

**Use of Test Beds to Facilitate Implementation of Innovative Technologies
at Complex Sites – 17147**

Carol Eddy-Dilek and Kevin Kostelnik
Savannah River National Laboratory

ABSTRACT

The Department of Energy, Office of Environmental Management (DOE-EM) has invested significant resources targeted at reducing risk to the environment and to the public. Considerable progress has been achieved, yet major remediation challenges remain. DOE-EM recognizes that new, innovative technologies offer the potential to improve operational performance, accelerate schedules, and reduce cost for environmental cleanup. One challenge that often limits the adoption of new technologies is the lack of information about their performance under real-world conditions. This is particularly true of the complex radiological and chemical environments present at many DOE-EM sites.

Testbeds provide a useful approach to test new technologies and technical approaches. With the ability to be field-scale, meso-scale, and/or lab-scale in size and scope, testbeds allow scientists and researchers to explore theories, technologies and tools within replicated, 'real-world' physical, chemical and environmental conditions. To address this challenge, DOE-EM is managing a suite of testbeds and prototype test facilities. The focus of testbed efforts is on several key issues and challenges that confront site operators. Priority environmental remediation concerns are technetium-99, cesium-137, and strontium-90. Additionally, DOE-EM has determined that advanced robotic and remote sensing techniques offer promise in increasing operational efficiency, reducing personnel exposure, and enhancing safety.

Savannah River National Laboratory is implementing a testbed program. Selection of technologies and alignment with testbeds will depend on applicability to DOE-EM issues, technology maturity, a site's ability to host vendors (industry, SBIR, academia, national laboratories), and availability of supporting infrastructure. Viable results are generated through the testbed process so that these solutions can be utilized in larger-scale thereby facilitating quick implementation of new technologies at DOE sites.

INTRODUCTION

The Department of Energy Office of Environmental Management (DOE-EM) has invested significant resources over the last three decades to develop technologies to solve high priority environmental problems in the DOE complex, and as a result, has made significant progress. Still, significant environmental issues and challenges remain. DOE-EM recognized that new innovative technologies offer the potential for improved operation performance, schedule acceleration, and cost savings for the remaining environmental cleanup. However a challenge facing the acceptance and efficient development and deployment of new technologies is the lack of information about their performance under real world conditions, especially in the harsh real world and chemical conditions and multi-contaminant plumes associated with EM applications which cannot easily be simulated in the laboratory.

In FY16, DOE-EM has identified key issues/challenges that site operations currently face – specifically, issues associated with the remediation of facilities, and soils and groundwater contaminated with technetium (Tc-99), mercury (Hg), cesium (Cs-137), and strontium (Sr-90). Additionally, DOE-EM has identified that advanced robotic and remote sensing techniques offer the potential for increasing operational efficiency, reducing personnel exposures and enhancing safety. Operational drivers and detailed technical issues are being summarized in a series of technical roadmaps.

A key resource that is needed to effectively manage efficient technology development is access to well characterized representative test beds within the DOE complex where technologies can be field tested under real world conditions to support targeted development and efficient implementation of innovative technologies.

DESCRIPTION AND DISCUSSION

In FY16, SRNL identified a suite of testbeds at the Savannah River Site (SRS) and developed supporting protocols (safety, security and intellectual property) for hosting technology testing and for evaluation of the technologies that include the documentation of the results. Individual testbed descriptions were developed for the specific testbeds shown below.

- Highly Radioactive Material Processing Testbed
- Radionuclide Field Lysimeter (RadFLEx) Testbed
- Regional Groundwater Network Testbed
- Groundwater Testbed
- Stream Scale Ecosystem Testbed

- Virtual Subsurface Testbed

Each of these testbeds is discussed in detail in the following section.

Highly Radioactive Material Processing Testbed

The Savannah River National Laboratory (SRNL) shielded cells serve as a testbed for highly radioactive material processing and provide the ability to safely work with a wide variety of highly radioactive materials in support of nuclear technology development. Skilled operators are able to safely remain outside the cells, using manipulator arms to securely perform complex tasks inside the contained environment. Manipulator arms are designed to handle the most precise tasks and endure exposure to harsh, high-level radiation.

The cells are arranged in two sections. Cell Block A has six cells and is equipped with a one-ton crane for transferring material between cells. Cell Block B has 10 cells and is equipped with two one-ton cranes. Both an exterior truck dock and a receiving bay area have 10-ton cranes to move material into and out of the cells. Full-scale replica, non-radioactive mockup cells also provide opportunities for testing compatibility of research equipment with remote operations prior to placement inside the radioactive cells.

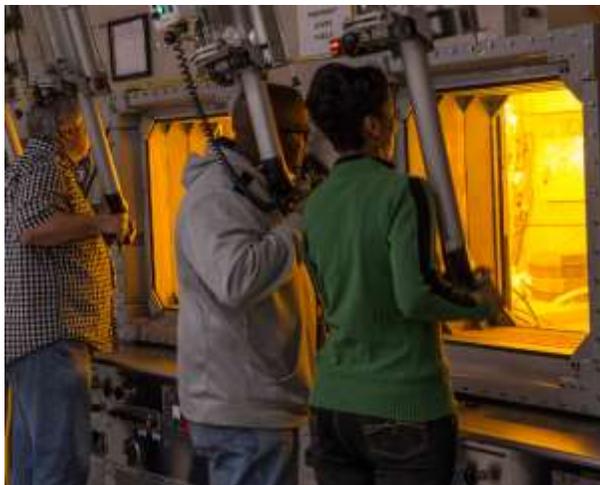


Figure 1. Shielded cells allow for safe manipulation of highly radioactive material.

Attributes of the Highly Radioactive Material Processing Testbed

- Robust facility design allows for safe radioactive material handling up to 10,000 rem/hour
- Cells are independently equipped with manipulator arms and have access to fire suppression, electricity, air, gases and water

- High airflow filtration/exhaust system is triple HEPA-filtered and routed through a sand filter system before the air is discharged to the atmosphere
- Infrastructure includes several shielded ports, allowing for easy introduction and removal of samples and supplies, and removable cell covers, plugs and transfer ports, providing for safe movement of equipment and material into the cells
- Specialized equipment is available, such as in-cell gamma counter, examination periscope, analytical balances, drying ovens and an 1100° C furnace
- Additional equipment and services can be added

Radionuclide Field Lysimeters (RadFLEx) Testbed

RadFLEx is a one-of-a-kind facility designed to quantify radionuclide biogeochemical behavior under field conditions at the meso-scale (cubic meter), providing test data between laboratory-scale (cubic centimeter) and field deployment scale (cubic kilometer). This testbed offers the opportunity to conduct experiments under natural rainfall, temperature and groundwater-flow field conditions.

Unlike standard field studies, RadFLEx provides the ability to replicate, control and test multiple treatments under identical conditions. As such, it is ideal for conducting waste form or remediation technology evaluations and demonstrations, as well as long-term fate-and-transport experiments. Further, the RadFLEx testbed has the ability to incorporate in-situ instrumentation to provide detailed characterization of porewater flow and chemistry properties. With regulatory, safety and maintenance infrastructure in place, it is convenient to introduce new tests as unused experimental test modules (lysimeters) capacity becomes available.



Figure 2. Scientist collecting moisture and chemical properties data

Attributes of the Radionuclide Field Lysimeters (RadFLEx) Testbed

- The RadFLEx testbed consists of 48 independent lysimeters that can support experiments of varying durations, typically between one and 10 years. As tests are completed, new tests can be readily initiated by replacing the interchangeable sleeves holding the experiments.
- Lysimeter results can provide important information regarding waste form performance, radionuclide transport and remediation technology efficacy.
- Experiments involving dozens of different radionuclides have already been conducted, supporting the evaluation of technologies and approaches related to colloid transport, plant and microbial-enhanced transport, waste-form performance, and long-term radionuclide transport through sediment.

Regional Groundwater Network Testbed

The Savannah River Site encompasses 310 square miles along the Savannah River in south-central South Carolina. SRS is underlain by a thickening sequence of unconsolidated Coastal Plain sediments consisting of alternating beds of sands, silts, clays and carbonate facies. Although thousands of wells and borings had been drilled at SRS, very little data existed outside major SRS facilities. In 1984, an effort was initiated to collect data in the remote areas of the site to garner a better

understanding of the geology and groundwater geochemistry, especially in the deeper stratigraphic units to the top of the crystalline basement. As a result of this work, over 120 wells were installed at 18 clusters around the SRS. The depth of the wells range from near surface to depths exceeding 900 feet below land surface.

The wells are located in non-contaminated areas, are representative of the full range of geologic conditions at SRS, and are easily accessible. They provide an excellent opportunity to evaluate various sampling techniques and new technologies, collection for further studies on regional geochemical changes and modeling, in situ long-term monitoring applications/approaches, and instructional learning for environmental and engineering students.

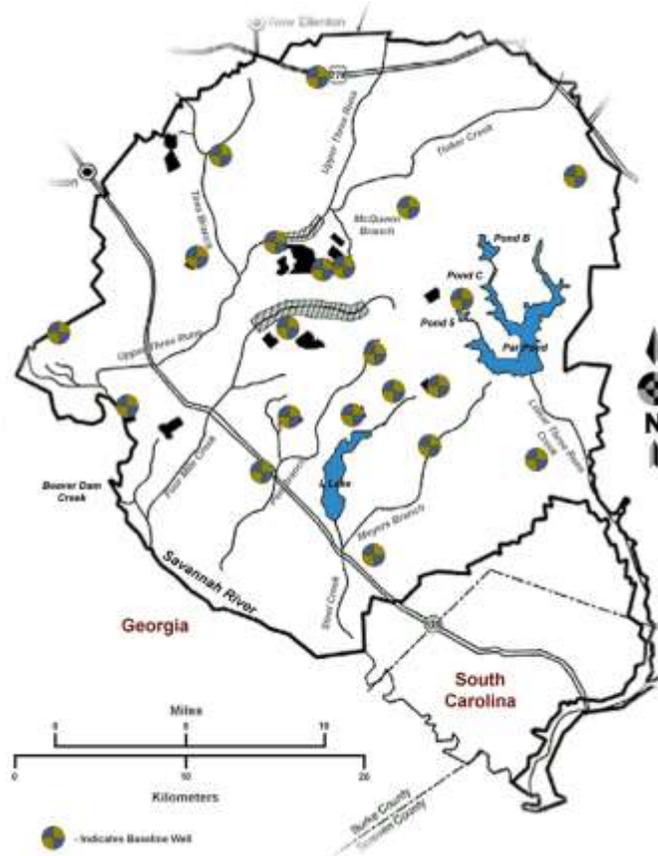


Figure 3. Regional Baseline Wells

Attributes of the Regional Network Testbed

- Mature conceptual site model that includes detailed information on site hydrology and geologic features
- Numerous wells installed at varying depths within multiple aquifers across SRS

- Availability of supporting geologic, geochemical, geotechnical, and geophysical data
- Subsurface access to a wide range of geochemical conditions
- Availability of archived core collected during drilling campaign
- Ease of accessibility to conduct studies

Groundwater Testbed

The Groundwater Testbed is a two square kilometer field site located down gradient of the F Area separations facility. Liquid process waste was disposed into unlined seepage basins during the period between 1955 and 1988. The associated groundwater plume contains dissolved uranium, strontium, iodine, technetium and tritium, as well as other radionuclides and metals. Implementation of a phased remedial strategy that combines standard and innovative remedial approaches over several decades has resulted in the development of a rich database of supporting measurements.



Figure 4. Aerial view of groundwater testbed (left), and main features and topography of the groundwater testbed (right)

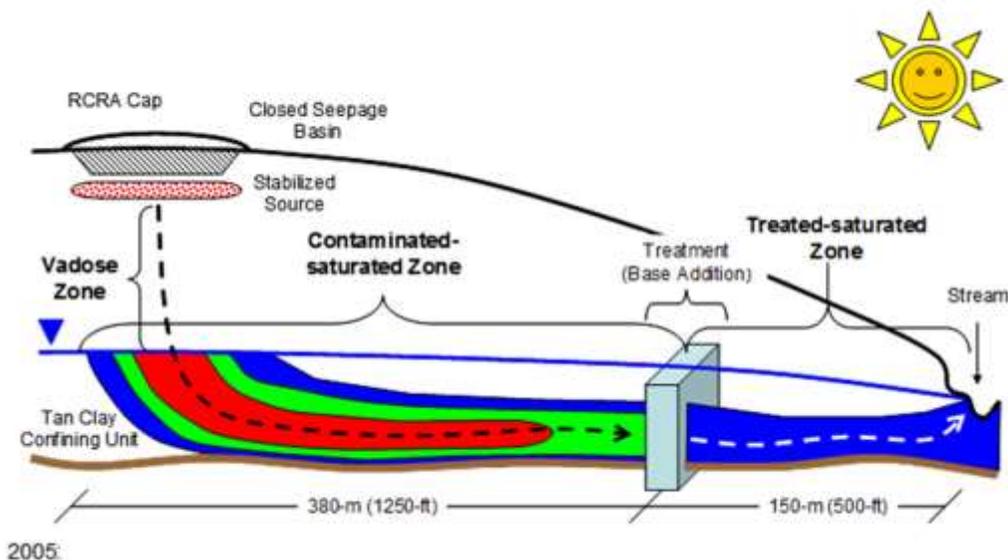


Figure 5. General Conceptual Model of the Groundwater Testbed

Attributes of the Groundwater Testbed

- Chemically complex, shallow groundwater plume in layered coastal plain sediments
- Mature conceptual site model that includes detailed information on site hydrology, geologic features and contaminant distribution
- Comprehensive monitoring history with 60 years of high quality groundwater data
- Access to applied research measurements made to support deployment and testing of over 20 innovative technologies
- Subsurface access to vadose, saturated, and wetland zones, including critical interfaces (vadose zone-groundwater, geochemical treatment interface, and groundwater seepage)
- Climatic, geologic, and hydrologic framework that allows for effective and accelerated testing of technologies due to high precipitation rates
- Administrative infrastructure with a regulatory framework that calls for phased implementation of regulatory actions to encourage continued development and deployment of innovative technologies

Surface Water Testbed

In most groundwater systems contaminated with Tc-99 or I-129, the primary location where attenuation is likely to occur by natural processes is the intersection of the groundwater with the organic-rich sediments of seepines or wetlands; environments also found at the Hanford and Paducah sites. Understanding mechanisms associated with the dynamic geochemical and microbiological interactions in these environments affect attenuation and release of Tc-99 and I-129 is challenging, but it is thought that, under some conditions, these organic-rich sediments bind these contaminants and provide the opportunity to implement cost effective attenuation remedies, stabilizing contamination in place.

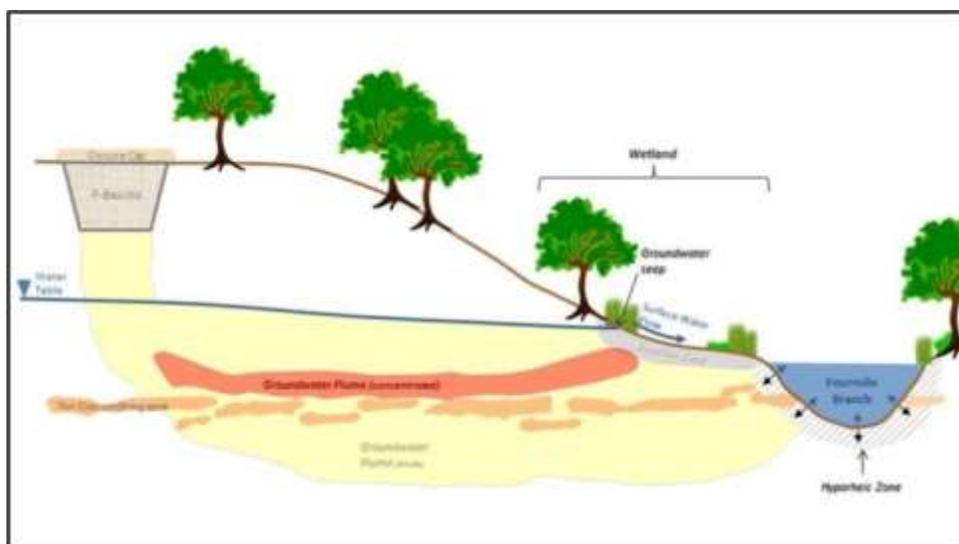


Figure 6. Cross Section of the F-area Basins plume showing the seepage interface with the surface stream

Attributes of the Surface Water Testbed

- Easy access to seepage and wetland zones where Tc-99 and I-129 have accumulated and are being slowly released to surface streams
- Comprehensive monitoring history with decades of high quality data
- Climatic, geologic and hydrologic framework that allows for effective and accelerated testing of technologies due to high precipitation rates

Stream-scale Ecosystem Testbed

Stream-scale Ecosystem (Tims Branch) provides a control site for studying the fate and availability of mercury in streams, sediment and biota. Local streams and wetlands are the primary point of exposure for contaminants at many industrial sites, receiving contaminants directly from outfalls and indirectly via groundwater.

Stream ecosystems are complex and include many types of plants and animals and multiple trophic levels. This Stream-scale Ecosystem Testbed (Tims Branch) is a small stream ecosystem located in A and M Areas of the SRS.

Tims Branch received direct discharges of process wastewater from metallurgical operations (1950s - 1982) and of treated groundwater and non-contact cooling water (1983-present). These direct discharges contained uranium, nickel, aluminum and other metals and radionuclides. The lower portion of Tims Branch also receives discharging groundwater containing trace organic solvent contaminants.

A number of innovative treatment systems have been deployed to limit the contaminant flux to Tims Branch, including a wetland treatment system (northern tributary in 2000) and a mercury removal system that uses tin(II) reagent and air stripping (outfall tributary in 2007). Together, these treatments eliminated all local anthropogenic mercury inputs to this ecosystem. The tin-based treatment resulted in a known step function addition of inert tin oxide particles – the released tin is a potential tracer for sedimentation and particle transport processes in the stream.

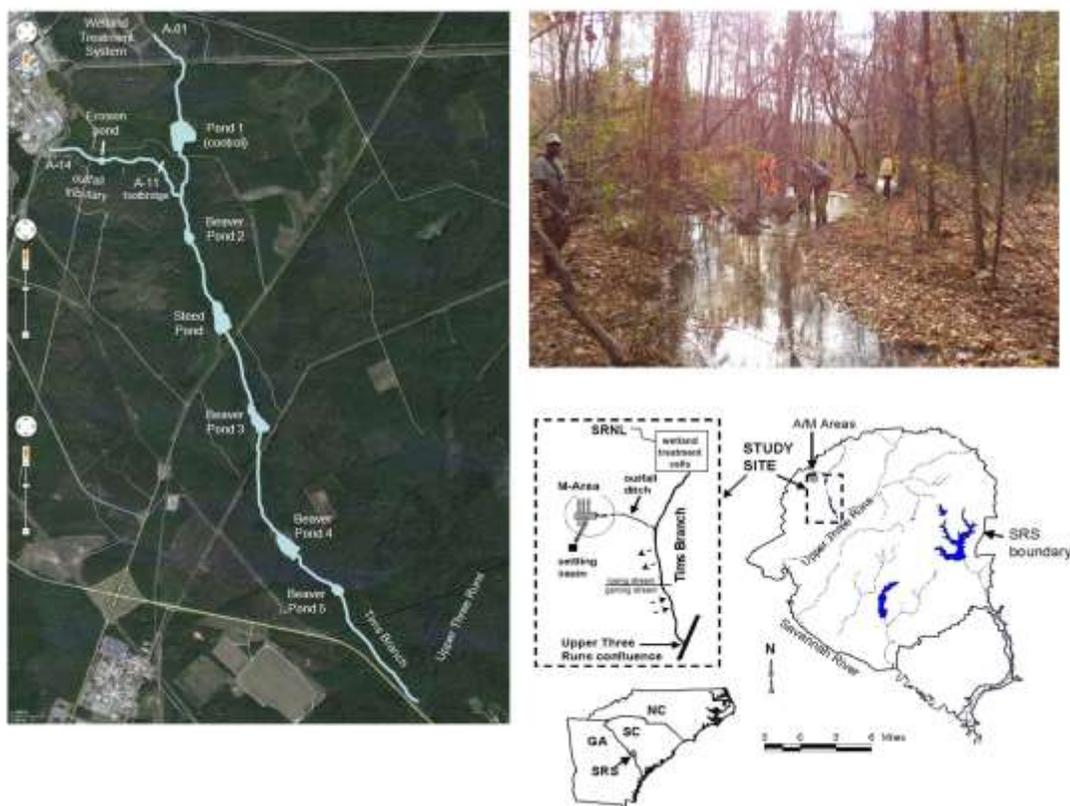


Figure 7. The Stream-scale Testbed involves the Tims Branch ecosystem.

Attributes of the Stream-scale Ecosystem Testbed

- Baseline data for flora and fauna, including trees, fish, reptiles, amphibians and mammals
- Detailed GIS coverage, including land use, vegetation, elevation, soil type, rainfall and many others
- Availability of hydrology, geochemistry, geotechnical and geophysical data
- Access to an ecosystem to conduct studies
- Some archived biota and sediment samples

Virtual Subsurface Testbed

The Virtual Subsurface Testbed provides a 3-D model to evaluate remediation and long-term monitoring strategies, and to evaluate boundary conditions and controlling variables which can serve as cost-effective “leading indicators” of changing groundwater conditions. To ensure that contaminants remain sequestered, implementation of attenuation-based remedies requires long-term monitoring over decades. One challenge associated with the development of long-term monitoring approaches is the development of effective strategies without conducting years of monitoring. Following years of remedial actions, SRNL has developed a “virtual” subsurface testbed at the SRS F Area site that allows for testing of strategies that incorporate measurement of controlling variables that can be monitored remotely, in addition to standard methods.

To facilitate this work, Lawrence Berkeley National Laboratory has developed a state-of-the-art, three-dimensional flow/reactive transport model and incorporated statistical analysis of years of contaminant monitoring data that can be used to predict contaminant concentrations and distribution in the future.

The well-documented changes in boundary conditions and controlling variables (i.e. basin closure and capping, and pump and treat, followed by base injection) at F Area can be used to evaluate changes as they occur over time.

Attributes of the Virtual Testbed

- A well-characterized, mature groundwater plume with dissolved uranium, strontium, iodine, technetium and tritium, as well as other radionuclides and metals
- Mature conceptual site model that includes detailed information on site hydrology, geologic features and contaminant distribution
- Comprehensive monitoring history with 60 years of groundwater data with a complex, well-documented remedial history
- State-of-the art, three-dimensional flow and reactive transport model to evaluate changes into the future

- In-situ sensor network that remotely monitors key groundwater controlling variables for real-time data analysis and early warning systems

CONCLUSIONS

DOE-EM is developing and managing a suite of testbeds and prototype testbed facilities at the SRS to facilitate testing of new technologies that address high priority DOE needs. These testbeds will be used to obtain the necessary performance data for innovative solutions, so that they can be more readily incorporated into DOE-EM operations. Private industry and academia will be encouraged to demonstrate their technology at these testbeds. Selection of technologies and alignment with testbeds will depend on applicability to DOE-EM issues, technology maturity, a site's ability to host vendors (industry, small business innovative research, academia, national laboratories) and availability of supporting infrastructure.