

REMTEC 2007

COUPLED CHEMICAL OXIDATION AND ENHANCED BIOREMEDIATION PILOT TEST

PETROLEUM HYDROCARBON PLUME MIGRATING IN FRACTURED ROCK

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Outline

- Project Objectives
- Project Background
- Proposed Remedial Strategy
- Site Conceptual Model Driven Characterization
- Pilot Test Strategy
- Pilot Test Results
- Conclusions

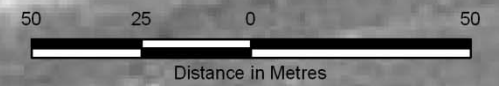
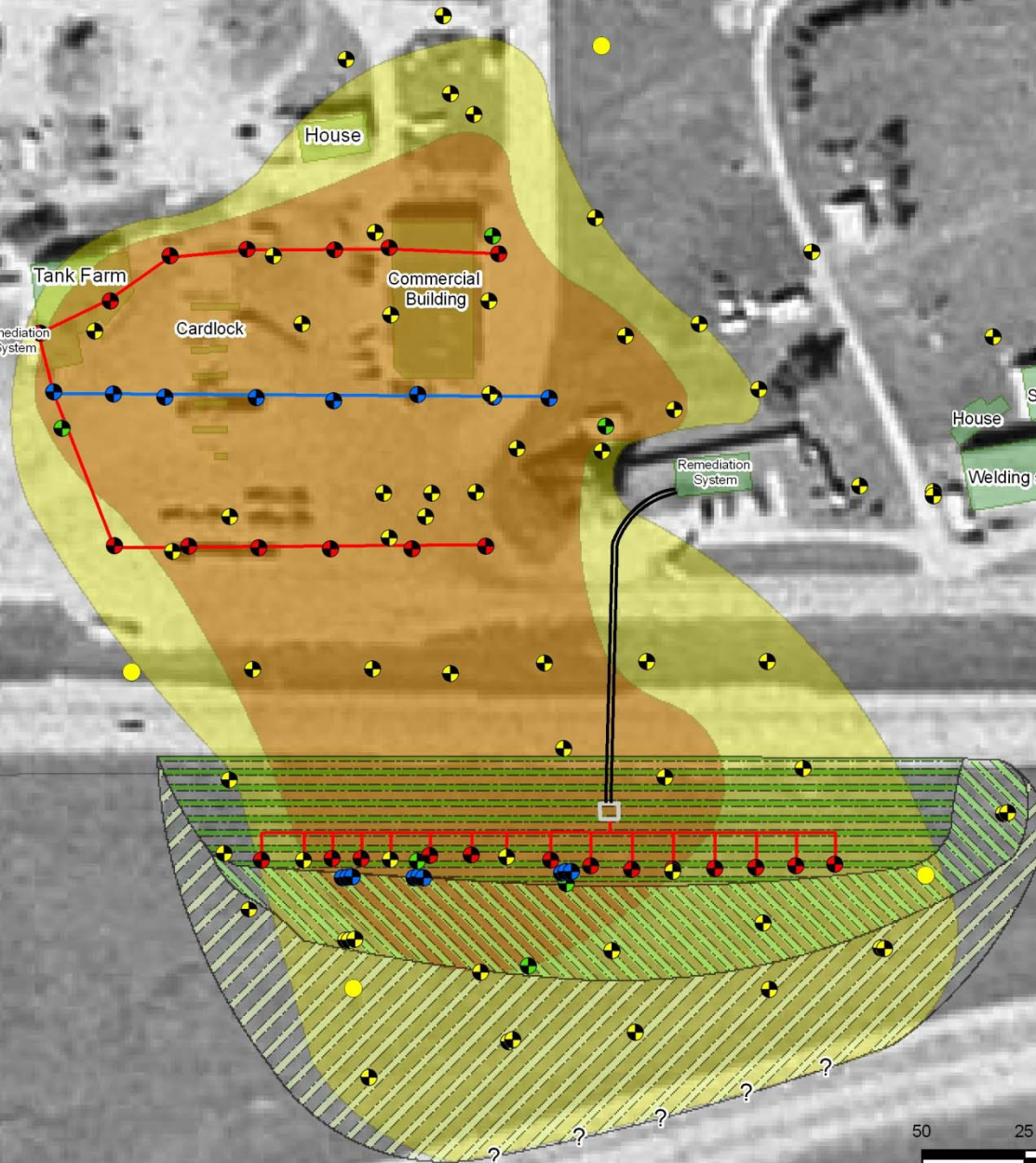
Project Objectives

- Enhance Site Conceptual Model
- Test Hydraulic Characteristics Under Injection
- Determine Geochemical Effects of Chemical Injection
- Evaluate the Efficacy of the Proposed Remedial Strategy
- Collect Data for Full Scale Design



Proposed Remedial Strategy

- Based on SCM developed and refined through 2005 – 2006, NAPL and dissolved-phase PHC migration to south is most urgent remedial driver.
- SCM suggests plume stabilization strategy consisting of integrated physical removal, ISCO and BIO attenuation zones will be effective.
- Success depends on understanding the fractured bedrock hydrogeology, contaminant presence and migration and the effect of injected materials.
- Therefore, a pilot test program was designed to demonstrate the efficacy of the proposed remedial strategy.



Injection Chemicals

- PermeOx[®] Plus
 - Timed Oxygen Release Product consisting of Engineered Calcium Peroxide and manufactured by FMC Corporation.
- Klozur[®] OBC
 - Manufactured by FMC Corporation.
 - Klozur brand sodium persulfate activation by iron, hydrogen peroxide, heat and other alkaline agents.
 - Based on alkaline activation of Klozur sodium persulfate using PermeOx Plus which imparts alkalinity.
 - Oxygen from PermeOx Plus activator component of the product is available as electron acceptor for aerobic metabolism.

Key Advantages

- In-situ treatment avoids groundwater production and management issues
- Can be conducted in winter
- Persulfate anion is relatively stable with relatively low Soil Oxidant Demand
- Oxidation-Reduction Potential is 2.1 V
- Potential for Sulfate Radical is 2.6 V
- More stable than hydroxyl radical
- Oxygen is produced for bio-enhancement

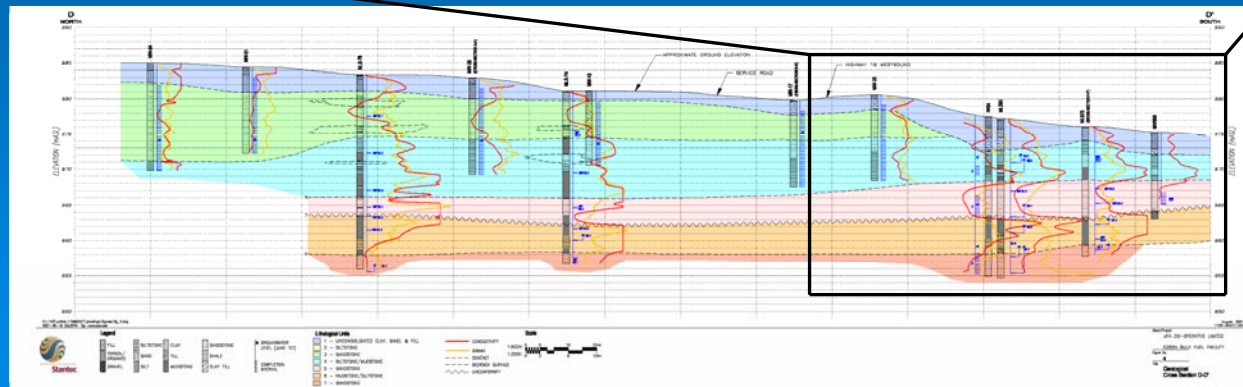
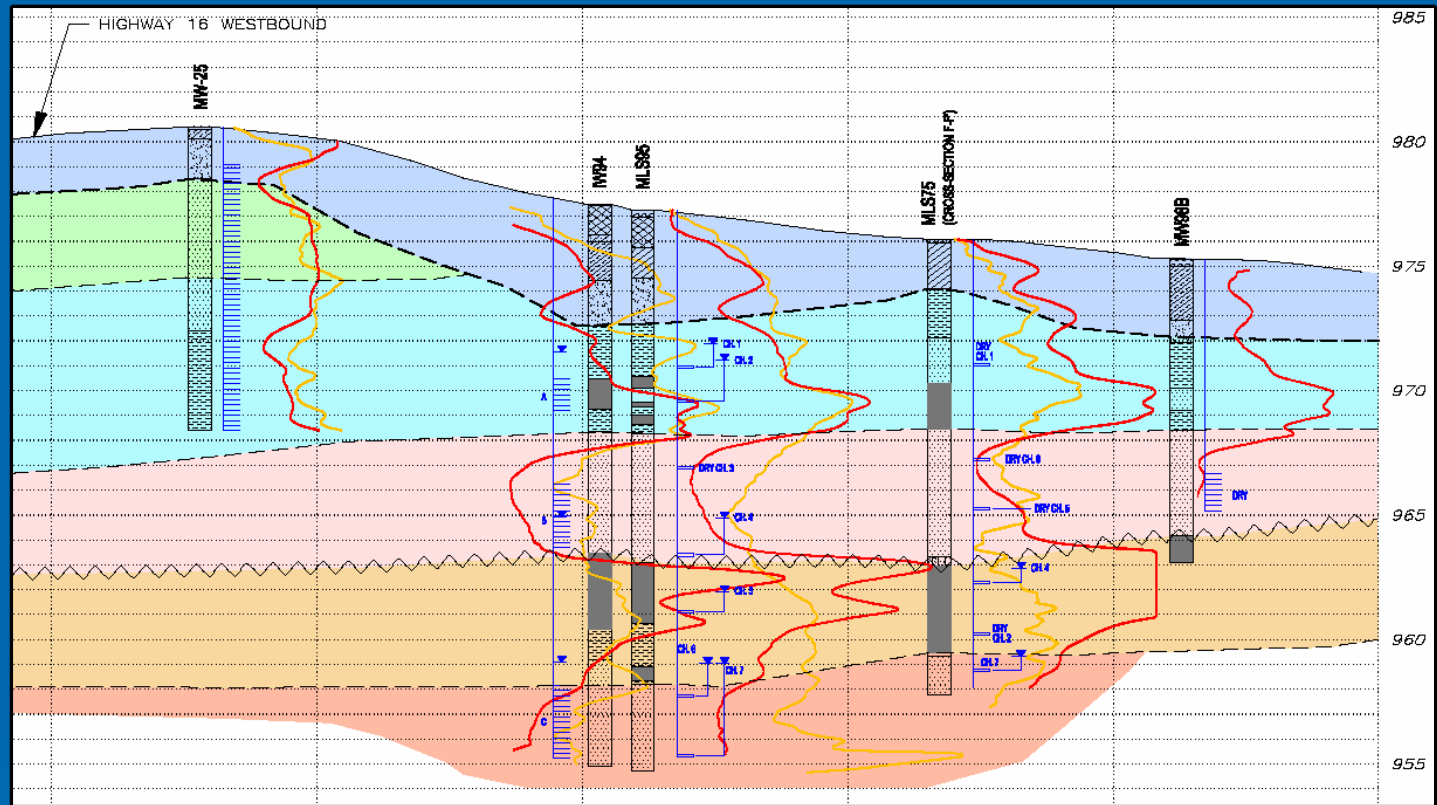
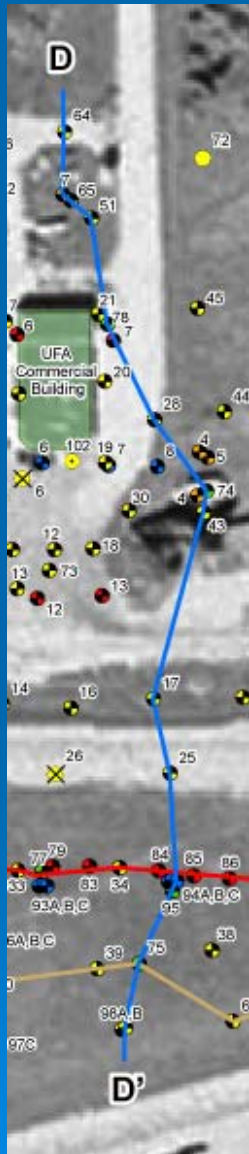
Proposed Pilot Test

- Installation of additional monitoring points and collection of baseline characterization information.
- Bench scale testing of core materials for oxidant demand.
- Injection of **Klozur® OBC** and **PermeOx® Plus**.
- Process monitoring during injection phase.
- Performance monitoring over three months following injections.
- Analysis.

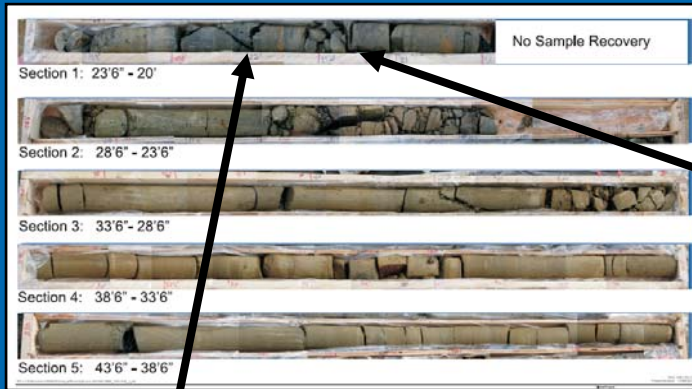
Pilot Test Characterization



North-South Hydrogeologic Profile



Unit 4 (Zone A) Core



PHC impacts
observed in
gradational
sequences.



970.555 m

970.865 m

MLS-95 from 21 to 22 ft (6.4 to 6.7 m bg)

Zone C Core (Upper Unit 7)

Weathered
fracture with
oxidation banding



Sandstone

955.924 m

956.228 m

MLS-95 from 69 to 70 ft (21.0 m to 21.3 m bg)

Klozur® OBC Total Oxidant Demand Test



Pilot Test Injections

92A – 1045 L 20% OBC

92B – 68 L 20% Permeox

92C – 1278 L 10% Permeox,
234 L 20% Permeox

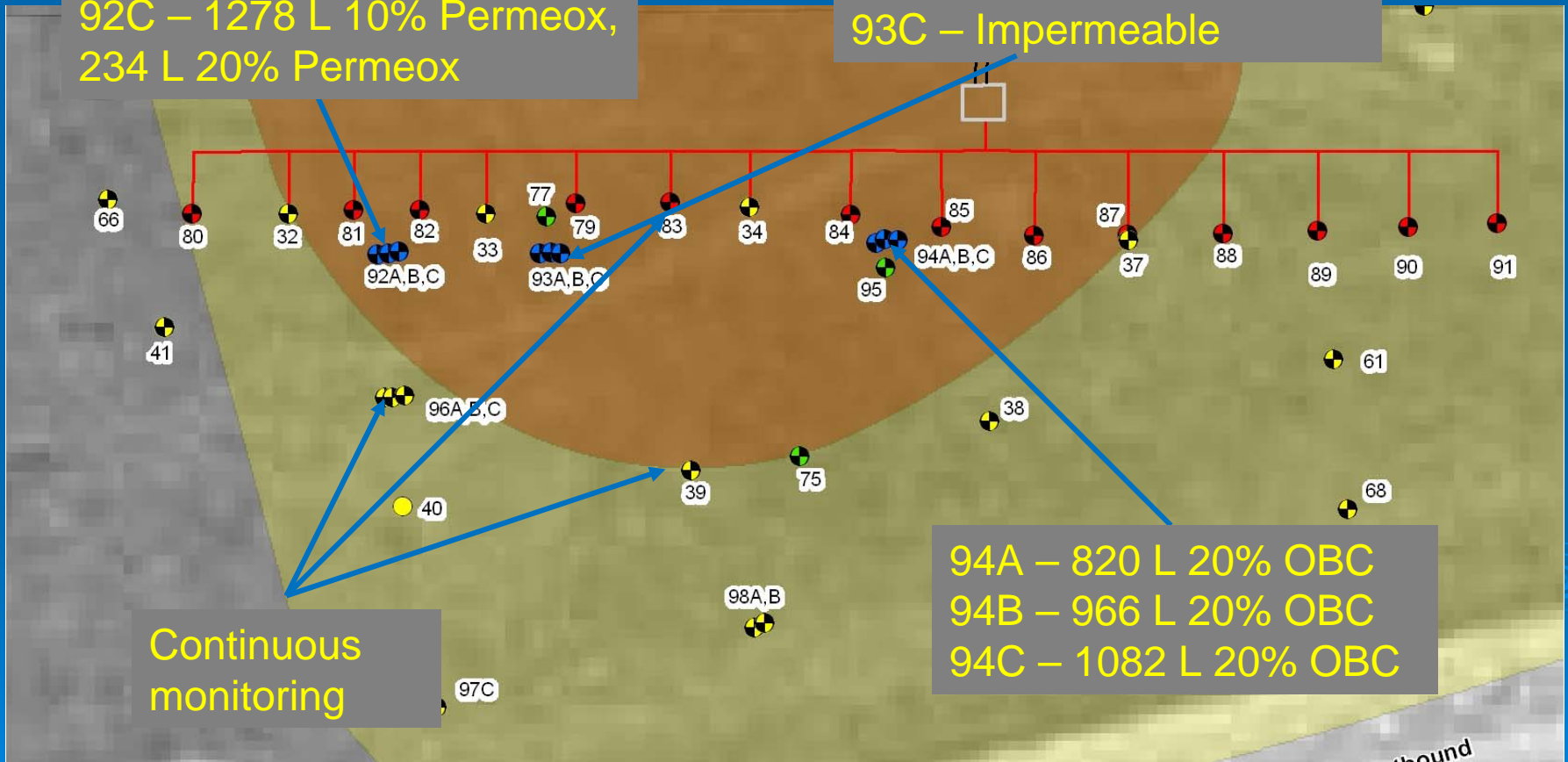
93A – 1057 L 20% OBC

93B – 148 L 10% Permeox

93C – Impermeable

Continuous
monitoring

94A – 820 L 20% OBC
94B – 966 L 20% OBC
94C – 1082 L 20% OBC

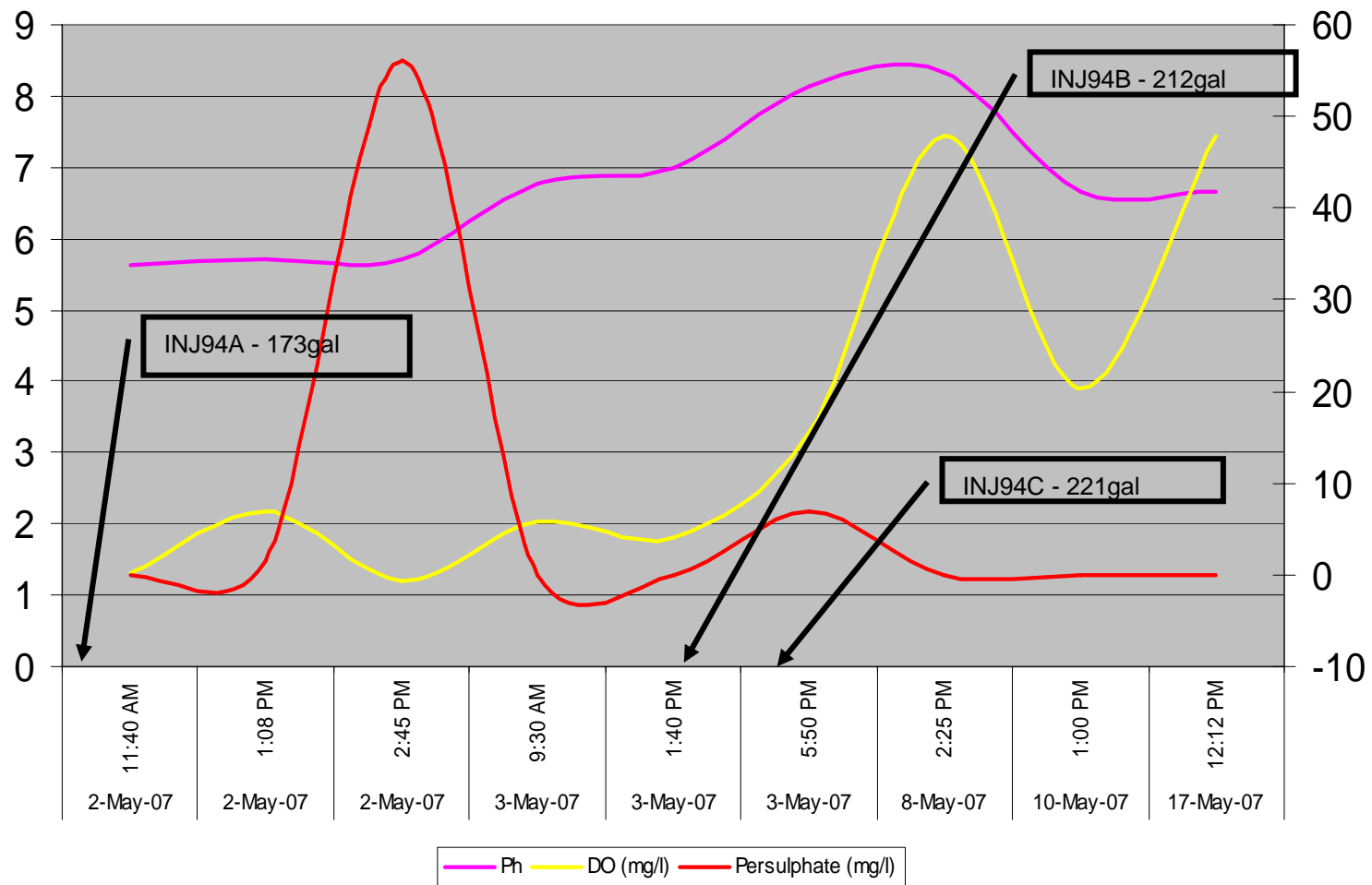


Process Monitoring - Hydraulic Response

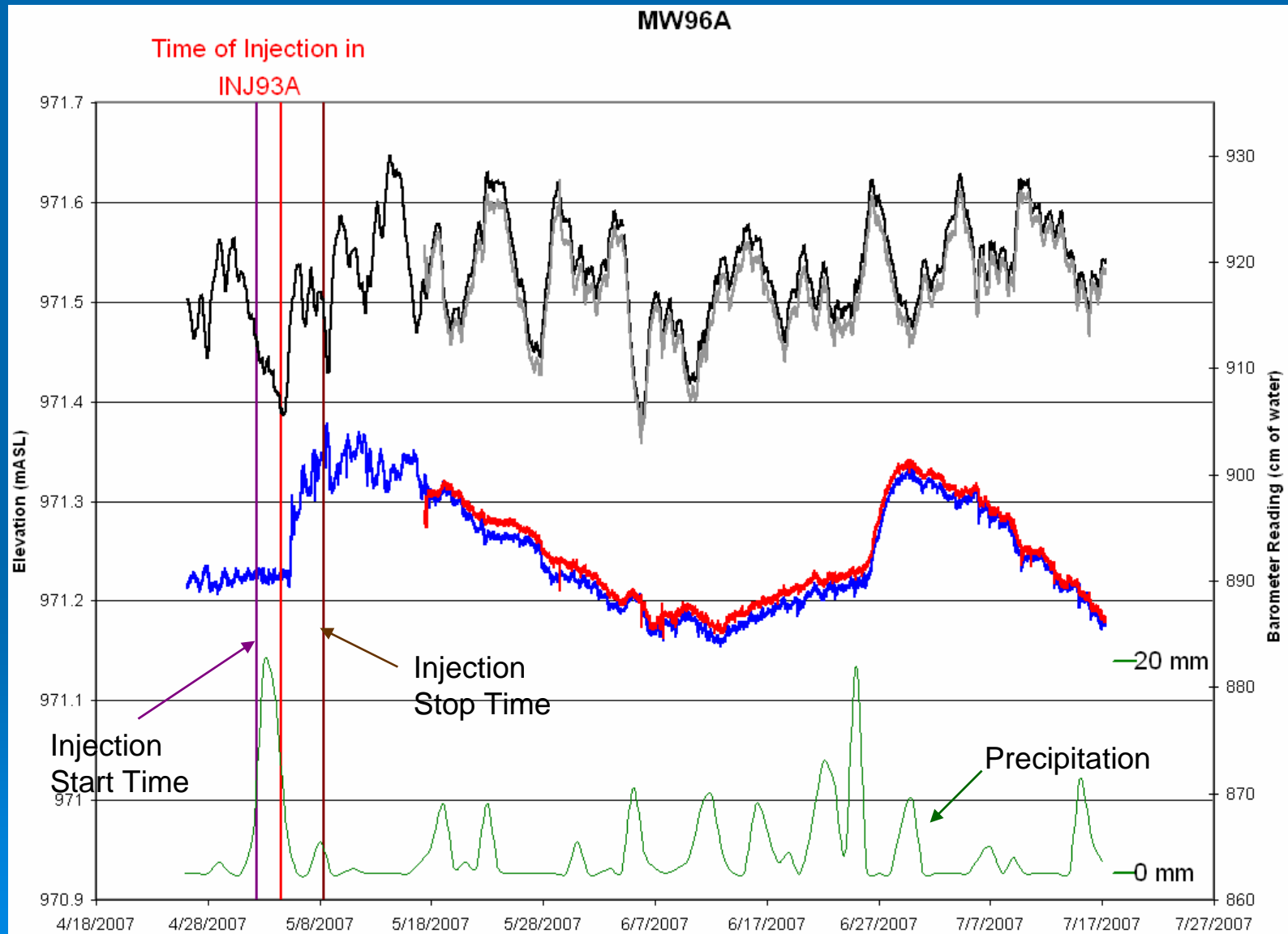
- Transport through fracture bedrock network
 - Injections into 94A started at 9:35am
 - Day lighting observed at MLS95-2 (Unit 4 Zone A Sandstone) at 10:16am.
 - MLS95-2 approximately 3 m south of INJ-94A

Process Monitoring - Geochemistry

RW85 Process Data - Field Parameters

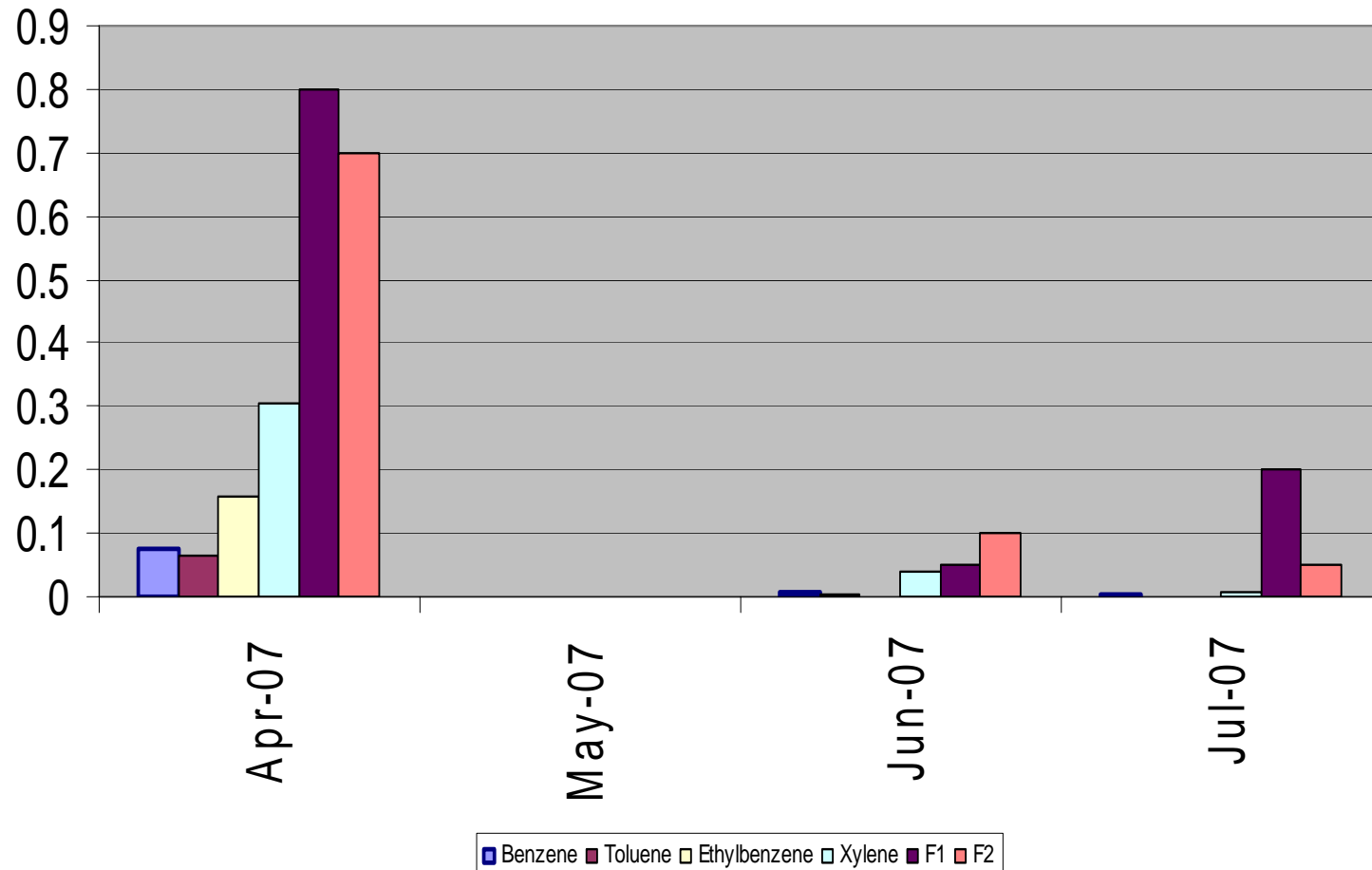


Performance Monitoring – Hydraulic Response



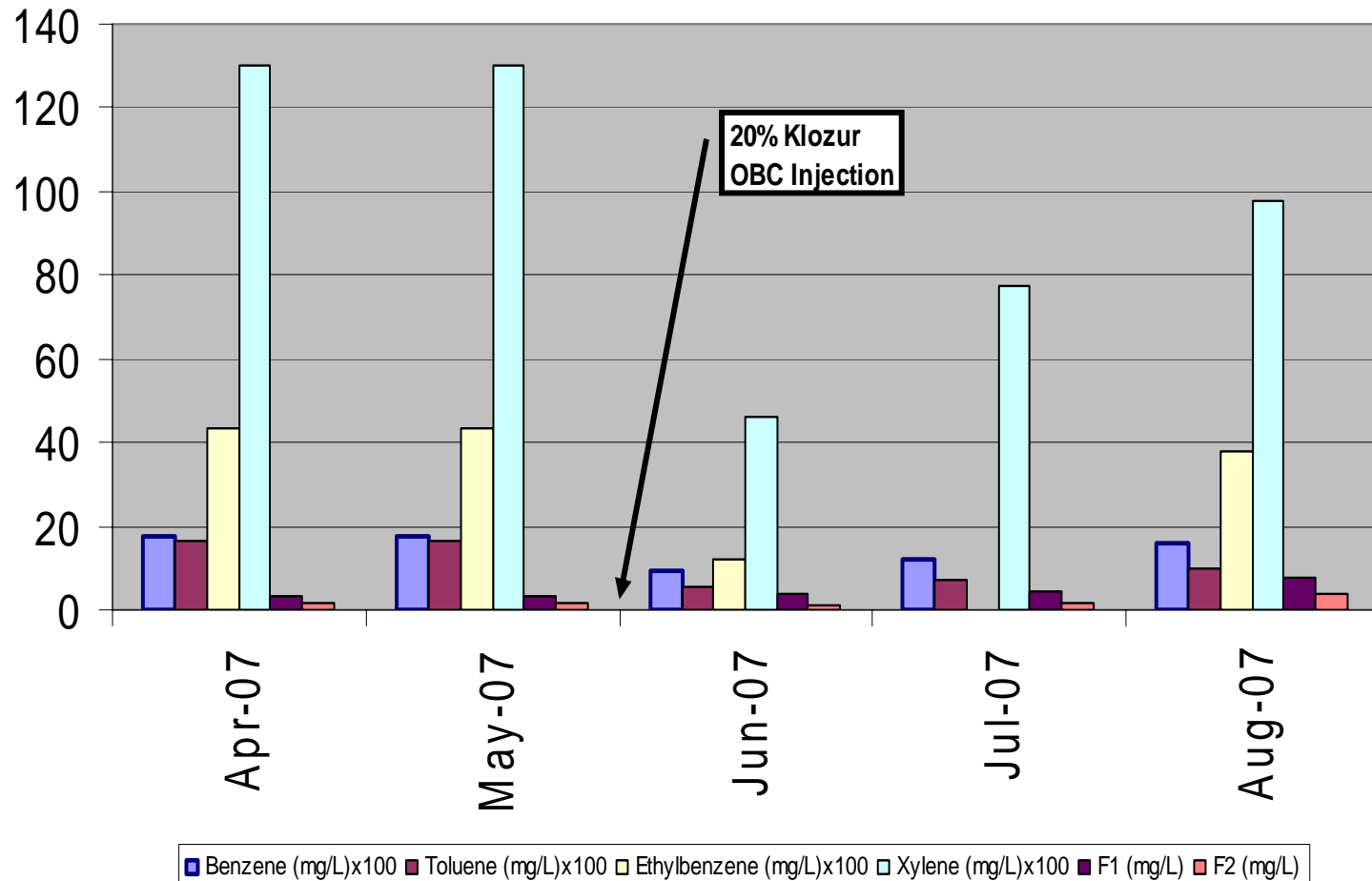
Performance Monitoring – Geochemistry

MLS95-2 Performance Data - Hydrocarbons

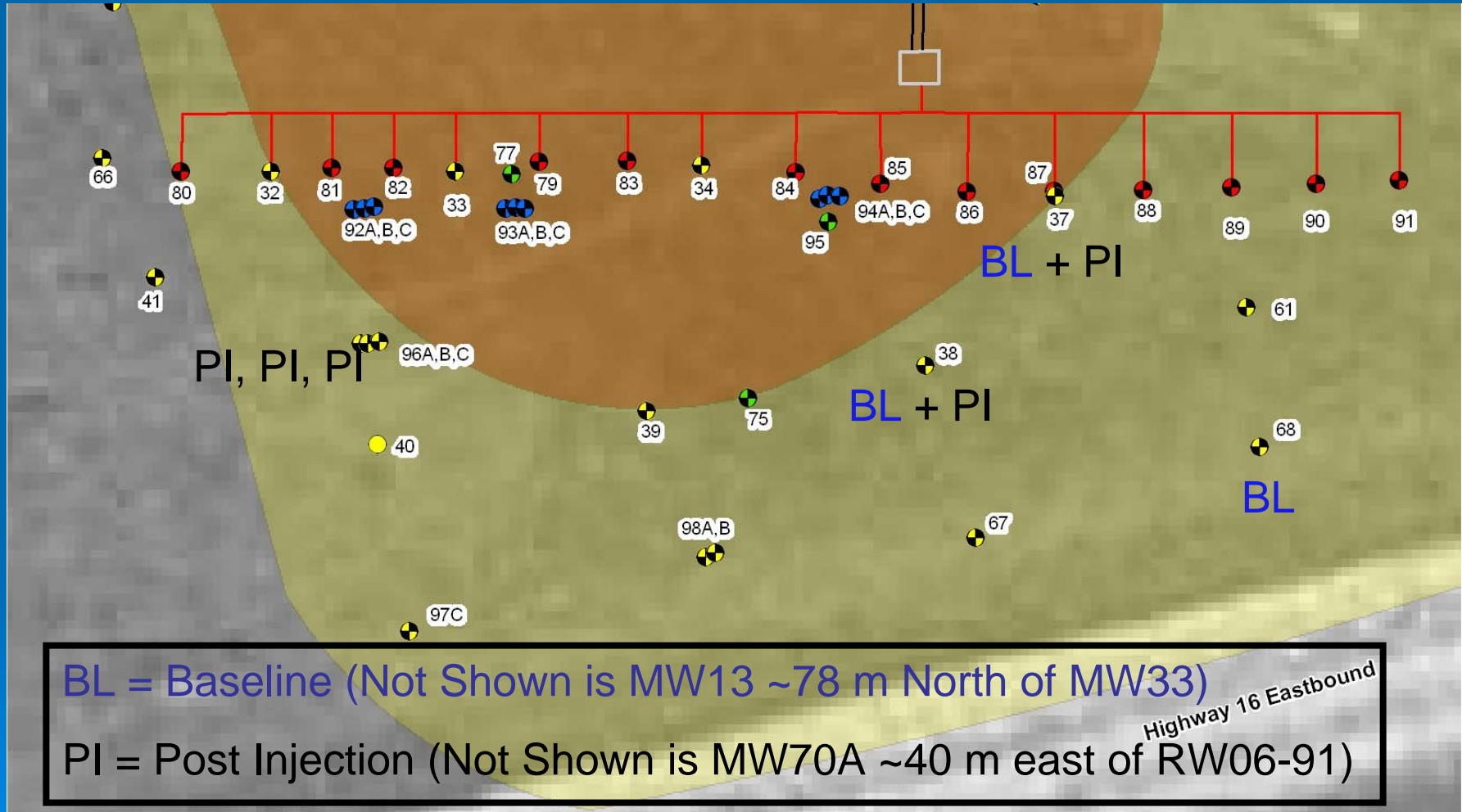


Performance Monitoring – Geochemistry

RW84 Performance Data - Hydrocarbons



BioTrap Incubation - Baseline and Post-Injection Locations

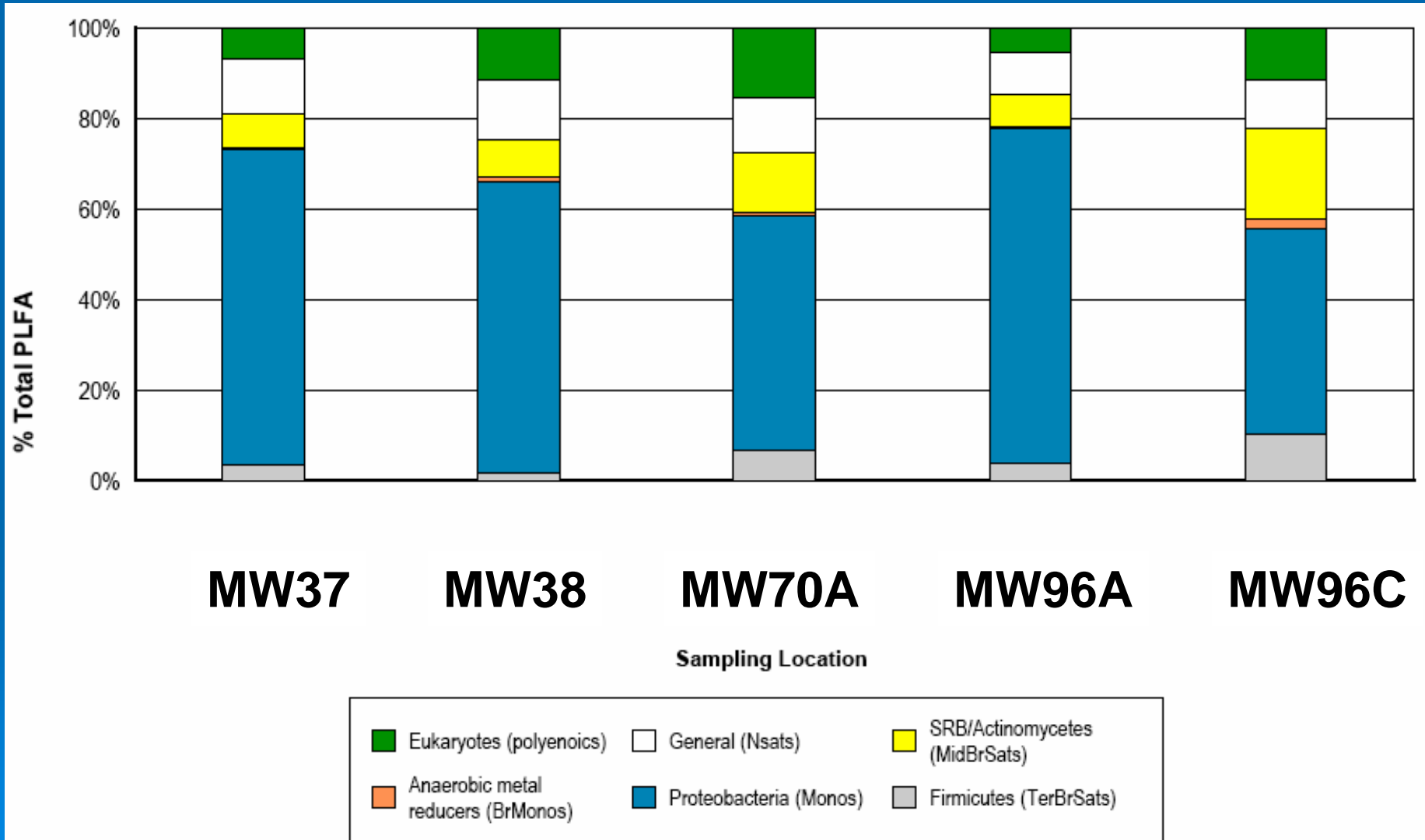


PLFA Results - Viable Cells/Bead and Percent Proteobacteria

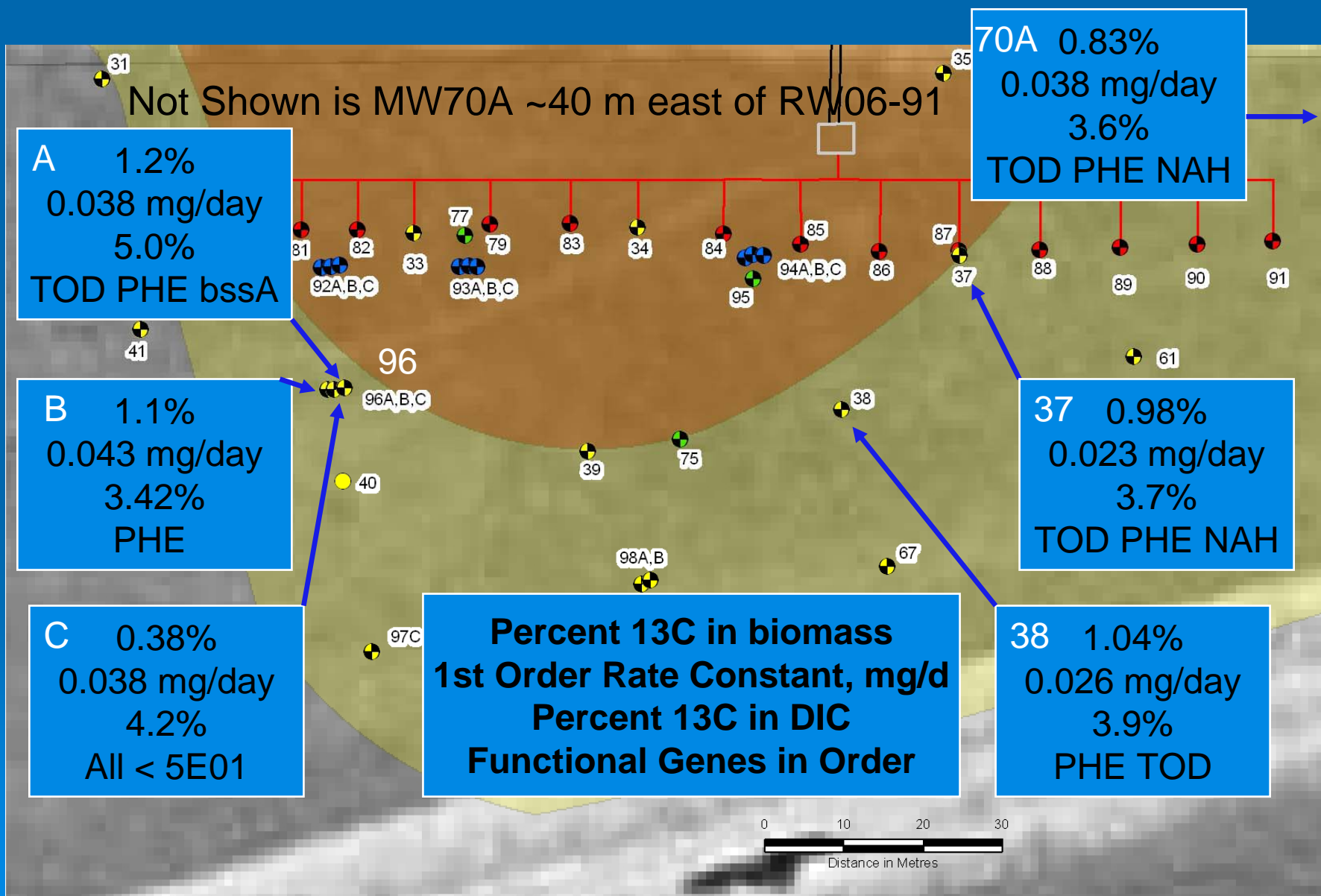
Well	13	37	38	68	96A	96B	96C	70A
Unit	NAPL	NAPL	NAPL	D.P	D.P	D.P	D.P	None
3	5.7E6 cell/b							
4 (A)	50 %	2.7E6 71 %	1.1E7 78 %		3.4E5 74 %			1.2E5
5 (B)		4.2E5 70 %	1.4E5 64 %	2.9E6		1.6E5 50 %		52 %
6				82 %				
7 (C)							9.3E4 45 %	

NAPL = inside Non-Aqueous Phase Liquid zone; D.P. = inside Dissolved Phase Plume; None = outside Plume

Relative Percent of Total PLFA Structural Groups



Benzene Utilization and Functional Genes



Conclusions

- Bench scale testing was a valuable first step.
- Hydraulic effect was local and short lived.
- Geochemical effect was broad and long lived.
- Biological effect was broad and long lived.
- Injection of **Klozur® OBC** and **PermeOx® Plus** was effective in reducing contaminant concentrations.

Did we meet our Objectives?

- The data collected has improved the SCM.
- Hydraulic effects were observed and recorded.
- Positive geochemical effects were apparent.
- Results indicate destruction of contaminants.
- Full scale design is underway.

