TIPS AND TRICKS TO IMPROVE GROUNDWATER REMEDY SELECTION AND PERFORMANCE

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EPA Region 5

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https://www.epa.gov/remedytech/technical-support-project-cleaning-contaminated-sites

What is the Groundwater Forum Mission?

Support **Technology Transfer** for GW Characterization and Remediation

Build Consistency Between EPA Regions in Application of Guidance

Develop Issue **Papers and Fact Sheets** on Pertinent Topics

Review and Comment on Groundwater Guidance, Publications, and Documents

Who Makes Up the Groundwater Forum?

- Hydrogeologists from Each Region
- Geologists, Scientists, and Engineers from ORD and HQ
- State Participants

Voting Members

- Regional Employee
- Support RCRA or Superfund
- Geology Degree or Substantive Geology Experience

Innovative Technology Evaluation

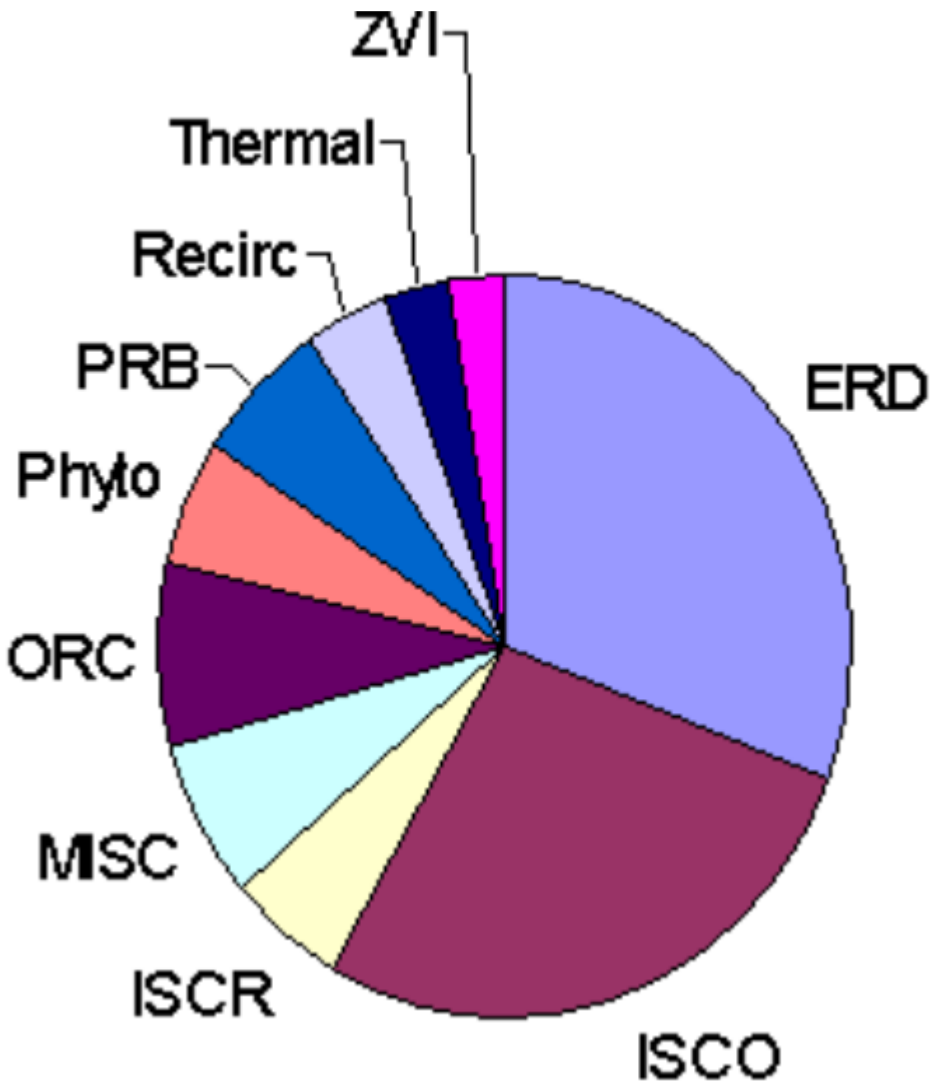
Evaluated technologies used to treat contaminated groundwater at 100+ sites

Certain technologies may be more effective than others

Several examples of success and failure and lessons learned

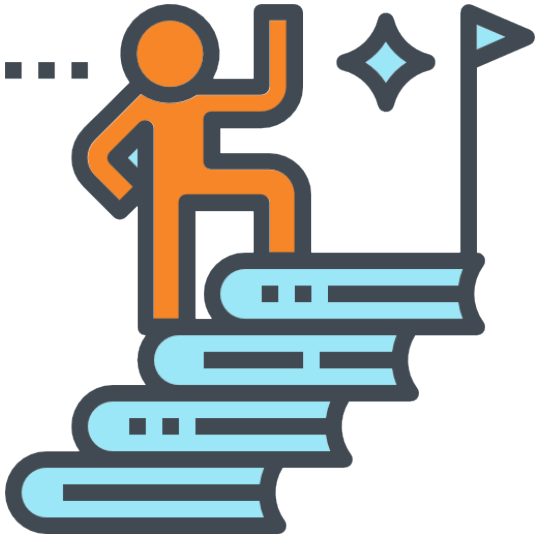
We can improve the success of technology selection, implementation, and monitoring

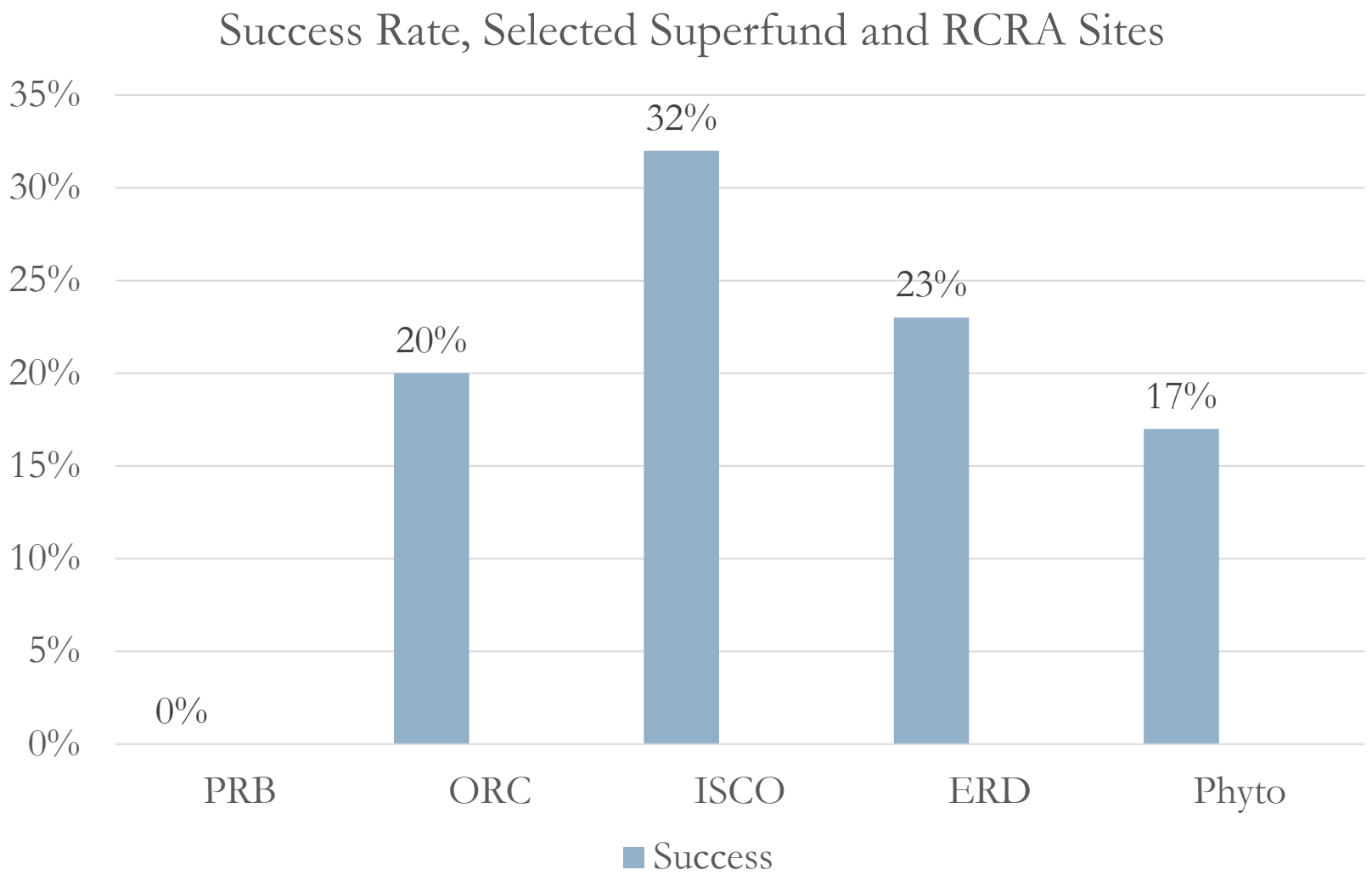
Technologies Evaluated



Technology	#Sites
ERD	39
ISCO	35
ORC	10
PRB	8
ISCR	7
PHYTO	7
RECIRC	5
THERMAL	4
ZVI/NZVI	3
MISC	9
TOTAL	126

WHAT IS SUCCESS?



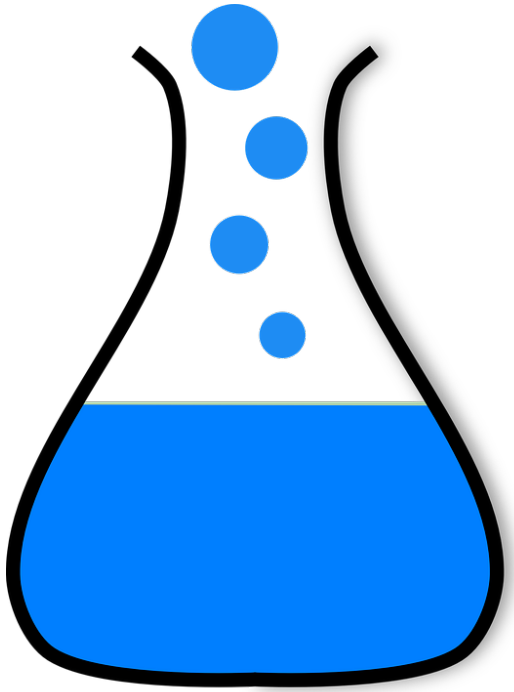

Success Rate, Selected Superfund and RCRA Sites
35%
30%
25%
20%
15%
10%
5%
0%
0%
20%
32%
23%
17%
PRB
ORC
ISCO
ERD
Phyto
Success

Primary Causes of Poor Remedy Performance

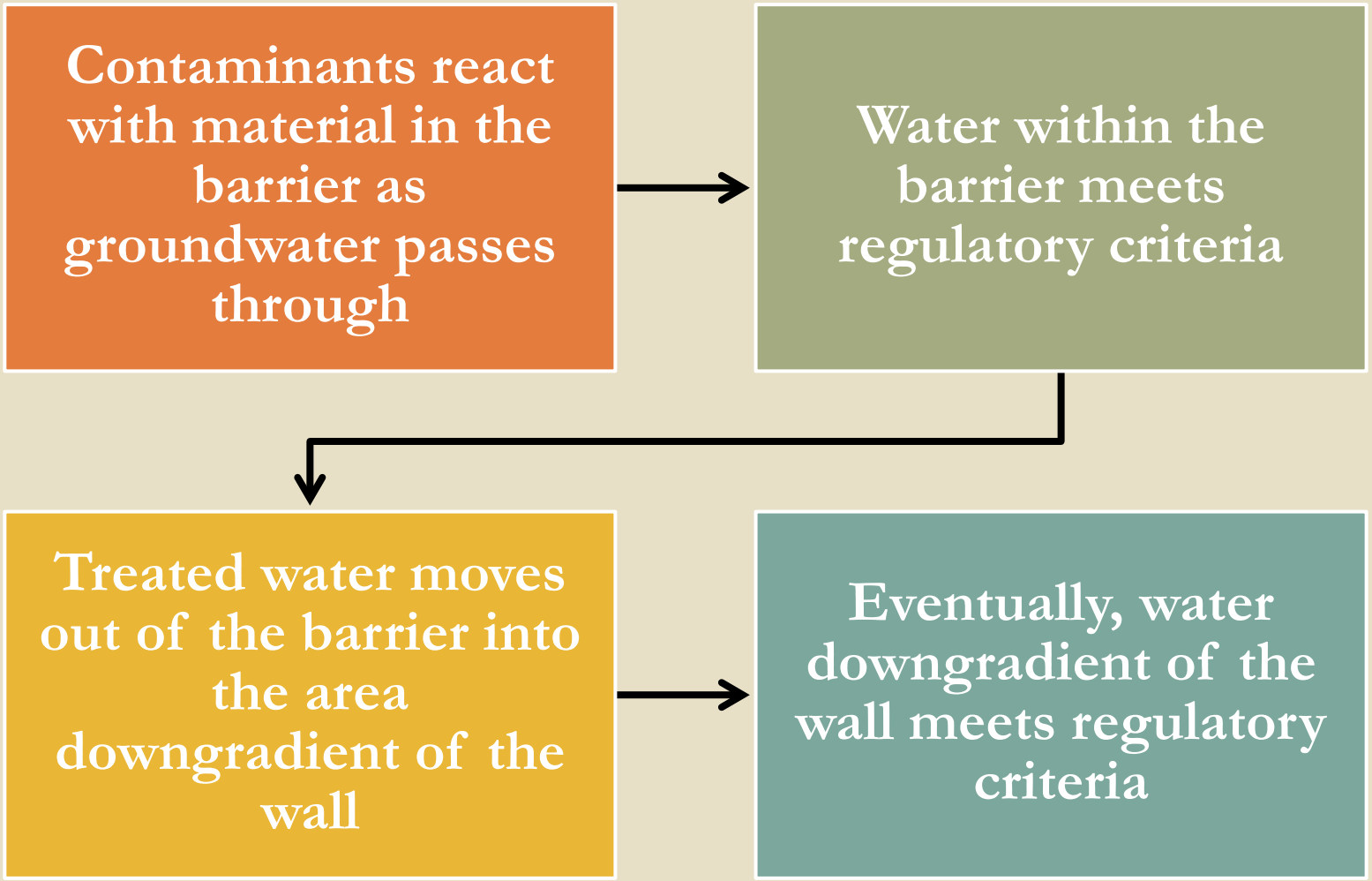
- Inadequate Characterization
- Incompatible Geochemistry
- Implementation Issues

PRBs
How do they work?

- Emplacement of permeable mixture of reactive material within water table.
- Barrier is placed perpendicular to groundwater flow direction
- Conceptually, contaminated groundwater flows into the barrier



PRBs: How do they work?(2)



PRB Longevity

Thickness of PRB affects longevity

Clogging of PRB may significantly reduce longevity

Estimates of 10-20 years **not uncommon**

Poll

Do you have one or more projects with a PRB?

- Yes
- No

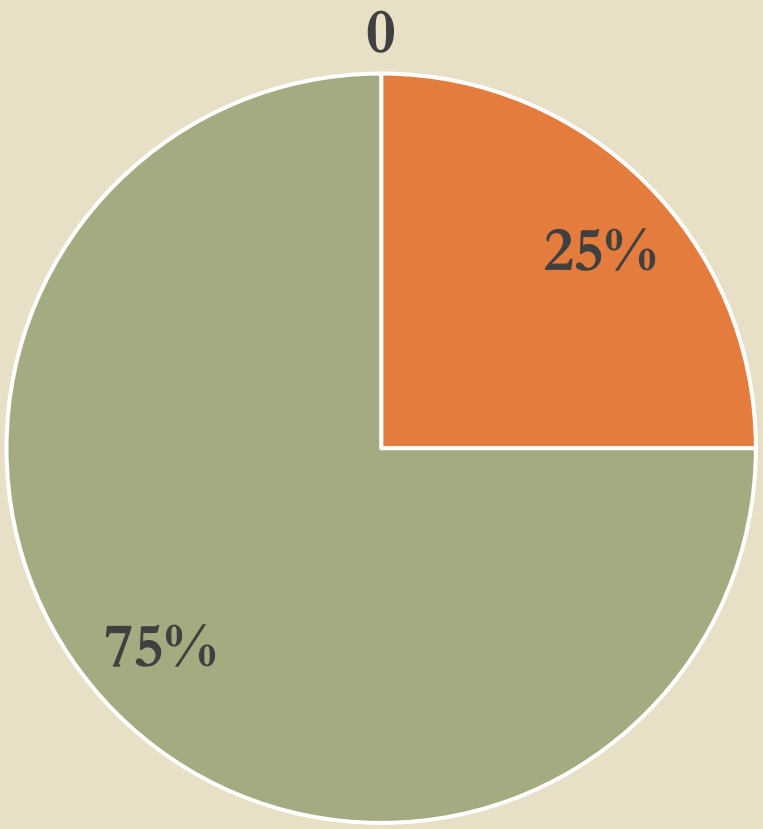
What type of contamination is being addressed?

- metals
- volatile organics
- other
- NA

What is the expected life span of the PRB?

- 10 years
- 20 years
- >20 years

PRBs: Success or Failure?



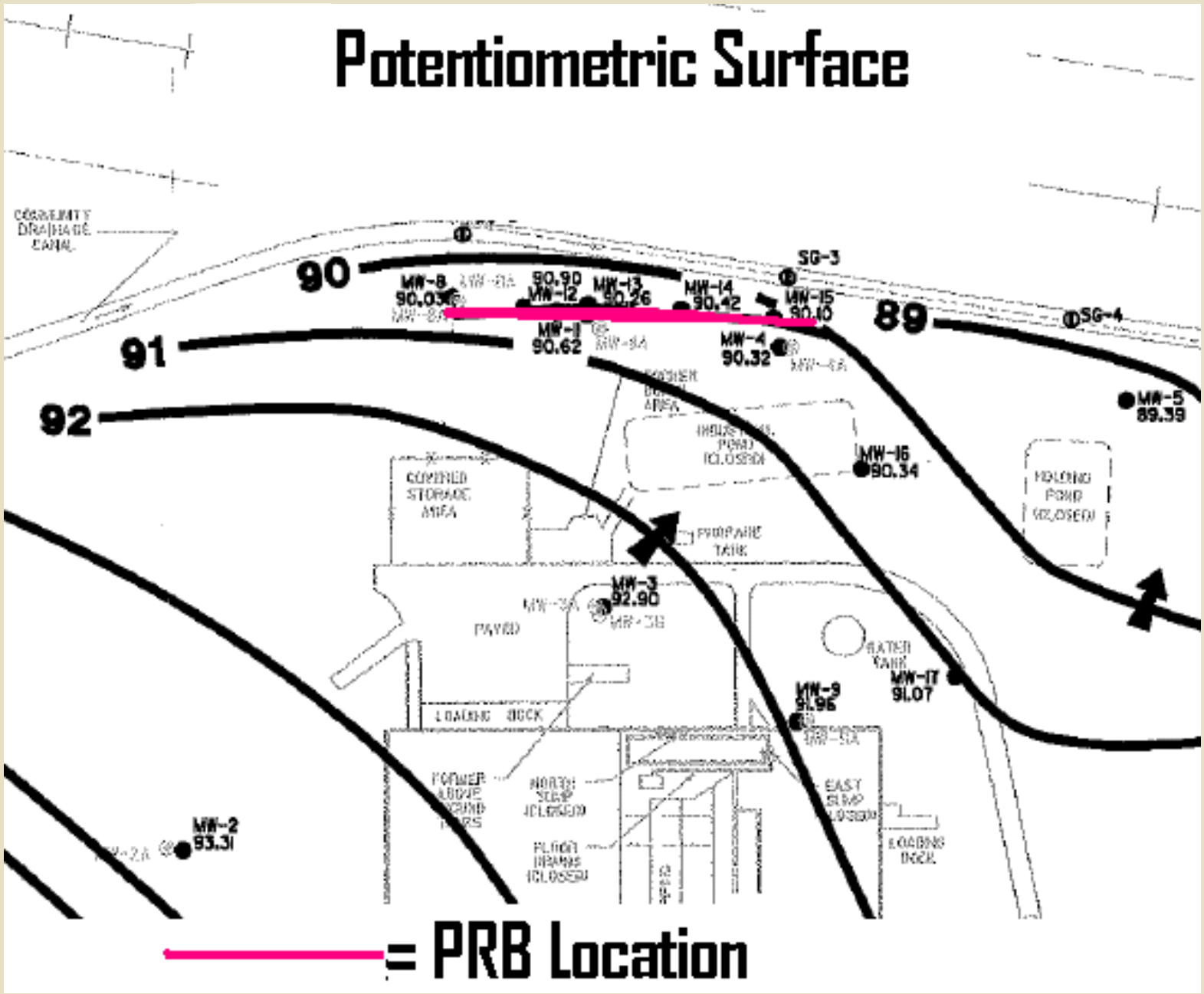
- **8 Sites**
- **Successful – 0**
- **Failure – 2 (clogging)**
- **Partially Successful-6**

  Update – 1 Success

Primary Causes of Poor Performance (PRB)

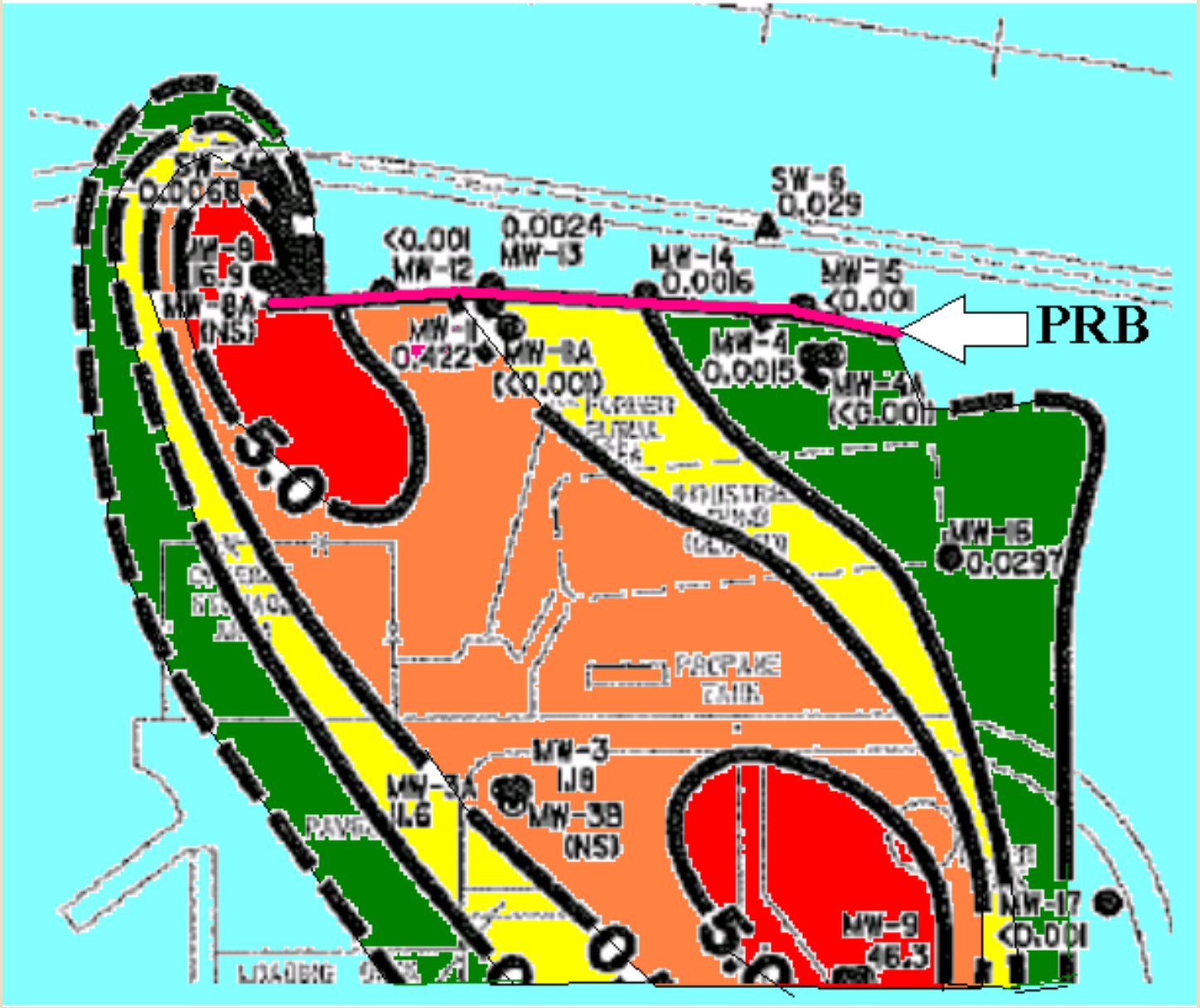
- Inadequate Characterization
- Incompatible Geochemistry
- Implementation Issues

Potentiometric Surface



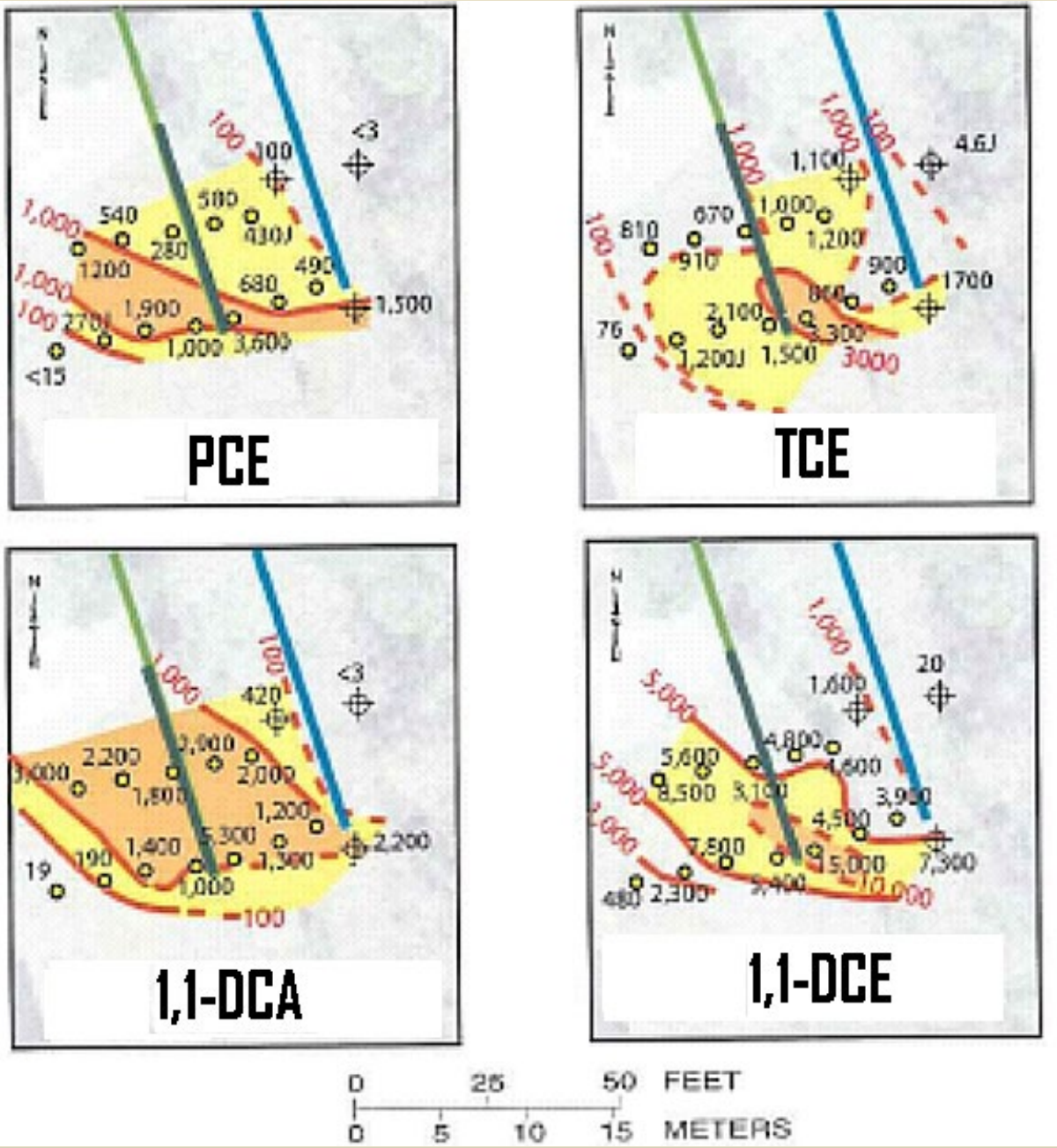
= PRB Location

TCE Concentrations (ppm)



Military Base

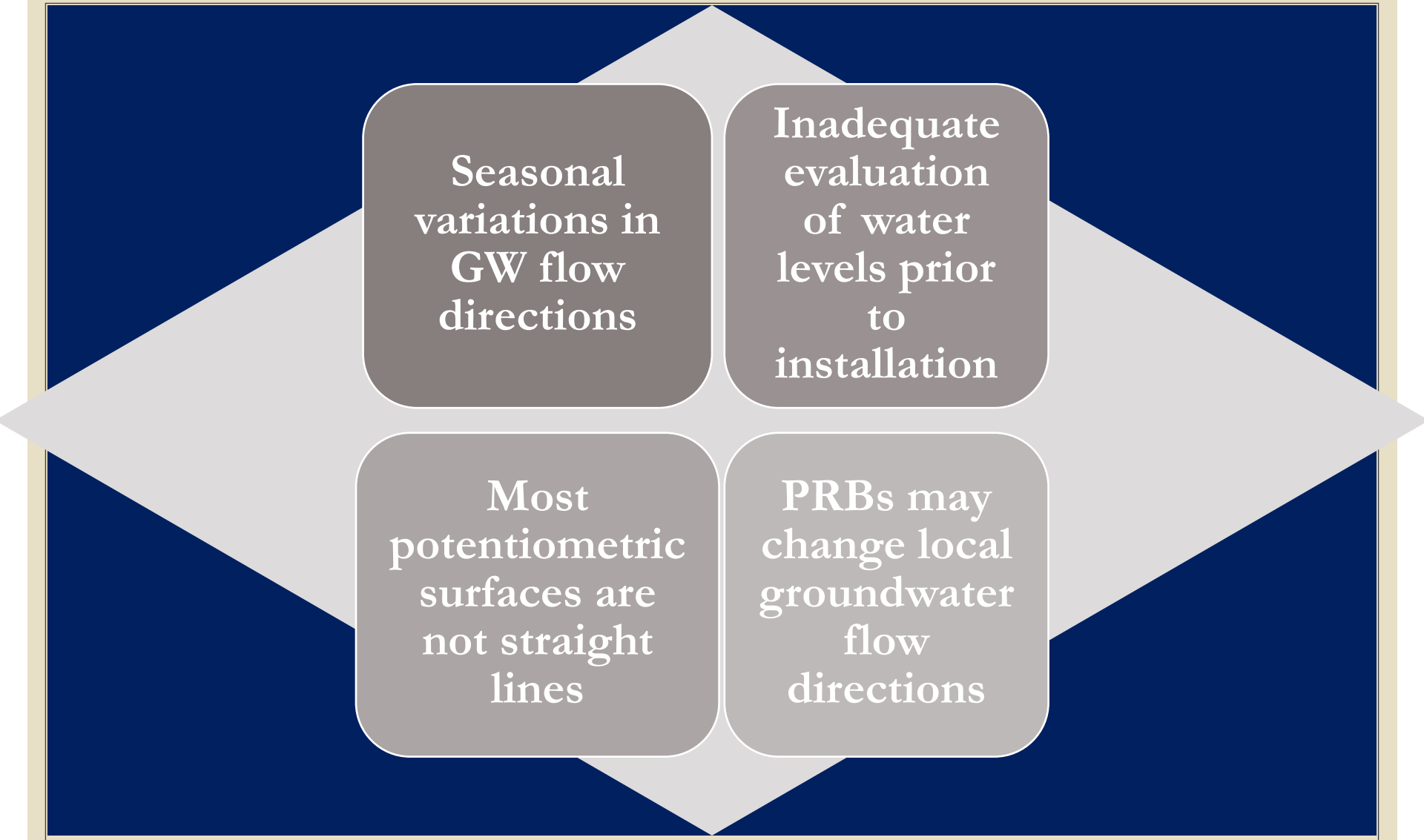
PRB



Why were PRBs not successful?

Difficult to match aquifer permeability

Groundwater flow around the ends



More PRB Implementation Issues

PRB Design Recommendations

V-SHAPE

ELBOWS AT ENDS

FUNNEL AND GATE

PRB-Recommendations

Site Characterization is Key

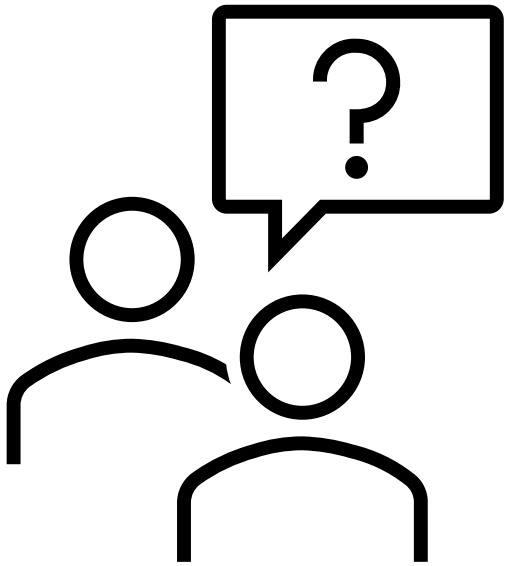
- **Determine and Evaluate Impact of Aquifer Heterogeneity on Effectiveness**
- **Perform Detailed Evaluations of Seasonal Impacts on Groundwater Flow Directions**

Make Sure Chemistry Works

Design the PRB to Address Groundwater Flow Perturbations

PRB
Performance
Monitoring
Recommendations

Install several multilevel monitoring wells within and around the ends of the PRB



Question Break

Please enter any questions or comments into the Q&A Box

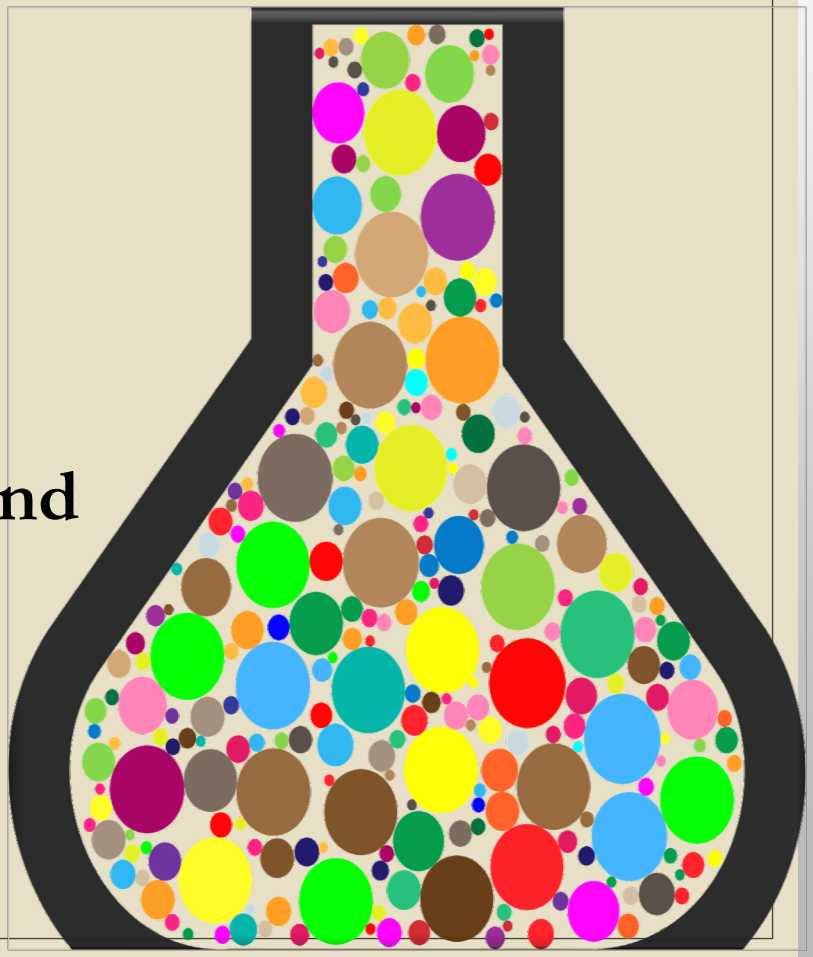
In-Situ Chemical Oxidation: How Does It Work?

Injection of oxidant or oxidant/catalyst into subsurface=>

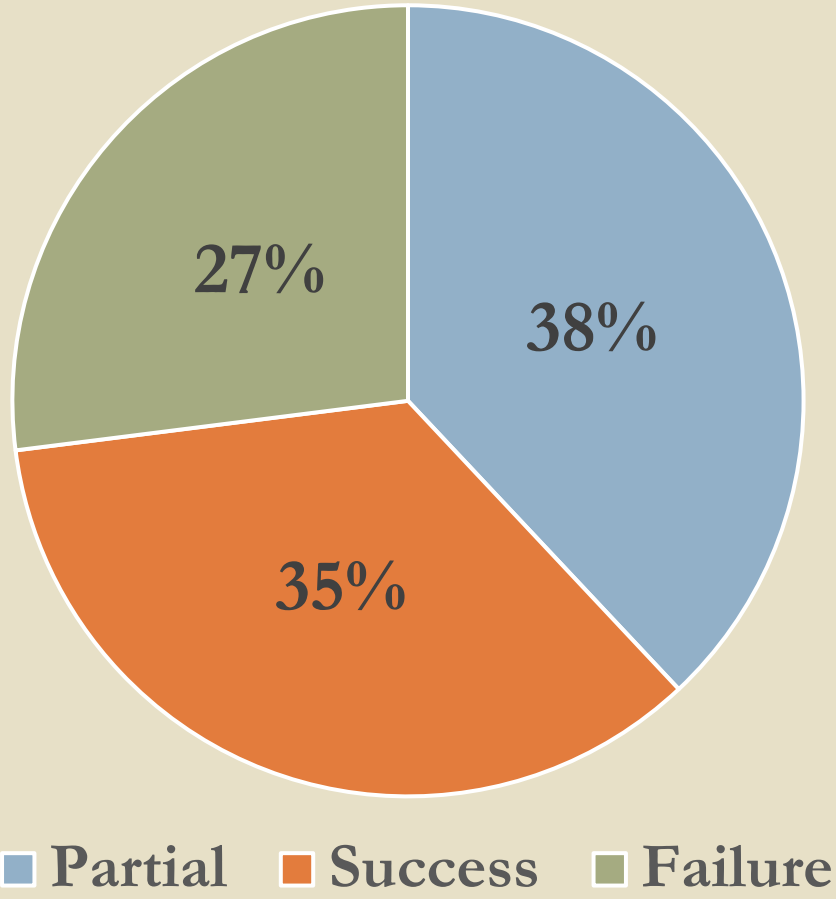
Oxidation of indigenous iron and organic matter (NOD)=>

Oxidation of contaminant

(partial or complete)



ISCO Performance – 35 Chlorinated Solvent Sites



In Process – 9

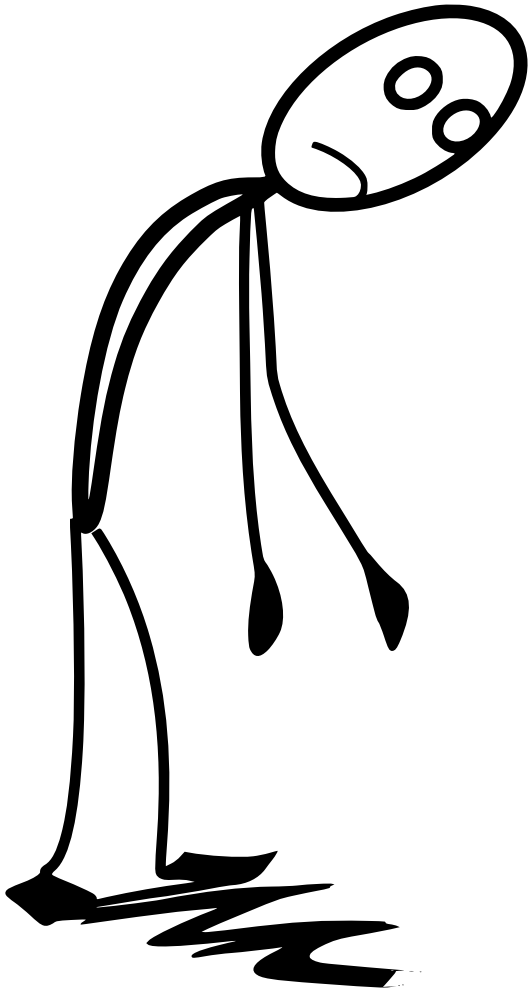
Successful – 9

Failure – 7

Partially Successful – 10

Primary Causes of ISCO Poor Performance

- Incompatible Geochemistry
- Implementation Issues



Poll

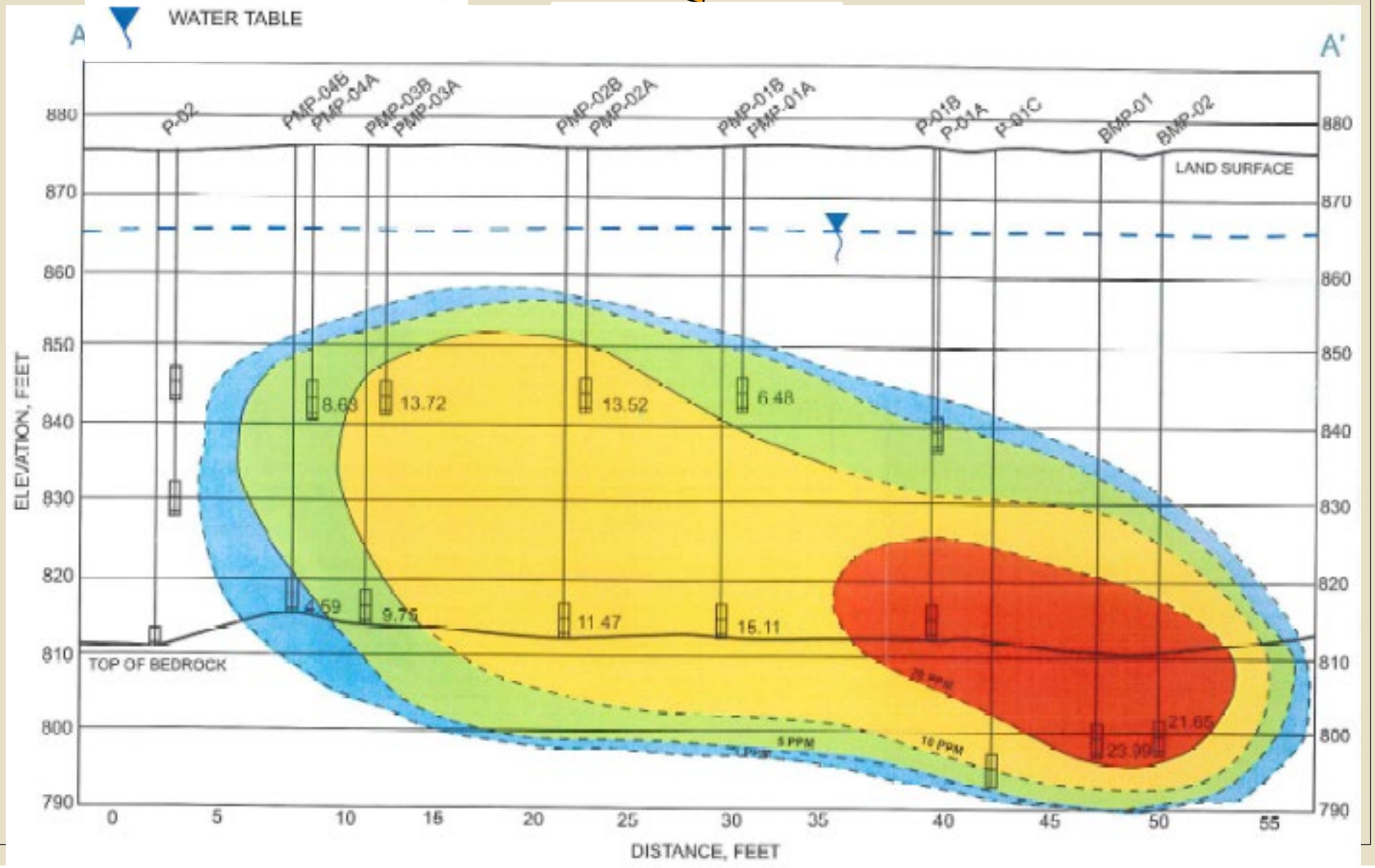
- **Have you used ISCO to treat groundwater contamination?**
  - Yes
  - No
- **How many ISCO sites have you reviewed?**
  - 0-5
  - 5-10
  - >10

ISCO CASE STUDY

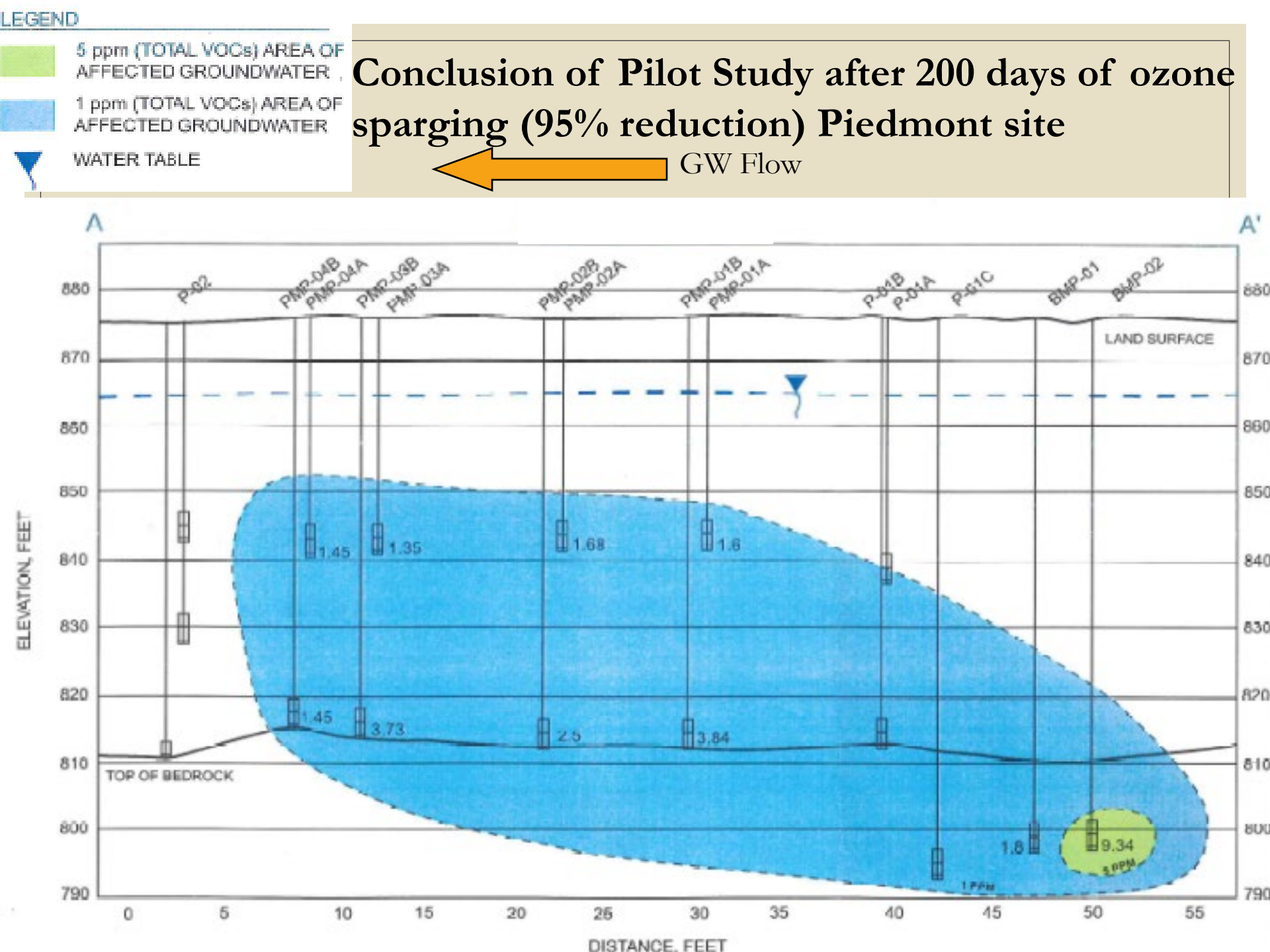
Piedmont Chemical Manufacturing Company: Ozone C-Sparge and Multi-level Sparge Pilot Study: Success

Baseline Total VOCs Piedmont Site

GW Flow

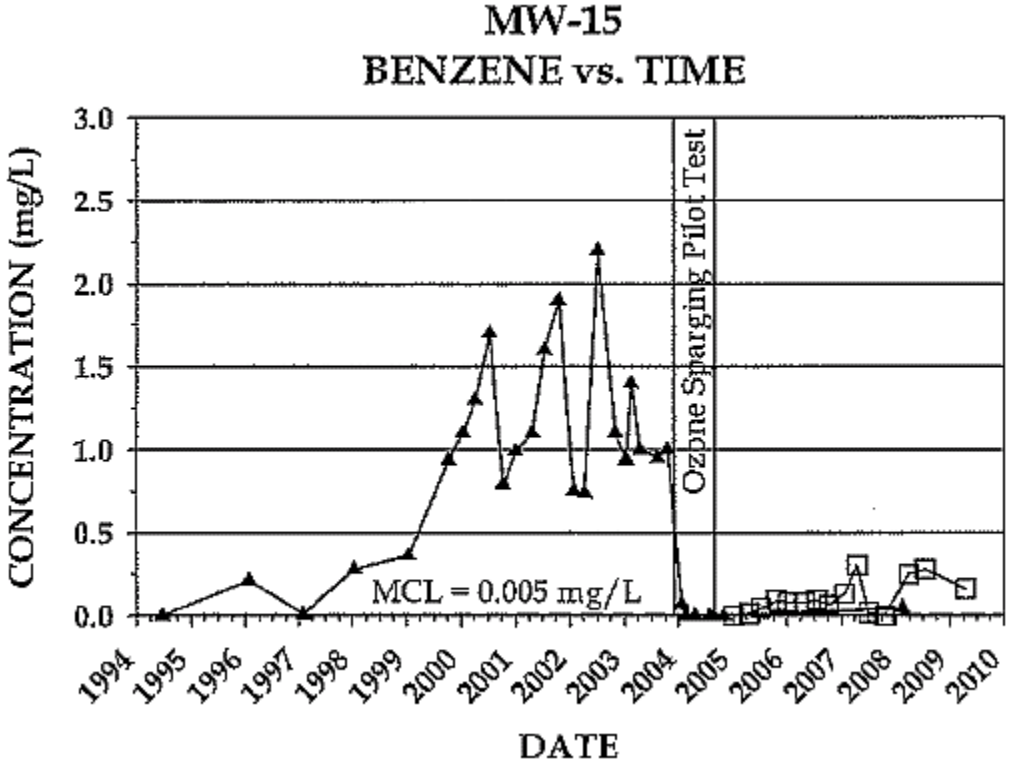


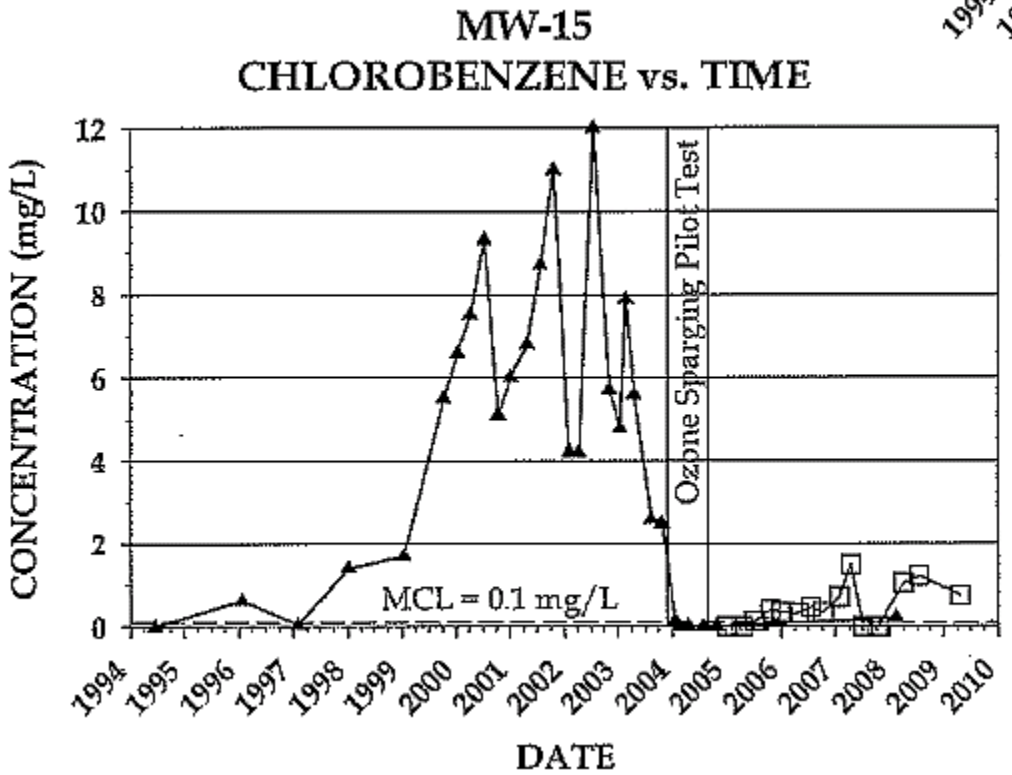
Conclusion of Pilot Study after 200 days of ozone sparging (95% reduction) Piedmont site



Piedmont Site

C-Sparging Pilot Test Results, MW-15





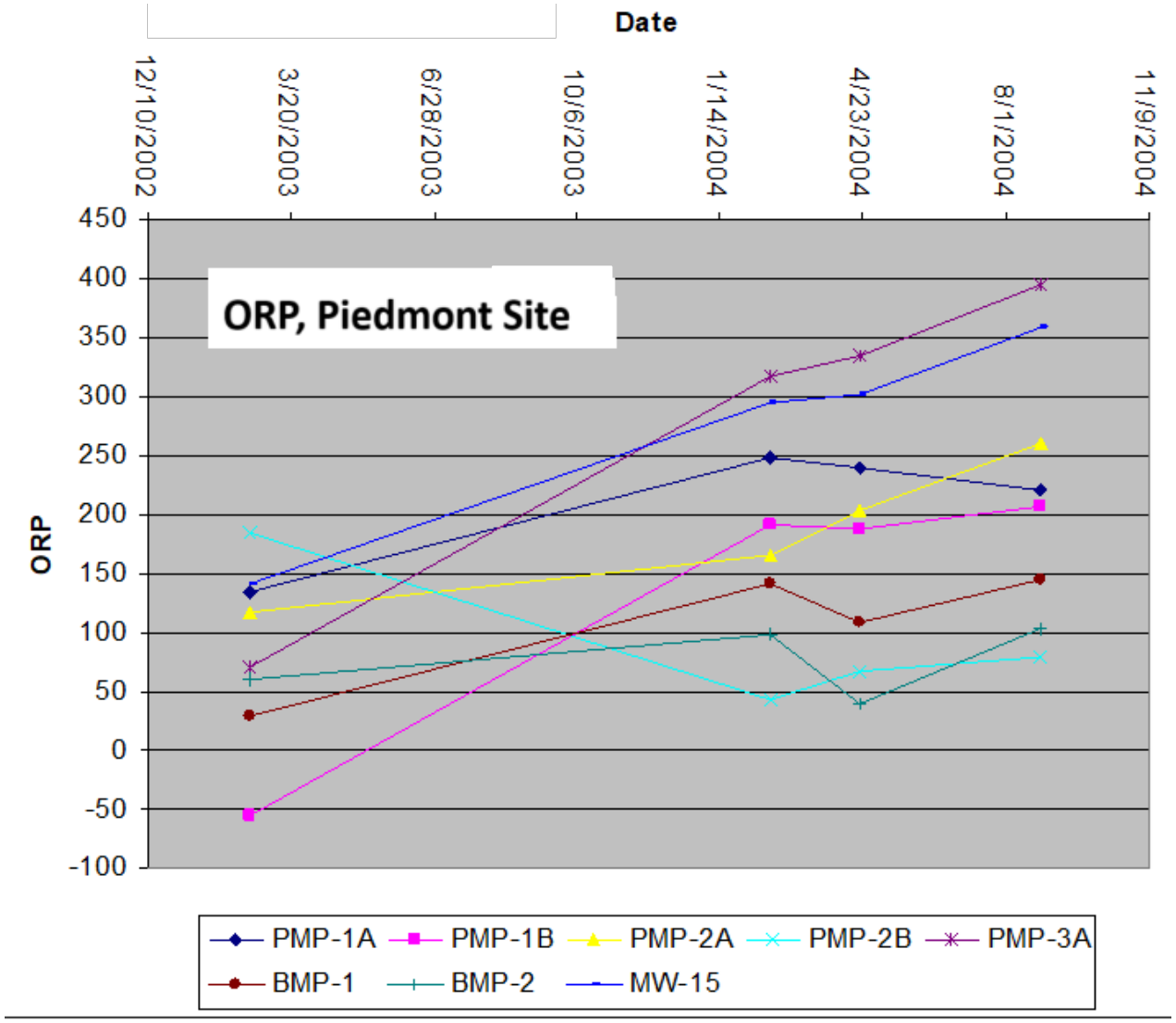
Note: Rebound monitoring at MW-15 continued several years after completion of pilot test

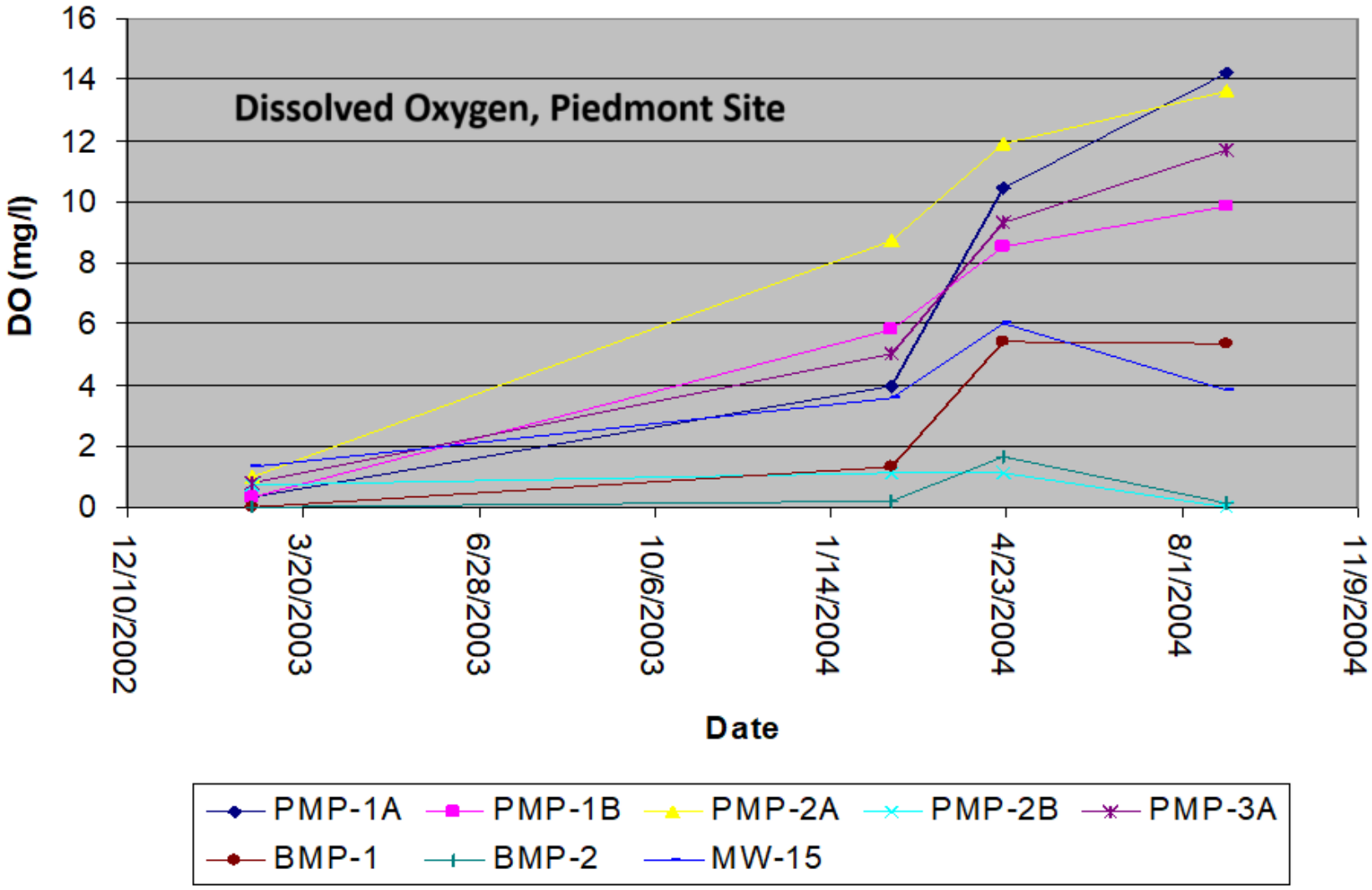
How can we know if C-sparging worked and not other processes?

Contaminant concentrations

Indicator parameters

- DO
- ORP
- Elevated DO and ORP in bedrock wells


Date
12/10/2002
3/20/2003
6/28/2003
10/6/2003
1/14/2004
4/23/2004
8/1/2004
11/9/2004
ORP, Piedmont Site
ORP
450
400
350
300
250
200
150
100
50
0
-50
-100
PMP-1A
PMP-1B
PMP-2A
PMP-2B
PMP-3A
BMP-1
BMP-2
MW-15


Dissolved Oxygen, Piedmont Site
DO (mg/l)
16
14
12
10
8
6
4
2
0
12/10/2002
3/20/2003
6/28/2003
10/6/2003
1/14/2004
4/23/2004
8/1/2004
11/9/2004
Date
PMP-1A
PMP-1B
PMP-2A
PMP-2B
PMP-3A
BMP-1
BMP-2
MW-15

ISCO CASE STUDY 2

Low Country Military Site Chlorobenzene

Low Country Military Site Details

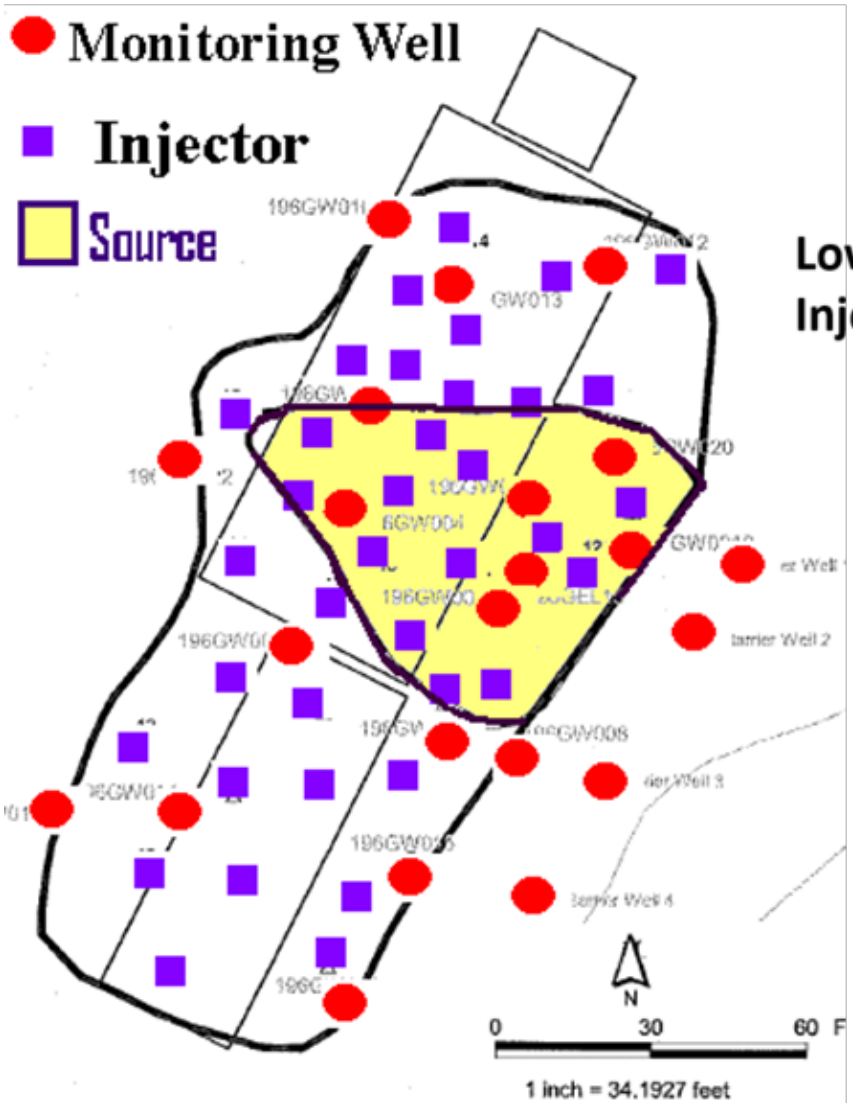
DNAPL suspected at 13 monitoring wells

Three injection events

- First event targeted "source material"
- Second and third events the entire area

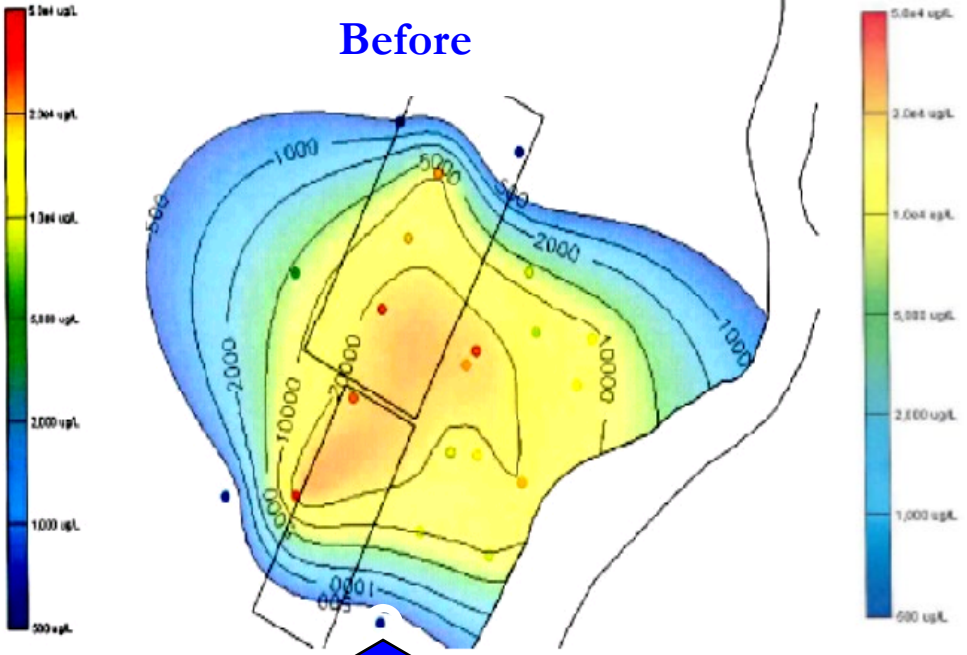
Treatment area 90' x 180'

Spacing between injection points ~20-30'



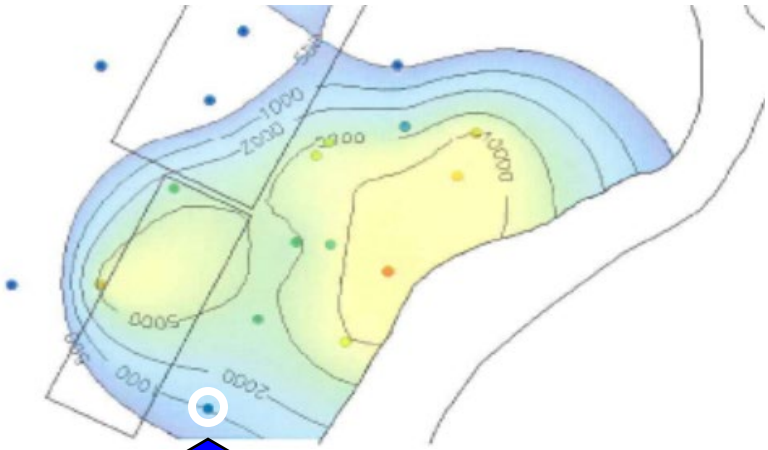
Low Country Military Site
Injection and Monitoring Well Array

Before

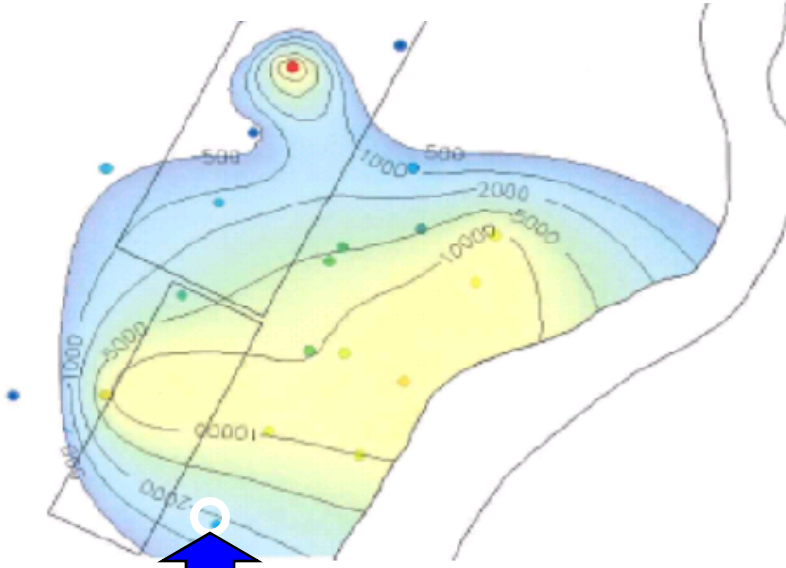


GW-11

Immediately After 3rd Inj.



note: GW-11 outside plume increased 3900%



Low Country Military Site

Total Chlorobenzenes

Rebound Monitoring

Why was ISCO not successful at Low Country Military Site

- **Clay lenses and lithologic heterogeneity confounded injection of oxidants.**
- **Injection of Fenton's reagent mobilized and redistributed organic contaminants**
- **Fouling limited injection quantities**

ISCO Implementation Issues

Oxidant must contact contaminant directly to be effective. This can be a problem in fractured rock or lower permeability material with higher clay content.

May cause clogging of aquifer or well screen through precipitation of minerals

ISCO can mobilize contamination

Primary Causes of Poor ISCO Performance at Low Country Military Site

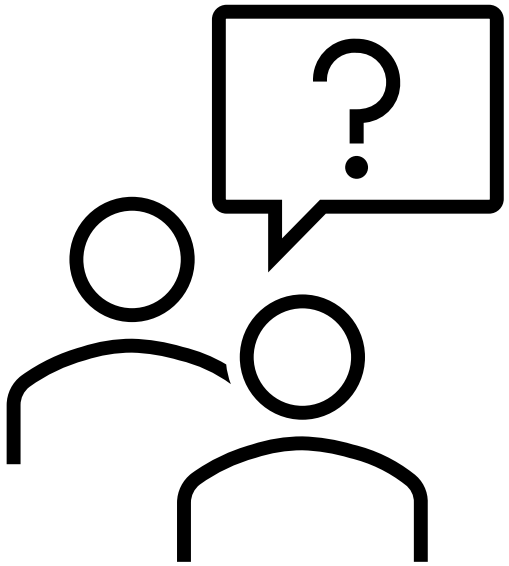
Incompatible Geochemistry

Implementation Issues

ISCO-Recommendations

ISCO is most effective when the initial subsurface geochemistry is oxidizing rather than reducing. Pilot study recommended if subsurface is reducing.

Use outside-in injection approach to reduce contaminant mobilization



Question Break

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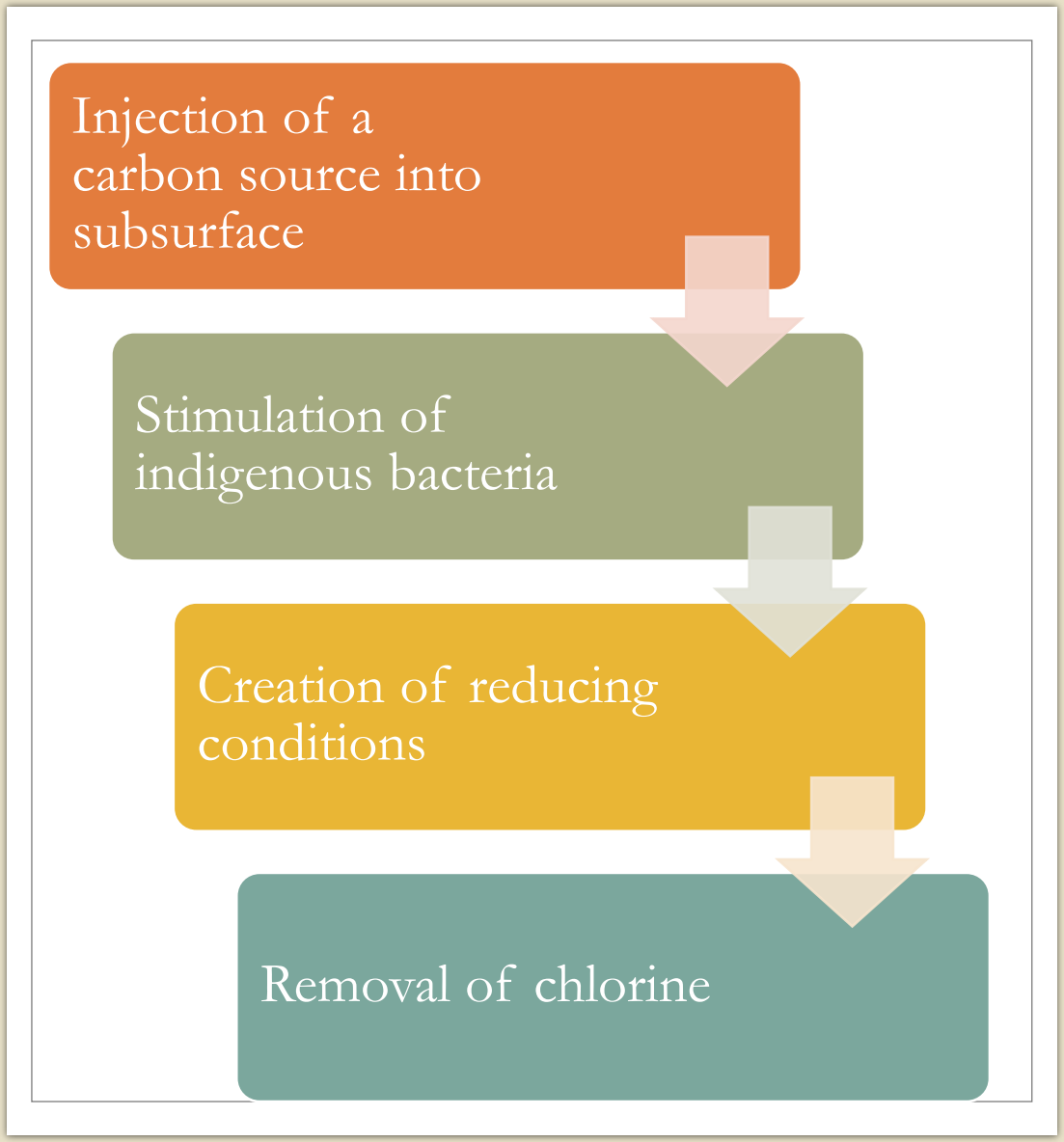
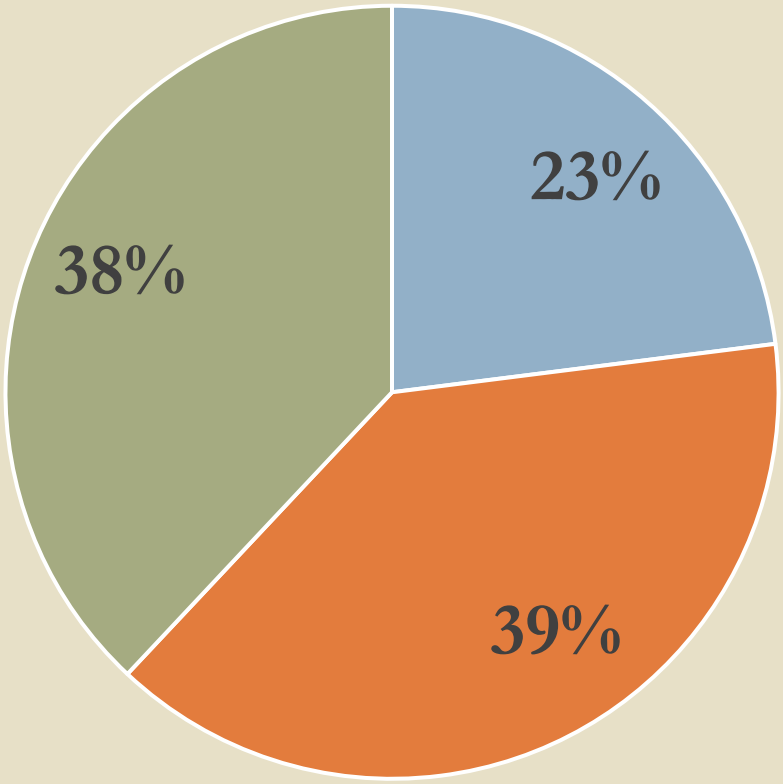


Enhanced Reductive Dechlorination:

How does it work?

Reductive Dechlorination Performance



39 Sites

In Process-6

Successful-7

Partially Successful-12

Failure-12

- *Note: stalling at DCE/VC primary cause of partial success*

Primary Causes of Reductive Dechlorination Poor Performance

- Inadequate Characterization
- Incompatible Geochemistry
- Implementation Issues

Poll

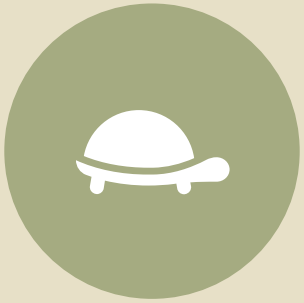
- **How many sites are you working with that have used reductive dechlorination to address chlorinated solvents?**
  - 0-5
  - 5-10
  - >10

HRC PILOT TEST CASE STUDY

Shoreline Military Site

What is HRC?

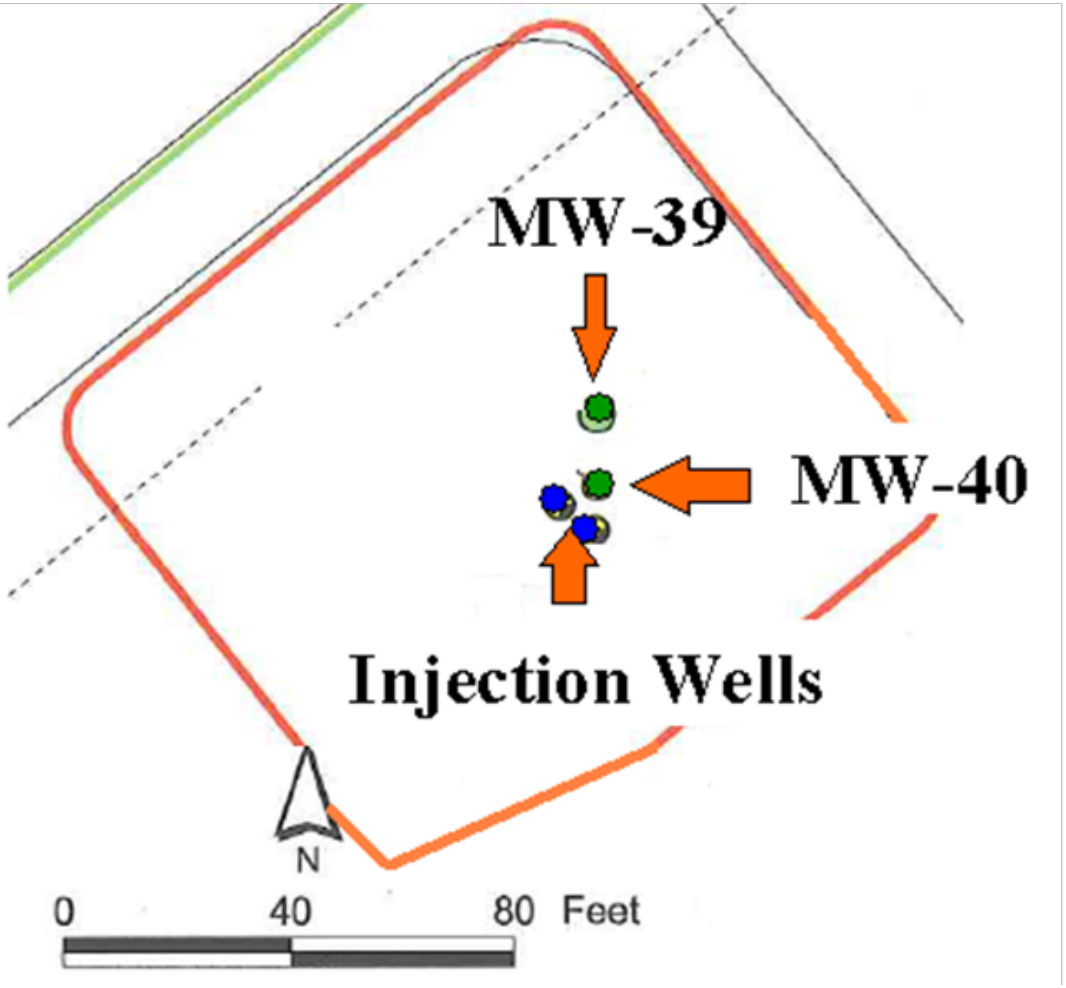
HYDROGEN RELEASE COMPOUNDS



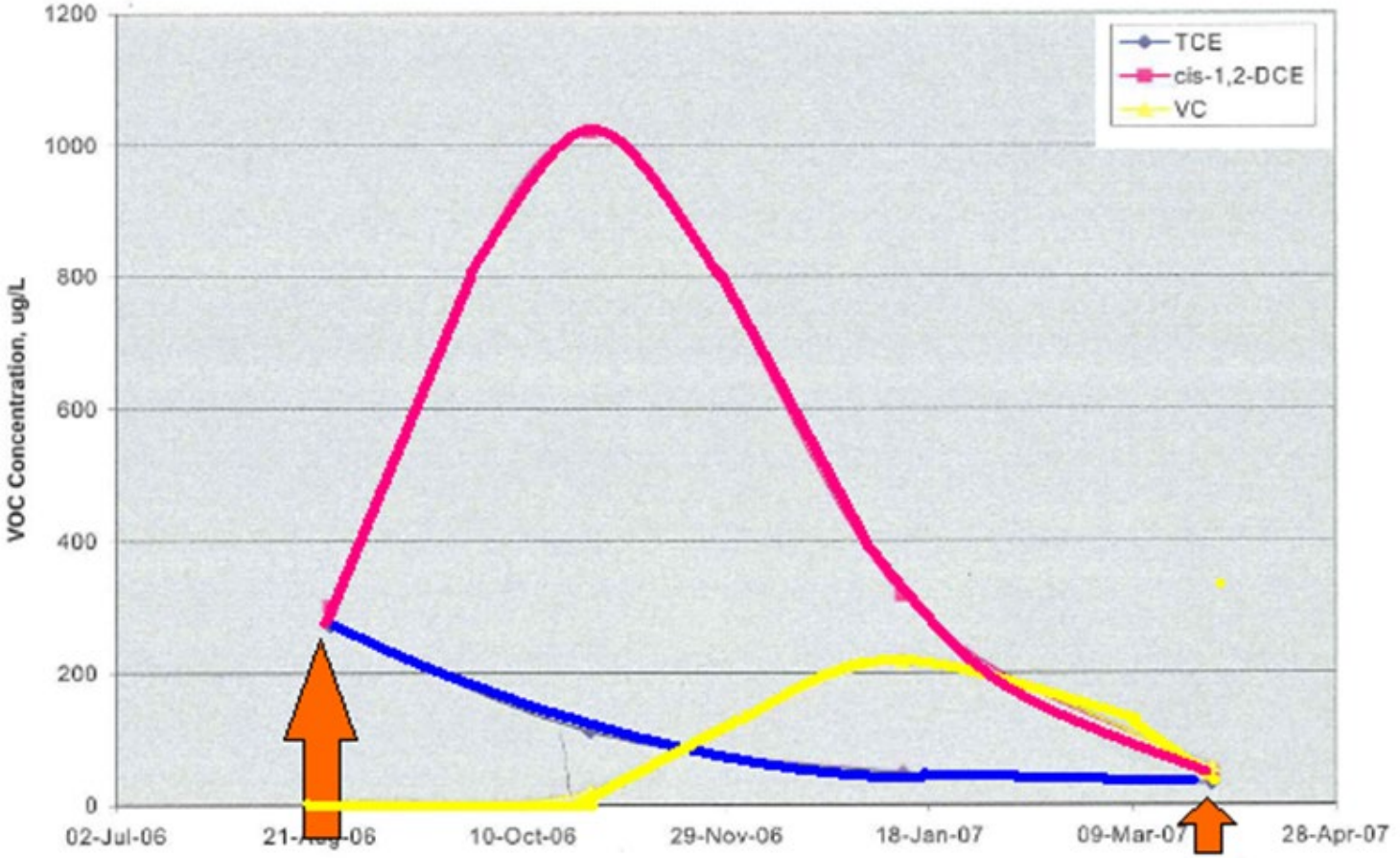
PROPRIETARY BLEND, SLOW RELEASE

VISCOUS GLYCEROL TRIPOLYLACTATE

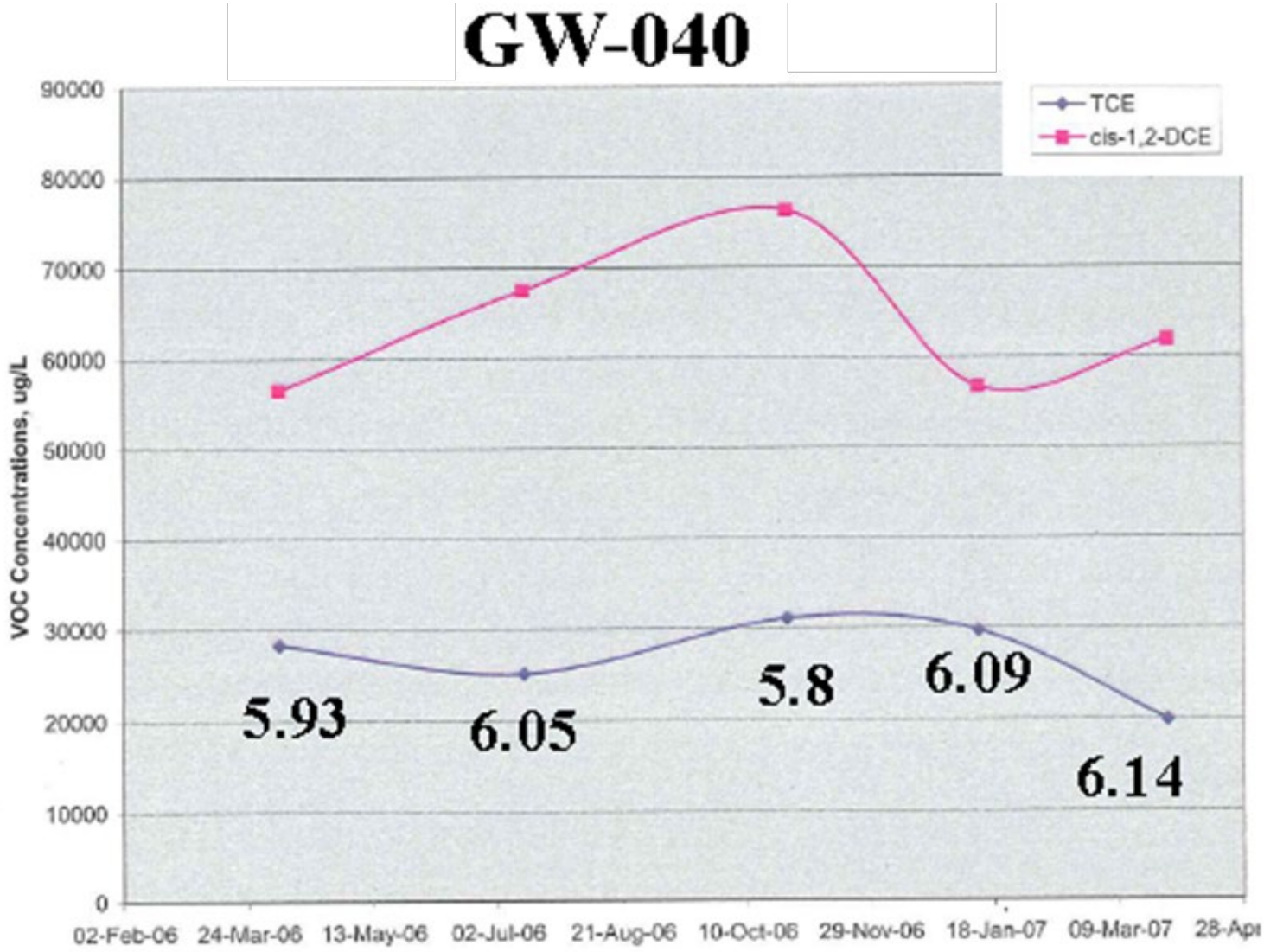
Reductive Dechlorination Pilot Study Area



MW-039



pH=6.3 pH=6.8 pH=6.2 pH=6.1


GW-040
TCE
cis-1,2-DCE
VOC Concentrations, ug/L
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
5.93
6.05
5.8
6.09
6.14
02-Feb-06
24-Mar-06
13-May-06
02-Jul-06
21-Aug-06
10-Oct-06
29-Nov-06
18-Jan-07
09-Mar-07

Why was Reductive Dechlorination partially successful at Shoreline Military Site?

pH not consistently above 6

DHC likely not present when pH<6

Poor characterization (DHC)

Good that it was pilot test and not full scale

Reductive Dechlorination Implementation Issues

- **Ineffective for PCE, TCE, DCE, VC if pH<6 and DHC is absent**
- **Will not work if DO>1**
- **Will not work in areas with high nitrate (Wilson, 2006)**

Reductive Dechlorination Recommendations

ERD is most effective when the initial subsurface geochemistry is reducing, creating ethene, and DHC is present

Always sample for DHC prior to selecting ERD

Bioaugmentation may help overcome an unfavorable geochemistry; microcosm study is helpful

TAKE HOME MESSAGES

Good Site Characterization

Critical for Success

Geochemistry

Know the limitations of site geology and site chemistry with respect to technology requirements.

Easier to enhance rather than change ambient geochemistry

If it's too good to be true, it probably is not true

More keys to successful implementation

- If injecting, check for mounding and fouling
- Indicator parameters
- Pilot studies

Technology	DO	ORP	TOC	pH
Reductive Dechlorination	<1	<-100	increasing	>6
In-Situ Chemical Oxidation	>8	>100	low	3-6
PRB	?	?	?	?

Ideal Indicator Parameters by Technology

The importance of pilot studies

Pilot studies should be used to help determine if technology is appropriate especially when changing aquifer chemistry

Pilot studies may overestimate success

For injection technologies, pilot studies help determine radius of influence, quantities that the aquifer can receive, and potential delivery issues


Discussion