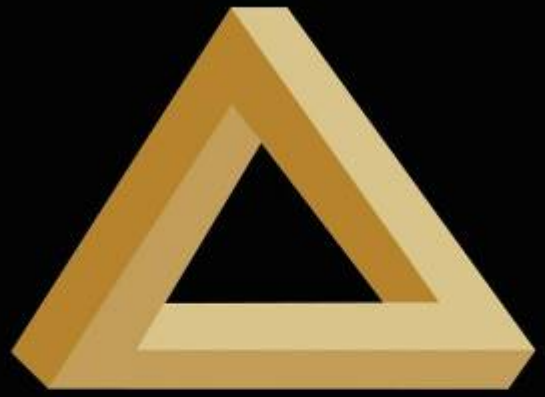


TRIUM

트 리 엄

Common Questions About Chemical Oxidation Using Modified Fenton's Reagent with Case Study Answers

Agenda

A few things you wanted to know about Chemical Oxidation but were afraid to ask

- TRIUM's TriOx Process
  - Principles
- Chem Ox Overview
  - Common Questions
  - Case Studies
- Discussion/Questions

TriOx

"Chemical remediation under the principles of ethical science and engineering for integrated remedial technology application and site management."

TriOx

- Specializing in advanced in-situ/ex-situ chemical oxidation
- Focus on oxidation applications for:
  - Groundwater remediation
  - Soil polishing
  - Limited access and deep conditions
  - Various organic contaminants
- Modified Fenton's Chemistry – preferred oxidant blend
  - Clean, efficient, no additive residuals

MFR

- Mineralization to CO2/H2O by free radical generation
  - Surfactant enhanced
    - Reaction often creates surfactant effect in soil to make contaminant available in water phase for reaction.
- As single step or part of remedial train approach
- No residual ion signature ($H_2O_{2)}$
- Rapid reaction, quick results
- Oxygenated groundwater conditions, longer term biological advantages

MFR

- All oxidants susceptible to:
  - Scavenging reactions (Fe, Ca, Mn, etc)
    - Imperative to possess knowledge in chelators and catalysts
    - Balance of natural oxidant demand, contaminant levels, and end points
  - Oxidant stability – compromise of reaction and application
    - Shorter reaction time = better destruction of light ends, more aggressive reaction, may compromise ROI.
    - Longer reaction time = better destruction of heavy ends, longer, slower injections/applications.

A Few Common Questions or Myths

1. Chem Ox is complex and unreliable

Complex

- True – Oxidant reactions are very complex
  - Concentrations and Oxidant Demand
    - High concentrations of any contaminant
    - Free product
    - Highly organic soils
  - Scavenging reactions (Fe, Ca, Mn, etc)
    - Chelators and catalysts
- Success can be achieved with recognition that not all oxidants are created equal or are best for all circumstances.

Unreliable

- True – Chem Ox is unreliable if applied poorly
  - ISCO
    - Low saturation
    - Channeling/Fracturing, Low ROI
    - Shallow or poorly backfilled areas
  - EXCO
    - Low saturation
    - Retention time and contact
    - Mixing technique
  - Simply apply via the correct method…
    - Not as easy as it seems, uniqueness to every site

Unreliable

← Unreliable

Reliable →

A Few Common Questions or Myths

1. ~~Chem Ox is too complex and unreliable~~
2. Geology –
   - Doesn't work in fine grained soils
   - Has a low ROI
   - >ROI is always better
   - Has to be fractured into bedrock
   - Only displaces the fluid present

Fine Grained Soils

- True fine grained soils can pose more difficulty
  - Overcome by properly conditioning the injection formations
  - Conditioning means…..
    - STOP thinking that more “force” = better results
    - Use chemical conditioning not necessarily excessive physical force
  - A lower ROI is expected
    - Use injection wells, provides access for multiple consecutive injections
    - Slow and consistent = fast and successful

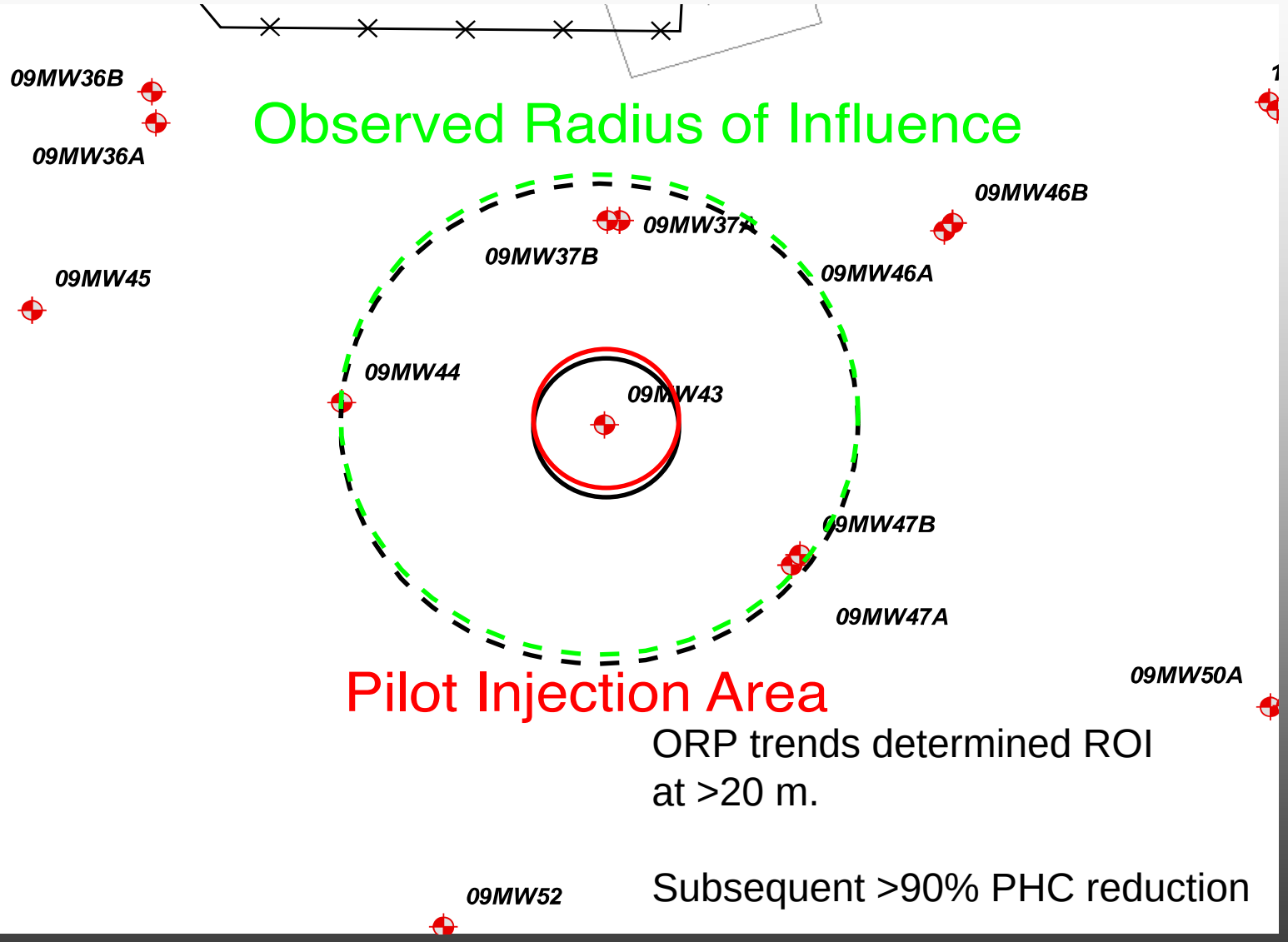
Fine Grained Soils

- Fracturing
  - Emplace sand
    - In extreme low conductive soil, > ROI for following treatments.
  - Emplace slurries (i.e. zero valent iron, etc).
- For everything else consider that:
    - Fracturing forces path of least resistance, directionally uncontrollable
    - Regardless of oxidant reaction time, a one shot injection via fracturing means that even if you get a large ROI the MFR is probably spent by the time it moves outside the fracture.

Low ROI

- True, improperly or unstabilized oxidant will have a low ROI.
  - If oxidant wastes itself, no unit contact possible
  - Oxidant selection and blending strategy
- True, low volume, non continuous injections will have low ROI
  - Single or small volume application will not contact unit sufficiently to allow dispersion
  - Application strategy and well conditioning

ROI



ORP trends determined ROI at >20 m.

Subsequent >90% PHC reduction

ROI Compromise

- Greater ROI often means longer remedial timeframe
  - Cost/Time balance

	Fractured Bedrock	Fractured Bedrock	Silty Clay
Planned ROI	10	5	2
Actual ROI	>20	>10	>2 (not defined)
Volume	>80,000 m3	>2,000 m3	100 m3
Duration	8 weeks	1 week	3 days
% Complete	60	100	100
Cost	Lowest unit cost		Highest unit cost
Timeframe	<2-3 years	<1 month	<1 week

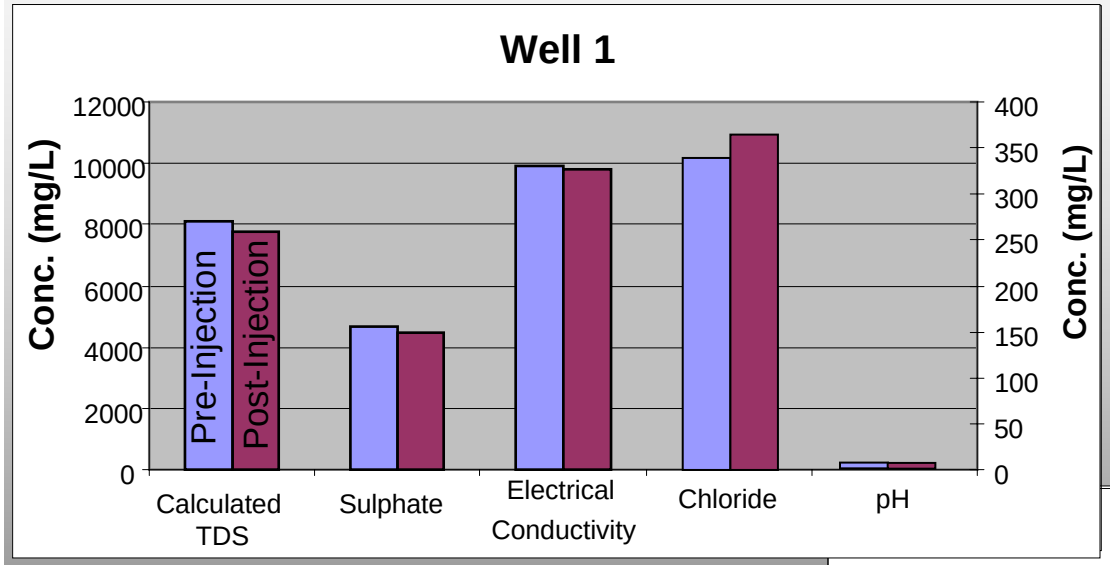
Bedrock

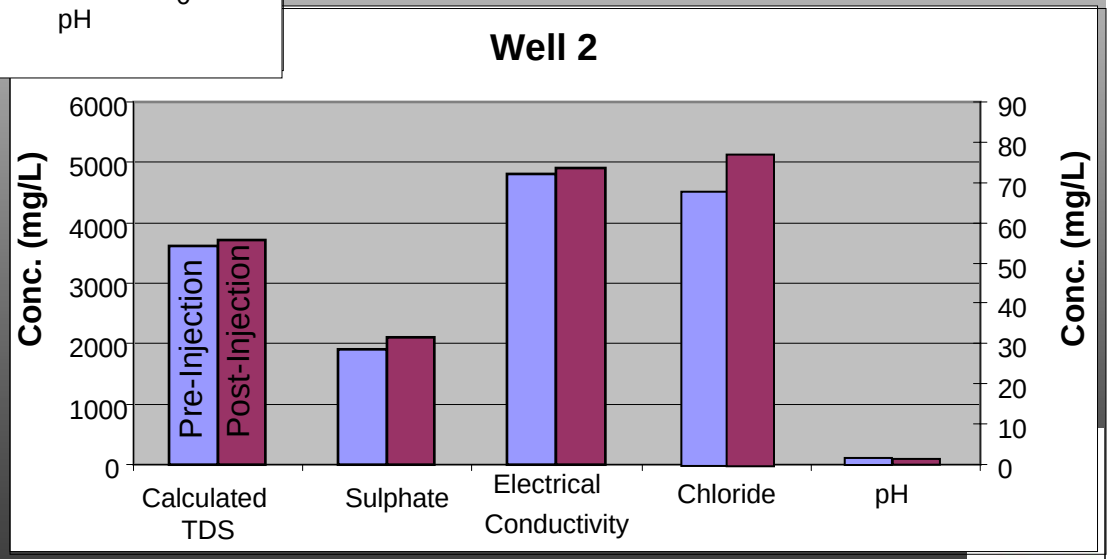
- True - doesn’t work if forcibly channeled or poorly emplaced injection intervals
- If contaminant is moving, bedrock has a transport mechanism
  - Proper exposure to unit and conditioning
  - Greater depth does not have to mean greater injection pressure
    - Greater overburden pressure can be overcome with dispersion and oxidant reactions

Displacement

- Slug flow vs Dispersion
  - True, a minor amount may occur at the immediate area of the injection point
  - H_2O_2 is extremely soluble, therefore when injected in low pressures behaves via dispersion
  - Consider that injection volumes often <10% of pore volume, yet ROI can reach 10's of meters
  - Water chemistry changes if displacement was occurring

Displacement





A Few Common Questions or Myths

- ~~Chem Ox is too complex and unreliable~~
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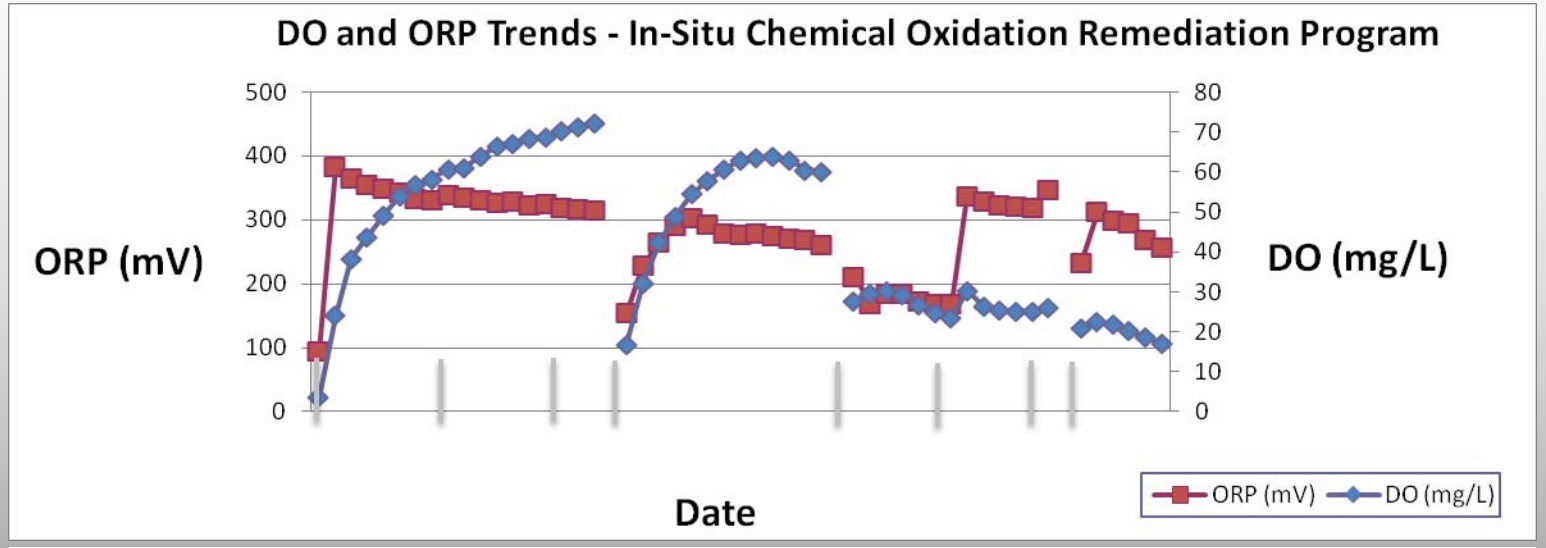
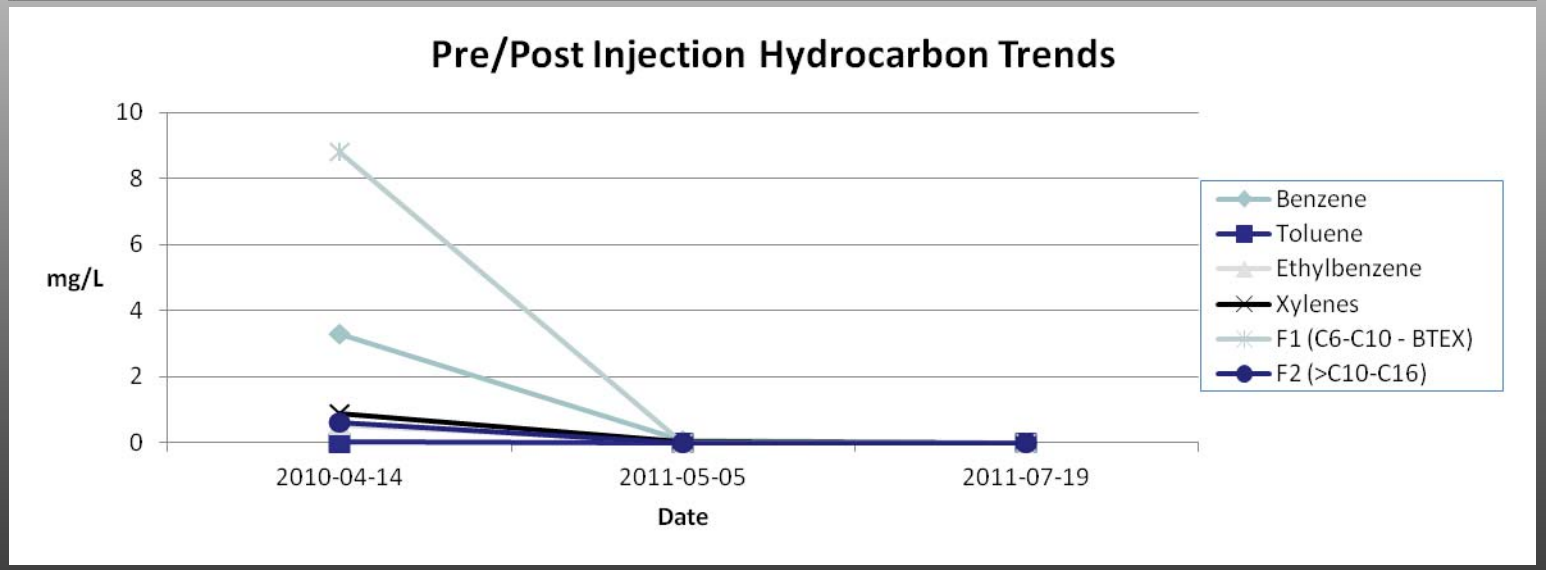
  - ~~Doesn't work in Fine Grained Soils~~
  - ~~Has a low ROI~~
  - ~~Just because you can, should you (too fast, too slow, large ROI, not always good~~
  - ~~It displaces the fluid present~~
- Cannot be field verified

Field Verification

- Only true if no proper point to measure.
  - DO/ORP probes
  - Peroxide test strips or kits, verify concentration
  - Laboratory analysis
- Sample from monitoring wells only.
  - Permanent monitoring wells allow continuous monitoring
  - Verification of ROI and oxidant migration
  - Test performance against perimeter monitoring wells

Field Verification





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- ~~It displaces the fluid present~~
- ~~Cannot be field verified~~
- It doesn't work

Doesn't work

- True – sometimes fails to meet target/uneconomical
  - Unknown contamination
  - High organics
  - No minimum saturation
  - Wrong loading or application technique
  - Etc.
- Imperative to know the limitations and be honest that it may not be the right solution

When it didn't work

Location	Depth (mbg)	TPH (mg/kg), (Removal %)	
		Pre Monitoring	Post Monitoring
1-3	2 to 3	36	209 (-480%)
1-4	3 to 4	36	1248 (-3367%)
1-5	4 to 5	1416	1010 (29%)
4-5	4 to 5	1096	ND (100%)
7-4	3 to 4	796	767 (4%)
7-5	4 to 5	377	1104 (-192%)
9-4	3 to 4	670	525 (22%)
9-5	4 to 5	6390	1082 (71%)
10-5	4 to 5	973	ND (100%)

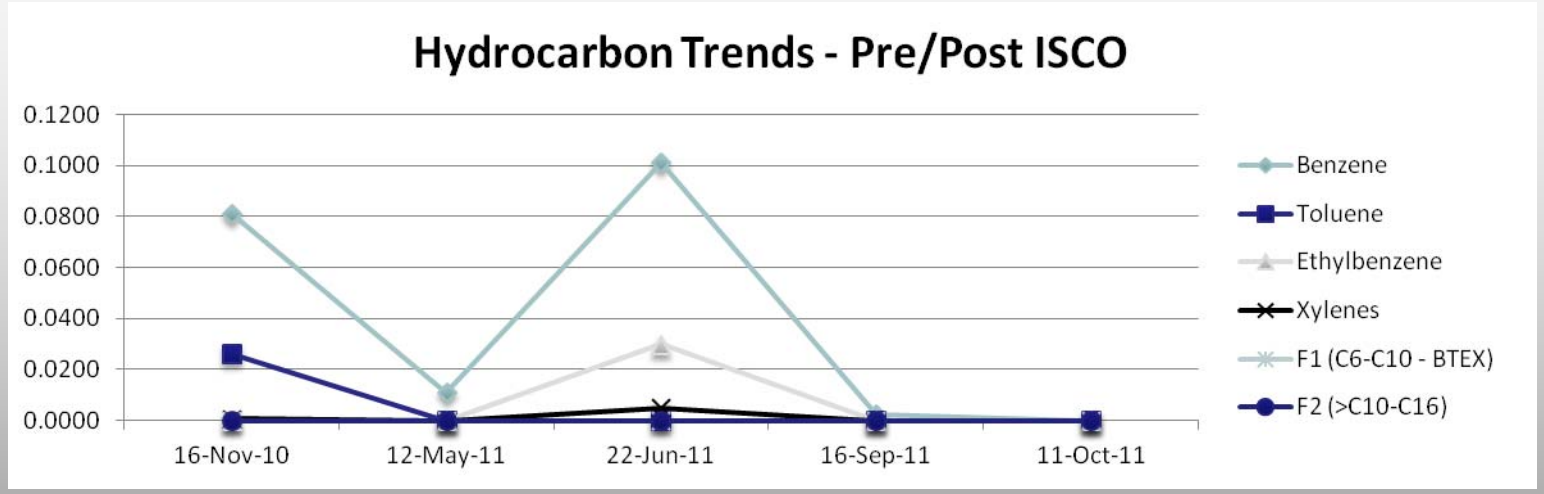
- Extreme seasonal fluctuations, vadose zone
- Homogeneity and backfill
- Near to sources
- Application Techniques

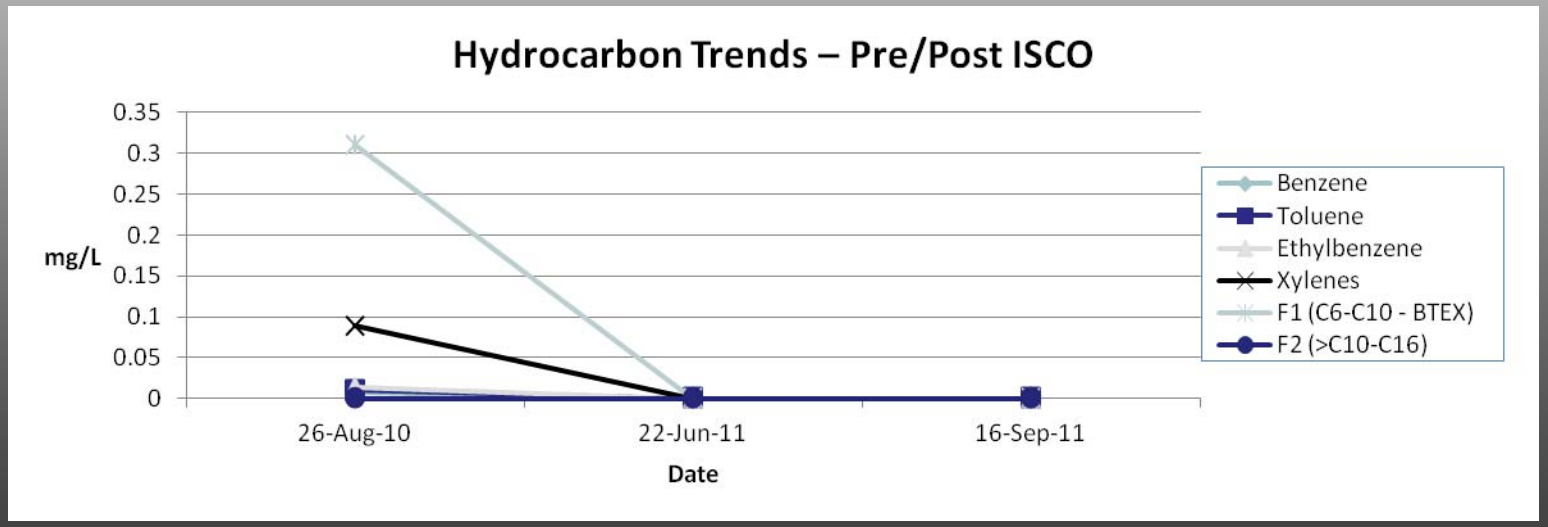
When it didn't work

	3-Nov-09	18-Nov-09	24-Feb-10
Benzene	<0.0004	<0.0004	<0.0004
Toluene	**0.14**	<0.0004	**0.055**
Ethylbenzene	0.0014	<0.0004	0.0009
Xylenes	0.0009	<0.0008	<0.0008
F1 (C6-C10 - BTEX)	0.29	<0.1	<0.1
F2 (>C10-C16)	--	--	0.3

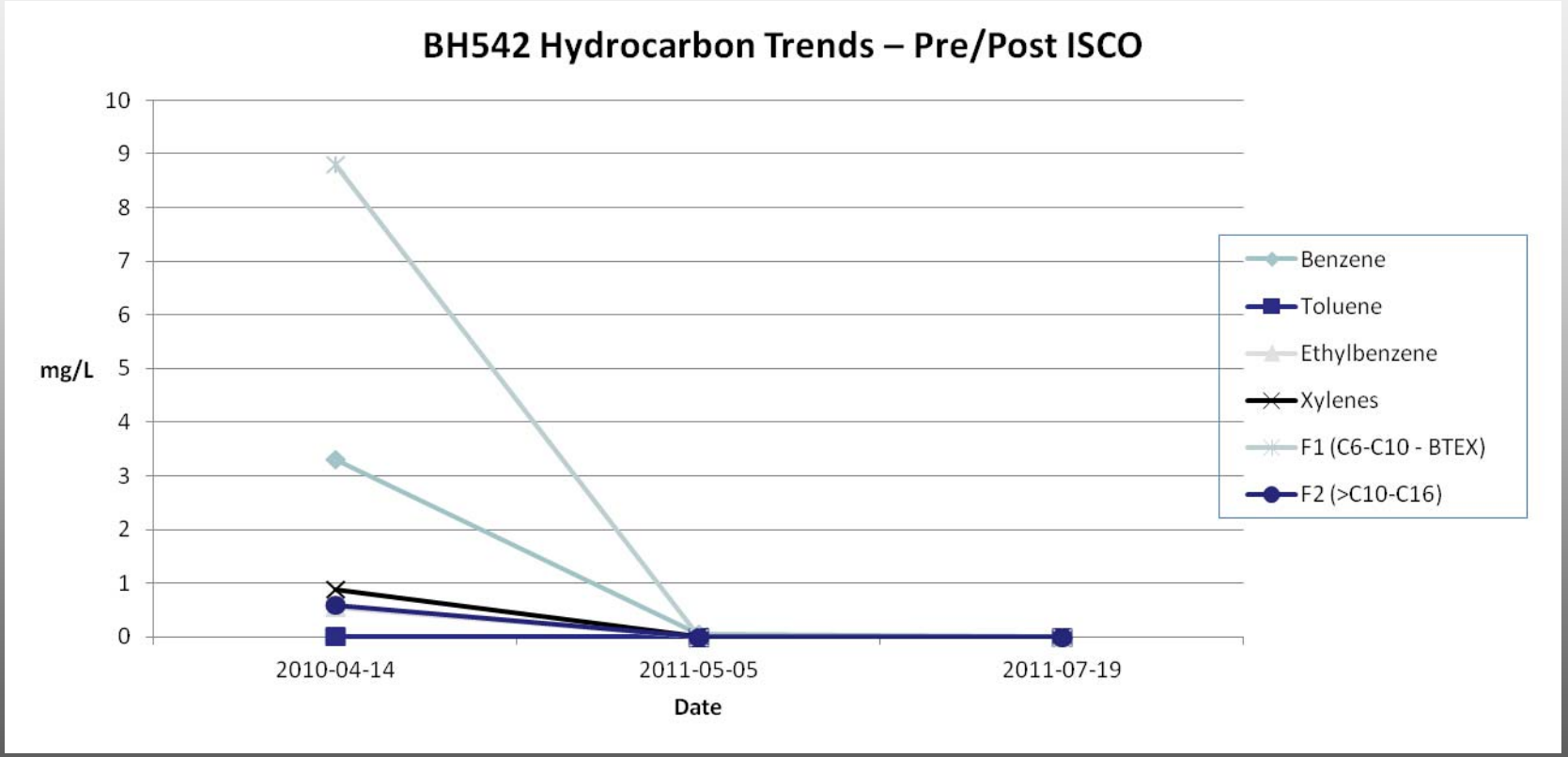
- On specific request/design
  - Shallow monitoring well (not suited to injection)
  - Very small volume (shallow and in backfill)
  - Maybe it won't come back…

Does Work - Bedrock





Does Work – Silty Clay



Questions?

More Information:
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www.triuminc.com