

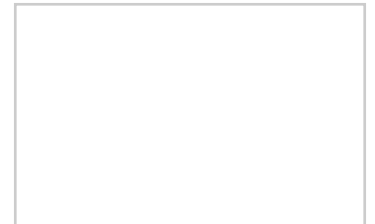
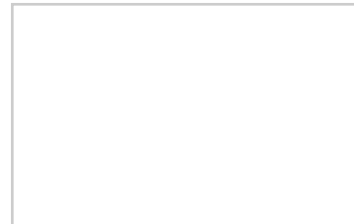
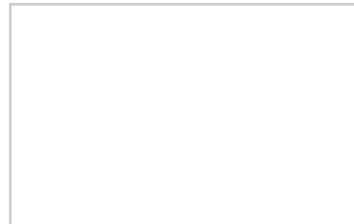
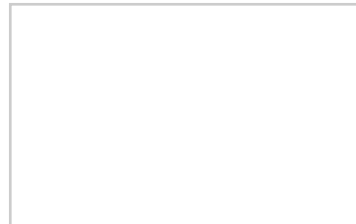


Jet Assisted Injection of Nano-scale Zero-valent Iron to Treat TCE in a Deep Alluvial Aquifer

Presented by Paula R. Chang, ERM

Coauthored by Dr. Anthony Pantaleoni, Crane Co. and David Abranovic, ERM.

Seventh International Conference for Remediation of Chlorinated and Recalcitrant Compounds, Session D7, 27 May 2010



Overview

- **Site Background**
- **Pilot Test Design**
- **Injection Method**
- **Performance Monitoring**
- **Results**
- **Conclusions**

Sub Unit A Plume Morphology

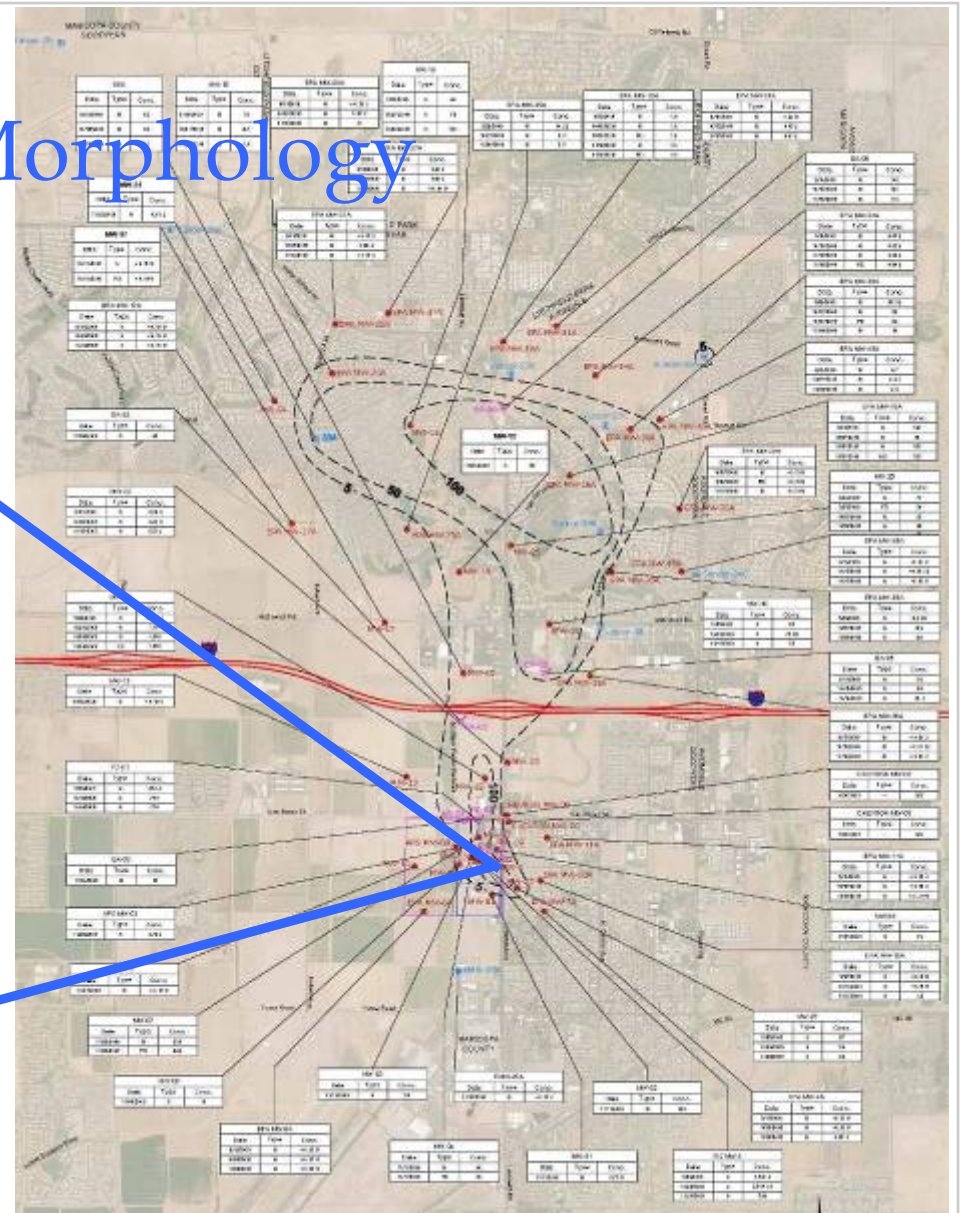


Image Sources: 2008 Google Earth Pro Ver. 4.3.7284.3916, and Matrix New World

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Previous Pilot Test Parameters



Date	January 2006	June 2008	February 2010
Injection Location	IRZ-IW-01 and -02	IRZ-IW-05	BW-01 and BW-02
Volume	224 gallons	2,751 gallons	7,421 gallons
Dosage	26 - 30 g/L	2.1 g/L	21 g/L
Injection method	low pressure injection between packed well screen	dispersant and colloid mill, gravity feed	jet-assisted, with dispersant
Pressure head	24 - 55 psi	26 psi	10,000 psi water + 200 psi PolyMetallix™ injection
Injection Period	3 days	3 days	4 days
Mass of PolyMetallix™	46 lbs	50 lbs	1,400 lbs
Radius of Influence	well screen	5 ft	30 ft

Pilot Test Design

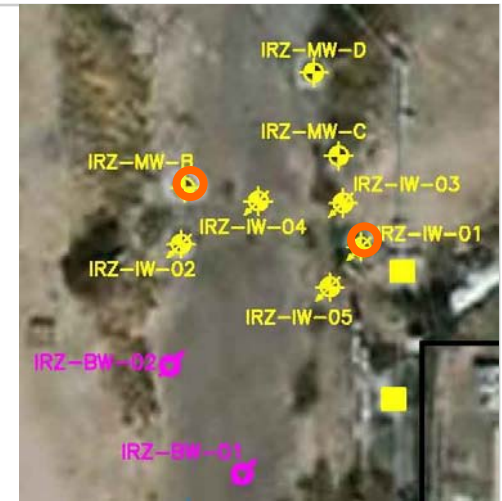
- **Two injection locations: blank-cased wells installed to 135 ft bgs.**
- **Two five-foot injection intervals per location,**
 - 108 – 113 ft bgs
 - 113 – 118 ft bgs
- **2,000 gallons of 21 g/L PolyMetallix dosage per injection interval.**
- **PolyMetallix nZVI formulated by Polyflon, a Crane Co. company, PATENT US 7,641,971**
- **Delivered to site in 275-gallon totes.**



Pilot Test Design

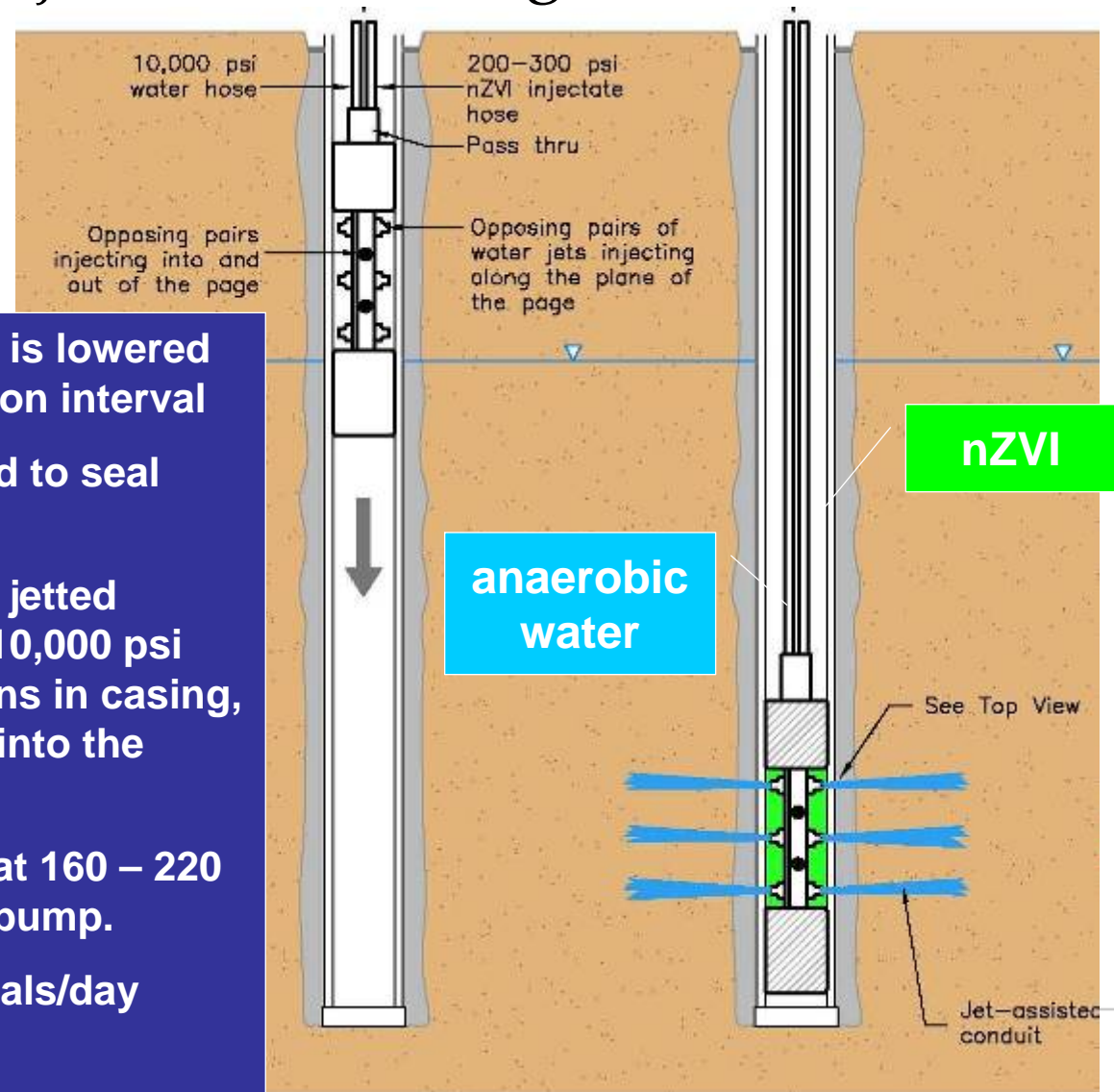
- **NZVI Dosage based on stoichiometric hydrogen demand:**
 - TCE, CT, CF, Perchlorate and Chlorate.
 - Other potential electron acceptors: oxygen, nitrate, sulfate.
 - Assumed radius of influence of 25 ft, and 10 ft thickness of treatment area, effective porosity of 30%.

Baseline TCE ranged between 46 µg/L at IRZ-MW-B, and 6,300 µg/L at IRZ-IW-01.



Jet Assisted Injection – Tooling and Procedure

- Fracture lance tool is lowered to the target injection interval
- Packers are inflated to seal casing
- Anaerobic water is jetted through casing at 10,000 psi creating perforations in casing, and extending out into the formation
- NZVI was injected at 160 – 220 psi using a piston pump.
- Completed 2 intervals/day

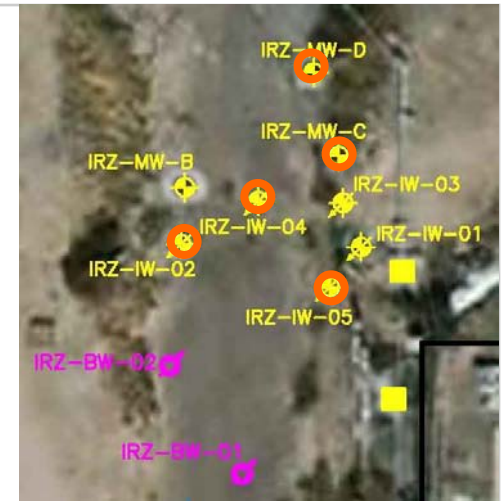


Jet-assisted Injection Short

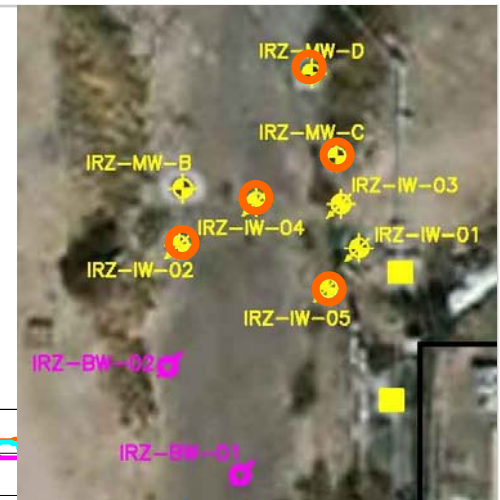
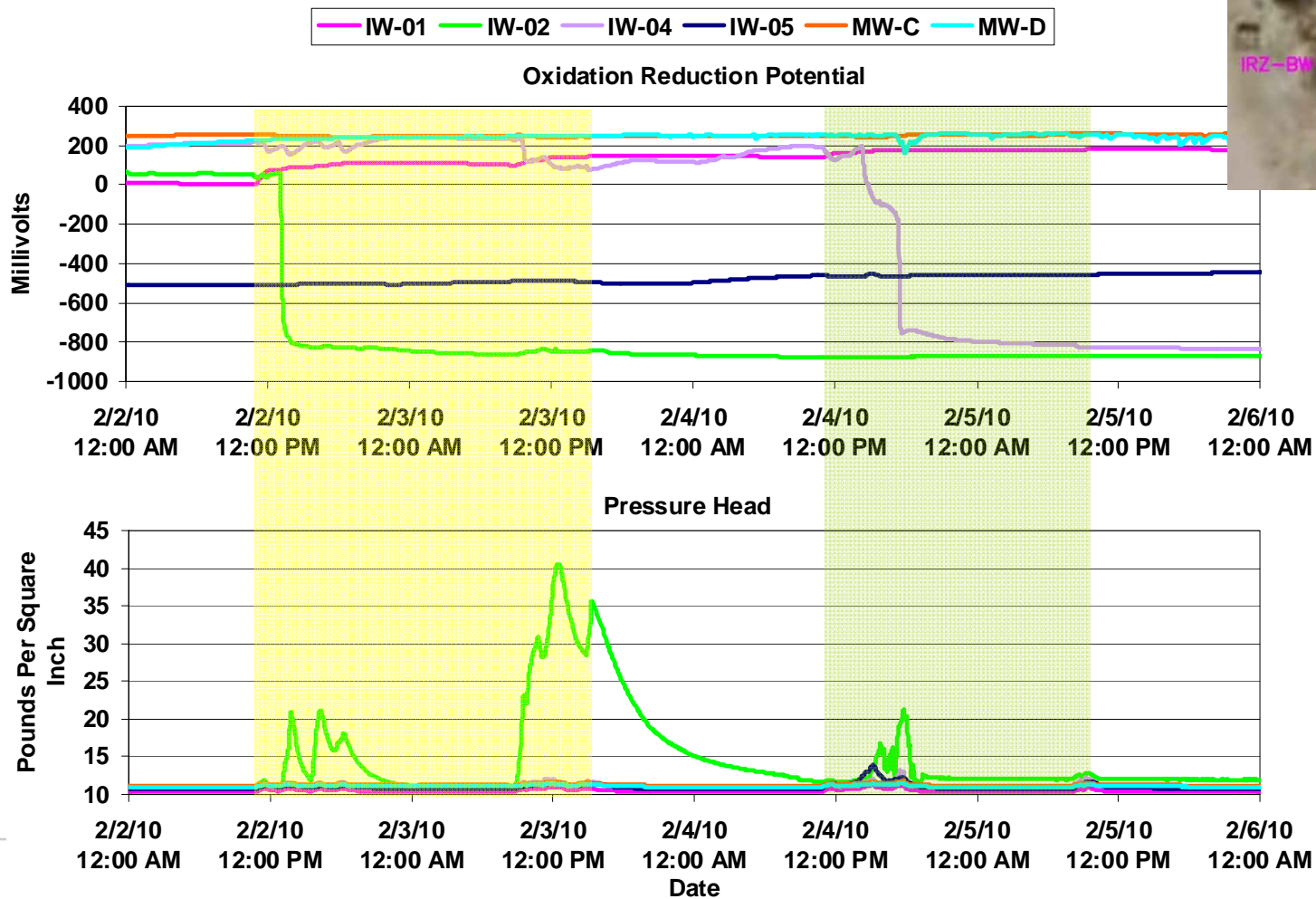


Performance Monitoring

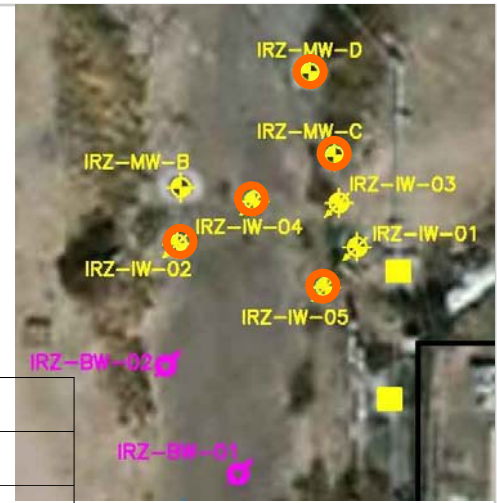
- **In-Situ Sensors**
 - pH, Temp, ORP
 - 15 minutes, frequency increase to 5 minutes
- **Pressure profiles during injection**
- **All monitoring and injection wells were sampled: 1 week, 2 weeks, and 4 weeks after injection**
 - Target compounds: VOCs and perchlorate
 - Potential by-products: chlorate, chloride, hydrogen
 - Metals: total and diss. Fe, total and diss. Mn, Na
 - Major ions and redox indicators: sulfate, nitrate, phosphate, alkalinity



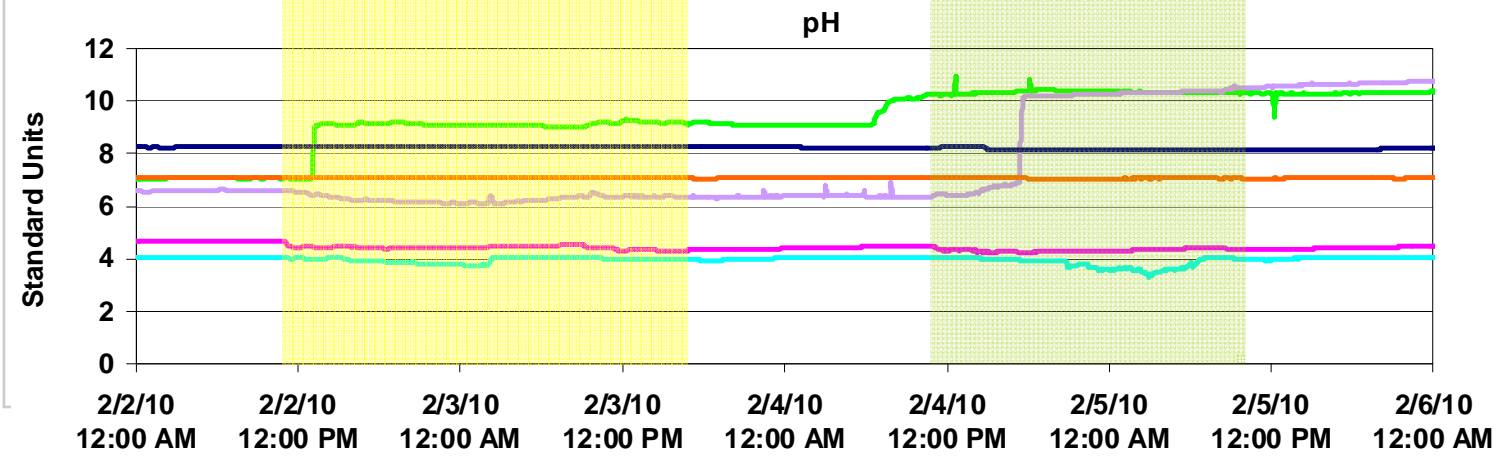
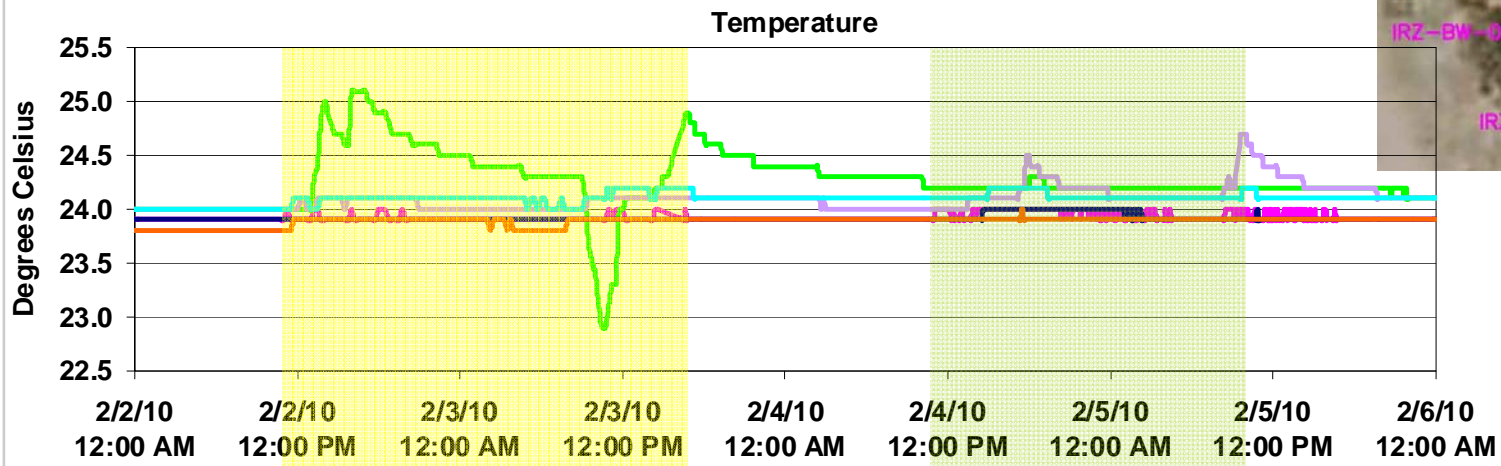
Real-time Data

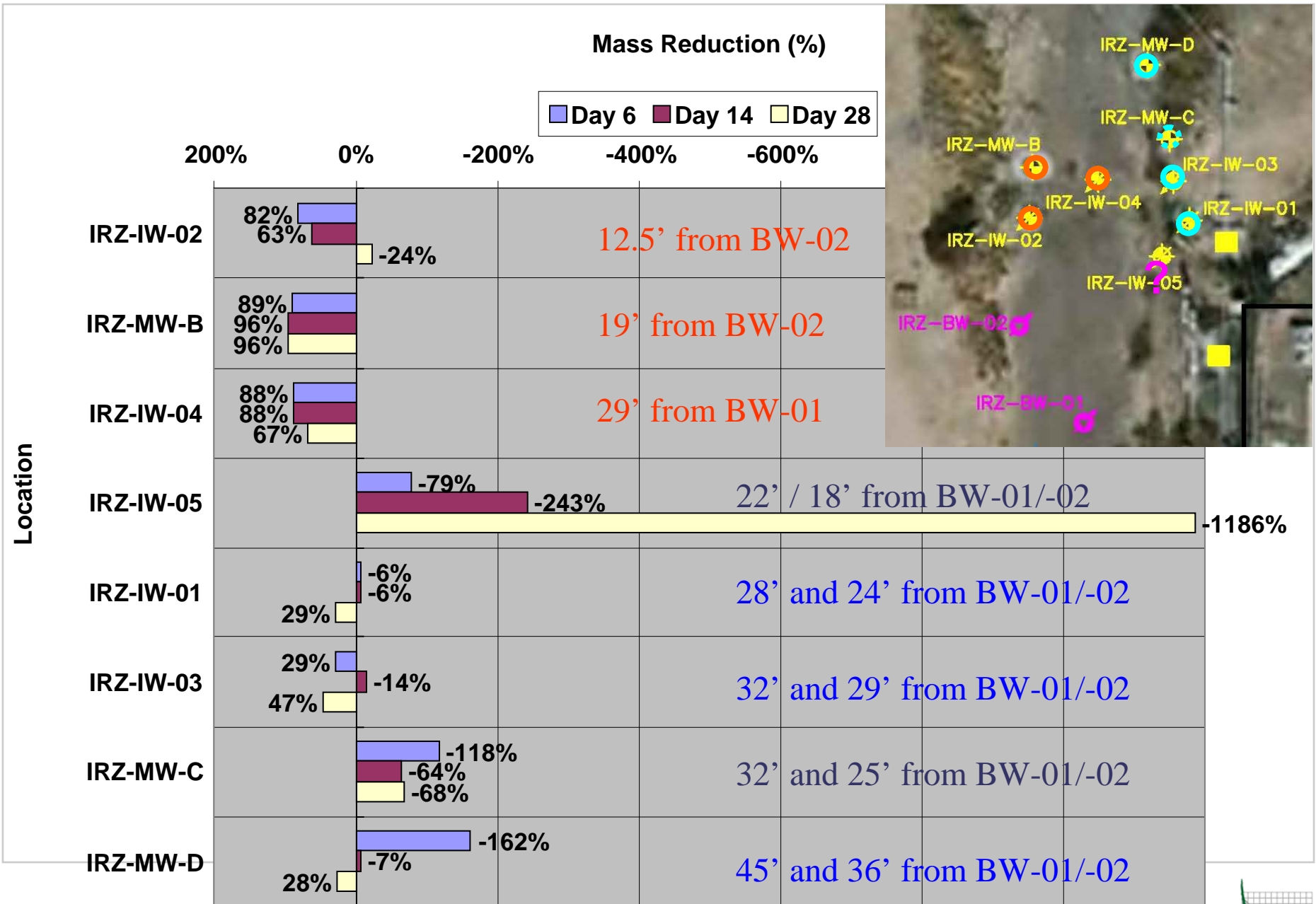


Real-time Data

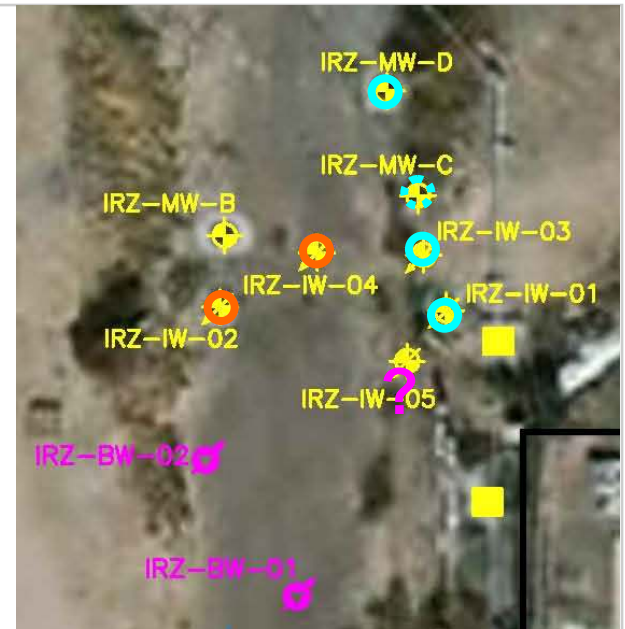
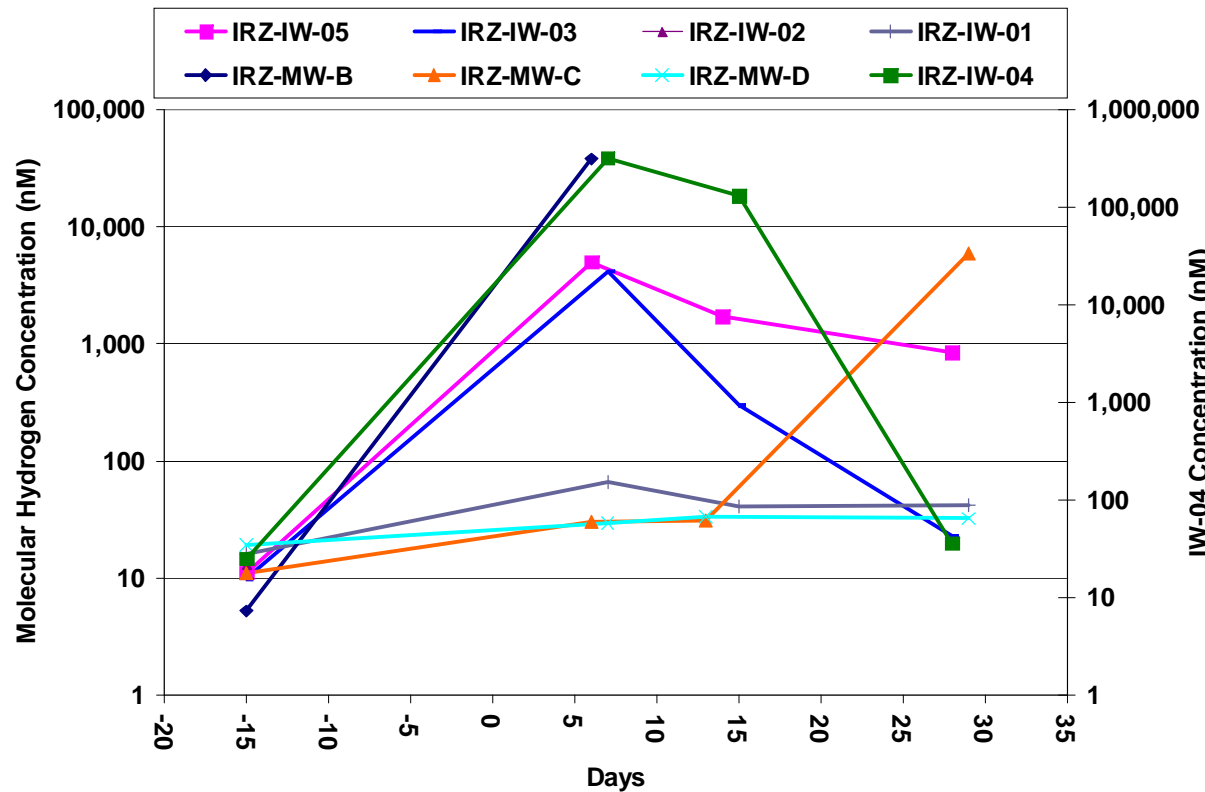


— IW-01 — IW-02 — IW-04 — IW-05 — MW-C — MW-D





Molecular Hydrogen



Conclusions



- **Immediate impacts observed at least 29 ft from injection location**
- **Iron and hydrogen data shows migration of nZVI and treated groundwater as far as 45 ft downgradient, one month after injections**
- **Groundwater data within the treatment area shows decrease in TCE mass ranging between 63 and 96% one month after injection.**
- **Injections also increased TCE concentrations downgradient of the injected nZVI particles, for capture at downgradient extraction wells.**

Kudos



- **Dr. Tony Pantaleoni, Crane Co. and Alan Bilzi, Nanitech LLC**
- **Polyflon: Will LaRusso and Peter Papagianakis for making the ZVI very small and putting it into very large totes.**
- **PGA-North Technical Working Group: Leanne Austrins, Catherine Brown, Dave Becker**
- **ERM Field Staff: Jason Hilker and Roy Courtright**
- **Frax: Dr. Bill Slack and Doug Knight for running bottle tests in the kitchen and video taping them**