

Advances in Coupling Chemical and Biological Oxidation Technologies

Troy Fowler, Biochemist, Hart Crowser
Craig Dockter, Engineering Geologist, Hart Crowser
Shane Kennedy, Earth Science Products
Tommy LaLonde, StabilEarth Technologies

Presentation Outline

- **Technology overview**
- **Evaluated technology**
- **Application examples**
- **Lessons learned**

Technology Overview

- Peroxide/Fenton's/Modified Fenton's
 - Radical chemistry – hydroxyl, superoxide
- Permanganate
 - Metal oxidation state change
- Persulfate
 - Radical chemistry – sulfate radical
- Ion exchange

Technology Overview

- **Concerns with peroxide/Fenton's**
 - **Activation chemistry**
 - **Highly exothermic**
 - **Generates gas**
 - **Self-reactions**
 - **Can volatilize contaminants**
 - **Homeland Security**

Technology Overview

- **Concerns with permanganate**
 - Doesn't chemically react (e.g. benzene, MTBE)
 - Water quality changes/sodium 'poisoning'
 - Persistence
 - Less cost effective for petroleum
 - Metal contaminants and mobilization (As, Cr, Pb)
 - Changes behavior of clay (cation flooding)

Technology Overview

- **Concerns with persulfate**
 - **Activation chemistry**
 - **Low pH**
 - **Sulfate accumulation**
 - **Expensive**

Technology Overview

- **Concerns with ion-exchange**
 - **Low pH prior to injection**
 - **Trace contaminants (e.g. benzene)**

Evaluated Technology

- **Couple chemical and biological oxidants**
 - **Chemical compatibility**
 - **Single mobilization**
 - **Fewer injection locations**
 - **Fewer health, safety, transport, and storage issues**
 - **More complete treatment**

Evaluated Technology

- **NovIOX™ colloidal ion-exchange resin oxidant**
 - **Uses proton radicals for activity**
 - **Generates volatile fatty acids**
 - **Minimal heat or gas generation**
 - **Most effective for weathered fuels**
 - **Injected at pH ~2, activity returns to pH ~7**
 - **Up to 7 days of degradation activity**
 - **Patented**



Atomized NovIOX™

Evaluated Technology

- **AnoxEA™ oxidative biological amendment**
 - **Blend of 5 oxidant sources**
 - **Nutrient fortified**
 - **Typical biological oxidation profile**
 - **High-, mid-, and low-mobility oxidants**
 - **Improves degradation by acclimated microbes**
 - **Patent-pending**



AnoxEA™ slurry

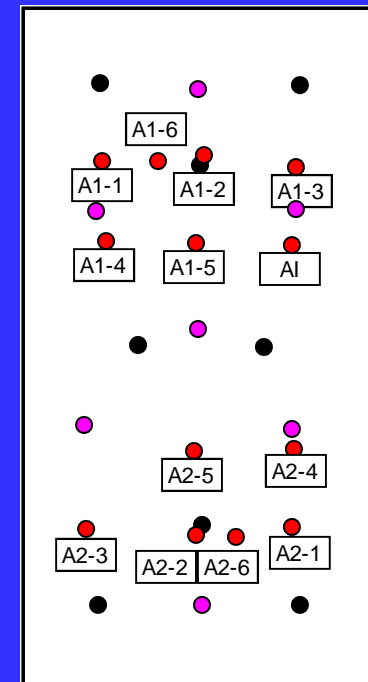
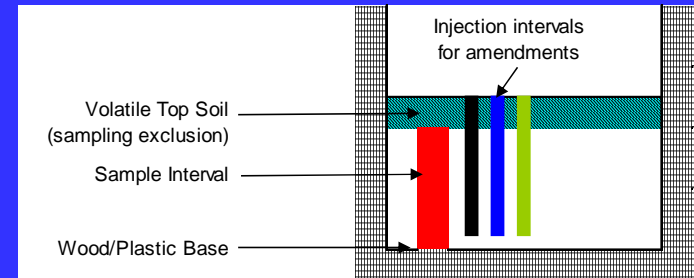
Evaluated Technology

- **Petroleum testing to date**
 - Land farm application
 - 3 active fueling stations
- **Validated lance-injection technique**
 - Minimally invasive
 - 1-inch borehole
 - Reduced risk to subsurface infrastructure
 - Faster and less expensive

Application Examples

Land farming application

- Treating gasoline & diesel
- 7 soil cells – 5 yd³ each
- Total TPH up to 8,500 mg/kg
- Treated using NovIOX™ and/or AnoxEA™
- No tilling, no turning



Application Examples

Land farming application

- Petroleum reduced by 45% to 84% in 4 months
- NovIOX™ destroyed all contaminants equally
- AnoxEA™ destroyed BTEX, TPH-G, then TPH-D

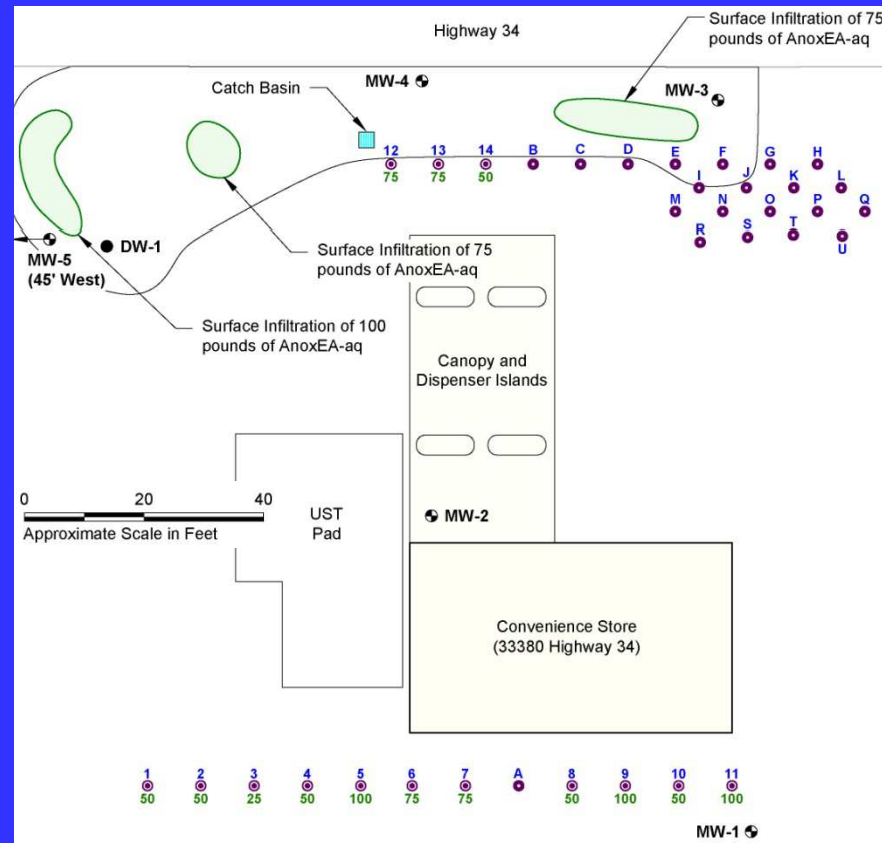


Application Examples

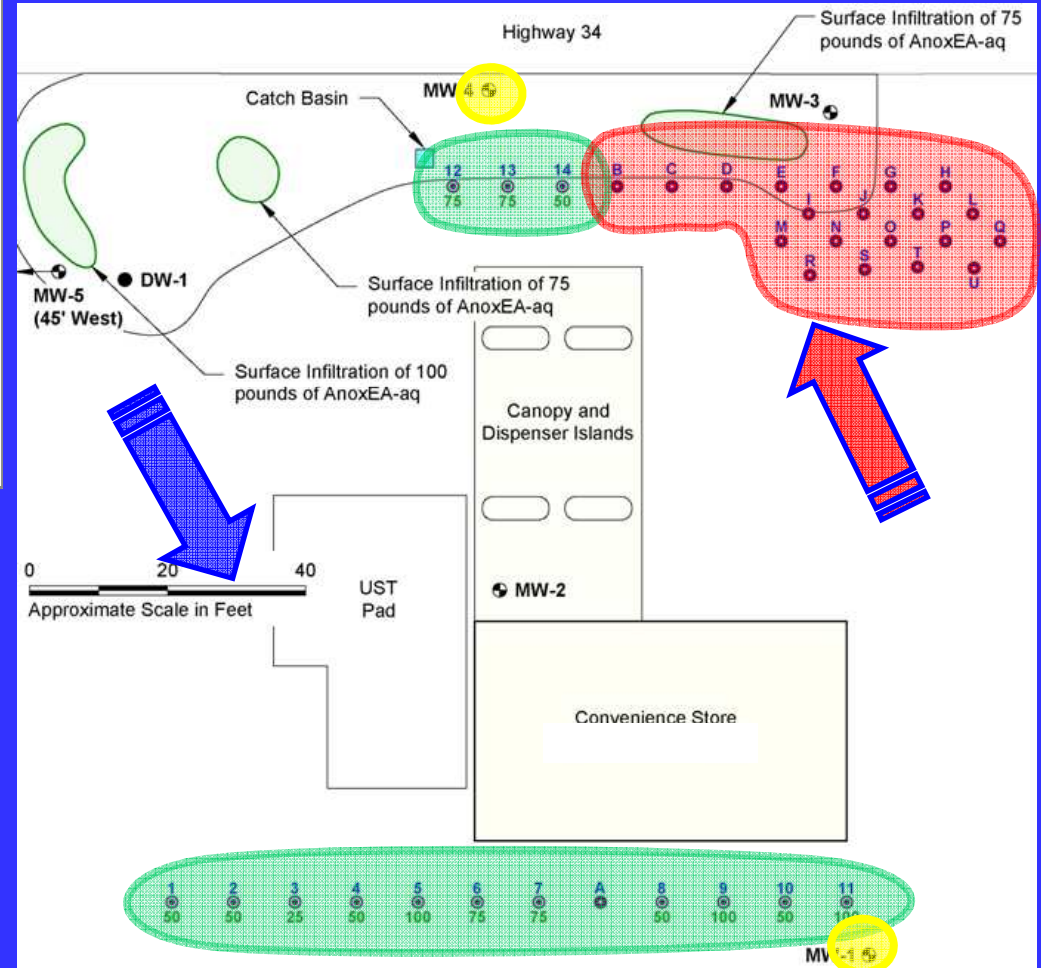
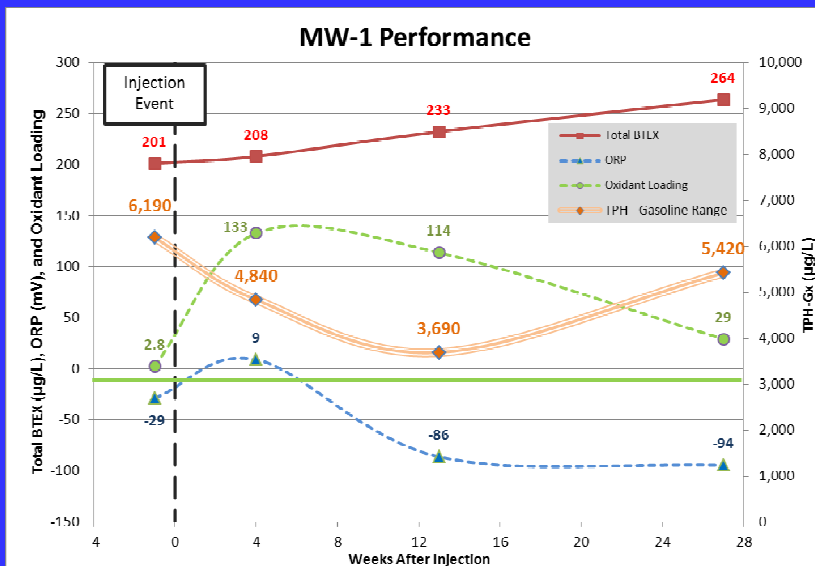
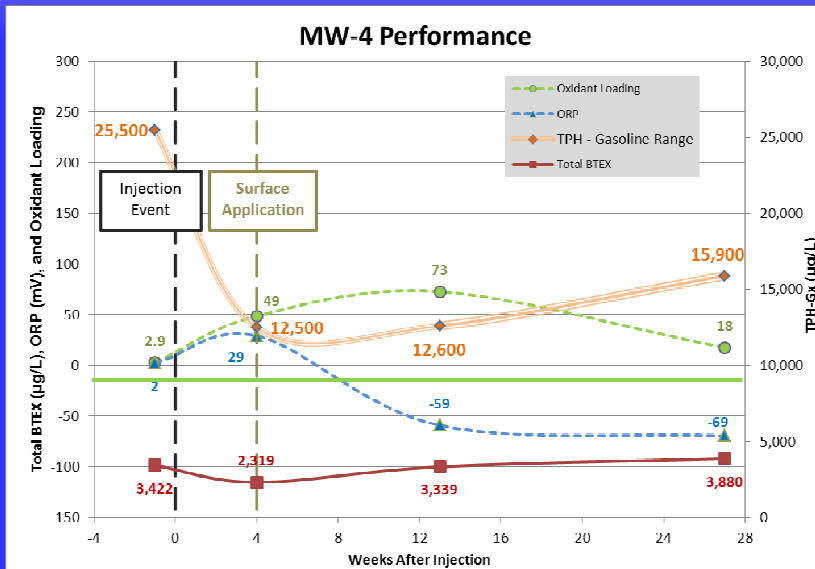
Active fueling station #1

- Primarily gasoline
 - TPH-G up to 25,500 $\mu\text{g/L}$
- Minimal application
 - 6 gallons of NovIOX™
 - 1,000 pounds of AnoxEA™
- Assess 'barrier effect'
- Assess lance injection





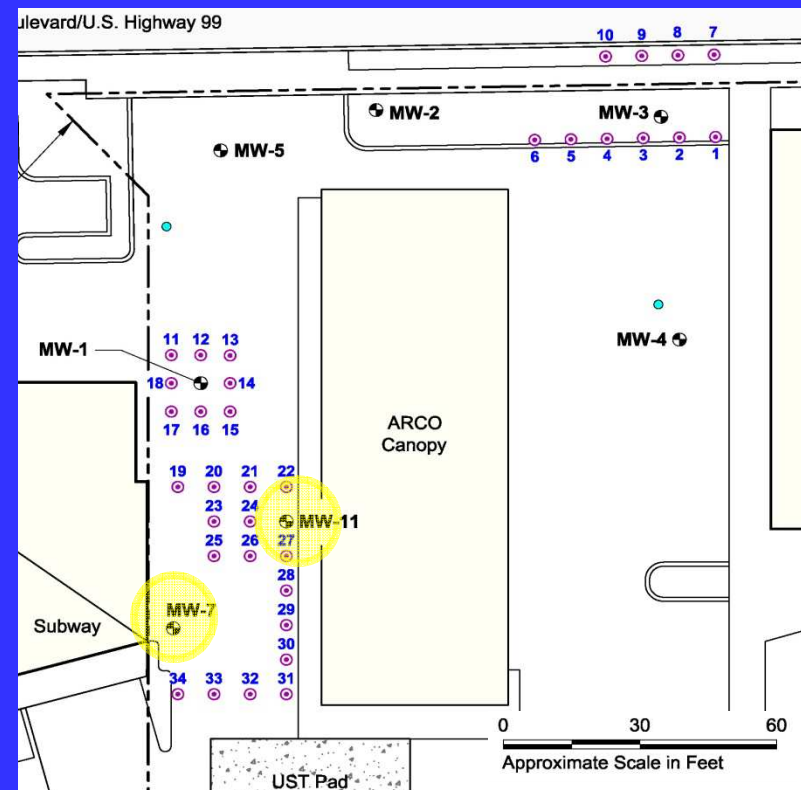
Performance



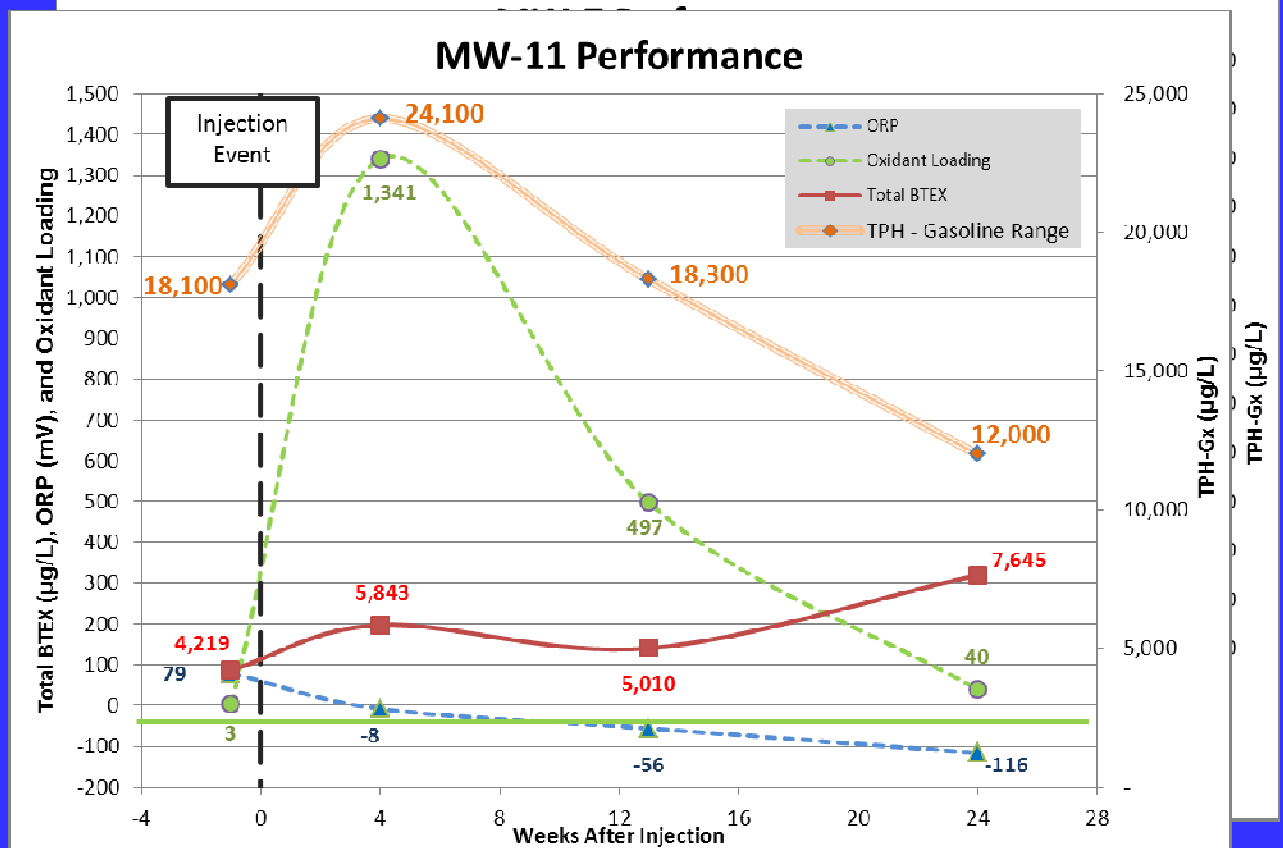
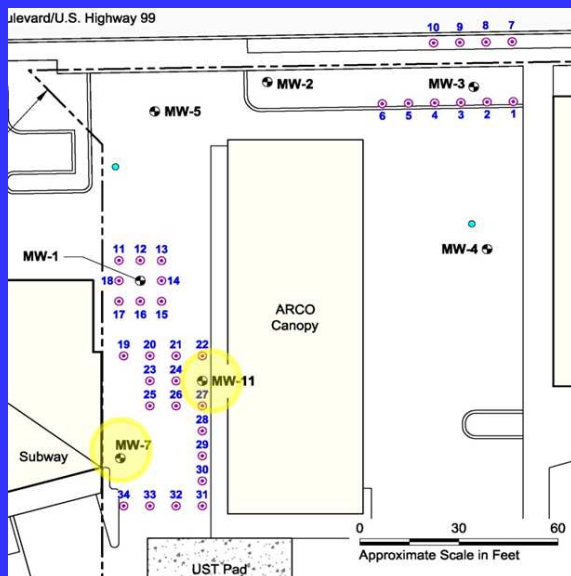
Application Examples

Active fueling station #2

- Primarily gasoline
 - TPH-G up to 57,000 $\mu\text{g/L}$
- Same goals as station #1
- ‘Ringed’ application
- Incomplete treatment
 - 6 gallons of NovIOX™
 - 1,550 pounds of AnoxEA™



Performance



Application Examples

Active fueling station #3

- Primarily gasoline
 - TPH-G up to 57,000 $\mu\text{g/L}$
- Complete treatment
 - 70 injection points
 - 7.5 gallons of NovIOX™
 - 5,000 pounds of AnoxEA™
- 2.5 days to complete injections



Performance

Station #3 – +1 Month Results

- High oxidant loading detected
- 51% reduction in TPH-G
- 48% reduction in TPH-D
- 41% reduction in BTEX



Lessons Learned

- **Chemical and biological oxidation treatments can be completed in one mobilization**
- **Application strategy preserves microbes**
- **Lance injection technique has both advantages and limitations**
- **Good understanding of the site is key to eventual success**
- **Oxidation is sustained for 6+ months**

Questions?

Presenter & Bioremediation Design

Troy Fowler

Hart Crowser Biochemist
troy.fowler@hartcrowser.com

Bioremediation Engineering

Craig Dockter

Hart Crowser Engineering Geologist
craig.dockter@hartcrowser.com

Applicators

Earth Science Products

Aurora, Oregon

Shane Kennedy

President

earthscienceproducts@hotmail.com

StabilEarth

Arlington, Texas

Tommy LaLonde

President

tommy@stabilearth.com