

Overview of Results from the Integrated Field-Scale Subsurface Research Challenge Site (IFRC) at Rifle, Colorado



Phil Long, Pacific Northwest National Laboratory
and the Rifle IFRC Research Team

ERSP PI Meeting, Lansdowne, VA

22 April 2009

Co-Principal Investigators:

Field Experiments, geophysics, Geochemistry: Ken Williams

Microbiology:

Proteomics: J. Banfield, Mary Lipton, Bob Hettich, Nathan Verberkmoes

In-field microarray: D.P. Chandler

Stable Isotope Probing: Lee Kerkhof

Lipid analysis, qPCR: Aaron Peacock

Uranium Sorption: Jim Davis

Column Experiments: Peter Jaffe

Mineralogy: Ravi Kukkadapu

Natural bioreduction: Aaron Peacock

Modeling: Steve Yabusaki

Key Collaborators:

Gene expression, metagenomes: D. Lovley

Geophysics, RTM, isotopes: S. Hubbard, Carl Steefel, Mark Conrad et al., LBNL SFA

Hydrology: Frank Spane

Sedimentology/geostatistics: Chris Murray

Database: Roelof Versteeg

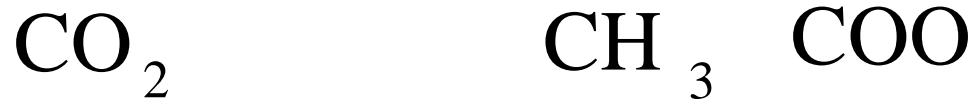
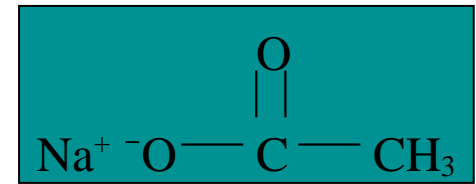
Field Site Manager: Dick Dayvault

DOE Site Representative: Rich Bush



Metal Reducing Bacteria

Acetate structure



Geobacter uraniireducens,
Isolated from the Rifle Site
and a Member of the
Subsurface Clade I
Geobacter



Lovley et al., 1991;
Suzuki et al., 2002;
Suzuki et al., 2003;
Gu and Chen
2003; Anderson et
al., 2003; Singer et
al., 2007

Fe(II)

Fe(III)

U(IV)

U(VI)



The Rifle Integrated Field Research Challenge Site: *Goals and Objectives*

Overall Goal: *develop a mechanistic understanding of subsurface mobility of uranium at the field scale, with emphasis on on bioreduction of U(VI)*

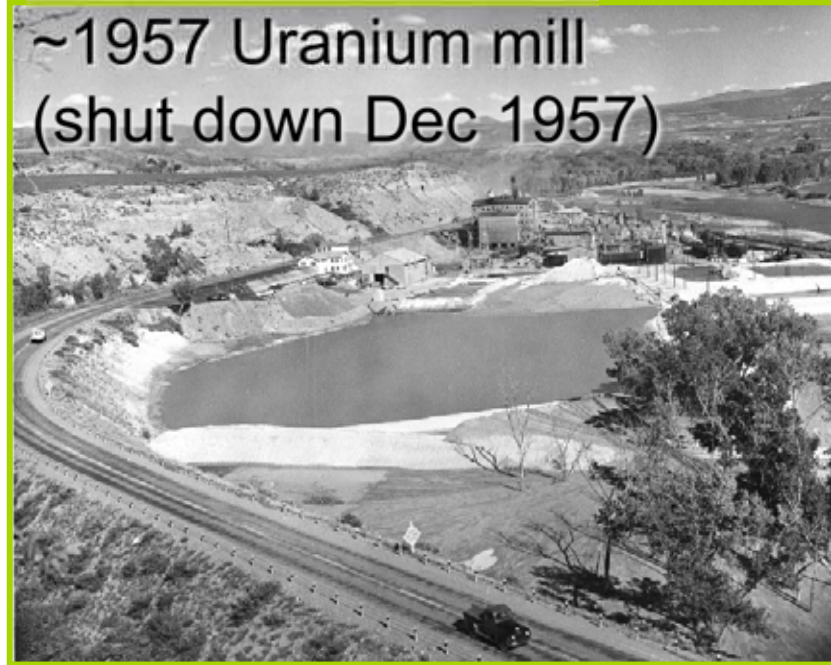
- ▶ The ability to manipulate (extend) Fe reduction during *in situ* biostimulation
- ▶ Determine the effect of bioreduction on U(VI) sorption
- ▶ Understand and enhance post-biostimulation U removal from groundwater
- ▶ Estimate rates of unstimulated bioreduction at the Rifle IFRC
- ▶ Combine desorption and bioreduction to enhance extent of U remediation and stability of bioreduced products
- ▶ Reactive transport models that enable prediction for a broad range of alluvial aquifers

Rifle Site History

~1924 Original vanadium mill



~1957 Uranium mill
(shut down Dec 1957)



~1960



Fall 1967





BIG AND LITTLE
RIFLE IFC
RUSTY

- PROTEOMICS
- GENOMICS
- BIOGEOCHEMISTRY
- GEOPHYSICS
- HYDROLOGY

WINCHESTER
Rifle IFC

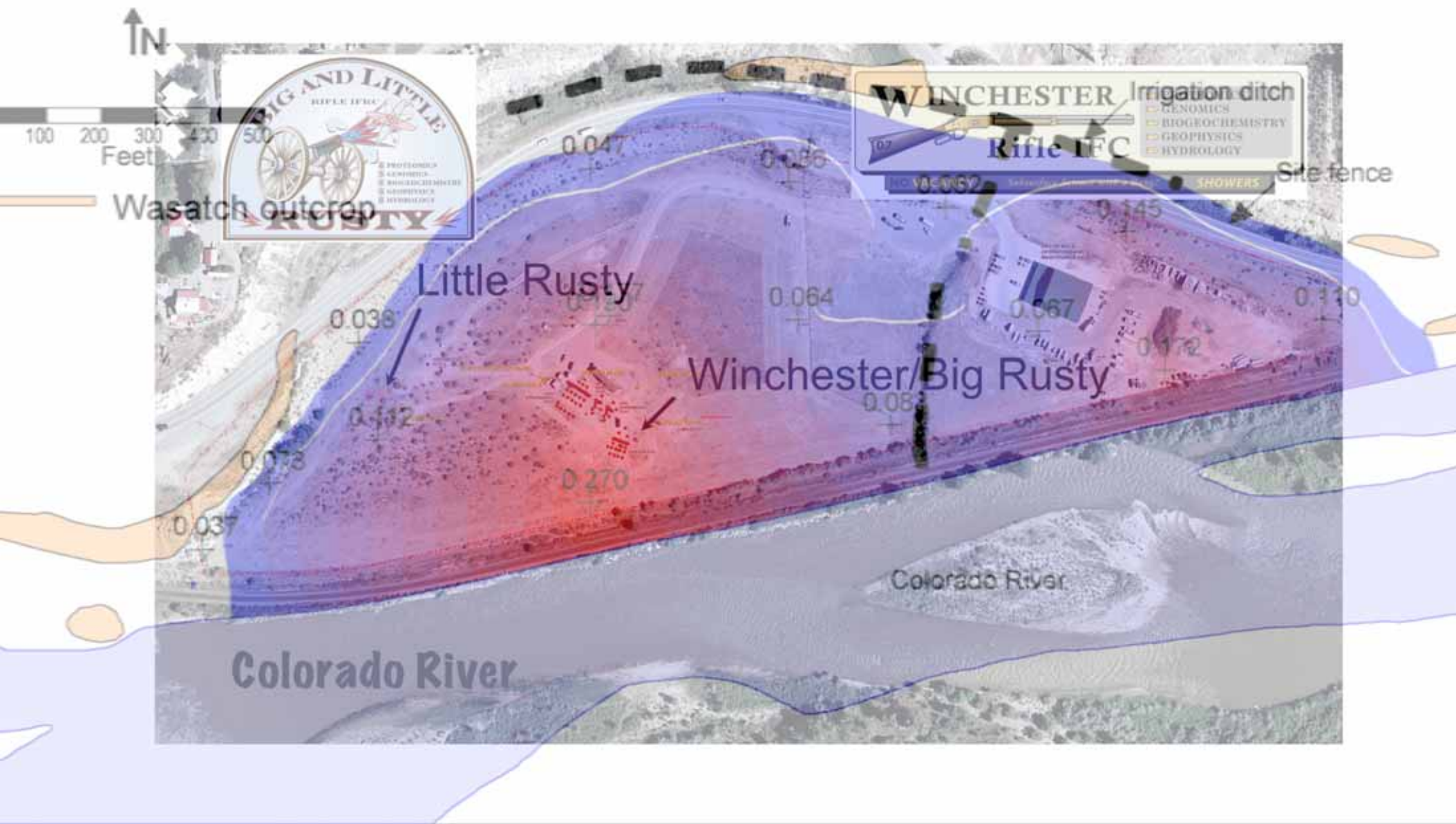
- PROTEOMICS
- GENOMICS
- BIOGEOCHEMISTRY
- GEOPHYSICS
- HYDROLOGY

NO VACANCY *Subsurface Science with a Bang!* SHOWERS

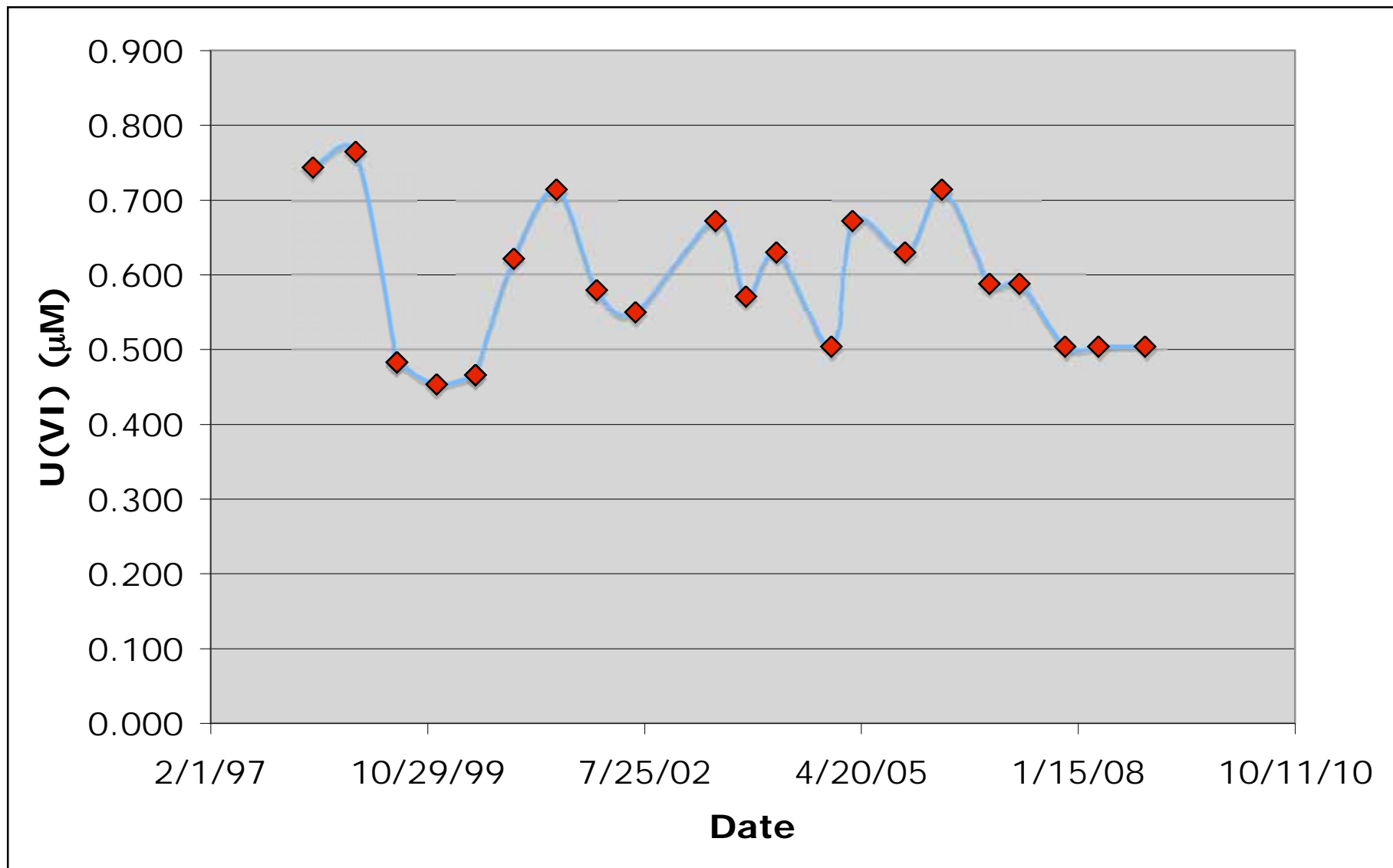
Little Rusty

Winchester/Big Rusty

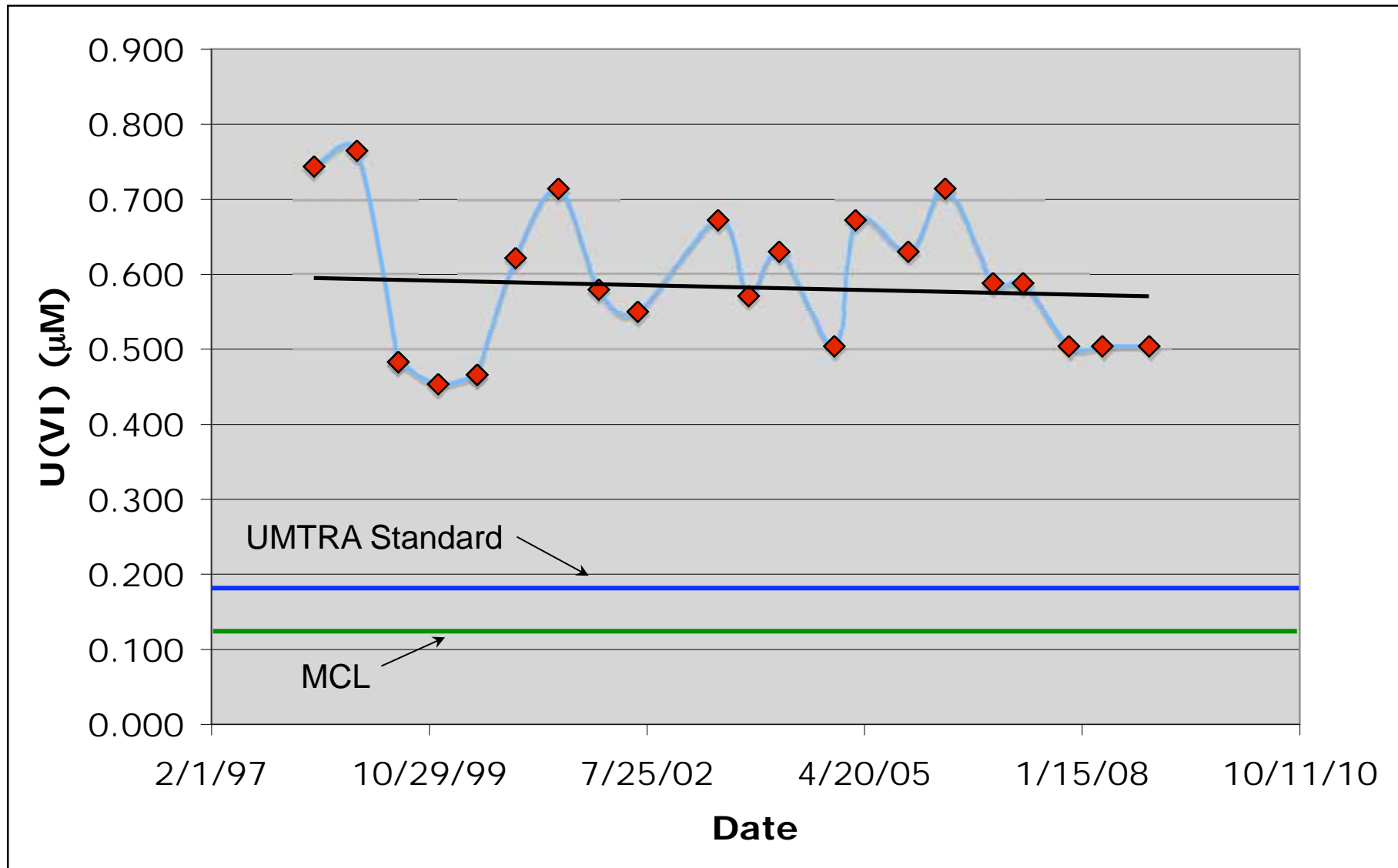
Colorado River



Well 655: Ten Years of U(VI) Conc. Data



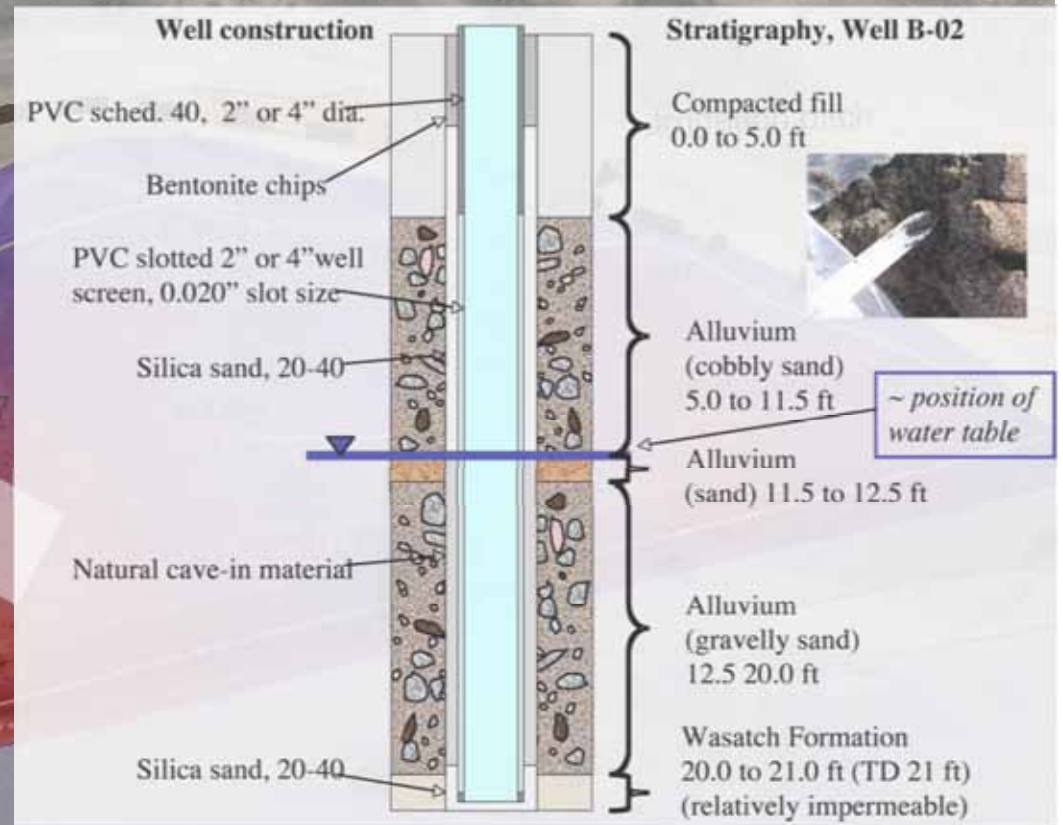
Well 655: Ten Years of U(VI) Conc. Data



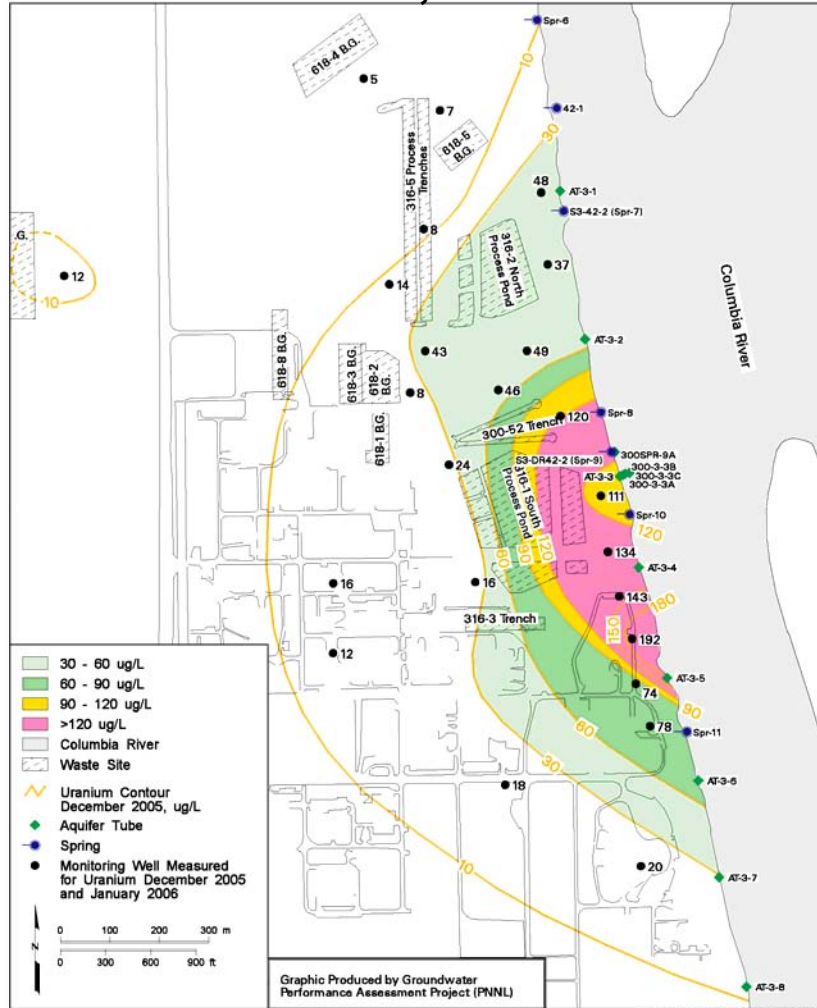
Overlay of U(VI) Concentrations (mg/L)



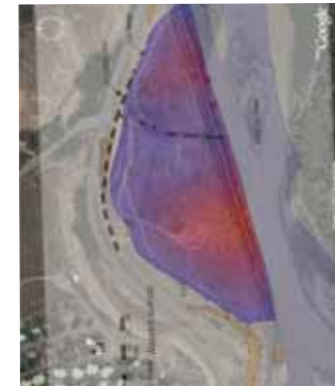
Hydrologic Parameters	
Saturated Thickness	2.4 to 3.4 m
Hydraulic Conductivity	5 to 20 m/d
Porosity	0.15 to 0.35
Pore Velocity	0.3 to 0.5 m/d
Water Chemistry	
Uranium	~0.7 – 1.5 uM
pH	~7.0 – 7.2
Alkalinity	~7-10 meq/L
ORP	-150 to 250 mV
Dissolved Oxygen	0.1 to 0.7 mg/L
Fe(II)	15 to 50 uM
Nitrate	2 to 3 uM
Sulfate	8 to 11 mM
Sulfide	0.03 to 0.5 uM



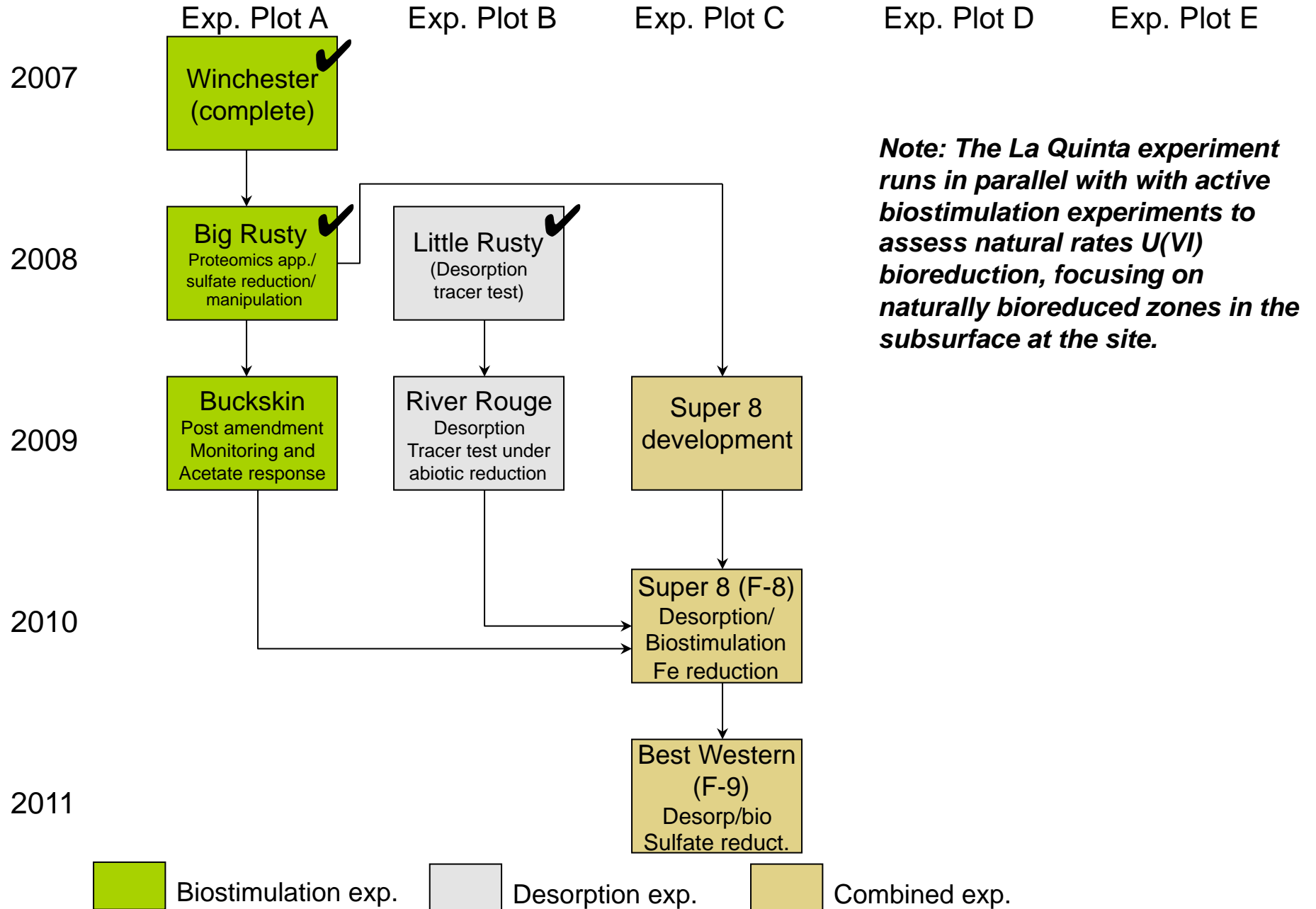
300 Area Uranium, December 2005



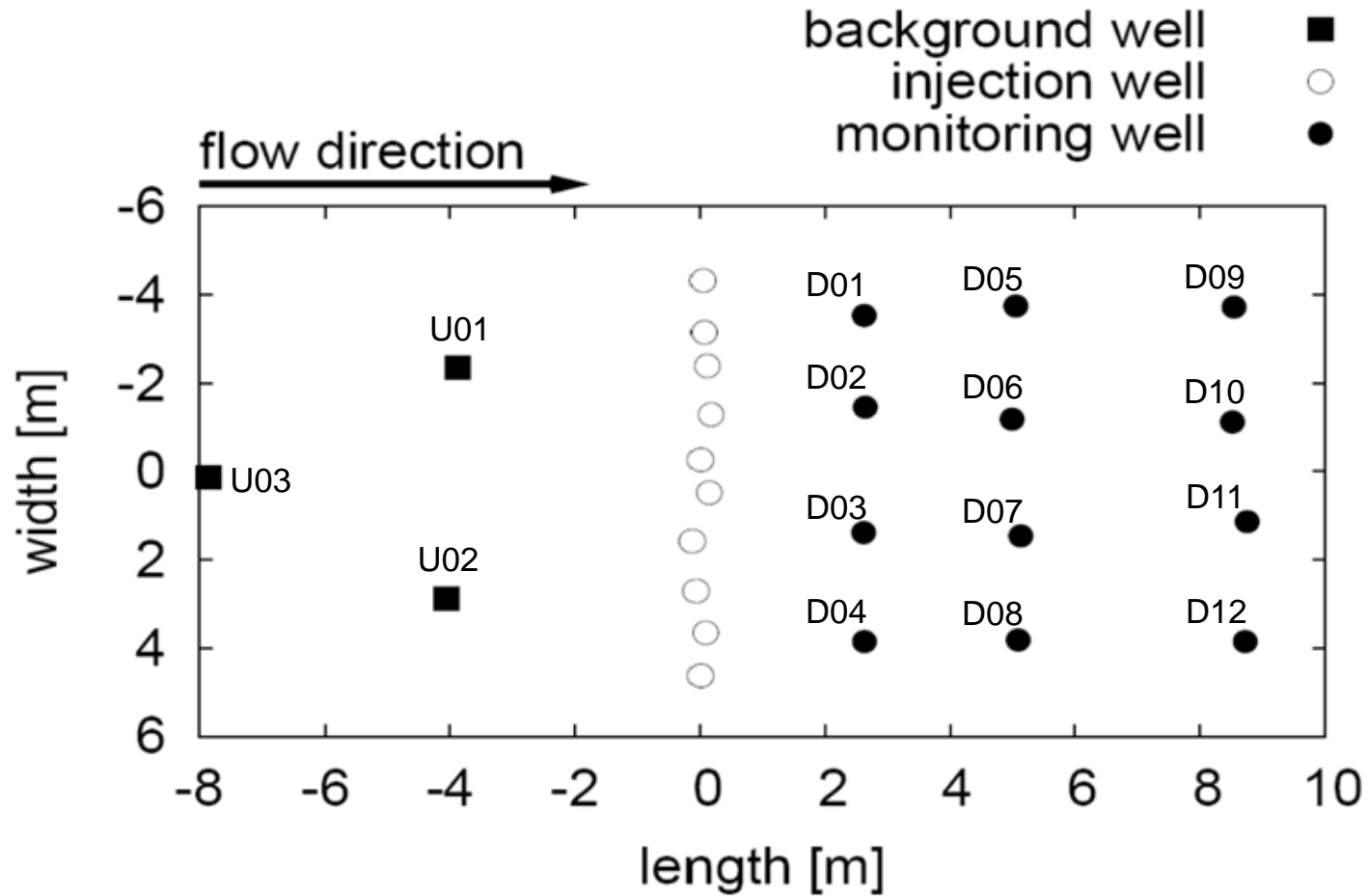
Old Rifle UMTRA Site Uranium, 1998



Rifle IFRC Field Experiment Schedule (Rev. 06Feb09)

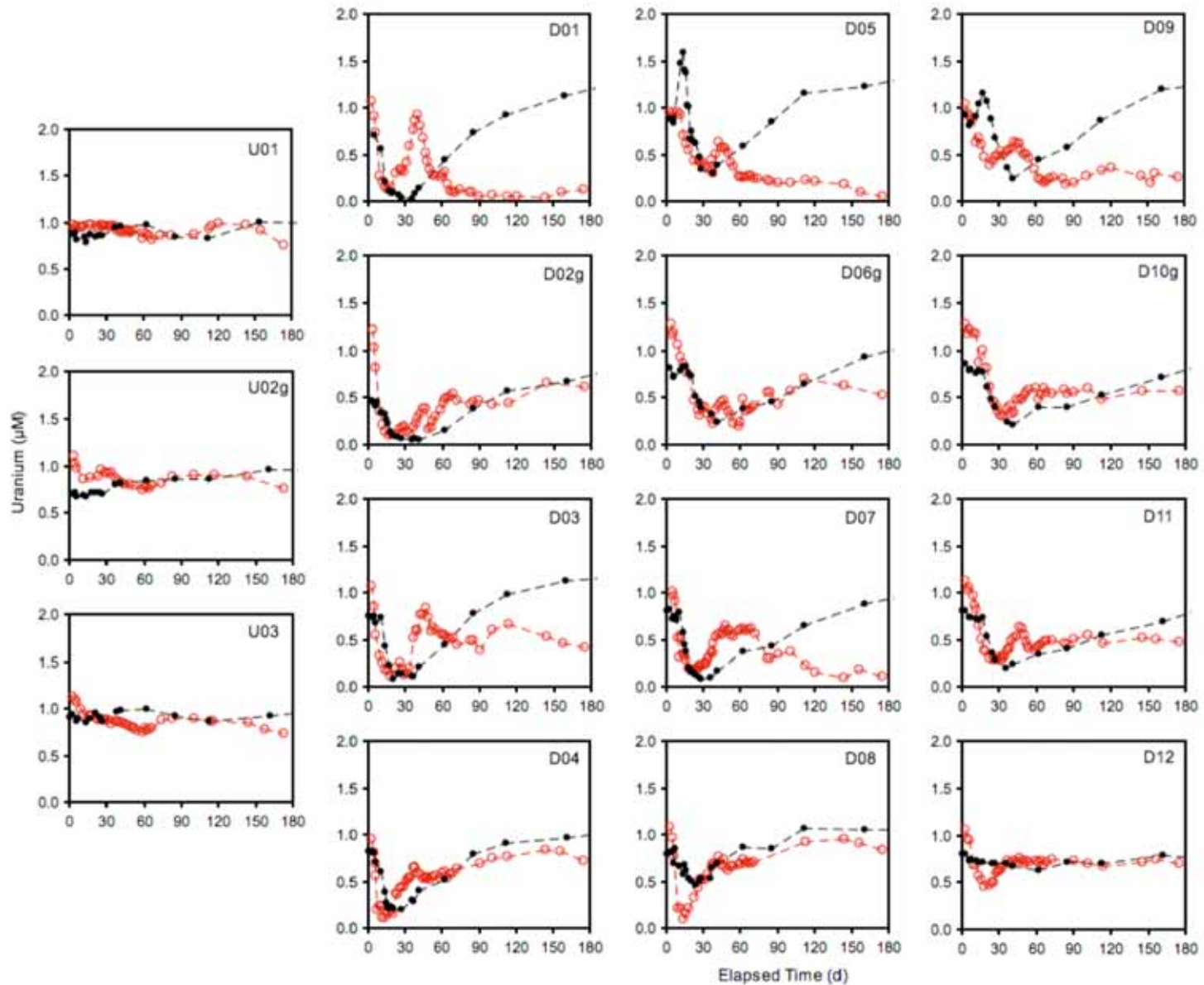


Winchester/Big Rusty: Experimental Plot A



GEOCHEMICAL RESULTS: Big Rusty-Winchester

U(VI) comparison



Sediment colors pre- and post-biostimulation

Pre-biostimulation

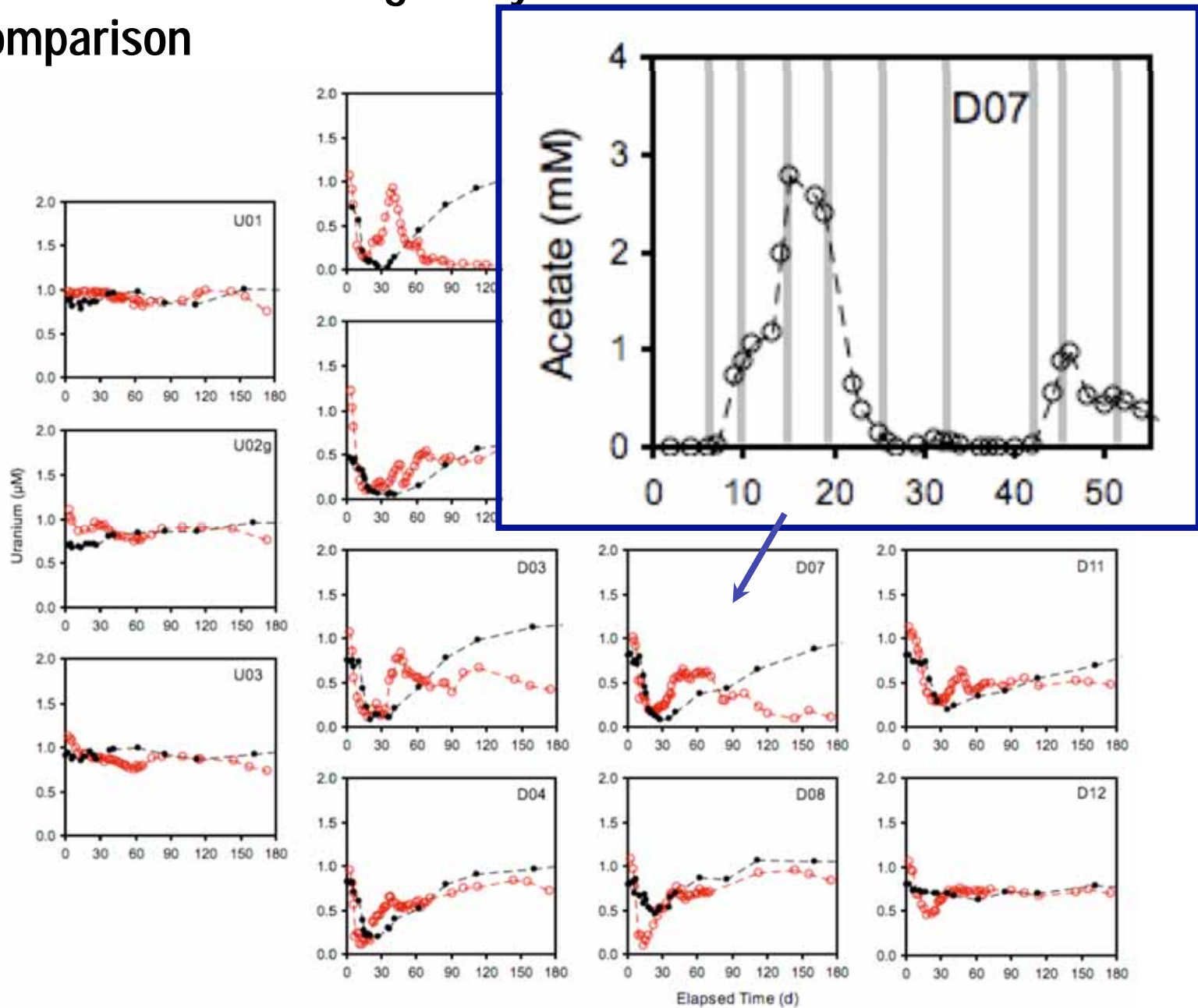


**Post-biostimulation
(Sulfate reduction)**

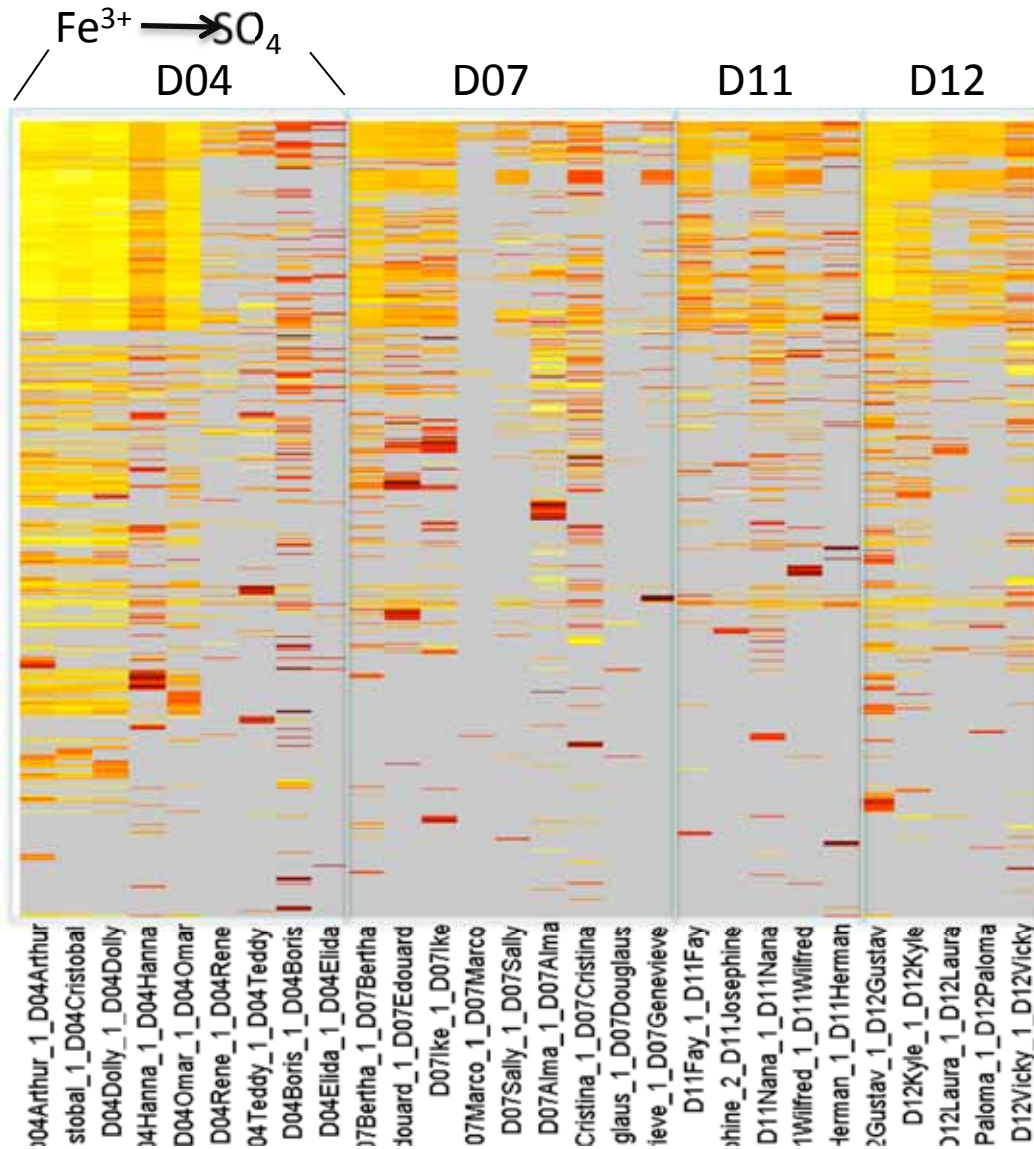


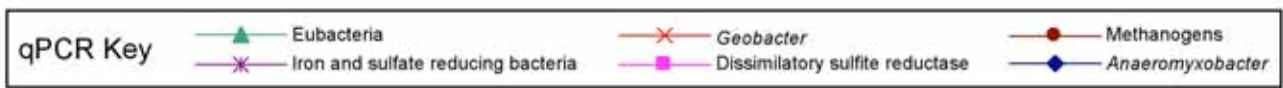
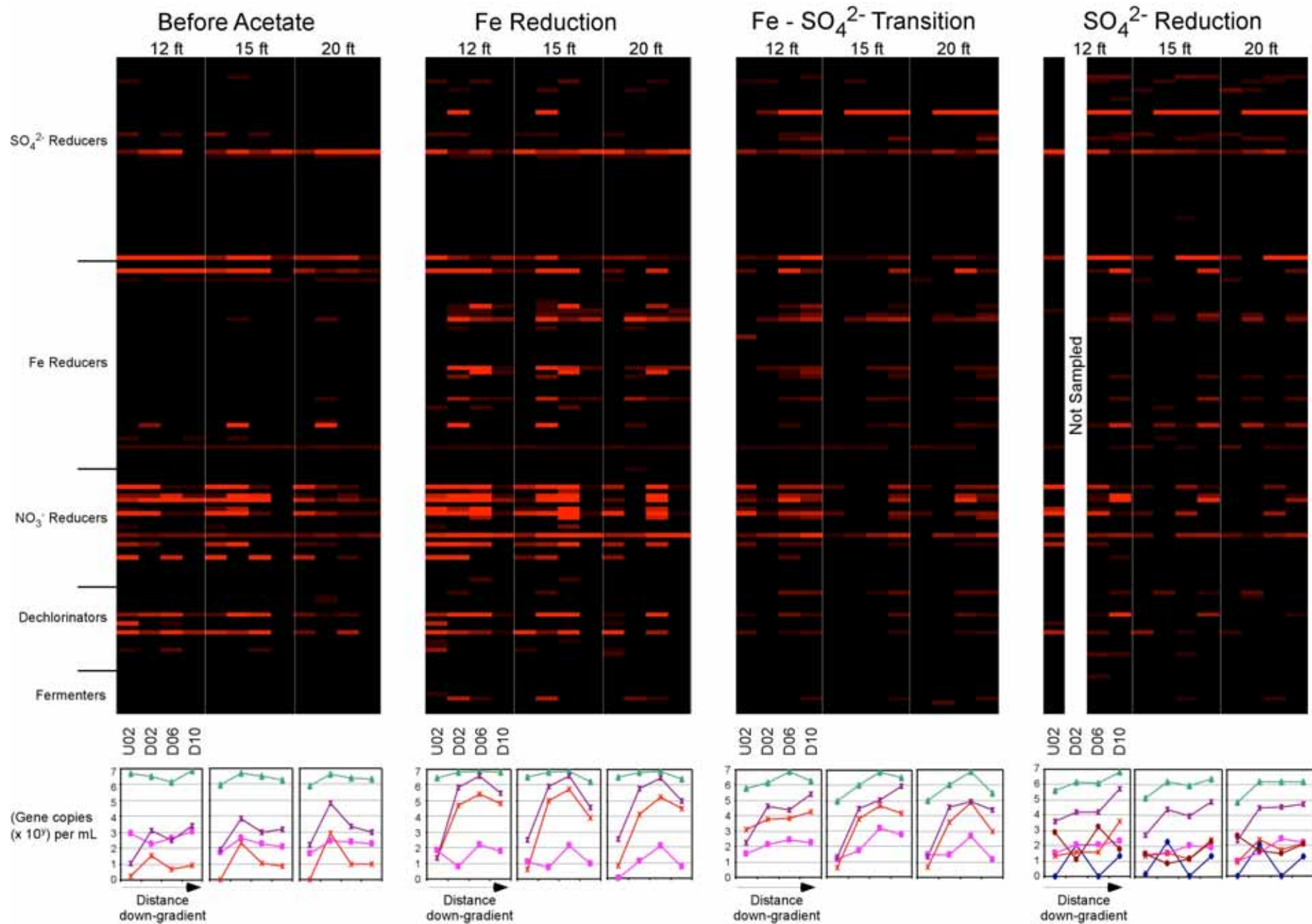
GEOCHEMICAL RESULTS: Big Rusty-Winchester

U(VI) comparison

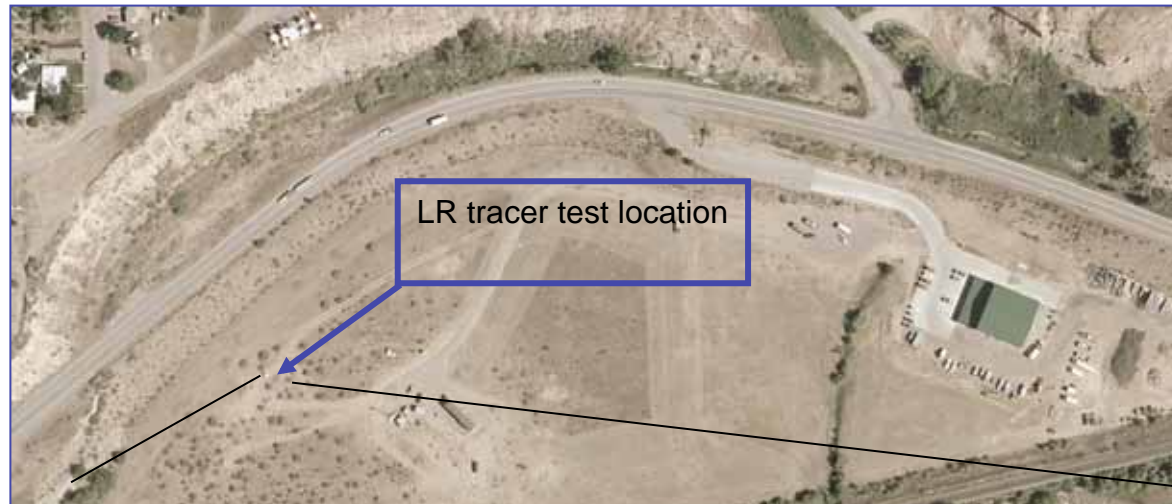


Heat map of Geobacter proteins from ground water during acetate amendment - Big Rusty, 2008





Little Rusty Location and Well Layout



Rifle IFRC Presentations

- ▶ **3:30 PM Overview of Results from the Integrated Field-Scale Subsurface Research Challenge Site (IFRC) at Rifle, Colorado.** Phil Long
- ▶ **3:45 PM Assessing the Prospects for Metals Remediation During Prolonged Acetate Amendment: Results from the "Big Rusty" Field Experiment.** Ken Williams
- ▶ **4:10 PM Evolving Geochemical Conditions Drive Changes in Geobacter Physiology During Stimulated Early-Stage Uranium Bioremediation.** Jill Banfield
- ▶ **4:30 PM Uranium Release from Contaminated Sediments at the IFRC Site in Rifle, CO.** Jim Davis
- ▶ **4:55 PM Estimating the *in situ* Rates of Natural Bioreduction of U(VI) at the Rifle IFRC Site.** Aaron Peacock
- ▶ **5:15 PM Reactive Transport Modeling: Closing the Knowledge Gaps for Uranium in Biostimulated and Naturally Bioreduced Alluvial Aquifers.** Steve Yabusaki

Rifle IFRC Posters (Boards 39 to 47)

- ▶ *The Integrated Field-Scale Subsurface Research Challenge Site (IFRC) at Rifle, Colorado: Overview of biostimulation and desorption tracer experiments conducted in 2008.* Philip E. Long, et al.
- ▶ *Microbial growth, activity, and succession in response to electron donor amendment at the Rifle IFRC: I. Results from field experiments.* Lucie N'Guessan, et al.
- ▶ *Microbial growth, activity, and succession in response to electron donor amendment at the Rifle IFRC: II. Results from column, and batch experiments.* Peter Jaffe, et al.
- ▶ *Proteomic assessment of Geobacter physiology during field-scale uranium bioreduction.* Kim Handley, et al.
- ▶ **Geophysical approaches for monitoring *in situ* bioreduction of U(VI) during Fe-reducing and sulfate reducing conditions.** Kenneth H. Williams, et al.
- ▶ **Estimating the *in situ* rates of natural bioreduction of U(VI) at the Rifle Integrated Field-Scale Subsurface Research Challenge (IFRC) Site.** Aaron Peacock, et al.
- ▶ **Uranium desorption from contaminated sediments at the IFRC site Rifle, CO: from batch to field.** Patricia Fox, et al.
- ▶ **Sedimentology, mineralogy and geochemistry of the Rifle IFRC alluvial sediments: implications for *in situ* bioremediation and long-term behavior of U(VI) in groundwater,** Ravi Kukkadapu et al.
- ▶ **Reactive Transport Modeling of *In situ* biostimulation experiments at the Rifle IFRC: progress to date and remaining knowledge gaps.** Steve Yabusaki et al.

Collaborator Presentations/Posters

- ▶ Lovley Posters: Tues. Miletto et al. (Gene expression), #36; Wed. Fang et al. (*In silico* modeling #28)
- ▶ LBNL SFA Posters: Wed. Hubbard Overview #5; Steefel #8
- ▶ SLAC SFA Poster: (Wed. Bargar #10A), Biogenic Uraninite stability presentation Thursday 9:00 AM
- ▶ Steefel: Modeling presentation (Thursday 10:30 AM)
- ▶ Hatfield: U flux presentation (Tuesday); Poster Wed #23
- ▶ Student poster Jenny Druhan et al. Sulfur isotopes, Wed #27
- ▶ Student poster Valerie Stucker et al U flux measurement resins, Wed # 38
- ▶ Rob Sanford et al. Poster: Tues: Uranium isotopic shifts with bioreduction during 2007 Winchester
- ▶ Brad Tebo et al. Poster (Tues: Mn oxidation of U(IV)-- used Rifle sediments for batch and column experiments.

Additional Information

- ▶ Rifle IFRC Website: <http://ifcrifle.pnl.gov/>
- ▶ Long-term monitoring data:
<http://gems.lm.doe.gov/imf/imf.jsp?site=rifleoldprocessing&title=Rifle+Old,+CO,+Processing+Site>
- ▶ Annual report copies available at poster session