Geosyntec consultants

Overview of Uncertainties Associated with Complex Sites: Technical Challenges and Ongoing National Efforts

Rula Deeb, Ph.D., BCEEM
Claire Wildman, Ph.D.

Federal Remediation Technologies Roundtable• Arlington, VA
May 14, 2014

Geosyntec consultants

Presentation Outline

- What makes a site “complex”?
- Technical challenges and limitations at complex sites
- Case study of a complex site
  - Watervliet Arsenal, New York
- Overview of past and ongoing national efforts

Uncertainties Associated with Complex Sites

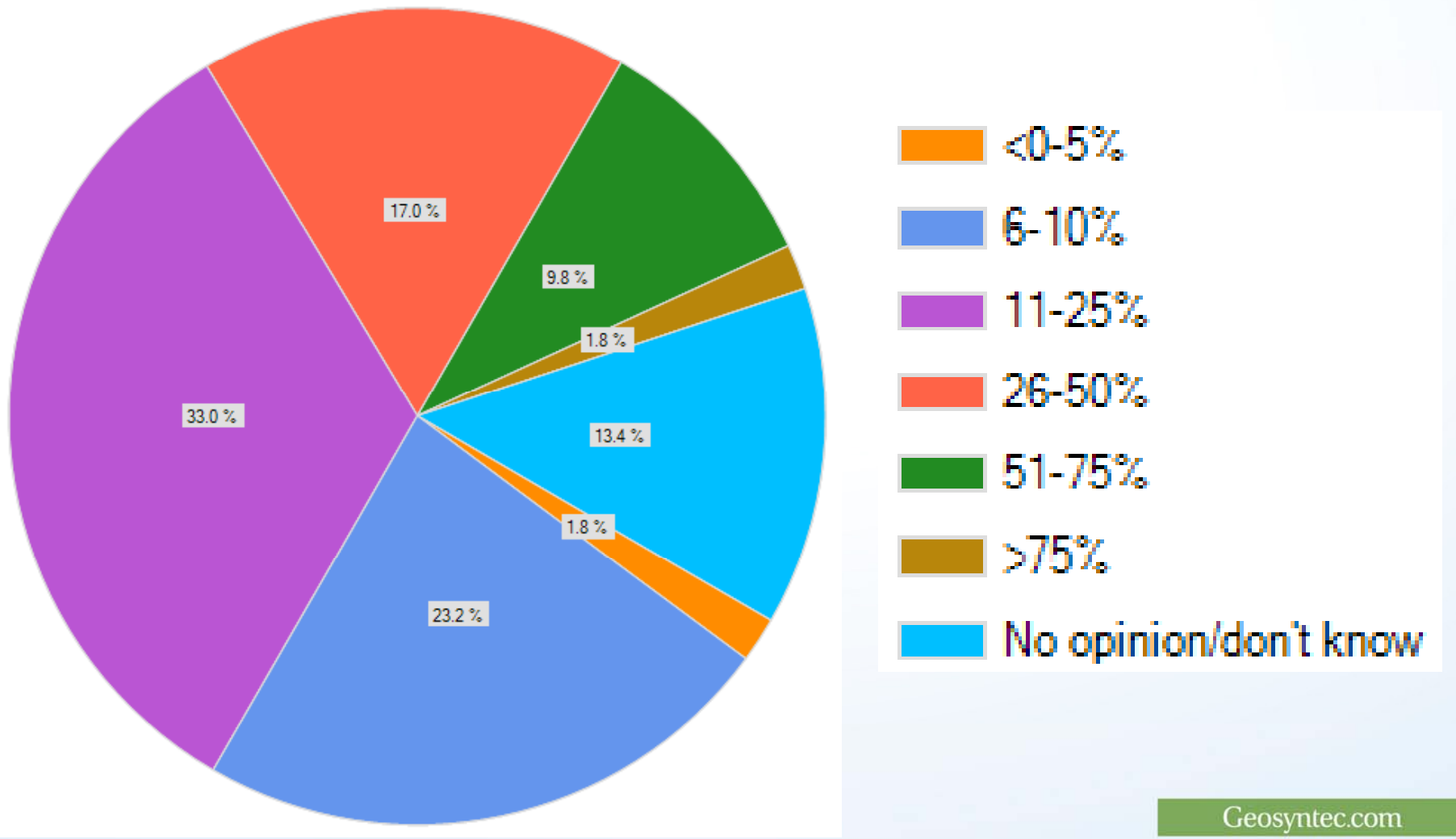
- Significant uncertainty around the term “complex site”
  - Not a term with a formal or generally-accepted definition
- Little agreement in the industry
  - Attributes of a complex site
  - Percentage of complex sites

Survey (ITRC, 2014)
Remediation Management of Complex Sites

- 22 questions
- 116 respondents
  - Academia, EPA, DoD, DOE, State/local government, Public/tribal stakeholders, Private sector
- Background information on team members and individual experience at complex sites
- Specific questions about attributes of complex sites

Geosyntec consultants

Percentage of Sites that are Complex ITRC Survey (2014)



Geosyntec consultants

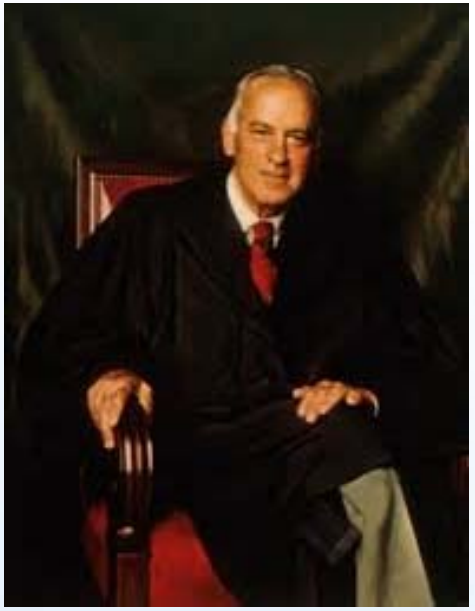
How Many Sites Are Likely to Be "Complex"?

From NRC 2013

- 126,000 sites have not yet reached closure
  - Likely an underestimate
- Could not determine the total number of sites with residual contamination above levels allowing for UU/UE
  - Must be > 126,000
- More than 12,000 sites likely "complex"
  - This represents the approximate sum of high priority sites (CERCLA, DoD, DOE, RCRA CA)
  - <10% of sites that have not yet reached closure

Definition of a “Complex” Site

- “I shall not today attempt further to define the kinds of material I understand to be embraced within that shorthand description; and perhaps I could never succeed in intelligibly doing so. But I know it when I see it…”



Justice Potter Stewart

Jacobellis v. Ohio 378 U.S. 184 (1964)

General Attributes of Complex Sites

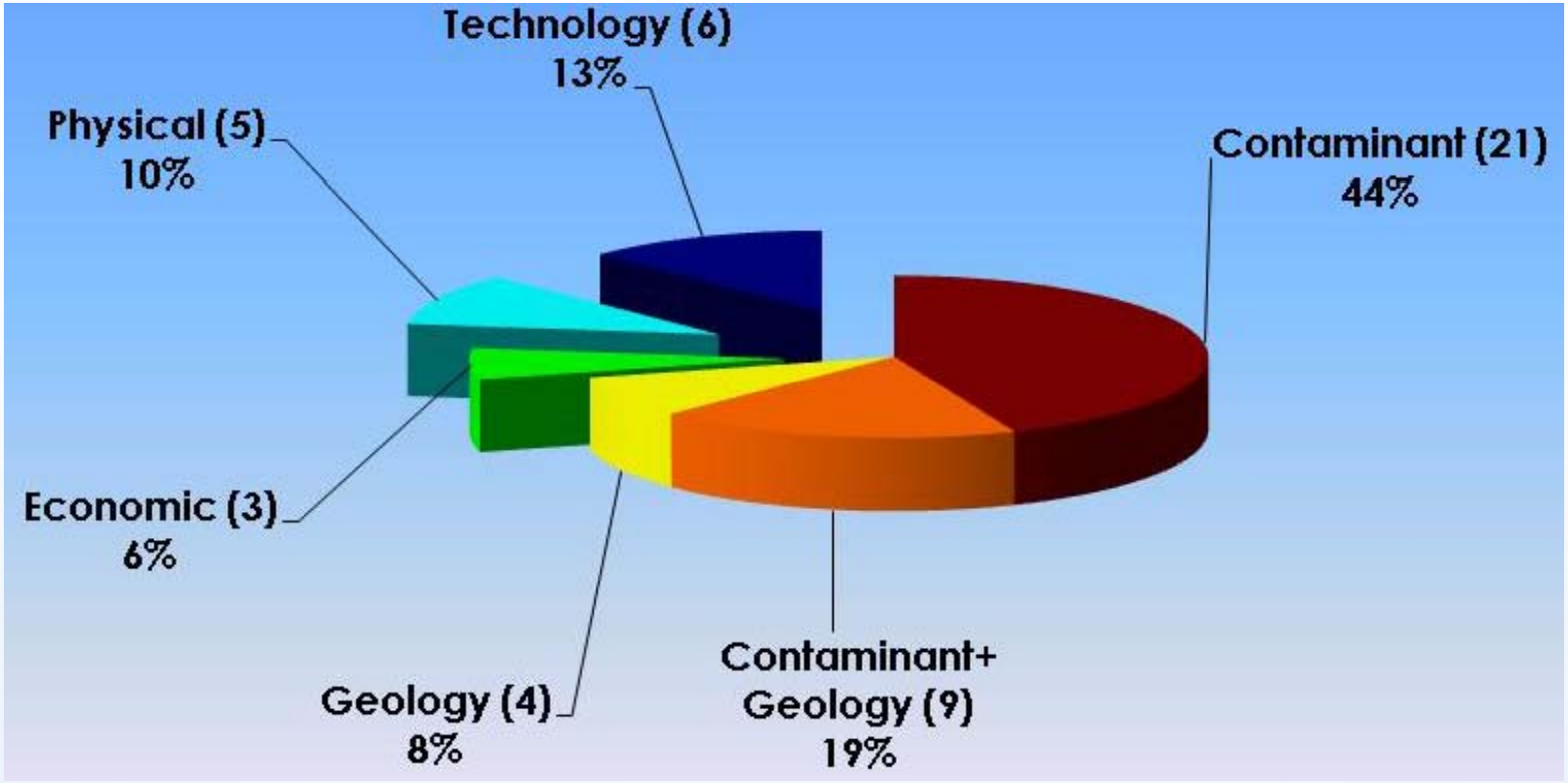
Limitations to groundwater restoration

- Heterogeneous geology
- Depth to groundwater
- Characterization of DNAPL distribution
- Mass transfer limitations
- Magnitude of contamination

Hydrogeologic Setting
Fractured rock/karst/mining voids
High heterogeneity
High heterogeneity overlying bedrock
Layered high- and low-permeability
High-permeability sands and gravels
High-permeability sands and gravels overlying bedrock
Low-permeability silts and clays
Low-permeability silts and clays overlying bedrock

Geosyntec consultants

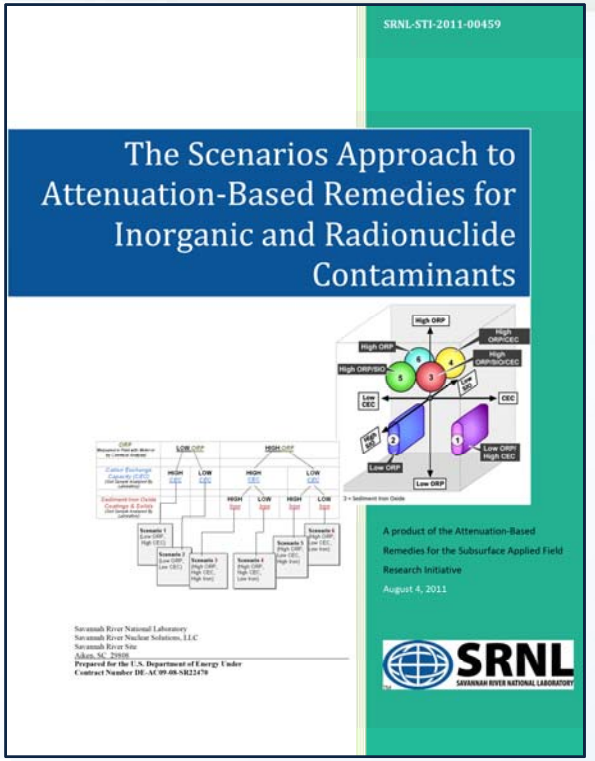
General Attributes of Complex Sites (Cont'd)

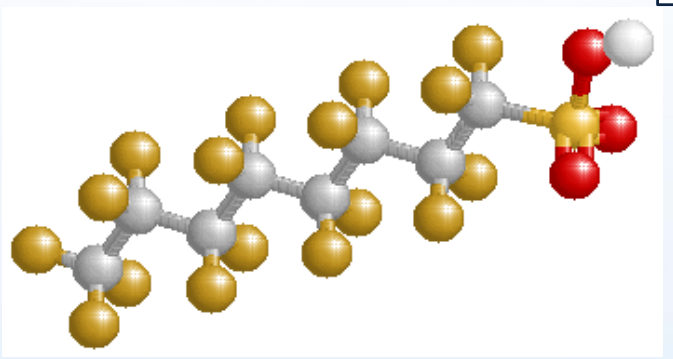


General Attributes of Complex Sites (Cont'd)

Nature and extent of contamination

- Presence of NAPL
- Mixtures of contaminants
- Recalcitrant or persistent contaminants
  - PCBs, metals, PAHs
  - Radionuclides (e.g., Pu half-life = 24,100 years)
  - Emerging chemicals and changing regulations





General Attributes of Complex Sites (Cont'd)

- Other
  - Political and legal issues
  - Active site with contaminants below buildings or sensitive areas

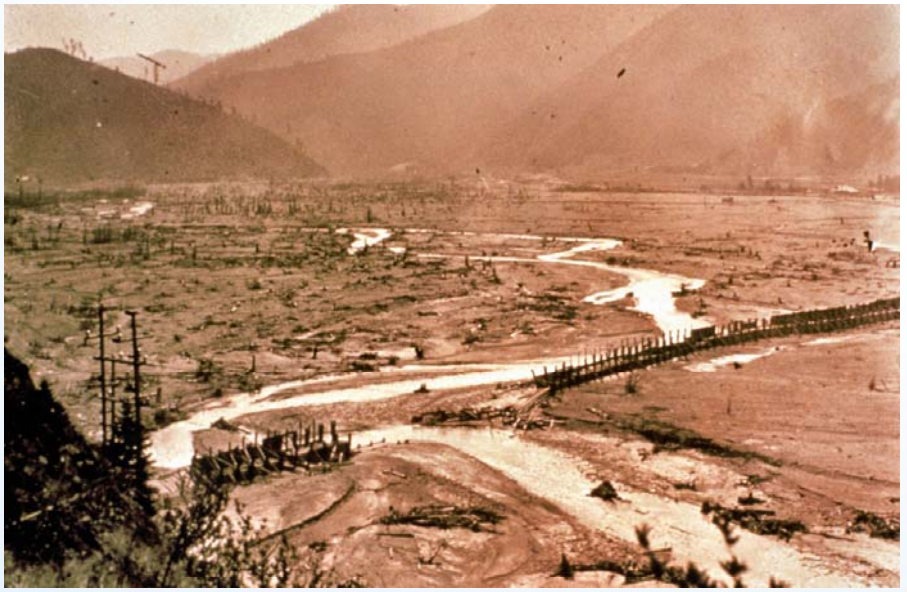
Attributes of Complex Sites
NRC, 2013

- Large releases of contaminants over long timeframes
- Highly heterogeneous subsurface geologic environments
- Contaminants recalcitrant and persistent
- Levels of contaminants several orders of magnitude above MCLs

- Several years of remedial efforts likely with an indication of “asymptotic” performance (multiple 5-year reviews)
- Lifecycle costs to achieve restoration exceeding $20 - $50 million

Specific Technical Challenges at Complex Sites

- Large releases over long timeframes
  - Mining sites: acid mine drainage, low pH, high metals
  - Military/industrial sites: extensive dilute plumes, regional off-site sources



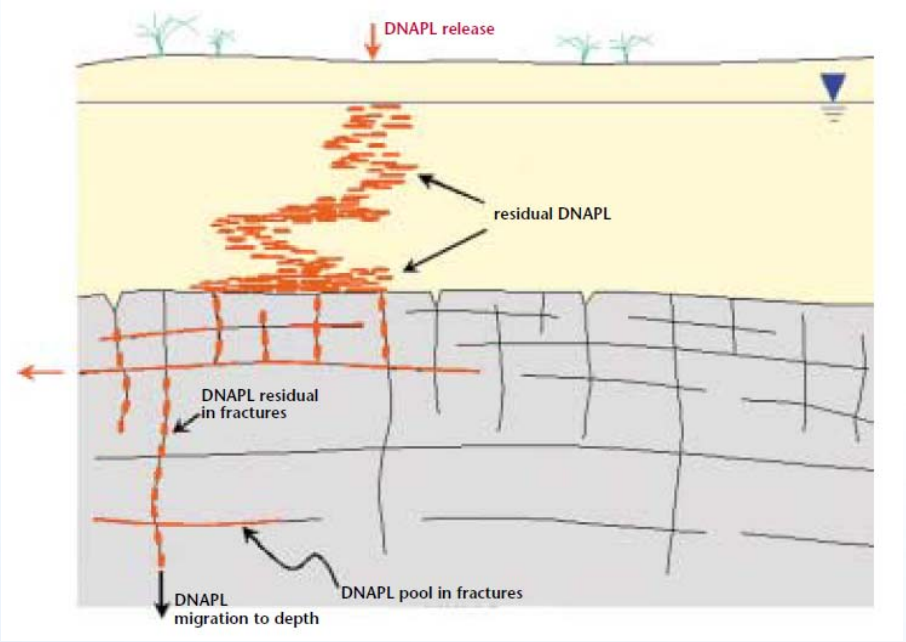
Couer d'Alene Superfund site – tailings circa 1900

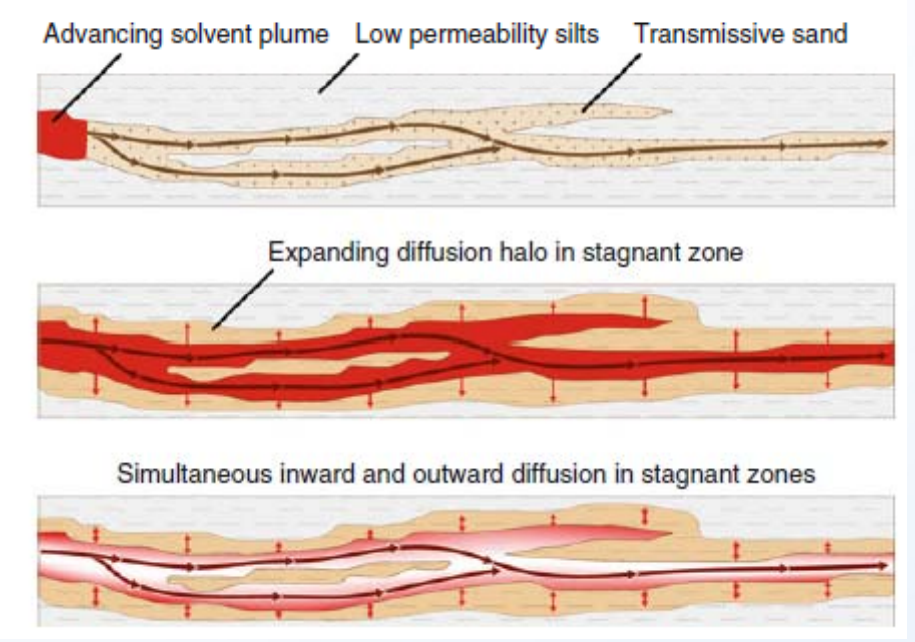
circa 1993

http://geology.isu.edu/Digital_Geology_Idaho/Module7/mod7pg2.htm

Specific Technical Challenges at Complex Sites (Cont'd)

- Karst / fractured bedrock
- Low permeability units





Kueper, Wealthall, Smith, Lehame (2003)

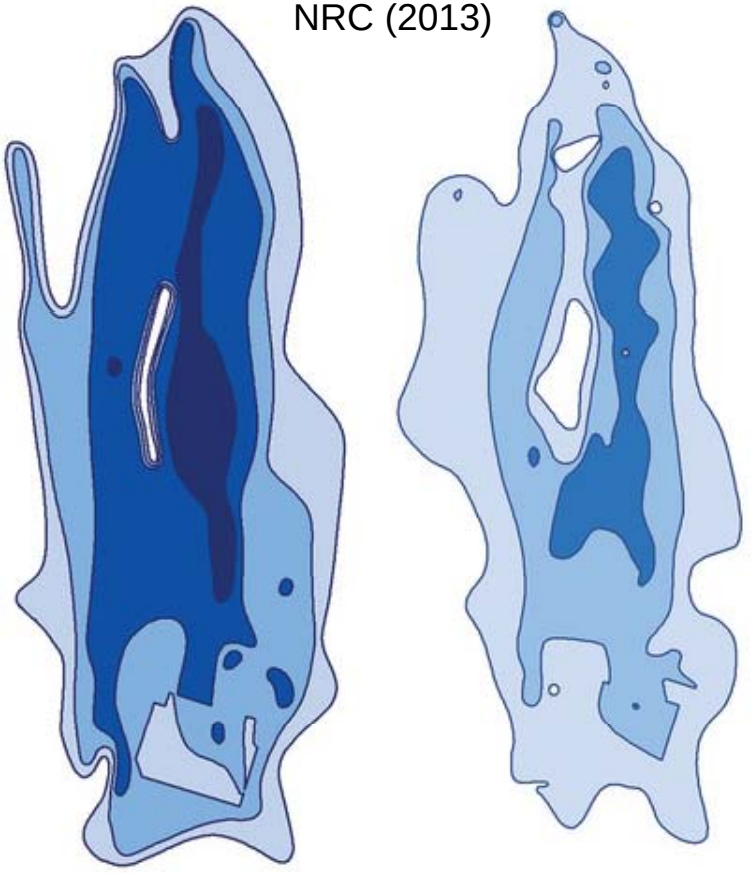
Sale and Newell (2010)

Specific Technical Challenges at Complex Sites (Cont'd)

Asymptotic remedy performance: Middlefield-Ellis-Whisman Site

- 1980s: Slurry walls, pump-and-treat
- Today: ~100 recovery wells, ~500 gpm
- Removal: ~97,000 pounds VOCs
- Reduction: one order of magnitude decrease in average TCE concentration from 1992-2009

NRC (2013)



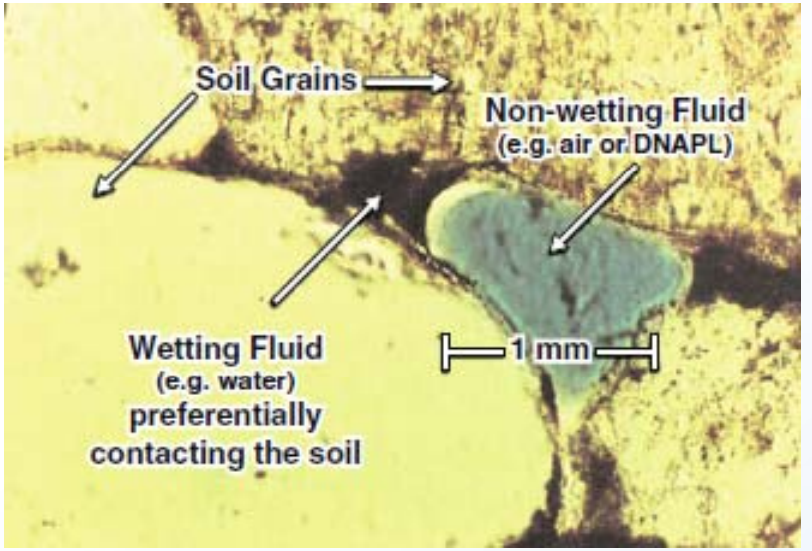
before

after 17 years P&T

Specific Technical Challenges at Complex Sites (Cont'd)

DNAPL

- As contaminated groundwater is removed, more contaminant dissolves from DNAPL into groundwater, keeping concentrations high over time.
- Inability to characterize the DNAPL zone – complicated geology or heterogeneous distribution in pore spaces (ganglia)

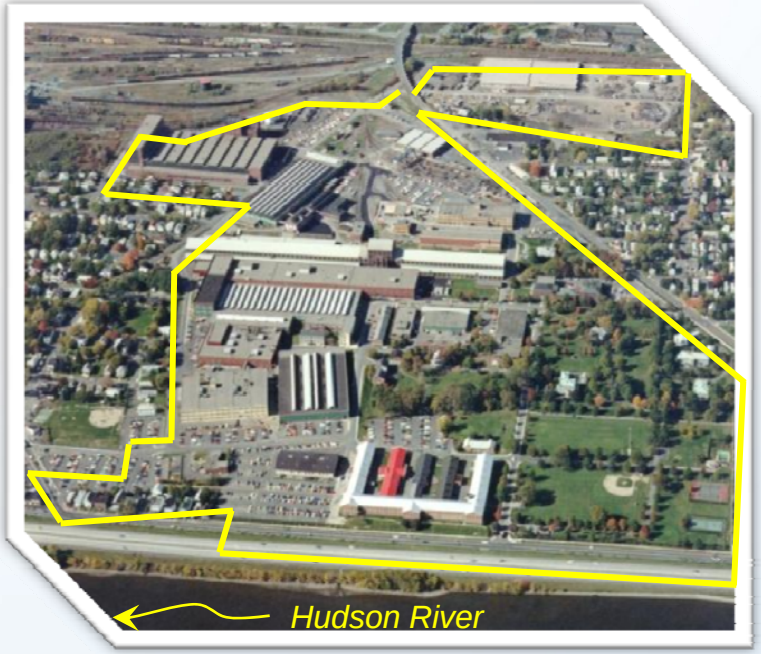


Sale and Newell (2010) in *In Situ Remediation of Chlorinated Solvent Plumes*, Stroo and Ward (eds).

Geosyntec consultants

Case Study
Watervliet Arsenal, NY

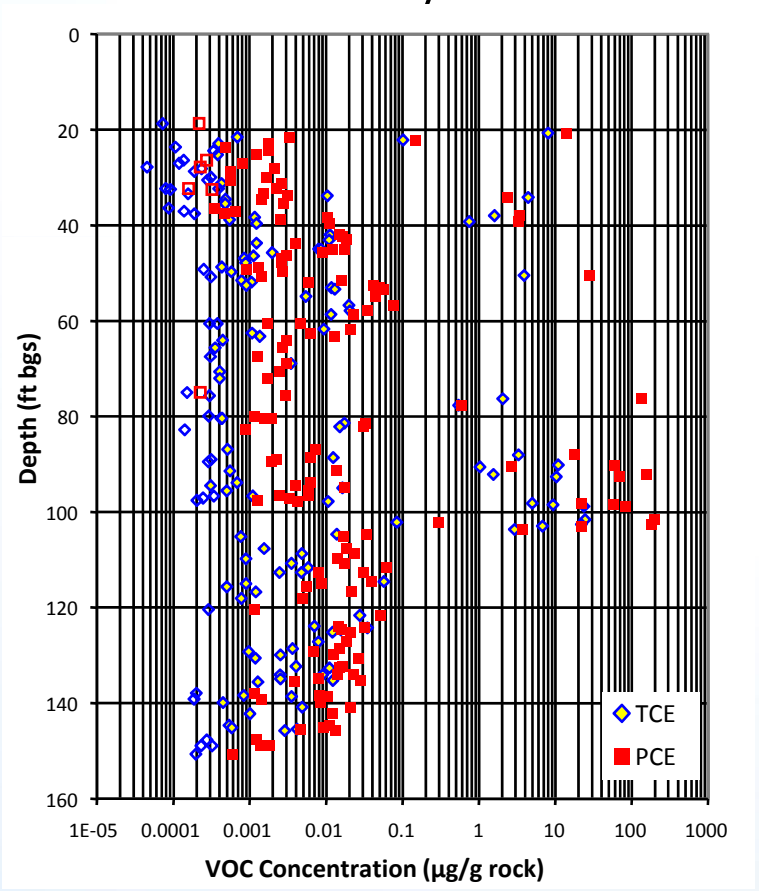
- RCRA site, under lead agency NYSDEC
  - Chlorinated solvents from suspected degreaser, up to 170 mg/L PCE DNAPL
  - Fractured black medium-hard laminated shale to 150 ft
- MCLs are long-term objective
- Approach
  - Five years of NaMnO4 injections
  - Metrics: mass flux, rock crushing, multi-level well network
  - Monitor post-injection rebound



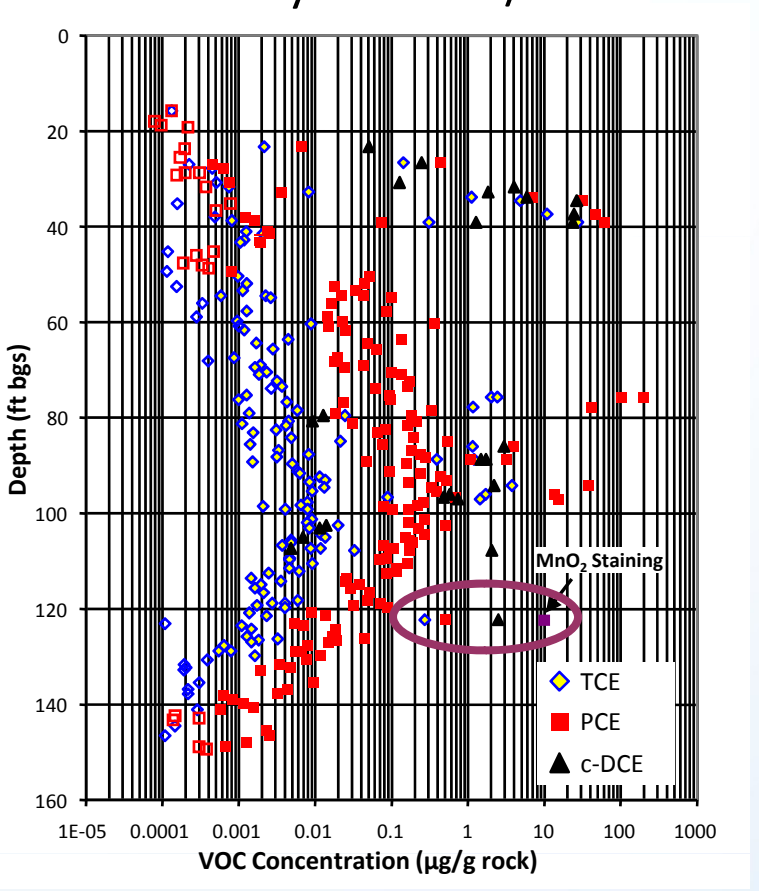
Geosyntec consultants

Case Study
Watervliet Arsenal, NY

Before – 10/2003



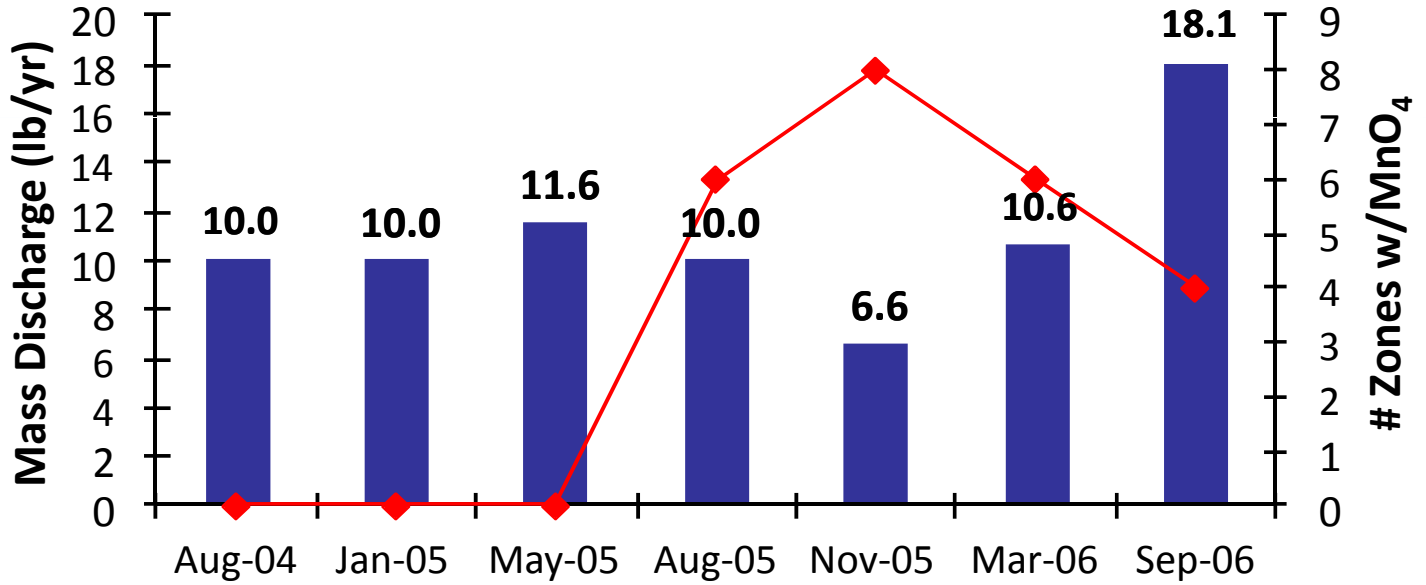
After 3 years – 12/2006



Similar peak concentrations indicate that no substantial remediation was accomplished

Case Study
Watervliet Arsenal, NY

Mass discharge increased at boundary over time*



** Increase attributed to calculation method, which assumed baseline hydraulic conductivity values. MnO_4 injections likely changed the aquifer hydraulics*

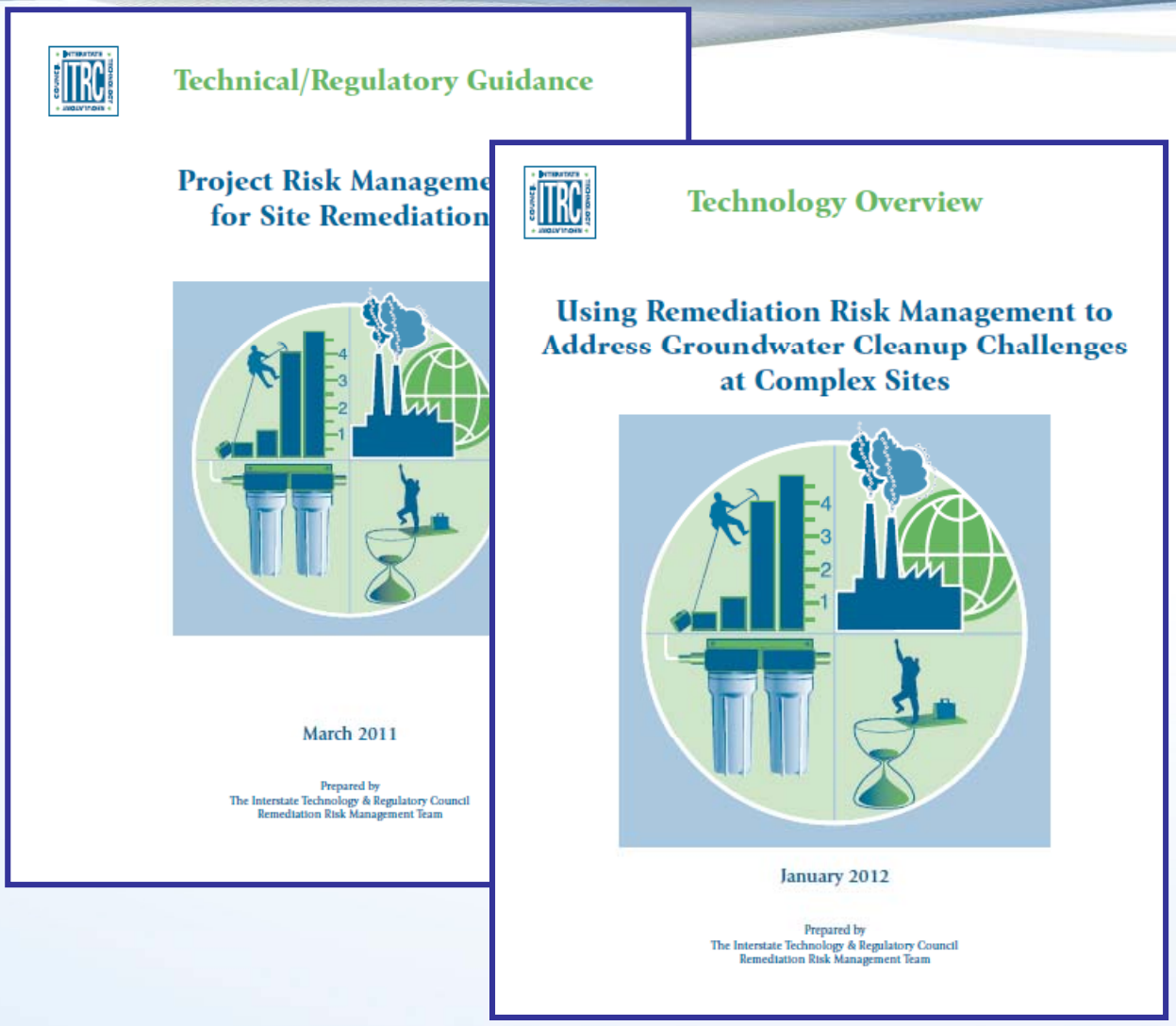
Geosyntec consultants

Case Study
Watervliet Arsenal, NY

- Attempted mass removal “to the extent practicable”
  - Concluded that MCLs are not achievable within “reasonable timeframe” in matrix-dominant fractured rock
  - Estimated 50 years for MnO_4 to diffuse into matrix
- Limited change in VOC mass discharge at site boundary (increase due to change in hydraulic conductivity)
- Technology testing provided a technical basis for alternative endpoint
  - Stakeholders are considering ACLs based on post-injection monitoring data and analyses

Geosyntec consultants

National Efforts



2014 – 2017

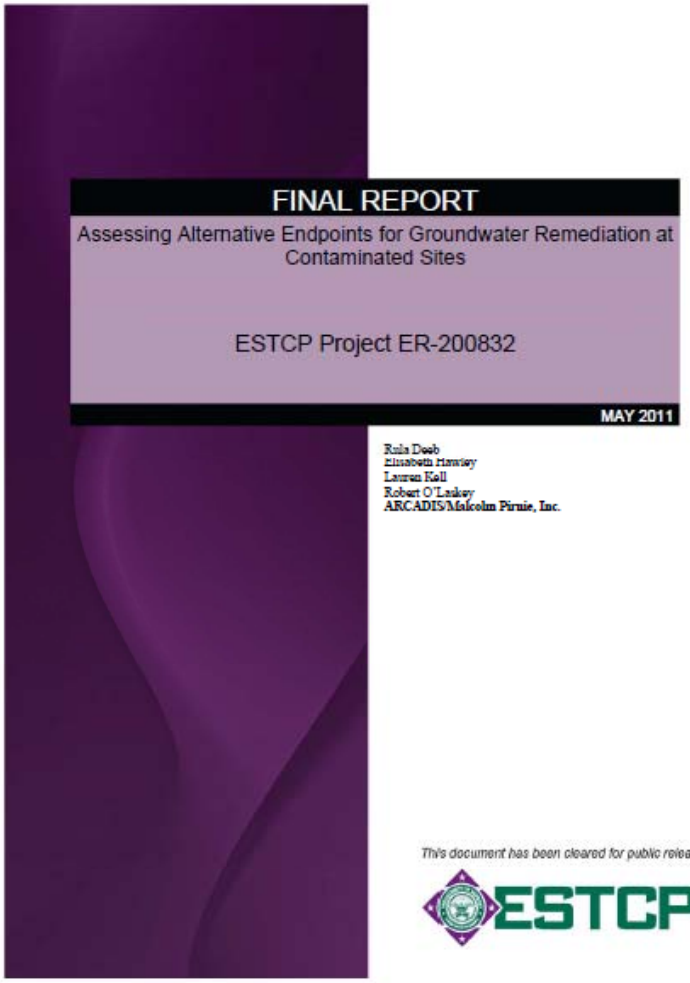
Remediation Management of Complex Sites

Geosyntec consultants

National Efforts

National Research Council

National Efforts

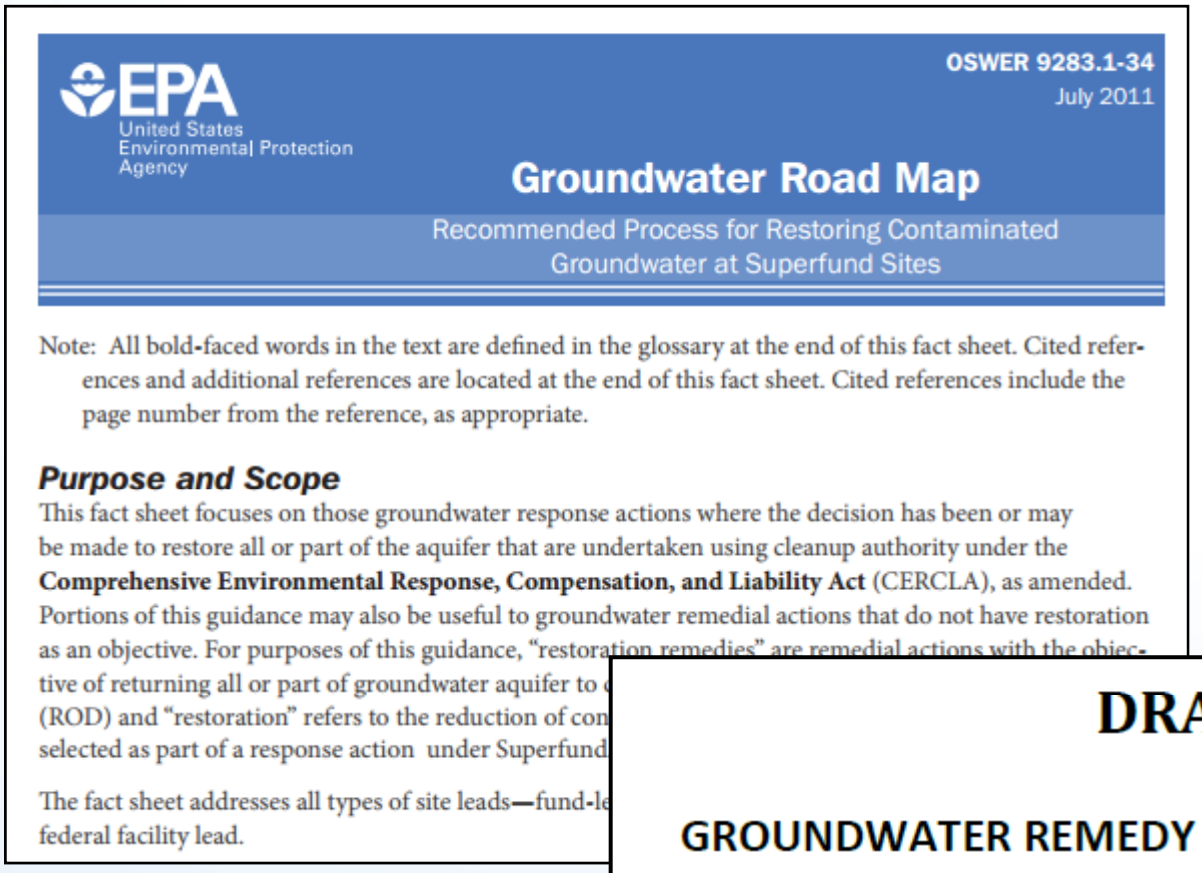


SERDP & ESTCP

Several program focus areas relevant to complex sites:

- Fractured bedrock
- DNAPL source zone remediation

National Efforts



EPA United States Environmental Protection Agency

OSWER 9283.1-34
July 2011

Groundwater Road Map

Recommended Process for Restoring Contaminated Groundwater at Superfund Sites

Note: All bold-faced words in the text are defined in the glossary at the end of this fact sheet. Cited references and additional references are located at the end of this fact sheet. Cited references include the page number from the reference, as appropriate.

Purpose and Scope

This fact sheet focuses on those groundwater response actions where the decision has been or may be made to restore all or part of the aquifer that are undertaken using cleanup authority under the **Comprehensive Environmental Response, Compensation, and Liability Act** (CERCLA), as amended. Portions of this guidance may also be useful to groundwater remedial actions that do not have restoration as an objective. For purposes of this guidance, "restoration remedies" are remedial actions with the objective of returning all or part of groundwater aquifer to
(ROD) and "restoration" refers to the reduction of con
selected as part of a response action under Superfund

The fact sheet addresses all types of site leads—fund-le
federal facility lead.

DRAFT

GROUNDWATER REMEDY COMPLETION STRATEGY:

Moving Forward with Completion in Mind

National Efforts

- State guidance on managing complex sites (e.g., Washington)
  - ~1% of its sites are complex
  - 1,671 sites currently listed on state's Hazardous Sites List out of 11,700 confirmed and suspected sites.
    - Voluntary Cleanup Program sites are typically not ranked nor on the "Complex" sites list.
    - 167 Superfund sites on list: State is lead or co-lead on many of these and/or Federal facilities
  - 19 identified "Complex" sites*
- **Attributes**: multiple sources, area-wide contamination, contaminated sediments, state priority sites (Puget Sound Initiative)

Geosyntec consultants

Questions

Rula A. Deeb

510-932-9110

rdeeb@geosyntec.com