Multiple lines of evidence in land contamination assessment and remediation

From active remediation to monitoring to site closure

18 April 2024

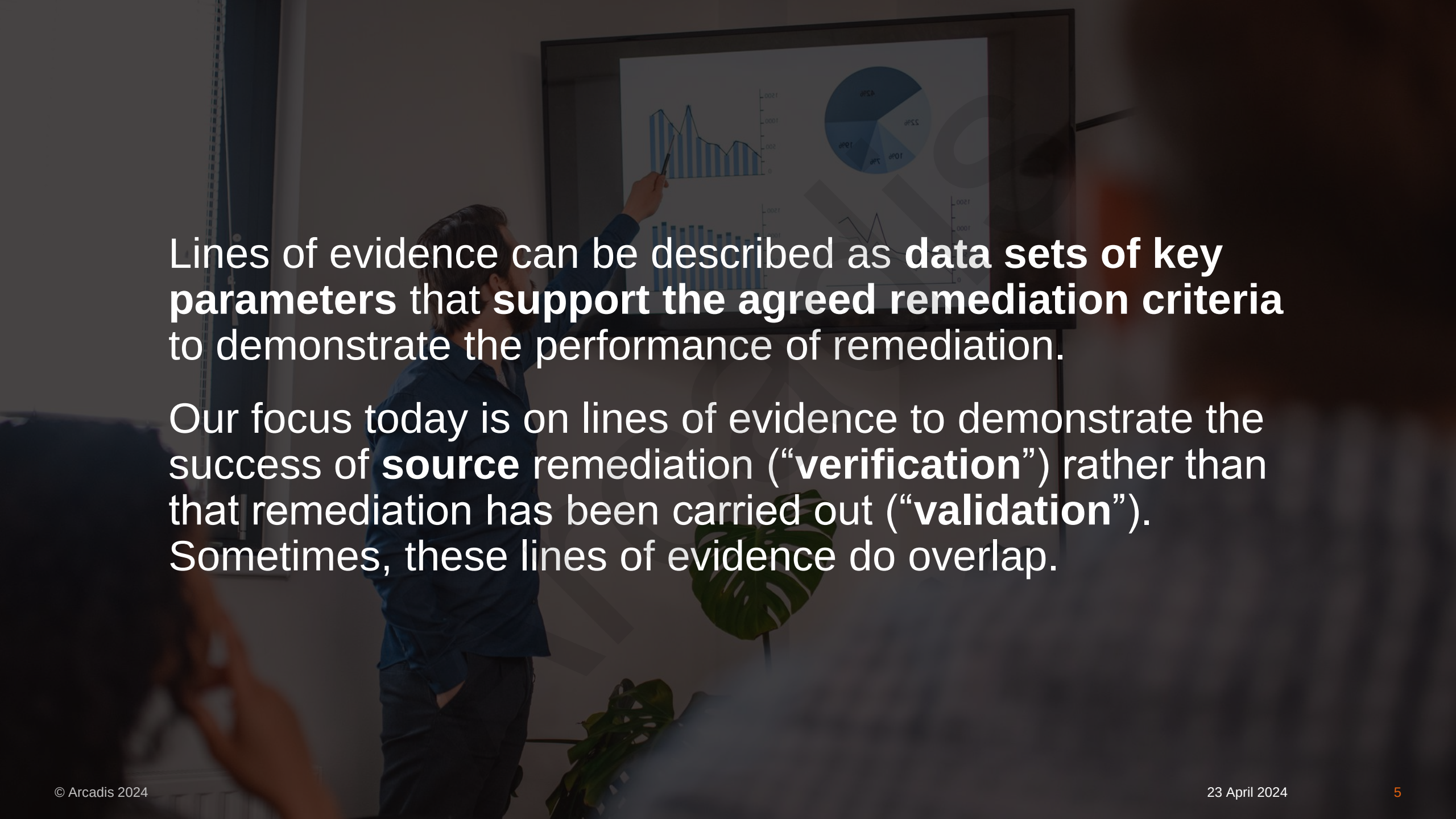
What does “great” look like for contaminated site management?

Why does achieving “great” often feel difficult?

All of this can affect contaminated site management requirements and timescales

How can we overcome these challenges?

- Build a team which understands local jurisdiction requirements
- Don’t forget the importance of risk perception for different stakeholders – we need to think psychology!
- **Use Multiple Lines of Evidence to support remediation closure**



Lines of evidence can be described as **data sets of key parameters** that **support the agreed remediation criteria** to demonstrate the performance of remediation.

Our focus today is on lines of evidence to demonstrate the success of **source** remediation (“**verification**”) rather than that remediation has been carried out (“**validation**”). Sometimes, these lines of evidence do overlap.

When can I use lines of evidence to support closure?

1. Site conditions are stable or improving; **and**

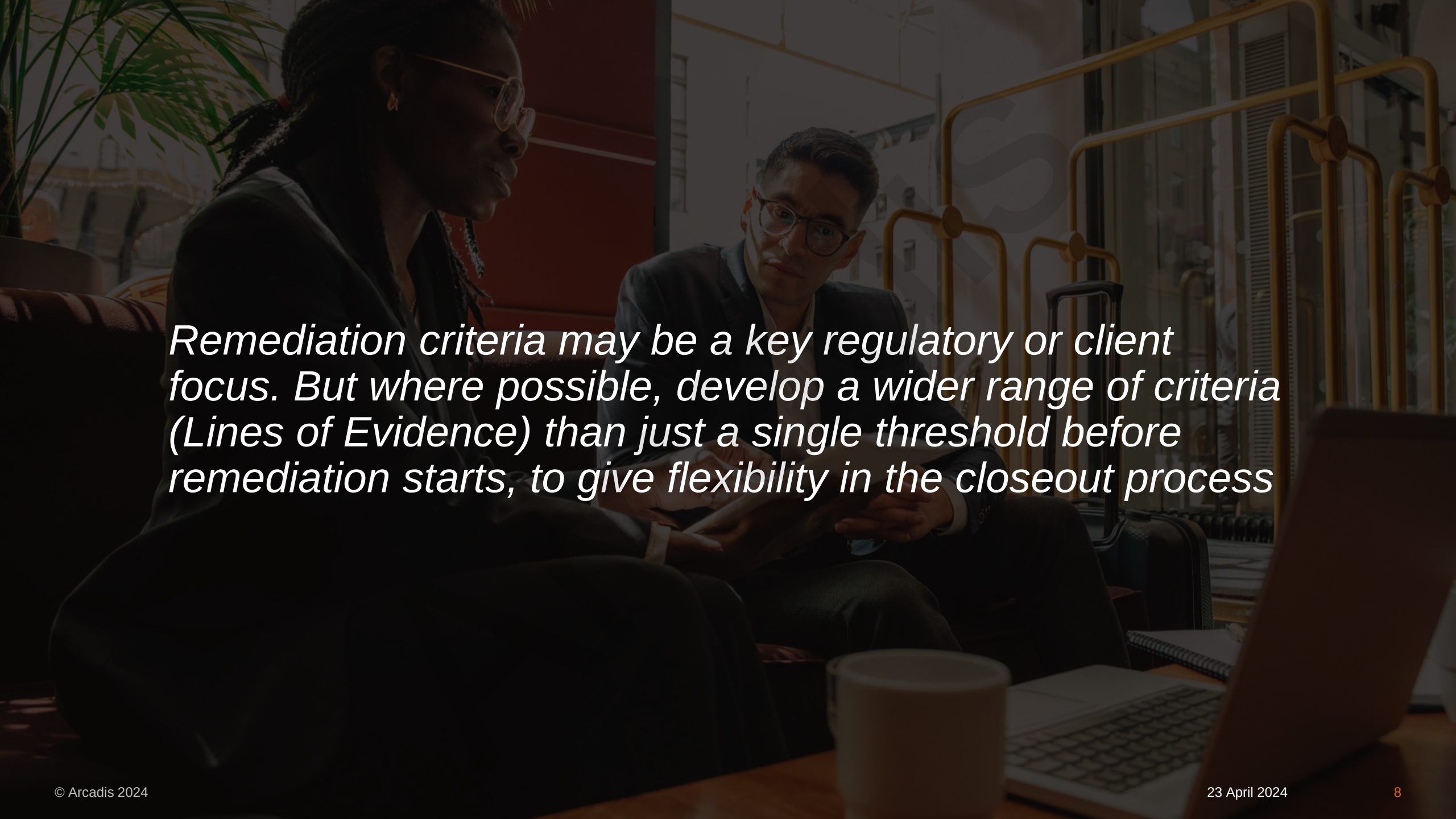
2. Identified **significant** risks to humans, ecology or property can be demonstrated to be acceptable

So, what type of lines of evidence can we consider to help close out remediation?

Examples include…

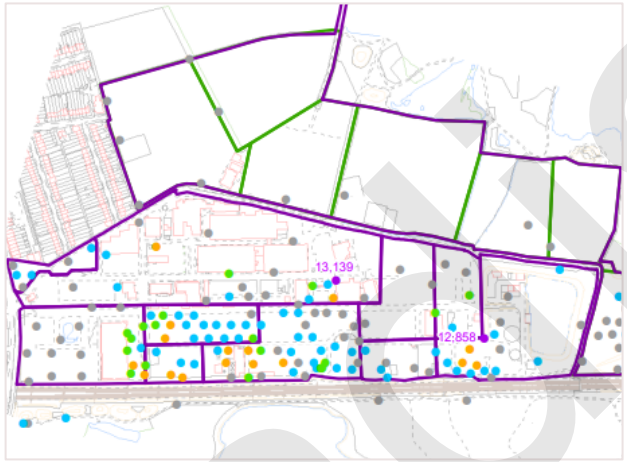
- Trend analysis
- Remediation system/solution performance data
- Post remediation characterisation
- Updated quantitative risk assessment (modified remediation criteria)
- Statistical testing
- Field-based evidence of attenuation processes
- Simulation of future attenuation processes
- Sustainability appraisal

Quantitative lines of evidence tend to give the greatest confidence.

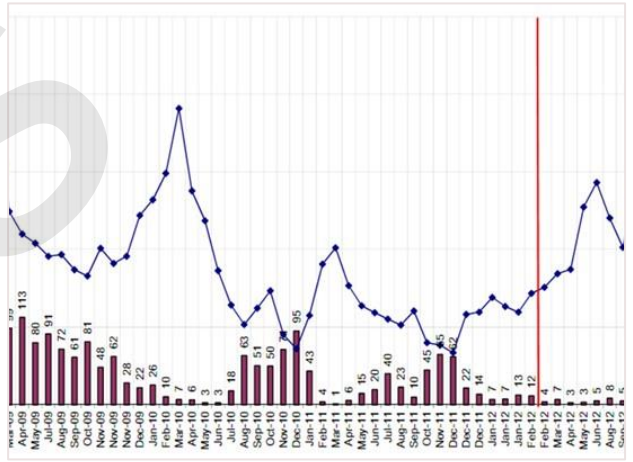


Remediation criteria may be a key regulatory or client focus. But where possible, develop a wider range of criteria (Lines of Evidence) than just a single threshold before remediation starts, to give flexibility in the closeout process

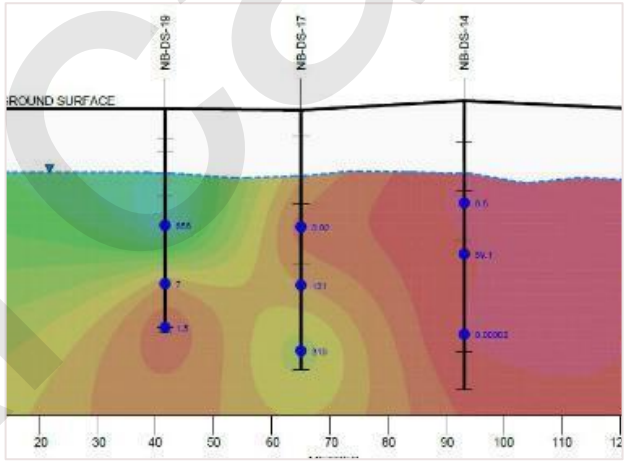
Trend Analysis



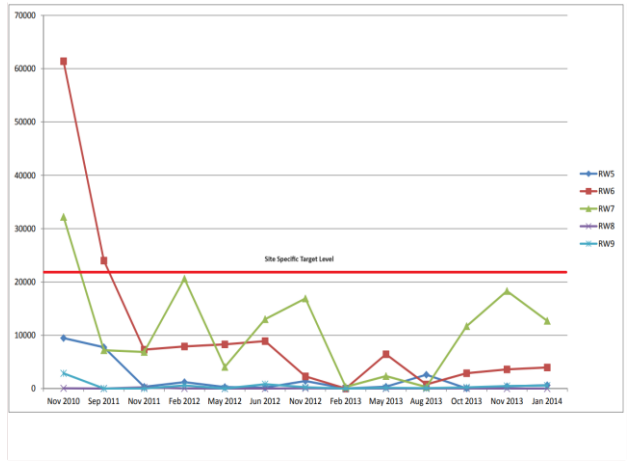
Reduction in plume extent



Reduction in concentrations

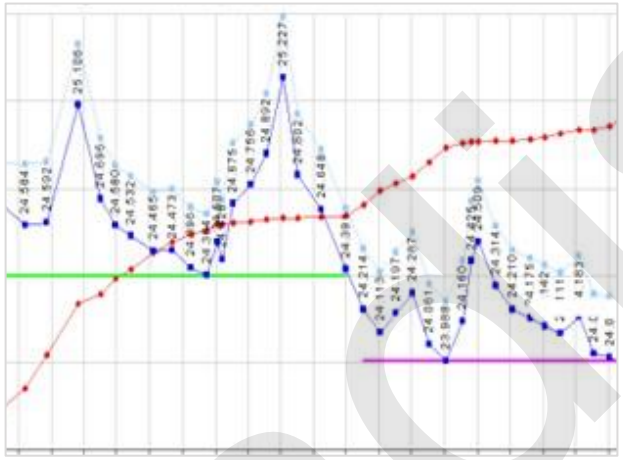


Reduction in mass flux



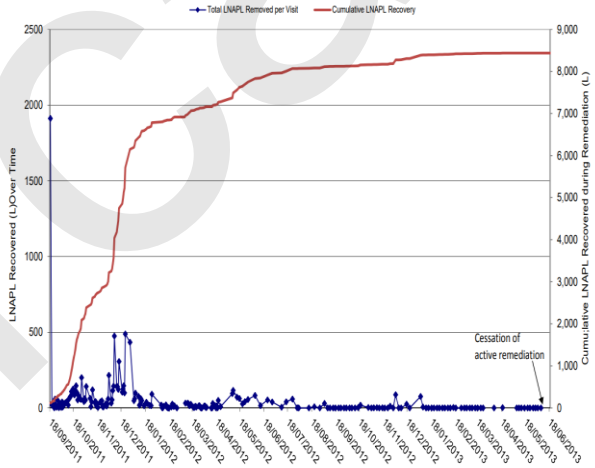
Consistently below remediation threshold

Remediation System or Solution Performance

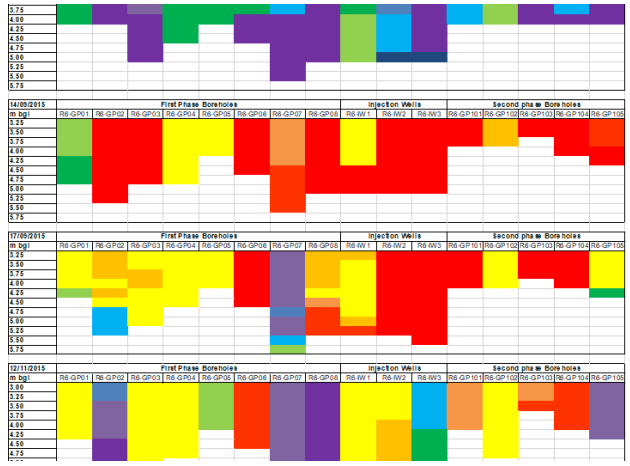


Contaminant recovery rates

Pre/Post-treatment materials testing



Asymptotic conditions



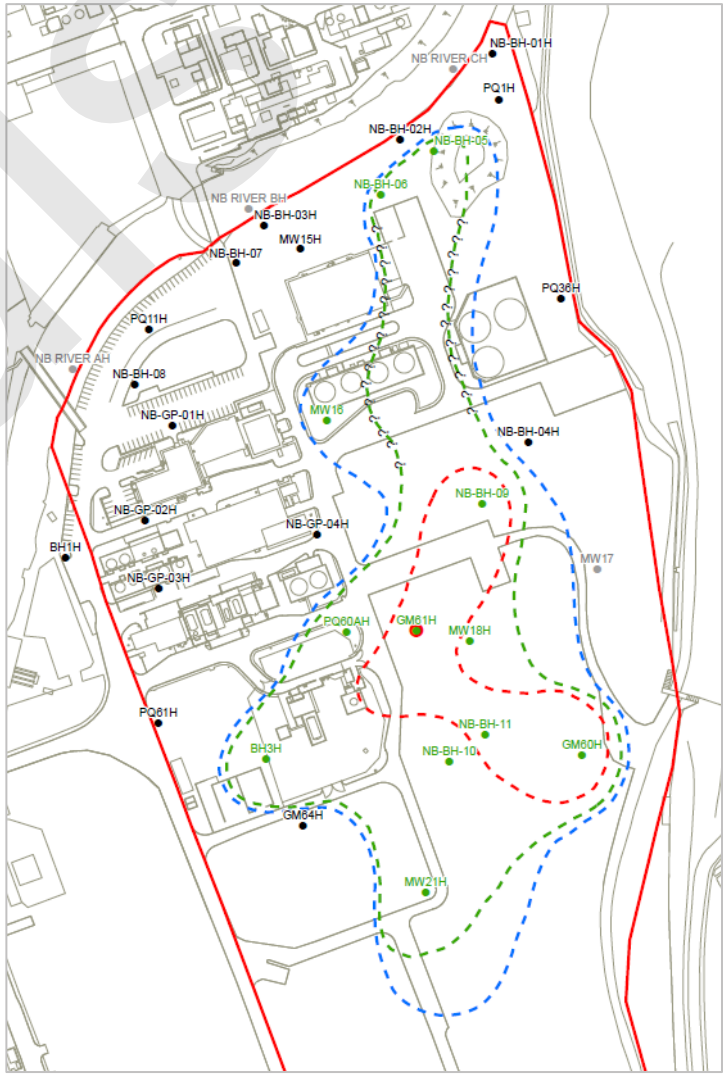
Barrier performance testing

Statistical testing

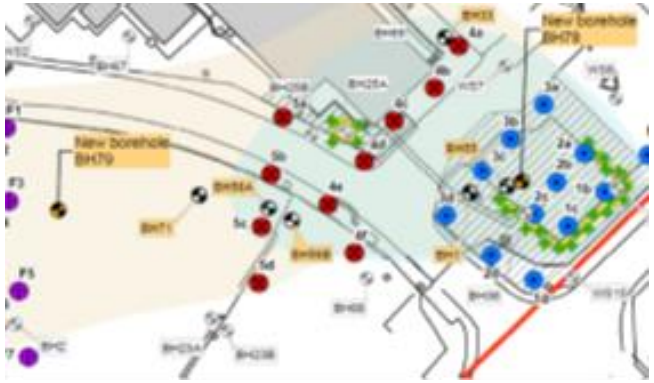
Statistical analysis can be hugely powerful, especially for trend analysis for gas and groundwater systems

But before using statistical tests, factors to consider include:

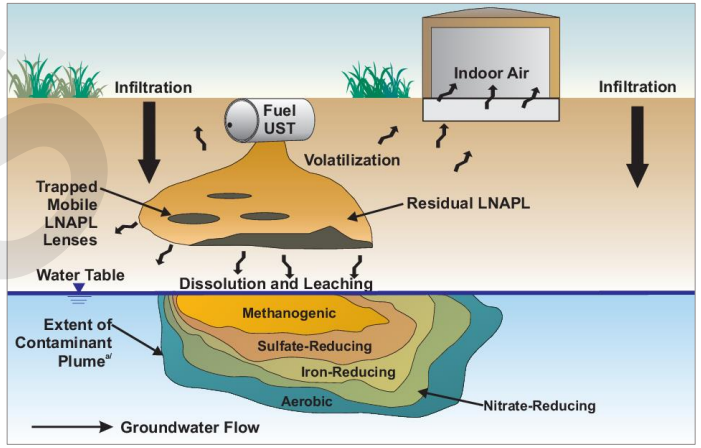
- Whether there is country-specific guidance which should be adopted?
- What averaging areas are appropriate? E.g.
  - Geology
  - Depth
  - Assumptions in remediation threshold calculation
- How to account for outliers?
- What confidence level?



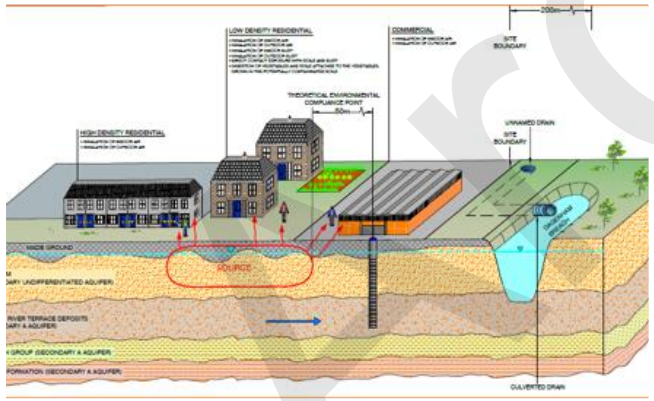
Post-remediation characterization
e.g. further soils or groundwater testing to demonstrate reduction in source extent



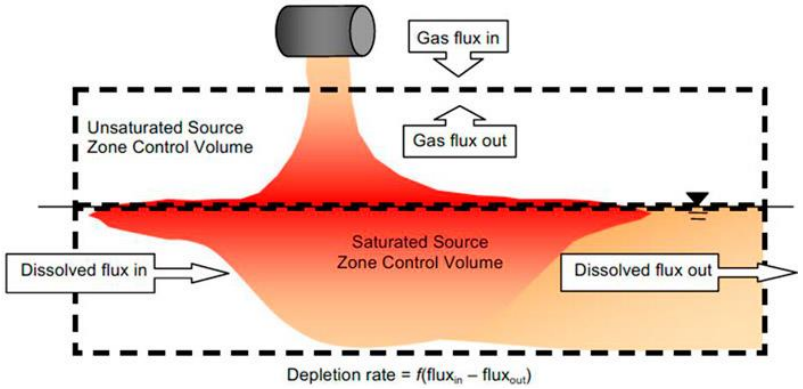
Field-based attenuation evidence
e.g. natural attenuation parameters for microbial degradation, measurement of specific microbes in groundwater



Updated Quantitative Risk Assessment
e.g. modification of input parameters based on data collected as remediation was implemented



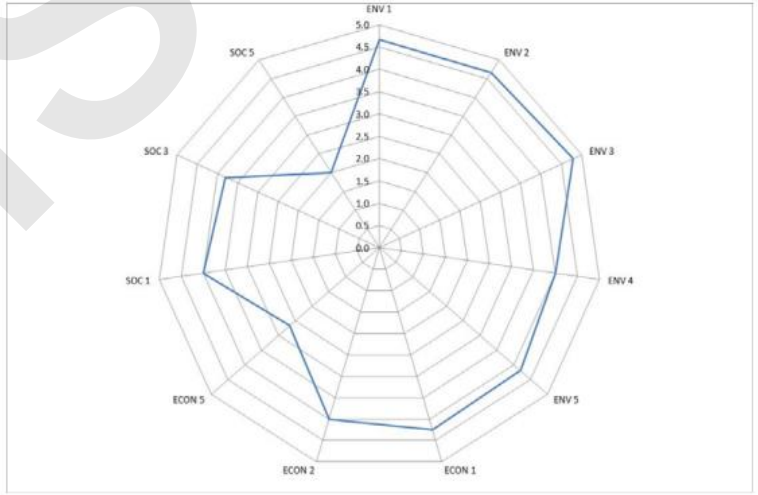
Simulation of future attenuation
e.g. natural source zone depletion, 3D modelling of residual plume over time



Sustainable Remediation

Environmental	Economic	Social
ENV1: Emissions to air	ECON1: Direct economic costs and benefits	SOC1: Human health and safety
ENV2: Soil and ground conditions	ECON2: Indirect economic costs and benefits	SOC2: Ethics and Equity
ENV3: Groundwater and surface water	ECON3: Employment and employment capital	SOC3: Neighborhoods and locality
ENV4: Ecology	ECON4: Induced economic costs and benefits	SOC4: Communities and community involvement
ENV5: Natural resources and waste	ECON5: Project lifespan and flexibility	SOC5: Uncertainty and evidence

Bio Sparging:



Multiple ways in which sustainable decision-making can be included both in remediation optioneering and design, as well as to support remediation closure

Langley Terminal

bb AWARDS 2014 10 ANNIVERSARY

Former Langley Terminal, South England

Remediation Driver

- Light non aqueous liquid across circa 50% of the 7ha site. LNAPL Distribution and Recovery Model methodology estimated ~517,000L of LNAPL
- Concentrations of petroleum hydrocarbons in groundwater above risk-based thresholds protective of the aquifer and human health (vapour intrusion)

Remediation Solution

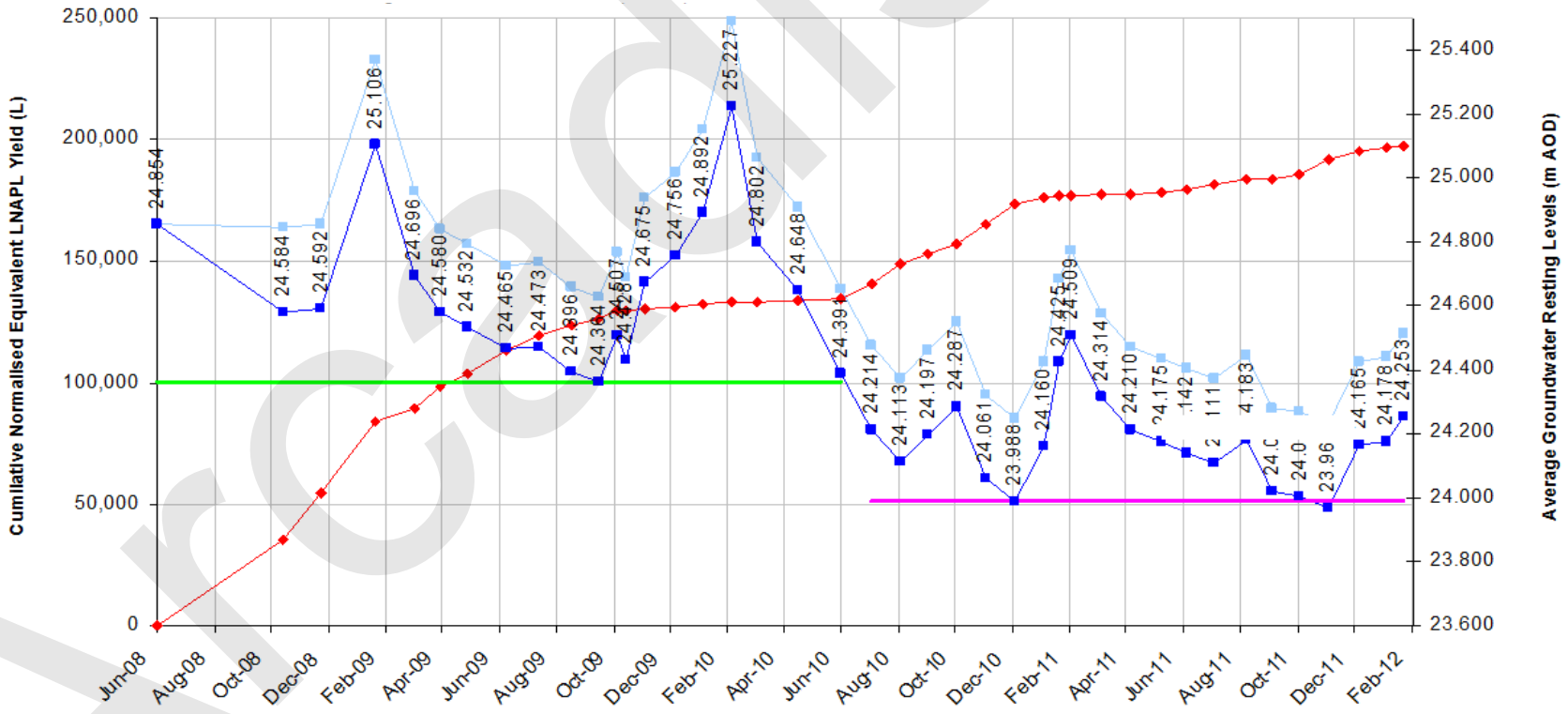
- Dual Phase Extraction (DPE) system consisting of a Total Fluid Pumping (TFP) combined to a Soil Vapour Extraction (SVE)
- Temporary soil mixed wall which provided a Low Permeability Barrier (LPB) around the treatment area
- Network of 292 extraction and monitoring wells

Lines of Evidence for Closure

- Decline curve analysis
- New field data – soil gas
- LNAPL mobility and recoverability assessment
- Updated quantitative risk assessment
- LNAPL plume stability
- Groundwater concentration trends
- Assessment of natural attenuation via biogeochemical parameters in combination with BART™ and deployment of Biotraps®

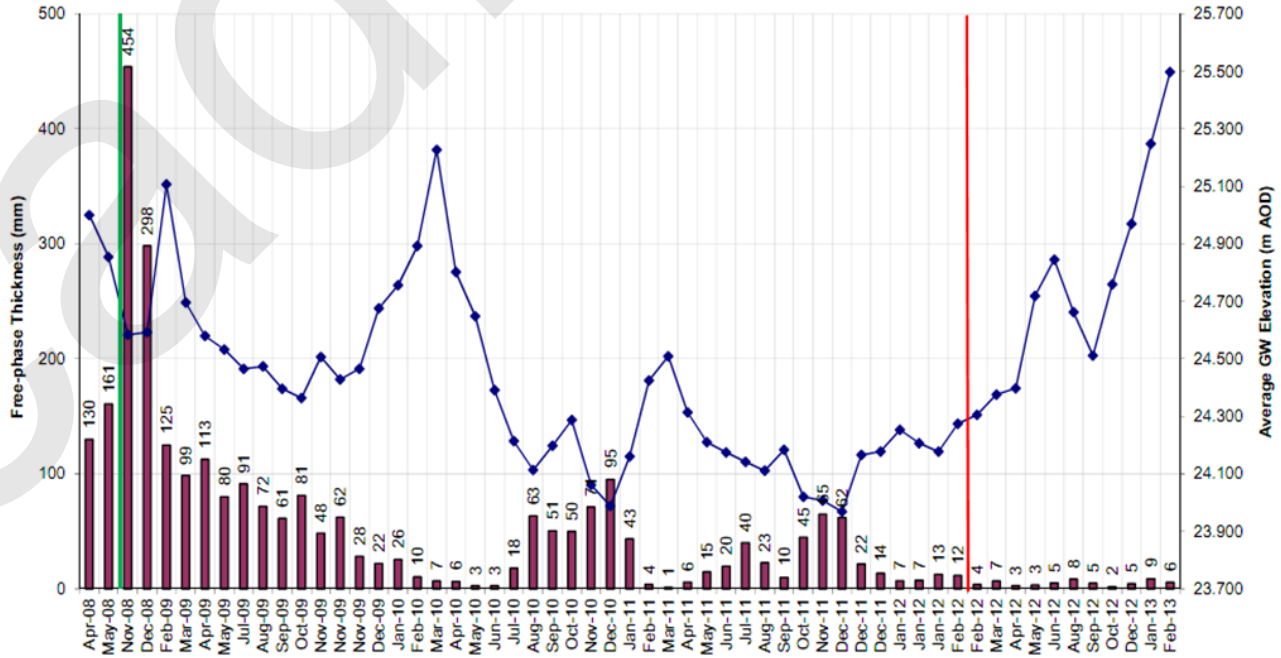
Recovery and decline curve analysis

Decline curve analysis for the site predicted a LNAPL recovery of >96% has been achieved at the site by the DPE system, which was in excess of the 95% target available in literature and adopted as an endpoint for LNAPL recovery operations. **Key is that LNAPL remained present and measurable in wells at closure!**



Trend Analysis – LNAPL over time

Pre- and post-remediation LNAPL presence and thickness

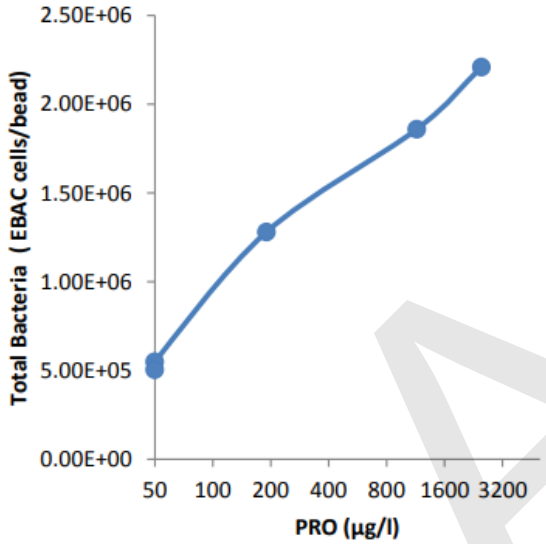


Average LNAPL thickness with time

Natural Attenuation Evidence

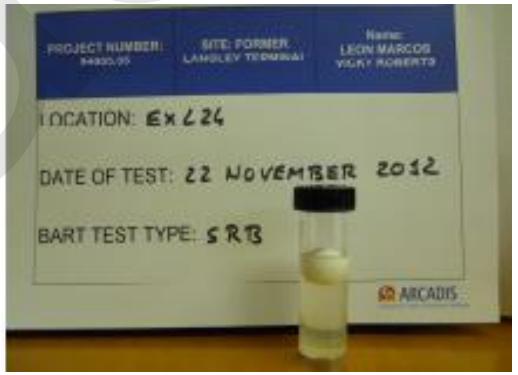
Biotraps®

Biotrap® sampling devices were used to collect indigenous bacteria from groundwater monitoring wells and to quantify the presence of specific genetic markers known to be associated with the biodegradation of Petroleum Hydrocarbons



BART™

IRB-BART™, SRB-BART™ and DN-BART™ to test for evidence of differing types of microbial communities being present. Reliant upon degree of foaming and colour changes



BART™ Test Type:
Sulphate Reducing Bacteria

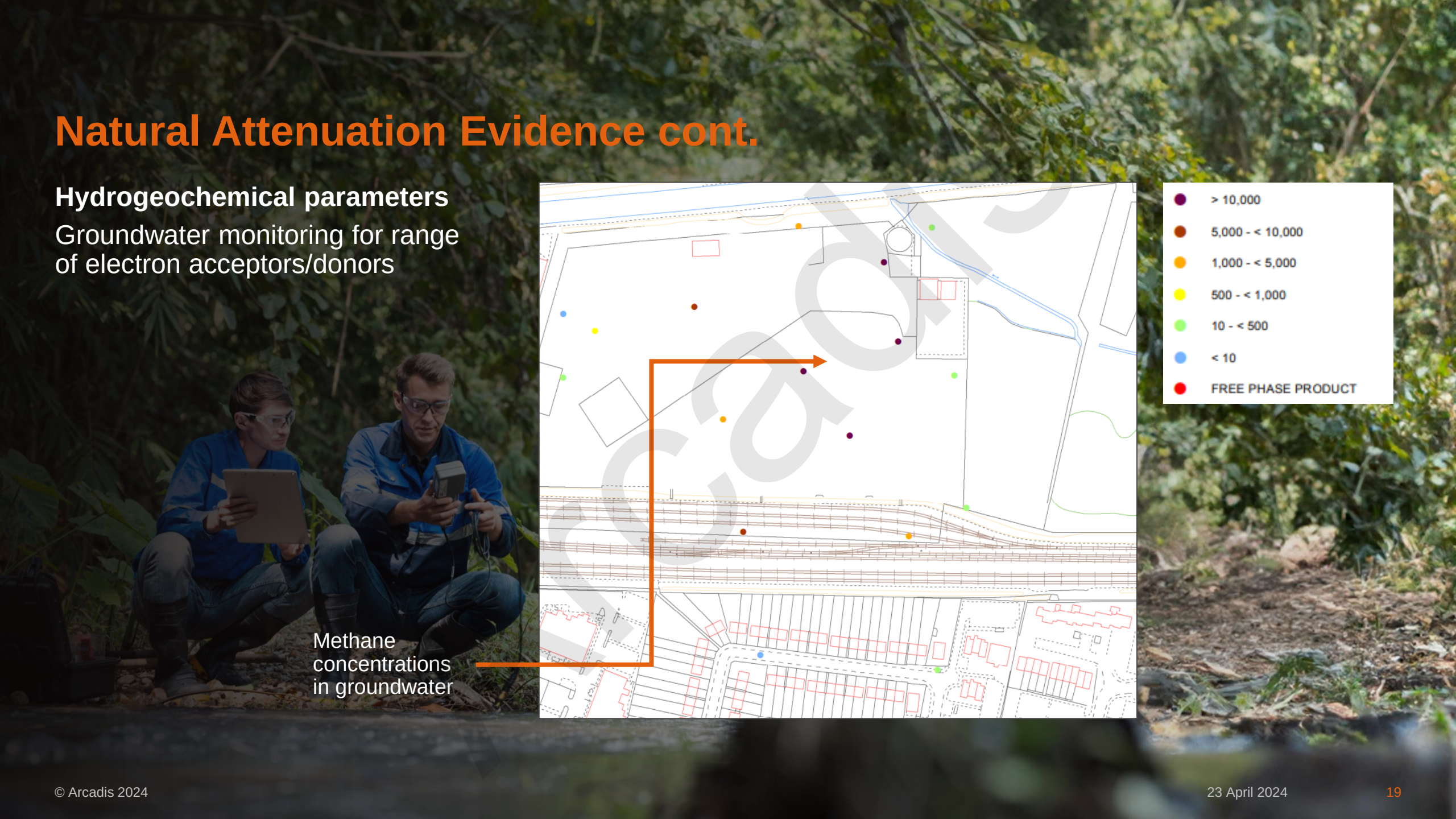
Comments:
Black Specks within creamy deposit noted on the base of the cone and spreading 2-3mm up the vial after 9 days including that sulphate reducing bacteria are present.

Cloudy result after 13 days indicating that anaerobic bacteria are present.

Natural Attenuation Evidence cont.

Hydrogeochemical parameters

Groundwater monitoring for range of electron acceptors/donors

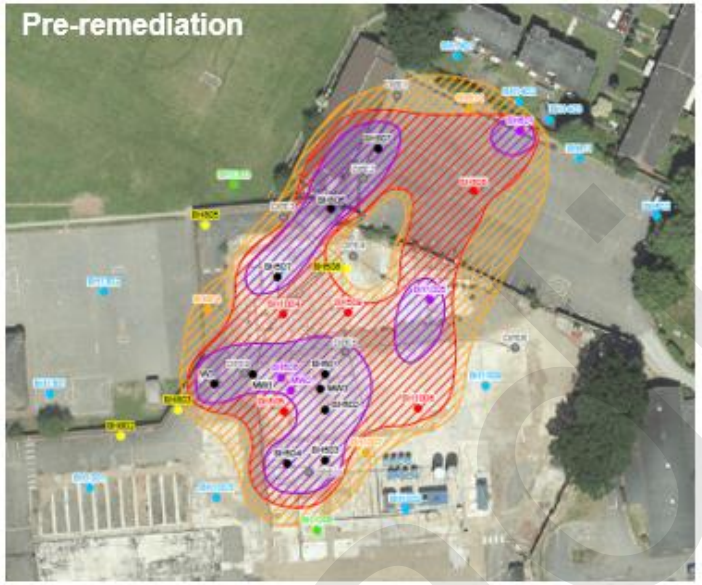


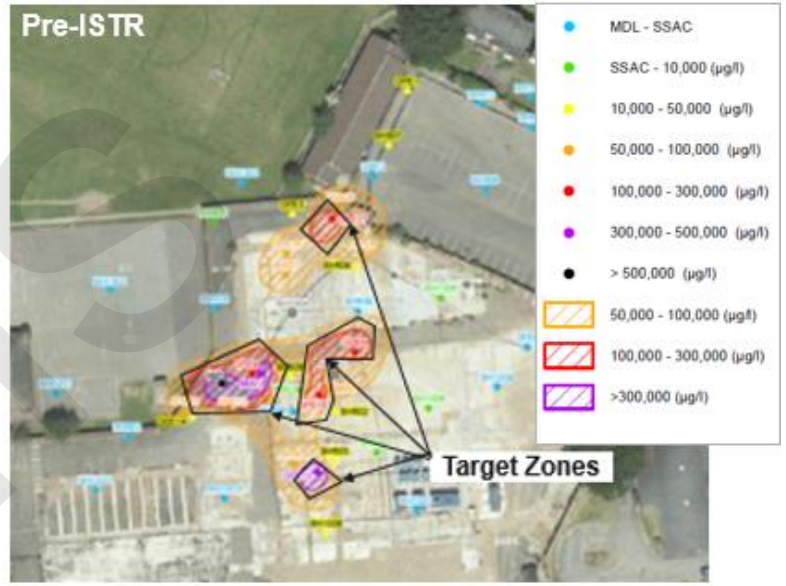
Methane concentrations in groundwater

Mere Green

Brownfield Award Winner

Former Mere Green Brake Manufacturing Site, Central England





Remediation Driver

- Chlorinated solvents present in an interbedded sand and clay aquifer
- Concentrations above remediation thresholds developed for protection of the underlying aquifer- extensive soil gas investigations on- and off-site had already confirmed no significant risk to human health receptors

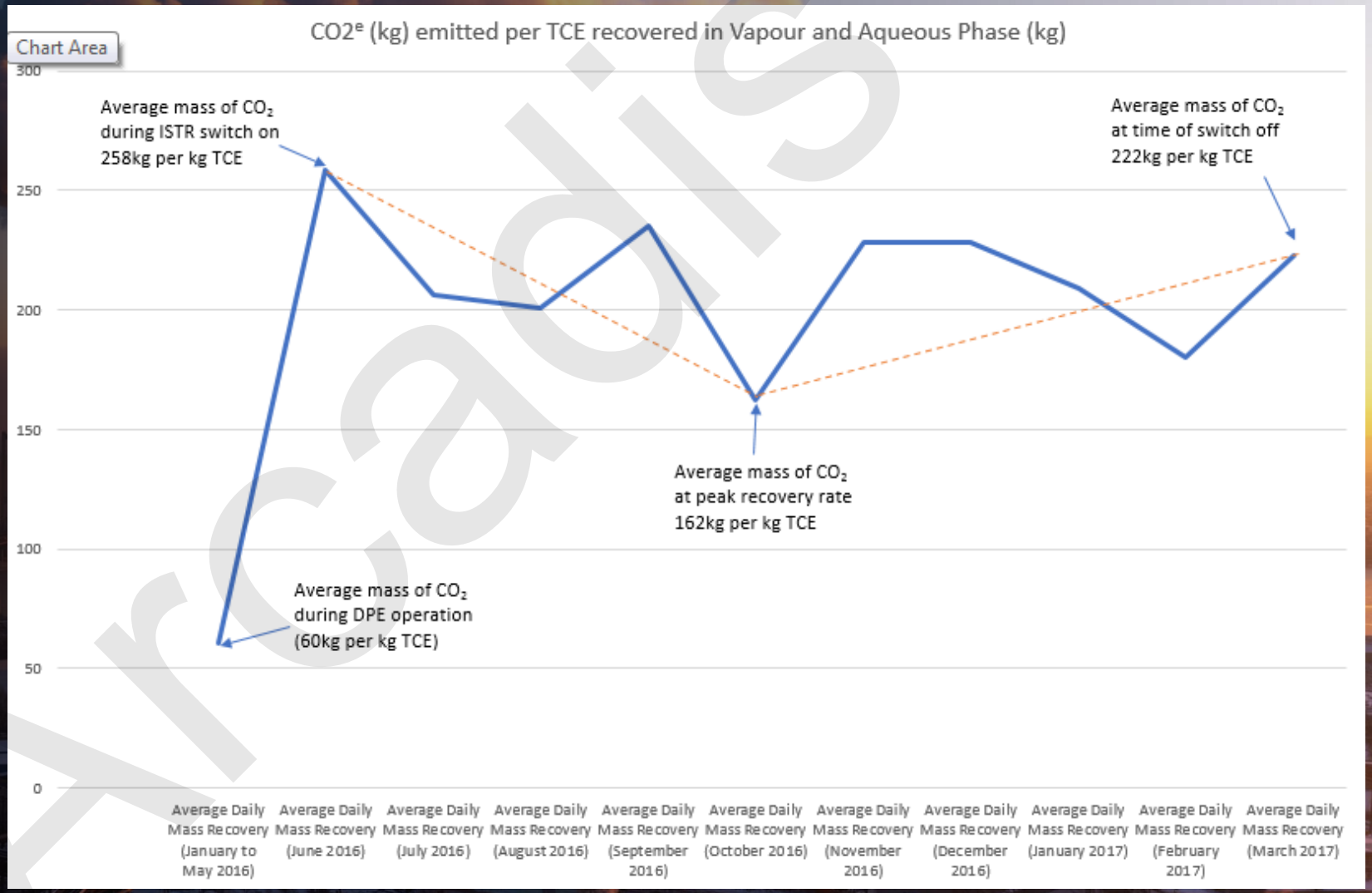
Remediation Solution

- Dual Phase Extraction (DPE) system consisting of a Total Fluid Pumping (TFP) combined to a Soil Vapour Extraction (SVE)
- Enhanced using In Situ Thermal Remediation (ISTR) approach for final 10 months
- 8,500kg trichloroethene removed using DPE (36 months) with a further 1,520kg removed during final 10 months

Lines of Evidence for Closure

- Trend analysis by well and spatially with time
- Reduction in source area by >95% and reduction in plume area of >85%
- >90% reduction in TCE concentrations in groundwater
- Recovery trend analysis
- **Sustainability appraisal to support cessation of active remediation**

Focus on carbon emissions



Key Takeaways

What are the key takeaways?

- Significant source-pathway-receptor linkages must be addressed before remediation can be completed **and** site conditions must be stable or improving
- But – there are many options to support closure of remediation projects which often lead to **more efficient** and **straightforward** regulatory approval
- Plan your **“exit ramps”** for remediation as early as possible!
- Build in as much **flexibility** as possible given the regulatory regime – what lines of evidence could be applied?
- Talk to **remediation colleagues** – someone in Arcadis has probably “done it before” and may be able to support

Any questions?

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