Geosyntec consultants

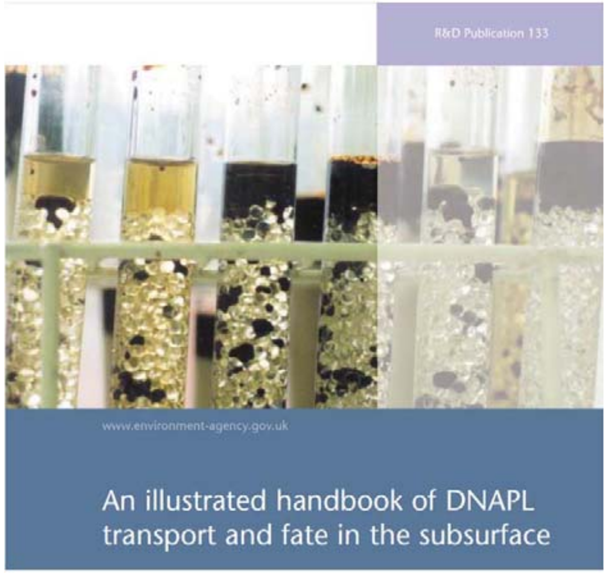
Recent advances in the assessment of DNAPL sites

Professor Gary Wealthall

Presentation Outline

1. Introduction
2. Phases and Zones
3. Immobile, mobile or migrating
4. Accuracy of DNAPL CSMs
5. Take home messages

2003 [Environment Agency]
An Illustrated Handbook of DNAPL …….

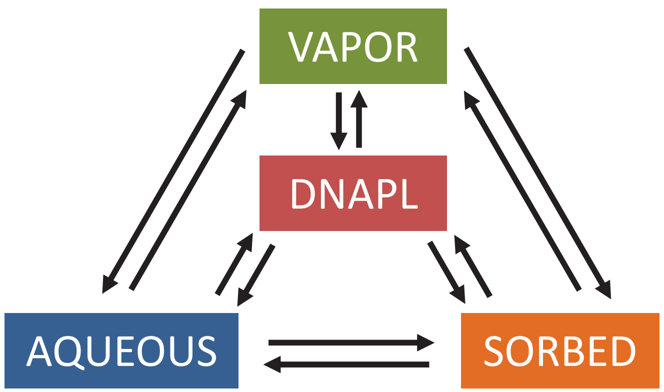


ENVIRONMENT AGENCY

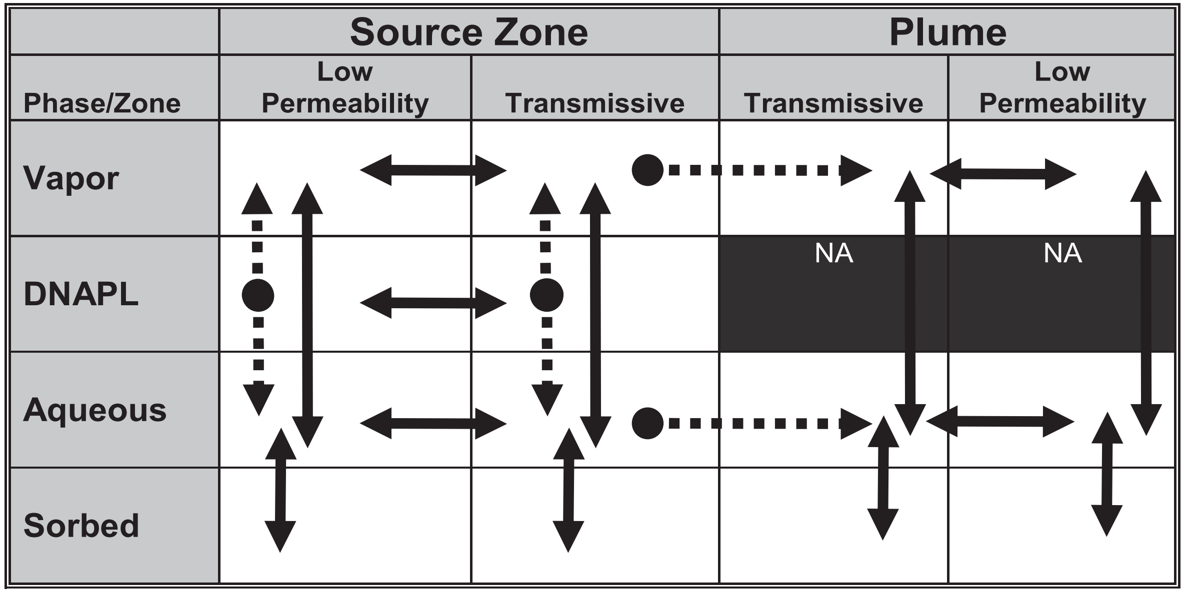
"***The purpose of this handbook is to provide a user-friendly overview of the nature of DNAPL contamination in a UK context***. It is intended to assist site investigators, site owners and regulators in conducting site investigations and risk assessments, and in selecting remediation approaches. ***While this handbook reflects the state-of-the-art at the time of publication***, it should be noted that the discipline of groundwater and soil contamination by hazardous organic liquids is evolving continuously and is relatively 'young' in comparison with many other areas of science and engineering. ***The reader is therefore advised to keep abreast of the new advances in understanding and approaches expected in the foreseeable future.*** "

2011 [ESTCP*] PHASES and ZONES

FUGACITY is a thermodynamic term for a substance's propensity to escape from one environmental compartment to another (Fundamentals of Air Pollution, Fifth Edition, 2014)



4 phase model, described by partitioning coefficients



*Environmental Security Technologies Certification Program
A Guide for Selecting Remedies for Subsurface Releases of Chlorinated Solvents

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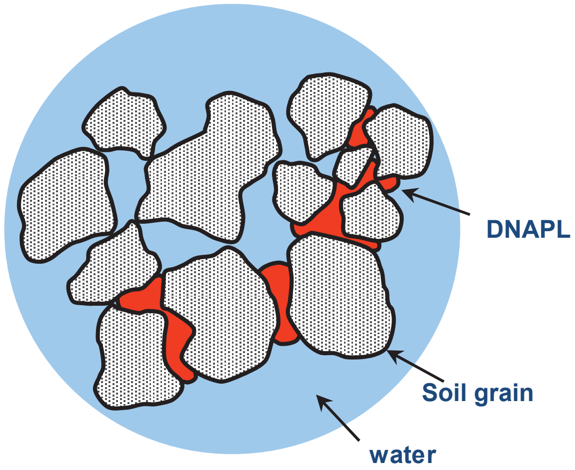
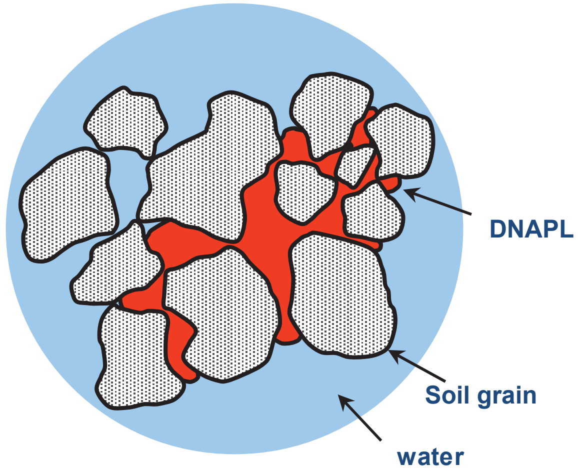
http://estcp14cmodel.com

2015 [EPRI*]
Immobile, Mobile or Migrating DNAPLs?

IMMOBILE DNAPL
- Also termed residual DNAPL
- Low saturation
- NAPL trapped, by capillary forces, in pore space
- **Typically not mobilized by groundwater flow**

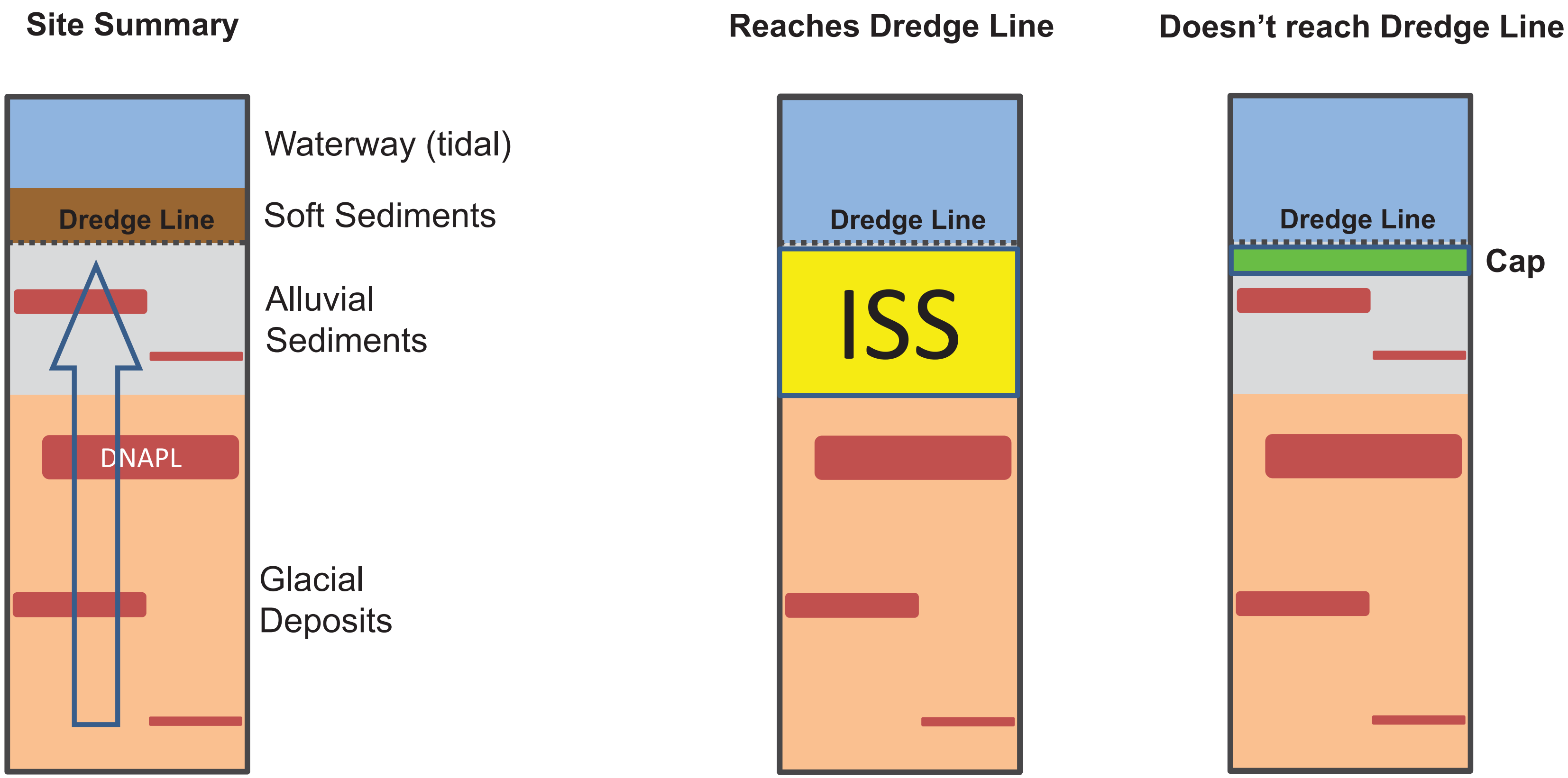


MOBILE DNAPL
- Also termed pooled DNAPL
- High saturation
- NAPL is contiguous and can flow between pores
- **May be mobilized by groundwater flow**



MIGRATING DNAPL occurs when in situ conditions include mobile DNAPL and elevated groundwater gradients

2019 Remediation of DNAPLs in Sediments

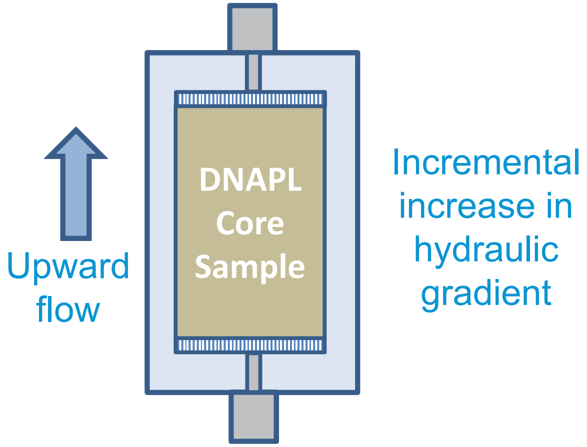


Predicting migrating DNAPL zones

Empirical Assessment

1) Centrifuge (**DNAPL stops moving**)

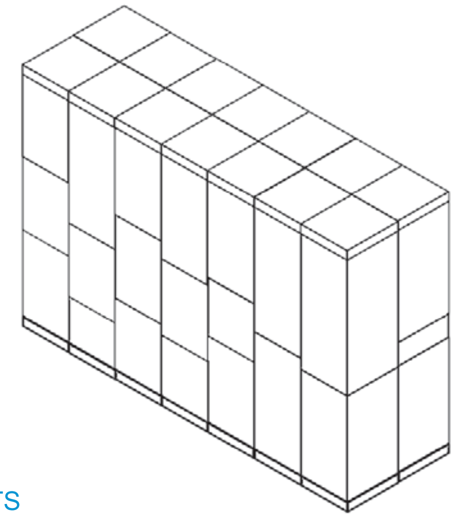
2) Triaxial flow cell (**DNAPL starts moving**)



Modelling Assessment

2-phase flow simulator (UTCHEM)

Pre-remedy → ***Post-remedy***



How do we determine the accuracy of Conceptual Site Models for DNAPL remediation?

Created 'perfect worlds' or 'virtual battlefields' to simulate & evaluate site characterization, conceptual site model development and remediation at DNAPL sites

Drs Dave Major, Mike Kavanaugh, Dave Reynolds, Gary Wealthall (Geosyntec)
Drs Bernie Kueper and Kevin Mumford (Queens) Peter Kitanidis (Stanford)

SERDP DOD • EPA • DOE | ESTCP

Strategic Environmental Research and Development Program | Environmental Security Technology Certification Program

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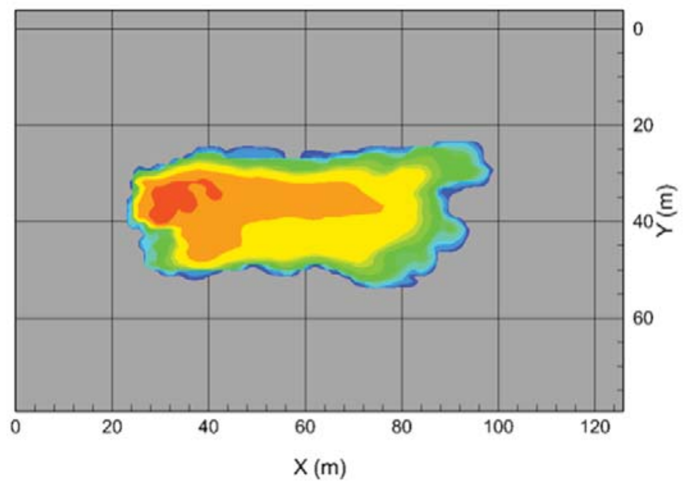
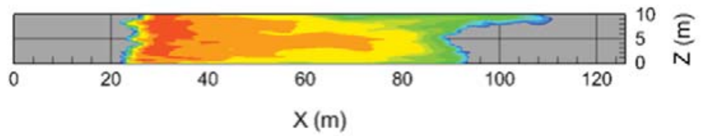
"Perfect" Understanding – Virtual Site Datasets





Series of 3 virtual site datasets (VSD-A, -B, -C)

- Known geological, hydrogeological and biogeochemical parameters
- Increasing heterogeneity

Created using DNAPL3D-RX

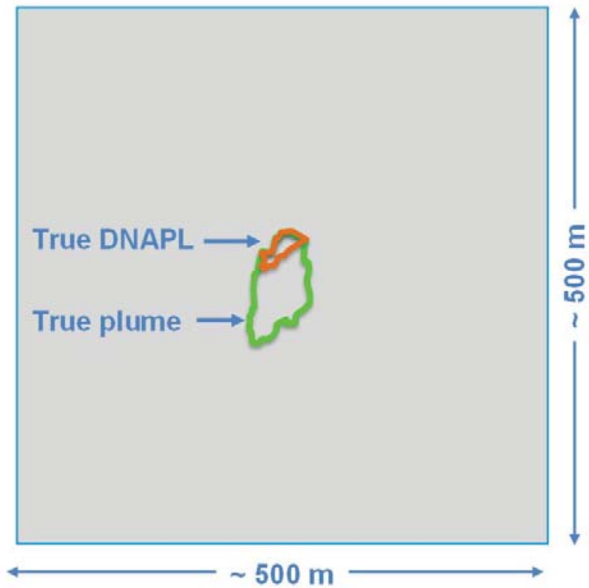
- Multiphase flow of water and TCE
- Dissolution and reactive transport

Large, high-resolution domains

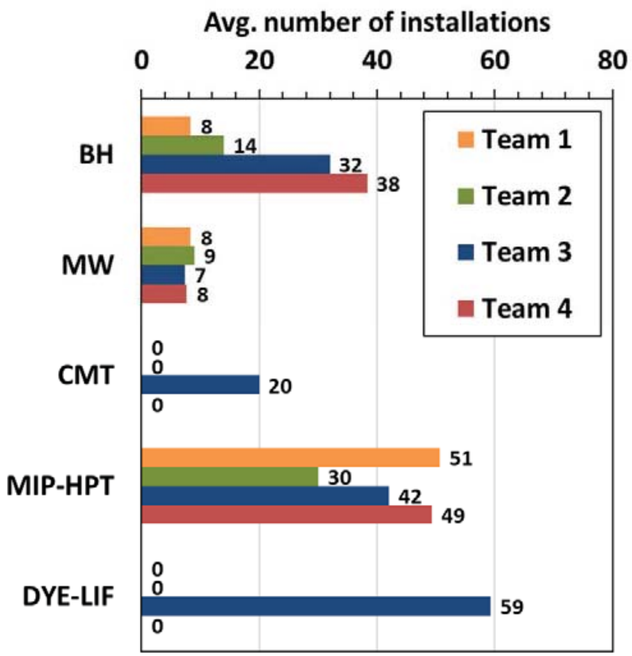
- 300 to 500 m in lateral extent
- Discretization ~1 m (X,Y) and ~10 cm (Z)
- 0.5 to 1.0 Billion data points per VSD

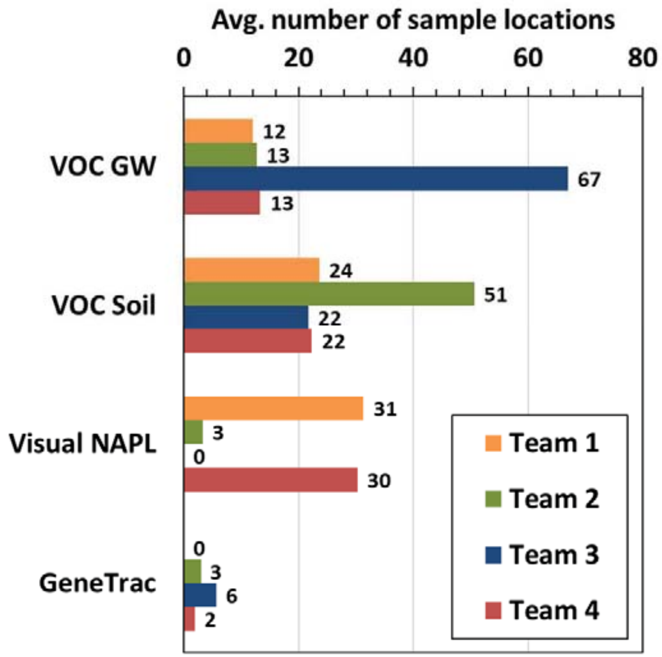
Tested by 4 Consulting (DM) Teams

- 4 Decision Maker (DM) teams from the consulting sector
- DM teams characterized the virtual sites and developed CSMs to inform the design of engineered in-situ bioremediation (EISB)
- Metrics from the DM teams compared to true metrics from the VSD simulations



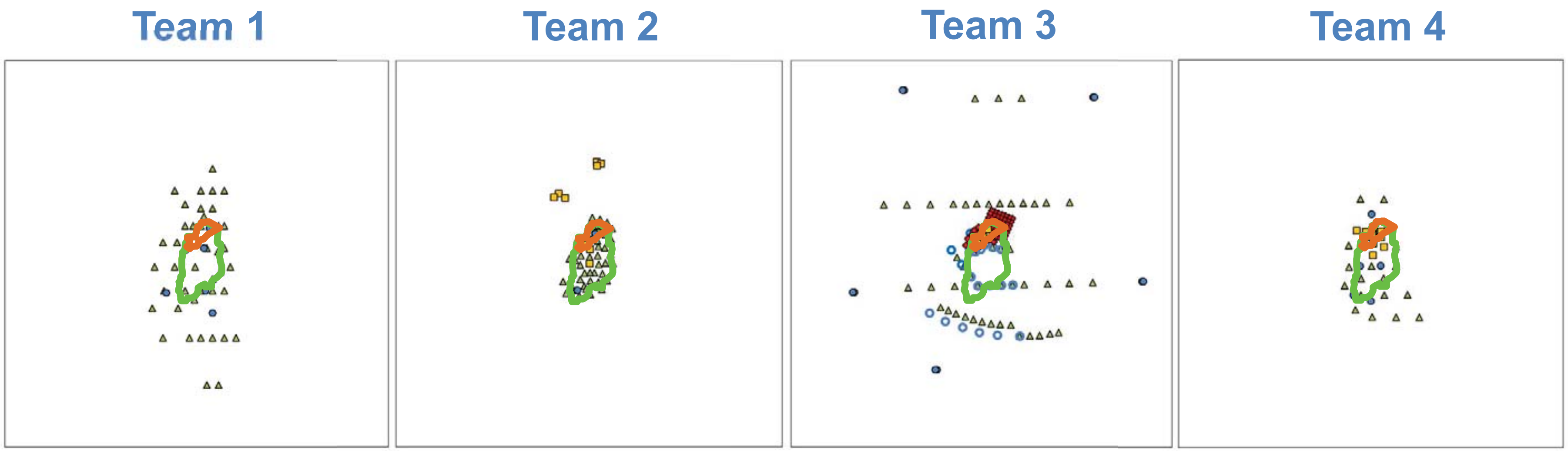
DM Team Tool and Sampling Choices





Averages are calculated across all three sites

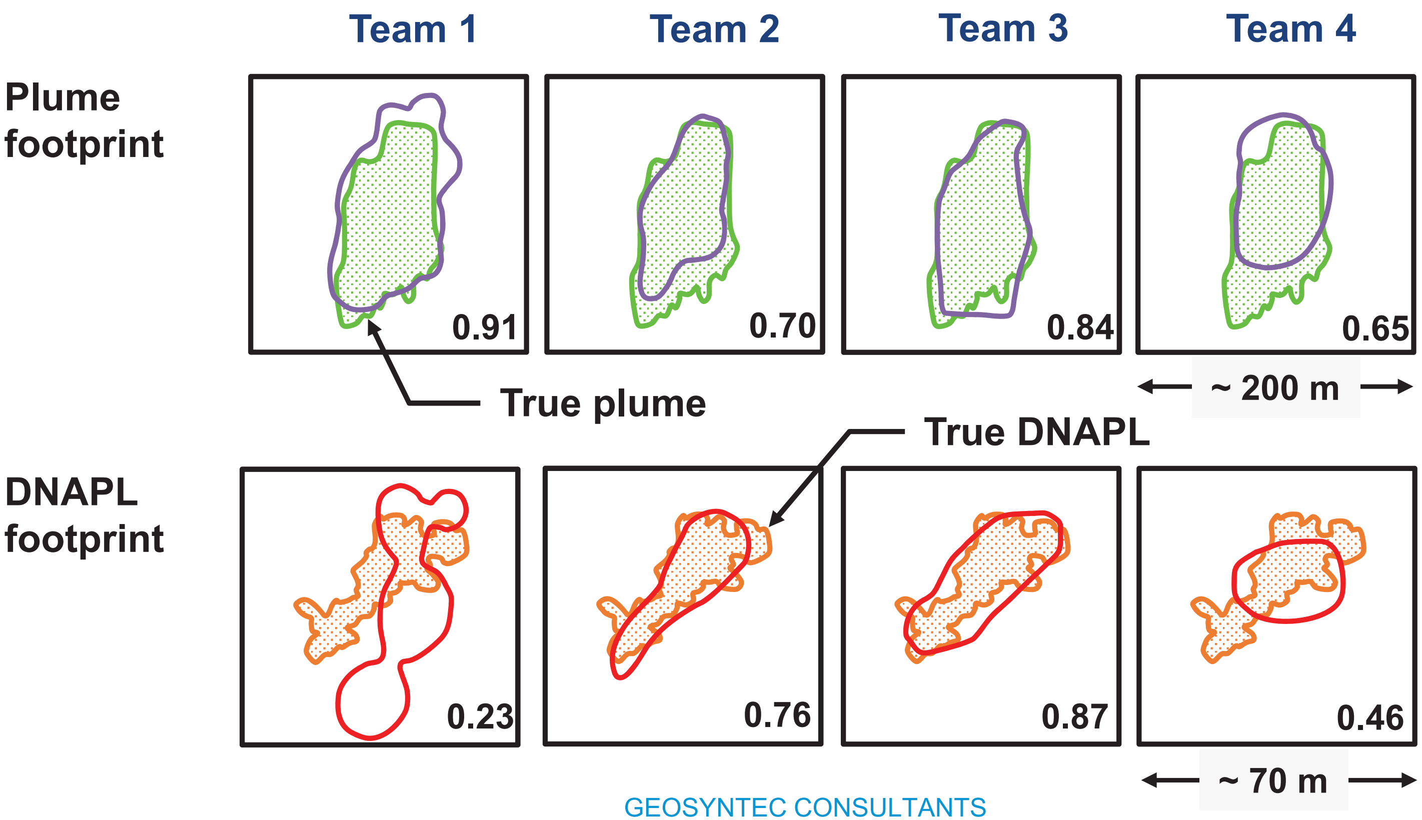
DM Teams Characterization Strategies [VSD-A]



- Monitoring well
- CMT well
- Borehole
- MIP-HPT
- DyeLIF

- **Different strategies between teams for a given site**
- **Similar strategies between sites for a given team**

Evaluation of DM Teams: Delineation [VSD-A]



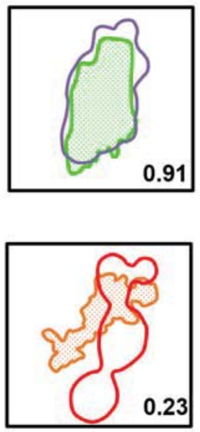
Evaluation: Remediation Performance [VSD-A]

Performance Metric	Remedial Goal	DM Team 1	DM Team 2	DM Team 3	DM Team 4
DNAPL Mass Removal (%)	30%	64%	43%	41%	71%
Total cVOC Mass Discharge Reduction (%)	50%	53%	-27%	25%	43%
Average TCE Concentration Reduction (%)	60%	81%	19%	39%	65%
Cost (Million USD)		$1.6	$0.5	$1.2	$1.5

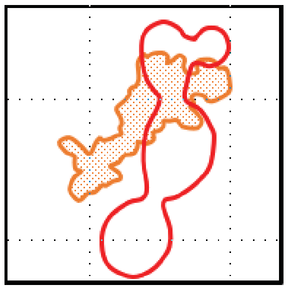
Why did DM Team 1 do so well?

Team 1 achieved all 3 remediation performance metrics

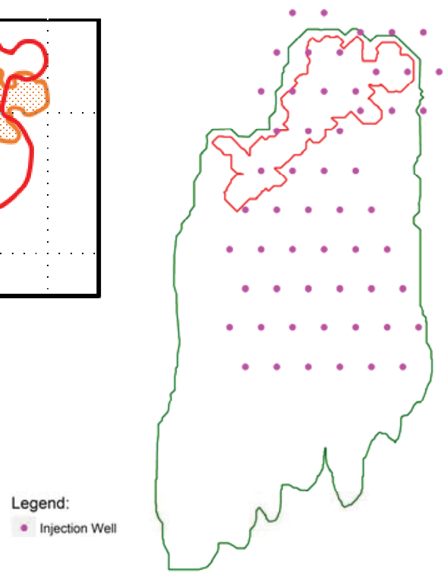
Did not excel on the CSM metrics



Missed the DNAPL footprint



Overdesigned the injection well network



Overall conclusions

- Massive excess of electron donor
- CSM dictated 776 kg
- Team 1 proposed 246,634 kg
- Factor of Safety = 318

Take home messages

- The value of information project highlights inconsistencies in the characterization of DNAPL sites
- Low accuracy CSMs can be overcome by design, but at a cost
- Not all DNAPLs sites are created equal …… data analysis is as important as data collection
- Despite the availability of best practice guidance, and advanced tools, different strategies are used to characterize DNAPL sites

What leads to the variability amongst our hydrogeological professionals and are advances in understanding so significant that we need a 2020 DNAPLs Handbook?

Thank you for your attention

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