

Developing a Site Characterization Plan

NEWMOA

Back to Basics Part 1: Developing the CSM and Site Characterization Plan

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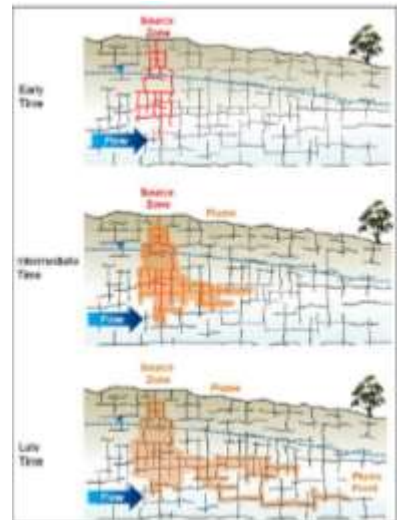
March 27-29, 2018



**CDM
Smith**

Introduction

- Initial CSM is already developed
- Data gaps likely exist that need to be filled
- An iterative approach is recommended for filling these data gaps
- **Recommended process is the ITRC Integrated Site Characterization (ISC) Process**



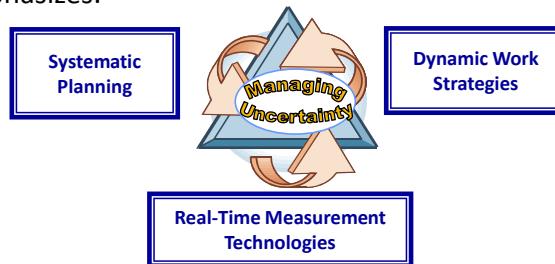
Parker et al. 2012

Integrated Site Characterization

ISC relies on the concept of an *objectives-based site characterization*.

This emphasizes the importance of establishing clear, effective objectives to drive characterization data collection.

It is a systematic, stepwise process that encourages use of a characterization approach which emphasizes:



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Integrated Site Characterization

► Integrated Site Characterization flow chart

- Planning
- Tool Selection
- Implementation

► Planning module

- Step 1: Define problem and uncertainties
- Step 2: Identify data gaps & resolution
- Step 3: Develop data collection objectives
- Step 4: Design data collection & analysis plan
- Similar to DQO process

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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

Data Quality Objectives are “Built in”

USEPA Data Quality Objectives

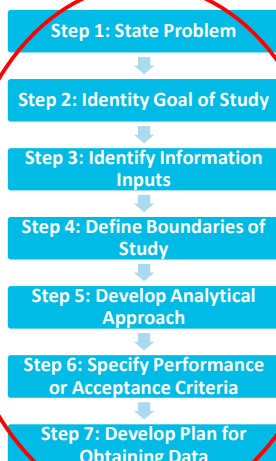


Figure 4-1 Integrated Site Characterization

Step 1: Define Problem and Assess CSM Uncertainties

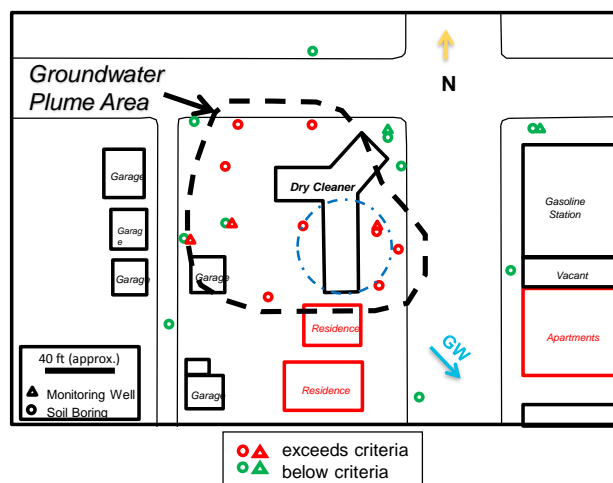
- Assess existing CSM
- Define problem
- Define uncertainties



Case Example – Dry Cleaner Site

Case Example

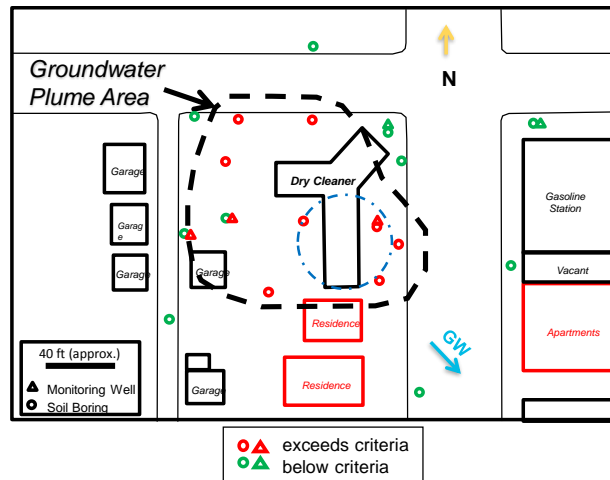
1. Commercial & residential location
2. Shallow groundwater (<20' bgs)
3. Five MWs; 10-ft screens
4. 18 soil borings; 5-ft samples
5. No soil-gas evaluation
6. In situ chemical oxidation (ISCO) & enhanced in situ bioremediation (EISB) injections in source area & plume



Step 1: Define Problem and Assess Uncertainties

Case Example

1. Uncertain plume delineation; no down-gradient control
2. Source area inferred, not confirmed
3. No remedy evaluation
4. No soil gas or VI assessment



Step 2: Identify Data Needs & Spatial Resolution

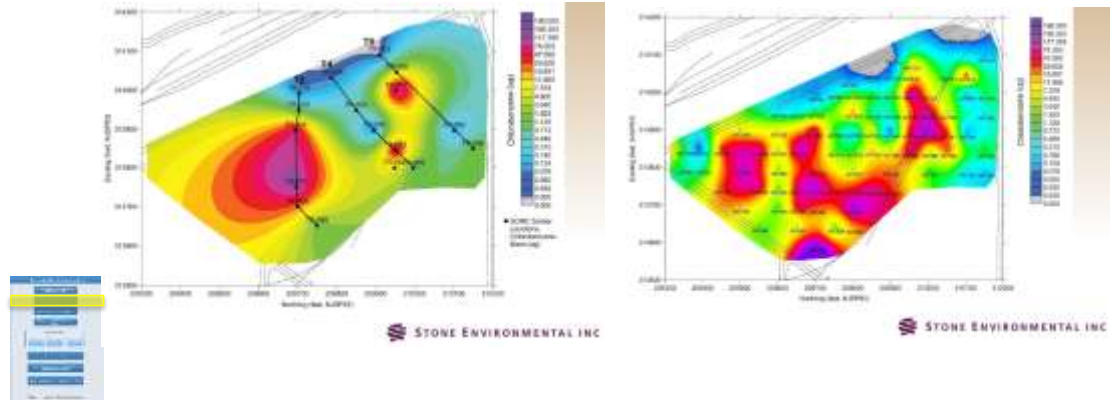
- Translate uncertainties into data needs
- Determine resolution needed to assess controlling heterogeneities



Figure 4-1 Integrated Site Characterization

2. Identify Data Needs / Gaps and Resolution

- Once the uncertainties in the existing CSM are recognized, specific data needs (e.g., type, location, amount, and quality) as well as data resolution (i.e., spacing or density) can be described. Spatial resolution should be assessed laterally and vertically.



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2. Identify Data Needs / Gaps and Resolution

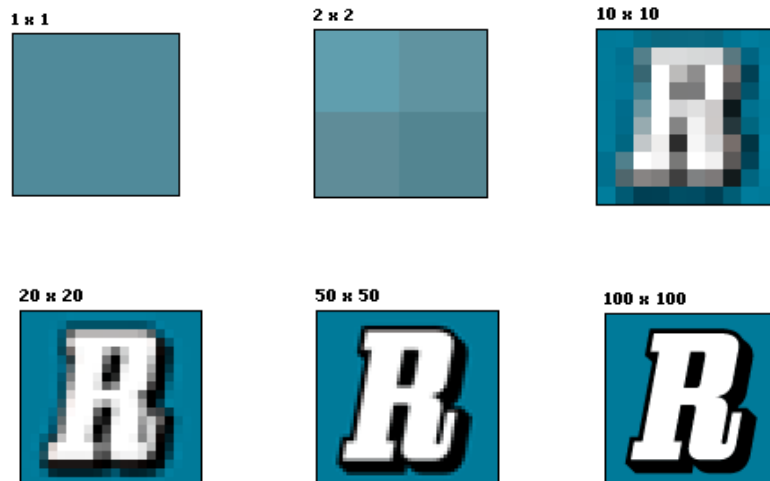
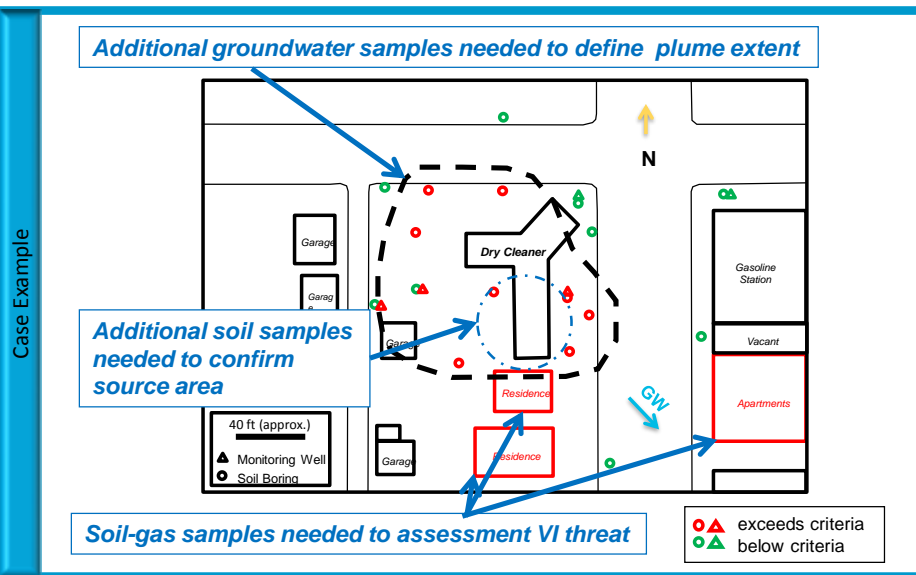


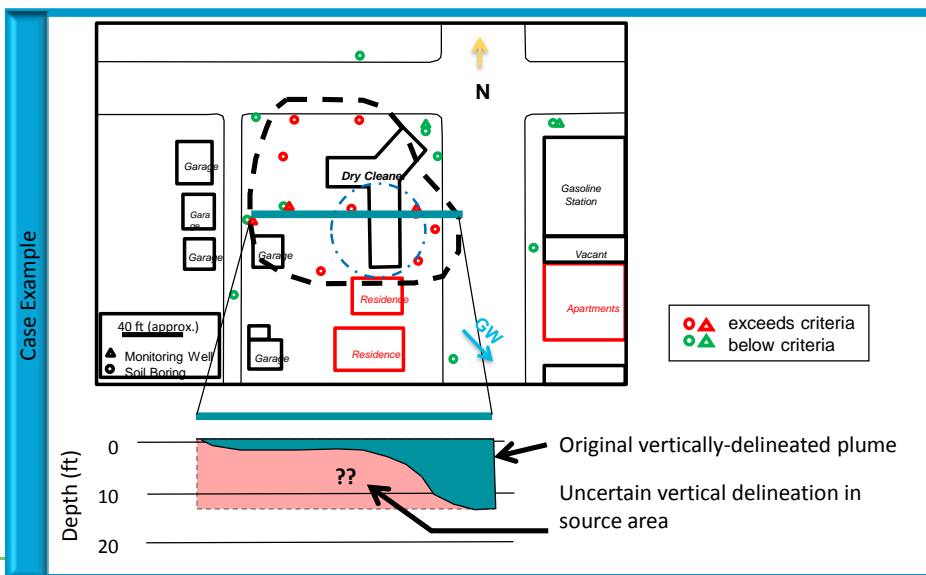
Figure courtesy of Seth Pitkin

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Step 2: Identify Data Needs & Spatial Resolution



Step 2: Identify Data Needs & Spatial Resolution



Identify Significant Data Gaps

- Missing information limits the formulation of a scientifically defensible interpretation of environmental conditions and/or potential risks in a bedrock hydrogeologic system. A data gaps exists when:
 - it is not possible to conclude with confidence whether or not a release has occurred
 - evaluation of all data, in proper context, does not/cannot support the CSM
 - if more than one interpretation of existing data set
- Fractured rock CSMs will unavoidably have data gaps throughout the process**
 - the lateral and vertical extent of contamination
 - the direction the contamination is moving
 - identification of imperiled receptors
 - the rate at which the contamination is moving
 - what areas should be targeted for sampling.

Each data gap can be transformed into one or more specific characterization objectives

Step 3: Establish Data Collection Objectives

- Specific, Clear, Actionable
- Consider data types, quality, density, and resolution



Formulate-Revise Characterization and Data Collection Objectives

- Data collection objectives (DQOs)- determine specific data needs and to select tools to be used in the investigation
- DQOs should be clear, focused, specific, & consider:
 - fracture orientation,
 - spacing and aperture,
 - hydraulic head,
 - and flow velocity
- **Characterization Objective:** Determine the lateral and vertical extent of dissolved phase VOCs.
- **Data Gap:** The vertical and lateral extent is unknown.
- **Data Collection Objective:** Gather data on: fracture location, orientation, connectivity and VOC concentration in the source, plume and towards receptors.

Step 3: Example Data Collection Objectives

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

- Grab groundwater samples at X and Y depths
- Soil borings every X feet to capture subsurface variability
- Delineate to drinking water standards
- Install three to five wells; monitor along axis of flow
 - Quarterly for two years
 - Evaluate C vs T and C vs. distance trends
 - Specify COCs and geochemical parameters

Step 3: Drycleaner Site Data Collection Objectives

Case Example

- Objectives
 - Define plume extent exceeding standards
 - Assess remedy progress – soil and GW samples
 - Assess shallow soil vapor & VI threat
 - Streamline assessment – days not weeks
- Data types & resolution
 - Continuous cores; samples at lithologic boundaries
 - Groundwater samples every 4'
 - Soil gas at 5 and 10 feet

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Step 4: Data Collection & Analysis Plan

- Write work plan
 - Recognize data limitations
 - Select data management tool
 - Develop data analysis process
- Consider real-time analysis

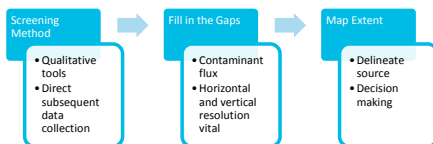


Figure 4-1. Integrated Site Characterization

4. Design Data Collection and Analysis Process

- There are generally three types of data collected:

- Quantitative:**

- A tool that provides compound-specific values in units of concentration based on traceable standards (e.g., $\mu\text{g/L}$, ppm, and $\mu\text{g/m}^3$)

- Semi-quantitative:**

- A tool that provides compound-specific quantitative measurements based on traceable standards but in units other than concentrations (e.g., ng or ug) or provides measurements within a range.

- Qualitative**

- A tool that provides an indirect measurement (e.g. LIF and PID measurements provide a relative measure of absence or presence, but are not suitable as stand-alone tools for making remedy decisions.



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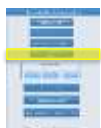
4. Design Data Collection and Analysis Process

Accuracy:

- How “close” a result comes to the true value?
- Requires careful calibration of analytical methods with standards

Precision:

- The reproducibility of multiple measurements
- Described by a standard deviation, standard error, or confidence interval.



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4. Design Data Collection and Analysis Process

Develop Site Investigation Work Plan

- The plan should be Dynamic-Flexible-Adaptable
 - This concept works for large and small sites
- Consider use of field laboratory
- Incorporate real time data collection and analysis to continuously up date CSM
- Continuously adjust work plan to incorporate evolving CSM and to address data gaps as they are understood



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Step 4: Drycleaner Site Data Collection & Analysis Plan

Case Example



Soil vapor sampling



Triad ES mobile lab and Geoprobe

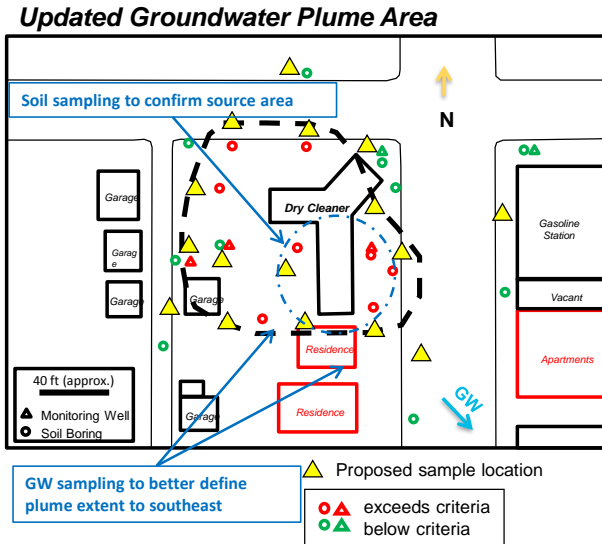


Direct sampling ion trap mass spectrometry (SW846 Method 8265) with mobile lab provides up to 80 soil/groundwater and 60 soil vapor VOC analyses per day

Step 4: Data Collection & Analysis Plan

Case Example

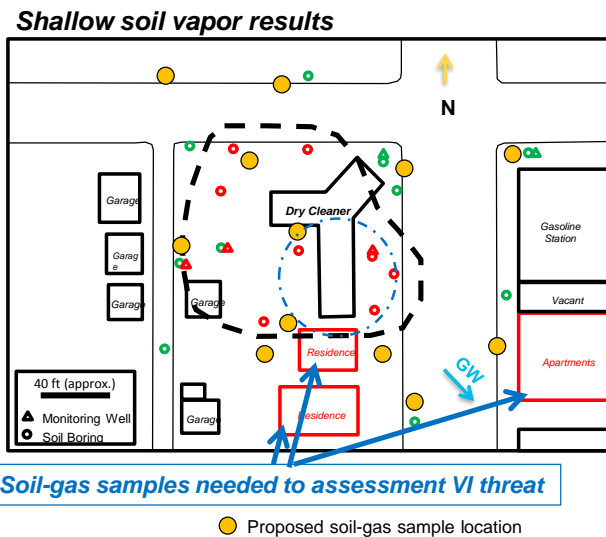
- 16 borings
- 80 soil samples (~5 per boring)
- 48 grab groundwater samples (~3 per boring)



Step 4: Data Collection & Analysis Plan

Case Example

- Soil gas
 - 12 points
 - 24 samples



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

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

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

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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



Tool	Data Quality	Sub-surface	Zone
	Bedrock	Unconsolidated	Saturated
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			

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Tools Matrix Functionality

Click any box for a description or definition

Click

Tool	Sub surface		Zone		Geology	
	Bedrock	Consolidated	Unconsolidated	Saturated	Hydrogeology	Geology

3.1 Geology

Geologic data provide a means to describe the physical nature and structure of the subsurface and to classify the sedimentary, igneous, or metamorphic environment. Data related to lithology and distribution of rocks and facies changes are generated through a variety of qualitative and quantitative collection tools and methods.

Initial methods and tools used to characterize site geology include site walkovers to help gain a preliminary understanding of the site prior to a major field mobilization, which can involve the use of both intrusive and nonintrusive tools. Outcrops offer insight into structural features of the bedrock, and much information can be obtained through basic geologic mapping techniques (for example, measuring strike and dip of planar features and plotting on a stereonet).

Following a surface investigation, the next step is site characterization, commonly involves collecting a continuous core of sediments and bedrock. Data provided by this core sampling may include lithology, grain size and sorting, crystallinity, geologic contacts, bedding planes, fractures, and faults, depositional environment, porosity, and permeability. Generally, numerous boreholes are drilled to determine the vertical and horizontal variability of the site-specific geology. The depositional environment and facies changes should also be mapped as much as possible, and these data may be combined with surface and subsurface geophysical data to determine consistency between the layers. Considerable geophysical tools and direct push tools – for example, continuous vertical probe (CVP), hydraulic probing tool (HPT), and Slurrier probe – can provide detailed information on the geology and contaminant distribution at a site.

Effective site geology characterization requires that personnel are trained and experienced in field geology and are able to accurately assess the collected data. It is also important that the team use consistent investigation methods – for example, characterizing soil or rock types using the same, agreed upon classification system. The team must determine the level of data resolution necessary to adequately characterize a specific site and whether surface and subsurface geophysical data are of sufficient resolution.

Unfortunately, collection efforts at contaminated sites often yield insufficient geologic data, leading to a high degree of uncertainty in natural fate interpretation. Historically, there has been a tendency to oversimplify conceptual site models (CSMs), which has led to the misperception that physical (geologic) conditions of the site can be engineered around – that is, limitations in site characterization data can be compensated by overdesigning remediation systems. However, remedy performance success rates have been poor under such circumstances, whereas investing in adequately detailed site characterization has provided a positive return on investment in terms of improved remedy success rates and reduced life cycle costs.

Overengineering of CSMs is particularly relevant to ground regions with complex depositional environments, in the northeast and Midwest, many ground water contain both bedrock and glacial aquifers that have DNAPL issues. Under such conditions, hydrogeological and geological expertise specific to glacial environments and their depositional characteristics is required for developing an accurate and complete CSM, and a key to the success of a DNAPL remedy.

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Detailed Tool Descriptions (Appendix D)

Click on any tool

- Additional reference material
- Description
- Applicability
- Limitations

Click

Tool	Data Quality	Sub surface		Zone
		Bedrock	consolidated	unsaturated
ToolReference	Description	Data Quality and Applicability/Advantages	Limitations/Disadvantages	
Ground Penetrating Radar • Arntsen 2003 • Day et al. 2011 • Reese et al. 1999 • Bradford 2006 • Bradford and Davis 2009 • Bradford, Dwyer, and Braden 2010 • Bradford and Braden 2013 • Carroll, Davis, and Hunt 2009 • Dwyer 2007 • USEPA 2004	Ground penetrating radar (GPR) creates a cross-sectional imaging of the ground based on the reflection of an electromagnetic (EM) pulse from boundaries between layers of different dielectric properties. The quality depends on soil and water conditions as penetration is reduced by clay, water, and salinity. GPR is useful in resolving stratigraphic layers; however, independent confirmation of lithology is required. GPR generates a 2D profile, but it can be run with multiple lines in a grid pattern to generate a pseudo-3D image. Penetration and resolution of features depend on antenna frequency and substrate conductivity and stratification, and are generally limited to 20 meters (m) deep. GPR can identify internal structures between material-bonding refractory (e.g., cross-bedding) in some cases. GPR can be used to locate geologic material or property contacts associated with dielectric property contrasts (e.g., clay, fill, boulders or dense water-saturated clastic sediments) as well as subsurface infrastructure (e.g., pipes, tanks, cables).	Data Quality • works with potential and subsurface EC • relatively sharp boundaries • qualitative to quantitative depending on field conditions, prior knowledge, subsurface calibration, experimental quality, appropriate modeling Applicability/Advantages • relative to EC, ground, and processing mathematics well established • primarily used in materials with low EC (sand, gravel, or rock except slates) • can be run repeatedly in time-lapse mode to track changes in moisture balance water table or EC of dielectric properties (grains or soil bodies, including several experiments tracking presence and changes in dense nonaqueous phase liquid (DNAPL) in sandy aquifers)	• minimal penetration in dry, highly conductive soils and clay-rich or conductive (high water) units • Misinterpretation of features and specific comparisons without integrated reference level or cone penetrometer (CPT)	

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Shaded Boxes Denote Tool Meets Objective

Tools collect these types of information

Tool	Data Quality	Sub surface				Geology											
		Bedrock	Unconsolidated	Unsaturated	Saturated	Lithology	Lithology Contacts	Porosity	Permeability	Dual Permeability	Faults	Fractures	Fracture Density	Fracture sets	Rock Competence	Mineralogy	
Geophysics																	
Surface Geophysics																	
Shallow Penetration Radar (SPR)	QL - G	✓	✓	✓	✓												
High Resolution Seismic Reflection (HRSR)	QL - G	✓	✓	✓	✓												
Seismic Refraction	QL - G	✓	✓	✓	✓												
Multi-Channel Analysis of Surface Waves (MASW)	QL - G	✓	✓	✓	✓												
Electrical Resistivity Tomography (ERT)	QL - BQ	✓	✓	✓	✓												
Very Low Frequency (VLF)	QL	✓	✓	✓	✓												
ElectroMagnetic Induction (EMI) Conductivity	QL	✓	✓	✓	✓												
Overhead Telemetry																	

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

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1. Select Category

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

The screenshot shows the CDM Smith data tool interface. The 'Type' dropdown menu is open, displaying a list of categories: All, Geology, Hydrogeology, Chemistry - All, Chemistry - Soil Gas, Chemistry - Groundwater, and Chemistry - Solid Media. The 'Subsurface' dropdown is set to 'All', and the 'Data Quality' dropdown is also set to 'All'. The 'Subsurface Zone' dropdown is set to 'All'. A 'Search' button is visible. The main table has columns for 'Tool', 'Data Quality', 'Sub surface', 'Zones', 'Lithology', 'Lithology Contacts', and 'Porosity'. The 'Sub surface' column is further divided into 'Bedrock', 'Unconsolidated', 'Unsaturated', and 'Saturated'.

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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

The screenshot shows the CDM Smith data tool interface. The 'Parameter' dropdown menu is open, displaying a list of parameters: All, Lithology Contacts, Porosity, Permeability, Dual Permeability, Faults, Fractures, Fracture Density, Fracture Sets, Rock Competence, and Mineralogy. The 'Type' dropdown is set to 'Geology', the 'Subsurface' dropdown is set to 'All', and the 'Data Quality' dropdown is set to 'All'. The 'Subsurface Zone' dropdown is set to 'All'. A 'Search' button is visible. The main table has columns for 'Tool', 'Data Quality', 'Sub surface', 'Zones', 'Lithology', 'Lithology Contacts', and 'Porosity'. The 'Sub surface' column is further divided into 'Bedrock', 'Unconsolidated', 'Unsaturated', and 'Saturated'.

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3. Identify Geologic Media

All
Bedrock
Unconsolidated

The screenshot shows a web application interface for identifying geologic media. At the top, there are three dropdown menus: 'Type' (set to 'Geology'), 'Subsurface' (set to 'All'), and 'Data Quality' (set to 'All'). Below these is a 'Parameter' dropdown set to 'Lithology' and a 'Search' button. A red box highlights the 'Subsurface' dropdown, which is open, showing three options: 'All', 'Bedrock', and 'Unconsolidated'. Below the dropdowns is a large blue area labeled 'Tool'. To the right of the 'Tool' area is a 'Data Quality' section with a grid of buttons: 'Bedrock', 'Unconsolidated', 'Unsat', 'Saturated', 'Lithology', 'Lithology Contacts', and 'Porosity'.

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4. Identify Zone

All
Unsat
Saturated

The screenshot shows a web application interface for identifying zones. At the top, there are three dropdown menus: 'Type' (set to 'Geology'), 'Subsurface' (set to 'Unconsolidated'), and 'Data Quality' (set to 'All'). Below these is a 'Parameter' dropdown set to 'Lithology' and a 'Search' button. A red box highlights the 'Subsurface Zone' dropdown, which is open, showing three options: 'All', 'Unsat', and 'Saturated'. Below the dropdowns is a large blue area labeled 'Tool'. To the right of the 'Tool' area is a 'Data Quality' section with a grid of buttons: 'Bedrock', 'Unconsolidated', 'Unsat', 'Saturated', 'Lithology', 'Lithology Contacts', and 'Porosity'.

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5. Choose Data Quality

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

Tool	Data Quality	Sub surface	Zones	Lithology
		Bedrock	Unconsolidated	
			Unconsolidated	
			Saturated	
				Lithology
				Lithology Contacts
				Porosity

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6. Apply Filters, Evaluate Tools

Tool	Data Quality	Sub surface	Zones	Lithology
Geophysics				
Surface Geophysics				
Ground Penetrating Radar (GPR)				
High Resolution Seismic Reflection (2D or 3D)				
Seismic Refraction				
Multi-Channel Analyses of Surface Waves (MASW)				
Downhole Testing				
Induction Resistivity (Conductivity Logging)				
GPR Cross-Well Tomography				
Optical Telemetry				
Natural Gamma Log				
Neutron (porosity) Logging				
Nuclear Magnetic Resonance Logging				
Solid Media Sampling and Analysis Methods				
Solid Media Sampling Methods				
Solid Spoon Sampler				
Single Tube Solid Barrel Sampler				
Dual Tube Sampler				
Solid Media Evaluation and Testing Methods				
Core Logging				
Direct Push Logging (in-Situ)				
Cone Penetrometer Testing (CPT & CPTu)				
Hydrosphere (CPT)				
CPT In-Situ Video Camera				
Discrete Groundwater Sampling & Profiling				
Hydraulic Profiling Tool - Groundwater Sampler (HPT-GWS)*				

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Perform Additional Searches to Find More Tools for Different Objectives

Additional parameters
can be added or
removed from any
given search

[illegible]

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Add Parameters to a previous search

Multiple searches
can be saved on
one matrix

The screenshot displays the 'Subsurface Data' window. At the top, there are input fields for 'Tool', 'Survey', 'Subsurface Data', and 'Radial Search'. The 'Radial Search' button is highlighted with a red circle. Below the window, a table titled 'Search 1' shows the results of the search. The table has columns for 'Tool', 'Survey', 'Subsurface Data', and 'Radial Search'. The 'Radial Search' column contains a red circle, indicating the search method used.

Tool	Survey	Subsurface Data	Radial Search
1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16
17	18	19	20
21	22	23	24
25	26	27	28
29	30	31	32
33	34	35	36
37	38	39	40
41	42	43	44
45	46	47	48
49	50	51	52
53	54	55	56
57	58	59	60
61	62	63	64
65	66	67	68
69	70	71	72
73	74	75	76
77	78	79	80
81	82	83	84
85	86	87	88
89	90	91	92
93	94	95	96
97	98	99	100

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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

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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

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Case Example – Select Tools Matrix Filters

Filters

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

Case Example

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Case Example – Apply Filters

Type: Chemistry All Parameter: Contaminant Concentration Subsurface: Unconsolidated Zone: Saturated Quality: (Q) Quantitative

Case Example

Tool	Tool Quality	Subsurface		Zone	Geology										Hydrogeology					Soil Gas	Chemistry		Soil Media					
		Relevant Microorganisms	Vibrating Head		Borehole	Logging	Seismicity	Permeability	Soil Penetration	Field	Features	Fracture Density	Porewater	Rock Composites	Mineralogy	Spore and Fungi	Groundwater	Nutrient Availability	Hydrologic Interactions		Nutrient Availability	Soil Gas		Groundwater	Microbial Community	Nutrient Availability	Groundwater	Soil Media

Case Example – Applicable Tools

[illegible]

Case Example – Tools Selection

- 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

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Conducting Investigation – Details in Subsequent Workshop!

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



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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



Additional Words of Wisdom

- Understand the difference between characterization and monitoring
 - Don't use monitoring wells for site characterization (fractured rock sites excepted)
- Value quantity of data collected over quality
 - Profiling tools
 - Field laboratories/instrumentation
- Don't wait to deploy innovative tools and technologies
 - Molecular diagnostics
 - In situ microcosms
 - Mass flux/mass discharge evaluations

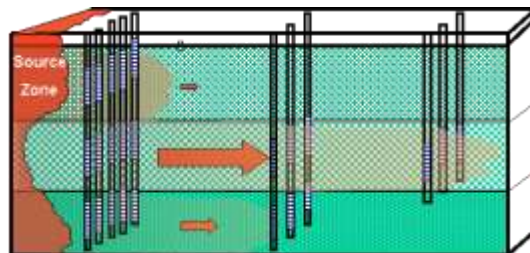
Molecular Tools

- Don't wait until late stages of project (e.g. pre-design or later) to evaluate microbial community/degradation potential
- Valuable information can be gained from a small number of samples
- One example is QuantArray from Microbial Insights, which can provide data on several key types of microbes and enzyme systems

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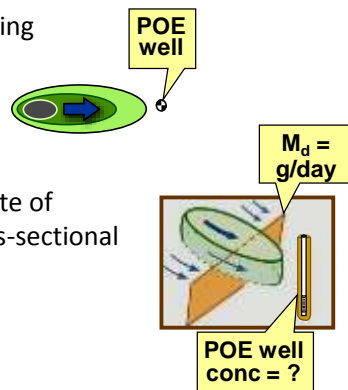
Use and Measurement of Mass Flux and Mass Discharge

An ITRC Technology Overview Document (published 2010)



Mass Discharge vs. Traditional Approach

- Traditional Approach:** Measure existing plume **concentrations** to assess
 - Impact on receptor wells
 - Natural attenuation rates
 - Remedial options
- Mass Discharge Approach:** Define rate of **mass discharge** across specified cross-sectional areas of plume to assess
 - Impact on receptor wells
 - Natural attenuation rates
 - Remedial options



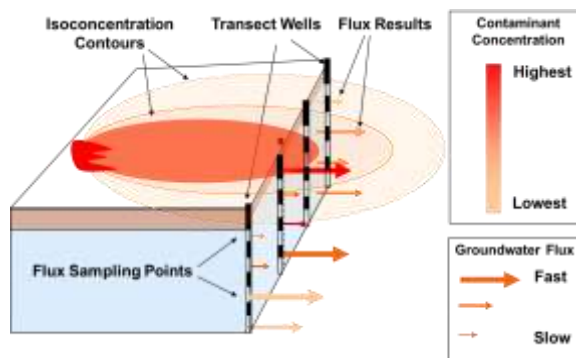
KEY BENEFITS:

Mass discharge approach sometimes offers a better understanding of potential risks and attenuation rates, and can lead to sounder remediation strategies.

Mass discharge approach based on Einarson and Mackay (2001) ES&T, 35(3): 67A-73A

Mass Flux/Mass Discharge

- ITRC guidance provides thorough discussion of this topic, including measurement methods
- If this is a goal for your site characterization plan, it will impact the data to be collected
 - Mass flux/mass discharge evaluations can be very data intensive
 - Difficult to “retrofit” data into a mass flux/mass discharge evaluation
- Can be very useful to understand your site





Case Study Examples

Commerce Street Plume Superfund Site

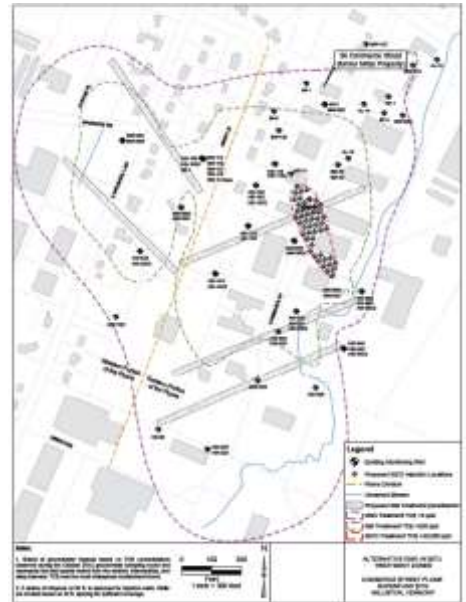
- TCE plume in mixed-use area
- ROD-selected remedy:
 - In situ chemical oxidation (ISCO) for TCE > 50,000 ppb
 - In situ bioremediation (ISB) for TCE > 500 ppb but <50,000 ppb
 - Monitored natural attenuation (MNA) for TCE < 500 ppb
- Follow ISC process to define data gaps, set objectives, and select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



High Resolution Site Characterization

Initial CSM

- 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

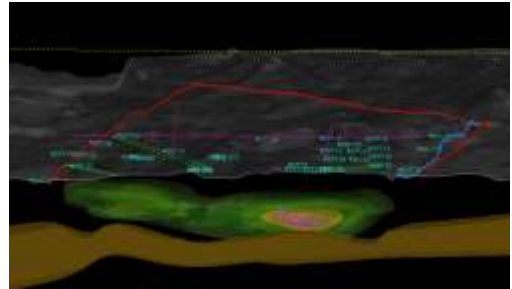
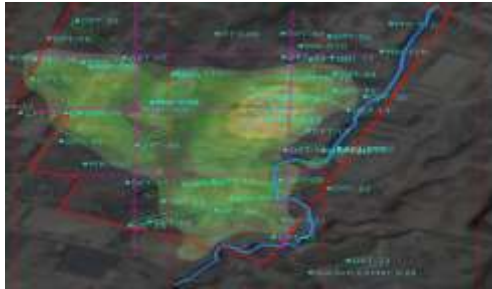
- Membrane interface probe/hydraulic profiling tool (MiHPT)
- Waterloo Advanced Profiling System (APS)
- DPT soil and groundwater sampling
- Onsite VOC analysis

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
- 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



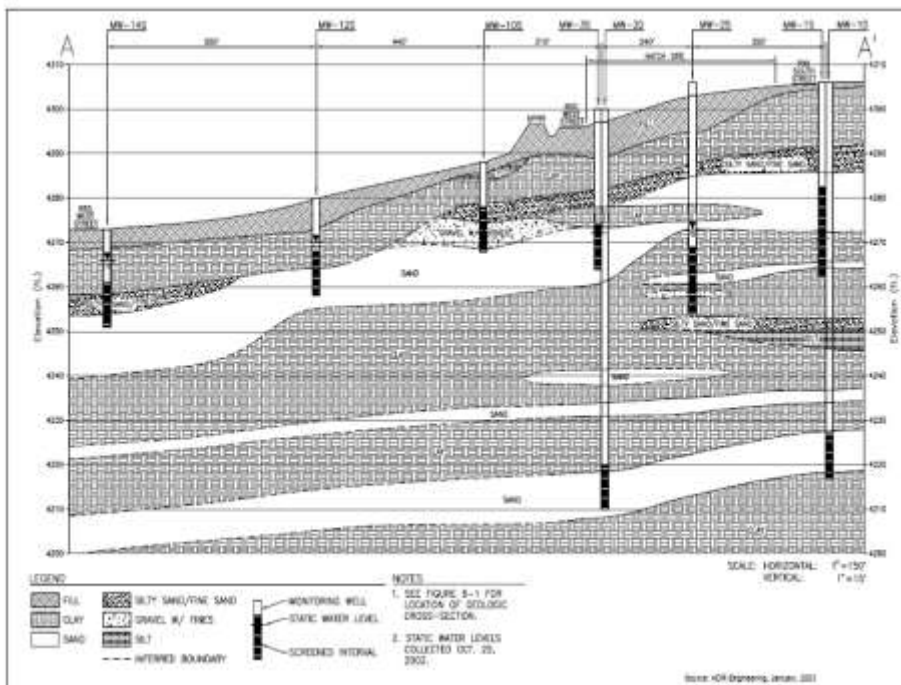
Bountiful OU1 Site

- 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



Full-Scale Design



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 $\mu\text{g/L}$
 - 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

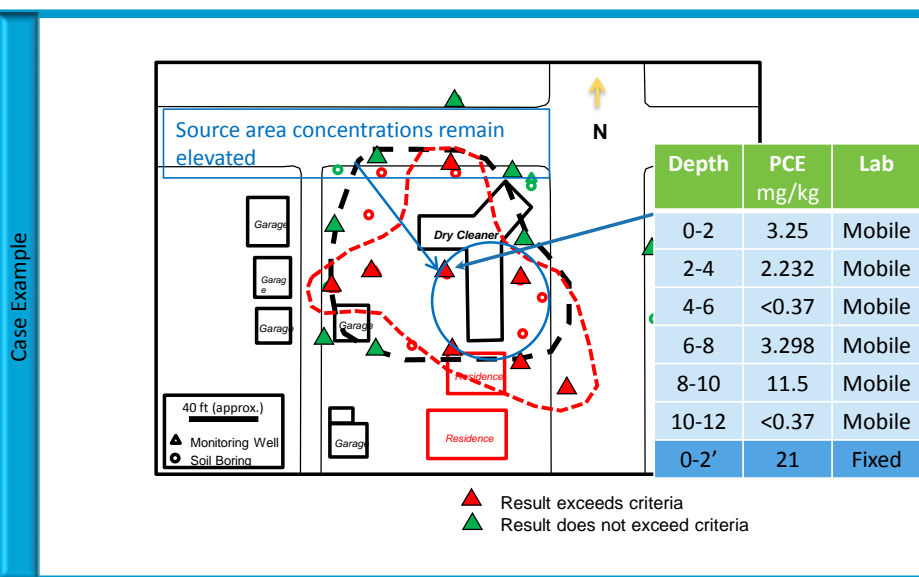
Pre-RA Characterization Results: Hydrogeology

- 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

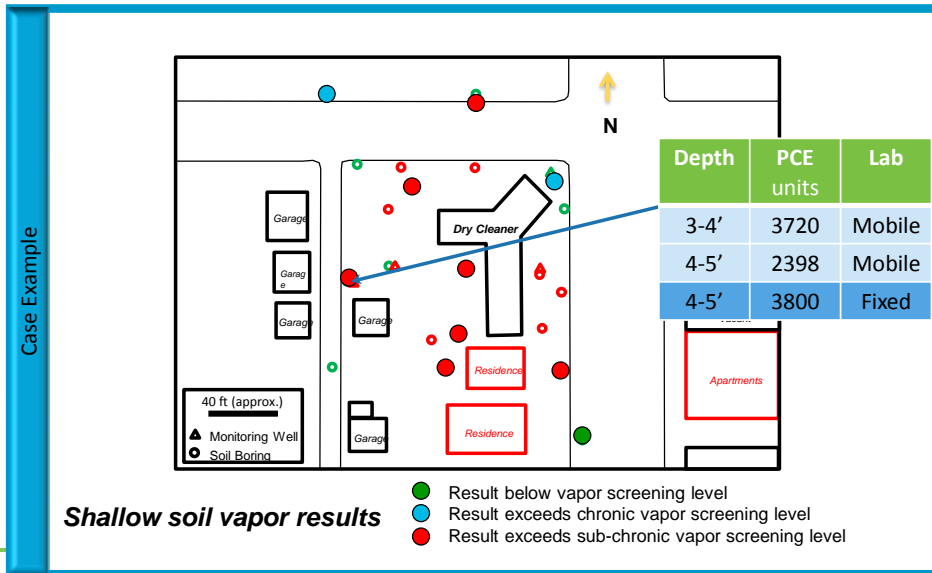


Wrapping up the ISC case study

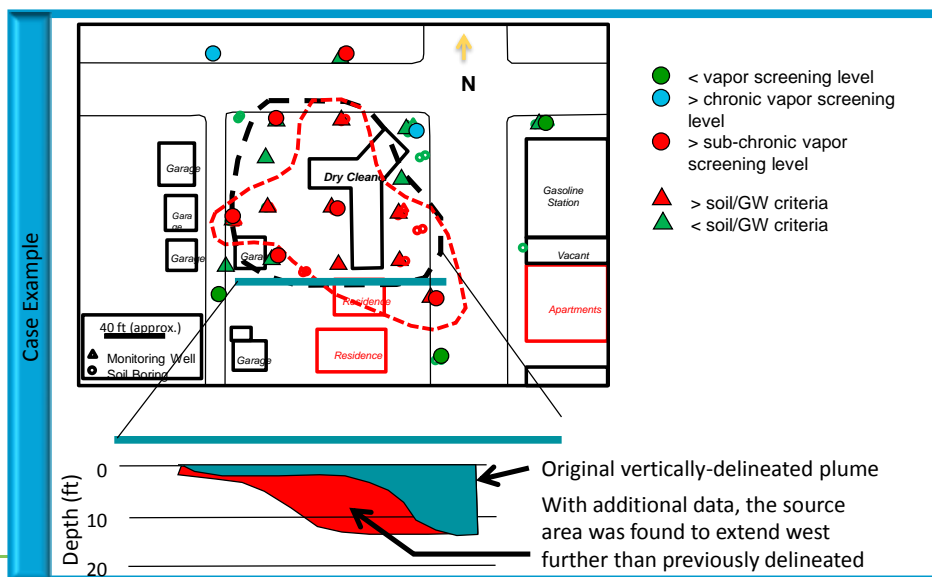
Step 7. Soil and Groundwater Data Evaluation and Interpretation



Step 7. Soil Vapor Data Evaluation and Interpretation



Step 8: Dry Cleaners – CSM Update



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%)

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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

Ryan A. Wymore, PE
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