A Practitioners Guide to the Evolution of High Resolution Site Characterization

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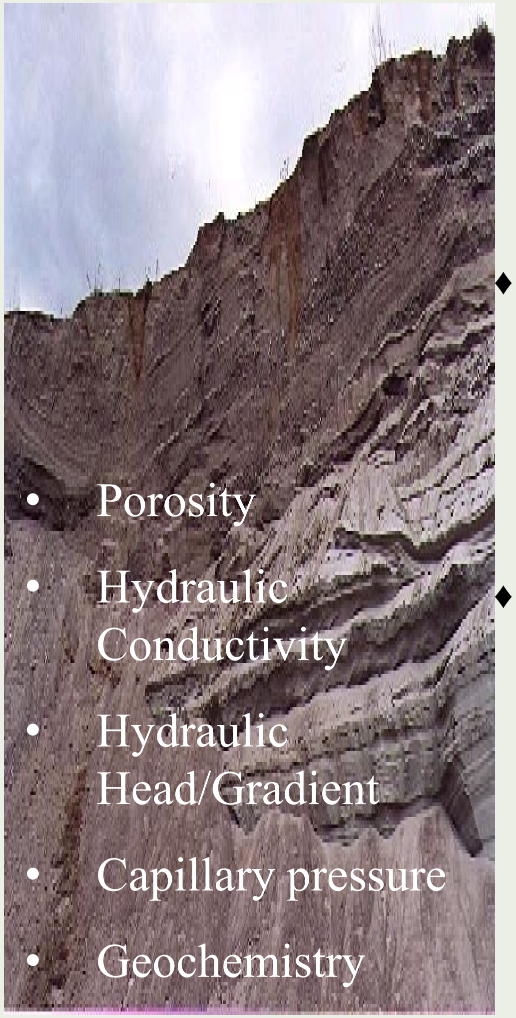
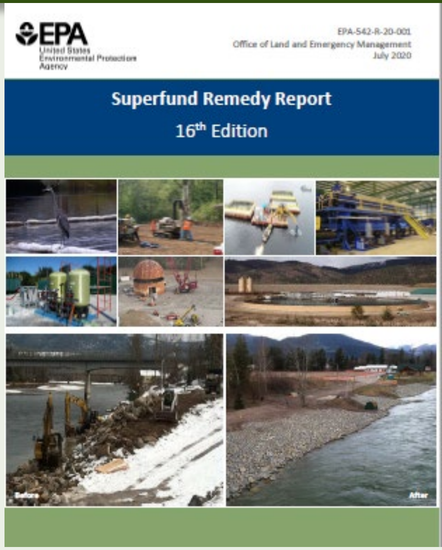
Recent Experience Leads to New Thinking- Characterization



- **Historical perspective**
  - Soil-EPA superfund has historically focused on high quality analytical samples collected at discrete soil locations
  - Groundwater-APA 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/sample 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 Experience Leads to New Thinking- Remediation

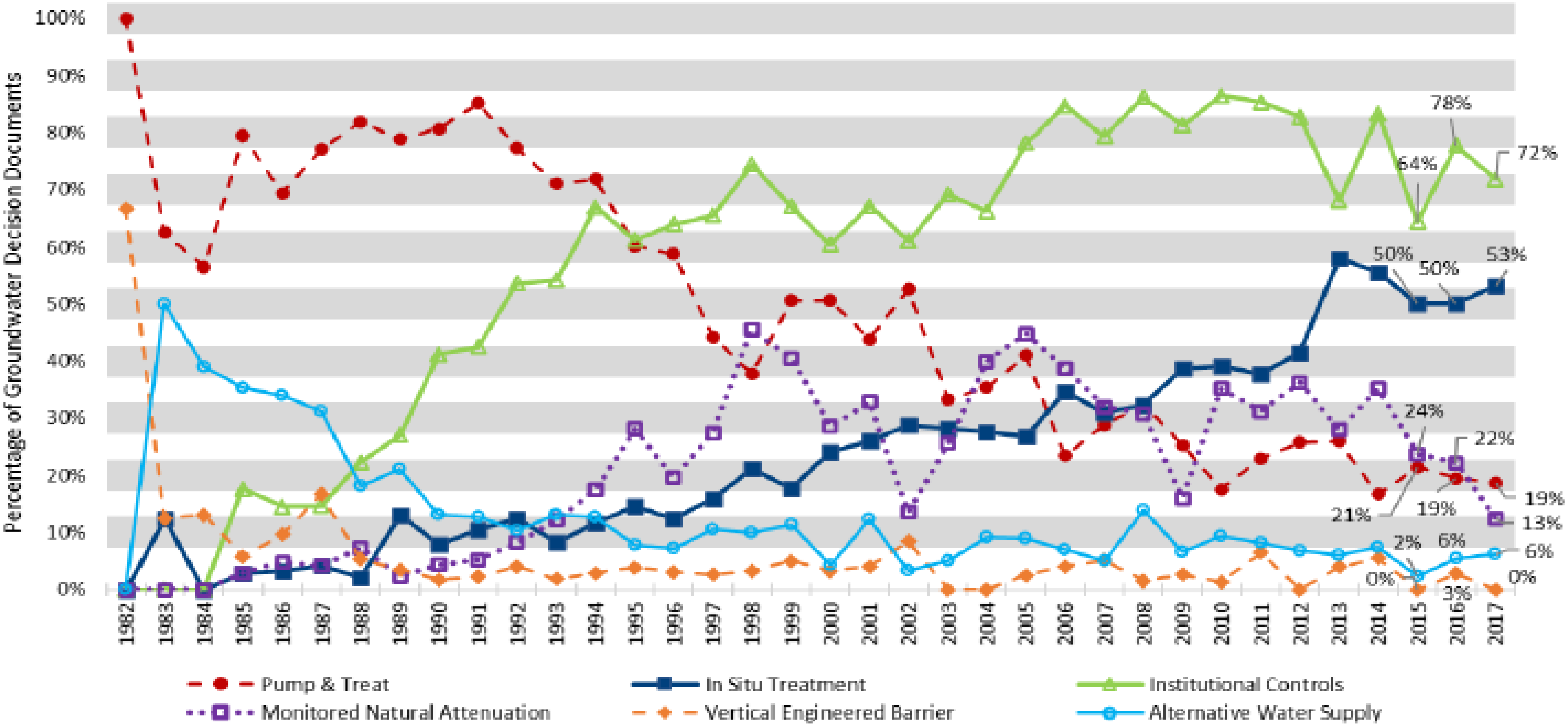
- Historical Perspective in Superfund
  - Lots of pump and treat systems early on
  - Restoration often the goal
  - Single concentration goal "throughout aquifer"
- Challenges Encountered
  - Insufficient characterization leads to poor placement of wells/screens
  - Missed sources
  - Matrix diffusion challenges
  - Limited flexibility to use adaptive techniques
- New Thinking
  - High quality characterization and a good CSM lead to improved remedy performance. Cost/benefit.
  - Use of Adaptive Management approaches



Recent Experience Leads to New Thinking- Remediation

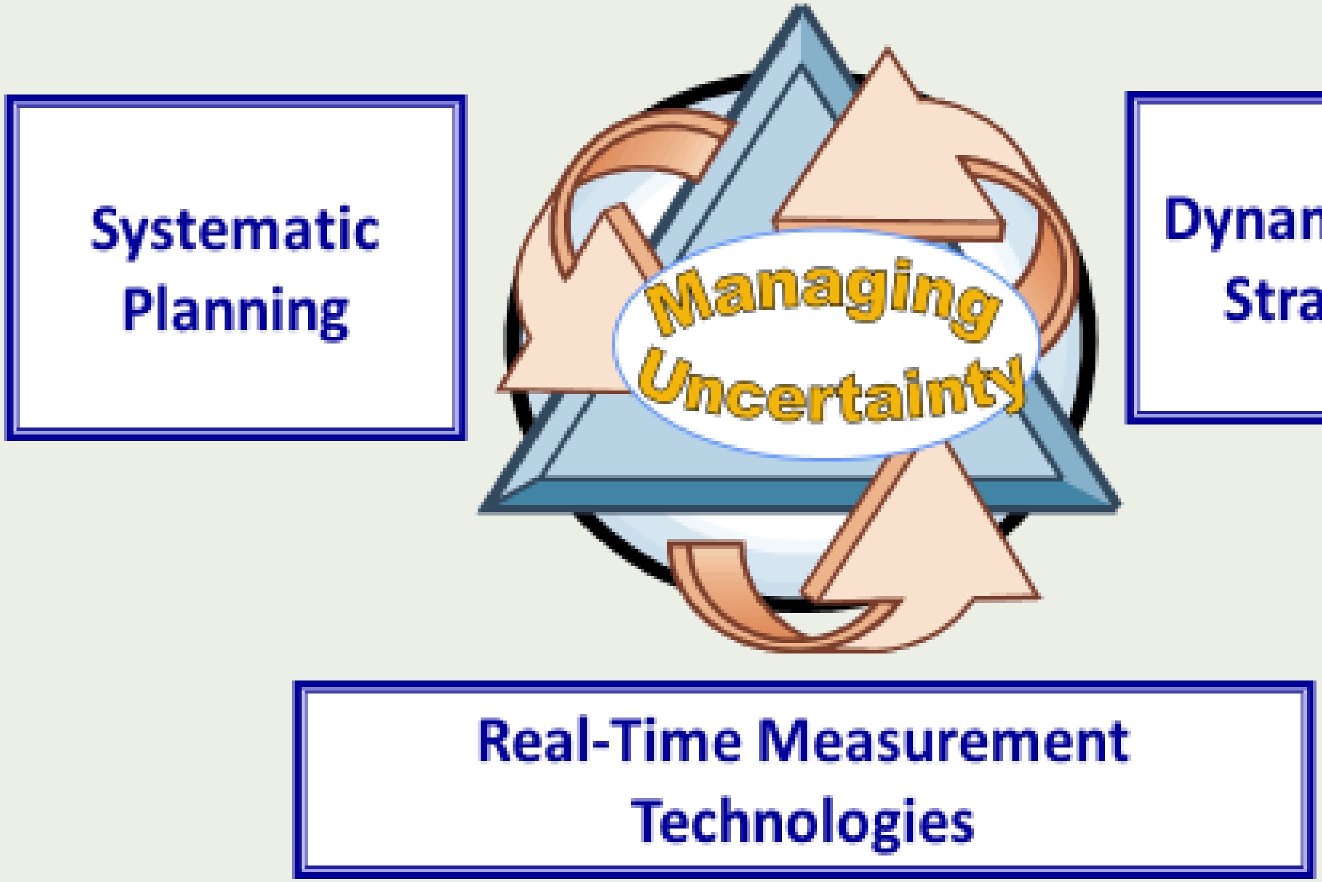
Superfund Remedy Report, 16th Edition

Figure 13: Selection Trends for Decision Documents with Groundwater Remedies (FY 1982-2017)



- Number of groundwater decision documents with remedies: FY 1982-2017 = 2,541.
- One decision document from FY 1981 not included.
- Decision documents may be included in more than one category.

Tools and Strategies
The Triad Approach – Source of Many BMPs



Synthesizes practitioner experience, successes, and lessons learned into an institutional framework

Tools and Strategies
The Triad Approach – Source of Many BM

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

A process for building a consensus vision for conducting environmental investigation and remediation

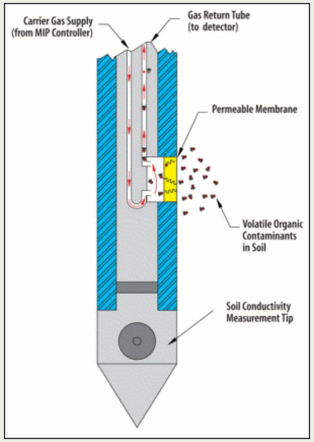
A work strategy that incorporates the flexibility to adapt to information generated by real-time measurement technologies

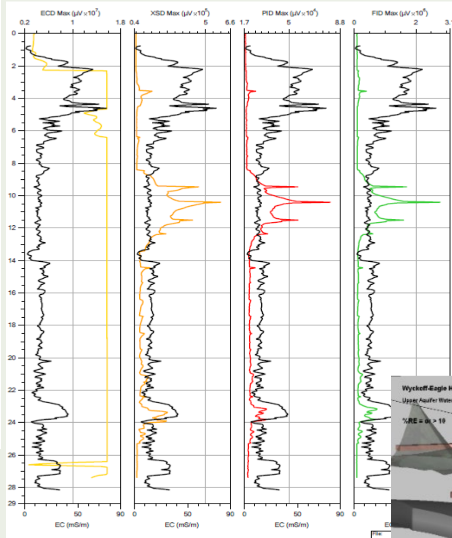
Real-time = within a timeframe that allows the project team to react to the information while in the field

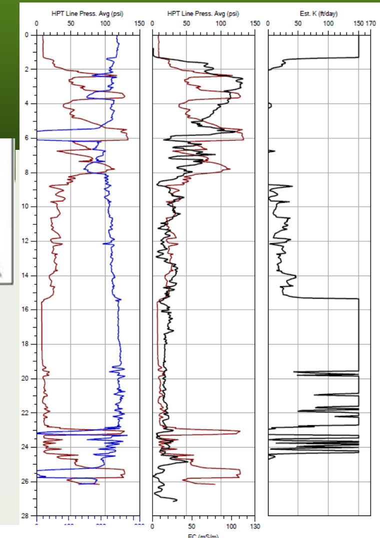
Synthesizes practitioner experience, successes, and lessons learned into an institutional framework

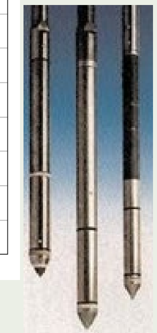
HRSC- Profound Effect on CSMs

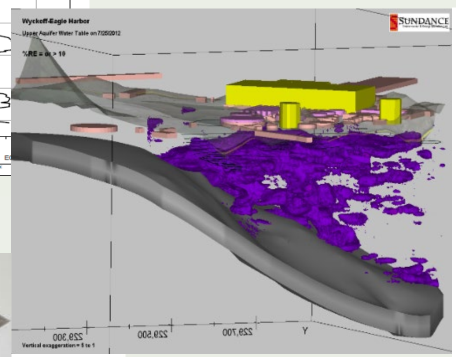
Many Advances in Tools- Just A Few Examples

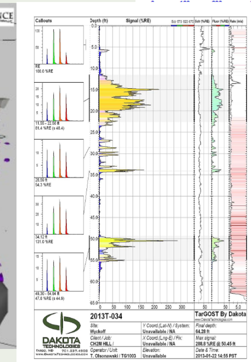


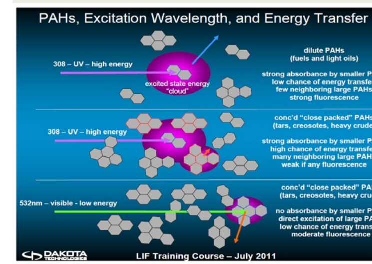




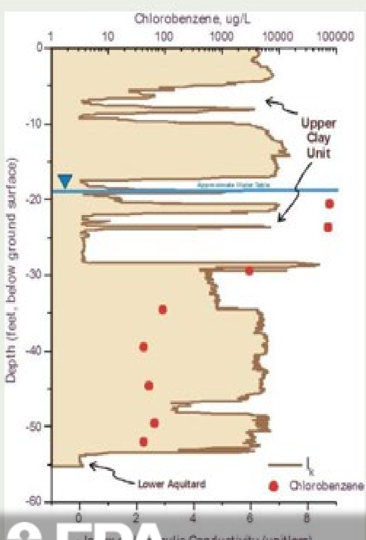




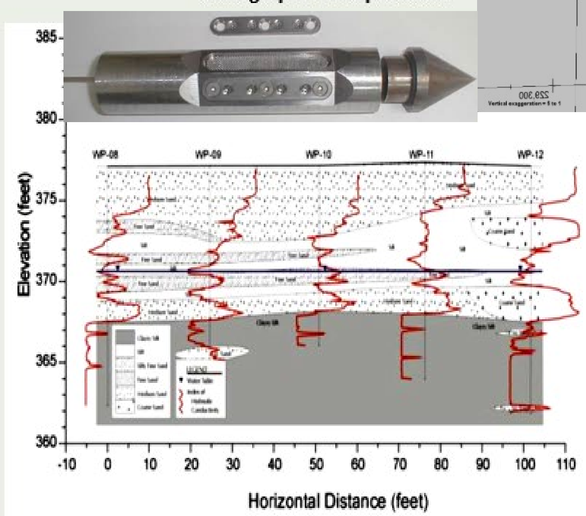


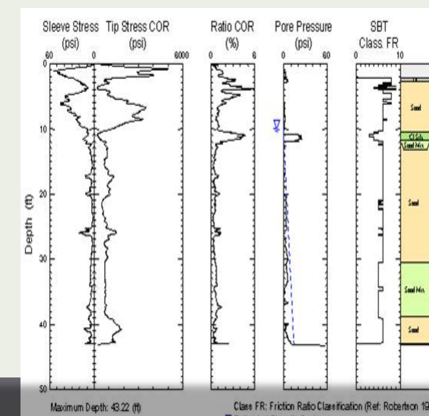


Sample depth selection

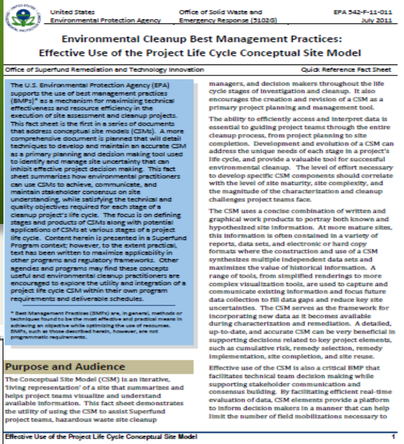


Stratigraphic Interpretation





Evolution of Conceptual Site Models in Superfund

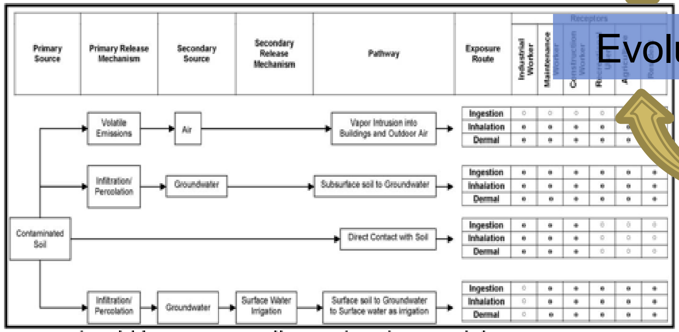


1980's—1990s

2000's

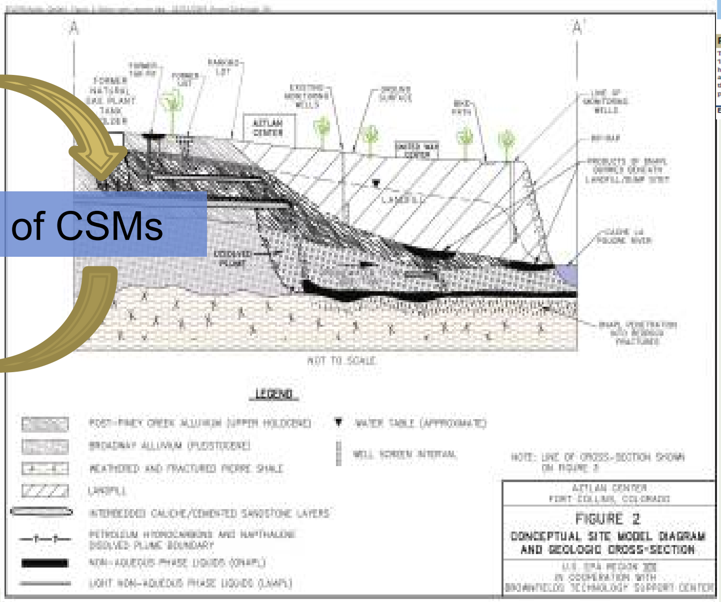
Pathway-Receptor Network Diagrams

- P-RN diagrams NOT CSMs – too simple to serve all CSM functions
- However, they are a critical COMPONENT of CSMs

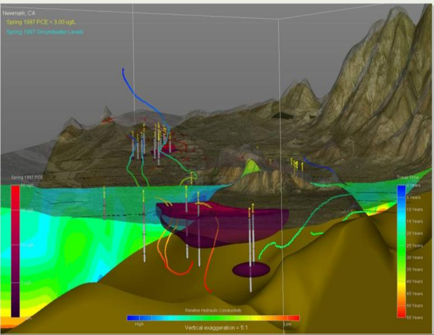


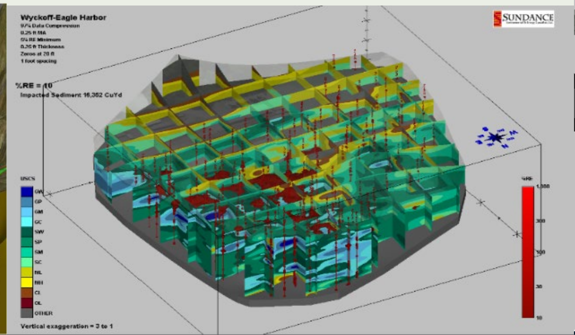
- CSM should incorporate all actual and potential P-RNs
- Investigation efforts confirm or refute each element of P-RNs

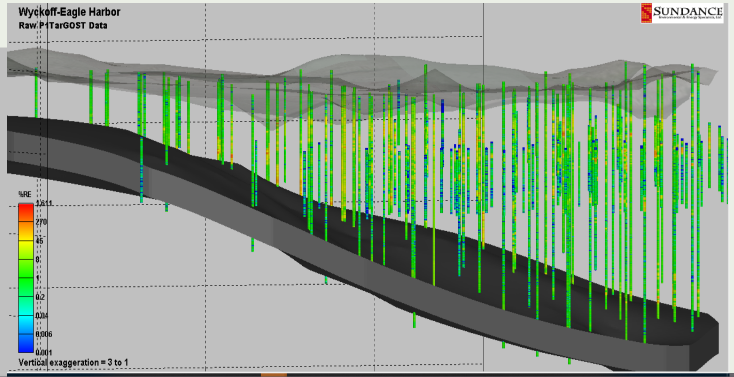
Evolution of CSMs



2010 to present







Evolution of Conceptual Site Models in Superfund

General Environmental Cleanup Steps	CSM Life Cycle	Best Management Practices: SPP	Best Management Practices: DWS/ RTMT	CERCLA - Superfund	RCRA	Brownfields	UST	VCUP Varies by State	IRP/ERP	MMRP
Site Assessment	Preliminary CSM Baseline CSM Conceptual			Preliminary Assessment (PA) Site Inspection (SI) National Priorities List (NPL) No Further Remedial Action Planned (NFRAP)	Facility Assessment (RFA)	Phase I Environmental Site Assessment (ESA)	Initial Site Characterization Initial Response	PA SI	PA SI	PA SI MR Site Prioritization Protocol (MRSPP)
Site Investigation and Alternatives Evaluation	Characterization CSM Stage			Remedial Investigation/ Feasibility Study (RI/FS) Removal Actions - Emergency/ Time Critical/Non-Time-Critical	Facility Investigation (RFI) Corrective Measures Study (CMS)	Phase II ESA	SI Corrective Action Plan (CAP)	RI/FS	RI/FS NFRAP	RI/FS
Remedy Selection	Design CSM Stage			Proposed Plan Record of Decision (ROD)	Statement of Basis (SB) Final Decision and Response to Comments	Remedial Action Plan (RAP)	Cleanup Selection	ROD	Proposed Plan ROD	Remedy Selection
Remedy Implementation	Remediation/ Mitigation CSM Stage			Remedial Design (RD) Remedial Action (RA) – Interim and Final	Corrective Measure Implementation (CMI)	Cleanup and Development	Corrective Action - Low-impact site cleanup - Risk-based remediation - Generic remedies - Soil matrix cleanup	RD RA	RD RA – Interim and Final Remedy in Place (RIP)	RD Time Critical Removal Action (TCRA) RA RIP
Post-Construction Activities	Post-Remedy CSM Stage			Operational & Functional Period Operation & Maintenance (O&M) Long term monitoring (LTM) Optimization Long Term Response Action (Fund-lead groundwater/surface water restoration)	O&M On-site inspections and oversight	Property Management Long-term O&M Redevelopment Activities (Private- and Public-led)	LTM	O&M LTM	Shakedown period Operating Properly and Successfully O&M LTM	Shakedown period Long Term Management
Site Completion	Quantitative			Construction Complete (CC) Preliminary or Final Close Out Report (PCOR/FCOR) Site Completion - FCOR Site Deletion O&M as appropriate	Certification of Completion Corrective Action Complete with Controls or without Controls	CC Property Management	No Further Action (NFA)	CC	Response Complete (RC) NFA	RC NFA

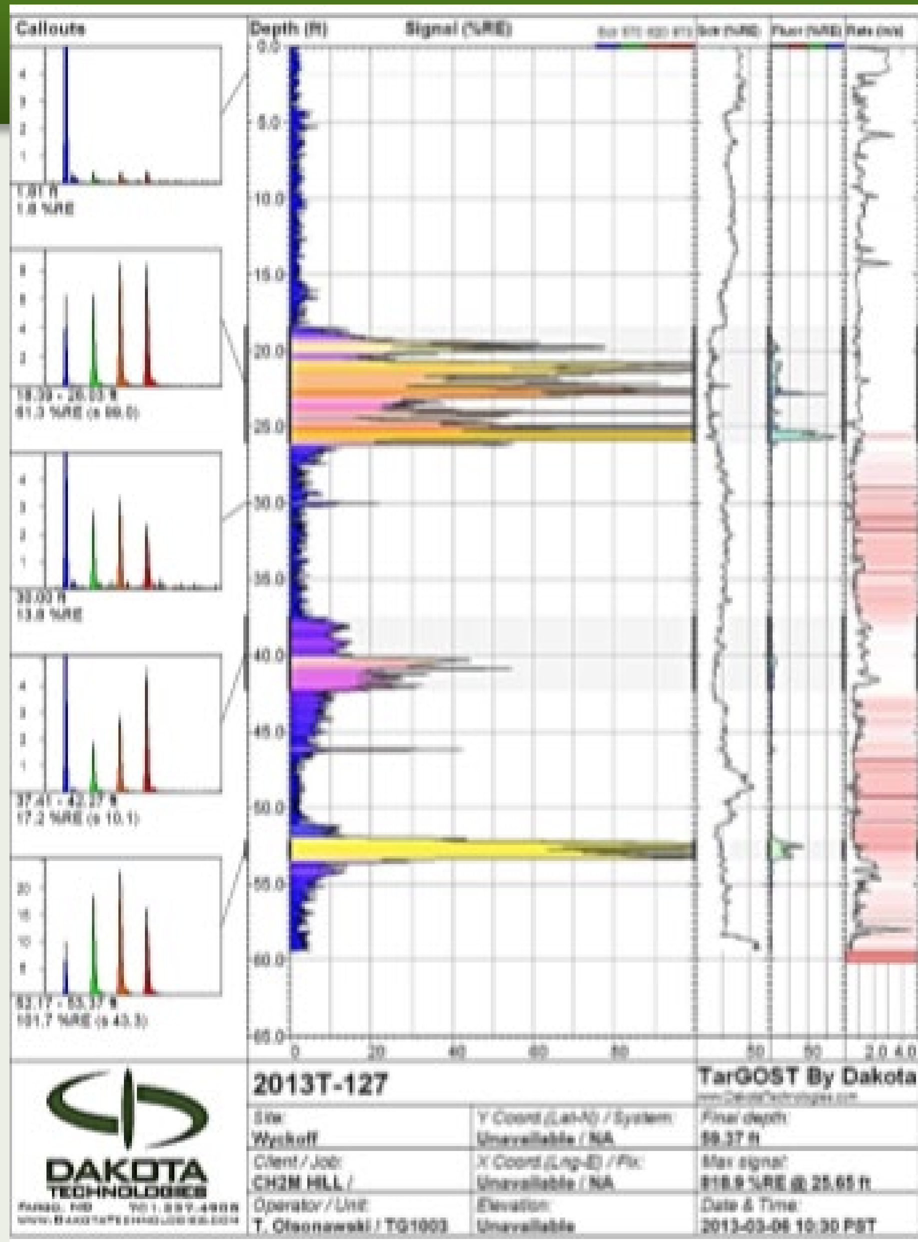
Abbreviations:

SPP = Systematic Project Planning
DWS = Dynamic Work Strategies
RTMT = Real Time Measurement Technologies

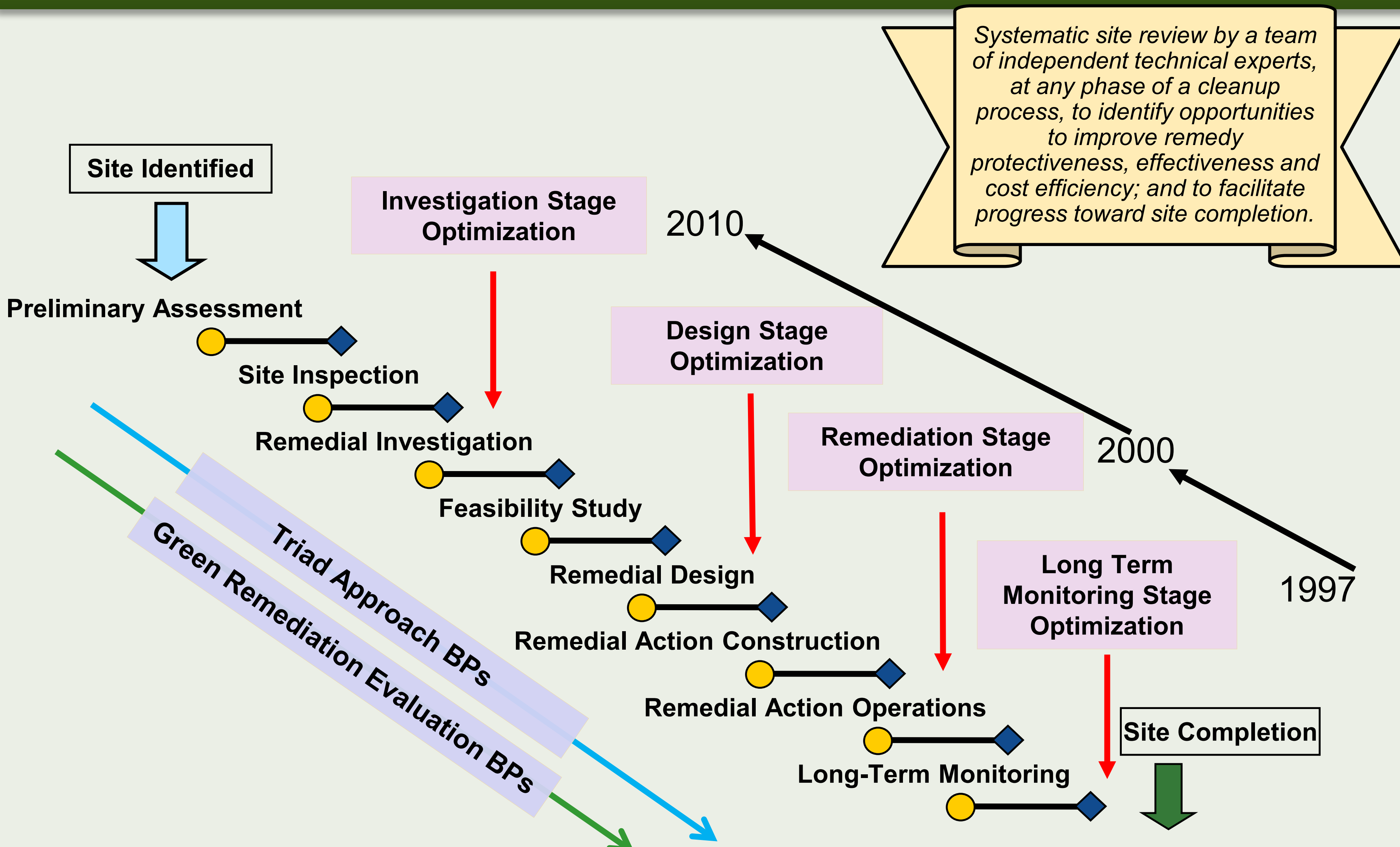
CERCLA = Comprehensive Environmental Response, Compensation and Liability Act
RCRA = Resource Conservation and Recovery Act

UST = Underground Storage Tanks
VCUP = Voluntarily Clean Up Programs

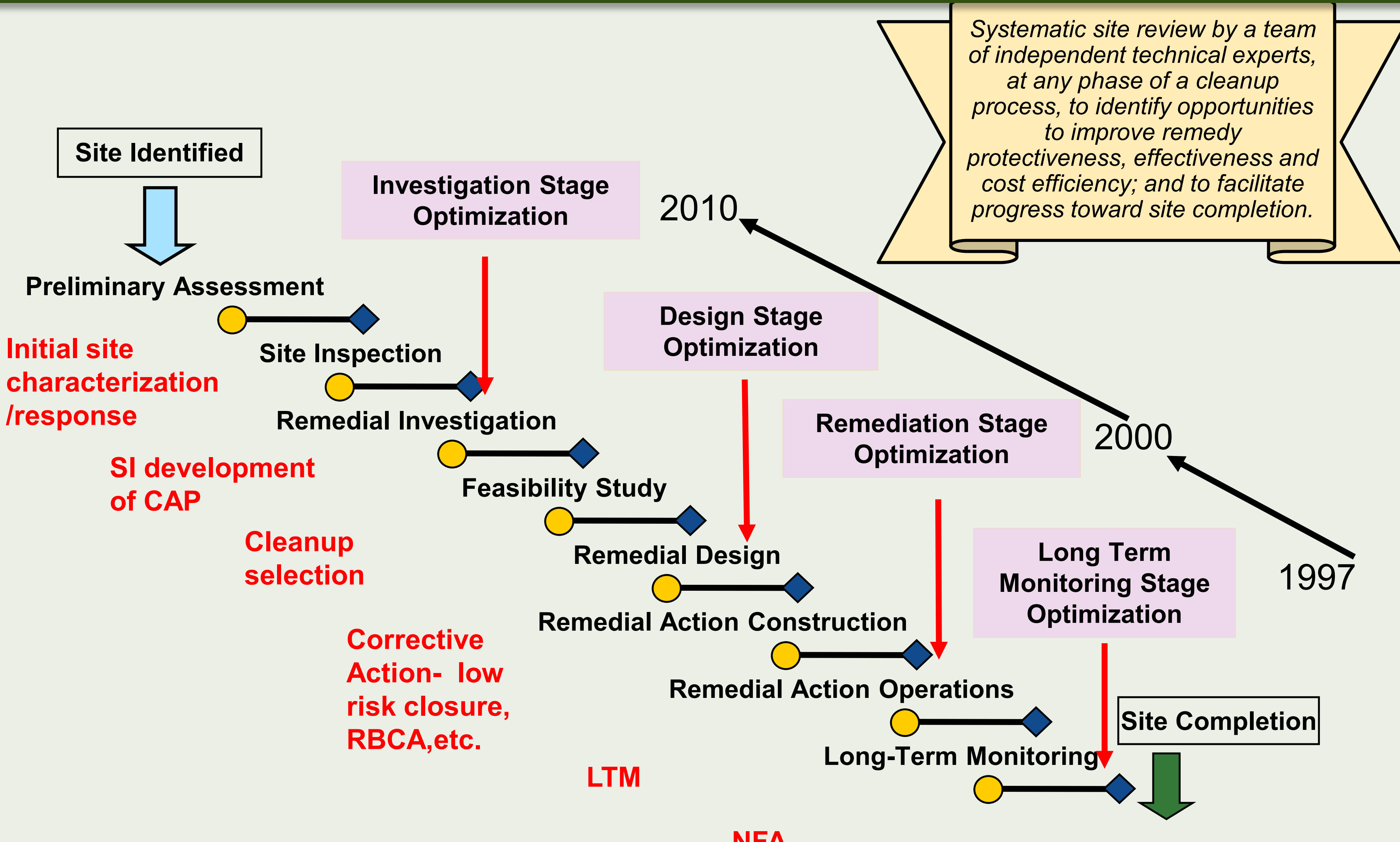
IRP/ERP = Installation Restoration Program/ Environmental Restoration Program
MMRP = Military Munitions Response Program


Callouts
Depth (ft)
Signal (%RE)
2013T-127
TarGOST By Dakota
DAKOTA
TECHNOLOGIES
Site:
Wyckoff
Client / Job:
CH2M HILL /
Y Coord (Lat-N) / System:
Unavailable / NA
X Coord (Lng-E) / Fix:
Unavailable / NA
Elevation:
Unavailable
Final depth:
59.37 ft
Max signal:
Date & Time:
2013-03-06 10:30 PST

History of EPA Superfund Optimization Program

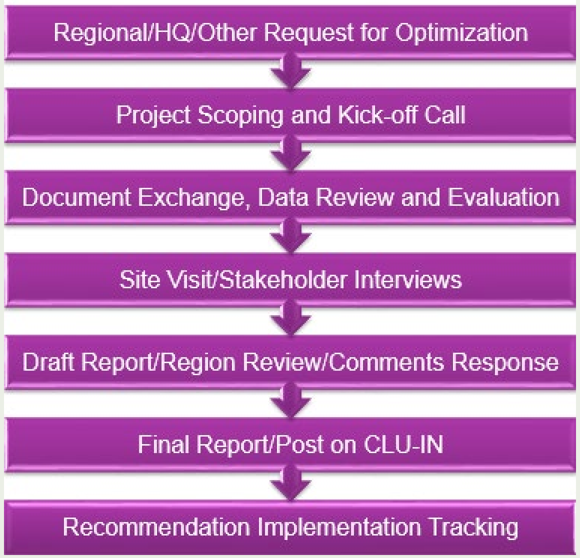


History of EPA Superfund Optimization Program



www.epa.gov/superfund/cleanup/postconstruction/optimize.htm
www.cluin.org/optimization/

Optimization Review Process



Optimization Support in Superfund Completed Events 1997-2016

*Events/Region

Region	1997-2010*	2011-2015*	2016 to Date*	Total Events 1997 to Date	% per Region
1	10	7	4	21	10%
2	12	12	1	25	12%
3	18	6	1	25	12%
4	11	1	0	12	6%
5	12	4	0	16	8%
6	5	11	0	16	8%
7	6	13	0	19	9%
8	4	11	2	17	8%
9	6	20	1	27	13%
10	10	14	1	25	12%
Total	94	99	10	203	100%

Optimization Characterization Phase Typical Findings/ Recommendations

1. Low density/high uncertainty
2. CSM out of date or underdeveloped
3. Existing data not fully leveraged
4. Over-reliance on high cost traditional methods
5. Scale of measurements not sufficient for heterogeneity
6. End data users not adequately considered

Optimization Design/Remedy Phase Typical Findings/ Recommendations

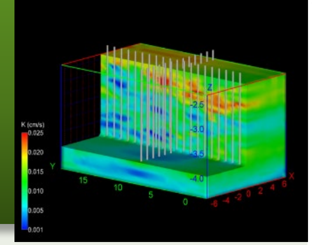
1. Gaps in CSM
2. Shortcomings in modeling
3. Unaddressed issues in design
4. High cost estimates
5. Remedy effectiveness can be improved by conducting phases
6. Explanations for uncertainties can become apparent during start-up
7. Can confirm validity of current site plans and progress

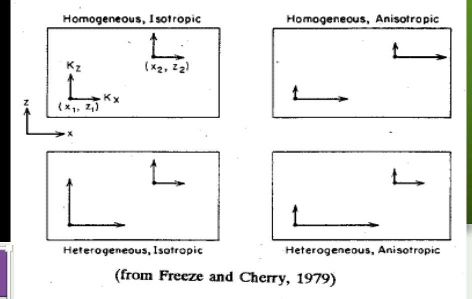
Optimization Long term O&M Phases Typical Findings/ Recommendations

1. CSM needs update
   a) Sources
   b) Low/ high permeability zones
   c) NAPL
2. Endpoint and metrics for site completion need better definition
3. Need for improved data management, analysis and reporting
   a) Tracking/reporting performance
   b) Spatial/temporal data
   c) Historic data (paper → electronic)

HRSC for Groundwater-

Challenges, Strategies, and Tools



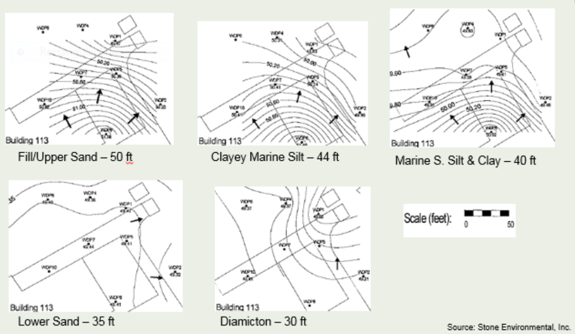


Challenges

- **Heterogeneous, anisotropic conditions**
- **Hydraulic gradient- 3 dimensional, temporal variation**
- **Advection/Dispersion**
- **Contaminant phase**
  - NAPL (density, viscosity, mobility, dissolution)
  - Gas
  - Solute (dissolved)
  - Sorbed

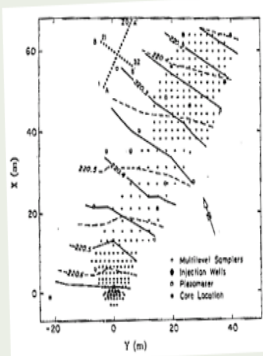
Location	Horizontal K Correlation Length (m)	Vertical K Correlation Length (m)	Investigator
Borden, Ontario	2.8	0.12	Sudicky (1986)
Otis, ANGB	2.9 – 8	0.18 – 0.38	Hess et al. (1992)
Columbus AFB	12.7	1.6	Rehfeldt et al.
Aefligan	15 – 20	0.05	Hess et al. (1992)
Chalk River, Ontario	1.5	0.47	Indelman et al. (1999)

Hydraulic Gradient Variability with Depth at Pease AFB Site 32

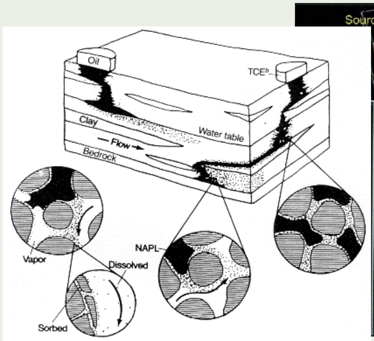


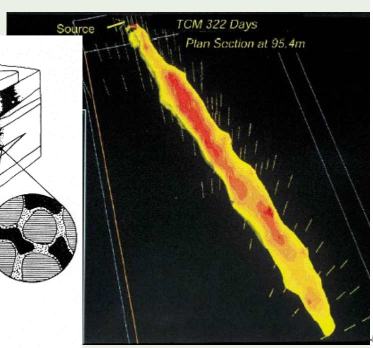
Hydrodynamic Dispersion

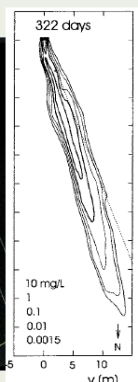
- **Natural Gradient Tracer Tests**
  - » Sudicky 1979
  - » Stanford/Waterloo – 1982
  - » USGS Cape Cod – 1986
  - » Rivett et al. 1991
- **Dispersion is scale (time/distance) dependent**
- **Transverse horizontal dispersion is weak**
- **Transverse vertical dispersion is even weaker**
- **Longitudinal dispersion is significant**

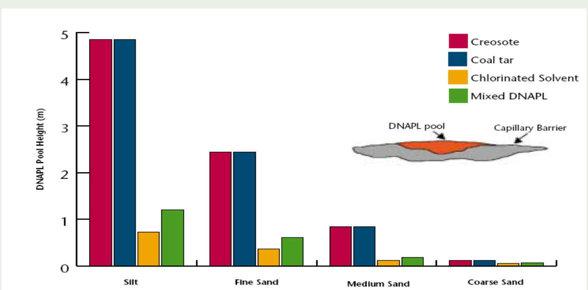


Stanford-Waterloo Natural Gradient Tracer Test Layout, Water Resources Research, 1982





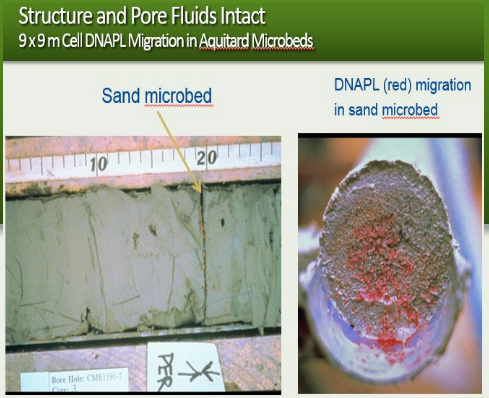


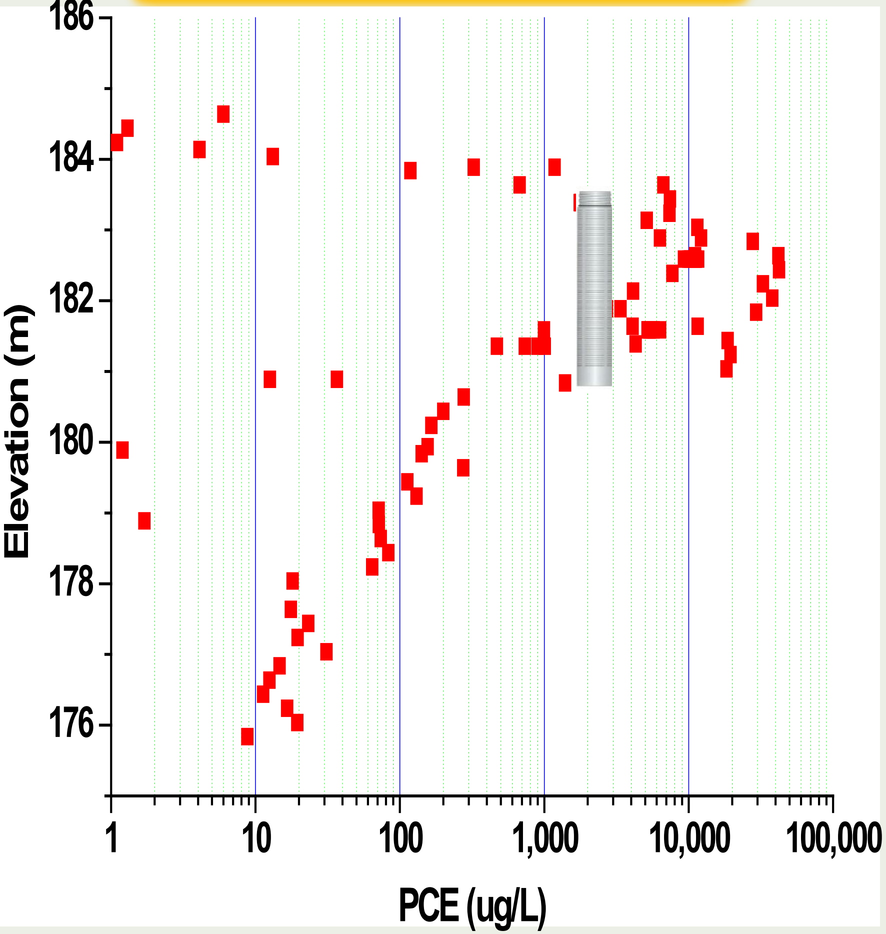


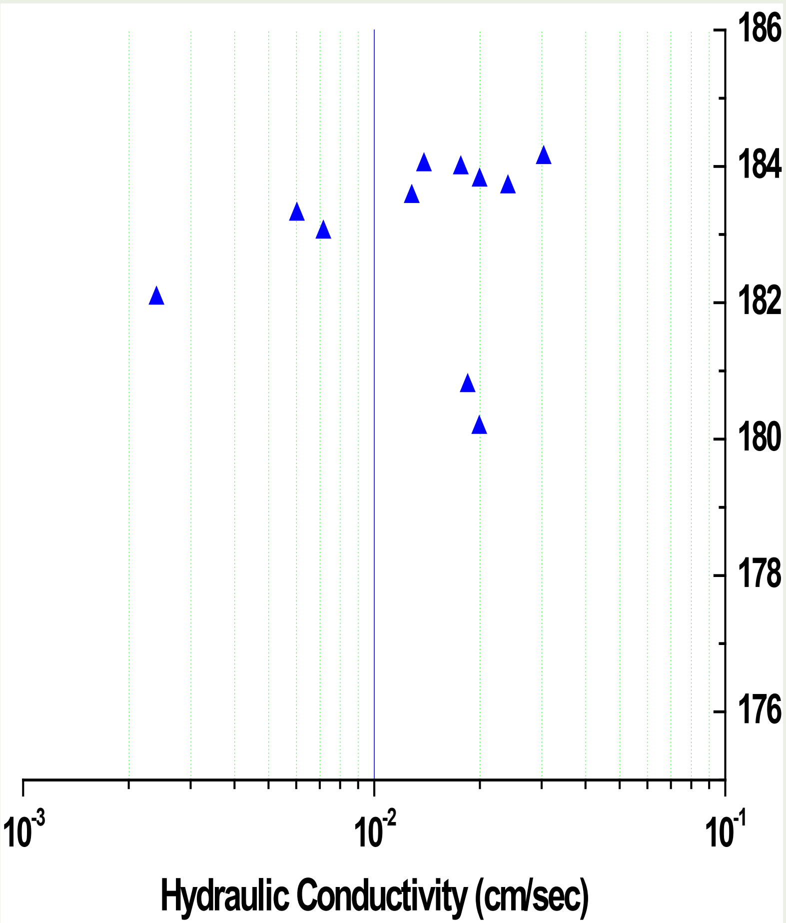
Sampling Scale and Averaging

How "Well" Do You Know Your Site

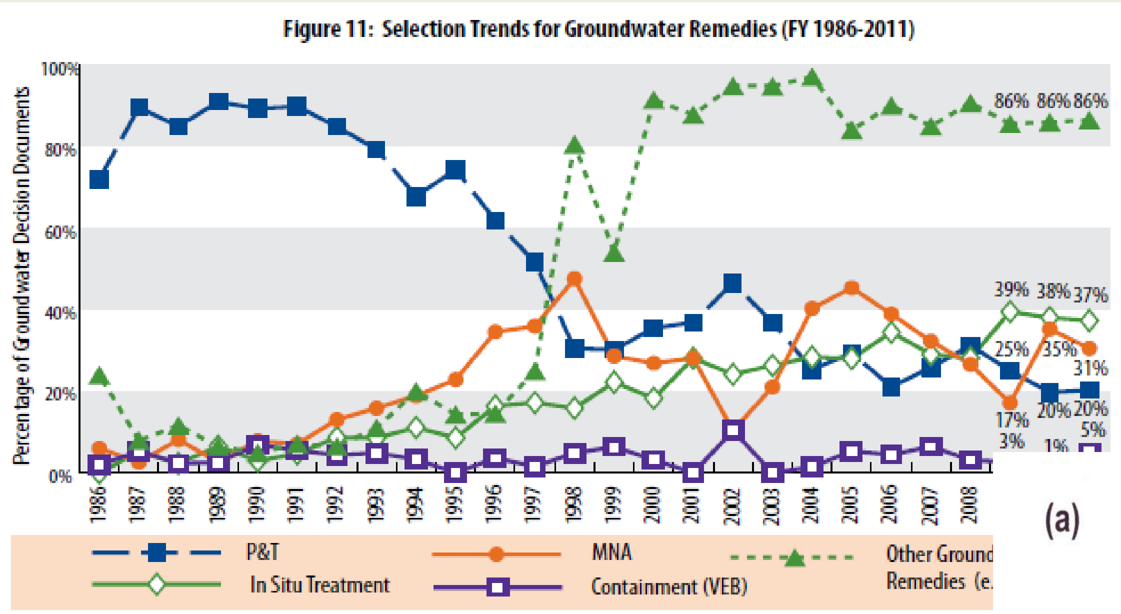
Monitoring wells yield a depth integrated flow weighted average







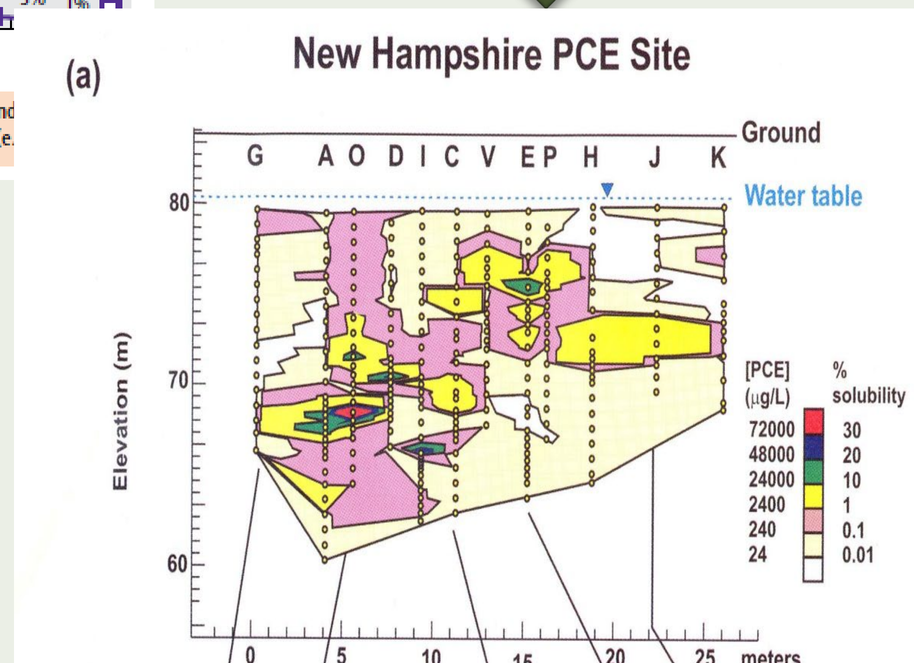
Mass Flux Distribution- And The Rise of In-Situ Remedies



Guilbeault et al., 2005

75% of mass discharge occurs through 5% to 10% of the plume cross sectional area

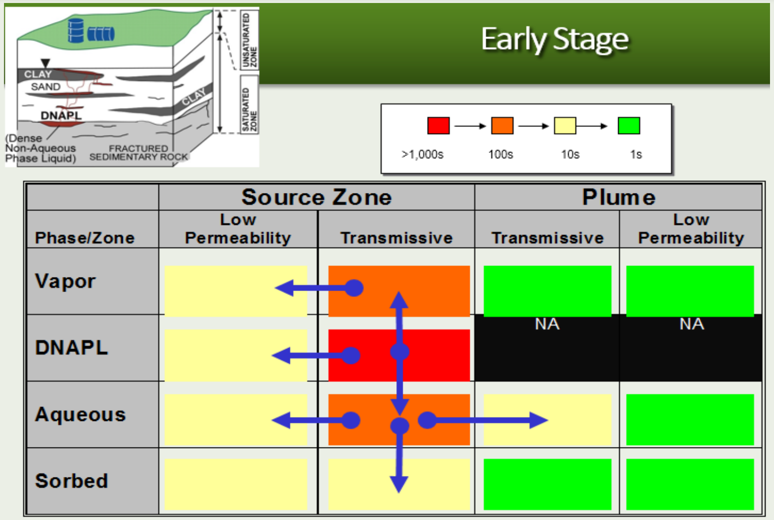
Optimal Spacing is ~0.5 m



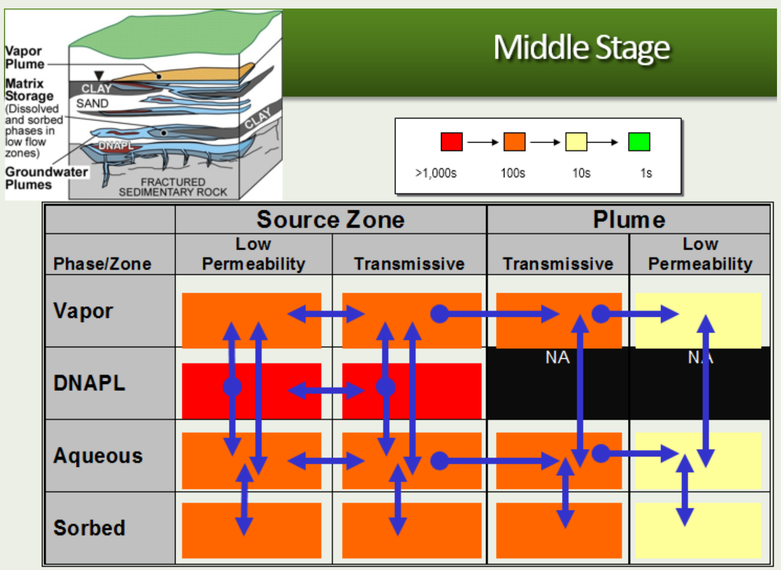
Superfund Remedy Report 14th edition

- **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



Tom Sale and Chuck Newell



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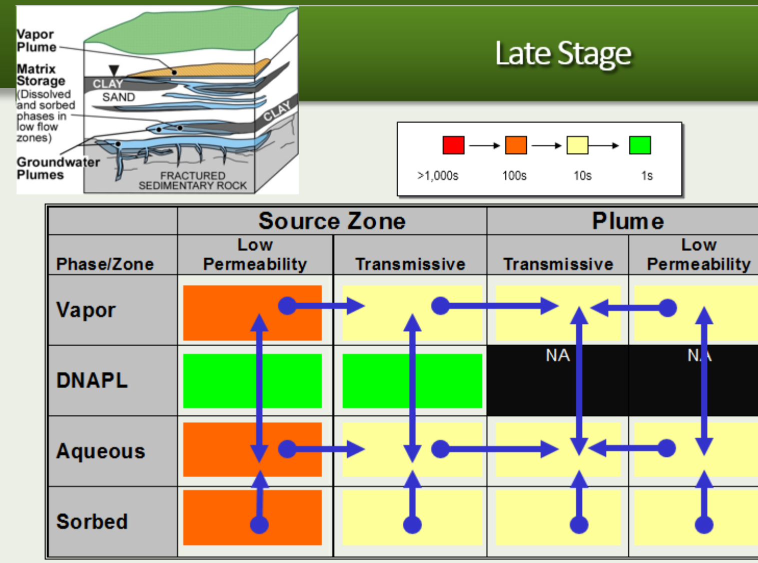

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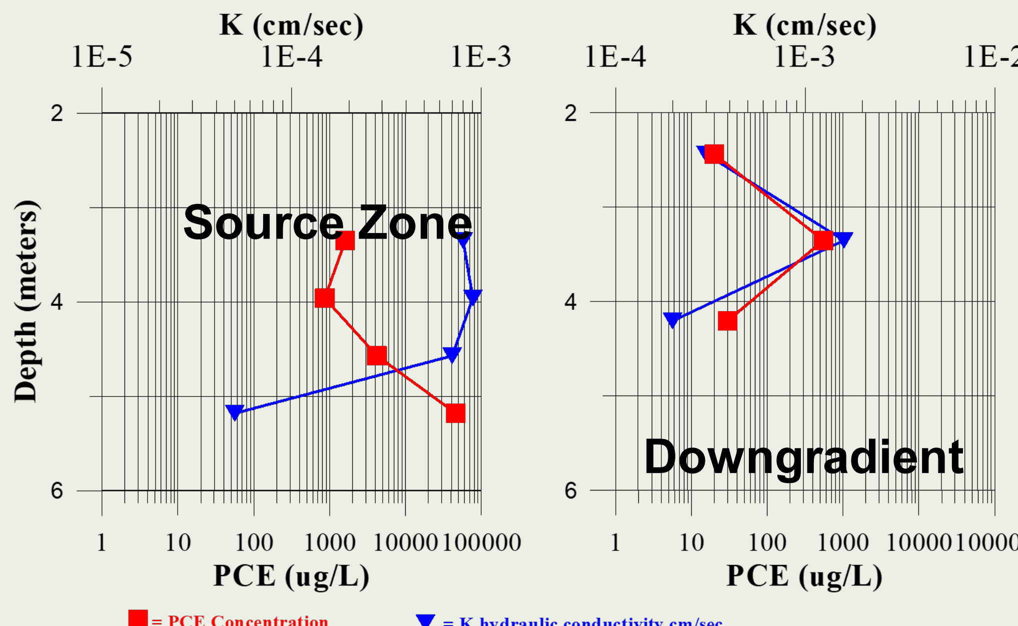
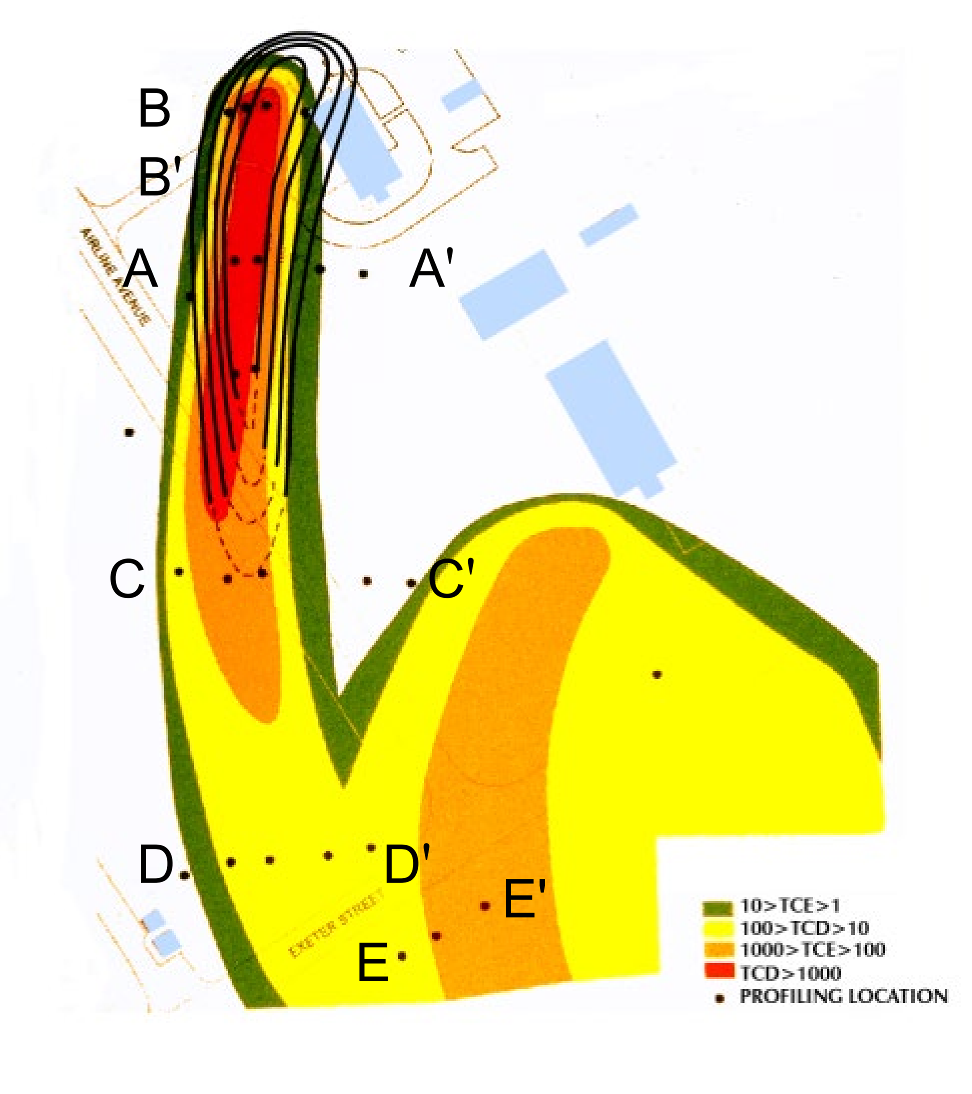
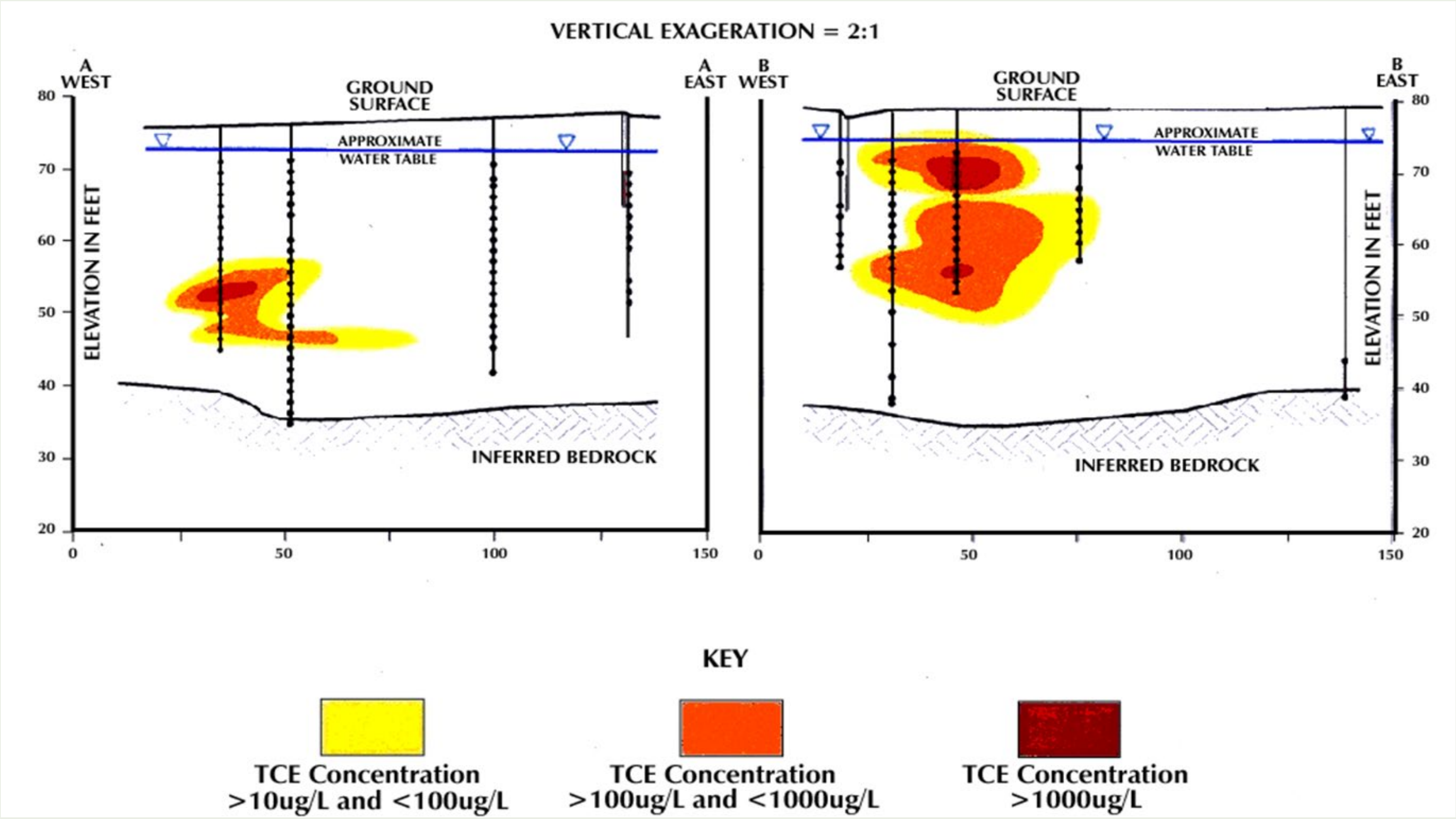


Transect/Vertical Profiling Case Study: Secondary Groundwater Plume Characterization, Pease AFB, NH

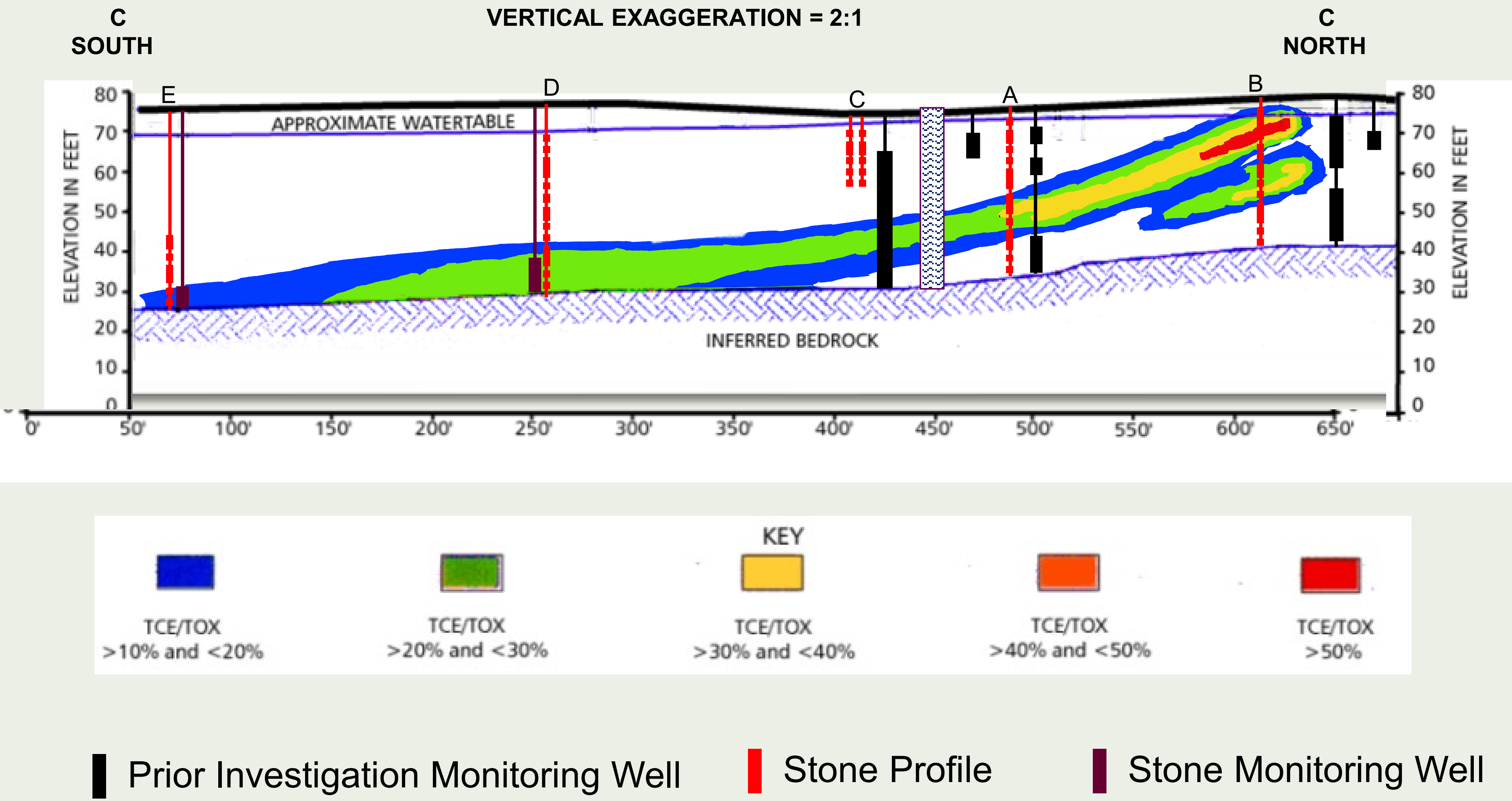


- **VOC and POL release site**
- **VOCs potentially affecting two bedrock supply wells**
  - Concern over DNAPL in bedrock
- **Prior monitoring well investigation did not accurately characterize the plume**
  - Defined as “short plume”
- **5 Modified Waterloo Profiler transects performed normal to plume axis**
  - A - A’ = Downgradient of source
  - B - B’ = Through source area
  - C - C’ / D - D’ / E - E = Downgradient plume delineation

Transect/Vertical Profiling Case Study: Secondary Groundwater Plume Characterization, Pease AFB, NH



Plume Anatomy Characterization & Remediation: Vertical Profiling vs. Monitoring Well



To Infinity and Beyond
Expansion of HRSC Tools and Strategies

- **Groundwater**
  - Transects
  - Vertical profiling
  - Direct push and direct sensing tools
  - Flux based approaches
  - Site investigation through system optimization and remedy completion
- **Soil**
  - Incremental and composite designs
  - Depth discrete intervals
  - Field based analytical methods
  - Risk based decision making controlling heterogeneity, particle size effects
  - Site investigation through system optimization and remedy completion