Summary of a 2005 NABIR PI Meeting Breakout Session
Tuesday, April 19, 2005

Building on NABIR research: What are the next field challenges?

Conveners: Susan Hubbard – *Lawrence Berkeley National Laboratory*
Derek Lovley – *University of Massachusetts*
Invited Presenters: Peter Kitanidis – *Stanford University*
David Lesmes – *DOE, Office of Basic Energy Sciences*
Brian Looney – *Savannah River National Laboratory*
Tommy Phelps – *Oak Ridge National Laboratory*
Eric Roden – *University of Alabama*
John Zachara – *Pacific Northwest National Laboratory*

Abstract

The need for effective field-scale research is becoming increasingly important as DOE moves towards closure and long-term stewardship of legacy waste sites. The primary purpose of this breakout session is to identify the major challenges that can or should be addressed through field-scale experimentation, and that build on experimental lab and field-based NABIR research. The secondary purpose of the session is to bring together NABIR- and EMSP-funded investigators to identify different approaches and to explore opportunities for collaboration on field-based research. The session will commence with short statements from the conveners and panelists that relate, in their opinion, what are the major field challenges. As the intent of the statements is to stimulate a lively audience discussion about field challenges, the audience will be asked for their input. All input will be captured within a report, which will subsequently be posted on the NABIR website.

Building on NABIR research: What are the next field challenges?

Introduction and Workshop Format

NABIR provides the fundamental science that serves as the basis for the development of cost-effective bioremediation of radionuclides and metals in the subsurface at the DOE sites. The need for effective field-scale research is becoming increasingly important as DOE moves towards closure and long-term stewardship of such legacy waste sites. The primary purpose of this breakout session was to identify the major challenges that can or should be addressed through field-scale experimentation, and that build on experimental lab and field-based NABIR research. The secondary purpose of the session was to bring together NABIR- and EMSP-funded investigators to identify different approaches and to explore opportunities for collaboration on field-based research.

The session commenced with short statements from the conveners and panelists that related, in their opinion, what are the major field challenges and how we can build on NABIR advances. Workshop attendees were then asked to contribute, both through verbal discussion and through writing suggestions on a white board in response to a number of questions. The discussions indicated that problems of scale, data integration, and prediction of processes in natural environments, which hydrogeologist have been grappling with for decades, are magnified when trying to understand and manipulate biogeochemical processes in natural, field-scale environments. The oral and written comments and suggestions that were provided by the participants are summarized below, followed by a list of participants and some images from the breakout session.

Discussion Summary

1. In your opinion, what is the largest 'gap' that prohibits us from performing successful and sustainable field-scale remediation of organics, metals and radionuclides?

The inability to sufficiently measure, predict, and monitor linked biogeochemical-hydrological properties, rates, and processes at the field scale in the presence of heterogeneity, as well as the inability to translate properties and reaction rates across scales, were identified as major gaps. For example, it is challenging to predict the role of transport on biogeochemical processes in physically heterogeneous environments, to track the kinetic evolution of terminal electron accepting processes or various manipulation strategies over space and time, or to ascertain mass transfer and bioavailability. Some of the suggestions that were made to address these limitations included: developing practical and economical methods to identify critical macroscale parameters; gaining a better grasp of functional relations among variables that are relevant to and measurable at the field scale; better incorporation of realistic microbial processes into simulation models; and promoting a field research culture that includes integration of information base, process models, predictive models, and validation across scales.

Developing a better understanding of the similarities and contrasts between the NABIR study sites and other 'real world' DOE sites, especially those having extreme conditions, was recognized as a current gap. In order to assess the statistical significance of observations (concentrations, flux, plume movement), it was noted how important it is to develop long-term records of contaminant transport at field sites, which extend beyond the life of a typical DOE project. A philosophical 'science versus cleanup' question that emerged was: 'is "local" field-scale research relevant to the remediation at the plume field scale, and is it important for NABIR investigators to consider such relevancy or to closely link research with cleanup objectives'?

2. What issues arise in a natural field-scale setting that might not be present in bench-scale or more focused/fundamental studies?

Features, such as preferential flow paths, interfaces, hydrostratigraphy, and multiple space dimensionalities, are common to field study sites but are typically absent in bench-scale studies. These features are known to influence hydrological processes, and as such, they may focus microbial activity and significantly influence mixing and mass transfer. Field systems are typically thermodynamically 'open' compared with most laboratory systems. Relative to the laboratory scale, there are difficulties in isolating properties and processes, accounting for mass balance, and 'accelerating' processes (while maintaining mechanisms) to permit observation of processes within reasonable time scales at the field scale.

3. Microbial measurements: do we understand what needs to be measured within a field setting, and can have the sensors or techniques to collect those measurements?

Some participants suggested that the most important thing to do was to determine the microorganism(s) that can perform the desired function(s) and to identify those that hinder that function, while some participants questioned the need for a full characterization of the microbial community for field-scale studies. Other participant suggestions included: investigating the field signal that is expressing metal reduction gene and investigating how those compared with community structure and geochemistry; developing an understanding of how genomic or proteomic measurements are tied to the field scale; considering REV concepts for biogeochemical parameters, and developing a sensor for measuring the bacterial redox state of cells.

4. What are some of the emerging techniques and approaches that could help to (1) bridge between lab and field scale hydrogeological-biogeochemical measurements, conceptual models and predictions; (2) determine or elucidate the controlling parameters/processes at the field-scale and (3) predict field-scale processes?

The suggestions provided to this question primarily focused on using or extending our existing (proven) techniques (in conjunction with other techniques) or experimenting with the techniques across scales. Examples of these suggestions included well-to-well tracer and push pull tests. Suggestions were also made to use mesoscale physical models that replicate site mineralogy and contamination, and to explore the use of geophysical approaches for quantitative estimation of biogeochemical-hydrological parameters at an effective field scale. The importance of including more representative microbial processes in numerical models was mentioned as a necessity for understanding the connection between lab and field observations.

5. What analysis can be done across several field sites to address fundamental and crosscutting environmental problems important to DOE?

The responses to this question indicated that it would be important to use such datasets in a meta-analysis mode to study the extremes across several sites, such as flow conditions, level of contamination, and aging processes; to perform thermodynamic modeling to integrate data across range of sites and scales; and to investigate which microbes facilitate and hinder various remediation targets across a range of environmental conditions.

6. What components are needed to make a field research site a 'success'?

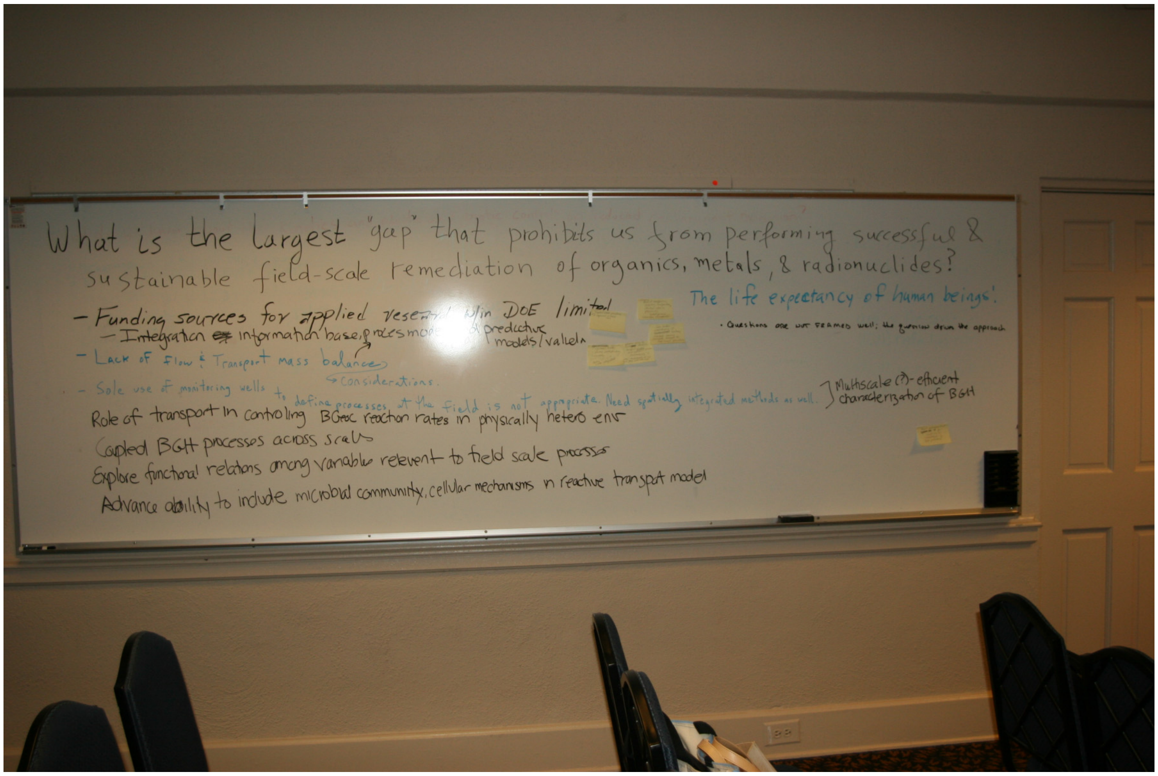
Many participants had opinions about what factors help to ensure a successful field campaign. Good suggestions about the importance of the field design included: developing a well defined scientific question and field study approach; aligning the project plan with budget constraints; starting simply and adding more complexity if possible; deciding up front how mechanistic one wants to be (i.e., which parameters will be obtained from literature and which will be measured); and not relying on lab experiments only to design large field scale experiments. It was also noted that it is important to maintain flexibility in the experimental plan and to consider results from other experiments (as well as historical data) from older sites. Several participants commented on the importance of involving a good research team with a wide range of expertise when dealing with natural and heterogeneous environments, and that it was critical to perform iterative and linked laboratory and field scale studies in parallel with numerical simulations across scales. Some participants suggested the utility of using outcrop, mesoscale, and analog site information for guiding or understanding field scale investigations.

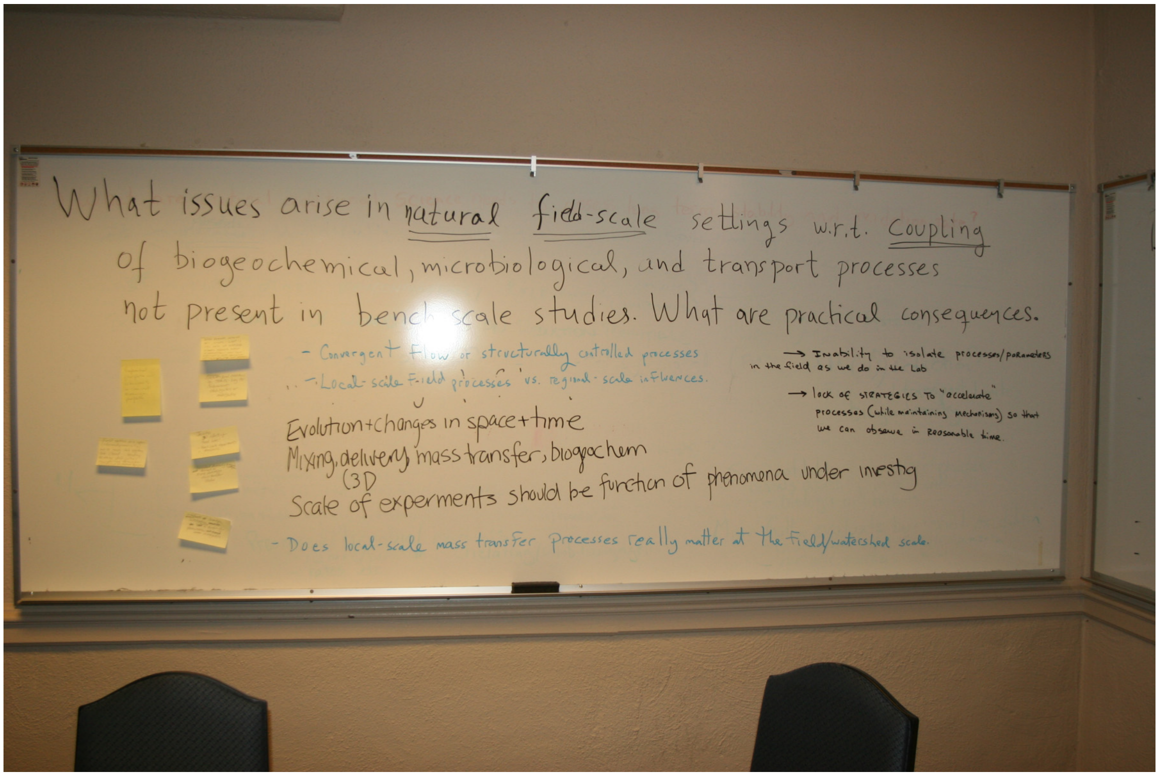
<u>Workshop Attendees</u>

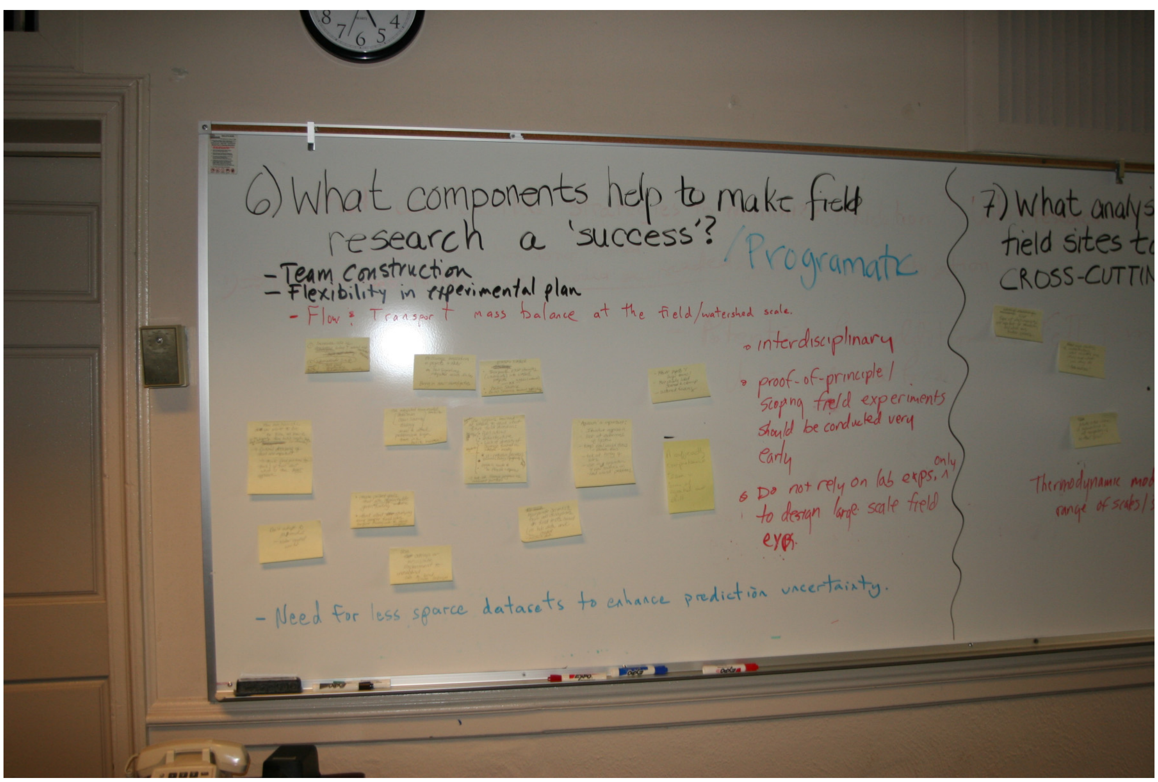
Name	**Affiliation**
Gary Jacobs	ORNL
Tim Scheibe	PNNL
Shawn Benner	Boise State
Anne O. Summers	U. of Georgia
Jack Istok	Oregon State Univ
Melora Park	OSU
Dick Dayvault	LM
Suraj Dhungana	LANL
Scott Brooks	ORNL
Scott Fendorf	Stanford
Vijendra Kotham	US DOE LM
Don Reed	Los Alamos
Gordon Southan	U. Western Ontario
Arthur Katz	DOE
Chuck Turick	SRNL
Andy Neal	SRNL
Steven Brown	ORNL
Karuna Chourey	ORNL
Bob Smith	Univ. Idaho
George Yeh	Univ. Central Florida
Michael Barcelona	Western Michigan Univeristy
Maxim Bogarror	Argonne NL
Ken Kemner	Argonne NL
Yilin Fang	PNNL
Matthew Reeder	Indiana University
Mathew Ginder-Vogel	Stanford
Paul Northrup	BNL
Tetsu Tokunaga	LBNL
Phil Jardine	ORNL
Boris Faybishenko	LBNL
Bill Burgos	PSU
Jim Fredrickson	PNNL
Craig Criddle	Stanford
Susan Hubbard	LBNL
David Lesmes	BES
Peter Kitanidis	Stanford
Brian Looney	SRNL
Eric Roden	Univ. Alabama
Tommy Phelps	ORNL
Derek Lovley	UMass
Diane Blake	Tulane
Kelly Nevin	UMass
Zhenya Shelobiline	UMass

Todd Anderson	DOE
G. Vazquez	BNL
Gilles Broussod	NER
David Watson	ORNL
Phil Long	PNNL
Dorthea Thompson	ORNL
Weimin Wu	Stanford
Jiamin Wan	LBNL
Susan Rishell	ORNL
David Shuh	LBNL
Martial Taillefert	Georgia Tech
Thomas Borch	Stanford
Karrie Weber	UCB
Baohua Gu	ORNL
Ken Williams	LBNL
Paul Bayer	DOE
Edward O'Loughlin	ANL
Bruce Ravel	ANL/APS
Geoff Puzon	WSU

Workshop Images




What issues arise in natural field-scale settings w.r.t. coupling of biogeochemical, microbiological, and transport processes not present in bench scale studies. What are practical consequences.
- Convergent flow or structurally controlled processes
- Local-scale field processes vs. regional-scale influences.
Evolution+changes in space+time
Mixing, delivery, mass transfer, biogechem
(3D
Scale of experments should be function of phenomena under investig
- Does local-scale mass transfer processes really matter at the field/watershed scale.
→ Inability to isolate processes/parameters in the field as we do in the Lab
→ lack of strategies to "accelerate" processes (while maintaining mechanisms) so that we can observe in reasonable time.


6) What components help to make field research a 'success'?
/Programatic
- Team Construction
- Flexibility in experimental plan
- Flow & Transport mass balance at the field/watershed scale.
interdisciplinary
proof-of-principle / scoping field experiments should be conducted very early
Do not rely only on lab exps. to design large scale field exps.
- Need for less sparce datasets to enhance prediction uncertainty.
7) What analys
field sites t
CROSS-CUTTIN
Thermodynamic mod
range of scales /