What is High Resolution Site Characterization (HRSC)?

Thanks to:
Steve Dyment, U.S. EPA ORD
Seth Pitkin, Stone Environmental

What Type of Investigation is HRSC ?

- **Subsurface investigation appropriate to the scale of heterogeneities in the subsurface which control contaminant distribution, transport and fate, and that provides degree of detail needed to understand:**
  - » Exposure pathways
  - » Processes affecting fate of contaminants
  - » Contaminant mass distribution and flux by phase and by media (mobile and immobile)
  - » Appropriate remedial approach
  - » How remedial measures will affect the problem

HRSC Addresses "Scale"

Matches the scale of measurement with the scale of the variability of the property being measured

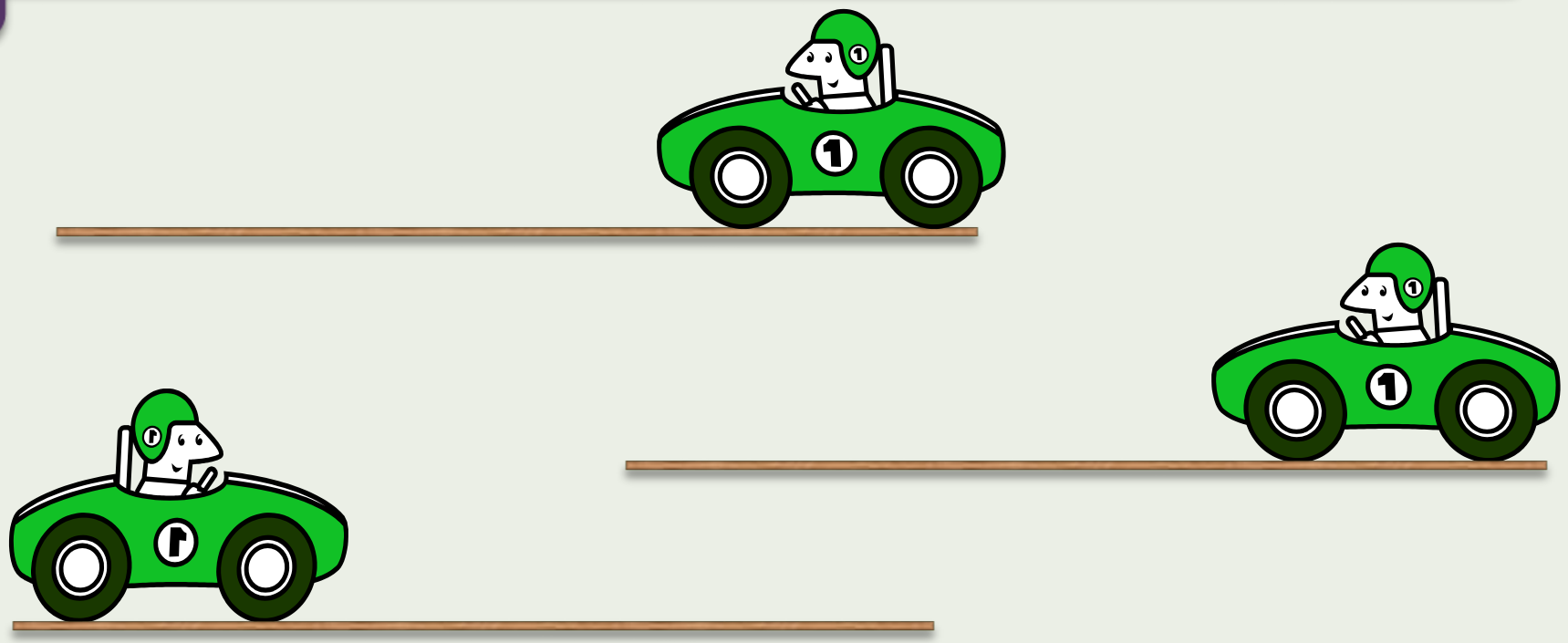
Analogies

- If you want to measure the width of this room you would not use the odometer on your car.
- On the other hand, your 10 meter tape measure will not help you figure out how many miles there are between Taipei and Taichung.

- If you want to see a bird across a field you use binoculars, but if you want to see microbes you use a microscope.
- Bird-watching with a microscope does not work.

HRSC Addresses Scale First

If measurements are made at the wrong scale it is very hard to understand that which is being measured no matter how many measurements are made



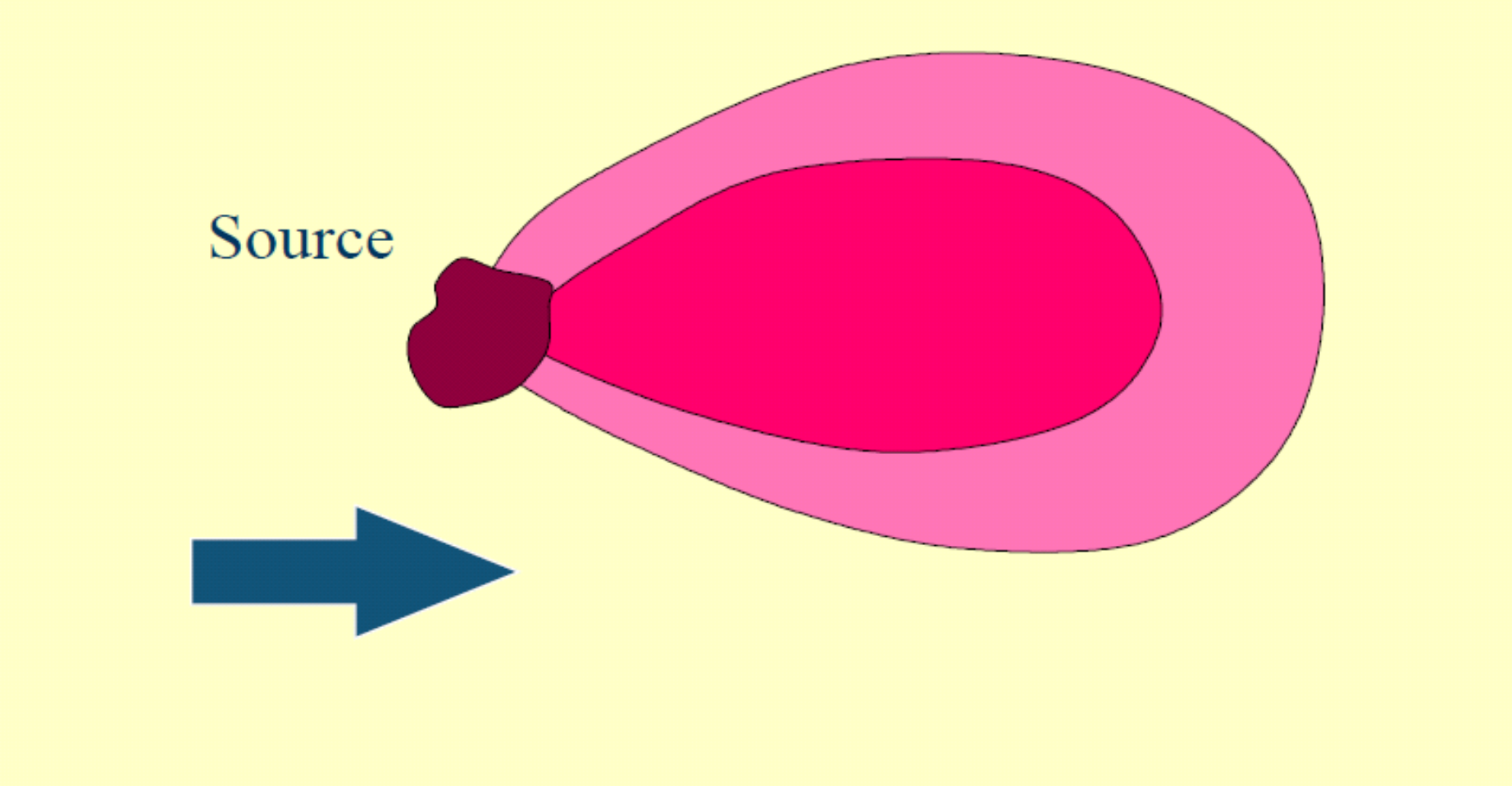
HRSC Addresses Measurement Spacing , Density, and Placement Second

However, even if measurements are made at the right scale it will not help unless a sufficient number of measurements are made at the right spacing and in the right places

Groundwater Characterization or Monitoring?

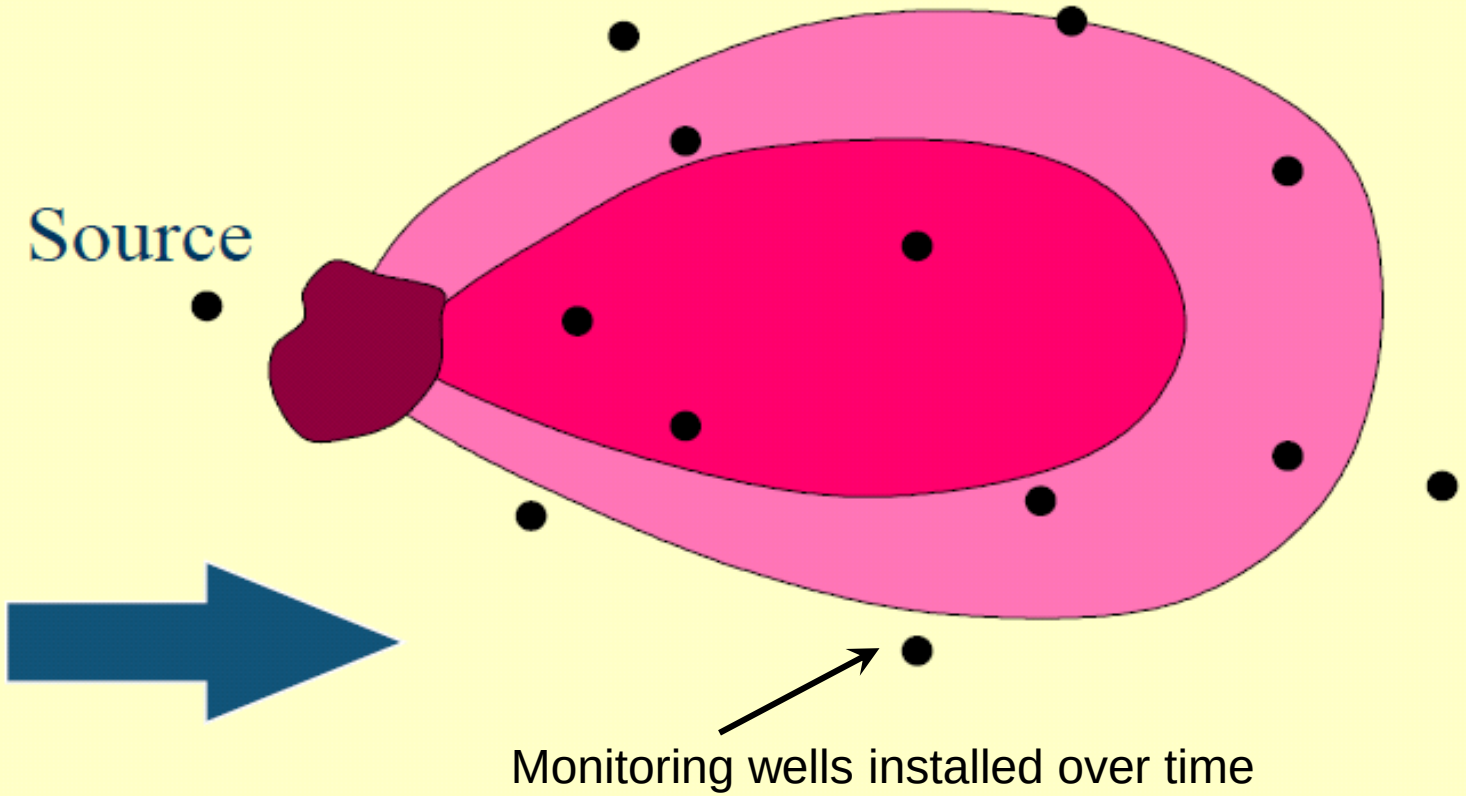
- **Contaminated Groundwater Characterization**
  - Objectives
  - Tools
  - Approaches
- **Contaminated Groundwater Monitoring**
  - Objectives
  - Tools
  - Approaches

1980's Conception of Plumes



Murray Einarson 2008

Conventional Investigation



Murray Einarson 2008

Conventional M[illegible]oring Well Place[illegible]t Strategy

How "Well" Do You Understand Your Site Conditions?

- **Technology used influences the understanding you develop**
- **The scale of measurement must be appropriate for the scale of the heterogeneity**
  - » Variability of hydraulic conductivity and other parameters
  - » Weak transverse hydrodynamic dispersion
  - » Heterogeneous distribution of DNAPL sources
- **Conventional MONITORING wells are not optimal investigation tools**
  - » Wells yield depth-integrated, flow-weighted average data
  - » Can not discern small scale heterogeneities controlling contaminant transport in groundwater
- **Monitoring wells have life cycle costs**

HRSC Addresses Two Critical Issues

- **Sampling Scale and Data Averaging**
  - » Measurements must be made at a scale that is meaningful with respect to the variability of the quantity being measured
- **Coverage**
  - » Enough measurements at the right locations
    - › Horizontal spacing
    - › Vertical spacing

Figure 1

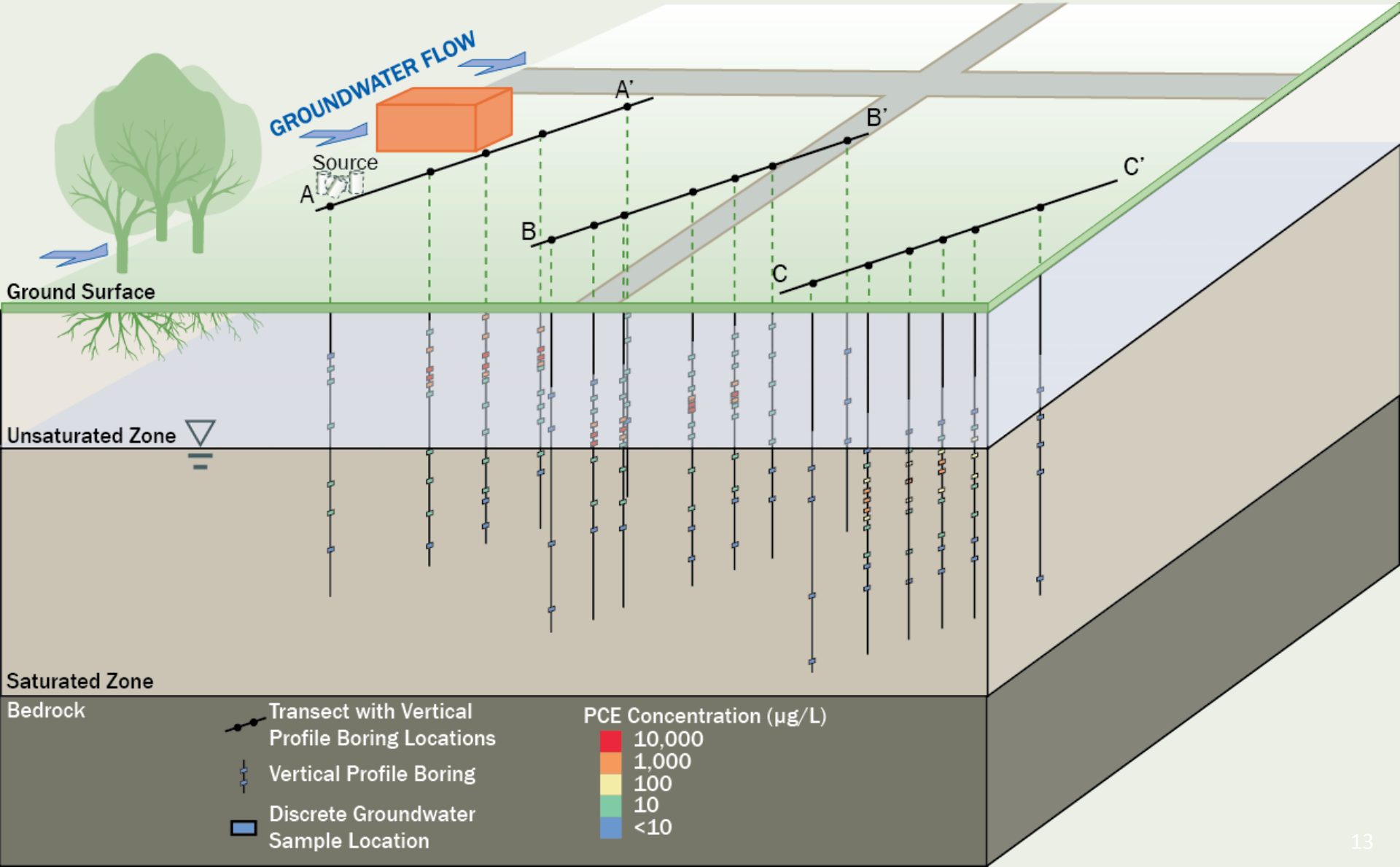
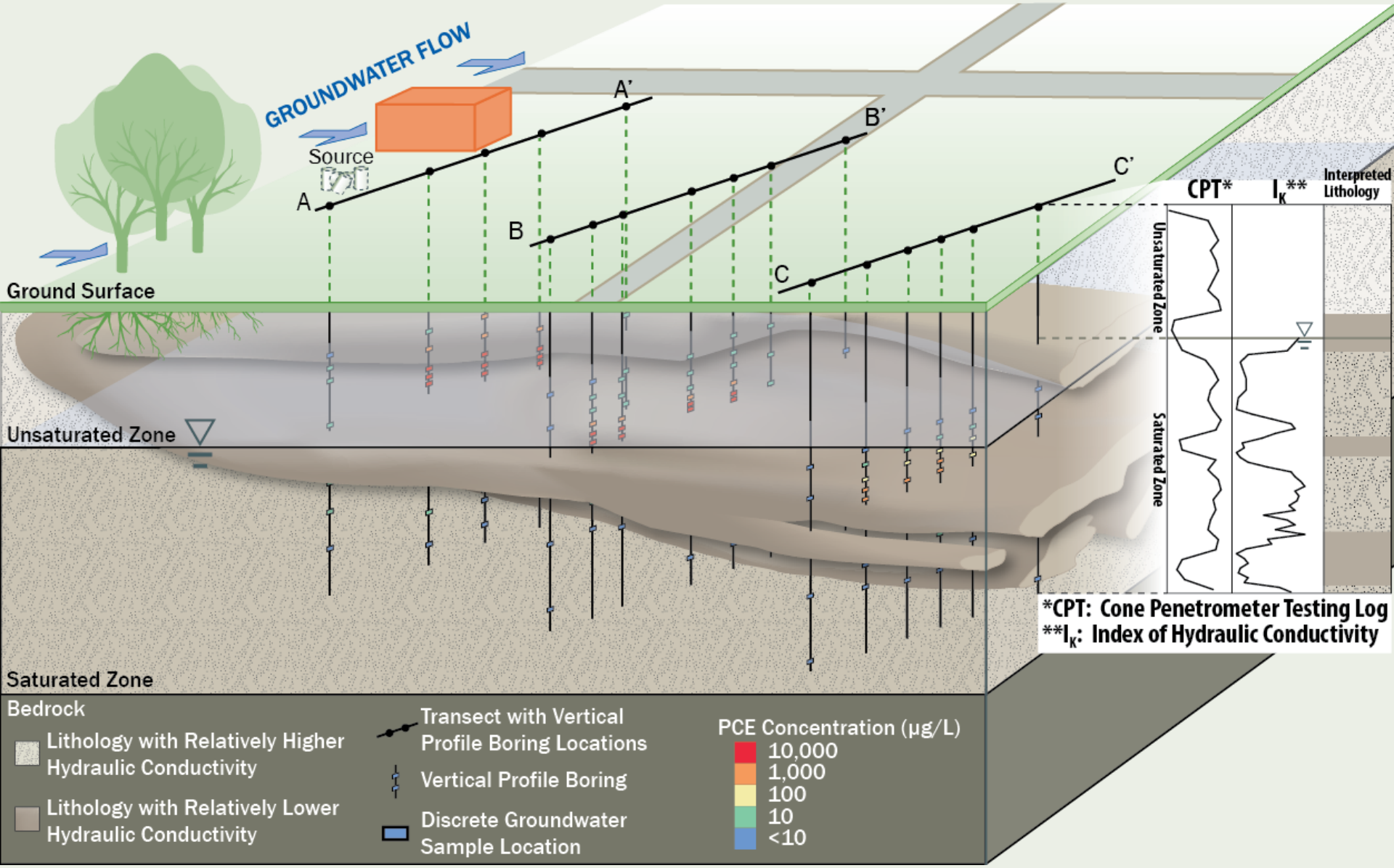

GROUNDWATER FLOW
Source
A
A'
B
B'
C
C'
Ground Surface
Unsaturated Zone
Saturated Zone
Bedrock
Transect with Vertical Profile Boring Locations
Vertical Profile Boring
Discrete Groundwater Sample Location
PCE Concentration (µg/L)
10,000
1,000
100
10
<10

Figure 2


GROUNDWATER FLOW
Source
A
A'
B
B'
C
C'
Ground Surface
Unsaturated Zone
Saturated Zone
Bedrock
CPT*
I_K**
Interpreted Lithology
Unsaturated Zone
Saturated Zone
*CPT: Cone Penetrometer Testing Log
**I_K: Index of Hydraulic Conductivity
Lithology with Relatively Higher Hydraulic Conductivity
Lithology with Relatively Lower Hydraulic Conductivity
Transect with Vertical Profile Boring Locations
Vertical Profile Boring
Discrete Groundwater Sample Location
PCE Concentration (µg/L)
10,000
1,000
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10
<10

Figure 3

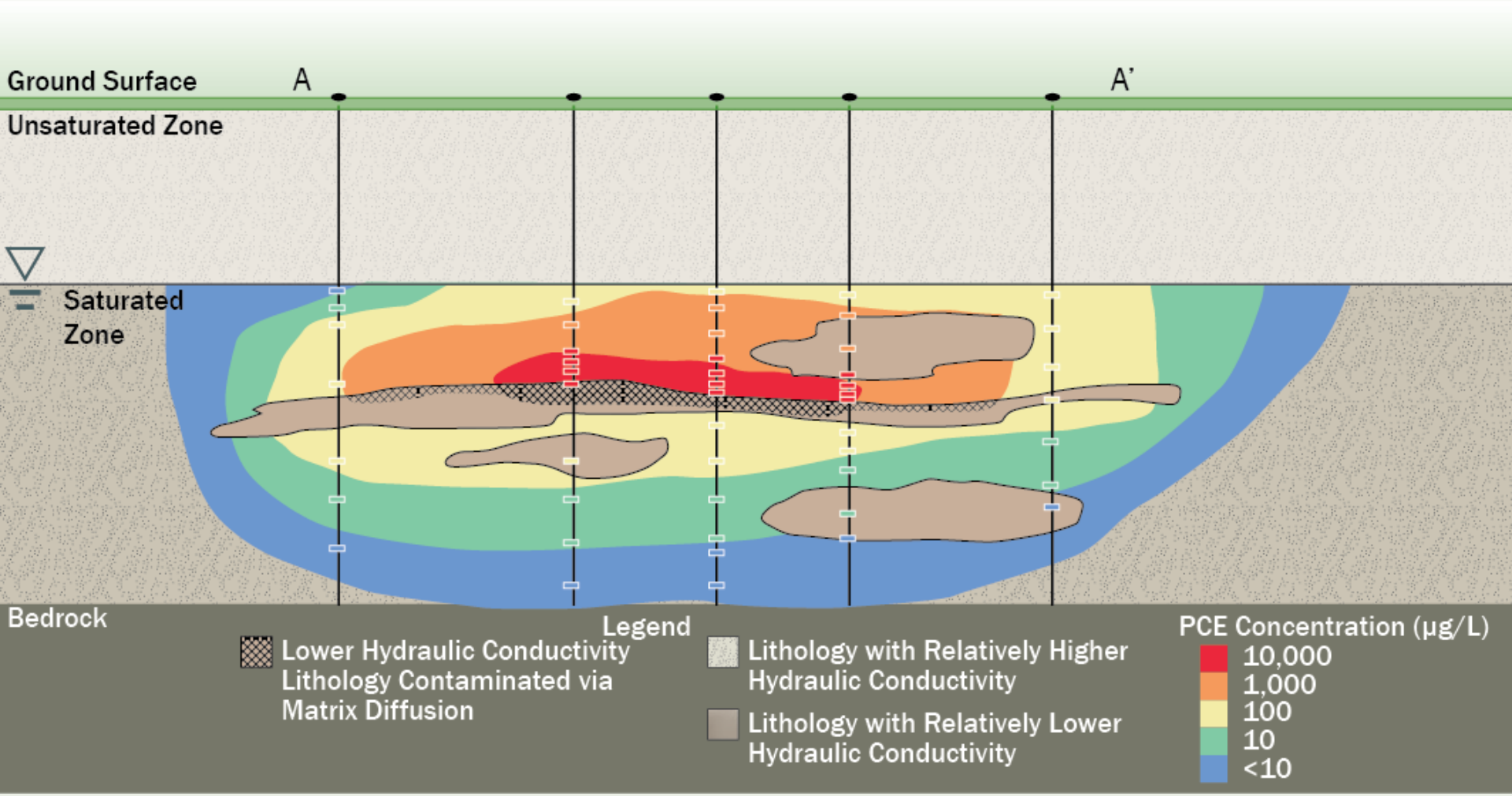

Ground Surface
A
A'
Unsaturated Zone
Saturated Zone
Bedrock
Legend
Lower Hydraulic Conductivity Lithology Contaminated via Matrix Diffusion
Lithology with Relatively Higher Hydraulic Conductivity
Lithology with Relatively Lower Hydraulic Conductivity
PCE Concentration (µg/L)
10,000
1,000
100
10
<10

Figure 4

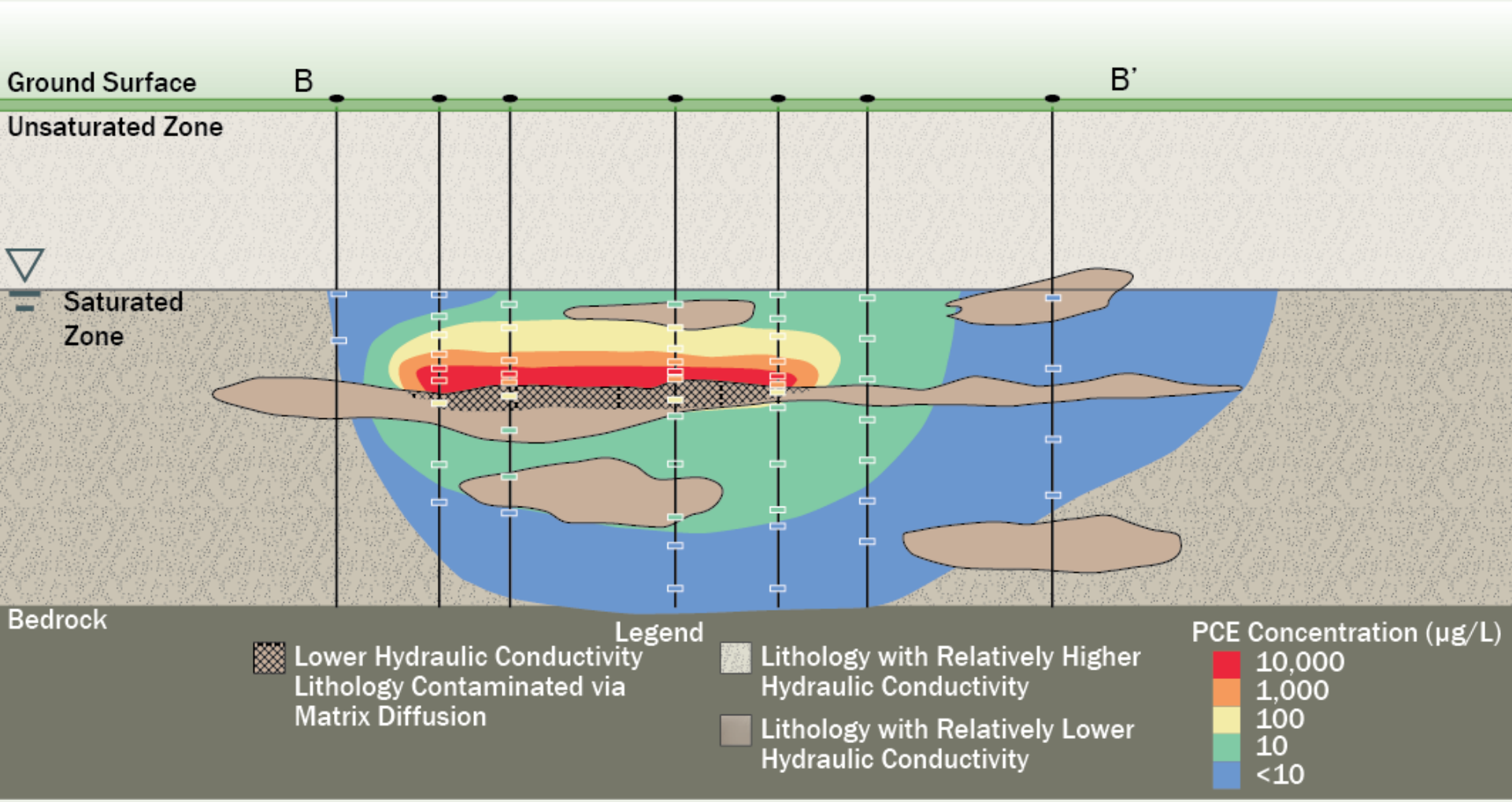

Ground Surface
B
B'
Unsaturated Zone
Saturated Zone
Bedrock
Legend
Lower Hydraulic Conductivity Lithology Contaminated via Matrix Diffusion
Lithology with Relatively Higher Hydraulic Conductivity
Lithology with Relatively Lower Hydraulic Conductivity
PCE Concentration (µg/L)
10,000
1,000
100
10
<10

Figure 5

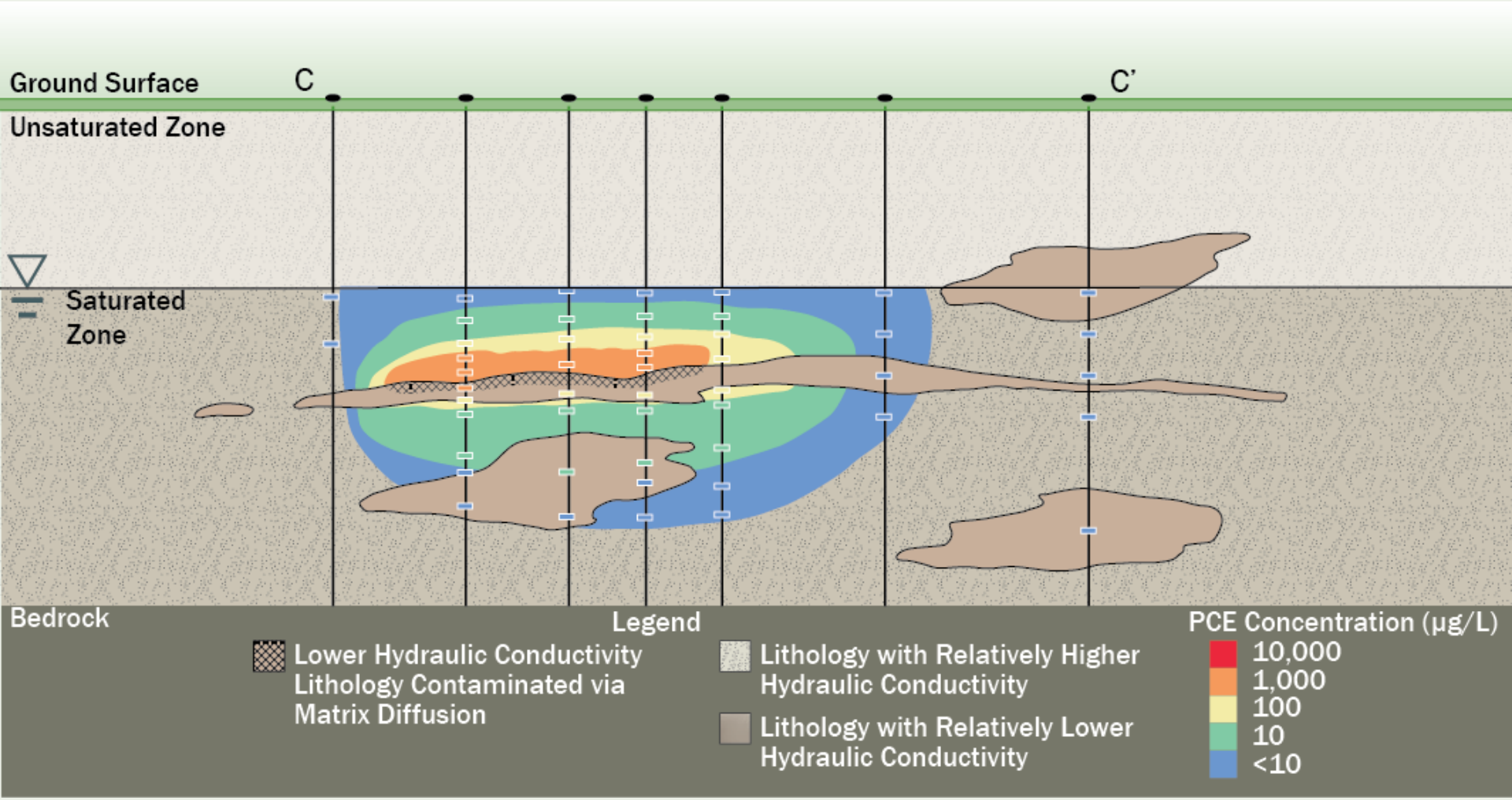

Ground Surface
C
C'
Unsaturated Zone
Saturated Zone
Bedrock
Legend
Lower Hydraulic Conductivity Lithology Contaminated via Matrix Diffusion
Lithology with Relatively Higher Hydraulic Conductivity
Lithology with Relatively Lower Hydraulic Conductivity
PCE Concentration (µg/L)
10,000
1,000
100
10
<10

Figure 6

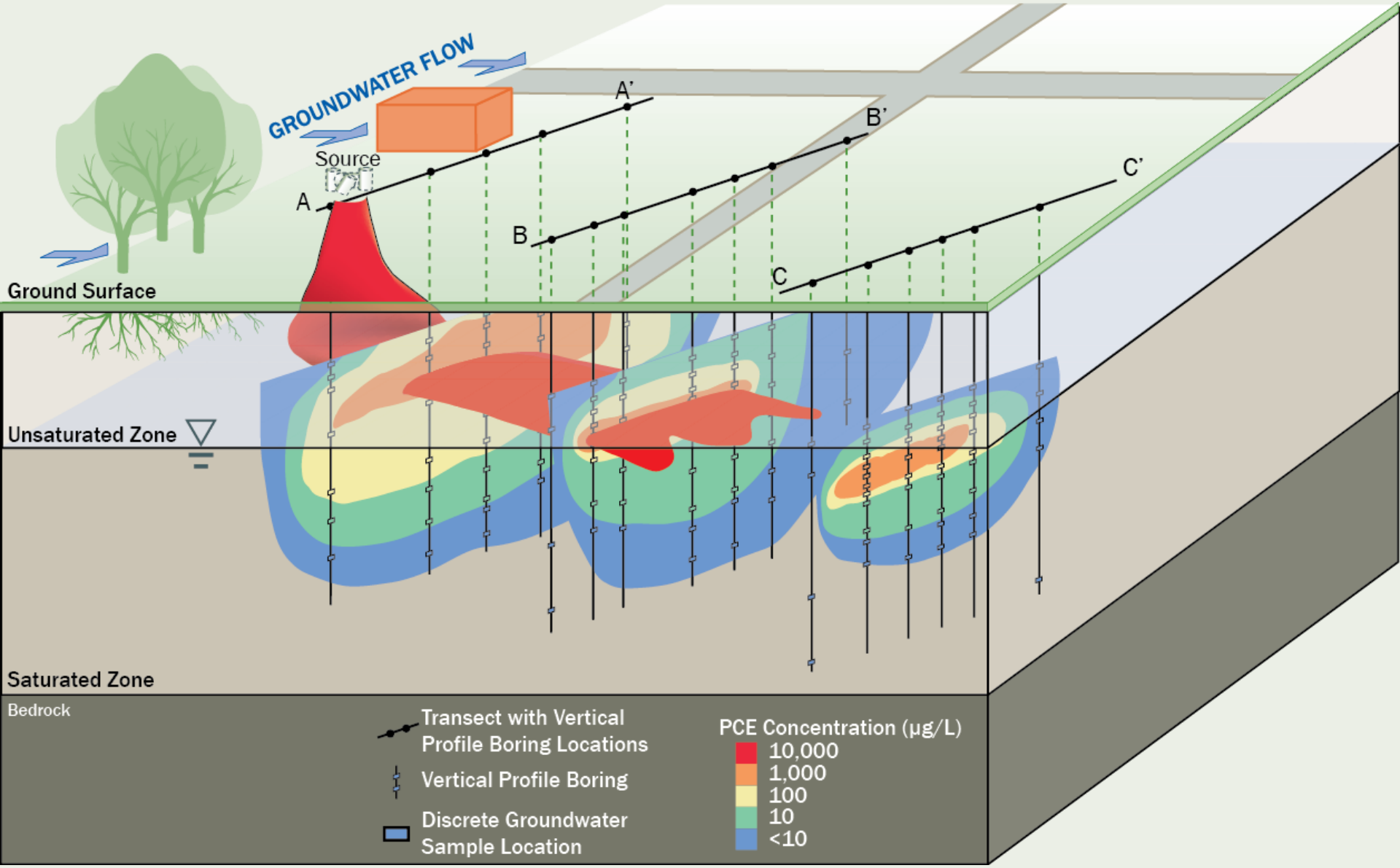
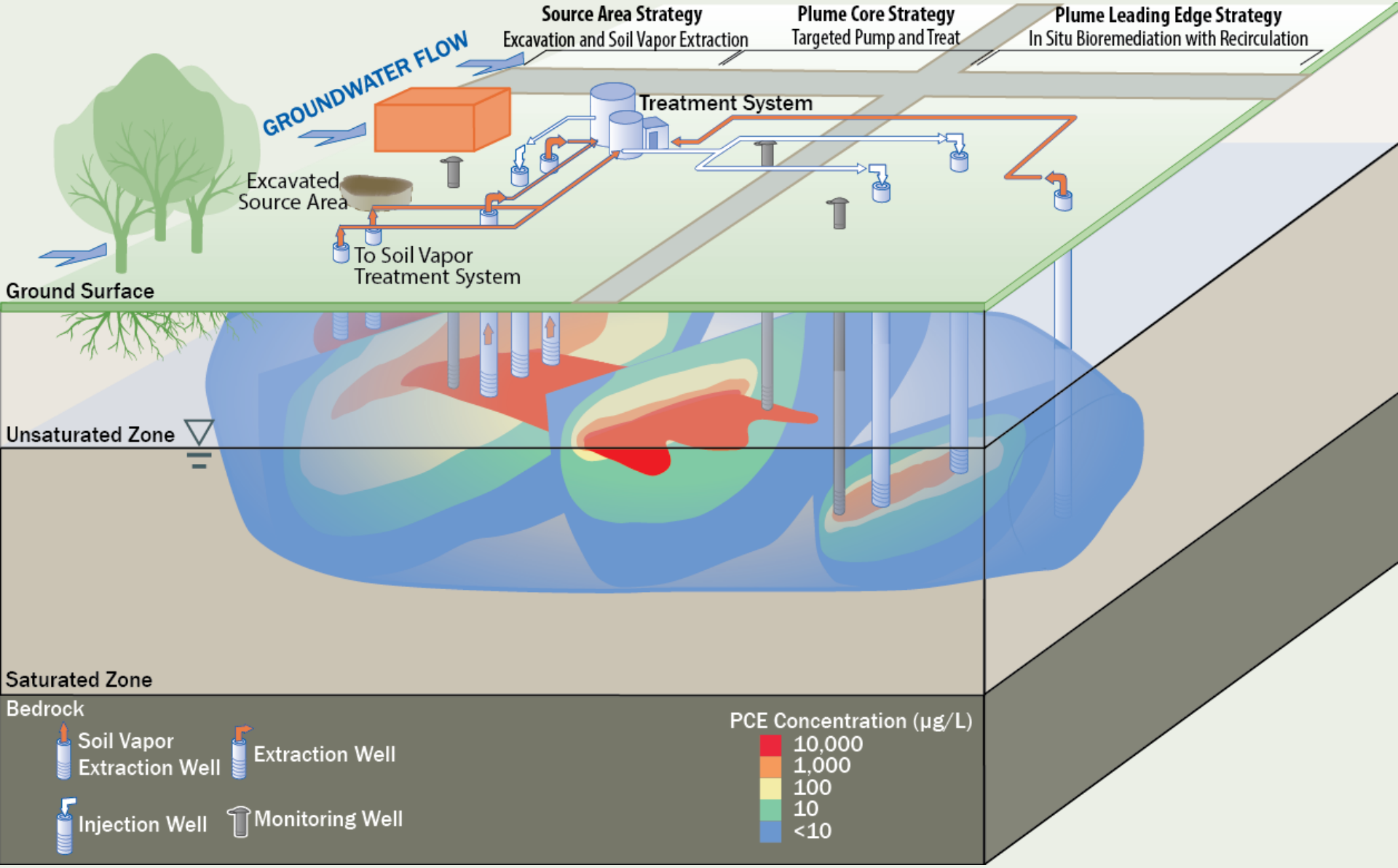
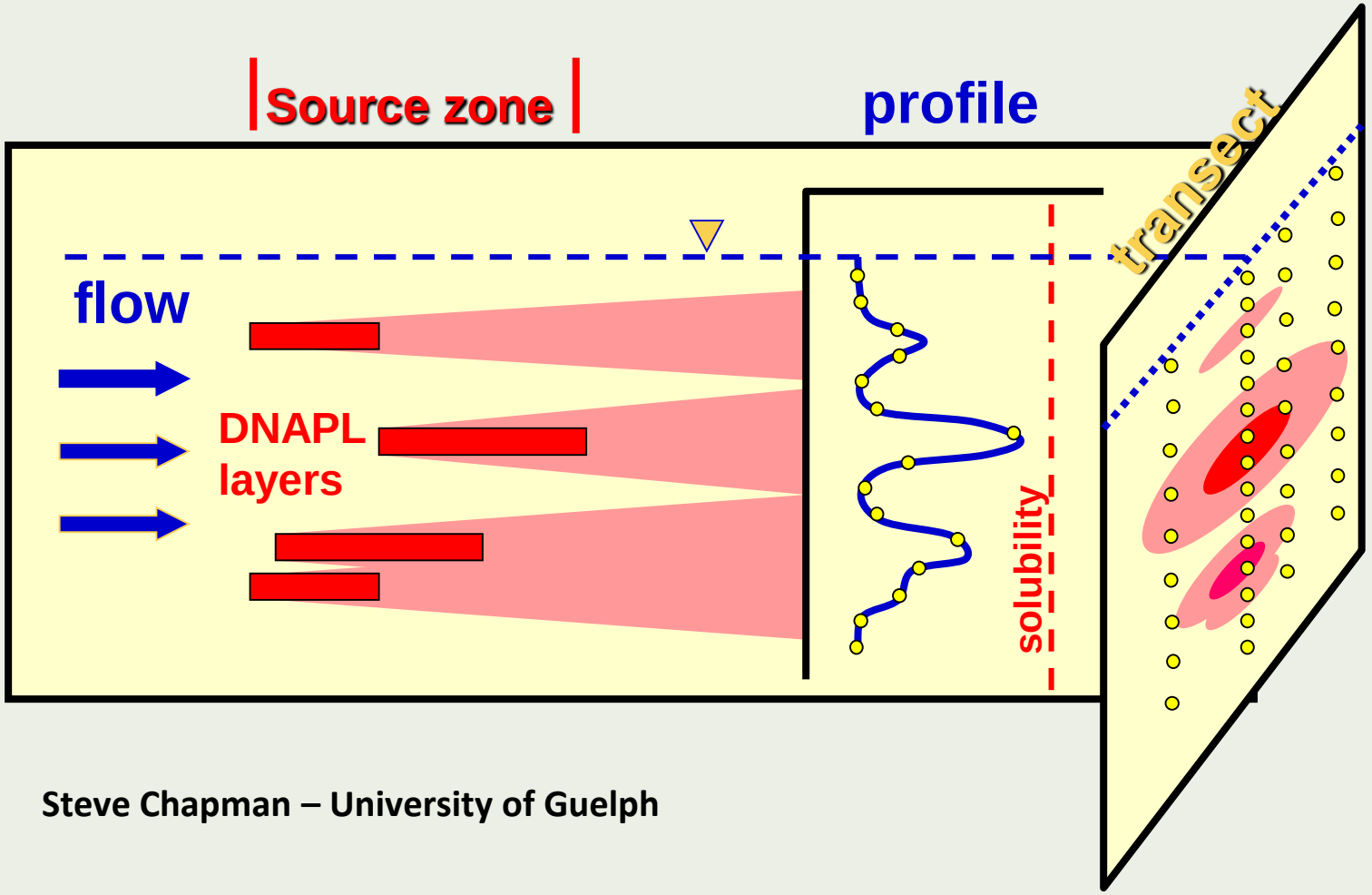

GROUNDWATER FLOW
Source
A
A'
B
B'
C
C'
Ground Surface
Unsaturated Zone
Saturated Zone
Bedrock
Transect with Vertical Profile Boring Locations
Vertical Profile Boring
Discrete Groundwater Sample Location
PCE Concentration (µg/L)
10,000
1,000
100
10
<10

Figure 7


Source Area Strategy
Excavation and Soil Vapor Extraction
Plume Core Strategy
Targeted Pump and Treat
Plume Leading Edge Strategy
In Situ Bioremediation with Recirculation
GROUNDWATER FLOW
Treatment System
Excavated Source Area
To Soil Vapor Treatment System
Ground Surface
Unsaturated Zone
Saturated Zone
Bedrock
Soil Vapor Extraction Well
Extraction Well
Injection Well
Monitoring Well
PCE Concentration (µg/L)
10,000
1,000
100
10
<10

Transect Approach for Groundwater Contaminant Plumes

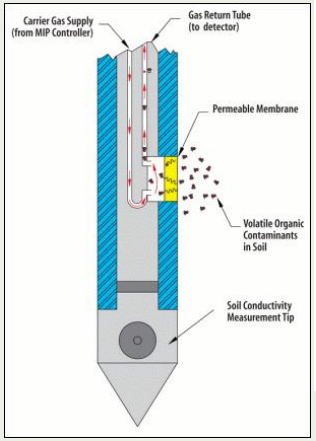


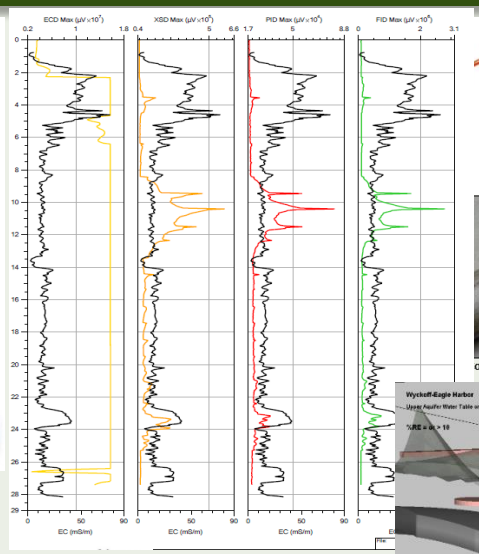
Steve Chapman – University of Guelph

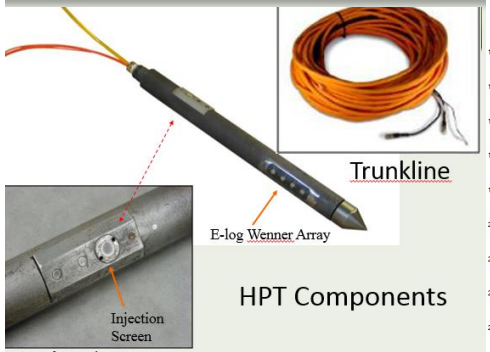
Tools for Obtaining Vertical Profiles in Unconsolidated Environments

- **Direct push groundwater sampling devices:**
  - » Geoprobe SP16/SP21 – Waterloo^{APS} – BAT Sampler – Cone Sipper
- **Hydrostratigraphic measurements:**
  - » Electrical Conductivity (EC) – Cone penetrometer – Geoprobe Hydraulic Profiling Tool – Waterloo^{APS}
- **Qualitative contaminant data:**
  - » Membrane Interface Probe (w/FID, PID, ECD, XSD) – Laser-Induced Fluorescence (LIF) – Immunoassay – Colorimetric
- **Quantitative contaminant data:**
  - » Mobile laboratory – Fixed laboratory

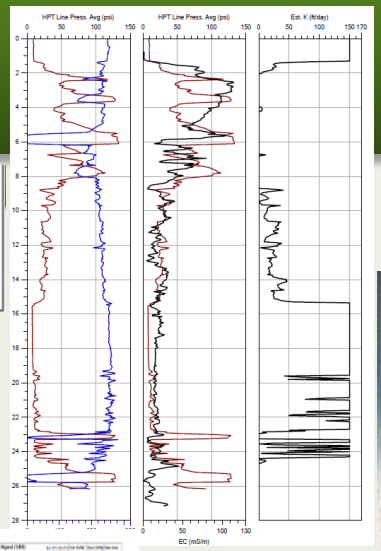
Tools

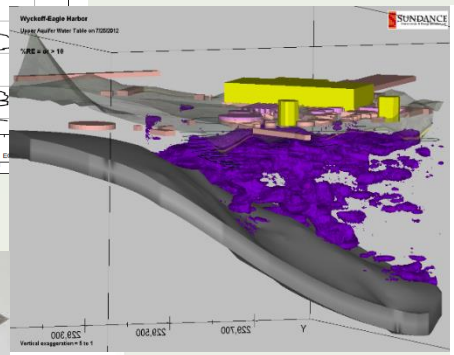


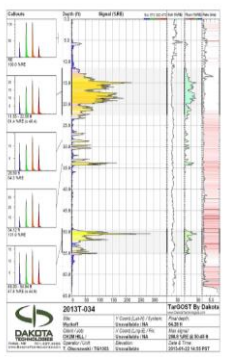


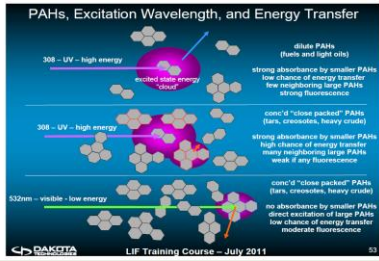


HPT Components

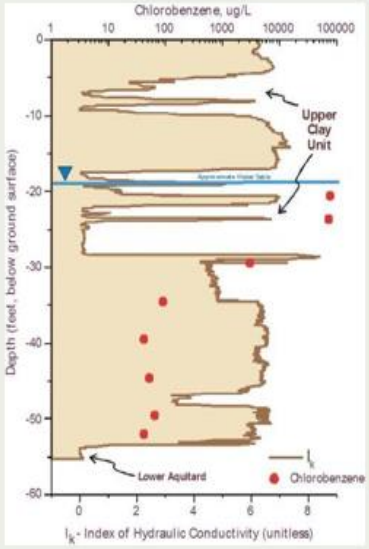




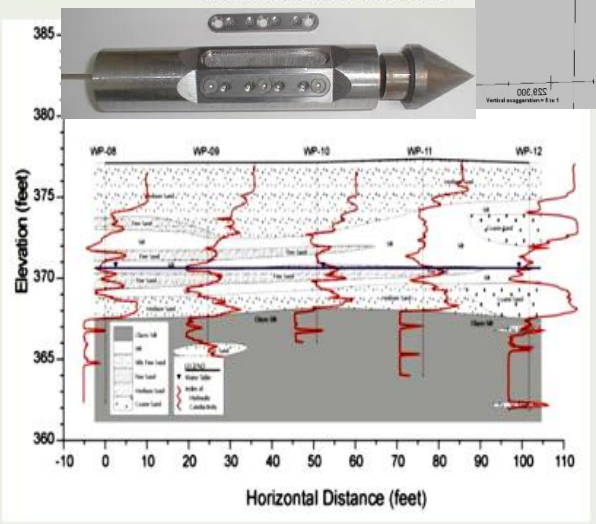


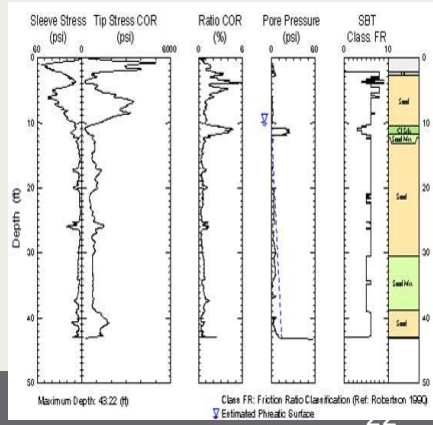


Sample depth selection



Stratigraphic Interpretation





Tools for Fractured Media

- **Rock core measurements**
  - » Contaminant analysis with microwave assisted extraction – Physical, mineralogical, and microbial measurements – Degradation microcosms
- **Open hole measurements (time during which boreholes are open should be minimized):**
  - » Groundwater sampling – Geophysics – Packer testing – Flow metering – Temperature
- **Lined hole measurements:**
  - » Geophysics – Temperature – Transmissivity profiling – Multi-level sampling

Why HRSC?

What Are the Benefits of HRSC?

- **Overall cost and time savings:**
  - Reduces remedial footprint
  - Increases remedial efficiency
  - Reduces project time frames

Increases Remedy Effectiveness

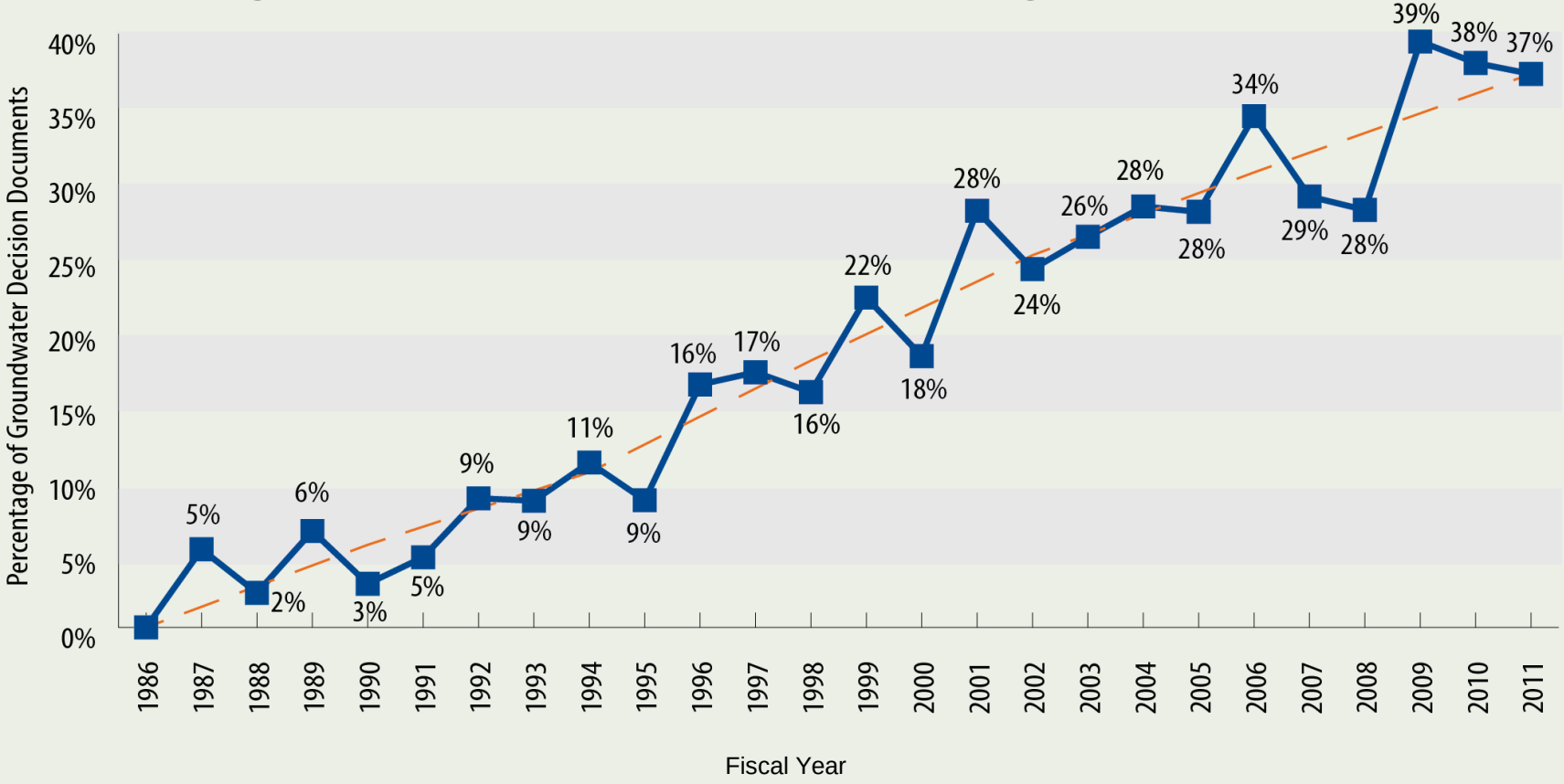
- **HRSC increases remedy effectiveness by providing a detailed and realistic CSM:**
  - » Correlating contaminant data with stratigraphic and lithologic data
  - » Identifying and delineating source zones
  - » Identifying contaminant mass flux
    - › In both mobile and immobile porosity zones
  - » Identifying plume core and evaluating plume stability
  - » Characterizing fate and transport of contaminants in the subsurface
- **A detailed and more realistic CSM allows for evaluation of targeted in situ and ex situ remedies**

Cost of Remedies vs. Cost of Characterization

- **Remedies based on a flawed CSM may not perform as expected, increasing the time it takes to achieve remedial action objectives, and the overall cost**
- **HRSC makes the investment upfront to obtain a more complete and realistic CSM**
- **Pay a little more now to avoid paying a lot more later**
  - » Until the CSM reflects reality, investigation and cleanup will be costly – pay the costs upfront and get the CSM right the first time in order to avoid paying more later

HRSC Applies to Increased Use of *In Situ* Groundwater Remedies

Figure 13: Trends in Groundwater Decision Documents Selecting In Situ Treatment (FY 1986-2011)



In Review

- HRSC is a methodology for understanding and properly accounting for the affects of subsurface heterogeneity
- HRSC uses scale-appropriate measurements and sample spacings that are consistent with the scale of variability of the property being measured
- Transect-based vertical profiling planned and implemented
- Benefits of HRSC
  - » Reduces remedial footprint
  - » Increases remedial efficiency
  - » Reduces project time frames

Questions?

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