Evaluating and Refining the CSM

NEWMOA

Back to Basics Part 2: Data Collection & Interpretation: State of the Practice & Lessons Learned

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Outline

- Summary of characterization tools and technologies
- Data collection and interpretation
- Updating the CSM
- Case studies
- Available ITRC resources

Integrated Site Characterization

- Plan characterization (1-4)
  - Define the problem
  - Identify data needs and resolution
  - Develop data collection objectives
  - Design data collection and analysis plan
- Select tools (5)
- Implement investigation and update CSM (6-8)

Figure 4-1 Integrated Site Characterization

Tools Matrix Format and Location

- The tools matrix is a downloadable excel spreadsheet located in Section 4.6
- Tools segregated into categories and subcategories, selected by subject matter experts
- A living resource intended to be updated periodically

Tool
Geophysics
Surface Geophysics
Downhole Testing
Hydraulic Testing
Single well tests
Cross Borehole Testing
Vapor and Soil Gas Sampling
Solid Media Sampling and Analysis Methods
Solid Media Sampling Methods
Solid Media Evaluation and Testing Methods
Direct Push Logging (In-Situ)
Discrete Groundwater Sampling & Profiling
Multilevel sampling
DNAPL Presence
Chemical Screening
Environmental Molecular Diagnostics
Microbial Diagnostics
Stable Isotope and Environmental Tracers
On-site Analytical

Excel worksheet available at http://www.itrcweb.org/documents/team_DNAPL/DNAPL.xlsm

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Orientation to the Tools Matrix

- Contains over **100** tools
- Sorted by:
  - Characterization objective
    - Geology
    - Hydrogeology
    - Chemistry
  - Effectiveness in media
    - Unconsolidated/Bedrock
    - Unsaturated/Saturated
- Ranked by data quality
  - Quantitative
  - Semi-quantitative
  - Qualitative

Tools Matrix Functionality

Click any box for a description or definition

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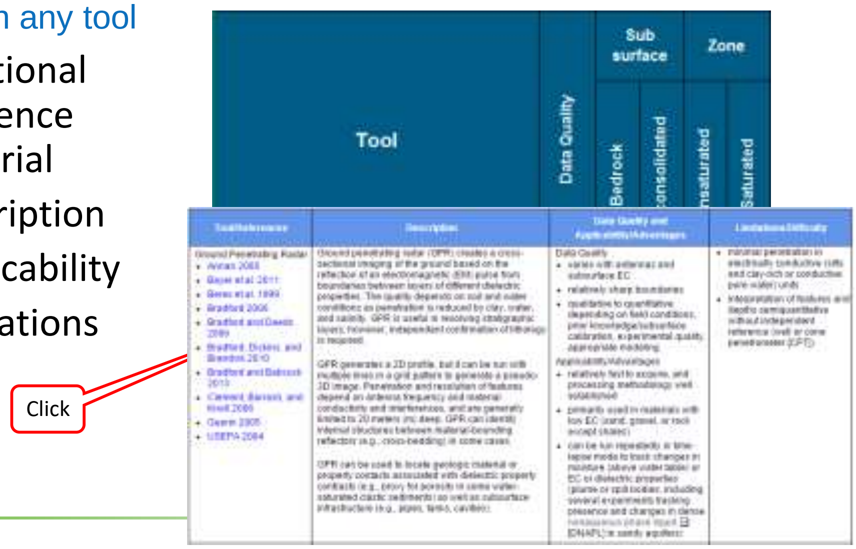
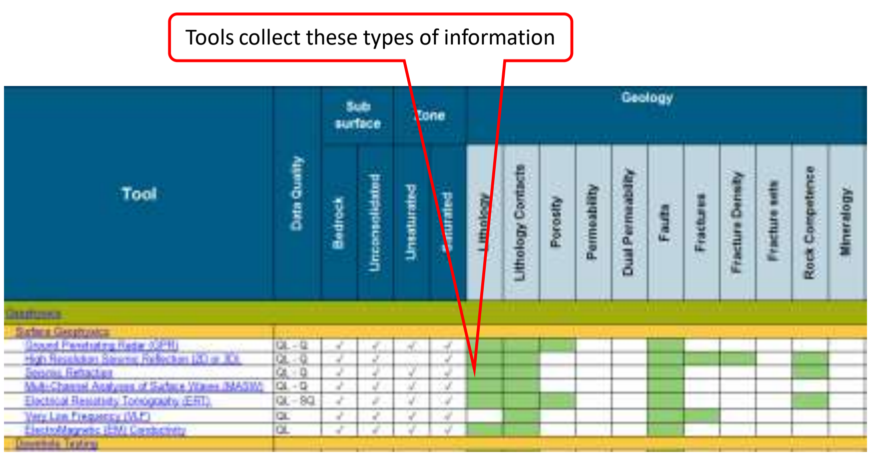
Detailed Tool Descriptions (Appendix D)

Click on any tool

- Additional reference material
- Description
- Applicability
- Limitations



Shaded Boxes Denote Tool Meets Objective



Green shading indicates that tool is applicable to characterization objective

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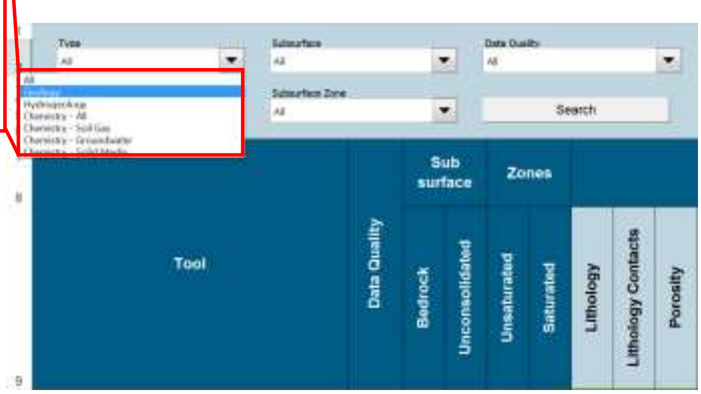
Using the Tools Matrix

- Down-selecting appropriate tools to meet your characterization objectives
- A systematic process
  - Select your categories: geology, hydrogeology, chemistry
  - Select parameters of interest
  - Identify geologic media (e.g., unconsolidated, bedrock)
  - Select saturated or unsaturated zone
  - Choose data quality (quantitative, semi-quantitative, qualitative)
  - Apply filters, evaluate tools for effectiveness, availability, and cost
- Ultimately, final tools selection is site-specific, dependent upon team experience, availability, and cost

1. Select Category

All
Geology
Hydrogeology
Chemistry
– All
– Soil Gas
– Groundwater
– Solid Media



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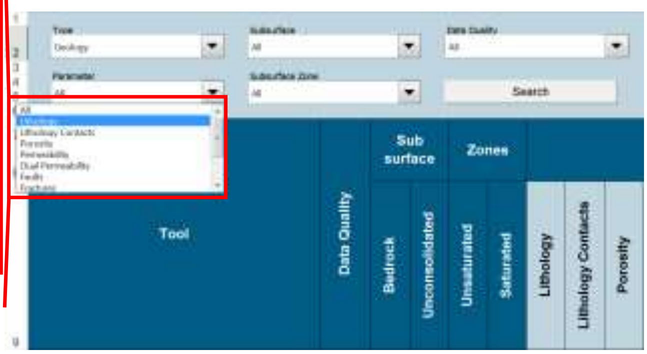
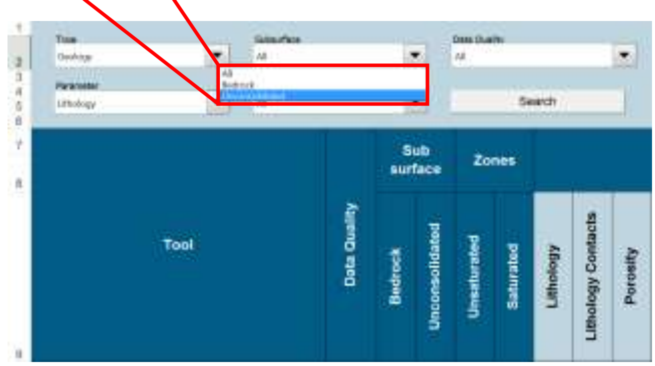
2. Select Parameters of Interest

- All
- Lithology Contacts
- Porosity
- Permeability
- Dual Permeability
- Faults
- Fractures
- Fracture Density
- Fracture Sets
- Rock Competence
- Mineralogy



3. Identify Geologic Media

- All
- Bedrock
- Unconsolidated



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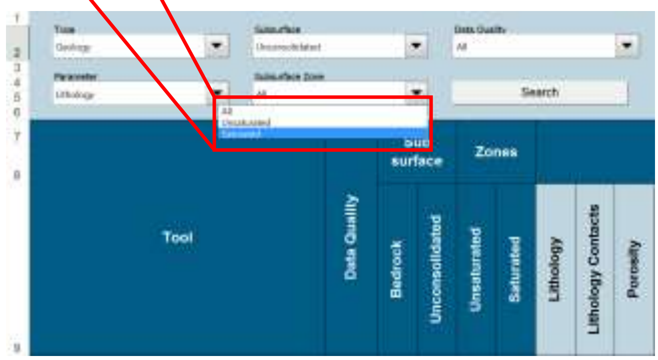
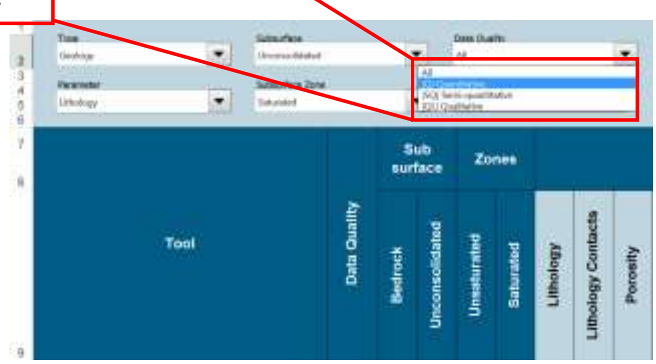
4. Identify Zone

All
Unsaturated
Saturated



5. Choose Data Quality

(Q) quantitative
(SQ) semi-quantitative
(QL) qualitative



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6. Apply Filters, Evaluate Tools

Perform Additional Searches to Find More Tools for Different Objectives

Additional parameters can be added or removed from any given search

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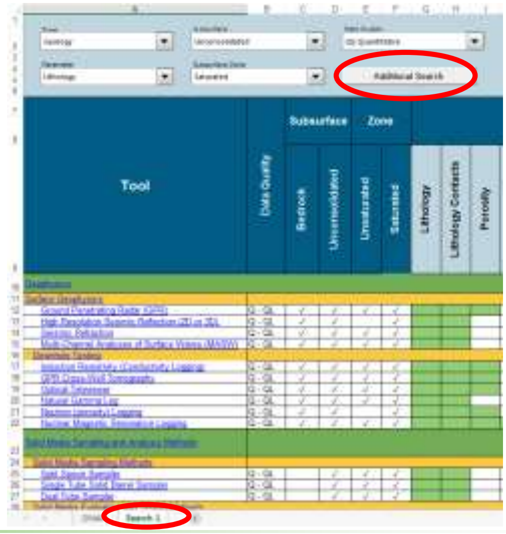
Add Parameters to a previous search

Multiple searches can be saved on one matrix



Apply Selected Tool(s)

- Incorporate selected tool(s) into characterization plan
- Implement plan, evaluate data, update CSM, reassess characterization objectives
- Repeat tool selection process as necessary

Case Example – Characterization Objectives

Case Example

Returning to Case Example from prior section

– Characterization Objective:

- Delineate lateral and vertical extent of dissolved-phase plume; determine stability and rate of attenuation.

Goal:

- Define boundary exceeding groundwater standards
- Assess remedy progress – soil and groundwater samples
- Assess shallow soil vapor impacts

Case Example – Select Tools Matrix Filters

Case Example

Filters

- Type
  - Chemistry
- Parameter
  - Contaminant Concentration
- Subsurface Media
  - Unconsolidated
- Subsurface Zone
  - Saturated
- Data Quality
  - (Q) Quantitative

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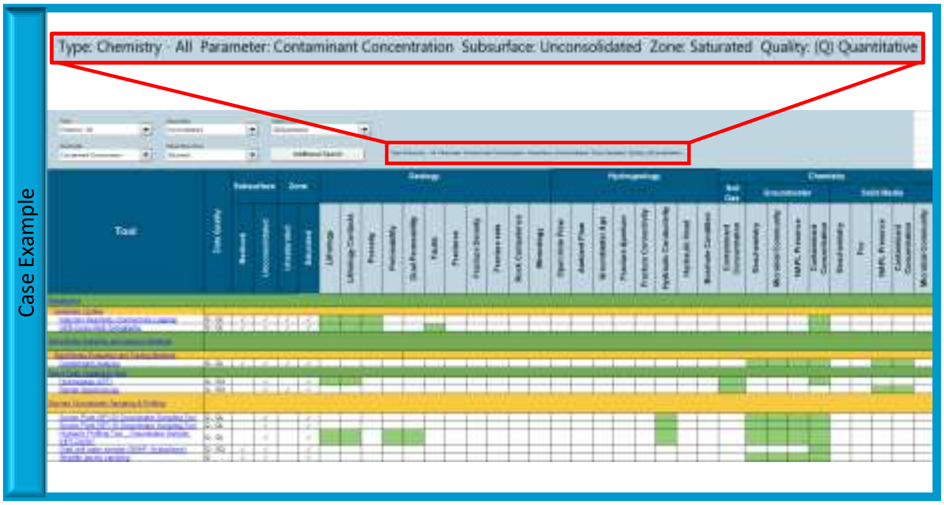
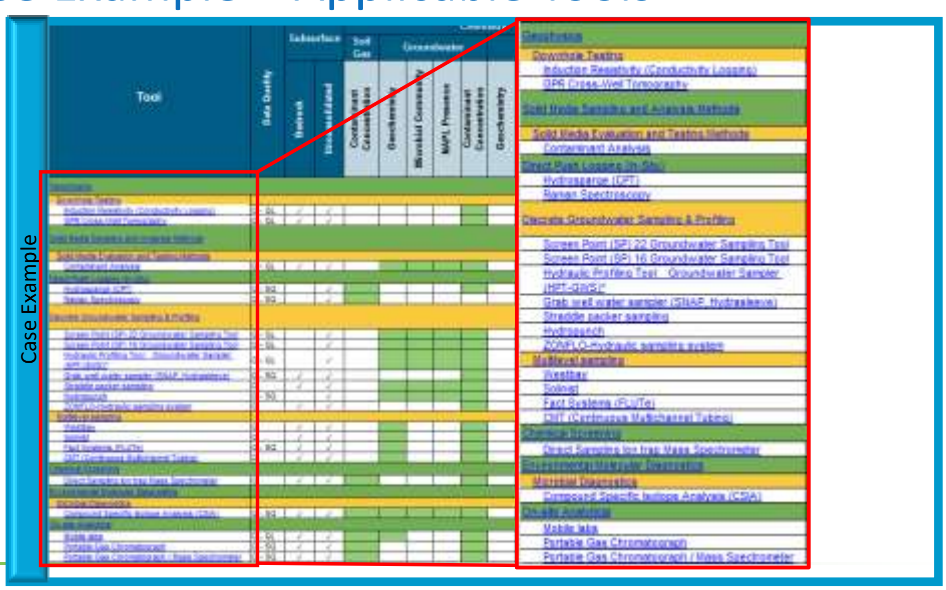
Case Example – Apply Filters



Case Example – Applicable Tools



Case Example – Tools Selection

Case Example

- Search returns 21 tools
- Considering desire to expedite the assessment, project team selected
  - Direct Push borings with continuous soil sampling and GW grab sampling on 4-foot intervals
  - Active Soil Gas Survey at two depth intervals
  - Direct Sampling Ion Trap Mass Spectrometer (DSITMS) mobile field lab

Active Soil Gas Survey

DSITMS Mobil Lab

ITRC Tools Matrix Summary

- Characterization objectives guide selection of tools
- Interactive tools matrix - over 100 tools with links to detailed descriptions
- A systematic tools selection process
- Select tools, implement work plan, evaluate results
- Align data gaps with characterization objectives, update CSM
- Repeat as necessary until consensus that objectives have been met

More on the Content of the Characterization Plan

Develop a Work Plan

A typical characterization work plan should:

- Emphasize characterization and data collection objectives
- Present a data collection process
- Include the tools selected
- Be forward-looking to discuss what procedures/software/models will be used for data evaluation and interpretation
- Include data evaluation process, particularly for fractured rock sites

More on the Content of the Characterization Plan

Develop a Work Plan

Use a dynamic field approach to site characterization to the extent practical, even at fractured rock sites

- The work plan should be flexible to allow changes to the work scope based on real-time results obtained during the investigation activities.
- The work plan should outline the process for documenting field changes or adjustments during implementing the site investigation

More on the Content of the Characterization Plan

Develop a Work Plan

A dynamic work plan can involve

- Real time data assessment
- Frequent (up to daily) calls or data uploads between the field team and project stakeholders to review field activities and data, to make decisions next steps for efficiently completing the characterization.
- Continuously or frequently updating the CSM

Conducting

- Step 6: Implement investigation
- Step 7: Perform data evaluation and interpretation
- Step 8: Update CSM

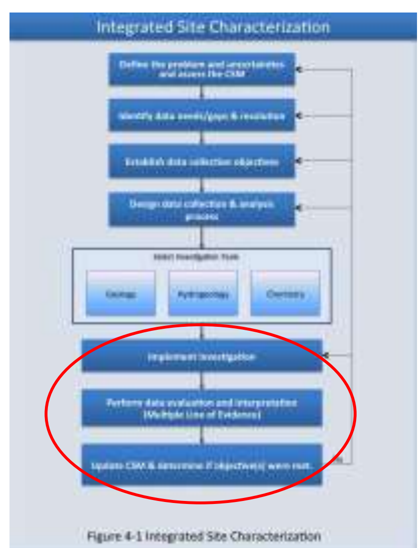


Figure 4-1 Integrated Site Characterization

Step 6. Implement Investigation

- Time to conduct the investigation
  - Go into field
  - Use flexible plan
  - Collect data
- Often concurrent with data evaluation (Step 7)

Figure 4-1 Integrated Site Characterization

Step 7. Data Evaluation and Interpretation

- Gain understanding of site
  - Integrate all data types
  - Generate collaborative datasets
- Multiple line of evidence
  - Contaminant transport
  - Storage
  - Attenuation

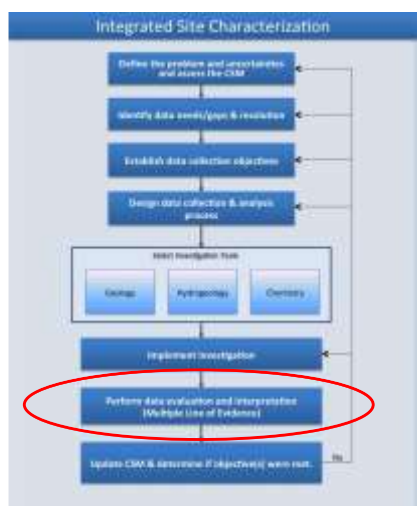


Figure 4-1 Integrated Site Characterization

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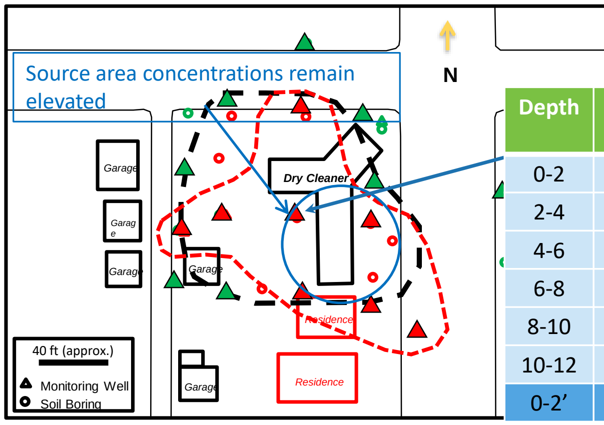
Step 7. Soil and Groundwater Data Evaluation and Interpretation

Case Example



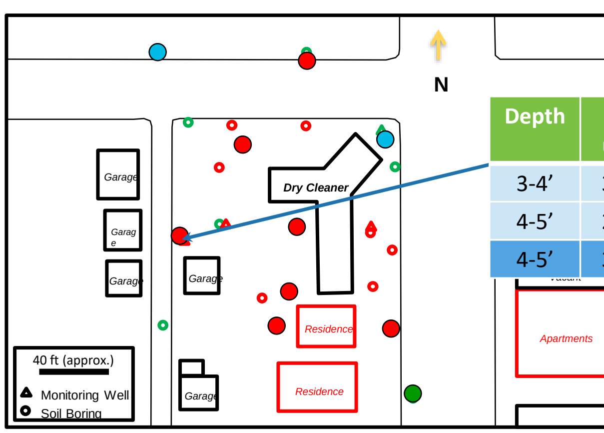
Depth	PCE mg/kg	Lab
0-2	3.25	Mobile
2-4	2.232	Mobile
4-6	<0.37	Mobile
6-8	3.298	Mobile
8-10	11.5	Mobile
10-12	<0.37	Mobile
0-2’	21	Fixed

Result exceeds criteria

Result does not exceed criteria

Step 7. Soil Vapor Data Evaluation and Interpretation

Case Example



Depth	PCE units	Lab
3-4’	3720	Mobile
4-5’	2398	Mobile
4-5’	3800	Fixed

Shallow soil vapor results

Result below vapor screening level

Result exceeds chronic vapor screening level

Result exceeds sub-chronic vapor screening level

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Poll Question

Poll Question

- When do you typically update your CSM at sites where you work?
  - Whenever new data is collected
  - When a remedial technology fails
  - Whenever the CSM is determined to be inaccurate
  - Every five years
  - Never

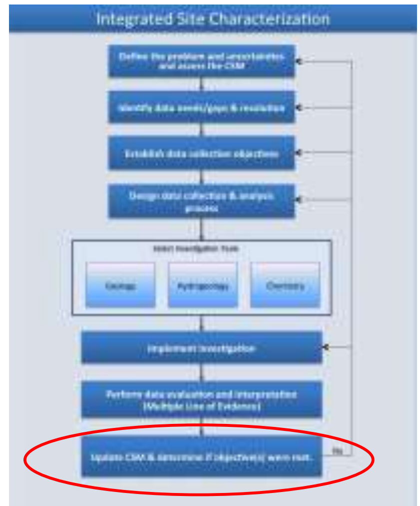

Figure 4-1 Integrated Site Characterization

Step 8. Update the CSM

- Data collected from all phases of a project can be used
- As a project progresses, data needs shift
- In late phases, additional data collection often driven by specific questions
- ISC continues as the CSM evolves

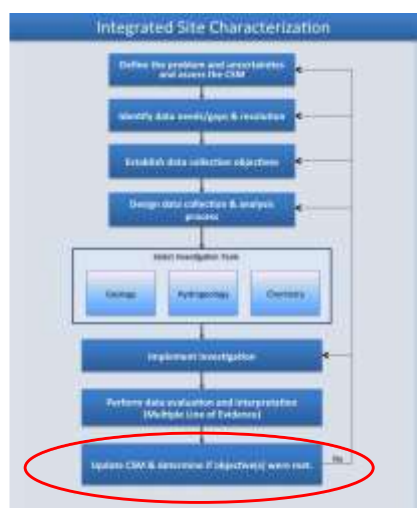

Figure 4-1 Integrated Site Characterization

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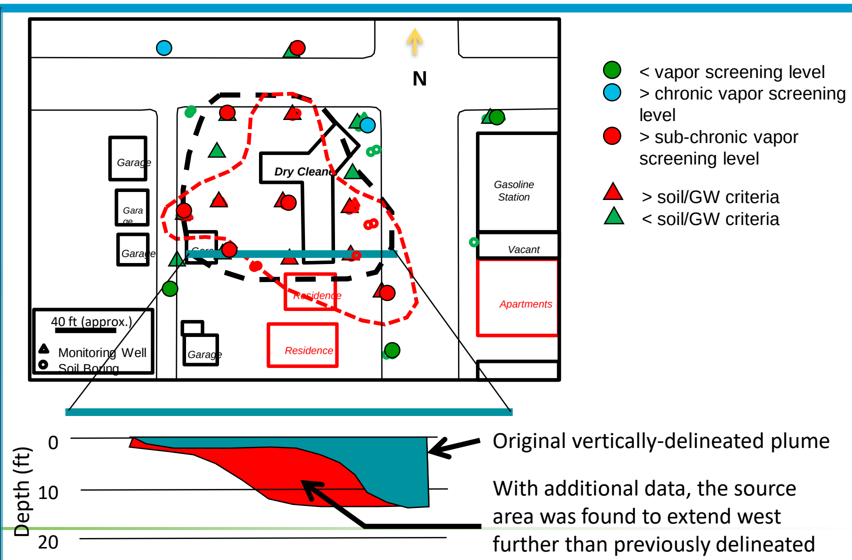
Step 8: Dry Cleaners – CSM Update

Case Example



Integrated Site Characterization Benefits for Dry Cleaners Sites

Case Example

- Confirmed need for residential indoor air evaluation and VI mitigation for commercial buildings
- Optimized data density in specific areas; avoided unnecessary / inconclusive data collection
- Accurately determined source zone and remediation target area
- Completed ahead of schedule; saved $50k of $150k budget (33%)

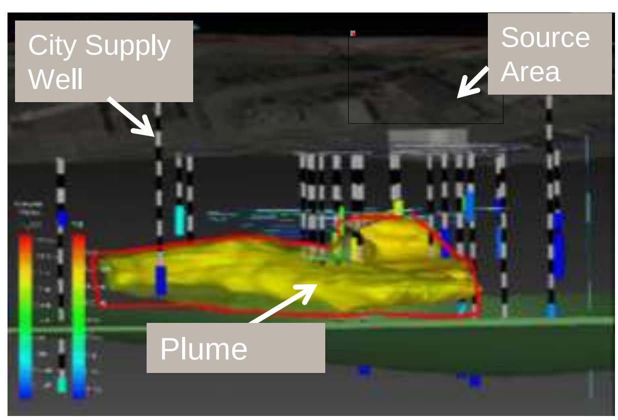
Case Study Examples

Well 12A Superfund Site, WA

Mass flux and mass discharge

Focused Feasibility Study evaluation: Reduce source strength (Md) by 90%, MNA sufficient to achieve compliance

ROD amendment: Multi-component remedy- reduce source discharge Md by 90% & transition technology (if necessary)



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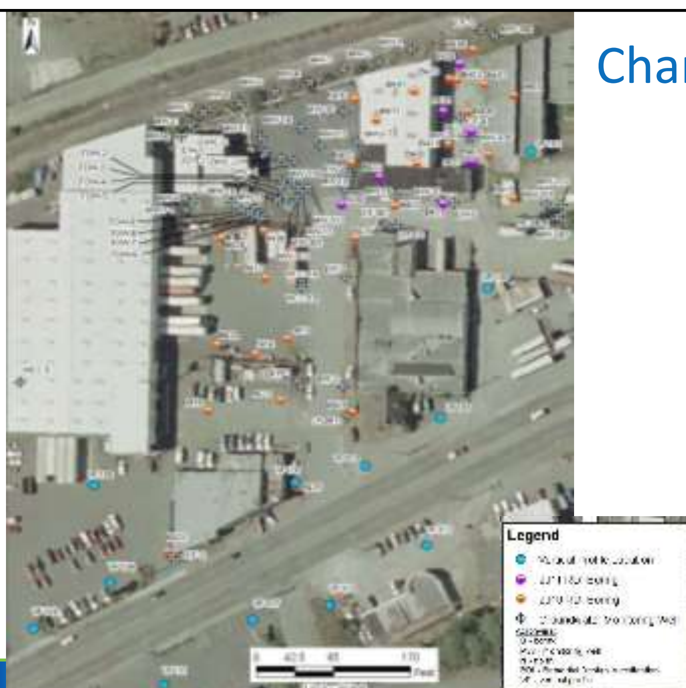
Starting CSM: 2D TCE Plume

- In situ bioremediation remedy selected for large areas of the plume, along with thermal and excavation
- Entire ~75 to 95 ft contaminated thickness required active ISB treatment



Characterization Objectives

•34 soil borings to reduce uncertainty and delineate sources
•12 locations for vertical profiling
•Depth discrete samples:
  •Groundwater
  •Soil
  •Slug testing
  •Stratigraphy
•Gradient assessment
•Mass flux assessment

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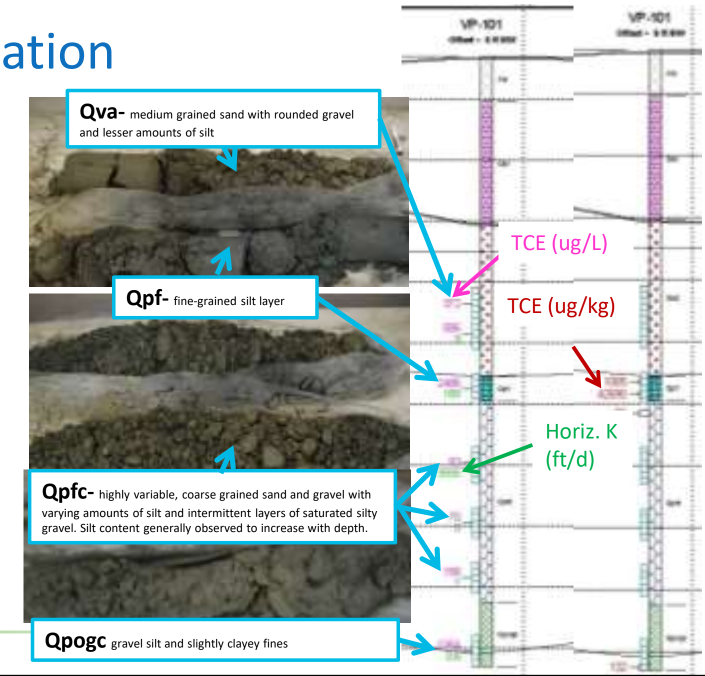
Vertical Characterization

- Install borings in transects
- Conduct depth-discrete soil and groundwater sampling
- Perform slug testing



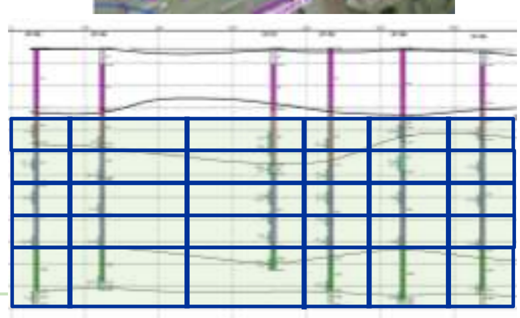
Calculating Mass Discharge: Transect Method

Steps for Well 12A:

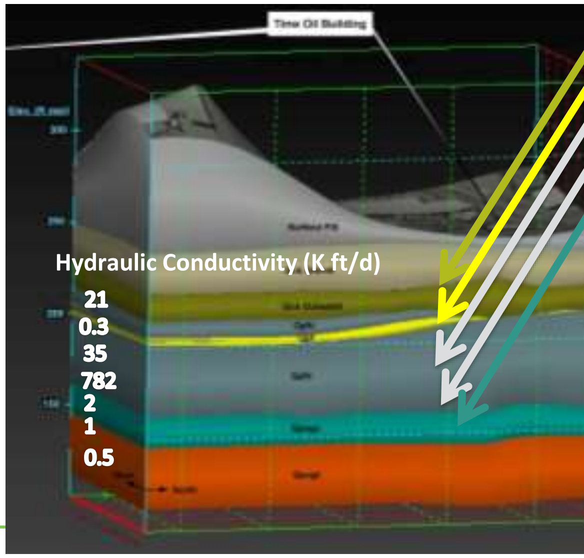
1. Draw polygons (use Theissen)
2. Calculate Darcy velocity (q) for each polygon: q=K•I
3. Characterize polygon flux ($Mf=q \bullet C_n$)
4. Determine area (W • b = A)
5. Evaluate mass discharge:

$$M_d = \Sigma (Mf \bullet A_n)$$

M_f = Mass flux
M_d = Mass discharge
C_n = concentration in polygon n
A_n = Area of segment n



Mass Discharge Across Transects

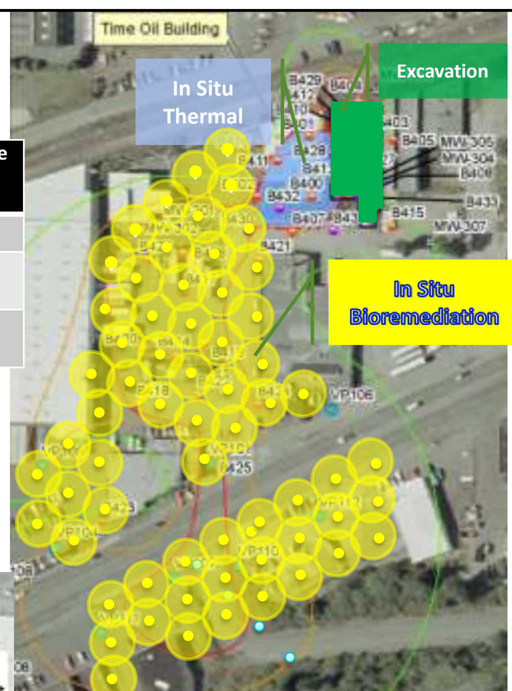


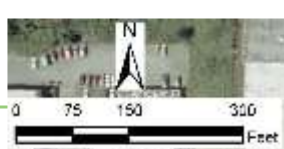
	Total VOC MD (kg/yr)	% of Total MD
Transect 1		
Qva	0.1	1%
Qpfc1/Qpf	2.9	31%
Qpfc2	5.9	64%
Qpfc3	0.06	1%
Qpogc	0.3	4%
Total	9.3	
% of Total		
Transect 2		
Qva	0.01	0.4%
Qpfc1/Qpf	0.2	7%
Qpfc2	1.7	57%
Qpfc3	0.1	3%
Qpogc	1.0	33%
Total	3.0	

96%

Mapping Technologies

Zone	Surface Area (ft²)	VOC Mass (kg)	% Discharge to GETS
Excavated Zone	3819	510	NA
Thermal Treatment Zone	11,746	~189	70 kg/yr
In Situ Bioremediation	162,005	~245	25 kg/yr





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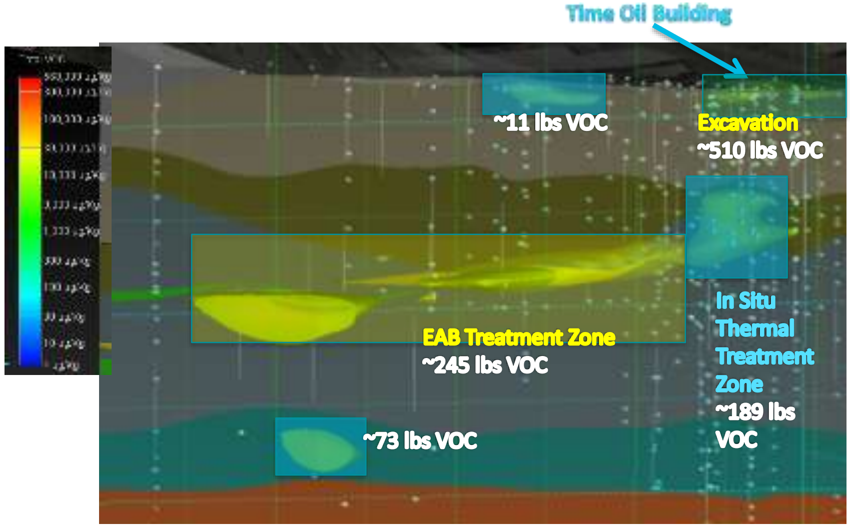
Treatment Zones: Selecting Vertical Intervals



Well 12A HRSC Conclusions – Updated CSM

- Revising the CSM to evaluate the plume in 3D:
  - Stratification of residual contaminant mass in soils
  - Transport through the groundwater plume
- Nearly 95% of the mass discharge was occurring within 20 feet of the 75 foot vertical extent of the contaminated aquifer near major source
- This reduction in target treatment volume will save nearly $3M on the remedy, resulting in a large return on the ~$350K characterization investment

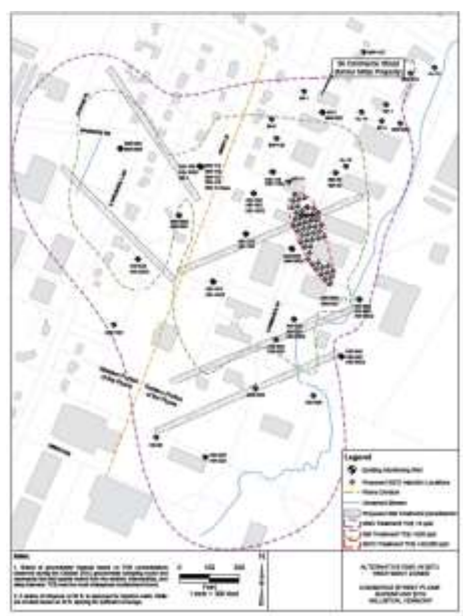
Commerce Street Plume Superfund Site

- TCE plume in mixed-use area
- ROD-selected remedy:
  - In situ chemical oxidation (ISCO) for TCE > 50,000 ppb
  - In situ bioremediation (ISB) for TCE > 500 ppb but <50,000 ppb
  - Monitored natural attenuation (MNA) for TCE < 500 ppb
- Follow ISC process to define data gaps, set objectives, and select tools
- Lesson Learned – site conditions can change over relatively short time frames

High Resolution Site Characterization

<u>Initial CSM</u>

- TCE DNAPL released into sandy aquifer
- Sand unit:
  - Shallow zone 10-20 ft below ground surface (bgs)
  - Intermediate zone 20-30 ft bgs
  - Deep zone 30-40 ft bgs
- Continuous clay unit underlying sand unit (40 ft bgs)



Characterization Activities and Preliminary Results

Characterization program

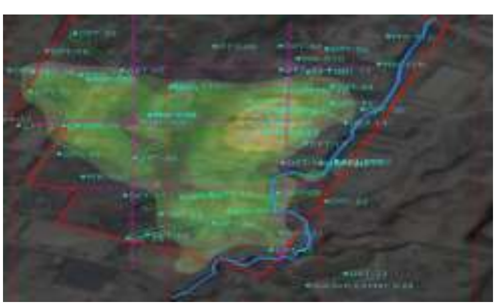
- Membrane interface probe/hydraulic profiling tool (MiHPT)
- Waterloo Advanced Profiling System (APS)
- DPT soil and groundwater sampling
- Onsite VOC analysis

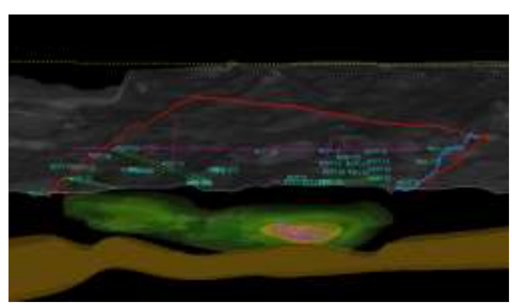
Results Summary

- 50,000 ppb hotspot no longer exists
- In east-central portion of site, TCE is almost completely converted to c-DCE
- Sand unit is hydraulically somewhat variable and not related to previous designations

Path Forward

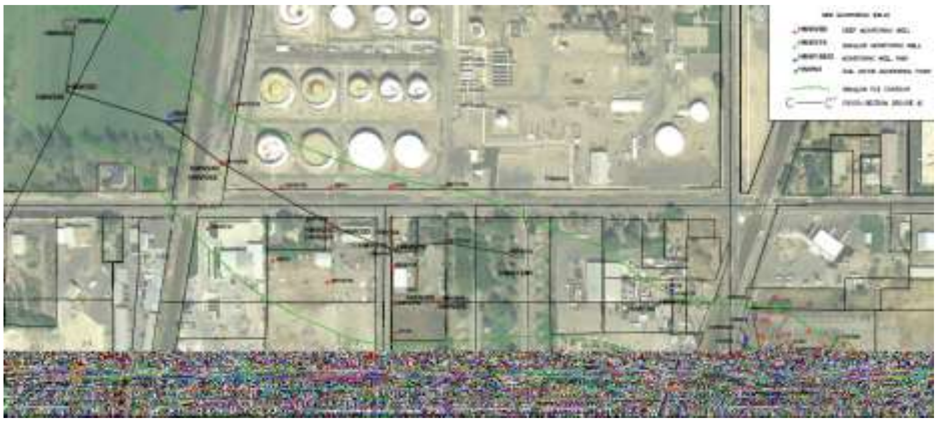
- ISCO may no longer be needed – potential savings of nearly $3M
- Current nature and extent of contaminants could be treated by ISB and MNA
- Bench and pilot testing approach is being modified
- RD will incorporate new CSM and bench/pilot results





Bountiful OU1 Site

- Lesson Learned: Be willing to challenge the current CSM



Site Hydrogeology - RI

- Water table generally at about 25-30 ft. bgs
- Sand and gravel zones present to 35-40 ft. bgs
- Clay aquitard present below sand and gravel unit
- Separate, uncontaminated sand and gravel unit below clay

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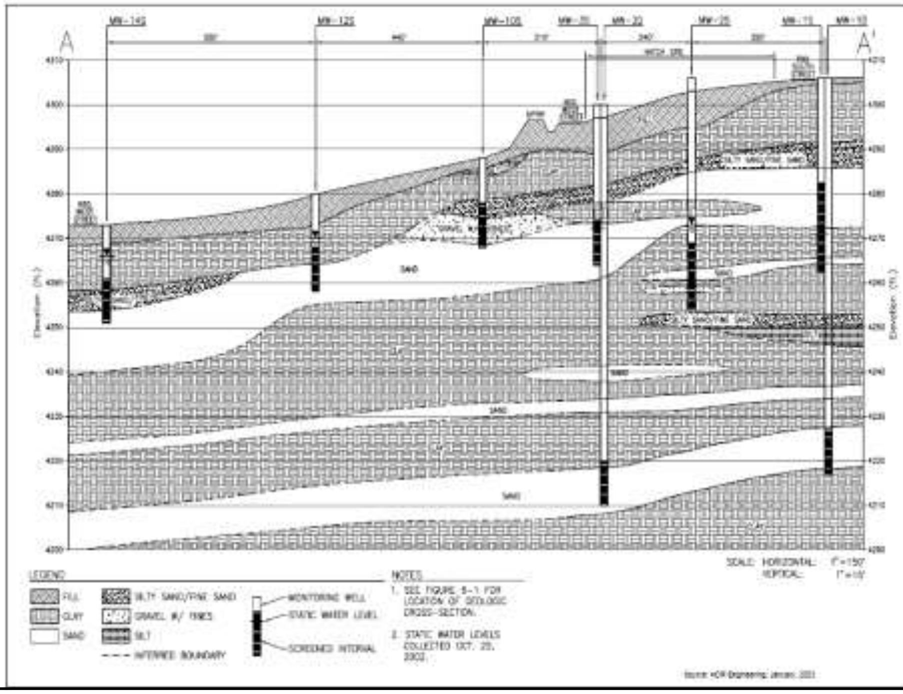

Full-Scale Design

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Pre-RA Characterization (2008-2009)

- Source area & Biobarrier # 1
  - Membrane interface probe (MIP) / Electrical Conductivity (EC) characterization to determine contaminant profile and lithology
  - Direct push technology (DPT) points to confirm MIP/EC results
- Biobarrier # 2 and # 3
  - MIP/EC and DPT along plume axis to look for hotspots > 200 µg/L
  - Additional MIP/EC and DPT at the identified hot spots to define biobarrier locations
- Monitoring well installation and baseline sampling

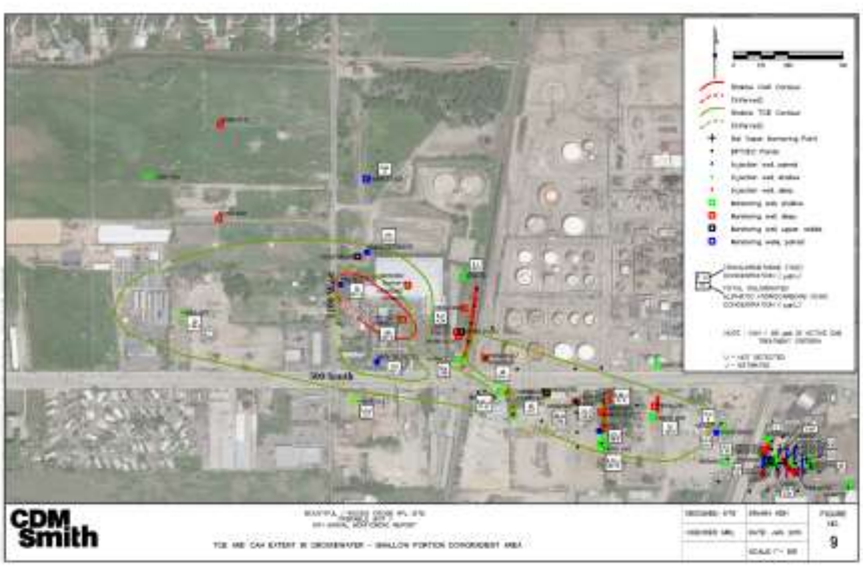
Pre-RA Characterization Results: Contaminant Distribution

- Membrane-interface probe (MIP) used to determine areas with high concentrations of VOCs
- MIP results showed responses at depths greater than 40 ft. throughout the source area and downgradient plume
- DPT sampling confirmed MIP results as source concentrations greater than 15,000 ppb were found below 40 ft.
- Downgradient concentrations were greater than 3,000 ppb in one location

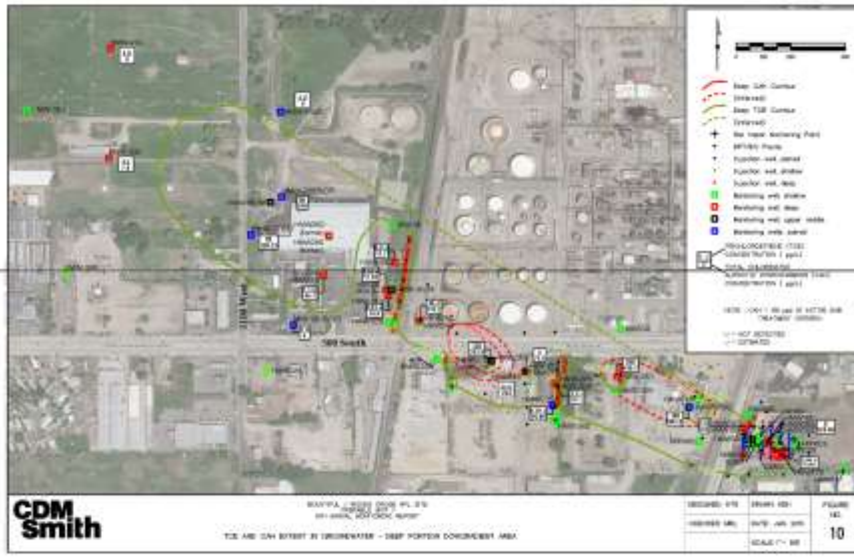
Pre-RA Characterization Results: Hydrogeology

- Clay layer at 35 ft. bgs was found to be laterally discontinuous
- Modified DPT/EC approach was used to investigate hydrogeology below 60 ft.
- Below 35 ft., layers of sand and gravel exist to 80 feet bgs, with intermittent thin clay layers present in some areas
- A several foot thick clay layer was found at depths of approximately 80 ft. throughout the source area
- The deep clay layer was confirmed in the downgradient area during other site drilling activities
- As a result, the remedial design was changed to include injection into deeper zones

Shallow Zone Results



Deep Zone Results

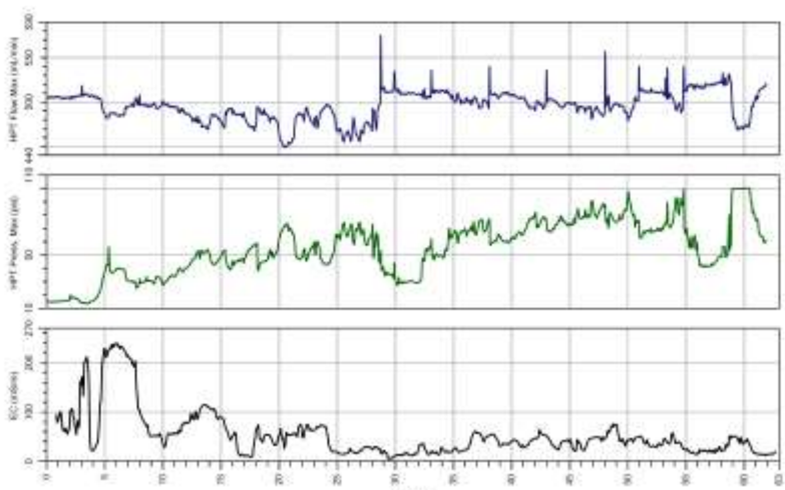


HPT-GWS investigation approach

- Objective: plume delineation to MCLs
- TRIAD approach with EPA mobile lab
- Continuous hydraulic profiling
- GW samples collected at high conductivity zone
- Lithologic and analytical data used to guide well installation

Downgradient plume

Example HPT log – HPT-D10



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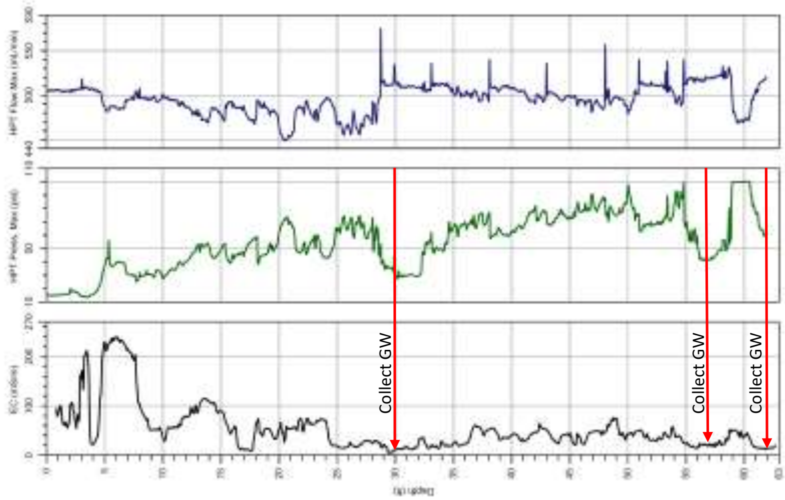
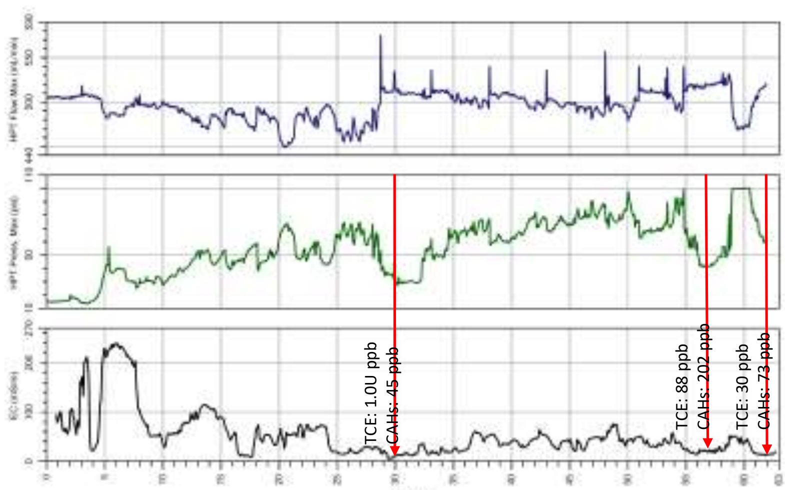
Example HPT log – HPT-D10



Example HPT log – HPT-D10



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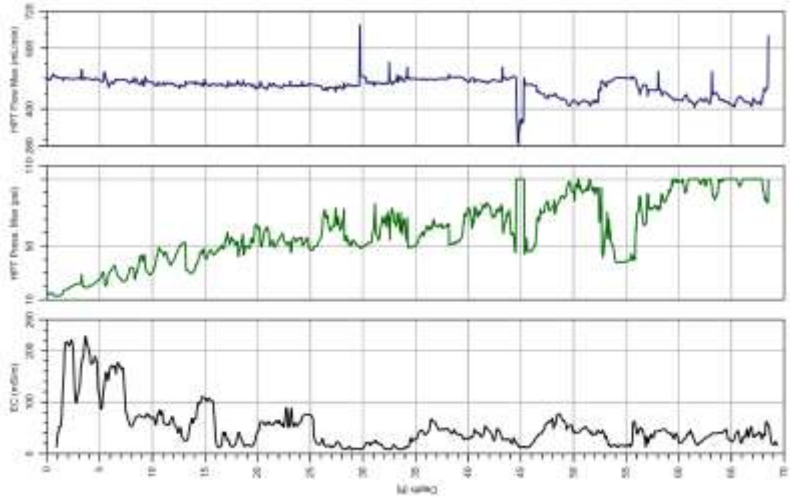
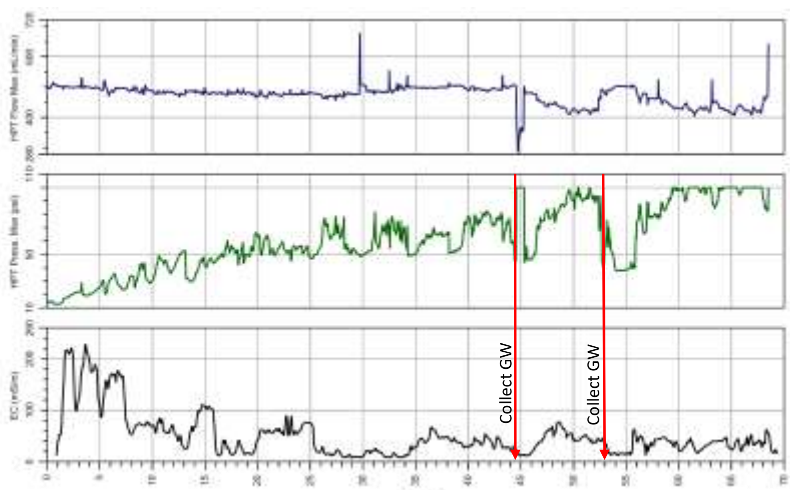
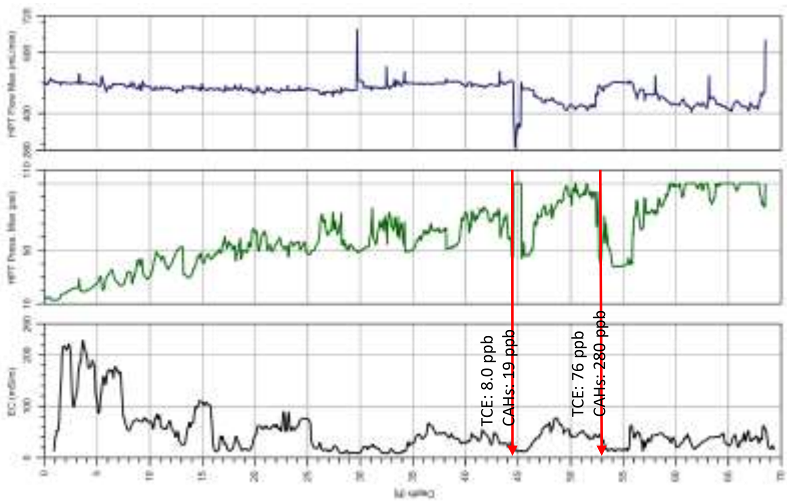
Example HPT log – HPT-D11



Example HPT log – HPT-D11



Example HPT log – HPT-D11



Delineated plume

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Summary: ITRC Resources

- Integrated DNAPL Site Strategy
  https://www.itrcweb.org/GuidanceDocuments/IntegratedDNAPLStrategy_IDSSDoc/IDSS-1.pdf
- Integrated Site Characterization and Tools Selection
  https://www.itrcweb.org/DNAPL-ISC_tools-selection/
- Characterization and Remediation in Fractured Rock
  https://fracturedrx-1.itrcweb.org/
- Incremental Sampling Methodology (ISM)
  https://www.itrcweb.org/ism-1/

Geology controls flow!

- Lithologic heterogeneity leads to differences in subsurface pore structure and capillary properties.
- These can be over very small distances/ intervals

Photo Courtesy of Fred Payne, Arcadis, Inc

Controlling Role of Geology in Matrix Diffusion

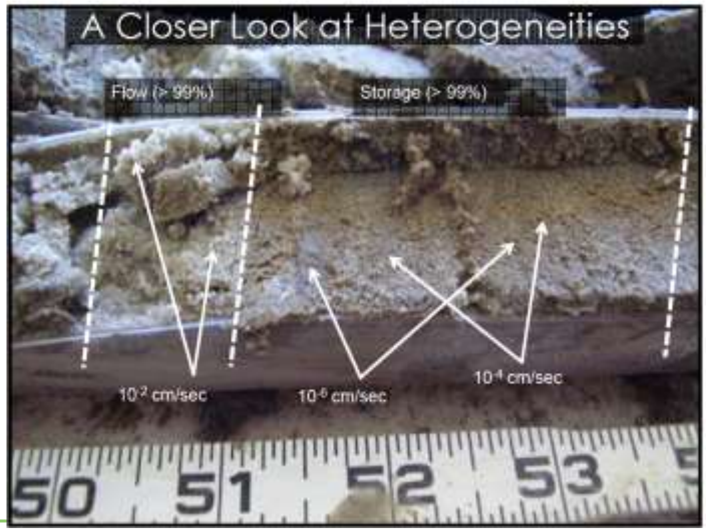

Figure courtesy of Fred Payne, Arcadis

Summary

- Characterization activities should be driven by objectives (e.g. SMART)
- Characterization plan should facilitate dynamic decision making
- **The CSM should be continuously updated during all project phases**

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