Federal Remediation Technologies Roundtable Meeting Summary

June 20, 2012

FEDERAL REMEDIATION TECHNOLOGIES ROUNDTABLE MEETING
Arlington, VA
June 20, 2012

ACTION ITEMS

- The FRTR Steering Committee will decide the topic for the Fall 2012 FRTR meeting
- Presenters will extract the resources on large and dilute plumes listed in their presentations and send them to Karla Harre (karla.harre@navy.mil), so this information can be posted on the FRTR website
- Karla Harre will try to identify case studies to post with the resources list for the FRTR website
- FRTR member agencies will provide their comments on the *Federal Remediation Technologies Roundtable Annual Summary of Activities* to Greg Gervais by July 7

WELCOME/INTRODUCTION/ADMINISTRATIVE BUSINESS

Karla Harre, Naval Facilities Engineering Service Center, welcomed the attendees to the 44th meeting of the Federal Remediation Technologies Roundtable (FRTR). The topic of this meeting was large and dilute plumes. FRTR has been meeting twice a year since 1991 and has discussed a broad range of remediation topics. Recent topics have included optimization, green and sustainable remediation (GSR), vapor intrusion, monitoring and characterization, and remediation of fractured bedrock. The future direction of FRTR has been considered and reviewed by the FRTR Present and Future Directions Subgroup, which is now the FRTR Steering Committee. The FRTR Draft Operating Principles were presented to the larger group at the last meeting. Karla noted that Greg Gervais would provide more information later during the day's program. However, FRTR remains to be focused on remediation technologies and collaboration.

Karla acknowledged the contributions of the meeting organizers: Greg Gervais (EPA/TIFSD), Ed Gilbert (EPA/TIFSD), Jean Balent (EPA/TIFSD), and Jessica Burns (EMS, Inc.). Karla then provided an overview of the day's meeting agenda, schedule, and logistics. Karla Harre asked remote participants to e-mail her comments or suggestions about their remote participation experiences (karla.harre@navy.mil).

FRTR ANNOUNCEMENTS AND MEETING OBJECTIVES

How ITRC Reduces Regulatory Barriers to Innovative Environmental Technologies

Anna Willett, Director of the Interstate Technology and Regulatory Council (ITRC), provided an overview of ITRC's mission and recent activities (Attachment A). She provided a list of the most recent documents published and training courses offered by ITRC, and then directed participants to www.itrc.org for access to the documents and trainings. Topics of recently published documents include incremental sampling methodology, remediation risk management, contaminated sediments – bioavailability, permeable reactive barriers, solidification/stabilization, biofuels, green and sustainable remediation, integrated dense non-aqueous phase liquid (DNAPL) site strategy, and environmental molecular diagnostics (fact sheets). She said that large and dilute plumes might become one of ITRC's focus areas in the future, depending on whether the topic eventually meets the qualifications required by ITRC to become a focus area.

Anna also provided a list of planned documents and courses to become available in 2013-2014. Topics include biochemical reactors for mining-impacted waters, contaminated sediments remediation, DNAPL characterization, environmental molecular diagnostics, geophysical classification for munitions response, groundwater statistics and monitoring compliance, petroleum vapor intrusion, and risk assessment. She invited meeting participants to participate in the development of these planned documents. Anna said that participation would require staff time of those individuals with the technical expertise particular to the document topic. Those interested should contact Anna at awillett@ecos.org.

Green Remediation Subgroup Report

Carlos Pachon (EPA/TIFSD) outlined recent EPA developments in green remediation. He noted that the FRTR GSR workgroup has not been active recently. In the past few years, however, a lot of activity at EPA has been centered on identifying protocol to quantify environmental footprints. Several tools are now available as a result of this effort. For example, a methodology document for footprint evaluation was released in the spring of 2012. This document has received a lot of positive input. In addition, EPA is conducting internal footprint evaluation. He added that EPA believes the time is right for FRTR to develop a template to quantify environmental footprints. The template could be similar to cost and performance reports. Carlos suggested that participants vote for GSR as the topic for the next FRTR meeting.

Vapor Intrusion

Greg Gervais said that he spoke with Rich Kapuscinski regarding any updates from the vapor intrusion subgroup. Rich did not have any recent activity to report but said that he will likely have a subgroup update available during the fall FRTR meeting. Greg then listed the individuals currently listed on the roster as participants of the vapor intrusion subgroup:

- Samuel Brock, U.S. Air Force, Joint Base (San Antonio, Texas)
- Deborah Burgin, Agency for Toxic Substances and Disease Registry (ATSDR)
- Tonia Burk, ATSDR
- Erik Dettenmaier, Hill Air Force Base
- Mark Fisher, U.S. Army Corps of Engineers (Omaha, Nebraska)
- Malcolm Garg, U.S. Army
- Kyle Gorder, Hill Air Force Base
- Amy Hawkins, Naval Facilities Engineering Command (NAVFAC)
- Donna Caldwell, NAVFAC (Norfolk, Virginia)
- Michael Helbling, NAVFAC (Headquarters)
- Andrea Leeson, Strategic Environmental Research and Development Program (SERDP), Environmental Security Technology Certification Program (ESTCP)
- Tara Myers, NAVFAC

Greg encouraged those participants who are not listed to contact Rich Kapuscinski (kapuscinski.rich@epa.gov).

FRTR Agency Announcements (Projects/Initiatives)

Emily Joseph, Department of the Interior (DOI) Office of Environmental Policy and Compliance (OEPC) reported that the OEPC provides cleanup funds for contaminated sites such as mines. The OEPC is meeting during the latter part of the week of June 18, 2012 to discuss how to allocate budget funding for site cleanup. She said that the DOI participates in a lot of workgroups with EPA, such as the Integrated Cleanup Initiative Workgroup and the 5-Year Review Workgroup.

Tom Nicholson, U.S. Nuclear Regulatory Commission (NRC), mentioned that he participates in another group called the Interagency Steering Committee on Multimedia Environmental Modeling, which may be of interest to FRTR. This group looks at remediation issues, conceptual site model (CSM) development, and understanding how to make regulatory and risk decisions through modeling. He mentioned a recent webinar discussing the Two-dimensional, Runoff, Erosion, and Export (TREX) model, which is used by the U.S. Army Corps of Engineers (USACE) to look at surface and groundwater mode of contaminant transport. The TREX code was recently updated to model radionuclides such as strontium-90 and its use at the Chernobyl site.

Robert Kirgan, U.S. Army Environmental Command (USAEC), said that his work at the Environmental Technology Branch involves examining new and different technologies available for remediation and helping the U.S. Army implement them, for example, for munitions response.

Paul Beam, U.S. Department of Energy (DOE), said that his office is looking for scientific opportunities for monitoring environmental remediation sites (SOMERS). The project is moving along and the SOMERS vision document is now available. It is not currently available for downloading, but those interested can send him an e-mail (paul.beam@em.doe.gov) to receive a copy. His office is currently working on the next document—the SOMERS Program Plan (an integrated systems-based approaches to monitoring). Those interested in participating in the development of this document can also contact him. He also introduced two DOE summer interns, Kristin Bernstein (Northwestern) and Claudia Cardona (FIU).

David Carrillo, U.S. Air Force, said that a lot of major reorganization will occur this upcoming fall. AFCEE is spending a lot of time visiting bases as a result of the reorganization.

Kim Brown, NAVFAC Headquarters, Environmental Restoration Division, said that her division develops policy and guidance for all regional NAVFAC offices. Her group has been working to update its optimization policy and released a finalized updated version in April. A GSR implementation guide that explains how GSR can be incorporated into the remedy was also recently finalized. She said that her division views GSR as part of the policy process and is incorporated in the finalized optimization policy. Her division also recently released a Remediation Alternatives Analysis document, which encourages third party reviews at the feasibility study stage. A management and monitoring approach document is also available. This document provides a systemized method to approaching the site when the goal is site closeout. Those interested in the documents can contact her (kim.brown@navy.mil) or Karla Harre for website information. She added that the Navy is interested in addressing large and dilute plumes, and has an optimization workgroup as well as a technology and restoration team that examines innovative technologies that are available for site cleanup.

Dennis Powers, USACE Baltimore District, provided the USACE update for FRTR on behalf of Carol Dona. USACE has recently published several documents. Those include:

- Risk and environmental liability elimination study.
- Effectiveness of performance-based contracting. That study is continuing.
- Groundwater cleanup and optimization. This study is complete.

- The military response program site investigation strategy. This study is complete.
- Green and sustainable remediation. For example, Army-wide GSR policy and guidance. The study is scheduled to be complete in September 2012. Those interested in learning more should contact Carol Dona (carol.l.dona@nwo02.usace.army.mil).

Greg Gervais, Chief of the EPA Technology Innovation and Field Services Division (TIFSD) Technology Assessment Branch, announced the release of new information products and resources:

- The draft *Federal Remediation Technologies Roundtable Annual Summary of Activities* is available. He asked that FRTR participants review the document and provide their comments to John Quander by July 9.
- Twelve new sites have been added to the National Priorities List since the November 2011 FRTR meeting. More information on these sites can be found at http://epa.gov/superfund/. Sites added to the list include a former gas works facility in Region 10, an adhesive manufacturing facility, a former metal fabrication facility, a wood preserver, as well as dry cleaning facilities.
- EPA's Office of Research and Development, in collaboration with the EPA Groundwater Forum, recently released *An Approach for Evaluating the Progress of Natural Attenuation in Groundwater* (EPA 600/R-11/204). This document is available at http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100DPOE.pdf. The purpose of this document is to present a simple statistically based approach for evaluating the progress of natural attenuation from the data collected during site characterization and long-term monitoring. The intended audience of this document is technical professionals that perform the data analysis, as well as project managers who review those analyses and/or make their decisions based on those analyses.
- In February 2012, the EPA Superfund program released a set of frequently asked questions about addressing vapor intrusion (http://www.epa.gov/superfund/sites/npl/Vapor_Intrusion_FAQs_Feb2012.pdf). The purpose of this document is to provide information and recommendations based on experiences in addressing vapor intrusion at Superfund remedial and removal sites and cleanup undertaken using other authorities.
- Greg announced that those who subscribe to the TIFSD electronic distribution lists should be aware that *Technology News and Trends* is going paperless and will only be available electronically in the future. The virtual newsletter will evolve over time. Issues can still be printed from the Clu-In website, however. Those not currently on the electronic distribution list can sign up at http://cluin.org/newsletters/.

Greg Gervais also provided an update on recent FRTR Steering Committee activities (Attachment B). The FRTR Steering Committee will provide updates during each FRTR meeting. He listed the current participating agencies. Greg stated that FRTR's goal is to be inclusive rather than exclusive and asked that the agencies who are not currently on the list but are interested in should contact him (gervais.gregory@epa.gov). The current participating agency list is as follows:

- U.S. Army Environmental Center
- U.S. Navy

- Strategic Environmental Research and Development Program (SERDP) - Environmental Security Technology Certification Program (ESTCP)
- U.S. Army Corps of Engineers
- U.S. Air Force
- U.S. Department of Energy
- U.S. Department of the Interior (Headquarters)
- U.S. Geological Survey
- U.S. Environmental Protection Agency
- U.S. National Aeronautics and Space Administration (NASA)
- U.S. Nuclear Regulatory Commission

Greg provided background on how the FRTR Steering Committee was developed. He reminded the larger FRTR group that a mutual consensus was reached in 2011 regarding forming a working group (FRTR Present and Future Directions Subgroup) that will look into the FRTR's future and explore the different ways that FRTR can have a broader, stronger impact in the remediation community. The purpose of the FRTR Steering Committee, which formed after the November FRTR meeting, is to provide focus and direction for semi-annual meetings, develop content, structure, and design for the FRTR website (www.frtr.gov), and work together to identify technical challenges of the highest priority to FRTR. The FRTR Steering Committee is also involved in the development of processes for both commissioning and decommissioning FRTR subgroups. Greg encouraged participation in the FRTR Steering Committee for calendar year 2013, and urged agencies to appoint a representative for the FRTR Steering Committee.

Recent FRTR Steering Committee activities include two conference calls to support Karla Harre in her effort to organize the spring 2012 FRTR meeting and address operational logistics, such as selecting a committee chair. Greg has been appointed as the 2012 FRTR Steering Committee chair, while Bill Lodder (DOI) has volunteered to be committee chair in calendar year 2013. He will coordinate with Greg through the rest of 2012 to prepare for his upcoming role.

The FRTR Steering Committee has worked to develop a set of procedures to operationalize the FRTR Operating Principles presented at the November 2011 FRTR meeting. The document is still under development, however, and in the future will describe procedures such as FRTR subcommittee commissioning and decommissioning, the decision-making process within FRTR, and selection of meeting topics. He added that the decision has been made to allow the FRTR Steering Committee to select FRTR meeting topics unless a better procedure can be identified.

Kim Brown asked about NASA's participation in the FRTR Steering Committee. Greg replied that he has not received any input from NASA regarding participation on the FRTR Steering Committee. He added that the FRTR Steering Committee strives to be inclusive rather than exclusive, and will work to engage agency members and keep them up to date on FRTR activities even when they are not actively participating in FRTR.

LARGE DILUTE PLUMES PRESENTATIONS

Large and Dilute Plumes of Chlorinated Solvents - Challenges and Opportunities

Brian Looney, Savannah River National Laboratory (SRNL), stated that a desire exists to actively remediate contaminated sites (Attachment C). However, as in the case of large and dilute plumes, treating large volumes of water with large areal footprints is associated with high costs and technical difficulties. Sometimes plumes are too deep for cost-effective interdiction or containment. Contaminants typically will be relatively inaccessible in some areas of the plume (immobile zones), resulting in persistent concentrations after the primary source mass is removed.

The general set of conditions that facilitate the development of large and dilute plumes is a permeable aquifer, usually with low organic carbon content and low biomass, aerobic systems where influx of electron acceptors makes it difficult to establish and maintain reducing conditions, slow attenuation processes, a deep area, and an area affected by mass transfer. Several large and dilute plumes exist on Department of Energy property, such as the Hanford Site 200 Area, the Savannah River Site M-Area, the Paducah Gaseous Diffusion Plant Northwest Plume, and the Idaho National Laboratory Test Area North. The large and dilute plumes in these areas have several common properties: presence of DNAPL in the source zone, a depth that ranges from 75-300 feet below ground surface (bgs), and a lateral extent of several square miles.

Brian suggested that it is useful to think of a plume as an area that has some subzonation. Different technologies can often be applied to a plume. He added that cost-efficient cleanups require a dynamic process that matches technologies to the area they should be applied. For example, source treatment technologies should be focused on source zones. If mass transfer is maintaining concentrations above final remedial action objectives, he suggested focusing on the interfaces and considering deployment strategies, density, viscosity, and other properties for an in situ design that would limit flux. A detailed site characterization is essential to addressing large and dilute plumes.

Brian discussed the idea of biodegradation/attenuation of large and dilute (aerobic) plumes. He said that the rate of attenuation in the plume impacts the ultimate plume size. The Savannah River National Research Laboratory has produced a document on enhanced attenuation, which provides a reference guide for approaches to increasing natural attenuation capacity of a system (http://www.clu-in.org/download/contaminantfocus/tce/DOE_EA_doc.pdf). The key concept to keep in mind for large and dilute plume management is that the size and scale of the steady-state plume will be larger than anaerobic sites. Best-case aerobic plumes with weak sources and half lives of about 10 years will stabilize within 1000 meters, while worst-case aerobic plumes with strong sources and a half life of about 30 years will stabilize within about 5,000 to 10,000 meters (about 3-6 miles).

Brian also briefly discussed the idea of abiotic degradation. He said that at several sites, significant attenuation has been documented for magnetite; at sites where magnetite is present, attenuation rates have been correlated to inexpensive magnetic susceptibility measurements (half lives of 4-6 years). Research also exists on aerobic cometabolism; half-lives of six to over 40 years have been measured. Aerobic cometabolism does not produce toxic daughter products and allows for maintenance of high aesthetic water quality. Natural attenuation processes through cometabolism appear sustainable and are consistent with the expected microbial ecology of oligotrophic systems. The Savannah River National Laboratory/Idaho National Laboratory/Pacific Northwest National Laboratory team is currently working on amendment technology to sustainably enhance aerobic cometabolic rates in settings where large and dilute plumes are present.

Brian suggested that when dealing with large and dilute plumes, it is helpful to first divide space and time into "reaction zones" and then solve the coupled parent-daughter reactions for chlorinated solvent degradation in each zone. Each of these space-time zones can have different decay rates for each chemical species. He provided an example from treatment at the Savannah River Site M-Area. The site is being treated by thermal (steam) technology, air sparging, cometabolic bioremediation, electrical resistance heating, radio frequency heating, and others. A mass balance equation was completed for each remediation technology in the late 1980s and early 1990s. Pump and treat has now been operating at the site for 12 years, while soil vapor extraction has been used for the past 15. Recent calculations show that 490,000 lbs of trichloroethene (TCE) have been removed by pump and treat (33% removal based on total from active treatments and 14% of total estimated release of 3.5 million lbs), 448,000 lbs of TCE have been removed by soil vapor extraction (30% from total treatment and 13% of removal based on total estimated release of 3.5 million lbs), and 508,163 lbs of TCE have been removed by steam/thermal treatment (34% removal based on total from active treatments and 15% of total estimated release of 3.5 million lbs).

Brian stated that any treatment should provide sustainable performance and be deployable over a large area. He added that successful remediation occurs when the technology used and deployment strategies are matched to site-specific conditions, when there is focus on actionable data for a reasonable cost, when technically-based realistic and achievable goals are set, when source treatment to desired impacts in the downgradient plume are linked together, and when technologies are combined as needed.

Question: What can you say about site characterization of a plume and how a targeted remediation approach can be applied given the heterogeneity of a plume?

Answer: The remediation approach should be site-specific. Plumes are sometimes composed of different types of contaminants (petroleum hydrocarbons and chlorinated solvents, for example). A geochemical gradient will often form along the contaminant gradient, and is crucial to include in site modeling and model interpretation.

Question: Can you say something about water table aquifers as opposed to confined aquifers, especially with respect to recharge that brings in oxygen to the system?

Answer: The influx of electron acceptors (oxygen, sulfate, and nitrate, for example) is very important for anaerobic degradation. These are not as important for aerobic degradation. Water table aquifers have more dissolved oxygen than confined aquifers.

Detailed Structure in Large, Dilute Plumes – Developing Actionable Intel from the Sub-Surface

Fred Payne, ARCADIS, described the shift in thought on site characterization (Attachment D). As site characterization models with higher resolution began to be developed, site hydrology received more attention. It became apparent that reanalyzing basic site geology with new conceptual framework can help make significant gains in site remediation, even if the remedy is already underway.

The previous school of thought assumed that sites were homogenous, but the shift in thinking on the characteristics of sites has facilitated the current assumption that sites are heterogeneous rather than homogeneous. The new working model focuses on contaminant storage and transport. The new model showes that contaminant mass transport is often concentrated in a small portion of the aquifer; remedies can be developed to take advantage of this distribution pattern.

There are several factors that facilitate the formation of large and dilute plumes. Those include high flow aquifers, contact of source mass with flow zones, long source exposure times, high-aqueous solubility of contaminants and others. Historically, the typical contaminant distribution pattern that was observed with large and dilute plumes was a high concentration of contaminants in the source zone and a declining contaminant concentration with increasing distance from the source zone. The observation of this pattern led to the assumption that the contaminants were dispersing over larger areas with increasing distance from the source zone. However, today it is evident that aqueous-phase concentrations along a plume path can decline as diffusion drives contaminants into the lower permeability zones of the aquifer, without significant lateral spreading of the plume.

The lower permeability aquifer zones tend to be less aerobic and more conducive to sorption; mass exchange occurs between high-flow zones and the low-permeability zones where contaminant storage occurs. Field research repeatedly confirms that transverse dispersivity (dispersion perpendicular to the aquifer groundwater flow direction) is near zero in contaminated aquifers; natural aquifers show near-zero transverse dispersivity.

The Muskegon Site is an example of contaminants migrating to lower-permeability zones of the aquifer. Historically, TCE DNAPL was deposited into a sand bottom lagoon at the site. In 1975, the disposal activities ceased and the lagoon was excavated. The source mass was not found at the lagoon bottom, however. Rather, sparingly small amounts of contamination were found. The conceptual site model showed that the aquifer in this area had high hydraulic conductivity, while monitoring wells indicated 100 µg/L TCE in the groundwater moving offsite. Site investigation conducted with high-resolution characterization tools indicated that the highest TCE concentrations were found in lower permeability sediments at the site. The next steps for the site will be to extend transect coverage to one mile off-site and to modify site monitoring.

At another cleanup site in Michigan, the contaminated area was located on top of a glacial esker. The zone had high hydraulic conductivity sediments. A mass flux transect was completed immediately downgradient of the primary source area. The mass transport was found to occur in the deeper zones of the aquifer; while mass in shallow areas was several hundred times less mobile than mass in the deep zones of the aquifer.

At the Reese Air Force Base in Texas, the large and dilute plume occurred in a low mass transfer aquifer (contaminant transport occurs in high-flow zones, with limited diffusive mass exchange into the lower-permeability zones).. The contaminant concentrations in the primary transport channel responded to directed groundwater recirculation. Aggressive in situ bioremediation was conducted in the secondary mass transport channels. As of June 2012, contaminant concentrations in all monitoring wells are found below maximum contaminant levels. The next steps for the site will be to shut down the system and begin post-treatment monitoring.

Question: How do you explain to your clients that you would be more efficient using your approach rather than a traditional approach?
Answer: Our first explanation would be that we can characterize the site at lower costs using this approach than through monitoring wells. In addition, it doesn't leave a monitoring well legacy. The second explanation would be that because we are so often able to find mass flow transport zones, we can implement much more targeted remedies. We find that the cleanup process works better once the contaminant transport zones are found.

Question: In terms of using groundwater recirculation at the Reese Air Force Base, are there any regulatory concerns with injecting clean water?
Answer: Clean water injection is a regulatory issue that falls under underground injection regulations. We have had good success with regulatory acceptance.

Question: Can you elaborate on the high-resolution tools you used?
Answer: There is a range of tools available. We have used a vertical aquifer profiler. We have also been using direct-sampling ion trap mass spectrometry that allows us to process 100 samples per day of either soil or water. The instrument can analyze high and low-concentration samples without dilution or downtime between samples, so the project team can submit samples without segregating high-concentration runs.

Aerobic Cometabolic Bioremediation to Address a Large, Dilute, Solvent Plume
Jim Cummings, EPA/TIFSD, presented EPA's evaluation of the potential use of aerobic cometabolic remediation to address a 7000-foot long dilute, shallow aerobic TCE plume at the Hopewell Precision Superfund Site in New York (Attachment E). No sources for the contamination have been found at the site. TCE contaminant levels generally are less than 100 ppb. However, possible plume core areas with higher concentrations exist. In areas where the plume exceeds maximum contaminant levels (MCLs), vapor intrusion impacts are possible. Therefore, there are mitigation measures in place, as necessary, for residences.

Due to slow remediation rates, aerobic cometabolic remediation has limited applications since enhanced reductive dechlorination has been used in the field. Remedial design generally consists of using substrates with the lowest possible cost with the lowest possible cost of delivery mechanisms. Potential substrates that can be used with aerobic cometabolic remediation and were considered for the Hopewell Site include propane, butane, and methane; liquid delivery substrates are currently under development by SRNL. Delivery mechanisms explored were the

Waterloo Emitter, Tersus iSOC, and the Tersus Ex-Situ Infusion system. A recirculating well configuration is currently being explored.

Additional characterization is planned using vertical profiling tools. Aerobic cometabolic remediation cost, performance and duration are still to be determined for the Hopewell site, but there is hope that the pilot will have a major impact on plume longevity and that it can actually end up being the bulk of the remedy. Abiotic natural attenuation using magnetite is a possibility. EPA is still in the design stages for the pilot-scale aerobic cometabolic remediation effort.

Question: I have a benzene plume at a former iron mine full of magnetite. Whom to talk to regarding potential remediation options?

Answer: Dr. John Wilson (EPA) can be contacted for assistance in conducting an assessment of the use of magnetite.

Question: What is the organic loading in the sediments and current dissolved oxygen levels at the site?

Answer: The fraction of organic carbon is quite low. Dissolved oxygen is 3-8 mg/L.

LUNCH-FACILITATED DISCUSSION

A facilitated discussion on the fall 2012 FRTR meeting topic was held during lunchtime. Greg Gervais provided a list of past meeting topics that could potentially be used as the fall 2012 meeting topics for the group to discuss. Kurt Gerdes said that the U.S. Department of Energy is at the cusp of releasing its SOMERS strategy and would be interested in attending a fall meeting where exit strategies and decision tools at federal facilities is the meeting topic.

Greg provided a list of past meeting topics in recent years and potential topics for the fall 2012 FRTR meeting as follows:

- Environmental footprints. For example, GSR, quantifying and addressing environmental footprints; developing common practices.
- Decision support tools (such as visualization tools)
- Sediments
- Ecological revitalization and reuse
- Tools being developed to support remediation end state decisions
- Heavy metals – site issues and solutions

He asked that participants inform the FRTR Steering Committee about which of the topics on the list would provide for a good subject for the next FRTR meeting. He asked the group to also let the FRTR Steering Committee know whether any of the agencies have interest or availability to be considered as the lead for that topic. The group discussed the idea of making environmental footprints the fall 2012 meeting topic. Paul Beam (DOE) and Skip Chamberlain (DOE) said they may be able to help with facilitation of the meeting if the site end state decision topic was chosen.

LARGE DILUTE PLUMES PRESENTATIONS (CONT.)

Dilute Groundwater Plume Management: Navy's Approach to Large and Dilute Plumes

Josh Fortenberry, NAVFAC Engineering Service Center, presented the Navy's approach to managing large and dilute plumes (Attachment F). He stated that there is pressure to actively remediate large and dilute plumes, but there are high costs and technical difficulties involved in treating large volumes of water dispersed over large areas. He added that plumes are sometimes too deep for cost-effective containment.

The Navy's approach to large and dilute plume management is based on its 2007-2008 Groundwater Risk Management Handbook. The first step to addressing large and dilute plumes is a thorough site evaluation, based on a good conceptual site model that should be presented in both table and graphic form. The approach to addressing these plumes should focus on groundwater usability, such as water yield, quality (total dissolved solids), and future use. Exposure pathways could then be examined.

Conceptual site models identify exposure pathways. However, creating a conceptual site model for a large and dilute plume is challenging, because sources are hard to define or already gone. Treating the plume is a challenge as well. Because the plume is large and concentrations are low, the plume is more expensive to treat. For groundwater, exposure pathways typically are ingestion, inhalation via vapor intrusion (a vapor intrusion evaluation tool is available through NAVFAC), and exposure via contact with surface water. Risk management is the key to the U.S. Navy's approach to treating large and dilute plumes. The Navy's goal is to manage risk rather the chemical. A checkerboard of regulatory regimes must be considered, including federal programs such as CERCLA and RCRA, as well as a wide range of state programs. In addition, green and sustainable remediation needs to be incorporated into the strategy.

Remediation concepts for large and dilute plumes need to focus on performance objectives and exit criteria. Performance objectives are crucial and need to be developed and clearly defined. Exit strategies can define when to stop, modify, or change the technology. Performance objectives using the mass flux approach are challenging to introduce to the remediation community, though the approach is a potential for evaluating remediation and site closure. Whether passive or active treatment is used depends on the location of the contamination, plume characteristics, and the site schedule. Factors to consider include the fact that source areas are sometimes difficult to delineate, remedial success is dependent on geology, and that most in situ technologies have typically only a single order of magnitude reduction in concentration. The downside to source treatment is mobilization of contaminants and secondary effects such as generation of methane.

The Navy has several guidance documents available to assist with large and dilute plume management. The Navy's Vapor Intrusion Assessment Tool is designed to provide consistent and technically defensible closure-oriented vapor intrusion strategies. The SiteWise™ Tool for Green and Sustainable Remediation accounts for a number of metrics other tools might overlook, such as worker safety and community impacts.

Question: Why do you think people are reluctant to go with the mass flux approach? What is the boundary you're trying to estimate that flux across?

Answer: We were trying to see what the amount of mass was coming off the site at the location where we applied this approach. Hopefully, down the road, the use of high-resolution approaches will allow us to bypass concentration-based limits.

Management Strategies Implemented at Navy Large Dilute Plumes

Ken Bowers, NAVFAC Atlantic, presented management strategies implemented by the Navy at large and dilute plumes using two case studies as examples (Attachment G).

The Test Engine Cell – SWMU 9 site is contaminated with petroleum and organic solvent from historical uses. The source has been removed but a groundwater plume exists. Groundwater is non-potable per Florida regulations because of the site's proximity to the ocean. A human health risk assessment was completed, but no unacceptable risk was found because the water was non-potable. Ecological risk assessment revealed that risk to aquatic receptors exists if the groundwater migrates to the surface water. Therefore, it was recommended that site groundwater be treated to reduce concentrations of organic compounds, which would reduce the possibility of future site-related risks to aquatic receptors.

An interim removal action followed by enhanced bioremediation was selected as the remedy. Bioremediation was enhanced with Oxygen Release Compound (ORC®) and Hydrogen Release Compound (HRC®) in 2001. At the time of the 5-year review, levels of benzene, *cis* and *trans*-1,2-dichloroethene (1,2-DCE) and vinyl chloride (VC) were found to be greater than Florida Groundwater Cleanup Target Levels. Two additional monitoring wells to further bound the plume were installed. However, because the concern was about risk to aquatic receptors, Marine Surface Water Criteria was decided to be the proper criteria for remedy evaluation rather than Florida Groundwater Cleanup Target Levels. Using Marine Surface Water Criteria, which permitted higher contaminant concentrations, the selected remedy was found to be successful and reduced contaminant concentrations to the no further action level.

The second case study involved two Navy sites in Florida and Maine. Both of these sites were similar in that they both had large and dilute plumes on the property, active remediation was used historically to remove the plume, the source had been removed, no unacceptable risk was found in the groundwater, and both were above applicable or relevant and appropriate requirements.

The plume at the Florida Navy site was stationary and land use controls prevented exposure to groundwater. Therefore, no unacceptable risk was found to nearby residents. Stakeholder concern about the site was minimal, so monitored natural attenuation was chosen as the remedy to address the plume. The remedy was effective and TCE concentrations significantly decreased over the course of seven years.

The plume at the Maine Navy site had surface water discharge, however. Though land use controls prevented exposure to groundwater and no unacceptable risk was found, stakeholder concern was high. Pump and treat was chosen to address the plume at this site. Significant amounts of volatile organic compounds (VOCs) were removed using this treatment from 1996 to 2009. VOC removal is now approaching zero and the cost to treat per mass removed is increasing due to decreasing concentrations. However, because of high stakeholder concerns in this area, the pump and treat is still in operation.

Overall, high costs and technical difficulties are involved in treating large and dilute plumes. A consistent approach needs to be developed to treat them. However, some states consider all groundwater drinking water, so the remedy must show progress toward achieving MCLs. Despite this, site managers should refrain from using active remediation when there is no unacceptable risk. In evaluating remediation options, a long-term perspective is necessary because attenuation often has peaks and valleys and there is no linear relationship.

Comment: The value of the water in the formation determines the cost of the cleanup. You may spend a fair amount of money on remediation per gram of contaminant, but the expenditure for treatment makes sense if you look at the ecosystem service value of the water.

Question: Was anyone telling you to look at the interaction of the contaminants with local biota?
Answer: At the Florida site, we did look at biota to develop risk values.

Approaches to Integrating Source and Plume Treatment Strategies for Long-Term Dilute Plumes

Kent Sorenson, CDM, presented several approaches to integrating source and plume treatment strategies for long-term dilute plumes using case studies to depict strategies for technology integration (Attachment H).

The Test Area North Site in Idaho contains a 1.5-mile long TCE plume in groundwater about 200 feet below ground surface. The contaminated area is 200 feet thick. An industrial wastewater injection well has been installed at source. The 1995 Record of Decision selected pump and treat as the remedy for the site, with a 100-year cleanup timeframe. However, the Record of Decision also established a timeline for post-decision studies that would consider technologies to potentially replace the pump and treat.

Several potential degradation mechanisms can be considered for large and dilute plumes, including anaerobic reductive dechlorination, aerobic cometabolism, aerobic bioremediation, and biogeochemical reduction by iron minerals. The anaerobic reductive dechlorination pathway, however, is not always applicable to large and dilute plumes, because TCE and DCE persist spatially over large areas rather than continuing to degrade to VC and ethene. Aerobic cometabolism is another option. The half-life of TCE undergoing degradation via aerobic cometabolism is about 12-15 years, while the half-life of DCE undergoing degradation via aerobic cometabolism is about 8-9 years. Aerobic biodegradation is also a possibility, based on evidence from nine plumes at four other Department of Energy sites, where aerobic TCE degradation was evident at eight of the nine plumes. Biogeochemical reduction by iron minerals is also possible; this method was used at the Twin Cities Army Ammunition Plant and TCE and DCE half-lives were found to be less than 2.5 years.

Integrating source and plume treatment strategies requires the identification of intrinsic degradation mechanisms, an estimate of the intrinsic degradation rate (separate from dispersion), and a reasonable assurance of the longevity of the degradation mechanism. Active treatment at the fringe at sites where the source area is removed or contained is needed when fringe concentration exceeds the capacity of monitored natural attenuation. An example is the Bountiful/Woods Cross Superfund Site, where both source treatment and fringe area treatment were employed. Anaerobic reductive dechlorination was used at the source, stopping the source flux, while biobarriers were installed downgradient to treat the fringe areas. Intrinsic treatment at fringe areas, on the other hand, can be effective when fringe contaminant concentrations are below the capacity of monitored natural attenuation. The OU 1-07B at the Test Area North Site and the Well 12A Superfund Site are examples of areas where intrinsic fringe area treatment was determined acceptable for cleanup. Monitored natural attenuation evaluation and performance monitoring is still underway at the Well 12A Superfund Site, where a detailed 3-D source characterization was performed prior to remedy design.

Question: Can you comment again on models and their ability to estimate risk reduction?
Answer: In the case studies introduced here, the link to risk is the maximum contaminant level. At a large-scale site, the risk is the aquifer drinking water.

Large Dilute Plumes: Use of Molecular Tools for Reaching Acceptable End States
Hope Lee, Pacific Northwest National Laboratory, provided several case studies to serve as examples of the use of molecular tools to reach acceptable end states (Attachment I). The Department of Energy is currently remediating 1,800 million cubic meters of contaminated groundwater and 75 million cubic meters of contaminated soil. Primary contaminants of high risk/and or contaminants expected to persist for a number of years include strontium, chromium, uranium, technetium, iodine, cadmium, mercury, lead, cobalt, cesium, organics such as carbon tetrachloride, TCE, tetrachloroethene (PCE), DCE, VC, *cis*-1,2-DCE, diesel fuel, and others. Chlorinated solvents, however, are the most common and widespread contaminants at Department of Energy Environmental Management sites throughout the country. Examples include the Savannah River Site in South Carolina, the Paducah Gaseous Diffusion Plant in Kentucky, the Idaho National Laboratory, and the Hanford Reservation in Washington.

The Department of Energy's goal is to reduce the Environmental Management site legacy footprint by 90 percent by 2015. Some of the ways to achieve these goals are to examine the work that has been completed at other sites, practice interagency collaboration, engage regulators and stakeholders, transfer expertise and technology, make risk-informed decisions, and practice robust long-term management of residual contamination. Scientifically defensible strategies are important.

Historic direct injection of industrial wastewater into the aquifer at the Test Area North Site in southeast Idaho has led to the development of a 2-mile long TCE plume at the site. The fractured basalt aquifer is contaminated at depths of 200-400 feet. In 1995, the Record of Decision selected pump and treat as the default remedy for the site with a 100-year remediation timeframe. The Record of Decision, however, also left options for evaluation of alternative technologies. Alternative technology evaluations were performed in 1997 and in 2001, a Record of Decision Amendment was issued, identifying alternative remedies for two of the three plume zones. Pump and treat was chosen to remain in the medial zone with TCE concentrations of over 1000 µg/L, while in situ bioremediation using lactate and whey powder as substrates was chosen for the source area where TCE concentrations exceeded 10,000 µg/L. Monitored natural attenuation was chosen for the distal zone of the plume where TCE concentrations were found below 1000 µg/L.

Pump and treat was found to be highly effective for the first three to four years but was recovering less contaminants through time and has now been shut down. Natural attenuation modeling showed that TCE concentrations decrease with distance from the source area. In addition, laboratory studies showed that organisms capable of aerobic cometabolic oxidation of TCE are native to Test Area North. Overall, the plume was found to be stable (although changing) between 1997 and 2009. In 2010, concentrations in monitoring wells at the leading edge of plume showed decreasing trends. As of 2011, the plume is shrinking at the leading edge, as shown by monitoring well data. The monitoring program is being modified on a year-to-year basis based on defensible concentration and risk data. A holistic systems-based approach was used at this site, using a scientifically defensible strategy that was reevaluated when new technologies or approaches became available. Strategies were optimized throughout the plume to enhance cost efficiency and performance.

A Record of Decision for an interim action was signed at the Paducah Gaseous Diffusion Plant in 2005. Electrical Resistance Heating (ERH) was selected to address the source area comprised of VOCs. ERH was applied from March through December 2010. The upper aquifer was heated to target temperatures, leading to a reduction in groundwater VOC concentrations from an average of 38,000 to 315 µg/L in the southwestern portion of the site and an average of 123,000 to 29,000 µg/L in the eastern portion of the site. Concentrations of TCE in the soil were reduced by 95 to 99 percent. Monitored natural attenuation evaluation was completed at this site as well. First order degradation rate calculations indicated that TCE is being attenuated along flow paths of the northwest plume faster than a co-contaminant (technetium-99). Molecular analyses using Enzyme Activity Probes also indicated the presence of microorganisms capable of cometabolic degradation of TCE in the aquifer, while other data indicated that aerobic cometabolic remediation of TCE was occurring at parts of the site. Site geochemistry evaluations indicated that sufficient quantities of organic carbon were present to support the identified microbial populations.

Question: Please comment on your approaches during your work at Test Area North and Paducah.

Answer: Maximum contaminant levels are never taken off the table. The approach that has been successful at both Test Area North and Paducah involves the set up of a monitoring program that allows for the team to decrease the number of wells that are being monitoring over time. We have been very successful at communicating with the regulators at both sites (EPA has been involved in every step).

Comment: Kent Sorenson stated that starting with a reasonable objective to clean up a complex site (e.g., 100 years rather than 10 years) gives the flexibility to hold discussions about the approach and allows the cleanup to be conducted within a rational framework, thereby facilitating the end state to be reached faster.

Managing a Large Dilute Plume Impacted by Matrix Diffusion: MEW Case Study
John Gallinatti, Geosyntec, discussed the performance of a groundwater remedy involving 25 years of pump and treat (Attachment J). He also discussed the issues associated with site management and the current feasibility study being conducted by the EPA.

The site—the Middlefield-Ellis-Whisman (MEW) Area—is located in Mountain View, California. The site is contaminated with TCE at 10 to 75 feet bgs. The TCE plume is 1.5 miles long. Site investigation and pump at treat at the site began in 1981. A Record of Decision was signed in 1989, selecting soil vapor extraction, excavation, slurry walls, and pump and treat, as the remedies. Twelve pump and treat systems and 100 extraction wells were installed. Between 2002 and 2006, 16,000 lbs of TCE were extracted by the combined pump and treat systems. However, the amount of TCE in the plume had decreased by only about 2,800 lbs., which indicated that about 80 percent of the TCE being extracted through the pump and treat system was originating from storage. In addition, by 2009, vast contaminant reductions were observed in areas with high initial TCE concentrations (1,000-10,000 µg/L) but little or no observable reduction was found in areas where initial TCE concentrations were low (5 µg/L).

Based on site geology and observed trends outside the contained source areas, matrix diffusion was determined to be the source of TCE storage and cause for the observed trends in the extraction wells. When matrix diffusion occurs, residual constituents that were loaded into low permeability zones before the source was controlled diffuse back into transmissive zones where they can be captured by extraction wells.

A focused feasibility study was then conducted by EPA in 2011, with expected completion in 2012. Five different alternatives were considered during this feasibility study: (1) continue existing pump and treat; (2) use optimized pump and treat; (3) use optimized pump and treat with monitored natural attenuation; (4) use optimized pump and treat with monitored natural attenuation and source treatment; and (5) use optimized pump and treat with monitored natural attenuation and permeable reactive barriers. Under all alternatives evaluated, models showed that it may take centuries to reach a cleanup goal of 5 ppb TCE. Setting a goal of 200 ppb, however, would allow for the target to be reached within decades and allow for use of monitored natural attenuation as a remedy. The feasibility study showed that matrix diffusion impacts need to be considered in remedy selection. Matrix diffusion can have impacts on the conceptual site model, alternative remedy effectiveness, cleanup times, cost, as well as other factors in site remediation. The feasibility study phase should account for the challenges of large-scale plumes and matrix diffusion. Accounting for matrix diffusion would allow for the development and comparison of realistic alternatives with realistic timeframes and costs.

Question: Why did Alternative 4 include source treatment but the others did not?
Answer: The current remedy already treats the source. In Alternative 4, it would have just been replaced with an in situ remedy.

Question: Instead of an end state, you have interim states. Have you thought of reduction or relocation?

Answer: We know we are removing contamination, because we are measuring it. Whether attempting to optimize the remedy by pumping in different locations would actually make any difference or yield the same result, remains to be a question.

Question: Is vapor intrusion an issue at the site and if so, how it would affect the 200 ppb level?

Answer: Yes, vapor intrusion is an issue at this site. There is currently a Record of Decision in place to address the vapor intrusion issue. We are focusing on addressing the highest concentrations in the shallow zone, which should minimize the need for vapor intrusion remedies.

Discussion of Future Collaborations among FRTR Member Agencies on Large Dilute Plumes

Karla Harre facilitated the group discussion on future collaboration among FRTR member agencies on large and dilute plumes. She displayed to the participants a list she complied, which contained resources on large and dilute plumes (Attachment K). Resources for large and dilute plumes were grouped by topic (agencies with currently available resources in parentheses):

- Risk management approaches (EPA, ITRC, ESTCP, NAVFAC, and USAEC),
- Green/sustainable remediation (EPA, ITRC, NAVFAC/USACE, AFCEE), MNA (ESTCP, AFCEE, ITRC, EPA)
- Passive technologies (ESTCP, ITRC)
- Optimization, treatment trains, and hot spot treatment (FRTR case studies, AFCEE, EPA, ESTCP, ITRC)
- Modeling and monitoring tools (BIOCHLOR Natural Attenuation Software, ESTCP, NAVFAC, Navy guidance, AFCEE, GTS, MAROS, and Sampling Optimizer)

Karla suggested that to add to this resource list, the presenters could refer back to their presentations and pull out the resources they listed there. These additional resources could then be placed on one sheet with links to their location on the internet. She asked all the presenters to pull out the resources in their presentations and send them to her, so that these could be made available on the FRTR website. Tom Nicholson asked if resources on radionuclides could be added to the list as well. Bill Hagel suggested putting a date on the resources Karla currently has listed to ensure they are current.

Karla asked the group for a recommendation on where the Department of Defense should invest in developing resources. For example, Fred Payne mentioned better vertical profiling tools. Fred agreed that these tools would be a worthwhile investment for the Department of Defense.

Linda Fielder (EPA/TIFSD) suggested that case studies are most useful to individuals. She said that providing a targeted list of references that points out which aspect of large and dilute plumes the reference is for, rather than a simple list of references, would be more useful. Karla asked Linda if she knows of any case studies that have already been written up. Linda said that EPA likely maintains a list of case studies, but will need to check. David Carrillo suggested looking at the FRTR Technology Screening Matrix for case studies and additional resources. Kim Brown agreed with Linda Fiedler's suggestion about adding case studies. She added that characterizing the issues and associating case studies with them would be most useful to people.

Tom Nicholson said that he would be interested in seeing the relationship between conceptual site models and determination of performance indicators. He mentioned that it would be useful for Fred Payne to put together a summary of what he discussed during his presentation. Kent Sorenson added that a traditional paradigm with the remedial investigation/feasibility study process is that after constructing the remedy, it is only re-evaluated at the 5-year review stage. However, it is being advocated at this meeting that when performance-monitoring data is collected each year, it should be compared to an expected outcome. Constant adjustments to both to the conceptual site model and the remedy should be made.

MEETING WRAP-UP/NEXT MEETING

Karla Harre announced that the FRTR Steering Committee would discuss the selection of the fall 2012 meeting topic in their June 21, 2012 meeting and disseminate that information to the FRTR audience. Karla thanked the meeting presenters, organizers, and attendees, and the meeting was adjourned.

ATTACHMENTS

A. Advancing Environmental Solutions: How ITRC Reduces Regulatory Barriers to Innovative Environmental Technologies
B. Update from the FRTR Interim Steering Committee
C. Large and Dilute Plumes of Chlorinated Solvents – Challenges and Opportunities
D. Detailed Structure in Large, Dilute Plumes – Developing Actionable Intel from the Sub-Surface
E. Aerobic Cometabolic Bioremediation to Address a Large, Dilute, Solvent Plume
F. Dilute Groundwater Plume Management: Navy's Approach to Large and Dilute Plumes
G. Management Strategies Implemented at Navy Large Dilute Plumes
H. Approaches to Integrating Source and Plume Treatment Strategies for Long-Term Dilute Plumes
I. Large Dilute Plumes: Use of Molecular Tools for Reaching Acceptable End States
J. Managing a Large Dilute Plume Impacted by Matrix Diffusion: MEW Case Study
K. Discussion of Future Collaborations Among FRTR Member Agencies on Large Dilute Plumes