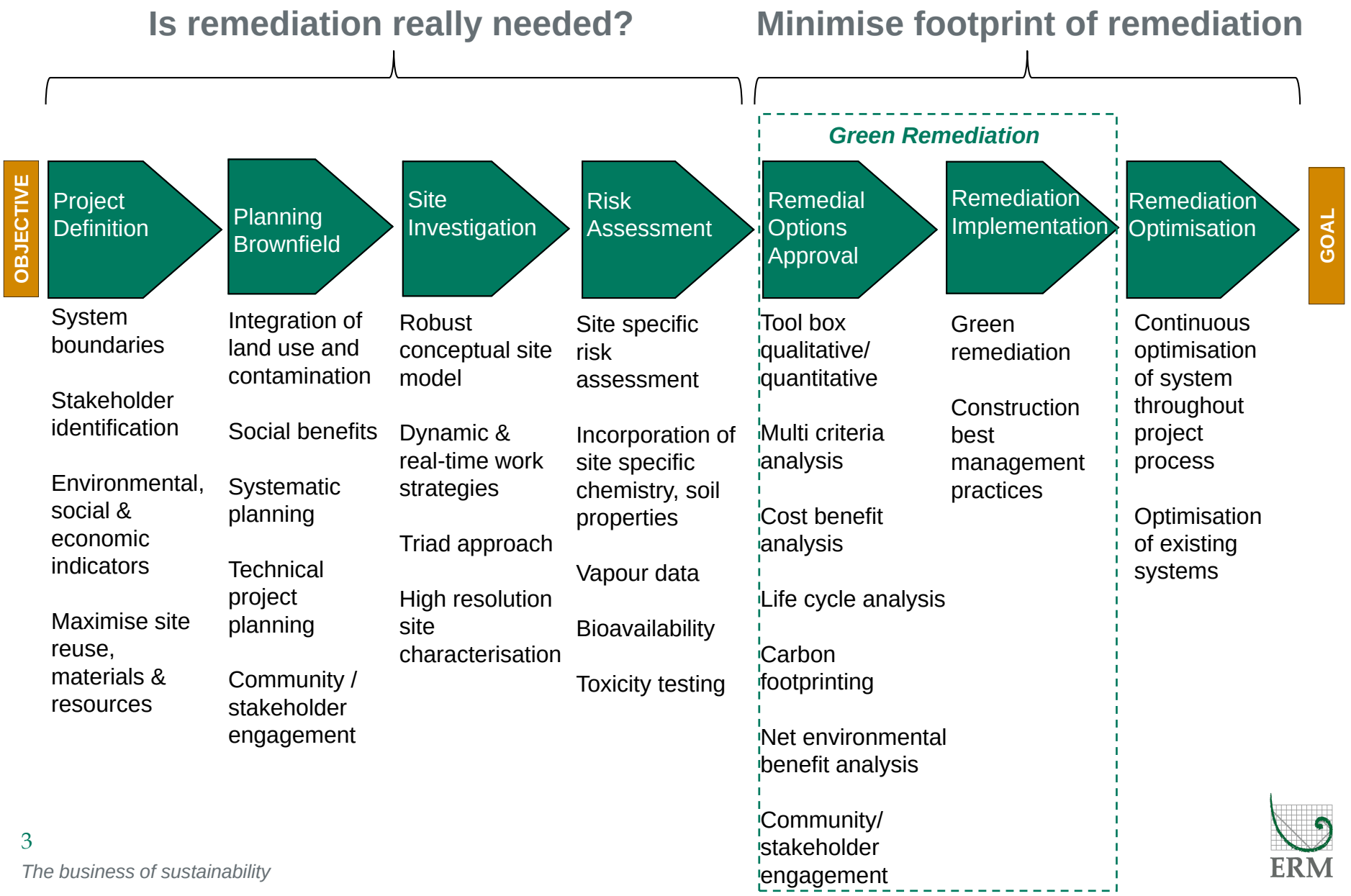
Presentation Outline

- The sustainable remediation approach
- Methods for assessing plume stability
- Case study:
  - Site setting
  - Plume area and mass calculations
  - Plume centre of mass
- Conclusions

ERM's Sustainable Remediation Approach



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MNA: A Sustainable Remedial Approach

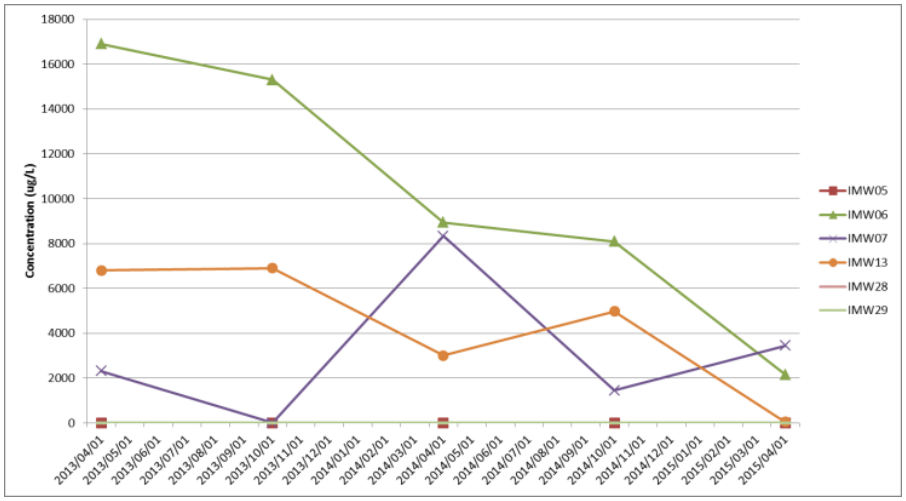
- Monitored Natural Attenuation (MNA) has been steadily gaining popularity as a plausible remediation strategy over the past two decades
- Three main criteria for adopting an MNA approach:

Criteria 1	**NA processes must be demonstrated to an acceptable level of confidence**
Criteria 2	**The intended land uses must not adversely affect the NA processes**
Criteria 3	**Identified receptors will be protected in the short and long term, and minimal expansion of the plume over the remedial timeframe**

Methods For Assessing Plume Stability

Graphical Analysis

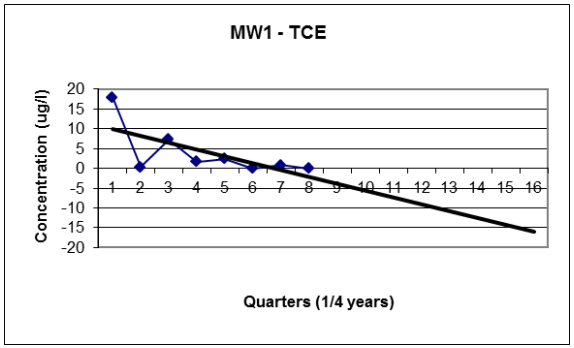
- Concentration isopleth maps
- Concentration vs distance
- Concentration vs time

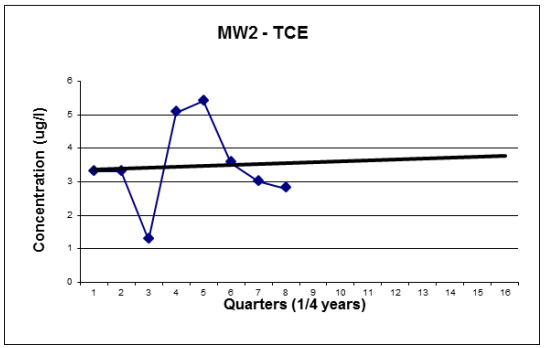


Statistical Analysis

- Mann Kendal Analysis
- Mann Whitney U-test

Mann-Kendall Results	
0-8 Quarter Evaluation	
MW1	Decreasing
MW2	Stable/No Trend
MW3	Stable/No Trend
MW4	Decreasing
MW5	Increasing





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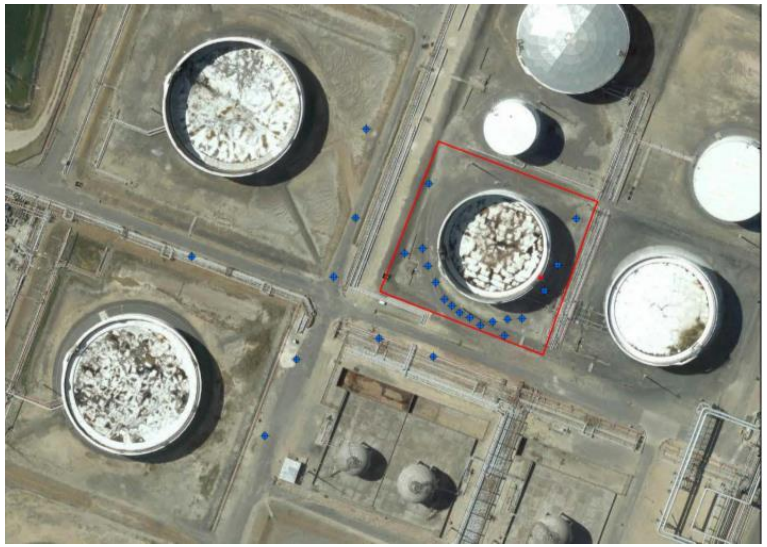
Site Setting

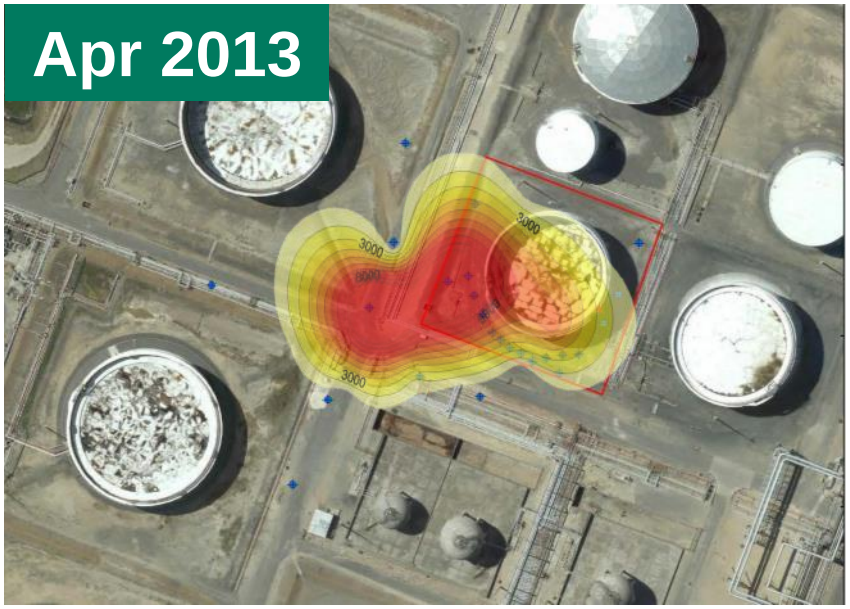
- Operational petrochemical facility
- Sand dominated sediments to 6m bgl, followed by dense clay
- Groundwater at 1-2m bgl, groundwater flow in a westerly direction
- Large gasoline spill in 2011

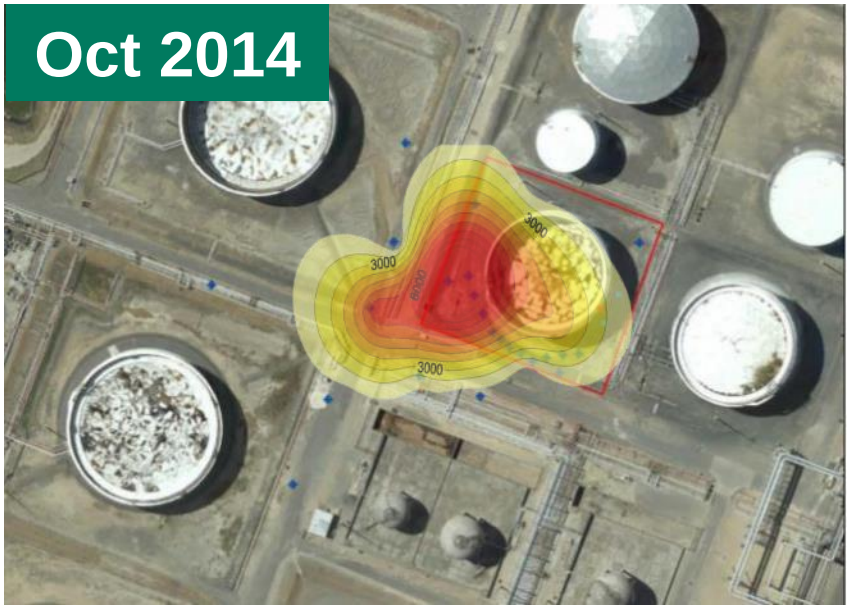


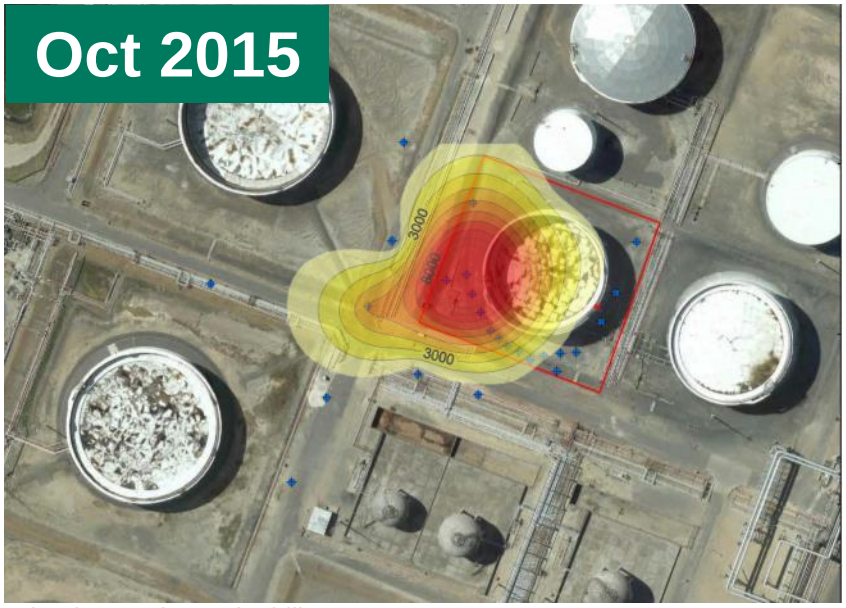
A site investigation and remediation programme was initiated which included:

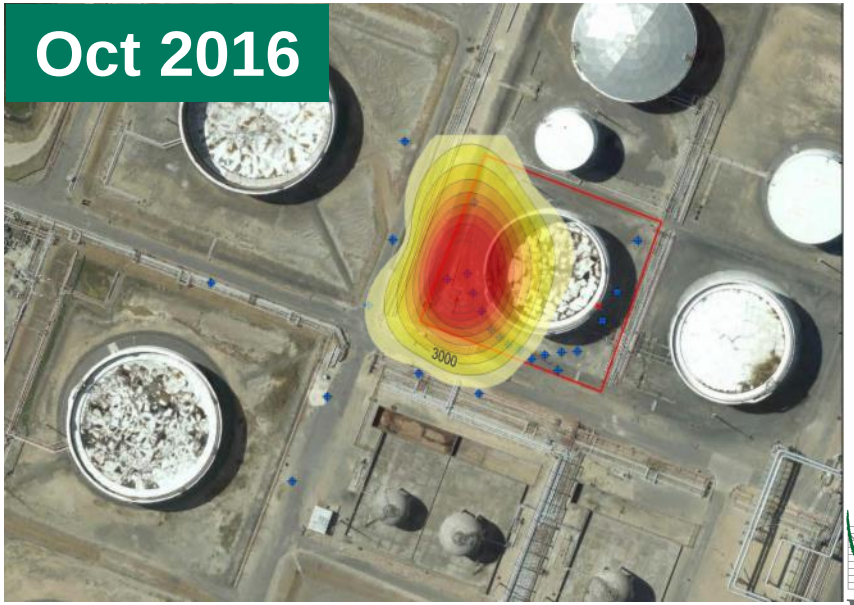
- ***Plume delineation & monitoring well installation,***
- ***Product recovery well installation & passive skimming; and***
- ***Groundwater monitoring of the plume & surrounding area***

Plume Area and Mass Calculation



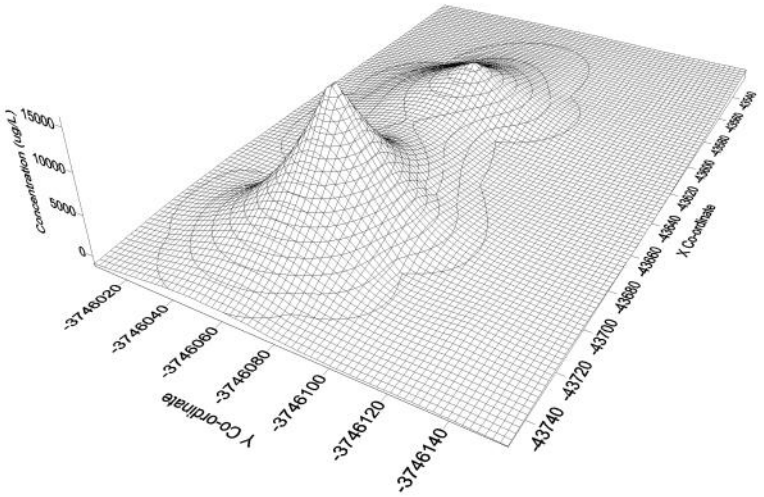


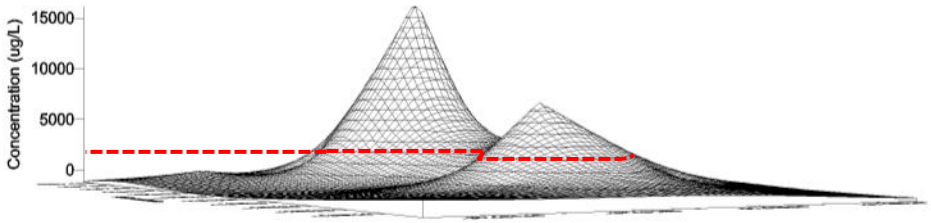




Plume Area and Mass Calculation

- Isopleth maps were generated as 3 dimensional surfaces
- Plume threshold value is set and a grid volume report is generated giving:
  - Planar area (m^2)
  - Grid volume ($\mu g/L \bullet m^2$)





$$Average\ [C] = \frac{Grid\ Volume\ (\mu g/L \bullet m^2)}{Planar\ Area\ (m^2)}$$

$$Actual\ Avg\ [C] = Average[C] + Plume\ Threshold\ [C]$$

$$Plume\ Mass\ (kg) = \frac{[Planar\ Area] \times [Actual\ (C)] \times [b] \times [n_{eff}] \times [\frac{1000L}{m3}]}{1E + 9\mu g/kg}$$

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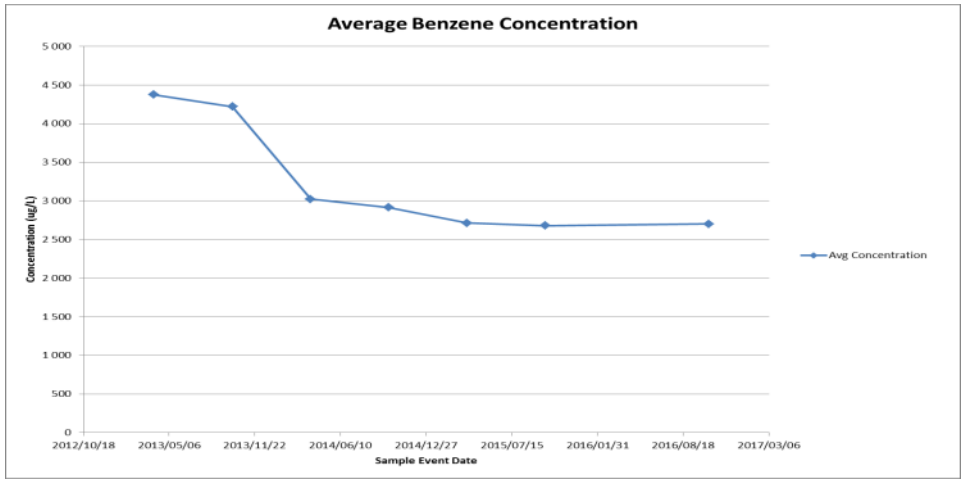
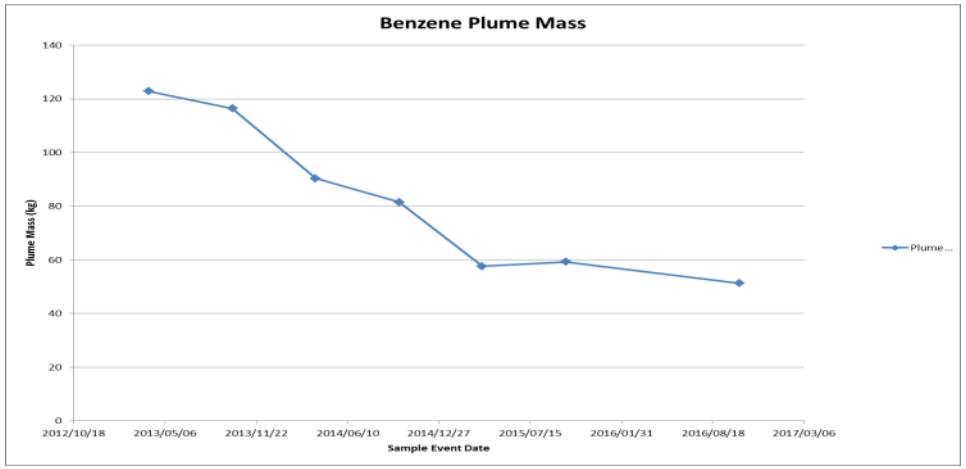
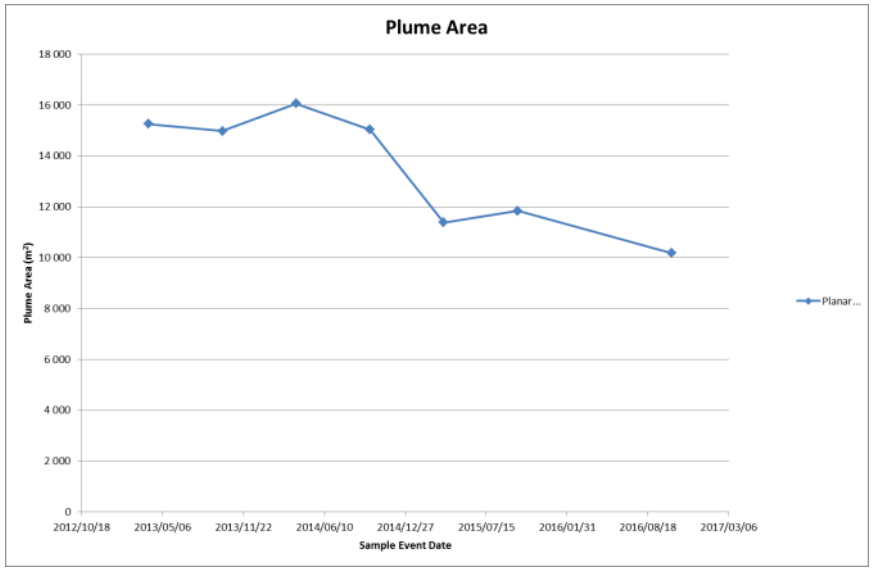
Plume Area and Mass Calculation







Parameter	R^2	Regression Line Slope	95% Lower Confidence Limit	95% Upper Confidence Limit	Trend Analysis Conclusion
Concentration	0.69	-1.3	-2.44	-0.32	Decreasing
Mass	0.88	-0.06	-0.08	-0.04	Decreasing
Area	0.77	-4.6	-7.47	-1.72	Decreasing

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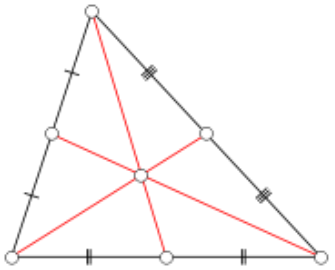
Plume Centre of Mass

- The plume centre of mass (COM) is essentially the geometric centre (or centroid) of the plume
- Plume COM is generated from Surfer grid files
- Grid file data (X,Y,Z) is filtered to remove all node points which are less than the defined threshold (Z) value



$$\mathrm{COM\ (X)} = \frac{\sum_1^n \mathrm{X} \times \mathrm{Z}}{\sum_1^n \mathrm{Z}} \qquad \mathrm{COM(Y)} = \frac{\sum_1^n \mathrm{Y} \times \mathrm{Z}}{\sum_1^n \mathrm{Z}}$$

Typical Plume COM behaviour:

- ***Expanding plume - migrates downgradient***
- ***Shrinking plume – migrates up-gradient (back towards source)***
- ***Stable plume – minimal lateral movement***

	A	B	C	D	E
1	X	Y	Z(ug/L)	X*Z	Y*Z
2	-43692.46	-3746066	1699.225	-74243342	-6365409922
3	-43694.78	-3746066	1696.621	-74133471	-6355652819
4	-43694.78	-3746063	1653.241	-72237990	-6193144531
5	-43692.46	-3746063	1648.424	-72023702	-6175100542
6	-43694.78	-3746068	1579.576	-69019243	-5917200603
7	-43692.46	-3746068	1571.028	-68642105	-5885179655
8	-43697.1	-3746066	1569.345	-68575821	-5878869454
9	-43697.1	-3746063	1547.318	-67613310	-5796351718
1052	Summation		471541.6	-2.06E+10	-1.7664E+12

Plume Centre of Mass

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Conclusions

- Total mass approach is a useful tool within the MNA toolbox to demonstrate that natural attenuation processes occurring within a plume
- Centre of Mass approach is a useful method to provide a meaningful assessment of plume stability
- Data generated from the case study supports the position that MNA is an appropriate and sustainable approach to employ at the site
- As always, there are limitations…



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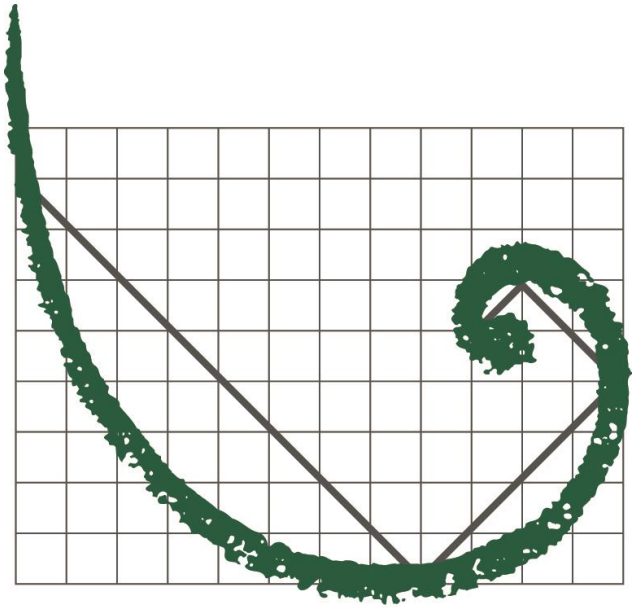

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