Monitoring of In-Situ Chemical Oxidation (ISCO) with Time Series Geophysical Surveys

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Review of Time Series Geophysical Surveys for ISCO

- Repeated geophysical surveys to identify temporal change in bulk (formation and fluid) “electrical” properties at discrete depths

  - Includes background or pre-injection survey

- Effective with electrically conductive injectate, i.e. permanganate
- Allows for a more complete picture of treatment
- Provides enhanced mapping capability when coupled with conventional monitoring

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Application of Time Series Geophysical Surveys for ISCO

- Signal to noise ratio and signal strength

  -Electrical signal > Measurement resolution

- Site infrastructure considerations

  -Interferences

- Well construction (tool specific)

- Selection of the correct method/tool

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Geophysical Survey Methods

- Surface (e.g. Electromagnetic (EM), Direct Current (DC) resistivity)
- Borehole Logging (e.g. EM, **Gamma, **Neutron, **ATV)
- Cross hole (e.g. Radar, Radio frequency, Electrical (ERT))
- Surface to Borehole (e.g. Electrical, Heat, Radar, etc.)

**Geologic characterization

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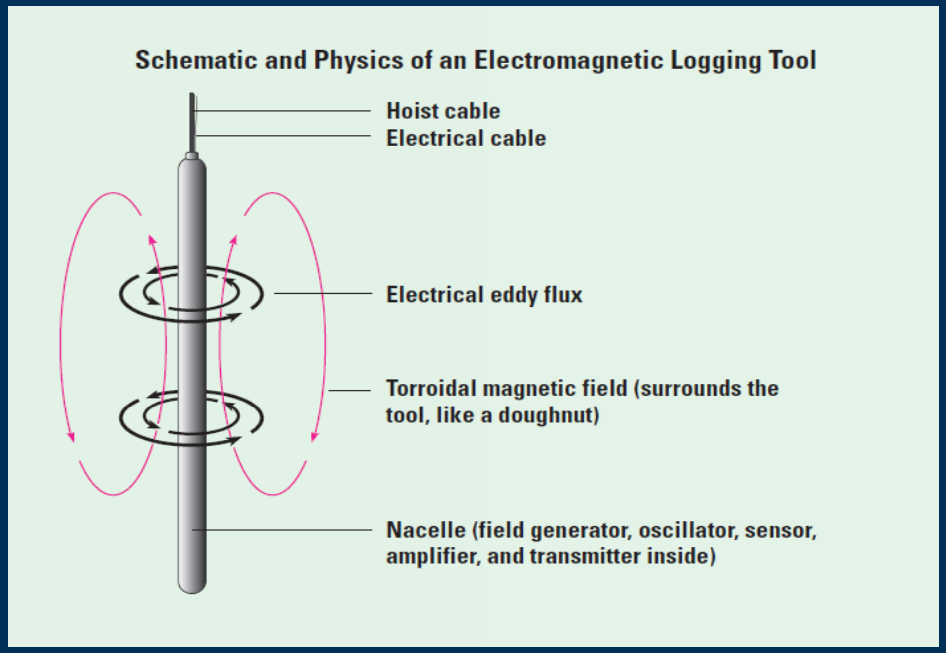
Method 1: Borehole Electromagnetic (EM) Log



- Works in open holes, pvc wells, 2 inches or greater
- Induces current and measures formation bulk electrical properties (including water conductivity) beyond solid wall pvc casing or screen
  - -Does not require direct fluid or formation contact

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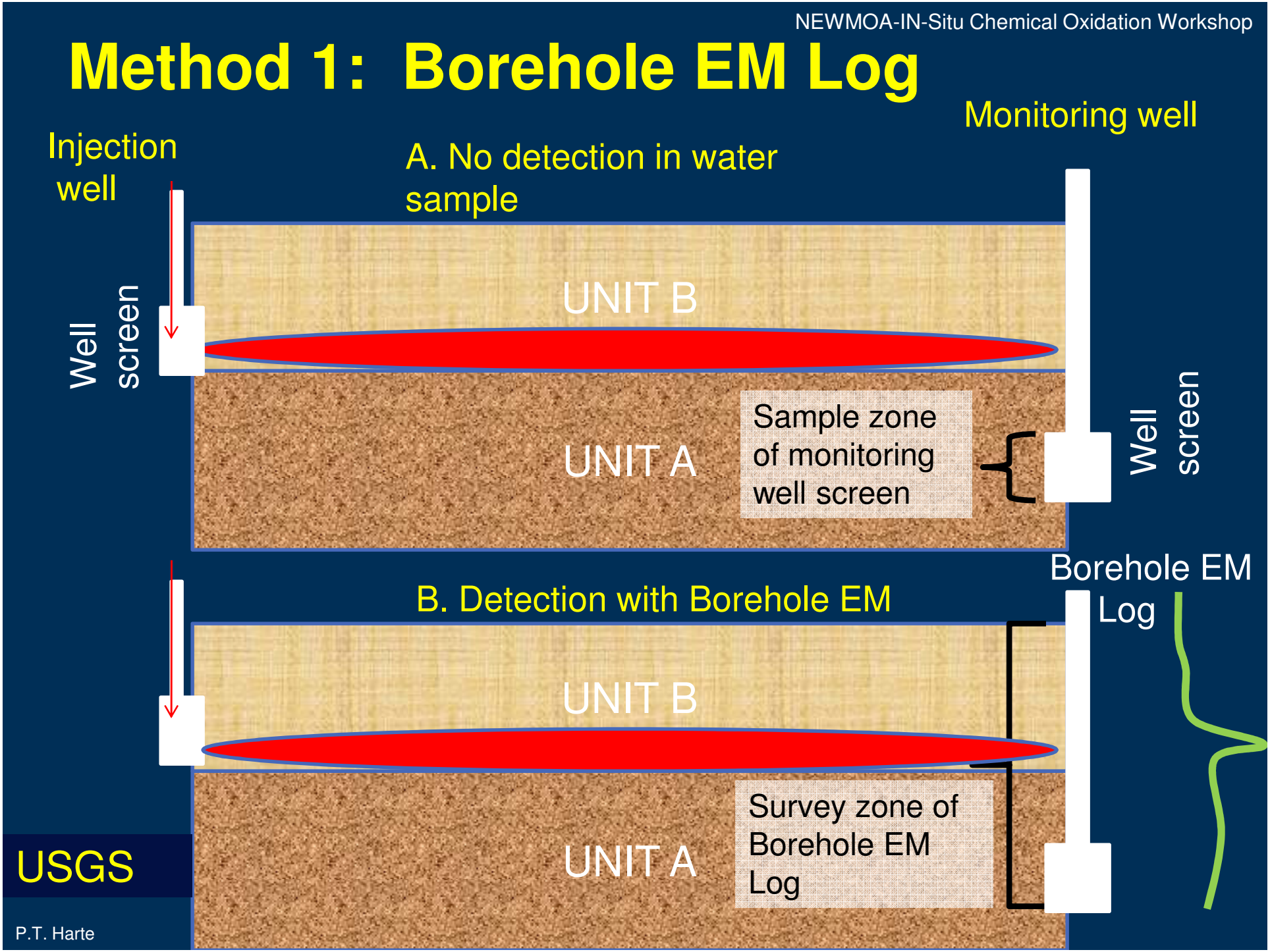
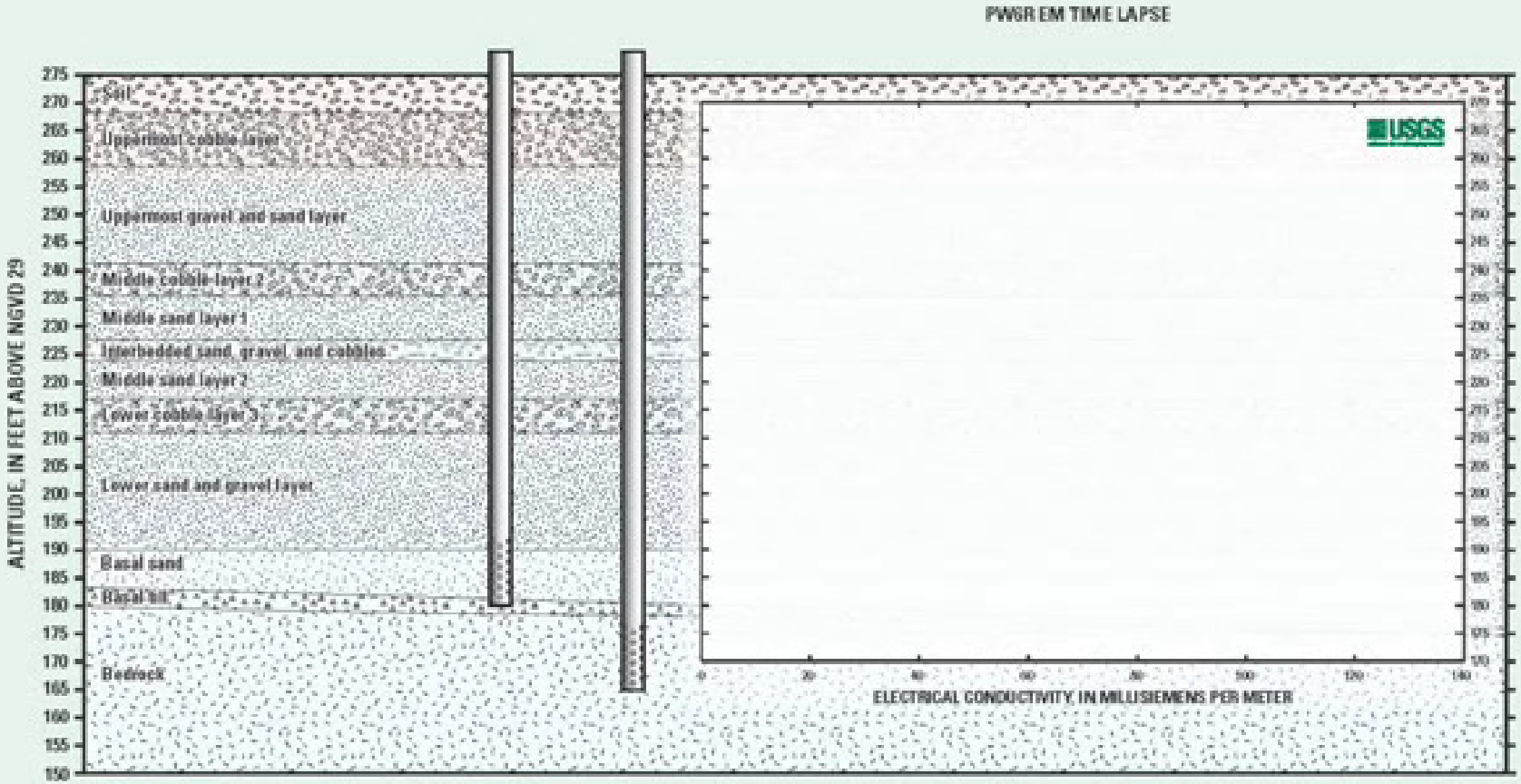
Method 1: Borehole EM Log



Animation of injection/EM logging



-Placeholder-

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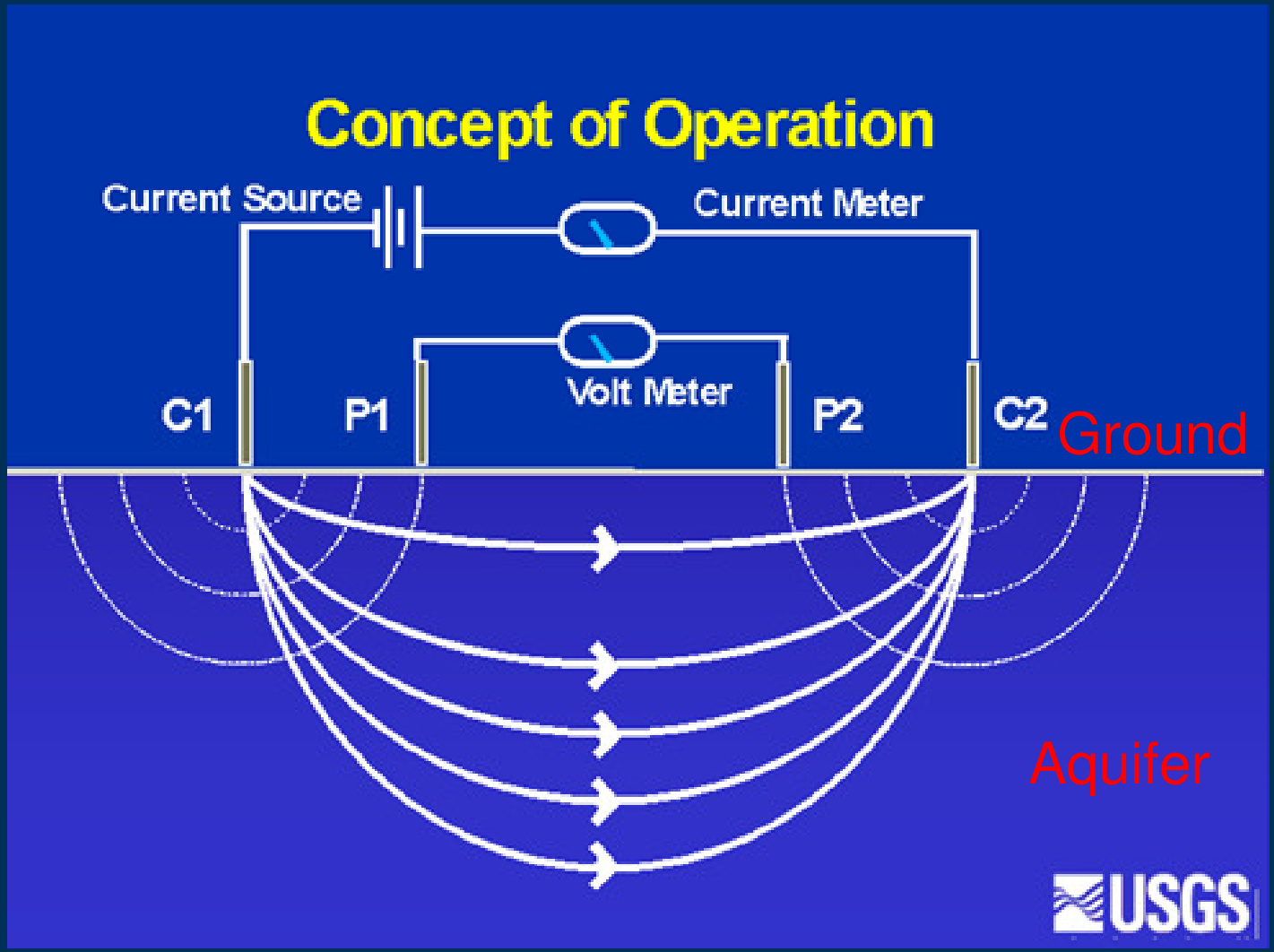
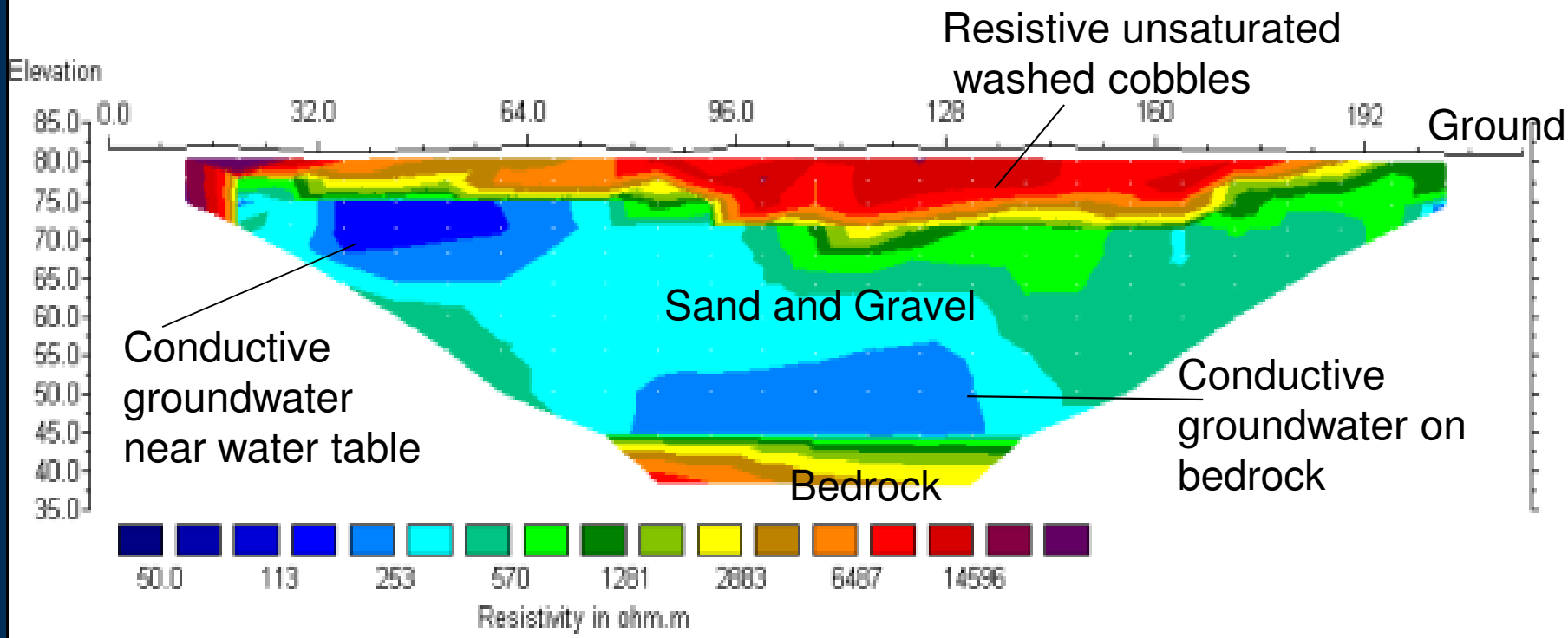
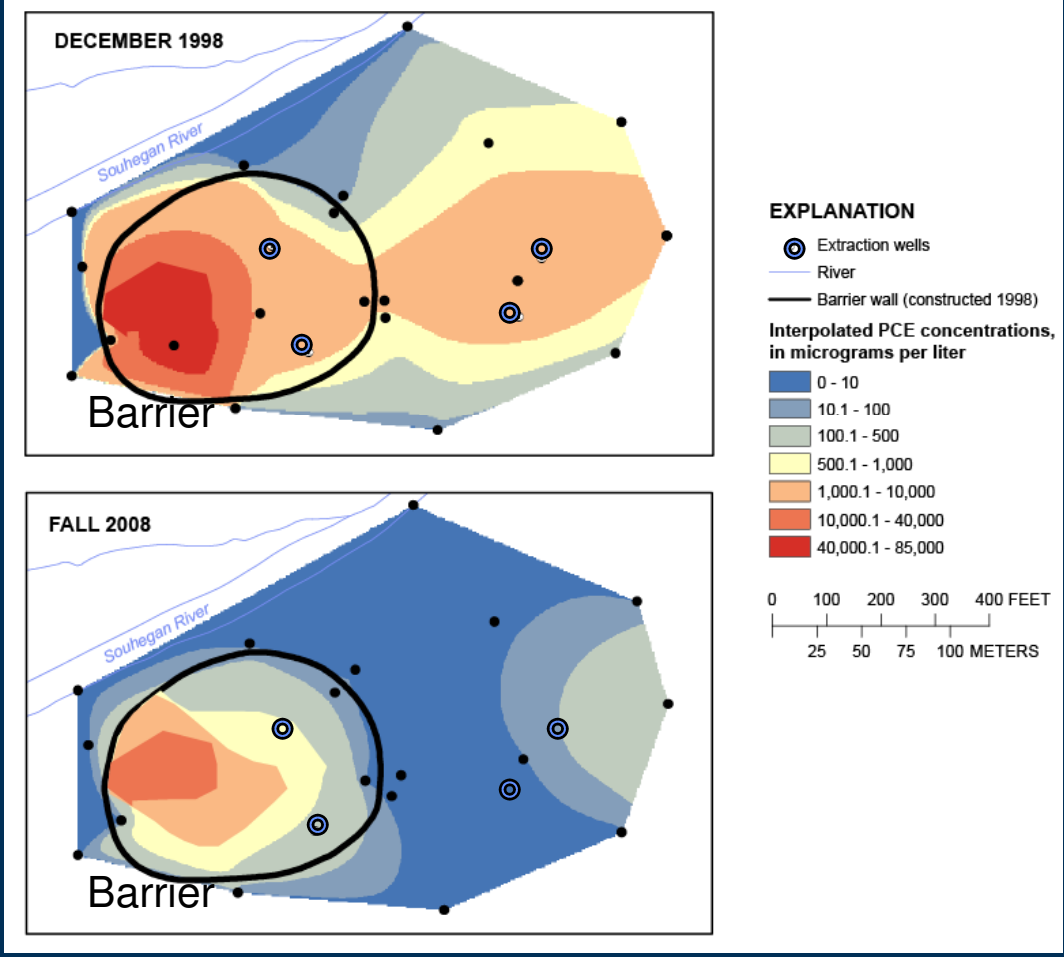
Method 2: Surface Direct Current (DC) Resistivity



Method 2: Surface Direct Current (DC) Resistivity



Permanganate Injection, OU1, Savage Superfund Site, Milford, NH



- PCE contaminant plume in a sand and gravel aquifer
- OU1 treatment system contains barrier wall, and pump-n-treat system (since 1999)
- Outside barrier, PCE declines to below 10 ppb in many areas
- Inside barrier, declines slow
- ISCO Treatment initiated several times with permanganate

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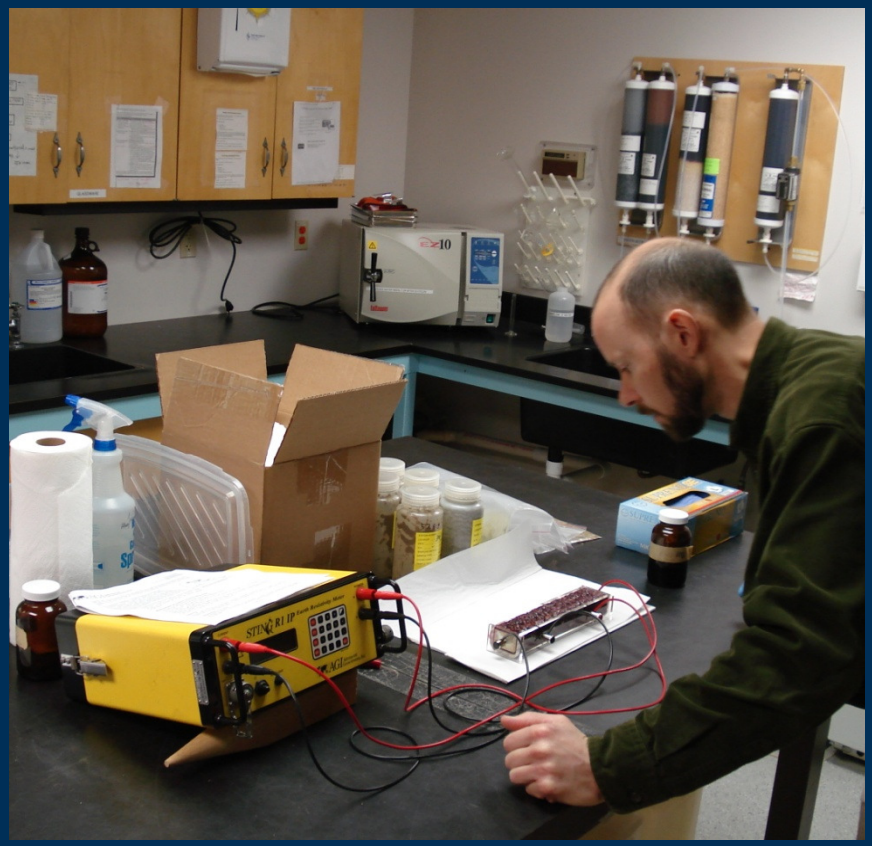
Permanganate-DC Resistivity/Conductivity Lab Testing



- Calibrate field results to geology
- Measure differences in bulk electrical conductivity with the addition of permanganate (and changes to pore fluid conductivity)

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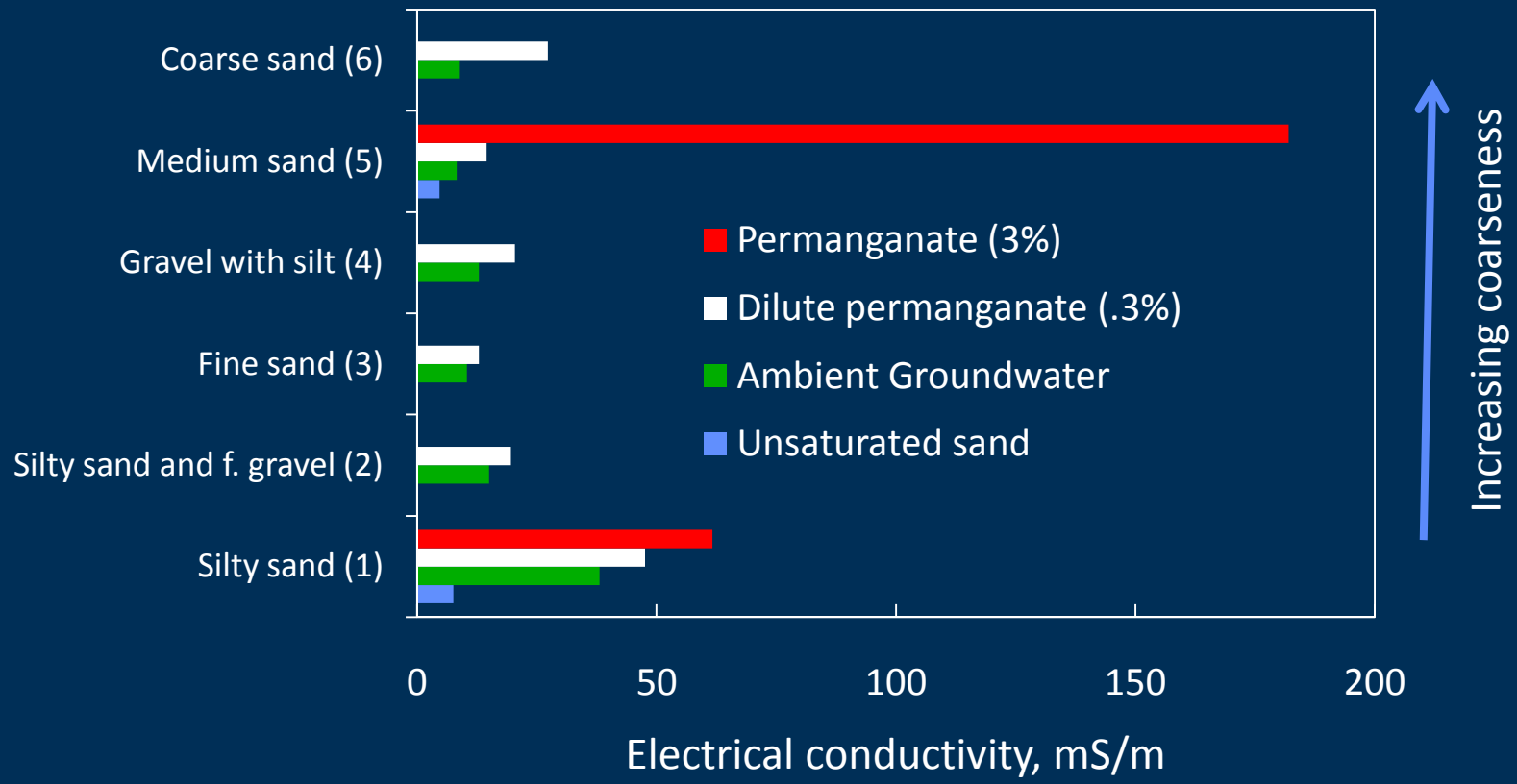
DC Resistivity Lab Testing Results



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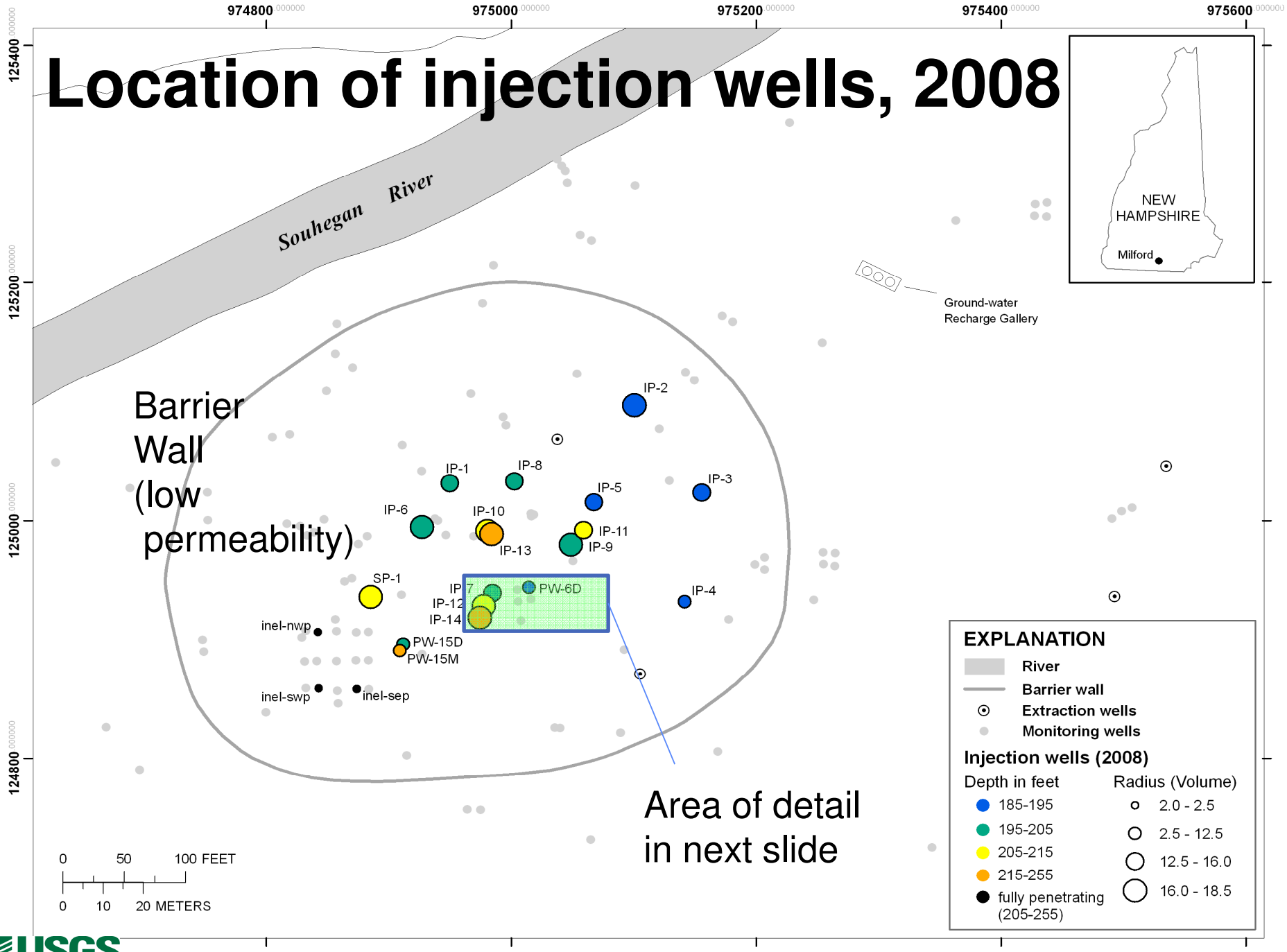
"Bulk measurement of formation and pore fluid"

Location of injection wells, 2008



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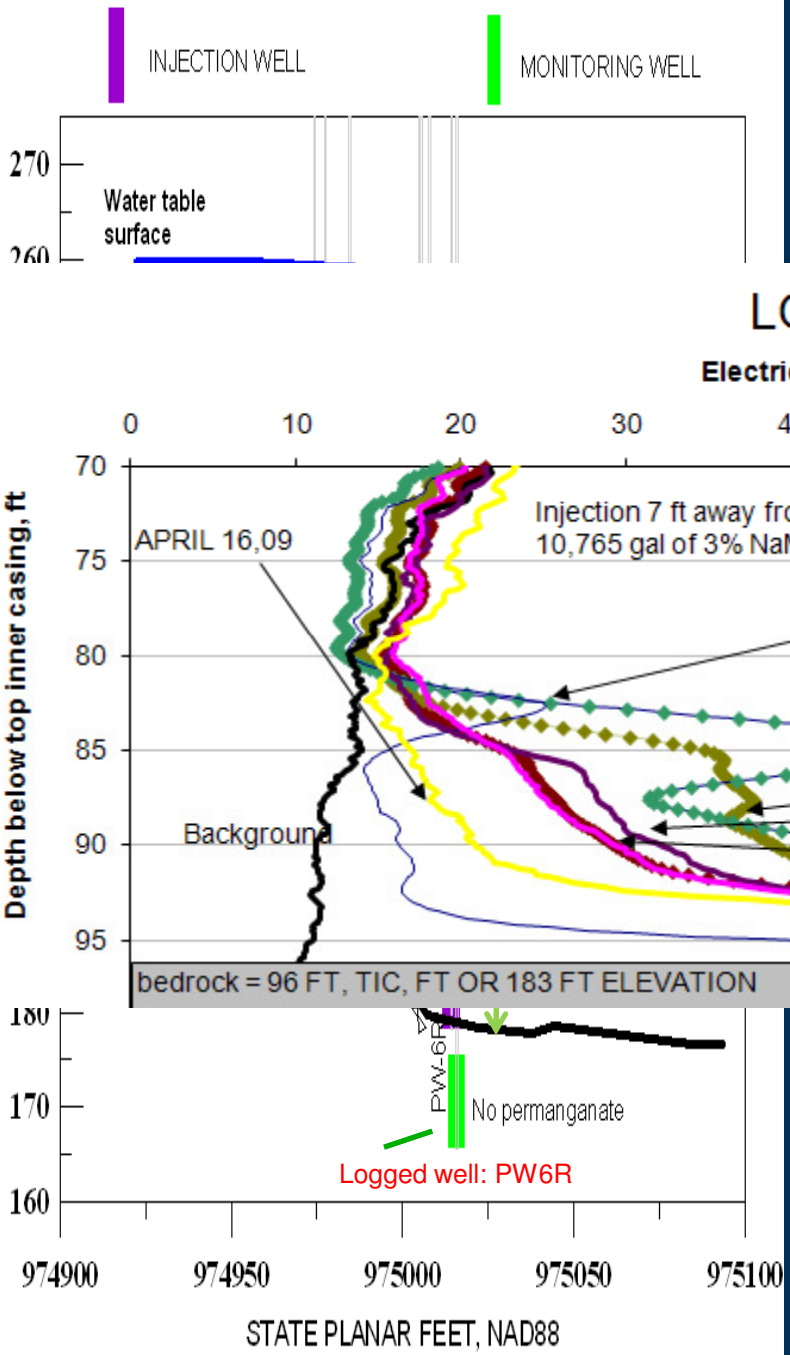
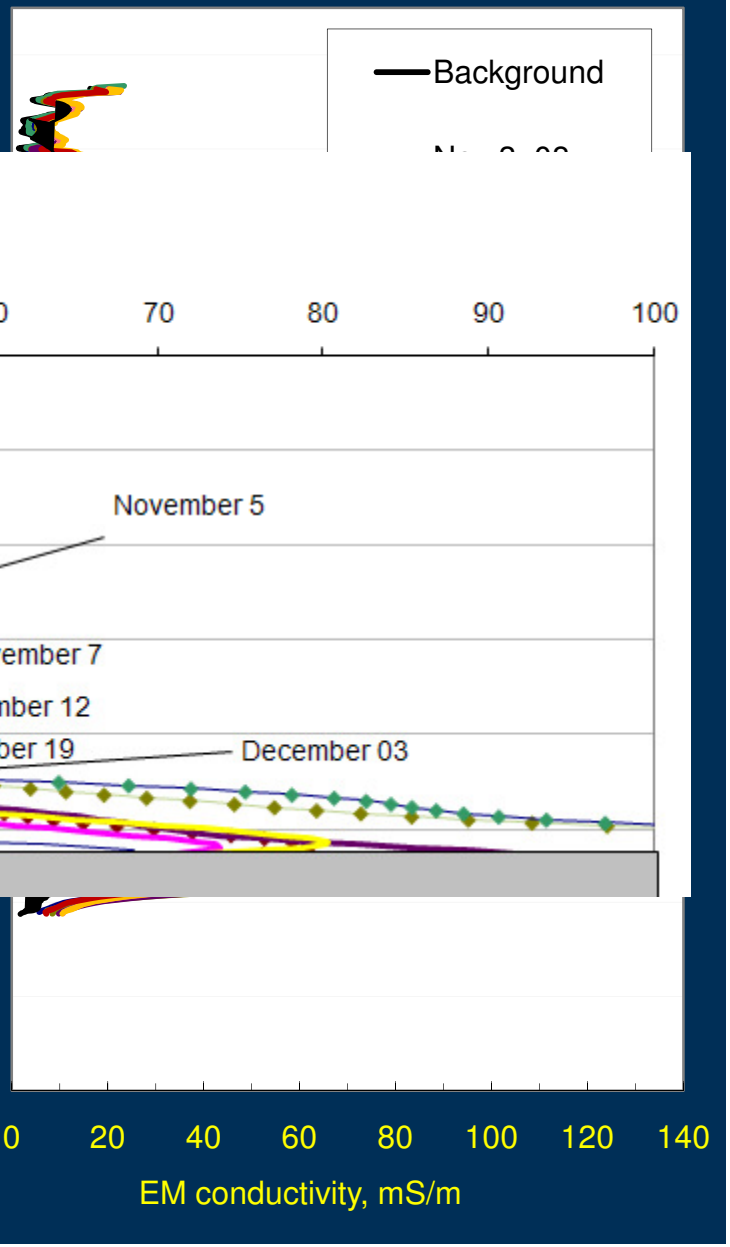
ISCO 2008 INJECTION SCREEN INTERVALS (PW-6R)



Stratigraphy

PW-6R EM time series



LOG -PW6R

Temporal PCE

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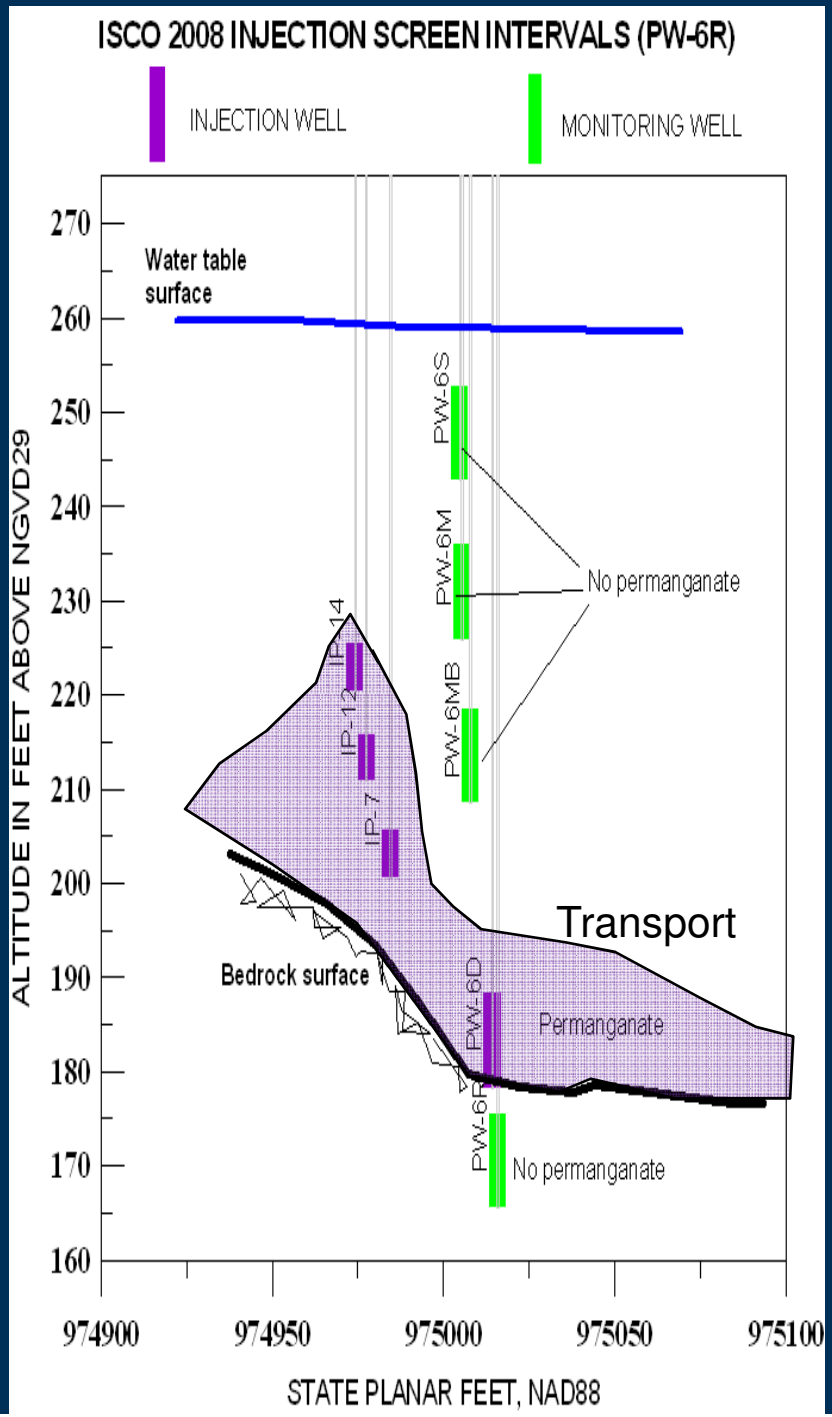

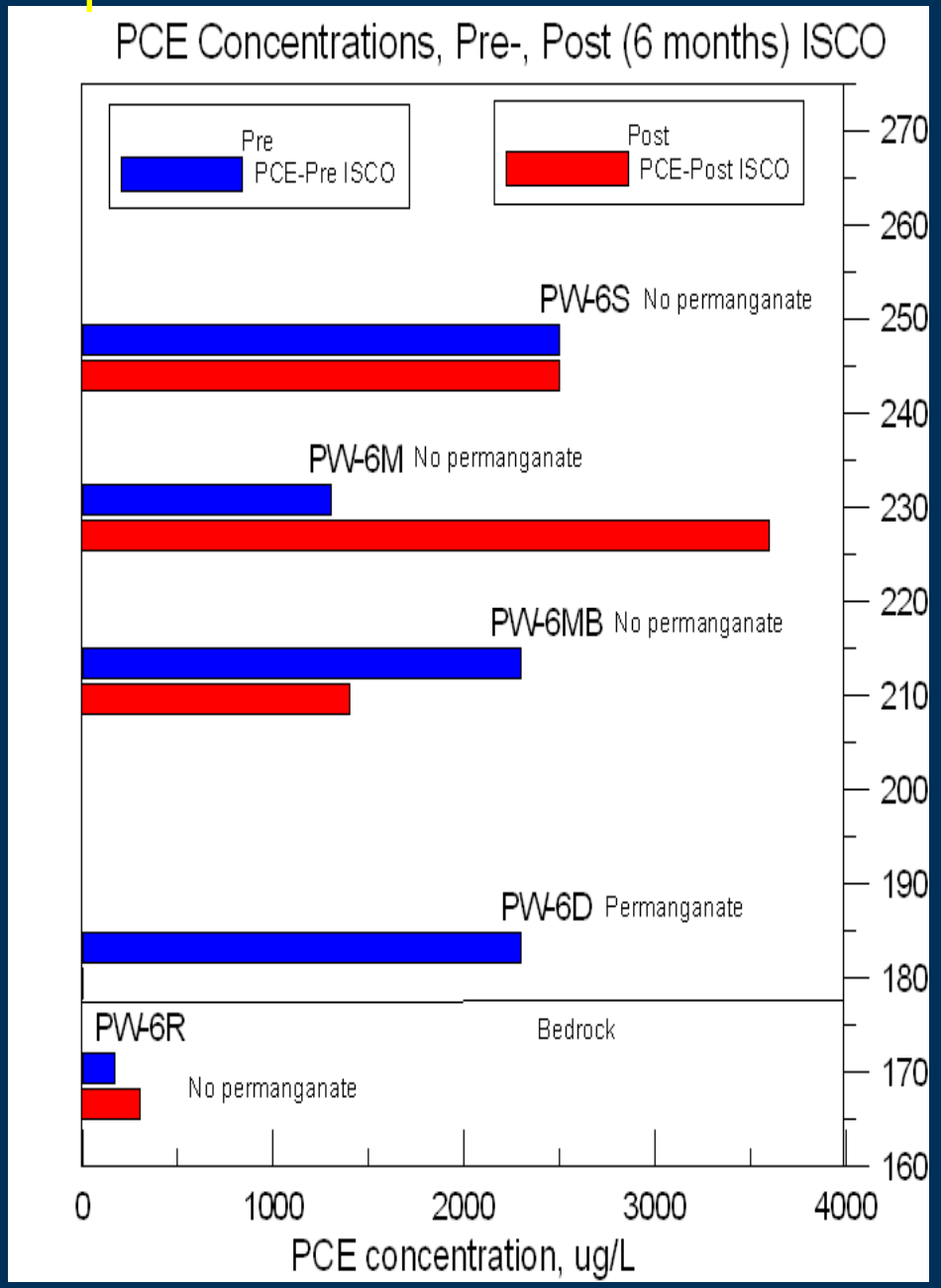

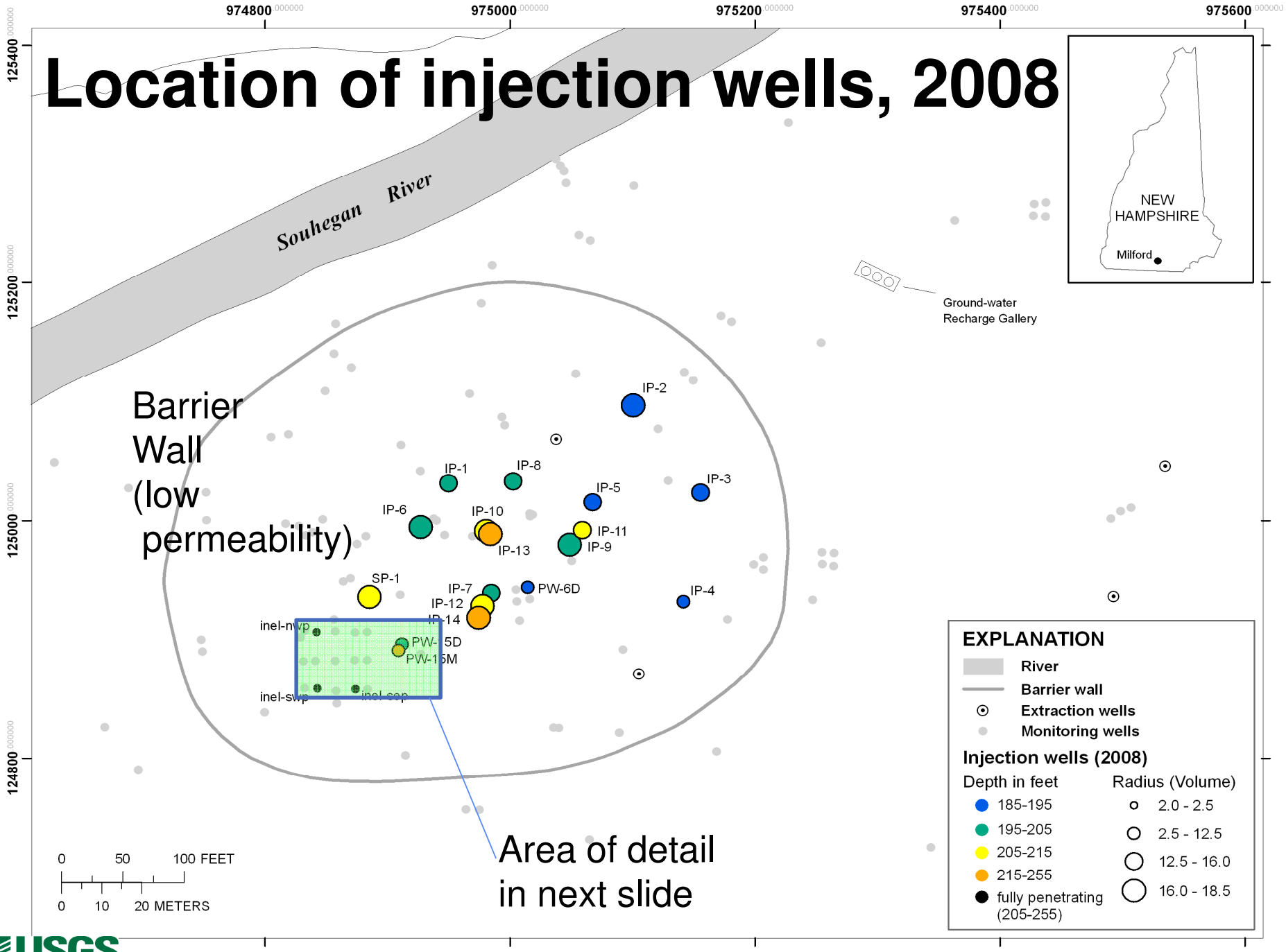

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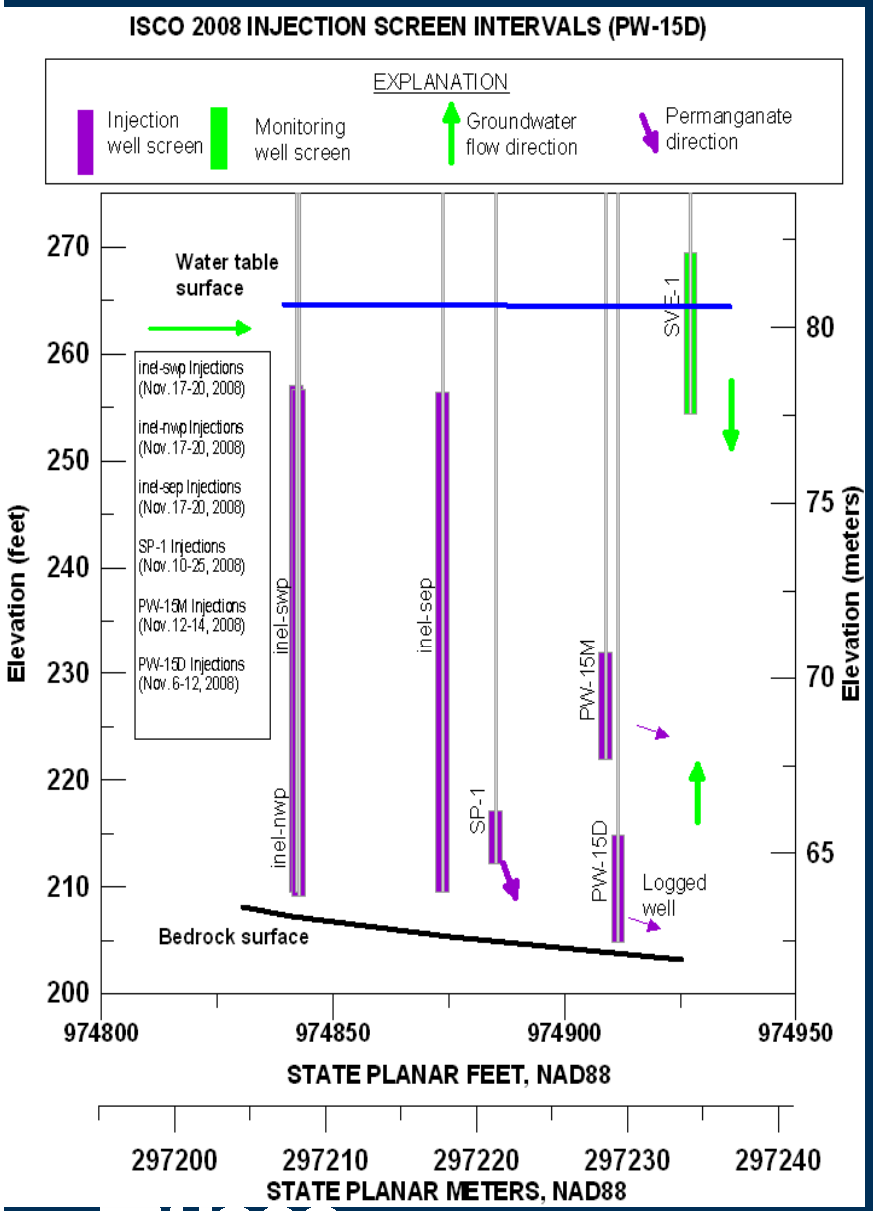
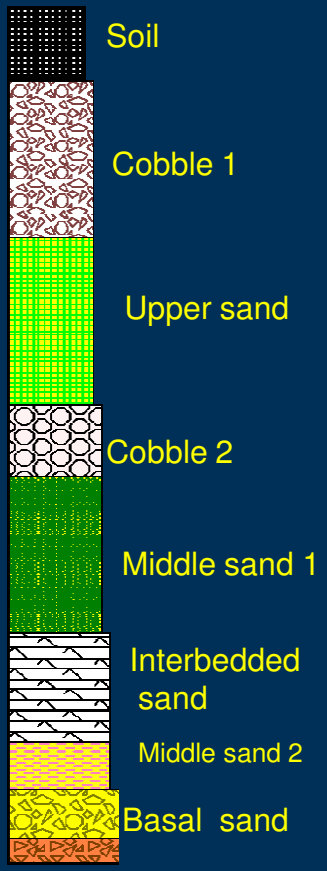
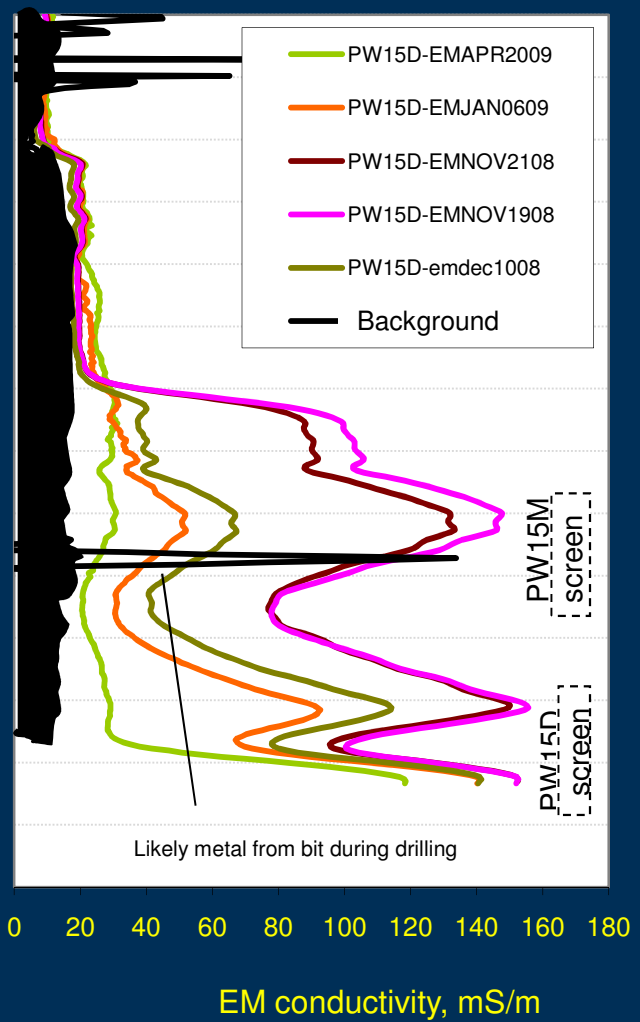


Stratigraphy



PW-15D EM time series



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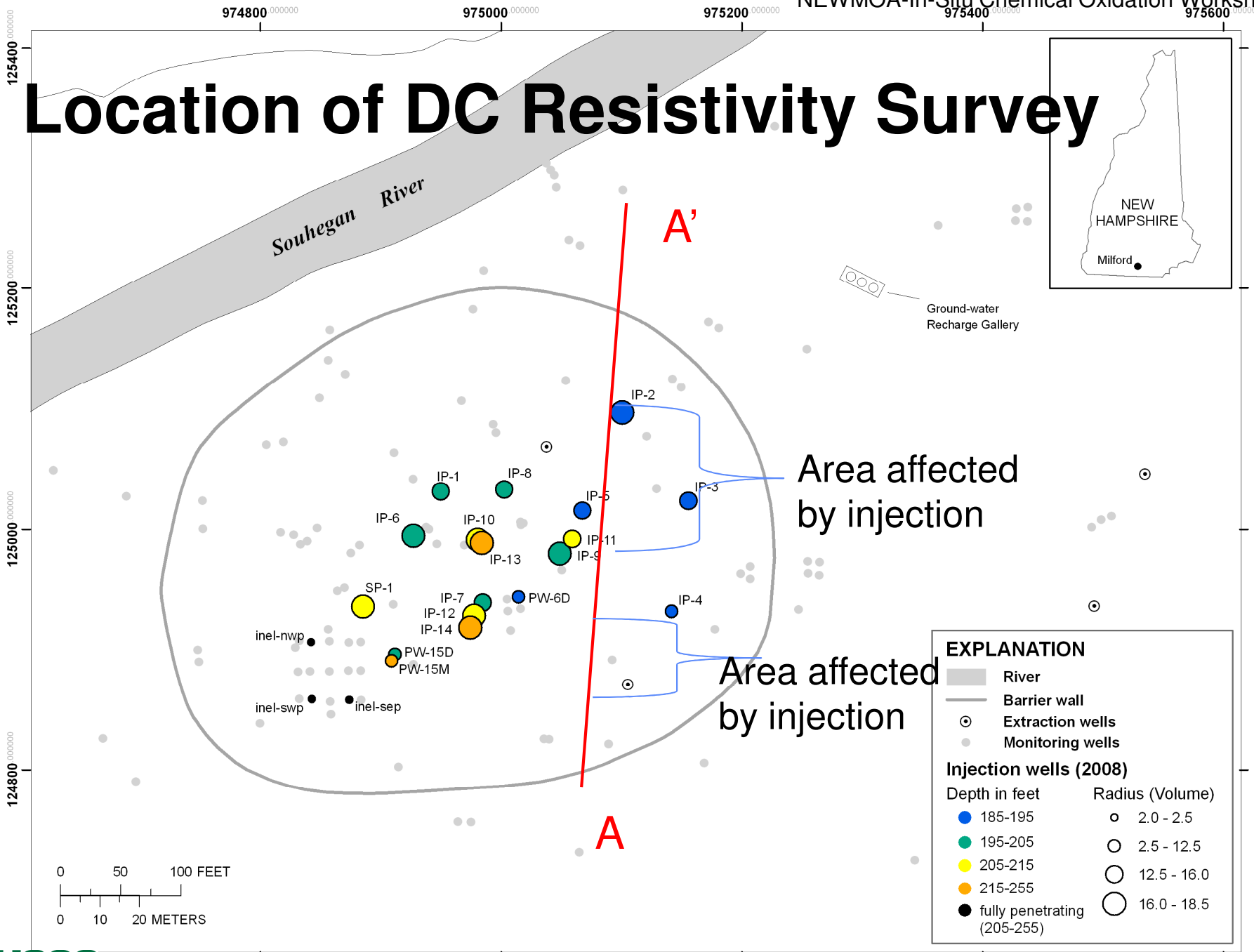
Location of DC Resistivity Survey



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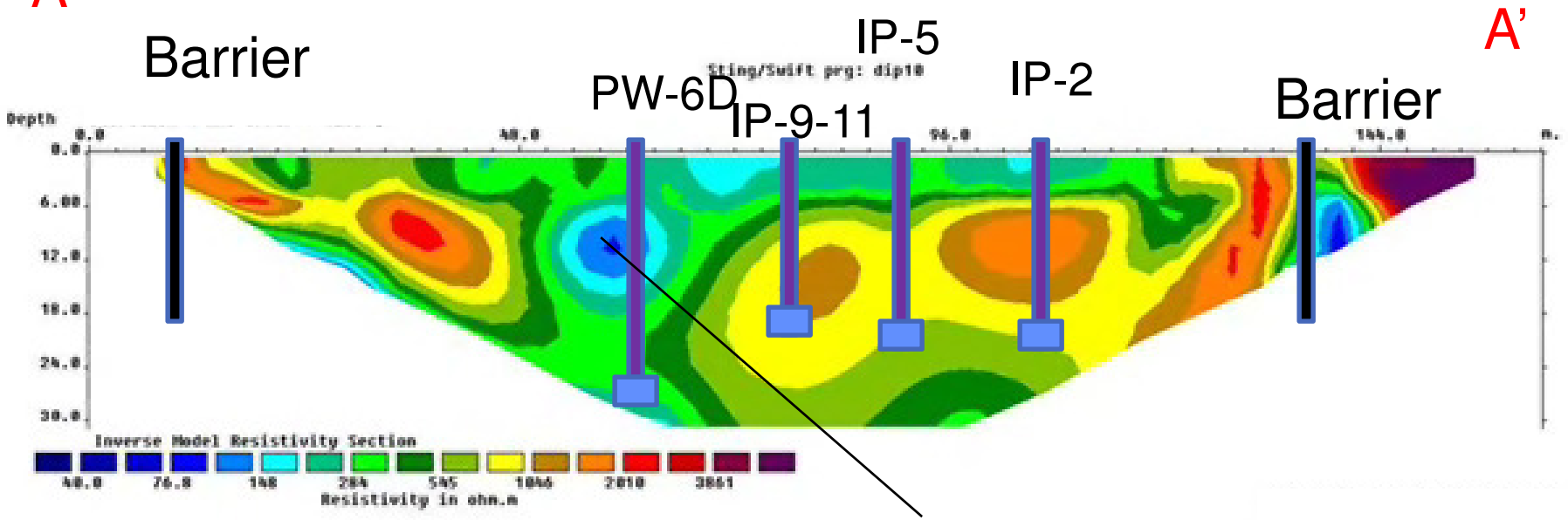
Background DC Resistivity Survey

30 Sept 2008



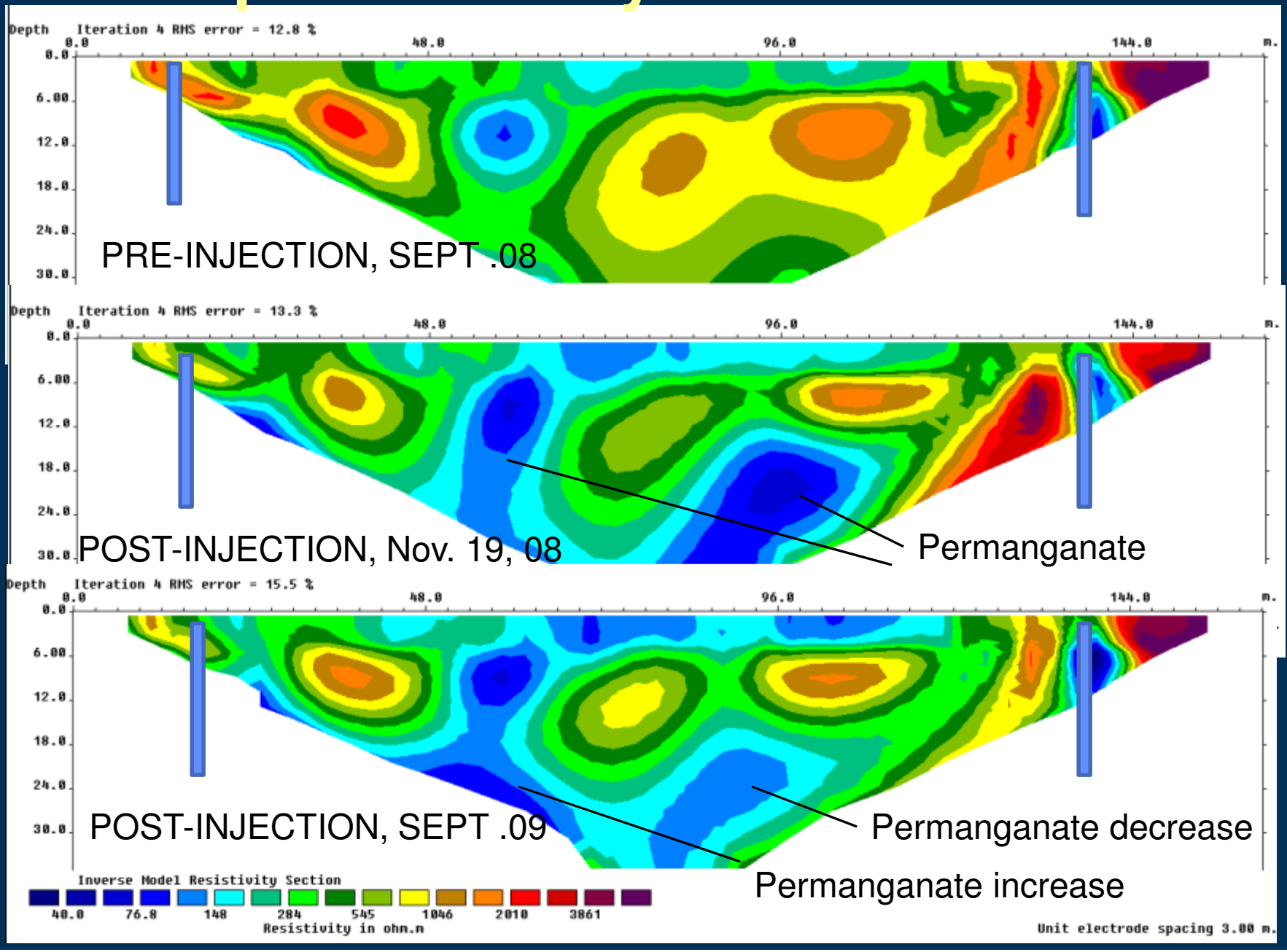
40 400 4,000

Resistivity, ohm-m

Temporal Surveys

A

A’



Summary- Time series geophysical surveys

- Provided enhanced mapping capabilities
- Effectively tracked spread of permanganate
- Established framework to interpret post-PCE trends
- Identified data gaps
- Identified density induced transport control
- Aided in formulation of alternate injection strategies

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Acknowledgments

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