High Resolution Site Characterization
Tools and Approaches

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Seth Pitkin
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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

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

1856 1870 1980 1986

1970's

Introduction

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.

Key Point
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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.”

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Development of (Contaminant) Hydrogeology

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.”

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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

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.
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Multi-Level Sampling Transect
PCE in a Sandy Aquifer

Shallow, medium, deep
10-ft vertical spacing
0.8-ft vertical spacing

mm-Scale Textural Changes Control DNAPL Migration

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

What is HRSC?
AEHS 2015: Site Characterization for DNAPLs

Pitkin–3

DNAPLs Commonly Encounter Aquitards

Will the aquitard stop the DNAPL?

(Weidley and Cheney, 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
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Areal Distribution of DNAPL within Aquitard

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

Example of NAPL Detection
Sudan IV Screening
Quantitative TCE Analyses

Soil Core Sampling - NAPL Detection

Groundwater Profiling - WaterlooAPS™
Integrated Data Acquisition
- Physical Chemical Data
- Concentration Data
- Hydraulic Head Data
- Index of Hydraulic Conductivity Data
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**WaterlooAPS™ Configurations**

- **Gas-Drive Pump**
  - Sample Line
  - Nitrogen Line
  - KPRO Line
  - Soil Valve
  - Orings
  - 1/8" Stainless Steel Tubing
- **Peristaltic Pump**
  - KPRO + Sample Line
  - 1/8" Tubing

**WaterlooAPS™ Data Acquisition Configuration and Process**

- Notebook computer
- Water pump
- Gas-drive pump
- Sample line
- Pressure transducer

**Two Uses of IK Data**

**Sample Depth Selection**

- Chlorobenzene (µg/L)
  - Lower Aquitard
  - 0
  - 10
  - 100
  - 1,000
  - 10,000

**Stratigraphic Interpretation**

- Lower Aquitard
- 0
- 10
- 100
- 1,000
- 10,000

**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
- WaterlooAPS™ (Advanced Profiler System)
  - Real-time hydrostratigraphy
  - Targeted groundwater sampling of higher K zones/interfaces
- Geoprobe® HPT (Hydraulic Profiling Tool)
  - Real time hydrostratigraphy

**Post-Remedy Investigation Northern England**

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

- **Key**
  - Use of low resolution (conventional) techniques resulted in remedy failure and need for second remedy.
Approximate boundary of low-K zone based on soil lithology

Soil Total CVOC Concentration (µg/kg)

Log PID Signal (µV)

Log ECD Signal (µV)

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.

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