Site Characterization for Improved Remediation

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Recent Experience Leads to New Thinking

Optimization and Technical Support

Good characterization — series of best practices

A set of methods or techniques found to be the most effective and practical means in achieving an objective while making the optimum use of resources

Identify challenges and opportunities

Porosity
Hydraulic Conductivity
Hydraulic Head/Gradient
Capillary pressure
Geochemistry

Historical perspective
- Soil - EPA Superfund has historically focused on high quality analytical samples collected at discrete soil locations
- Groundwater - EPA has historically used monitoring wells, pump tests, etc. to characterize and monitor sites

Challenges encountered
- Discrete soil sampling designs do not address matrix variability/heterogeneity - resulting in highly variable or statistically uncertain decision making
- Large scale averages of aquifer materials obscure primary contaminant transport and mass storage areas

New thinking
- Soil - Incremental and composite techniques that provide large scale averages are better suited to represent exposure scenarios, control matrix variability/sampling heterogeneity, and make statistically confident decisions
- Groundwater - large scale averages derived from aquifer materials can be misleading resulting in poorly performing or applied remedies. HRSC techniques provide measurements at scales more appropriate for remedy design.
Recent Successes Highlight Focus Areas

- **Data management**
  - Historically reports as mechanism to exchange information, now data as deliverable, active data management
  - Data warehouse, data interoperability, economies of scale

- **High Resolution Site Characterization**
  - Direct sensing tools, scale appropriate measurements
  - Collaborative data approaches

- **Real-time data visualization**
  - Conceptual Site Model (CSM) lifecycle management
Data Management is Key

Plans required - Region, Site, Project

- Data acquisition
  - Occurs quickly, involves large amounts of data
  - Data must be integrated into CSM quickly to inform continued data acquisition while mobilized

- Data input
  - Automatic/manual systems to QC at point of generation accurately transfer to databases

- Decision Support
  - Statistical, visualization, modeling

- Communicate
  - Force interpretation, compress timeframes
Data Management Leads to A Robust Conceptual Site Model

1980’s—1990s
Pathway-Receptor Network Diagrams
- P-RN diagrams NOT CSMs – too simple to serve all CSM functions
- However, they are a critical COMPONENT of CSMs

2000’s
- CSM should incorporate all actual and potential
- Investigation efforts confirm or refute each

2010 to present

“As we know, there are known knowns. There are things we know we know. We also know there are known unknowns. That is to say we know there are some things we do not know. But there are also unknown unknowns, the ones we don’t know we don’t know.”

Donald Rumsfeld, Feb. 12, 2002
U.S. Department of Defense

Sampling Scale and Averaging

Monitoring wells yield a depth integrated flow weighted average.

[Graph showing elevation vs. PCE (ug/L) and hydraulic conductivity (cm/sec)]
Mass Flux Distribution—The Rise of In-Situ Remedies

Guilbeault et al., 2005
75% of mass discharge occurs through 5% to 10% of the plume cross sectional area
Optimal Spacing is ~0.5 m

Superfund Remedy Report 14th edition
- 1980’s- Pump and Treat 90% of GW remedies, no in-situ remedies
- 2011- Pump and Treat 30%, In-situ almost 40%
Spatial Variability In Flux…… But Also Temporal

**Early Stage**

<table>
<thead>
<tr>
<th>Source Zone</th>
<th>Plume</th>
<th>Low Permeability</th>
<th>Transmissive</th>
<th>Low Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapor</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DNAPL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aqueous</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorbed</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Middle Stage**

**Late Stage**

**Source Zone**

- **Vapor**
  - Low Permeability
  - Transmissive
  - Low Permeability
- **DNAPL**
  - Low Permeability
  - Transmissive
  - Low Permeability
- **Aqueous**
  - Low Permeability
  - Transmissive
  - Low Permeability
- **Sorbed**
  - Low Permeability
  - Transmissive
  - Low Permeability

**Plume**

- **Vapor**
  - Low Permeability
  - Transmissive
  - Low Permeability
- **DNAPL**
  - Low Permeability
  - Transmissive
  - Low Permeability
- **Aqueous**
  - Low Permeability
  - Transmissive
  - Low Permeability
- **Sorbed**
  - Low Permeability
  - Transmissive
  - Low Permeability

**K (cm/sec)**

Source Zone

- 1E-5
- 1E-4
- 1E-3
- 1E-4
- 1E-2

**Depth (meters)**

**PCE (ug/L)**

- 10
- 1000
- 10000
- 100000

- **Source Zone**
  - PCE Concentration
  - K hydraulic conductivity cm/sec
Hail to the Tools!
Addressing Uncertainty and Matrix Heterogeneity

The Missing Link

Collaborative data sets and high-resolution also critical for geologic / hydrogeologic information.

• Not just analytical concept.

• In many cases, geologic / hydrogeologic context may be more critical for effective remedy design.
Example 1 - Wyckoff Region 10

Existing Work Products

<table>
<thead>
<tr>
<th>Y-Length, ft</th>
<th>X-Width, ft</th>
<th>Z-Height, ft</th>
<th>Treatment Box Soil Volume, cu. yds.</th>
<th>TarGOST Impacted Soil Volume @ 10%RE in Treatment Box, cu. yds.</th>
<th>TarGOST 10%RE Percent of Treatment Box Volume, cu. yds.</th>
<th>TarGOST 20%RE Percent of Treatment Box Volume, cu. yds.</th>
<th>TarGOST 50%RE Percent of Treatment Box Volume, cu. yds.</th>
<th>TarGOST 100%RE Percent of Treatment Box Volume, cu. yds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box A</td>
<td>160.00</td>
<td>170.00</td>
<td>45.00</td>
<td>33,836</td>
<td>12,882</td>
<td>38%</td>
<td>9%</td>
<td>6%</td>
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<tr>
<td>Box B</td>
<td>200.00</td>
<td>210.00</td>
<td>30.00</td>
<td>38,538</td>
<td>5,534</td>
<td>14%</td>
<td>7%</td>
<td>3%</td>
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<tr>
<td>Box C</td>
<td>180.00</td>
<td>165.00</td>
<td>23.00</td>
<td>13,302</td>
<td>4,091</td>
<td>33%</td>
<td>19%</td>
<td>5%</td>
</tr>
<tr>
<td>Box D</td>
<td>180.00</td>
<td>132.00</td>
<td>10.00</td>
<td>5,881</td>
<td>2,253</td>
<td>38%</td>
<td>15%</td>
<td>0%</td>
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<tr>
<td>Box E</td>
<td>305.00</td>
<td>300.00</td>
<td>28.00</td>
<td>77,146</td>
<td>13,371</td>
<td>17%</td>
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<td>Box F</td>
<td>300.00</td>
<td>300.00</td>
<td>22.00</td>
<td>72,706</td>
<td>14,734</td>
<td>20%</td>
<td>7%</td>
<td>1%</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>246,389</td>
<td>55,255</td>
<td>22%</td>
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</tr>
</tbody>
</table>

Total 10%RE TarGOST Impacted Soil Volume Inside Wall: 59,489
% Captured in Boxes: 93%
HRSC and Incremental Sampling
Translated for Remedial Designs

• In Groundwater
  - Limit large scale averaging, use scale appropriate measurements
  - Use transects and multi-level sampling
  - Use direct sensing and collaborative data sets

• In Soil
  - Use incremental and compositing techniques to control matrix variability, reasonably represent exposure and decision units
  - Many increments and replicate samples provide good estimate of mean, and ability to calculate UCL/LCL and statistical confidence

• Real-time CSM Updates/Data Visualization
  - Forces interpretation not just presentation
  - Includes all decision makers in the process- consensus, streamline
  - Save time and money- fewer repeat mobilizations, early ID of data collection errors
  - Keeps focus on root causes not symptoms- High mass footprint (where to remediate), Matrix distribution (how to remediate)