The Oak Ridge Field Research Center Conceptual Model

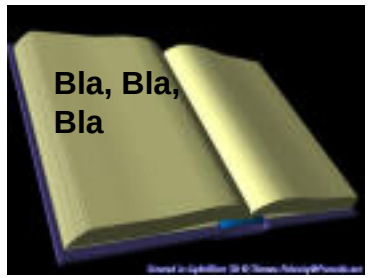
D.B. Watson[1], J.E. Kostka[2], M.W. Fields[3], P.M. Jardine[1]

[1]Environmental Sciences Division, Oak Ridge National Laboratory
[2]Department of Oceanography, Florida State University
[3]Department of Microbiology, Miami University (Ohio)

October 2004

Purpose

To provide investigators from various programs (e.g. NABIR, EMSP, GTL) with state of the art knowledge of subsurface processes that are operative at the FRC background and contaminated sites in an effort to support their research mission.



Text description

Describes the current conceptual framework of coupled hydrological, geochemical, and microbial processes that control the fate and transport of contaminants at the Oak Ridge FRC.

Structured to discuss the FRC background area, the overall contaminated area, and each of the five contaminated field areas (Area 1 through 5) with emphasis on field processes.

The text is a living document that will be updated as additional information is obtained.

Oak Ridge FRC Background Area

Geology

Bedrock and soil features

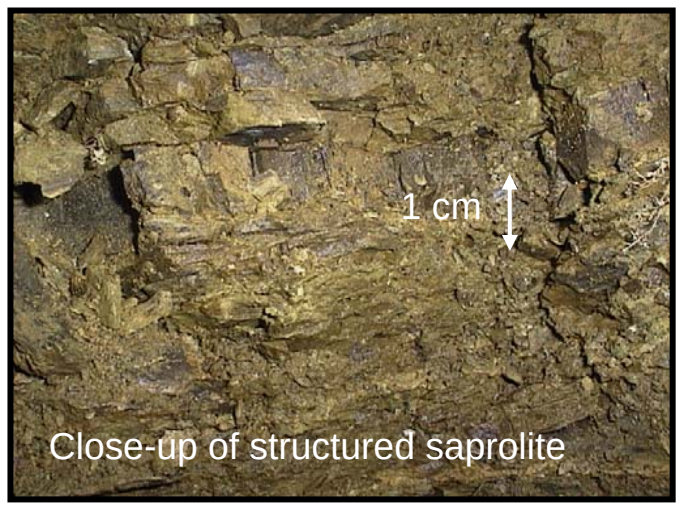
Fracture characteristics

Mineralogy and porosity

ORNL media consisting of interbedded fractured weathered shales and limestone

Overlying Saprolites

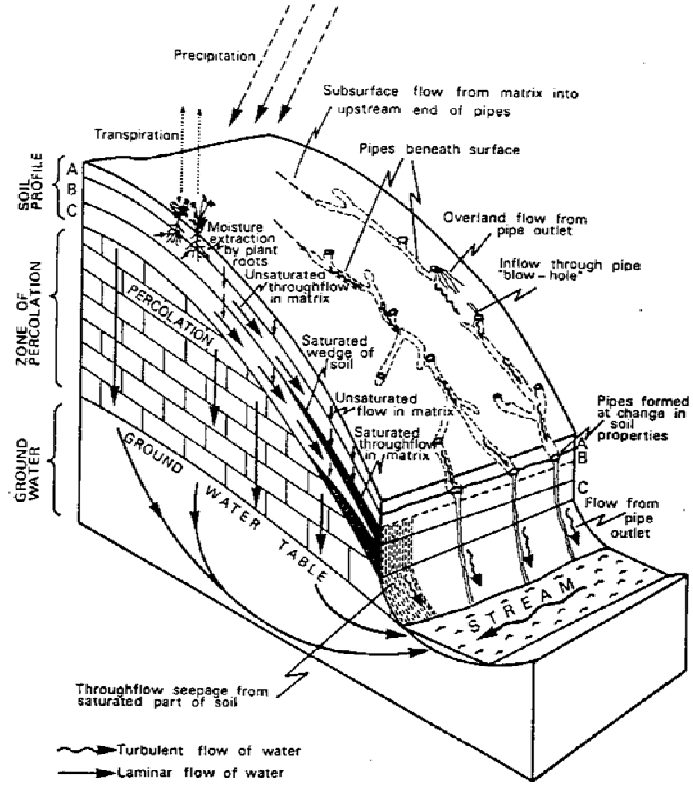
Underlying Bedrock



Oak Ridge FRC Background Area (cont.)

Hydrology

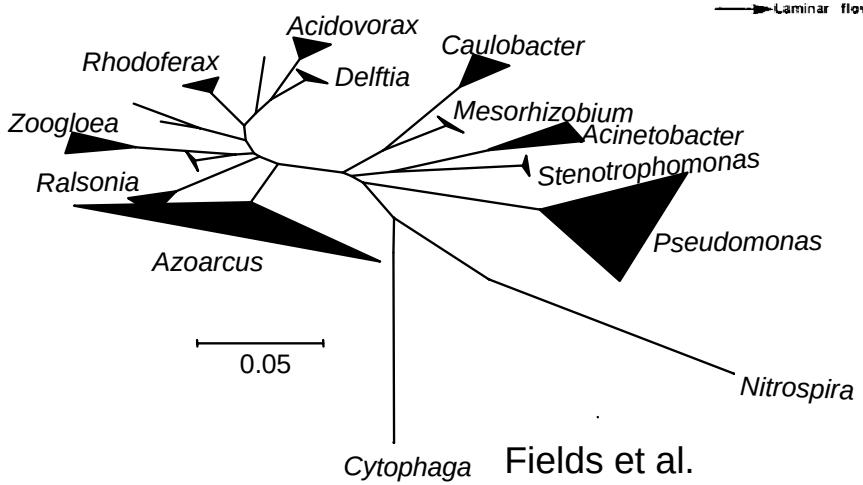
Vadose zone stormflow and recharge
Transition zone groundwater flow
Porosity and flow
Nonequilibrium processes
Multipore region flow and transport



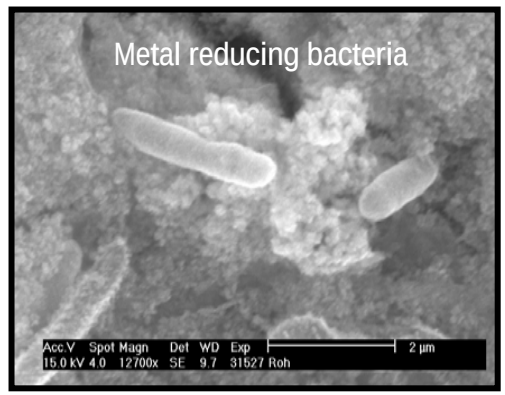
Geochemistry

Stormflow and groundwater flow
Interfacial geochemical reactions

Microbiology



Fields et al.



Oak Ridge FRC Contaminated Area

General Area Description

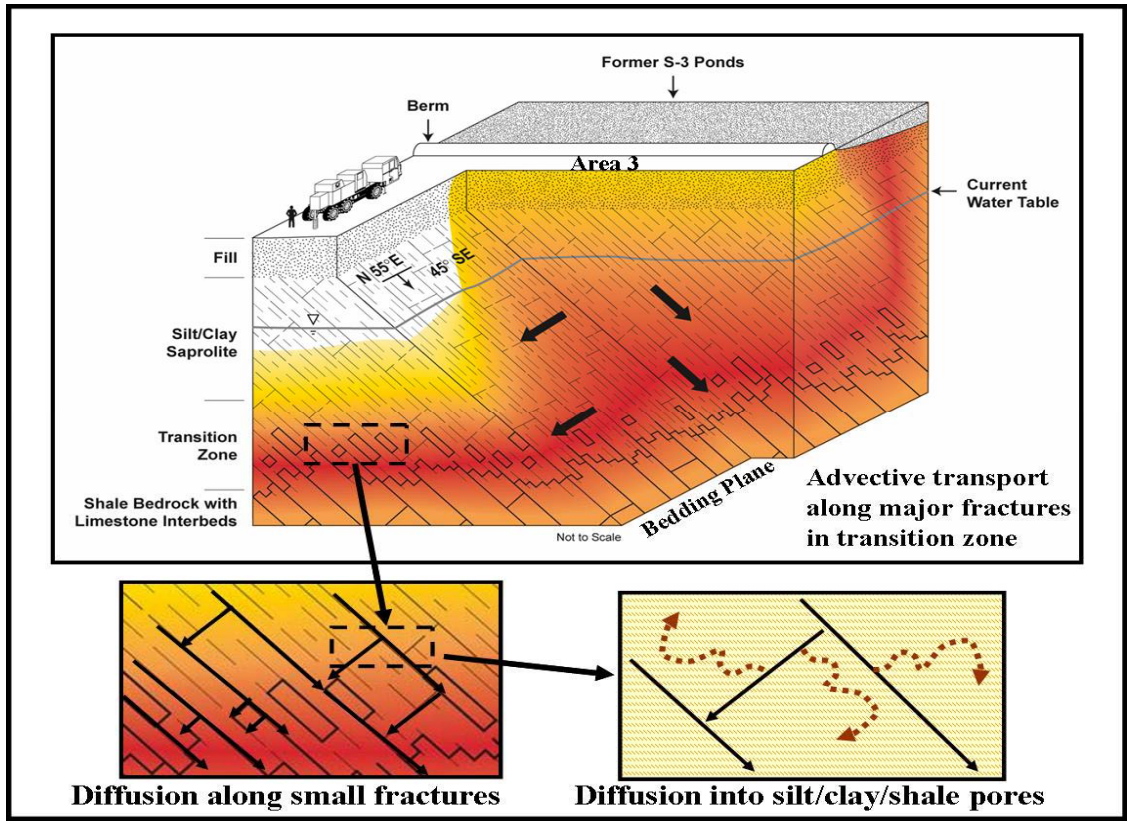
Waste Disposal Unit

Geology

Bedrock
Porosity
Overlying Saprolite

Hydrology

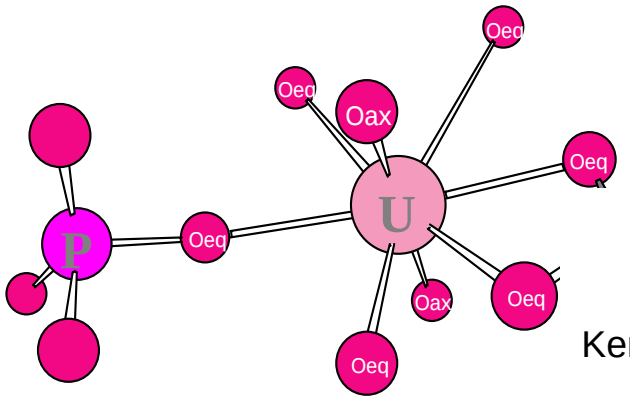
Recharge
General flow orientation
Groundwater flow in the unconsolidated zone and Nolichucky Shales
Groundwater flow in the Maynardville Limestone



Oak Ridge FRC Contaminated Area (cont.)

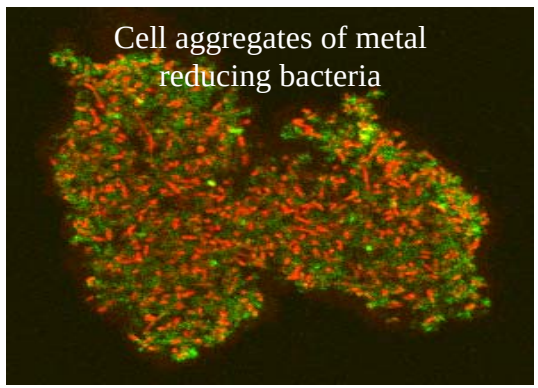
Geochemistry

Soils and sediments
Groundwater

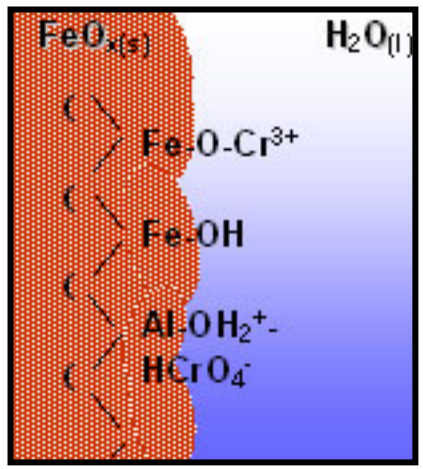


Kemner et al.

Microbiology



Fendorf et al.



Hydrological, Geochemical, and Microbial Characterization of Area 1

Down-dip with moderate distance from source

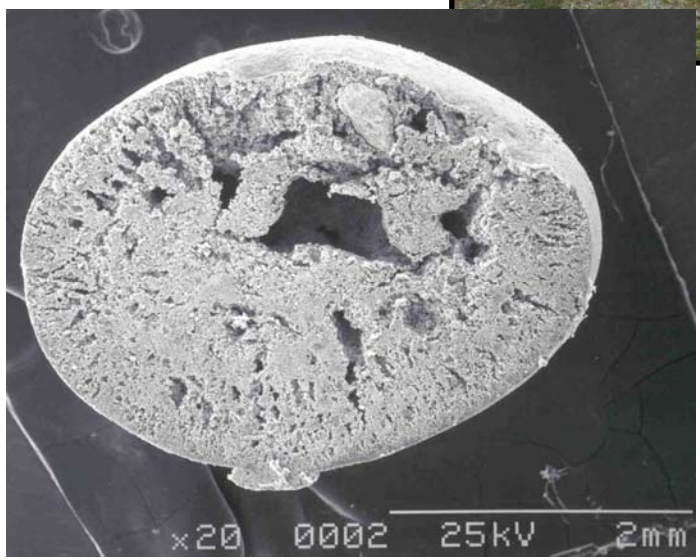
Geology and Hydrology

Geochemistry

Microbiology

Sediments
Groundwater
"Bug traps"

Istok et al.



White and Peacock

Biofilms Form Rapidly in Bio-Sep® Beads

Hydrological, Geochemical, and Microbial Characterization of Area 2

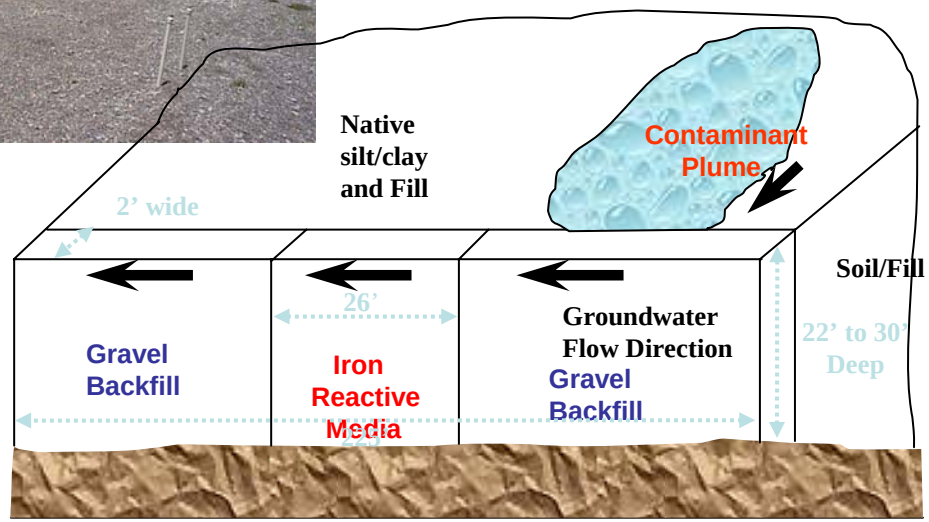
Far-field U(VI) plume in native weathered shale and fill

Geology and Hydrology

Geochemistry

Microbiology

Sediments
Groundwater



Watson et al. Scheibe et al.

Hydrological, Geochemical, and Microbial Characterization of Area 3

Geology and Hydrology

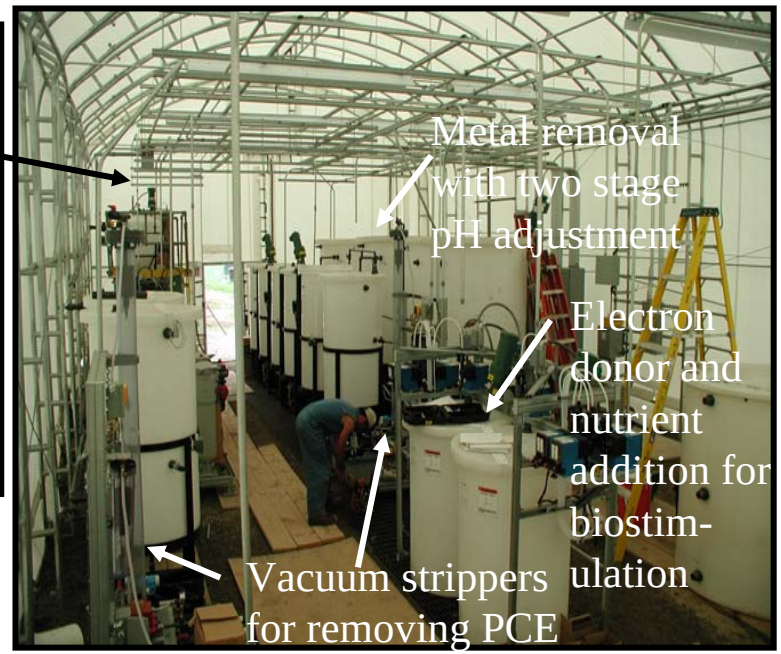
Geochemistry

Microbiology

Sediments
Groundwater
"coupons"

Near-field U(VI) plume

Near-source groundwater processing setup



Criddle et al.

HYDROLOGICAL, GEOCHEMICAL, AND MICROBIAL CHARACTERIZATION OF AREA 4

Under construction

HYDROLOGICAL, GEOCHEMICAL, AND MICROBIAL CHARACTERIZATION OF AREA 5

Under construction

RESEARCH NEEDS AT THE OAK RIDGE FIELD RESEARCH CENTER

General Microbiological Research Needs Across all the Contaminated Sites
General Hydrological Research Needs Across all the Contaminated Sites
General Geochemical Research Needs Across all the Contaminated Sites
General Numerical Research Needs Across all the Contaminated Sites

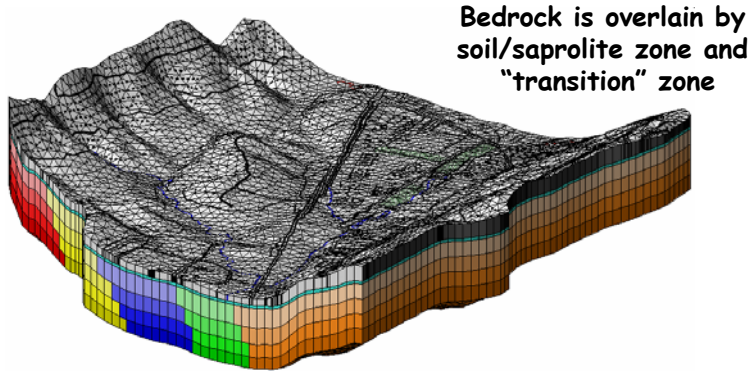
Site-Wide Numerical Model

Formulation of a site wide high-performance multiprocess, multipermeability flow and transport numerical model (Parker).

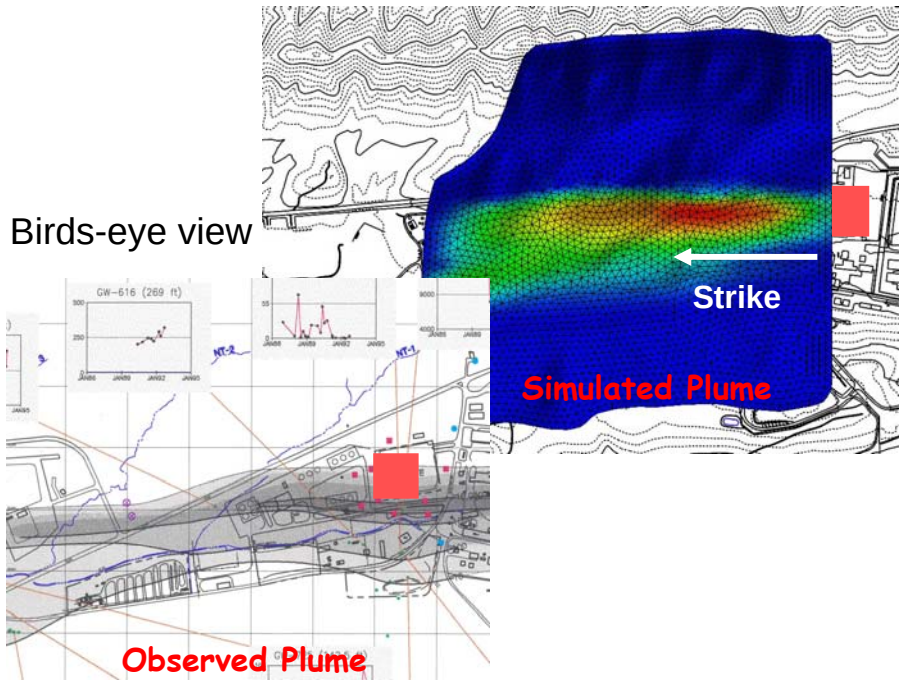
The FRC conceptual model provides the framework for the site wide numerical model.

Parameterized with experimental data acquired from the various research activities at the FRC and that are being organized within the working groups.

Discretized Model Domain



Birds-eye view

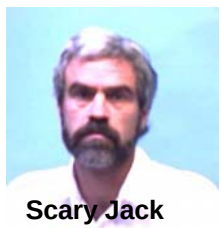


The Working Groups

Objective: To bring together scientists and engineers to resolve specific topical issues and work toward the overall goal of providing an improved understanding and predictive capability of the mechanisms that control microbially-mediated, *in situ* contaminant immobilization.

Four working groups have been established to implement collaborations and knowledge transfer among various projects associated with the Oak Ridge FRC.

(1) Microbial Community Analysis (Kostka)
(2) Rates of Microbially Mediated Metal Reduction and Oxidation (Burgos)
(3) Geochemical/Geophysical Characterization (Jardine)
(4) Numerical Modeling (Parker)



Microbial Community Analysis (Leader: Joel Kostka)

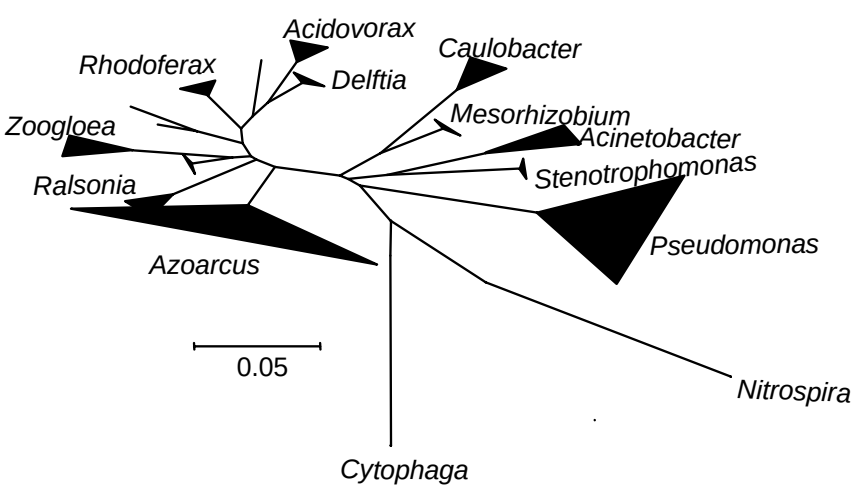
Working group objectives:

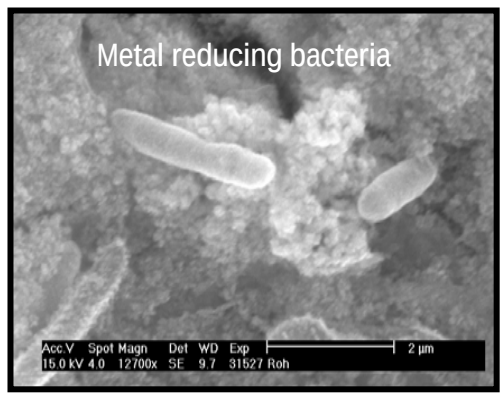
Discern the bioremediation potential of microorganisms in the FRC subsurface by:

1) cultivating organisms of biogeochemical significance
2) studying microbial community structure in parallel with function, focusing particularly on metal- and nitrate-reducing bacteria.

To determine structure/ function relationships of metal-reducing bacteria and competing heterotrophs during *in situ* bioremediation.

Current players: Barkay/ Sobecky, Fields/ Zhou/ Tiedje et al., Geesey/ Cummings et al., Kostka, Krumholz, Lovley, Marsh, Roden, Wan/Firestone/Hazen/Brodie, White/ Peacock





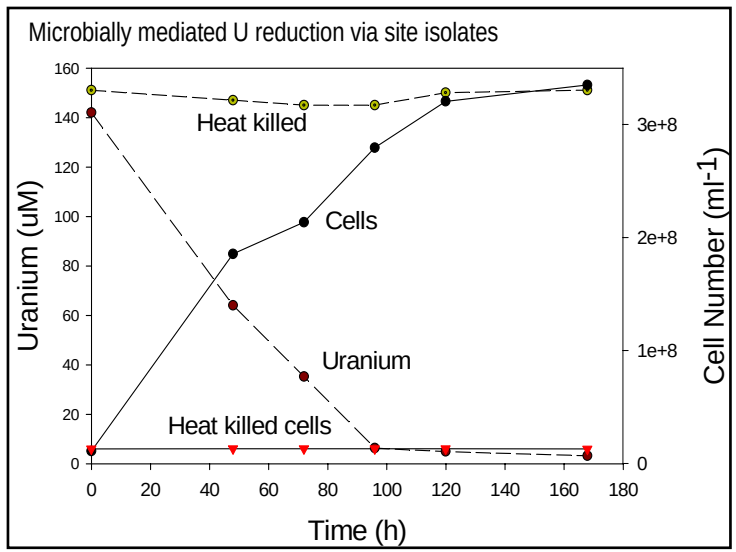
Rates of Microbially Mediated Metal Reduction and Oxidation Working Group (Leader Bill Burgos)

Working group objectives:

(1) share most recent research results obtained with FRC and other field sediments.

(2) encourage collaboration amongst NABIR investigators to establish more direct links to field-scale projects.

(3) provide support and information for reactive transport modeling of the FRC site, especially microbial and geochemical kinetic parameters for model input.



Geochemical/Geophysical Characterization Working Group (Leader: Phil Jardine)

Working Group goals

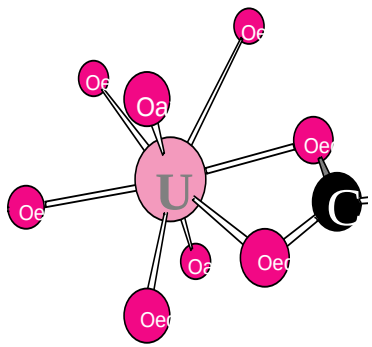
To provide an integrated set of research endeavors that provide an improved fundamental understanding of the geochemical and hydrological controls on bioremedation.

To couple this information with the research efforts within the other working groups in an effort to enhance the FRC site wide conceptual and numerical models and the research strategies of individual projects.

Working group objectives:

To provide specific and general site characterization endeavors designed to quantify *in situ* aqueous and solid phase contaminant speciation.

To provide select physical, chemical, and mineralogical properties of the FRC groundwater and solid phase before and after biostimulation.



Numerical Modeling Working Group (Leader: Jack Parker)

<u>Working Group objectives</u>:

Calibrate and validate a site wide high-performance multiprocess, multipermeability flow and transport numerical model based on HYDROGEOCHEM 5.0.

Parallelization of the numerical model to run on the EMSL supercomputer (similar to what was done with HBGC123D). Access has already been estabilished.

Parameterize with site specific and relevant experimental data in order to simulate time-dependent, coupled hydrological, geochemical, and microbial processes at the FRC.

The original Microsoft group (would you have invested?)

<u>Working Group goal</u>:

Achieve maximum leverage on investments in FRC field and laboratory studies by effective utilization of computer models to meet FRC strategic goals.