High Resolution Site Characterization Tools and Approaches

December 2, 2015
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Federal Remedial Technologies Roundtable:
Site Characterization for Effective Remediation

The Problem

One cannot effectively solve a problem which one has not adequately and accurately described

Many Remedial Investigations continue for years or even decades

Many remedies underperform or fail due to a lack of understanding of site conditions and processes

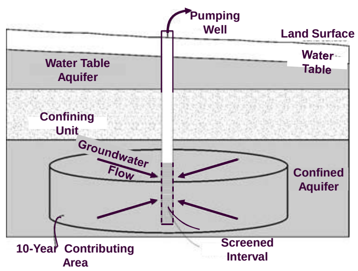
The cost of these failed/underperforming remedies is large

The costs of excessive long term monitoring programs related to investigating sites with monitoring wells is large

The costs of adequate site characterization (currently referred to as High Resolution Site Characterization) which allows one to avoid failed remedies is small in comparison, but requires an up front investment to result in lower life cycle costs.

History and Development of Contaminant Hydrogeology

Historical Perspective – Water Supply

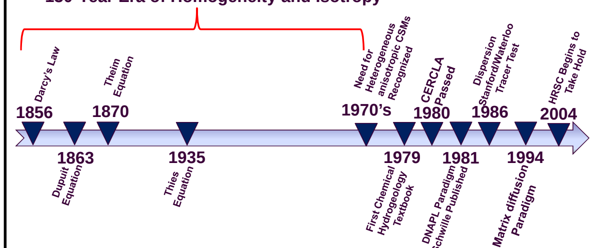


Aquifers are:
- Homogeneous
- Isotropic
- Infinite extent

Treated as a single bulk entity
- Transmissivity
- Storativity
- How much water can we get out of it?

Development of (Contaminant) Hydrogeology

~130-Year Era of Homogeneity and Isotropy



Key Point Our science is a young one. Our thinking on solute transport is powerfully and inappropriately influenced by the first 150 years of the development of hydrogeology.

Development of (Contaminant) Hydrogeology

John Cherry – 1981

"In the early nineteen seventies, it became apparent that … the approach used in the evaluation of contaminant migration in groundwater… involved direct adaptations of …monitoring methods and …models of the type traditionally used in groundwater resource studies. …the behavior of groundwater flow systems is … such that these direct adaptations are unsuitable or misleading because of the heterogeneous character of the geological deposits and/or the geochemical nature of the contaminant species."

Key Point Our science is a young one. Our thinking on solute transport is powerfully and inappropriately influenced by the first 150 years of the development of hydrogeology.

Development of (Contaminant) Hydrogeology

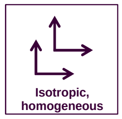

Charles V. Theis

C.V. Theis – 1967 "I consider it certain that we need a new conceptual model, containing the known heterogeneities of natural aquifers, to explain the phenomenon of transport in groundwater."

Key Point Our science is a young one. Our thinking on solute transport is powerfully and inappropriately influenced by the first 150 years of the development of hydrogeology.

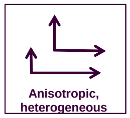
HRSC Today

Incorporation of major paradigms into CSM (e.g.)
- Heterogeneity and Anisotropy
- Awareness of spatial structures of key variables
- DNAPL
- Weak Transverse Dispersion
- Matrix diffusion/back diffusion
- Incorporation of geologic interpretation (e.g., sequence stratigraphy) in CSMs to provide framework for flow systems



Collaborative use of tools
- Direct sensing for screening, NAPL detection
- Groundwater/hydrostratigraphy profiling in permeable zones
- Soil coring and sub core profiling for aquitard/low K material
- On site analytical chemistry

Incorporation of the Triad Approach principles
- Dynamic work Strategies
- Real-time data
- Collaborative Data

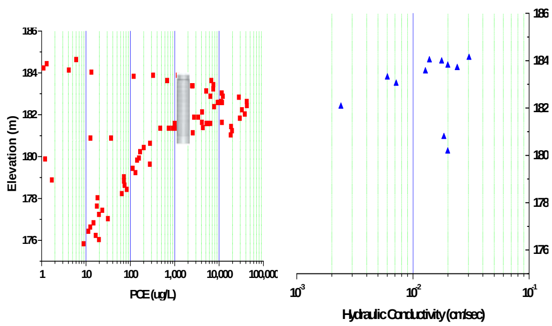


HRSC Addresses Two Critical Issues

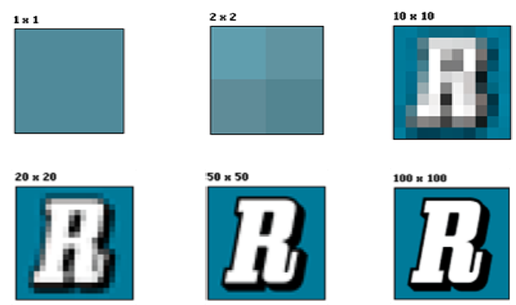
Sampling Scale and Data Averaging
- Measurements must be made at a scale that is meaningful with respect to the variability of the quantity being measured

Coverage
- Profiles and Transects
- Horizontal spacing
- Vertical spacing

Depth-Integrated, Flow Weighted Averaging



High Resolution (more pixels): Sampling Scale and Averaging



Sampling Coverage and Density: HRSC Wisdom Through the Ages

Pitkin

Cherry

Blake

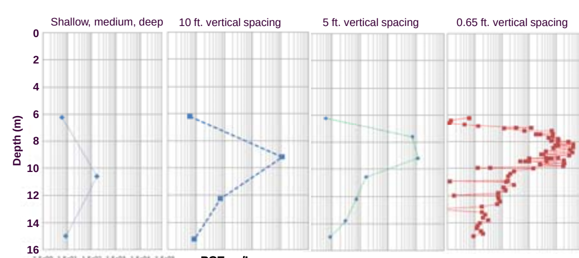
"You never know what is enough, unless you know what is more than enough"

William Blake

Key Point: The only way to know what degree of resolution you need is to look at a high level of resolution.

How Much is Enough? What is Right Vertical Spacing?

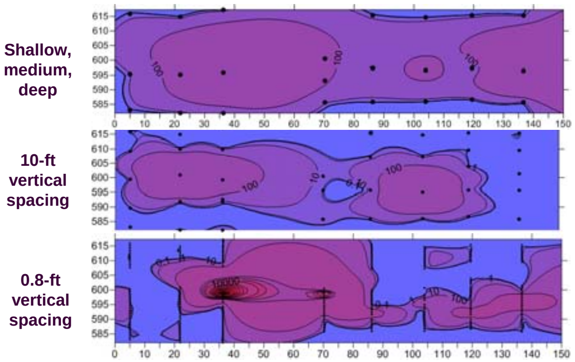
A Profile Through PCE Plume in Sandy Aquifer



Key Point: The vertical spacing you use determines whether you understand the nature of the plume or not.

Multi-Level Sampling Transect

PCE in a Sandy Aquifer

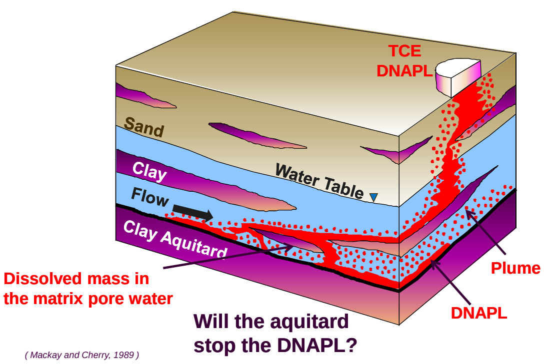


mm-Scale Textural Changes Control DNAPL Migration

Poulsen & Kueper, 1992

Key Point DNAPL distribution is controlled by capillary pressures that vary at the mm scale. Distribution is very complex.

DNAPLs Commonly Encounter Aquitards



(Mackay and Cherry, 1989)

Double Wall, Sealable Joint Sheet Piling Cell Keyed into Aquitard

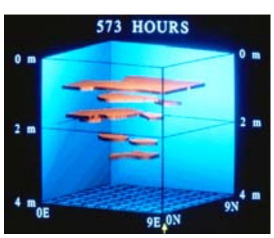
CFB Borden 9x9 m Cell

Courtesy of Beth Parker

9 x 9 Meter Cell Experiment CFB Borden

770 Liters DNAPL PCE
Injected July 1991

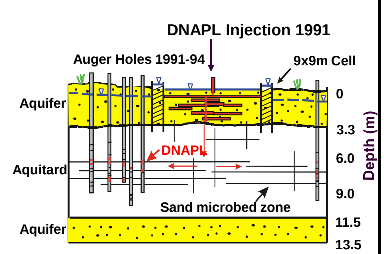
DNAPL Distribution after 573 Hours



Borden 9x9 m Cell Experiment

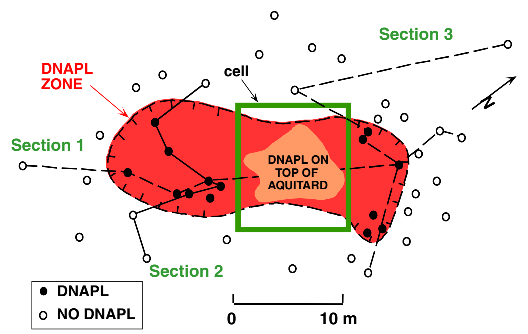
HSA Boring Outside Cell

Uh Oh!



Courtesy of Beth Parker

Areal Distribution of DNAPL within Aquitard



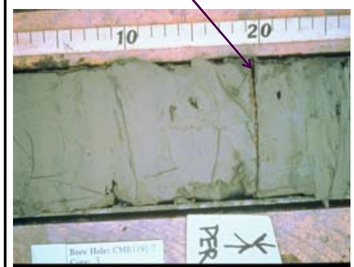
Courtesy of Beth Parker

Structure and Pore Fluids Intact

Small Scale Features are of Great Import

Sand microbed

DNAPL (red) migration in sand microbed

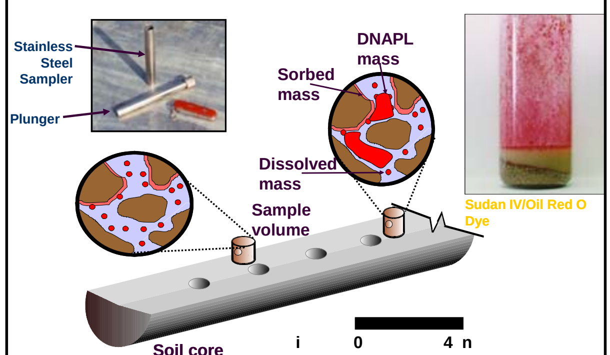


Courtesy of Beth Parker

Essential Information from Cores

- Geologic/hydrogeologic features
- Physical, chemical & microbial properties
- Contaminant mass distributions (high- & low-K zones)
- Contaminant phase distributions (detection of DNAPL)
- Concentration gradients/diffusive fluxes
- Effectiveness of remedial technologies

Soil Core Sampling - NAPL Detection

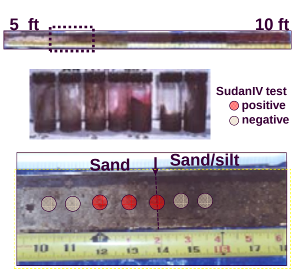


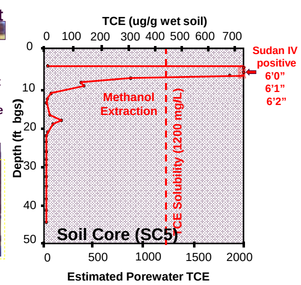
Courtesy of Beth Parker

Example of NAPL Detection

Sudan IV Screening

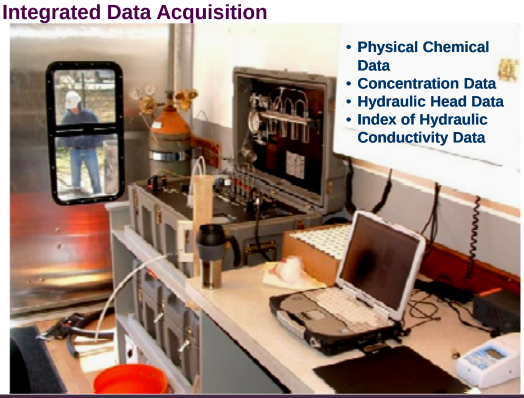
Quantitative TCE Analyses



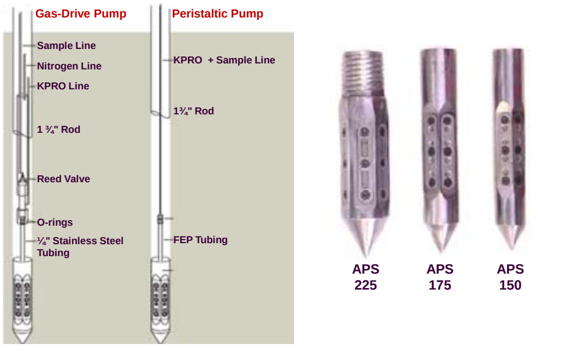


Courtesy of Beth Parker

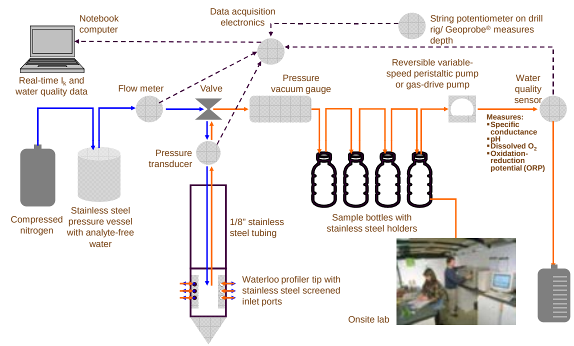
Groundwater Profiling - WaterlooAPS™ Integrated Data Acquisition



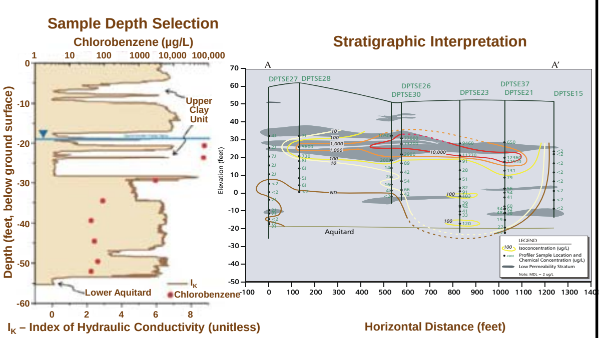
Waterloo^{APS}™ Configurations



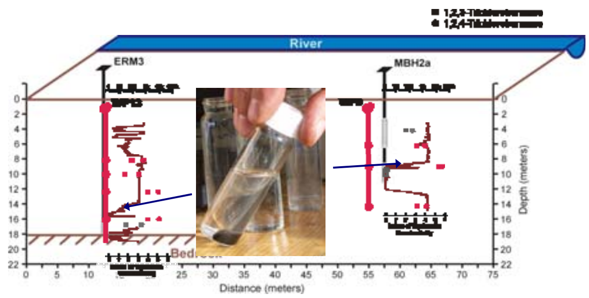
Waterloo^{APS}™ Data Acquisition Configuration and Process



Two Uses of I_K Data

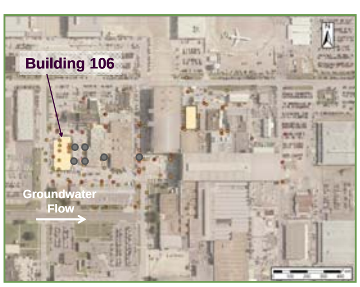


Post-Remedy Investigation Northern England



Key Point: Use of low resolution (conventional) techniques resulted in remedy failure and need for second remedy.

NAS Jacksonville Investigations (July/August 2011)



OU3 Building 106

- Former dry cleaner (1962 – 1990)
- PCE and TCE released to shallow aquifer
- Building removed
- Interim remedies (AS, SVE) have been discontinued after 5-yr review (2005)
- Strong interest in evaluating MNA as long-term remedy

● Detailed study locations

NAS Jacksonville: Characterization Methods

Membrane Interface Probe (MIP) screening
- Rapid lithology (EC) and contaminant (ECD, PID) delineation – qualitative

Waterloo^{APS}™ (Advanced Profiler System)
- Real-time hydrostratigraphy
- Targeted groundwater sampling of higher K zones/interfaces

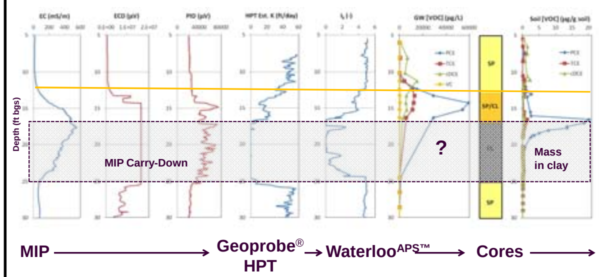
Geoprobe® HPT (Hydraulic Profiling Tool)
- Real time hydrostratigraphy

Continuous cores (Geoprobe® DT System)
- Detailed lithology delineation
- Subsampling for mass distribution (targeted to lower K zones)

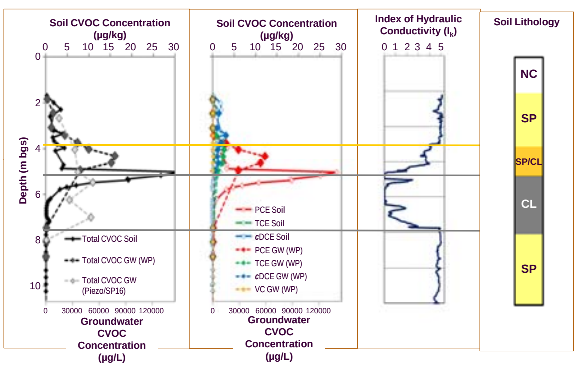
Onsite Laboratory

Layout of Points at Each Investigation Location

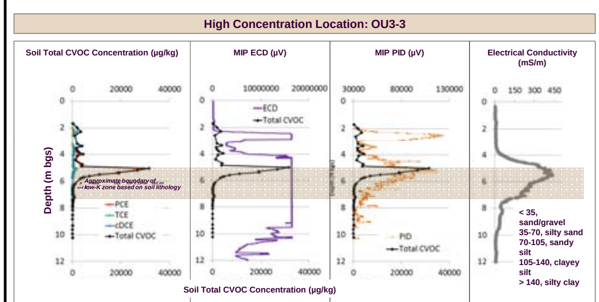
NAS Jacksonville Composite Dataset (OU3-3, Near Source)



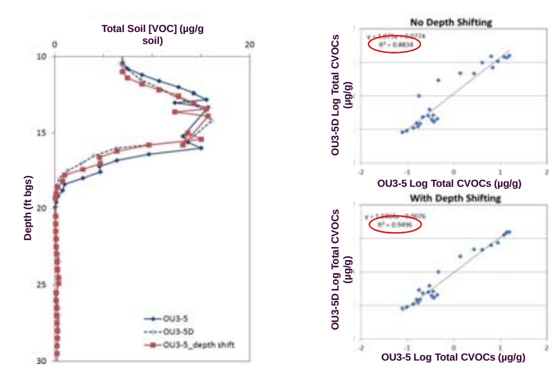
OU3-3: Soil and Groundwater Concentrations



OU3-3: MIP (ECD and PID) and Soil Concentrations



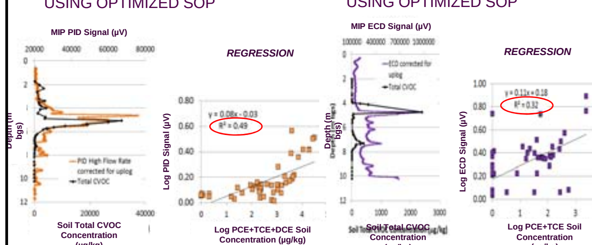
Collocated Soil Cores Demonstrate Good Correlation



MIP Provides Mass Location But Not Concentration Correlation

MIP: SOIL AT LOCATION OU3-3 (HIGH CONCENTRATION) USING OPTIMIZED SOP

MIP: SOIL AT LOCATION OU3-6 (LOW CONCENTRATION) USING OPTIMIZED SOP



Conclusion

The purpose of Site Characterization is to understand the pertinent conditions adequately enough to devise an effective remedy.

- aka CSM

"Standard" approaches such as monitoring wells are not well suited to the development of such an adequate understanding

- Depth-integrated, flow weighted averaging
- Large life-cycle expense

Scale of sampling and data coverage (density) must be appropriate to the spatial structure of the variable under consideration

- Hydraulic conductivity, capillary pressure etc.

Leverage existing data and use screening technologies used to reduce costs associated with definitive sampling/analysis programs

Perhaps it is time to stop calling it "High Resolution" since it is really an adequate degree of resolution to understand the problem. It is simply Site Characterization.

Acknowledgements

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