Federal Remediation Technologies Roundtable Meeting Summary

May 5, 2011

FEDERAL REMEDIATION TECHNOLOGIES ROUNDTABLE MEETING
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ACTION ITEMS

- ► Comments on the draft annual FRTR fact sheet should be sent to John Quander by May 31.
- ► Information suitable for the development of new cost and performance case studies of innovative technologies should be sent to Jim Cummings.
- ► Agency representatives who intend to participate in the FRTR future directions workgroup will send their contact information to Greg Gervais.

WELCOME/INTRODUCTION

Jeff Heimerman, Acting Director of the Technology Innovation and Field Services Division (TIFSD) in the U.S. Environmental Protection Agency's (EPA) Office of Superfund Remediation and Technology Innovation (OSRTI), welcomed the attendees to the 42nd meeting of the Federal Remediation Technologies Roundtable (FRTR).

Heimerman introduced Greg Gervais, the new Chief of the TIFSD Technology Assessment Branch. After providing a brief overview of his background in environmental work, including experience with a cleanup program on the Pribilof Islands in Alaska's Bering Sea, Gervais announced the addition of 20 new case studies to the FRTR Cost and Performance Database. He drew attention to the draft FRTR *Annual Summary of Activities: May 2011* in each attendee's meeting packet. Participants were asked to review the draft annual summary and send any suggestions and comments on it to John Quander by the end of May.

Jeff reminded the attendees that as a public meeting, the FRTR proceedings would be conducted using a Web conference tool to permit remote participants to watch the presentations live on line.

FRTR ANNOUNCEMENTS AND MEETING OBJECTIVES

FRTR Subgroup Reports

Green and Sustainable Remediation (GSR)

Carlos Pachon (EPA/TIFSD) outlined EPA developments in green remediation over the past few years, particularly the determination of what is meant by green remediation and what to expect from it. EPA's Office of Solid Waste and Emergency Response drafted a policy, *Principles for Greener Cleanups*, in 2009. The *Superfund Green Remediation Strategy* was issued in September 2010. More recent efforts have focused on determining how to consider green remediation during the remedy selection process, and preliminary guidance for use by EPA regional offices is nearing the final stages of development.

On the technical side, EPA has prepared technology-specific, best-practices fact sheets that discuss how to reduce the environmental footprint of the most energy-intensive and/or commonly used remedial technologies: pump and treat, excavation and surface restoration, soil vapor extraction and air sparging, and bioremediation. Recent fact sheets include *Clean Fuel &*

Emission Technologies for Site Cleanup and *Integrating Renewable Energy into Site Cleanup.* New fact sheets on thermal treatment, landfills, and underground storage tanks are in development. The website (www.clu-in.org/greenremediation/) has 28 profiles of green remediation in the field, many of them at federal facilities. Internet seminars on green remediation best practices have been popular, and the archived versions continue to receive attention (www.clu-in.org/live/archive/).

EPA is working with ASTM on the production of a standard guide to establish a common understanding of the process of achieving environmental footprint reductions. With respect to documenting best practices, a side-by-side evaluation of several environmental footprint methodologies is under way in Region 6. Going forward, EPA is working on measures for the five core elements of the green remediation principles, in addition to quantification measures.

Green remediation topics have received considerable attention at major conferences, such as Brownfields and those sponsored by Battelle. The Interstate Technology & Regulatory Council (ITRC) has distributed a draft document on Green and Sustainable Remediation (GSR) for review.

Carol Dona, U.S. Army Corps of Engineers (USACE), reported that the federal partners in the GSR subgroup have developed two half-day courses for presentation on June 27 at the Battelle Bioremediation and Sustainable Remediation Technologies Symposium in Reno, Nevada (www.battelle.org/Conferences/bioremediation/short.aspx#srt) (Attachment A). The first course, "The SRT™ and SiteWise™ Sustainable Remediation Tools," will describe how to choose and use tools within a GSR evaluation, and the second course, "Framework and Metrics for Incorporating Sustainability into Remediation Projects," will explain how to perform a GSR evaluation. Both tools are available on line (www.ert2.org/t2gsrportal/tools.aspx). Version 2 of SiteWise™ should be available by the end of May 2011 with several improvements: a renewable energy package and a cost package to cost out alternatives and calculate energy costs. Dona added that a potential project for the Roundtable, as a neutral body, is the development of a database of emission factors for equipment and materials as a resource to use for evaluating a project's environmental footprint.

An international conference—Sustainable Remediation 2011: State of the Practice (www.umass.edu/tei/conferences/SustainableRemediation/)—will be held June 1-3, 2011, at the University of Massachusetts at Amherst. The agenda features new research, field applications, and lessons learned in the areas of green chemistry, human health, and environmental response.

Vapor Intrusion

Rich Kapuscinski (EPA/OSRTI/Science Policy Branch) discussed the development of U.S. EPA's Vapor Intrusion Database Project (Attachment B). The project focus is on a factor referred to as "attenuation value." Simply put, this is a ratio between an indoor air concentration of a volatile chemical divided by the source concentration exterior to the building. Given that definition, a lower attenuation value is better from a perspective of human health protection. Generic attenuation values have been used for at least 10 years in the assessment and screening of properties for vapor intrusion potential. These generic values were incorporated into the Agency's 2002 draft vapor intrusion guidance based on evaluation of a limited set of data, primarily emphasizing residential properties. Since the release of the 2002 draft guidance, the Agency has collected a substantial quantity of additional data, mostly for residential sites, which will enable the refinement of the generic screening criteria for residential structures when a final vapor intrusion guidance is issued. The Agency is committed to issuing the new guidance in 2012.

The Vapor Intrusion Database (www.epa.gov/oswer/vaporintrusion/vi_data.html) was developed to store the collected data, and a report of preliminary findings was issued in 2009. FRTR formed a workgroup in 2010 to assist the Agency in collecting data from additional types of sites. Progress has accelerated recently thanks to the assistance of the Department of Defense (DoD) and other agencies in circulating a new survey form to identify sites that have suitable data. Site-specific data are currently being collated.

Mr. Kapuscinski urged the program managers in the audience to encourage and support data submissions to EPA by their remedial project managers. The data (preferably data that have already been submitted to applicable regulatory agencies) will be used by EPA solely for scientific purposes in support of refining guidance.

Question: Have you mined data from the ITRC vapor intrusion training courses? Course participants might be able to provide useful data from the sites they work on.

Answer: Good idea!

Question: Is OSRTI obtaining data from the vapor intrusion studies performed by the Office of Underground Storage Tanks (OUST)?

Answer: At present, the OUST focus primarily is on the potential for biodegradation of petroleum vapors in the interval between the source and a building's interior; however, the master plan calls for eventually bringing together vapor intrusion data from all available sources.

Question: Is information being gathered from facilities not regulated by OUST, such as refineries and fuel terminals?

Answer: State agencies and the EPA regional offices are submitting vapor intrusion data for all types of facilities.

Agency Announcements (Projects/Initiatives)

Tom Nicholson (Nuclear Regulatory Commission) announced that the American National Standards Institute has approved a new standard developed by the American Nuclear Society, ANSI/ANS-2.17-2010: *Evaluation of Subsurface Radionuclide Transport at Commercial Nuclear Power Plants*. Remediation is not part of this standard, but ANS is organizing a new workgroup to develop a standard for remediation of radionuclides in groundwater at nuclear facilities. He hopes EPA will be represented in the workgroup. Also available is a recent NRC publication: *Lessons Learned in Detecting, Monitoring, Modeling and Remediating Radioactive Ground-Water Contamination*. The report documents activities associated with managing a tritium plume and several strontium plumes at Brookhaven National Laboratory (www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr7029/). Thirteen years of data gained from this site were used in the development of the new ANS standard.

Ballot for Future Meeting Topics/Current Meeting Objectives

The meeting was conducted with the following overall objectives:

1. Improve communication and common understanding of characterization and monitoring of contaminated sites.
2. Share experience and lessons learned in advancing best practices.
3. Outline key issues and develop shared strategies to address them.

Greg Gervais went over the ballot of potential topics for the fall 2011 FRTR meeting and asked that a representative from each member agency present cast a ballot and return it after the lunch break, with the results to be announced at the end of the meeting. He noted that the agenda listed nine presentations—seven on characterization and two on monitoring—and then introduced Jim Cummings (EPA/TIFSD) as the moderator of the initial portion of the technical program.

SITE CHARACTERIZATION

Using High Resolution Site Characterization to Improve Remedy Design and Implementation

Steve Dyment (EPA/TIFSD) gave an overview of how the use of high-resolution site characterization tools can support site remedy optimization. (Attachment C). The EPA Superfund Optimization Program provides independent third-party evaluations of sites at strategic locations along the Superfund pipeline from remedial investigation through long-term remedial action. At many sites, these evaluations indicate opportunities for improvement to the conceptual site model (CSM), data collection tools and strategies, and data management and visualization platforms, which can significantly improve the protectiveness and efficiency of remedy implementation. Use of targeted high-resolution characterization techniques provides improved understanding of contaminant distribution and critical geologic and hydrogeologic features that control fate and transport mechanisms at meaningful scales necessary to optimize remedy implementation. The National Strategy to Expand Superfund and Optimization steering committee's current working definition of optimization is given as "A systematic site review by a team of independent technical experts, at any phase of a cleanup process, to identify opportunities to improve remedy protectiveness, effectiveness and cost efficiency, and to facilitate progress toward site completion."

Common site characterization challenges have been identified through third-party optimization reviews conducted at EPA Superfund sites. High-resolution characterization strategies and tools are available to address these challenges. Trends in remedies chosen at EPA sites continue to move toward in situ techniques, such as chemical oxidation and enhanced biological processes, further illustrating the need to gain an adequate understanding of source material and plume morphology with greater resolution in the subsurface. Remedial strategies that combine multiple remedy technologies along distinct geologic facies or those that target source, free-phase, residual, and dissolved-phase contamination differently further underscore the need to understand contaminant concentrations and hydrogeologic conditions at scales appropriate to optimize remedy applications.

High-resolution tools (see list on slide 16) and strategies can be applied at a variety of entry points along the assessment and cleanup process; however, optimization findings continue to show the potential for significant programmatic impact when considered before or during remedy design activities. Characterization investments that improve refinements of treatment zones potentially requiring more aggressive technologies and ensure appropriate reagent delivery location and mechanisms can have significant return on investment. Similarly, considering the extraction, destruction, or treatment of contaminants in light of subsurface heterogeneity and variations in hydraulic conductivity not only serves the potential improvement of remedy protectiveness and efficiency but is uniquely suited to streamline cleanup footprints and meet green remediation performance metrics.

Mr. Dyment provided several examples of optimization reviews at cleanup sites, including results achieved by an independent review conducted early in the design stage of the remedy for the Grants Chlorinated Solvents Plume, EPA Region 6. The Record of Decision, signed in June 2006, specified implementation of in situ thermal remediation, in situ chemical oxidation, in situ bioremediation, and vapor mitigation. The review highlighted the need for additional information to help refine or confirm the CSM. Based on additional source-area characterization results, more monitoring wells were installed and screened appropriately; the area for thermal remediation was reduced in size and relocated; monitored natural attenuation (MNA) is being considered for a portion of the plume (reducing the area for active remediation); and the amounts of treatment chemicals and nutrients needed are being reevaluated. The revised cost estimate for the remedy following the review was about $11 million lower than the initial $29 million estimate.

Mr. Dyment is particularly enthusiastic about the use of the lifecycle CSM as a planning, management, and decision-making tool. The Superfund Optimization Program is continuing outreach and training with the development of a one-day, high-resolution site characterization course, tying it to remedial design and remedy operation. Technical support will continue in the areas of 3D visualization, tools, strategies, and identification of research needs.

3D Site Characterization and Autonomous Remedial Process Monitoring Using High Performance Electrical Resistivity and Induced Polarization Tomographic Imaging

Tim Johnson (Pacific Northwest National Laboratory) acknowledged the work of many colleagues over decades in providing the information he came to share (Attachment D). His presentation highlighted the use of innovative technologies designed to take advantage of the electrical properties of the subsurface, which are sensitive to the hydrogeologic properties governing contaminant movement and to the geochemical processes functioning during contaminant transport or in situ remediation operations. Electrical resistivity tomography (ERT) and time-domain induced polarization (IP) tomography are methods of imaging subsurface electrical properties. These methods have been used extensively for subsurface characterization and demonstrated successfully for monitoring contaminant distributions and remediation processes through time-lapse imaging. The primary reason for using time-lapse electrical imaging as a characterization and monitoring tool is that changes in subsurface properties are detected throughout the sensitive domain (i.e., in 2D or 3D as opposed to a point measurement). Recent advancements in ERT and IP data collection hardware allow autonomous collection of large amounts of data over short periods of time, providing the potential to characterize and monitor at unprecedented spatial and temporal resolution. Realizing this potential requires 1) ERT and IP modeling and inversion codes capable of processing large data sets efficiently and 2) an understanding of the changes in electrical properties that correspond to the relationship between temporal and spatial changes in hydrogeologic and geochemical properties.

High-performance ERT and IP data collection hardware and parallel inversion software are used in conjunction with point measurements to characterize the subsurface and monitor remedial progress in 3D at two field sites. The first is a Superfund site in Brandywine, Maryland, where a lactate amendment was introduced in the saturated zone to facilitate in situ enhanced bioremediation of a chlorinated solvent plume. The second site is in the unsaturated zone of the Hanford BC Cribs area, which currently is undergoing a treatability test to evaluate the efficacy of using in situ soil desiccation to reduce contaminant flux to the water table.

Question: Referring to the precipitation of iron sulfide shown in the presentation, would it be possible to arrive at a quantitative estimate of the amount of contaminant present based on the electrical resistivity inversion?
Answer: Probably not. To arrive at an empirical relationship likely would require a lab study.

Question: Would a quantitative estimate be possible using core samples to calibrate against?
Answer: If the reaction that occurs in the field could be reproduced in the lab, then the ERT response for a given amount of iron sulfide precipitation might be measured.

Question: Would this type of imaging have an application for transport through bedrock or karst?
Answer: A study in fractured rock has just been funded by ESTCP (Environmental Security Technology Certification Program) and will start this year, so that question can be answered in greater detail about two years from now. One of the problems with fractured rock is the anisotropy of electrical conductivity, which makes it much harder to invert.

Comparative Analysis of Multi-Incremental Sampling Results with Conventional Sampling at the Ft. Eustis Superfund Site

Deana Crumbling (EPA/TIIB) presented the results of an incremental sampling (IS) pilot study conducted by EPA Region 3 at a former skeet/trap range on Fort Eustis, Virginia (Attachment E). The site is contaminated with lead shot and polycyclic aromatic hydrocarbons (PAHs) associated with historical use. The study was designed to evaluate, among other things, 1) the effectiveness of sample grinding and laboratory subsampling of metals and semivolatile organics following IS sampling, 2) variability between field and laboratory replicates, 3) contaminant variability within discrete samples, and 4) impacts of grinding on resultant sample concentrations.

There is a question about whether grinding a sample increases the acid solubility of the matrix due to the increase in surface area that grinding causes. The concern is that grinding might increase acid leaching of metals during sample preparation. If so, metals would be released into the solution that is then measured by the ICP instrument. This would increase the reported metal concentrations over what would have been reported if the soil had not been ground. The thinking is that grinding would thus misrepresent the metal contaminants of concern by contributing a metal fraction that probably would not be bioavailable. However, the evidence from two of the project's six decision units (DUs) indicated that grinding did not elevate metal concentration results.

It is likely that part of the explanation for occasionally higher metal concentrations in ground samples is simple chance—some ground sample results will be higher than unground sample results. It is also possible for "bleed" from the grinder to add certain metals, which seems to be the case for chromium in this study. Additionally, particle effects can make it appear that ground concentrations are higher than unground concentrations, depending on the particulate form of the metals analyzed. In large unground particles, for example, metals may be locked in the mineral matrix and thus are not available for biological uptake or dissolution into groundwater, whereas grinding releases the metals from the particle matrix. It is a good idea to evaluate any unusual matrices. Project results suggested that incremental sampling data can be comparable to discrete data sets at a high density of discrete samples.

Question: What is the purpose of the data? How does gaining an average concentration over a large area inform what needs to be done about it?
Answer: EPA guidance for risk assessment calls for the average concentration as calculated statistically by the upper confidence limit.

Comment: Using the average concentration could mask the presence of an area of high concentration, which could have a large impact.
Answer: Incremental samples are much more likely to pick up the existence of an area of high concentration than low-density discrete data sets, which might miss it completely. With a high density of increments, the high concentration area will pull the average up. With the higher average as an indicator, additional sampling can be done using a different sampling design. If using fixed lab methods, that would require two mobilizations. If using field methods, one mobilization could both detect the high-concentration area and locate it.

Question: Is there really a concern over the act of homogenizing the samples?
Answer: Yes, there is concern over the acceptance of incremental sampling by risk assessors because part of the incremental sampling methodology is the process of preparing the samples so that subsampling is reproducible, which goes beyond the acquisition of samples in the field.

Question: What would be the mechanism that would affect the extractability equivalent to bioavailability of metals in simply drying and grinding the soil?
Answer: Grinding the soil into smaller particles increases the available surface area, which allows the acid to access more surface area and leach out the metals—metals that otherwise would not be acid-soluble.

Comment: Another incremental sampling study was done in Region 3 at the former Nansemond Ordnance Depot in Virginia. A report, *Statistical Evaluation of Multi-Increment Soil Sampling (MIS) Approach and its Applicability in Addressing Various Project Objectives of Environmental Investigations*, was completed in

January 2009. It recommended incremental sampling as a cost-saving approach to sampling and analysis at the site.

Comment: ITRC is preparing a Web-based document on incremental sampling that should be out in spring 2012. It will contain about eight case studies.

In-Well Tests to Determine Indigenous Naphthalene Biodegradation under Sulfate Reducing and Methanogenic Conditions

As project manager for the title study, Carol Dona provided an overview of the use of Bio-Trap™ sampling devices to evaluate indigenous naphthalene biodegradation at the McCormick & Baxter Superfund Site, a former creosoting manufacturing facility (Attachment F). She recognized the individuals involved in the study and then introduced Aaron Peacock (Microbial Insights Inc.), the inventor of the device, who continued the discussion of remote isotope probing from an off-site location.

Located in Stockton, California, the McCormick & Baxter facility operated from 1942 until 1991. PAHs characteristic of creosote contamination are present in the groundwater, in addition to other petroleum hydrocarbons. Historical data show that naphthalene, which is widespread at the site, has migrated in the groundwater significantly less than expected hydrogeolologically, suggesting that degradation of naphthalene is occurring. The data from this study, along with data from additional biological studies, will be used in a groundwater model to evaluate the feasibility of using MNA as a stand-alone alternative and in combination with other technologies for remediating the groundwater.

Stable isotope probing couples molecular methods with stable isotopic compounds as a way to link biodegradation to the organisms responsible for it. The study evaluated the ability of the indigenous microbial community to degrade naphthalene under the generally sulfate-reducing and methanogenic conditions in the groundwater. Following the accidental destruction of one of the original monitoring wells, a replacement well was placed in a nitrate-reducing location. Field tests were conducted using Bio-Trap™ sampling devices enriched with ^{13}C-labelled naphthalene. Twenty-two in situ tests were conducted in 19 different locations, which generally represented either sulfate reducing or methanogenic conditions from source or fringe plume areas across the five different aquifer zones where PAH contamination is present. After field incubation, the Bio-Traps™ were analyzed for ^{13}C in the microbial lipid biomass, residual ^{13}C naphthalene in the trap, the ^{13}C in the carbon dioxide captured by trap beads, and ^{13}C in the methane captured by the trap. The groundwater in equilibrium with the Bio-Trap™ was also analyzed for anions and dissolved gases (methane and carbon dioxide) not enriched with ^{13}C.

Of the 19 locations tested, all locations had measurable enriched ^{13}C in the microbial lipid biomass. Measurable enriched ^{13}C CO_2 was detected at eight locations across the site. No ^{13}C above background measured in methane was recovered from the traps at any location. Although the microbial community appears to be stressed, its ability to degrade naphthalene seems to be widespread across the site, with both the type of terminal electron acceptor process and the physical location (aquifer zone) influencing the microbial community biomass, composition, and physiological status, and the resulting naphthalene degradation.

What's New in the Site Characterization Tool Box: Molecular Biological Tools to Identify Microorganisms that Degrade Contaminants and Contaminant-Specific Isotope Analysis to Identify Sources and Document Degradation

John Wilson (EPA/ORD/Ada) said that there is a tendency to over-rely on chemical concentration data to qualify a site based on a comparison to standards when it would be more useful to start collecting information about how the contaminants are behaving. Instead, the common practice is to collect more chemical data and try to tease out indications of chemical behavior from the trend data. This approach supports the "one more well" syndrome in the struggle to improve understanding of the site. The only way to break out of that loop is to collect other kinds of information to illuminate the behavior of contaminants and microoganisms in the subsurface environment (Attachment G).

In the past, it was necessary to conduct intensive sampling and monitoring of concentrations of contaminants in groundwater to trace plumes back to their true source. Now it is possible to determine the ratio of stable isotopes of carbon, hydrogen, or chlorine in the contaminants in groundwater. The analysis is called compound-specific isotope analysis, or CSIA. The particular ratios of isotopes in the contaminants in the plume and in a suspected source can be compared to associate the plume with its source (under favorable conditions).

In the past, the only way to determine whether microorganisms that can degrade a contaminant were present at a site was to isolate and characterize the microorganisms. It was necessary to make the organisms grow in culture media, which is often difficult. Now it is possible to determine the number of copies of particular genes for an active enzyme or the characteristic sequences of DNA from a known degrader organism without requiring growth. The DNA is isolated, and then the polymerase chain reaction or PCR is used to copy particular sequences of DNA repeatedly until the concentrations of DNA are high enough to be analyzed chemically.

In the past, the only evidence for degradation of a contaminant was attenuation in concentrations of the contaminant with distance from the source. Uncertainties associated with sampling groundwater at field scale makes this approach problematic at many sites. Now it is often possible to use changes in the ratio of stable isotopes of carbon, hydrogen, and chlorine to recognize degradation of a contaminant at field scale and estimate the extent of degradation that has already occurred. Under some conditions, it is possible to determine if a daughter product, such as cis-1,2-dichloroethene or vinyl chloride produced from trichloroethene, is degrading in groundwater.

Question: What additional costs might be involved with the use of stable isotope analysis at a site sampling for vinyl chloride?

Answer: The last six presentation slides identify commercial sources for molecular biological tools. For a single contaminant, current cost is about $250.00 per water sample. If looking for several contaminants, add about $50.00 for each additional one. The vendors prefer use of EPA Method 8260 prior to receiving the sample because concentration measurement is needed in addition to stable isotope analysis. Incorporating this technology into the program can double or triple the cost of analysis, but this procedure is not for use on every well—it is a tool that can be used to inform a decision.

Mercury Source Zone Identification and Characterization

David Watson (Oak Ridge National Laboratory) described current work at the Department of Energy's Y-12 National Security Complex, Oak Ridge, Tennessee, under the DOE EM-30 Applied Field Research Initiative. The Y-12 project is developing and demonstrating new tools and approaches for the characterization, remediation, and prediction of mercury and other contaminants in complex subsurface and surface water environments (Attachment H). The Applied Field Research Initiative has two additional projects: studies at Hanford of contaminants in the deep vadose zone (i.e., that portion of the subsurface resting below the practical depth of surface excavation or surface engineered barrier influence and above the water table), and investigations at Savannah River of attenuation-based remedies in the subsurface.

During past operations at Y-12, large quantities of elemental mercury (Hg^0) were inadvertently released to the environment, resulting in extensive soil and groundwater contamination. Subsequently transported into nearby surface water, the Hg was taken up by fish and other biota. The spatial distribution and forms of Hg present in the subsurface at these sites is poorly understood, making it difficult to select effective remedial actions and assess their potential effectiveness and cost. Development and demonstration of reliable measurement tools that can detect and help quantify the nature and extent of mercury in the subsurface are needed to reduce these uncertainties and increase the effectiveness of remedial actions.

Recent laboratory and field tests at Y-12 have shown that sampling and analysis of Hg vapors in the shallow subsurface (<0.3 m depth) can be an excellent indicator of the location and extent of Hg^0 releases in the subsurface. Several analytical methods, such as total Hg digest/Zeeman atomic absorption detection, sequential extraction, and scanning electron microscope, were used to quantify and characterize Hg in soil samples (n>75) collected from an area with known Hg contamination. Controlled head-space analysis of this Hg-contaminated material in the laboratory indicates that even very low-level Hg vapor concentrations are indicative of the presence of Hg^0.

For sampling, a pushprobe assembly was constructed and driven into the ground. Soil gas samples were collected through a sealed inner tube of the assembly and analyzed immediately in the field with a Jerome or Lumex Hg analyzer. Time-series sampling showed that Hg vapor concentrations were fairly stable over time, suggesting that the vapor-phase Hg was not being depleted and that the results were not very sensitive to the purge volume. Hg vapor data collected at over 200 pushprobe locations at three different release sites correlated well to areas of known Hg^0 contamination in the subsurface. These results suggest that soil gas sampling and analysis can be conducted rapidly and inexpensively on a large scale to help identify areas contaminated with elemental Hg.

Question: When using X-ray fluorescence (XRF) for mercury, there are challenges in the opposite direction, as in XRF overestimation of low concentrations versus laboratory methods. The Lumex soil attachment is useful for more than Hg in soil gas—it can also do solids and possibly liquids. It was used with some success at a mining site in Region 9. Is it being used in the Y-12 project?

Answer: The soil attachment was not part of this effort, but other people at Oak Ridge are using it.

Comment: XRF is being used successfully for uranium.

Answer: That must be a newer tube-based system. One of the challenges faced with trying XRF for Hg was an older isotope-based system with detection-limit issues. Was the underestimation issue for Hg from a newer tube-based system?

Answer: No, the reason is unknown as yet. It may be an analysis artifact of some sort, but it was so consistent as to be worth a cautionary note.

Approaching MCLs in a Large Dilute Plume: Reese AFB Case Study

Fred Payne (ARCADIS) explained how intensive site characterization plus an aggressive and adaptive remedial strategy has nearly achieved maximum contaminant levels (MCLs) across a 3-mile-long plume at the former Reese Air Force Base (AFB) near Lubbock, Texas (Attachment I). The former AFB is the site of an 18,000-foot-long dissolved-phase trichloroethene (TCE) plume covering more than 250 acres. As of 2004, the plume was contained by a 900-gpm groundwater extraction, treatment, and re-injection system that had established capture but was projected to operate for at least an additional 25 years. In 2004, the site was re-contracted under a guaranteed fixed-price instrument, with the objective of restoring groundwater to MCLs or better across the entire plume footprint in 10 years.

The TCE plume at the former Reese AFB lies in the Ogallala Aquifer, a regional alluvial fan formation that spans approximately 100 to 150 feet below ground surface in this area. The Ogallala is highly heterogeneous and anisotropic, with zones of extreme high and low hydraulic conductivity interspersed throughout the affected interval. Groundwater transport velocities in the formation have been measured at greater than 5 feet per day in some areas. Several key observations formed a basis for re-working the CSM:

- The aquifer is highly anisotropic and heterogeneous, so transport velocities will greatly exceed average groundwater velocities.
- The centerline of groundwater transport does not align directly with the groundwater elevation gradients. In the vicinity of Reese AFB, a 40-degree offset exists between groundwater transport and the elevation grade.
- Conventional groundwater modeling and pumping strategies derived from those models will not provide optimal pumping.
- In some areas, extraction well placements may have spread contaminants laterally.

Through an iterative reconstruction of the CSM, initially using existing data from more than 700 monitoring, extraction, and reinjection wells and then through additional monitoring and treatment well construction, a different picture of the site emerged. Among the key findings:

- Contaminant concentration patterns are much more complex than were depicted previously with “plume limits” mapping.
- Peak TCE concentrations are notably higher than previously recognized.
- Flow is highly organized in well-formed channel complexes that meander along the general flow axis.
- Many extraction wells were placed in locations that spread TCE laterally.

The updated site characterization data and the resulting CSM provided the basis for a substantial revision of the groundwater extraction and reinjection efforts. The CSM is adjusted continuously as new data become available, and remedial system operations are adjusted quarterly, including placement of new pumping wells as needed. By placing extraction points in more optimal locations and adjusting flow allocations in response to plume behavior, the pace of plume shrinkage accelerated dramatically, and the plume area (as of March 2011) has fallen to less than 25 acres. The site is on target to reach MCLs for chlorinated volatile organics, plume-wide, by 2014.

Question: So MCLs can be achieved if the water is moving fast enough, reaching equilibrium between how much is sorbing into the water and how much the water removes? Is this a case of the removal mechanism being faster than the release mechanism, rather than a complete removal of contamination?

Answer: Correct, it is an equilibrium function. The monitoring wells are seeing the conductive part of the formation, and MCLs can be met in all the wells, monitoring and pumping. If any mass is stored, the bleedback into the water is slow enough that the water will still meet MCLs. If the goal changed from 5 µg/L to 1 µg/L, the level of effort in this case would go up by a large margin, perhaps 10-fold.

LONG-TERM MONITORING

Air Force Long-Term Monitoring Optimization Tools

Phil Hunter (Air Force Center for Engineering and the Environment) discussed the major lifecycle consideration that long-term monitoring (LTM) represents for the Air Force and DoD (Attachment J). The Air Force has an estimated 100,000 monitoring wells, and sampling costs approach $30 million per year. With over 90% of the groundwater data captured by the Air Force below environmental standards (i.e., MCLs, PRGs), this information alone suggests that there is opportunity to sample less and be protective at the same time. Air Force experience reveals significant redundancy in sampling results both over time (sampling frequency) and space (well density). This notion is not new and was motivation for developing optimization techniques that have been around over 10 years. The technical literature shows that optimization can reduce sampling efforts by 15-50 percent with only a minor loss of information. Sacrificing some sampling information is reasonable, particularly if it does not impact risk or drive a necessary environmental decision.

The Air Force developed and currently endorses three user-friendly optimization tools:

- **Geostatistical Temporal-Spatial (GTS) optimization software**. GTS is a Windows-based application built with open-source software toolkits. It uses statistical and geostatistical techniques to determine the optimum number and placement of wells in an existing LTM network and the optimal sampling frequency for wells in the network.
- **Monitoring and Remediation Optimization System (MAROS) software**. MAROS is a decision support tool based on statistical methods applied to site-specific data that account for relevant current and historical site data as well as hydrogeologic factors (e.g., seepage velocity) and the location of potential receptors (e.g., property boundaries, wells). Based on site-specific information, the software suggests an optimization plan for the current monitoring system to achieve efficient termination of the monitoring program. A MAROS upgrade is in process. The new version should be out in September 2011.

- **3-Tiered Monitoring Optimization tool (3TMO)**. 3TMO is an updated version of Parsons' Three-Tiered Monitoring Network Optimization approach. It is 'new' in the sense that is it currently being translated to software. It should be publicly available in summer 2011.

These tools vary from being highly quantitative to qualitative in nature. Although they perform the same basic optimization function using transparent decision logic, their differences allow optimizations to be performed across varying site conditions and a wide technical audience. All of these tools are freeware and can be downloaded without cost. At the very least, they bring a standardized process and reproducible results to a complex problem. LTM tools also offer a green and sustainable approach to smart monitoring and good environmental stewardship.

Question: Is there any Air Force policy guidance for LTM, such as a requirement to incorporate LTM into 5-year reviews?

Answer: It is not necessarily written in as part of the 5-year review. In performance-based remediation (PBR), there are cost incentives to optimize the monitoring well network fence-to-fence across the installation. Our general guidance is to perform an optimization to coincide roughly with the 5-year review process. In most cases, both the 5-year review and the optimization would be addressed by the PBR. If not, the optimization would be conducted as a separate technical effort.

Question: Is there guidance on when to use one of the three optimization tools?

Answer: It depends largely on the user, site conditions, and the technical audience. To perform an installation-wide analysis, a user probably would default to GTS optimization software because it can do individual sites or the whole installation. The other tools are useful in a site-by-site approach. The most qualitative approach would be 3TMO.

Question: Is there guidance within the Air Force to require the use of this cost-saving program for certain types of sites, or sites with a certain number of wells, or monitoring that costs X amount? Are there any figures on how much has been saved using these types of tools?

Answer: The continuous improvement process outlined in the Defense Environmental Restoration Program (DERP) guidance is the umbrella guidance. These performance-based efforts have a cost incentive to optimize monitoring over time. Ultimately, the Air Force is dealing with stakeholders, and a performance-based environment requires a means for validating some of the approaches. For cost savings, the percentage of reduction in sampling effort found in the literature and in Air Force experience ranges from 20-50 percent, with improvement across the board. For example, the optimization proposal reduced the $2 million annual monitoring program at Tinker Air Force Base by half.

Scientific Opportunities for Monitoring of Environmental Remediation Sites

Amoret Bunn (U.S. DOE) said that the challenge of reducing risk and cleaning up the DOE nuclear weapons complex remains one of the most technologically difficult and financially costly problems facing DOE's Office of Environmental Management (Attachment K). DOE maintains the largest cleanup program in the world—currently involving over a million acres in 13 states. The inventory contains approximately 90 million gallons of radioactive waste, 1.7 trillion gallons of contaminated groundwater, and 40 million cubic meters of contaminated soil and debris. The sheer mass of contaminated soil and groundwater makes it impractical to completely restore many sites to predisposal conditions. Moreover, realistic physical constraints will, in some cases, leave contamination in places difficult to access, albeit at levels calculated not to pose a significant risk. This contamination will require continued monitoring to ensure protection of human health and environment.

Long-term monitoring will be the largest life-cycle cost. It is critical to identify innovative monitoring approaches and techniques that reduce costs and improve performance and protection. DOE is working on a framework, "Scientific Opportunities for Monitoring of Environmental Remediation Sites," to identify scientific, technical, and practical challenges that currently impede informative, timely, and cost-effective monitoring to support remediation actions. The framework covers the background and history of DOE long-term monitoring needs and the need for integration of advanced monitoring strategies into long-term surveillance and maintenance at DOE closure sites. Monitoring technology opportunities will involve a wide range of needs: processes for consideration of multiple lines of evidence; new tools for monitoring system configuration and flux monitoring; surrogate measures to reduce costs; remote sensing and geophysics; innovative sensors and sensor configurations; bioassessment tools; and information integration and modeling. Ideally, the tools will support continuous monitoring over very long periods of time.

The framework document is currently in development. The goal is to have an expert meeting at the end of October to finalize its ideas and collect other ideas from experts across the federal agencies who deal with similar problems

Question: Given the presence of both volatile organic contaminants and radioactive metals at DOE facilities, are monitoring techniques available to separate out the different contaminant types?

Answer: That is one of the major monitoring challenges DOE faces at many sites. It has had better results in treatment of multiple contaminants. For example, Savannah River has had success in altering the groundwater pH to let the metals drop out and then treating any remaining contaminants with another process.

Question: Given the variety of environmental monitoring scenarios across the complex, what type of spatial and temporal resolution is needed?

Answer: One example involves monitoring the groundwater-surface water interface. The tools used are flux-based, but if the methodology is not applied so that it synchronizes with environmental changes as they occur, the results obtained can apply a different type of periodicity to the system. Understanding the spatial and temporal changes is a major issue. At the Hanford site, surface water fluctuations can be observed one-quarter of a mile inland, influenced by daily fluctuations in the Columbia River. This interaction may result from the movement of river water into bank storage, where because of temperature and density gradients it is actually floating on top of the groundwater and not mixing before it moves back out. It is moving through the capillary fringe, which is where the highest concentrations of uranium are captured. In the bottom of the Columbia River, a biofilm collects the uranium at the groundwater-surface water interface, and little evidence of uranium is found in the surface water above it. This biofilm may introduce uranium into the food web if receptors consume it. Gaining a better understanding of groundwater-surface water interaction will help to explain the spatial and temporal exchange of uranium into the surface water.

Question: Will the framework document provide guidance?
Answer: It is not a prescriptive document. One of its purposes is to identify opportunities for future investments by DOE to improve technologies that support its long-term responsibilities. Another purpose is to help a risk manager understand options for addressing a particular environment by providing a description and links to additional resources.

MEETING WRAP-UP/NEXT MEETING AGENDA

Jeff Heimerman noted that the FRTR was established in 1990 to bring together the top federal cleanup program managers and other remediation community representatives to share information, learn about technology-related efforts of the individual agencies, discuss the future directions of the national remediation programs and their impact on the technology markets, interact with similar state and private industry technology development programs, and form partnerships to pursue mutual interests. The core members of the Roundtable have been EPA, the Defense services, DOE, the U.S. Geological Survey, and NASA. Since its inception, the collaborative efforts among the Roundtable members have led primarily to technology transfer tools, such as the screening matrices, the cost and performance case studies, and other decision support tools. That has been the largest part of the FRTR output.

Much has changed in the remediation/characterization community over time. The tools that are available today, particularly those for characterization, are far superior to what they were 20 years ago. Technology advances create policy and strategic options. Heimerman suggested that it might be time to step back and evaluate the mission of the Roundtable and what it might accomplish in the future. He proposed the establishment of a small workgroup with at least one member from each of the FRTR participating agencies to assess the organization’s current status, evaluate the level of energy for future projects, and discuss future directions—possibly in five or six conference calls between now and November 2011, with a report-out of results made at the next meeting.

The attendees affirmed the value of the work accomplished by the FRTR and agreed that a representative from each of the agencies present will participate with EPA in the workgroup. Each agency will send the contact information for a workgroup representative to Greg Gervais.

Balloting for the next FRTR meeting topic indicated remedy optimization as the topic of greatest interest to member agencies. Carol Dona and Steve Dyment volunteered to help plan the agenda.

The next meeting will be scheduled toward the end of 2011. Jeff Heimerman thanked everyone for attending, and the meeting was adjourned.

ATTACHMENTS

A. U.S. EPA's Vapor Intrusion Database Project
B. Green Remediation Update
C. Using High Resolution Site Characterization to Improve Remedy Design and Implementation
D. 3D Site Characterization and Autonomous Remedial Process Monitoring Using High Performance Electrical Resistivity and Induced Polarization Tomographic Imaging
E. Comparative Analysis of Multi-Incremental Sampling Results with Conventional Sampling at the Ft. Eustis Superfund Site
F. In-Well Tests to Determine Indigenous Naphthalene Biodegradation under Sulfate Reducing and Methanogenic Conditions
G. What's New in the Site Characterization Tool Box: Molecular Biological Tools to Identify Microorganisms that Degrade Contaminants and Contaminant-Specific Isotope Analysis to Identify Sources and Document Degradation
H. Mercury Source Zone Identification and Characterization
I. Approaching MCLs in a Large Dilute Plume: Reese AFB Case Study
J. Air Force Long-Term Monitoring Optimization Tools
K. Scientific Opportunities for Monitoring of Environmental Remediation Sites