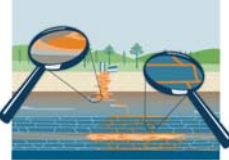


1

**Overview:
Integrated DNAPL Site
Characterization and Tools Selection**


Naji Akladiss, Team Lead
Michael Smith, Team Lead
Heather Rectanus, Team Trainer



2

The Problem: Dense Non-Aqueous Phase Liquid (DNAPL) Sites

- ▶ Not achieving cleanup goals
- ▶ Spending time and money, but substantial risk remains
- ▶ Common site challenges
 - Incomplete understanding of DNAPL sites
 - Complex matrix – manmade and natural
 - Unrealistic remedial objectives
 - Selected remedy is not satisfactory

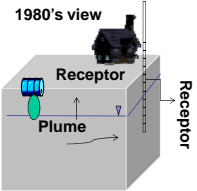


Coal Tar

3

The Problem: Outdated DNAPL Site Characterization Concepts

- ▶ Considered contaminant flow was similar to groundwater flow
- ▶ Simplifying assumptions in equations based on Darcy flow led to inadequate characterization of
 - Site geologic heterogeneity
 - Contaminant
 - Distribution
 - Characteristics
 - Behavior
- ▶ This approach limited success of site remediation activities



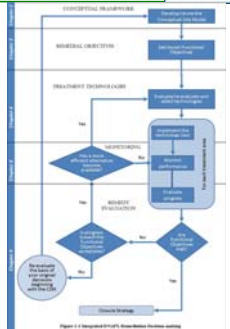
1980's view

4

The Solution: An Integrated DNAPL Site Strategy

[ITRC Technical and Regulatory Guidance Document: Integrated DNAPL Site Strategy \(IDSS-1, 2011\)](#)

- ▶ Comprehensive site management
- ▶ Use at any point in site lifecycle
- ▶ Key topics
 - Conceptual site model (CSM)
 - Remedial objectives
 - Remedial approach
 - Monitoring approach
 - Evaluating your remedy
- ▶ [Associated Internet-based training](#)



ITRC IDSS-1, Figure 1-2

5

Adding to the Solution: Integrated DNAPL Site Characterization

[ITRC Technical and Regulatory Guidance Document: Integrated DNAPL Site Characterization \(ISC-1, 2015\)](#)

Benefits

- ▶ More accurate conceptual site models (CSMs)
- ▶ Improved predictability of plume behavior and risks
- ▶ More defensible knowledge of contaminant distribution
- ▶ Facilitates communication
- ▶ Reduced uncertainty
- ▶ Better performing remedies

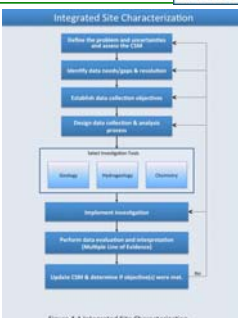


Figure 4-1 Integrated Site Characterization

ITRC ISC-1, Figure 4-1


6

Incorporated into the Solution: New DNAPL Site Characterization Approaches

- ▶ Heterogeneity replaces homogeneity
- ▶ Anisotropy replaces isotropy
- ▶ Diffusion replaces dispersion
- ▶ Back-diffusion is a significant source of contamination and plume growth
- ▶ Non-Gaussian distribution
- ▶ Transient replaces steady-state conditions
- ▶ Nonlinear replaces linear sorption
- ▶ Non-ideal sorption replaces ideal sorption

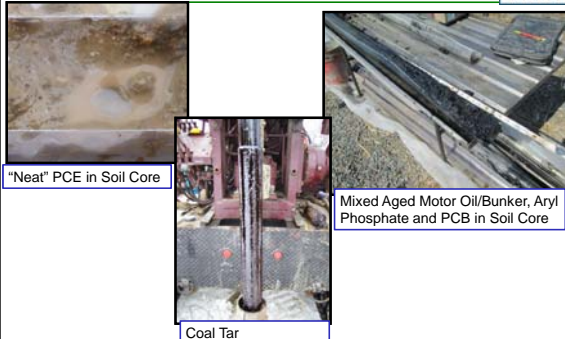
7 **Guidance Overview**

- DNAPL Characteristics
- Life Cycle of a DNAPL Site
- Integrated Site Characterization
- Tool Matrix
- Summary



ISC-1, Chapter 2

8 **DNAPLs – Not Just Chlorinated Solvents!**



"Neat" PCE in Soil Core

Mixed Aged Motor Oil/Bunker, Aryl Phosphate and PCB in Soil Core

Coal Tar

9 **Important DNAPL Properties Affecting Mobility**

Density	Solubility
Viscosity	Volatility
Composition	Sorption

Modified from ISC-1, Chapter 2

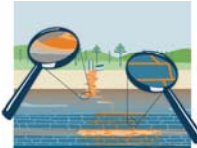
10 **DNAPL Interactions with the Sub-Surface Media Affecting Mobility**

Interfacial Tension	Wettability	Capillary Pressure
Saturation	Residual Saturation	

Modified from ISC-1, Chapter 2

11 **Guidance Overview**

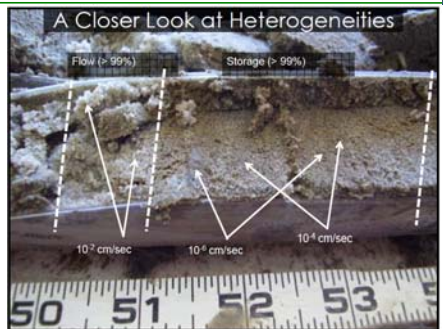
- DNAPL Characteristics
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ISC-1, Chapter 3

12 **Controlling Role of Geology in Matrix Diffusion**

A Closer Look at Heterogeneities



Flow (> 99%)

Storage (> 99%)

10^{-2} cm/sec

10^{-4} cm/sec

10^{-4} cm/sec

Figure courtesy of Fred Payne, Arcadis

13 Redefining the DNAPL Source Term: Apparent Secondary Sources

- DNAPL Source Areas
- Unsaturated (Vadose) Zone
- DNAPL may have dissolved or the DNAPL may be remediated
- Slow Desorption from aquifer solids
- Matrix Diffusion from sources within plume

Modified from ISC-1, Chapter 2

14 Diffusion Replaces Dispersion in Dissolved Phase Plumes

- ▶ As the length scale of interest decreases Diffusion replaces Dispersion in plume behavior
- ▶ Geologic heterogeneity and anisotropy also lead to numerous small plumes within each groundwater plume

Figures courtesy of Fred Payne, Arcadis

15 Heterogeneity Replaces Homogeneity

- ▶ Simplifying the subsurface as homogeneous & isotropic has not worked well for remediation-scale plume geometry
- ▶ Anisotropy replaces isotropy
- ▶ Non-ideal behavior is as pronounced in the vertical

Figure courtesy of Fred Payne, Arcadis

16 Guidance Overview

- ▶ DNAPL Characteristics
- ▶ Life Cycle of a DNAPL Site
- ▶ Integrated Site Characterization
- ▶ Tool Matrix
- ▶ Summary

17 Integrated Site Characterization

- ▶ Flexible, iterative 8-step process for CSM refinement

Figure 4-1 Integrated Site Characterization

18 Integrated Site Characterization

- ▶ Plan characterization (1-4)
 1. Define the problem
 2. Identify data needs and resolution
 3. Develop data collection objectives
 4. Design data collection and analysis plan

Figure 4-1 Integrated Site Characterization

19

Data Quality Objectives are "Built in"

USEPA Data Quality Objectives

- Step 1: State Problem
- Step 2: Identify Goal of Study
- Step 3: Identify Information Inputs
- Step 4: Define Boundaries of Study
- Step 5: Develop Analytical Approach
- Step 6: Specify Performance or Acceptance Criteria
- Step 7: Develop Plan for Obtaining Data

Integrated Site Characterization

Figure 4-1 Integrated Site Characterization

20

Integrated Site Characterization

- Plan characterization (1-4)
- Select tools (5)

Integrated Site Characterization

Figure 4-1 Integrated Site Characterization

21

Integrated Site Characterization

- Plan characterization (1-4)
- Select tools (5)
- Implement investigation and update CSM (6-8)

Integrated Site Characterization

Figure 4-1 Integrated Site Characterization

22

Guidance Overview

- DNAPL Characteristics
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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	
	Quantitative	Semi-quantitative	Bedrock	Unconsolidated	Unconsolidated	Saturated
Geology						
Hydrogeology						
Chemistry						

24

Shaded Boxes Denote Tool Meets Objective

Tools collect these types of information

Tool	Data Quality	Sub surface		Zone		Geology										
		Bedrock	Unconsolidated	Unconsolidated	Saturated	Lithology	Contacts	Porosity	Permeability	Dual Permeability	Faults	Fracture Density	Fracture sets	Rock Competence	Mineralogy	
Geology																
Hydrogeology																
Chemistry																

Green shading indicates that tool is applicable to characterization objective

25 **Apply Filters, Evaluate Tools**

The screenshot shows the ITRC tool selection interface. The search filters are set to 'Type: Geology Parameter: Lithology' and 'Quality: (Q) Quantitative'. The tool list includes:

- Surface Geophysics
 - Ground Penetrating Radar (GPR)
 - High Resolution Seismic Reflection (2D or 3D)
 - Seismic Refraction
 - Multi-Channel Analysis of Surface Waves (MASW)
- Geophysical Logging
 - 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
 - Split Spoon Sampler
 - Single Tube Solid Barrel Sampler
 - Dual Tube Sampler
 - Solid Media Evaluation and Testing Methods
 - Core Logging
 - Direct Push Logging (DPL)
 - Cone Penetrometer Testers (CPT & CPTu)
 - Hydrostratigraphy (CPT)
 - CPT In-Situ Video Camera
 - Discrete Groundwater Sampling & Profiling
 - Hydraulic Profiling Tool - Groundwater Sampler (HPT)
 - ISOP

26 **Guidance Overview**

- ▶ DNAPL Characteristics
- ▶ Life Cycle of a DNAPL Site
- ▶ Integrated Site Characterization
- ▶ Tool Matrix
- ▶ Summary

27 **Benefits of Integrated Site Characterization**

- ▶ Reduces uncertainties to Improve CSM
- ▶ Enables more efficient remedies
- ▶ Integrated DNAPL Site Strategy (2012) itrcweb.org/guidance
- ▶ Avoids costly do-overs
- ▶ Supports stakeholder needs and confidence