U.S. Department of Energy
Environmental Management

energy.gov/em/office-environmental-management

Testbed Program

What are Testbeds?

Designed to address a full array of both known and potential issues, testbeds are *contained*, *controlled* and *safe* research and experimentation systems.

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.

RadFLEx

SRNL's Radiological Field Lysimeter Experiment

- a meso-scale testbed for radioactive-element solubility exploration.

As effective, viable results are generated through the testbed process, then these solutions can be utilized in larger-scale, open-environment scenarios.

Issues

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

Solutions

DOE-EM is managing a suite of testbeds and prototype test facilities. In order to obtain the necessary performance data for innovative solutions to be more readily incorporated into DOE-EM operations, private industry and academia are encouraged to demonstrate their technology at these testbeds.

Priorities

DOE-EM is focusing its technology testbed efforts on several key issues and challenges that confront site operators. These operational drivers and technical issues are summarized in a series of technical roadmaps.

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.

Approach

For the application of results to best provide a viable, positive impact on baseline operations, innovative technology providers should familiarize themselves with current priorities and then contact DOE-EM with potential solutions.

Savannah River National Laboratory is coordinating the implementation of the testbed program across the DOE complex. 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.

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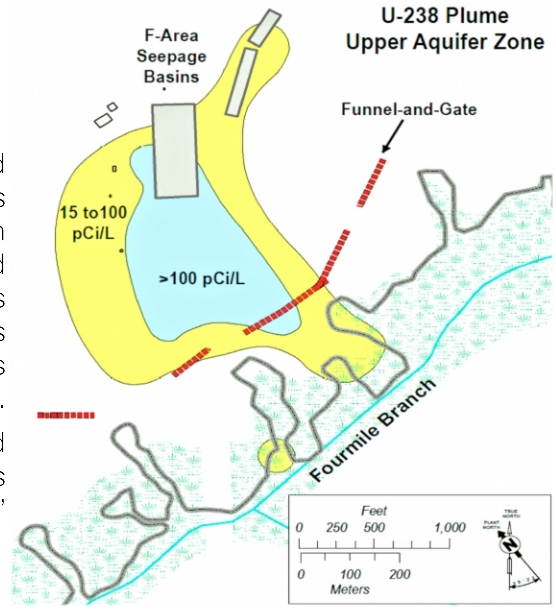
Testbed Program

SRS F-Area

Applied Field Research Initiative



The Savannah River Site (SRS) F-Area Test Bed 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, 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.

This test bed is suited for testing technologies for the characterization and remediation of subsurface contaminants and to evaluate boundary conditions and controlling variables which can serve as cost-effective “leading indicators” of changing groundwater conditions.

Attributes

- 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 seepline)
- Climatic, geologic, and hydrologic framework that allows for effective and accelerated testing of technologies due to high precipitation rates
- Established administrative infrastructure with a regulatory framework that calls for phased implementation of regulatory actions that encourages continued development and deployment of innovative technologies

Impact

- Field-based evaluation and implementation of monitoring and remedial technologies/strategies
- Demonstrated success in working with both research and commercial entities
- Supporting regulatory framework that facilitates acceptance of non-traditional approaches at real-world sites

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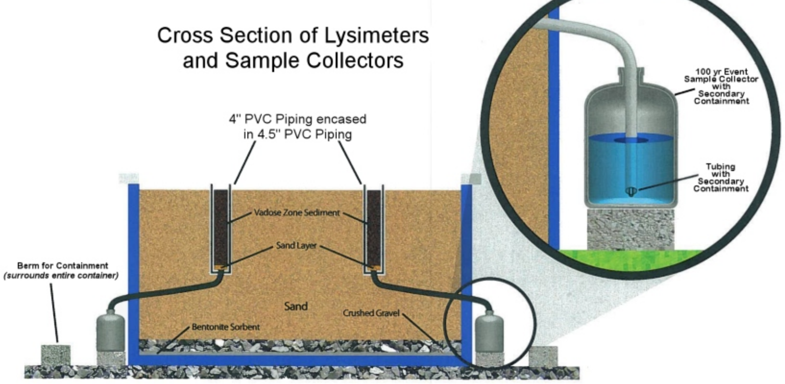
RadFLEx Testbed

Bridging Laboratory and Field-Scale Testing

Radionuclide Field Lysimeter Experiment - RadFLEx is a one-of-a-kind test bed facility that is 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 test bed offers the opportunity to conduct experiments under ambient/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's ideal for conducting waste form or remediation technology evaluations and demonstrations, as well as long-term fate-and-transport experiments. Furthermore, the RadFLex test bed 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 lysimeter capacity becomes available.

Innovation from Science to Successful Deployment



The RadFLex test bed consists of 48 independent experimental test modules (lysimeters) that can support experiments of varying durations (typically between one and ten years). As tests are completed, new tests can be readily initiated by replacing the interchangeable sleeves holding the experiments. Results from the lysimeters 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.

Impact

Provide knowledge for science-based decisions related to:

- Environmental remediation and monitored natural attenuation technologies and strategies
- Waste form selection and performance
- High-level and low-level waste disposal scenarios
- Benchmarking and validation of performance assessment and risk models

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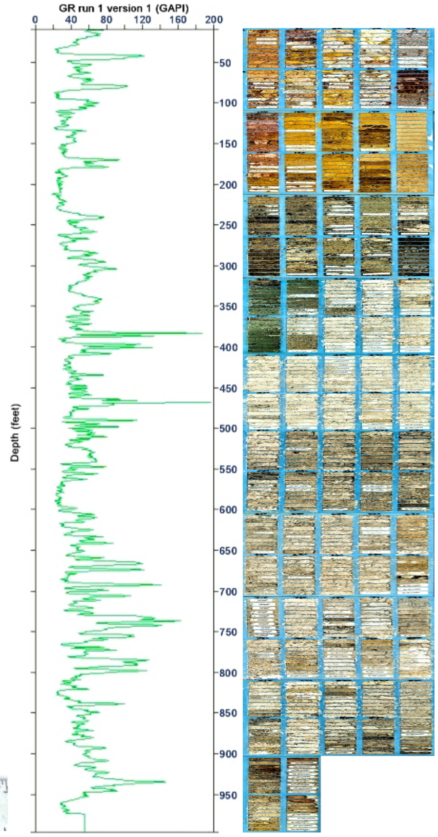
SRNL Core Repository:

A Lithologic Library

The geologic data catalog for the Savannah River Site includes more than 1200 soil and rock cores archived at the SRNL Geological Core Repository. The contents of the core repository constitute an unrivaled collection of unconsolidated sediments deposited in fluvial, deltaic, and shallow marine environments along the emergent southeastern Atlantic Coastal Plain during the Cretaceous and Tertiary time periods. The repository also contains many samples of buried Paleozoic bedrock and Triassic basin-fill sequences, rocks that are rarely sampled in this region. The primary uses of unconsolidated sediment cores are to understand sediment heterogeneity and physical properties; delineate boundaries of various stratigraphic units; predict groundwater movement and the behavior of contaminants and mitigants; and add geotechnical rigor to facility siting and foundation design. The bedrock cores are a record of continental rifting and tectonism along the southeastern US continental margin.

Attributes

- High-resolution sampling of the entire upper Atlantic Coastal Plain stratigraphic sequence, including sediments of the Floridan aquifer, an important source of drinking water for five southeastern states
- Many cores into and through the Santee Formation, which directly influences facility siting, design, and foundation stability
- Age constraints and movement history for basement faulting



Impact

- Tangible archive of 60+ years of subsurface investigations at SRS and surrounding region
- Ready access to sediments that compose regional aquifers and aquitards
- Important record of pre-remediation conditions at RCRA/CERCLA sites
- Hands-on availability of geologic samples to support geo-modeling, performance assessments, and remedial decision-making

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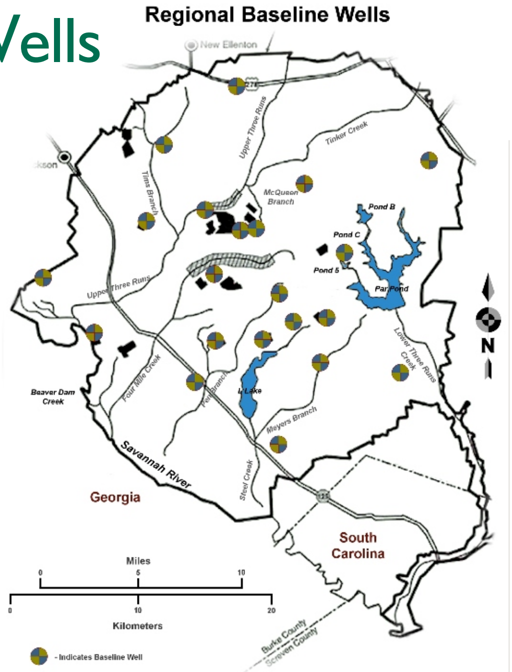
SRS Regional Baseline Groundwater Wells

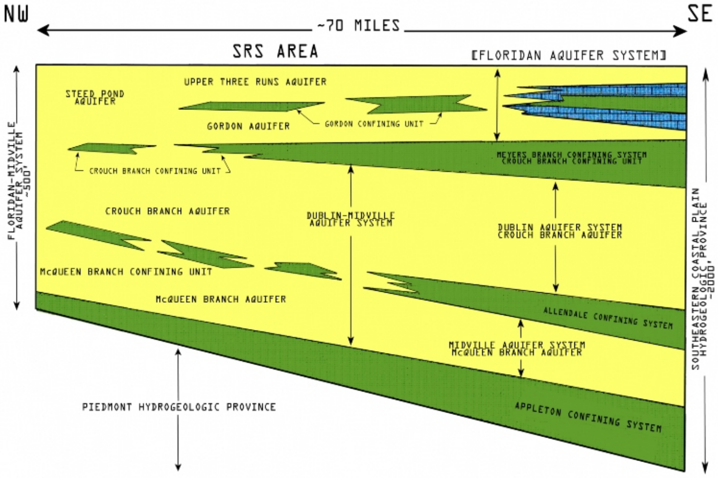


The Savannah River Site (SRS) encompasses 310 square miles along the Savannah River in south-central South Carolina. SRS is underlain by a thickening sequence of unconsolidated coastal plain sediments consisting of alternating beds of sands, silts, clays, and carbonate facies. Although thousands of wells and borings have been drilled at SRS, very little data exist 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 and easily accessible. They provide an excellent opportunity to evaluate various sampling techniques, 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.

Attributes

- 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 long-term head data and 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



Impact

- Benchmarking and validation of regional groundwater flow and contaminant models
- Impact evaluation on long-term storage/disposal of various waste forms
- Long-term monitoring
- Supporting regulatory decisions on facility area closure
- Supporting regulatory framework that facilitates acceptance of non-traditional approaches at real-world sites

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SRNL Shielded Cells

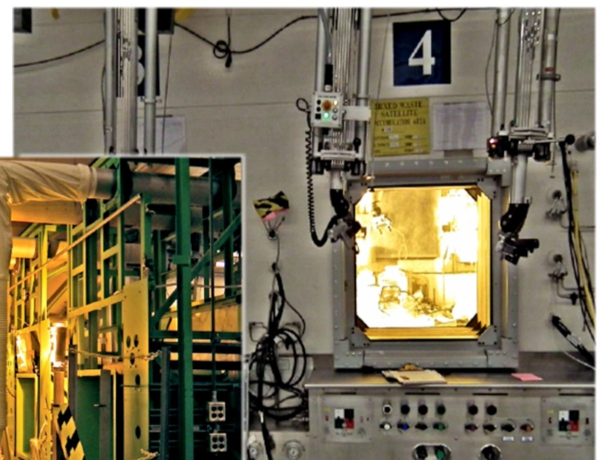
The Savannah River National Laboratory (SRNL) Shielded Cells provide the ability to safely work with a wide variety of highly radioactive materials in support of nuclear technology development. Skilled operators are able to safely remain outside the cells, using manipulator arms to securely perform complex 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 ten cells and is equipped with two one-ton cranes. Both an exterior truck dock and receiving bay area have 10-ton cranes to move material into and out of the cells.

Full-scale replica, non-radioactive mockup cells provide opportunities for testing compatibility of research equipment with remote operations, prior to placement inside the radioactive cells.

Attributes

- 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
- The 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 a furnace
- Additional equipment and services can be added



Impact

- Demonstrated success in a number of R&D initiatives involving highly radioactive materials
- Specialized equipment and trained operators available for a variety of research tasks
- Capacity for some customization and tailoring

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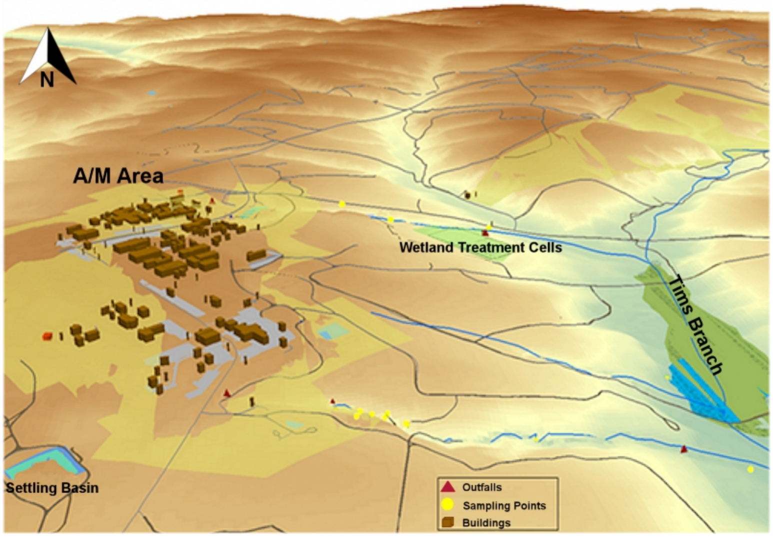
Tims Branch

Stream-Scale Ecosystem Studies



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, encompassing many types of plants and animals and multiple trophic levels. Tims Branch is a small stream ecosystem located in the A/M Areas of the Department of Energy Savannah River Site (SRS). Over the years, Tims Branch received direct discharges of process wastewater from metallurgical operations (1950s through 1982) and of treated groundwater and non-contact cooling water (1983-present). These direct discharges contained uranium, nickel, aluminum, and other metal and radionuclide contaminants. 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.

(L) Redfin Pickerel
(R1)Dr. Looney with intern
(R2) Ecofishing

Attributes

- Tims Branch has been a focus of research by the Savannah River National Laboratory (SRNL), the University of Georgia Savannah River Ecology Laboratory (SREL), Florida International University and numerous other collaborators
- 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 a ecosystem to conduct studies
- Some archived biota and sediment samples

Impact

- Mercury - Ecosystem scale response and recovery after removing all local mercury sources to a stream
- Nanoparticles - Behavior of small particles released into a stream ecosystem – deposition, accumulation and export
- Long-term monitoring strategies
- Regulatory framework that facilitates acceptance of innovative technologies at real-world sites

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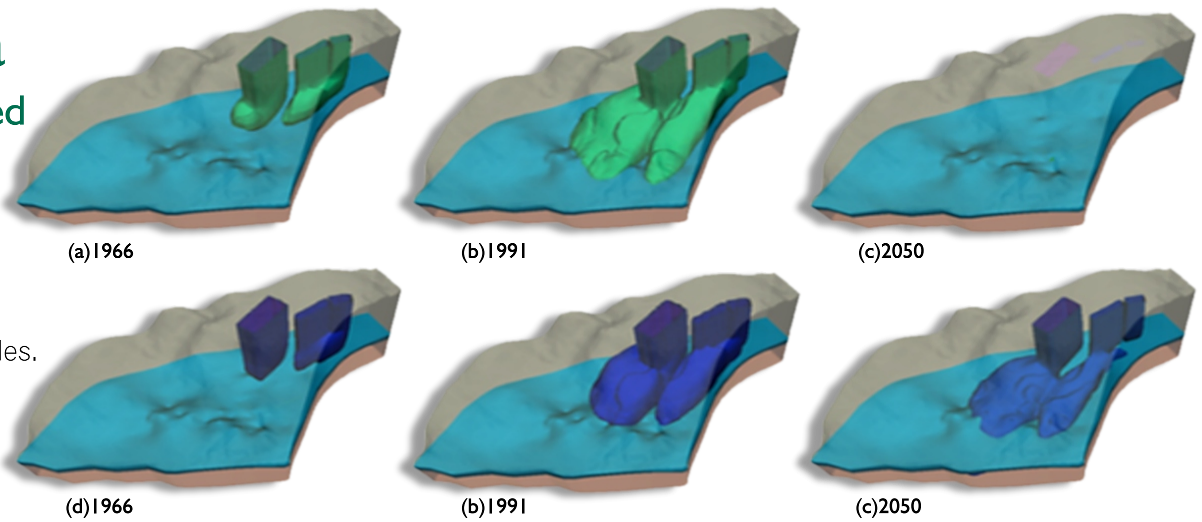
Testbed Program

SRS F-Area

Virtual Testbed



-The simulated evolution of (a - c) low-pH plume (pH> 4) and (d - f) uranium plume (concentration> 1x10-6 mol/L).
-The sky blue region is the low permeable Tan Clay Confining Zone, which separates the upper and lower aquifers.
-Vertical exaggeration = 15X.

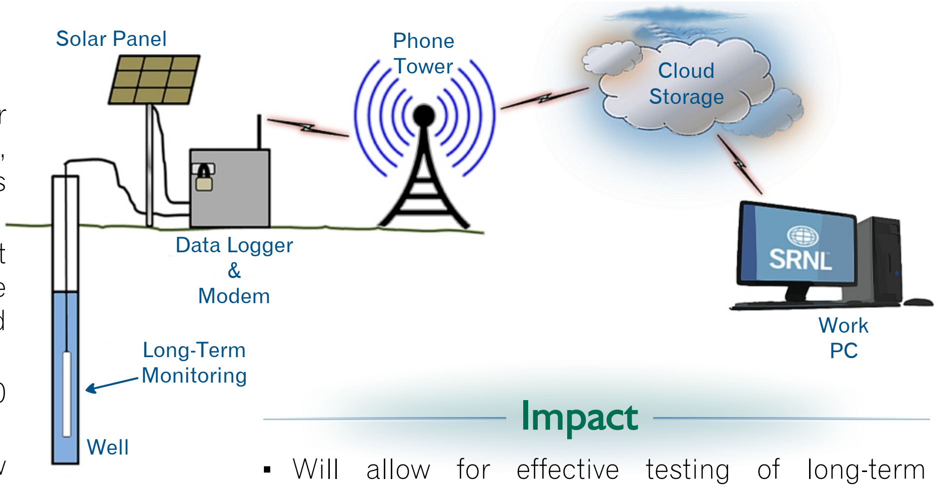
To ensure that contaminants remain sequestered, implementation of attenuation-based remedies will require monitoring over decades. One challenge associated with the development of long-term monitoring approaches is to be able to evaluate strategies without years of monitoring.

SRNL is developing a 'virtual' testbed at the SRS F-Area site, that will allow for testing of strategies that incorporate measurement of controlling variables, in addition to standard methods.

To facilitate this work, Lawrence Berkeley Lab developed a state-of-the-art, three-dimensional flow / reactive transport model. Then they incorporated the statistical analysis of fifty years of contaminant monitoring data, in order to better evaluate strategies into the future. Well documented changes in boundary conditions and controlling variables (i.e. basin closure and capping, pump and treat, followed by base injection) can be used to evaluate changes, as they occur over time.

Attributes

- 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
- State-of-the art, three-dimensional flow and reactive transport model



Impact

- Will allow for effective testing of long-term remediation and monitoring strategies without the need for decades of testing.

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U.S. Department of Energy Environmental Management

Testbed Program Overview

Risk Drivers	Issue / Need	SRNL Testbeds	DOE Complex Testbeds *(future)*
Technetium	Issue: Technetium-99 and other long-lived, soluble radionuclides (for example, iodine-129) are primary risk drivers affecting environmental remedial decisions at Hanford, Savannah River, Portsmouth, and Paducah. Characterization Needs: ▪ Tools/methods for improved detection and quantification of technetium-99 species ▪ Better understanding of technetium-99 chemistry and speciation ▪ More complete understanding of technetium-99 behavior in tank waste and subsurface geologic media ▪ Basis for environmental risk quantification and definition of remedial actions/goals Treatment/Remediation Needs: ▪ Improved methods for technetium-99 retention/immobilization ▪ Better quantification of waste-form performance	SRS F Area Seepage Basin provides a field site for natural and enhanced attenuation and for testing chemical/physical reactants to immobilize, precipitate, transform, or fix soluble contaminants in a shallow, multi-contaminant groundwater plume and in surface water. SRNL RadFLEx provides a meso-scale platform for characterization of technetium-99 speciation, solubility, and behavior in simulated waste forms (e.g. saltstone) and in real geologic media. SRNL Shielded Cells can receive actual tank wastes for demonstration of treatment methods. SRNL Radiological Laboratories can handle low activity tank wastes and radioactive simulants for demonstration of treatment methods. SRNL F Area Virtual Testbed is a reactive 3-D flow and transport model that is used to evaluate the efficacy of long-term monitoring and engineered treatment strategies.	SRS Technetium Seepline is the critical interface between groundwater and surface where technetium-99 and iodine-129 accumulated for over 50 years creating conditions similar to Paducah. Useful for study of attenuation of technetium species (FY16). Paducah C-400 for evaluation of methods to immobilize technetium-99 contaminated equipment for disposal (FY17). Hanford Central Plateau includes vadose zone contamination with a large dilute groundwater plume with complex plume that includes technetium-99 and iodine-129 (future). 222-S Shielded Cells or PNNL Shielded Cells can receive actual tank wastes for demonstration of treatment methods. PNNL Radiological Laboratories can handle low activity tank wastes and radioactive simulants for demonstration of treatment methods.
Mercury	Issues: At Savannah River Site, mercury exists in tank wastes and is recycled into the liquid waste system; mercury concentrations are increasing in the liquid waste stream and in saltstone. At Oak Ridge (OR), prior operations released mercury into facilities and the environment (soil, sediment, water, and biota). Characterization Needs: ▪ Better understanding of vapor phase chemistry and chemical speciation/transformation in alkaline solutions (SRS) ▪ Mercury detection/measurement, including remote sensing of mercury in infrastructure Treatment/Remediation Needs: ▪ Sorbents and techniques for removing mercury from alkaline waste solutions (SRS) ▪ Mercury "getters" for grout formulations (SRS) ▪ Decontamination methods/tools/applications, including pre-demolition, demolition, and debris stage decontamination (OR) ▪ In-stream source zone isolation, water chemistry manipulation, and food chain modification (OR)	SRNL Shielded Cells can receive actual tank wastes for development of characterization techniques and treatment methods. SRNL Radiological Laboratories can handle low activity tank wastes and radioactive simulants for demonstration of treatment methods. SRS Tims Branch provides a control site (e.g., vs Oak Ridge East Fork Poplar Creek) for studying the fate and availability of mercury in streams, sediment, and biota.	ORNL Lower East Fork Poplar Creek (LEFPC) creek located downstream of the Y12 mercury use facilities which provide a variety of environments, including stream water and sediments, to investigate the persistence and bioaccumulation of methylmercury in the EFPC, despite long term remediation efforts (ongoing). 222-S Shielded Cells or PNNL Shielded Cells can receive actual tank wastes for demonstration of treatment methods. PNNL Radiological Laboratories can handle low activity tank wastes and radioactive simulants for demonstration of treatment methods.
Cesium / Strontium	Issue: DOE requires disposal options for used nuclear fuel and high-level radioactive waste. DOE-EM is currently investigating Deep Borehole technology for cesium and strontium capsules stored at Hanford and cementitious waste forms for low activity liquids with onsite or offsite disposal. Treatment Needs: ▪ Enhanced separation methods for high-level liquid waste streams Disposal Needs: ▪ Containers, including deployment +/- retrieval systems, that will be accepted in a final repository	SRNL Shielded Cells can receive actual tank wastes for demonstration of treatment methods. SRNL Core Laboratory archives numerous bedrock cores; associated bedrock boreholes provide locations to test deployment and retrieval of various canister designs. SRS Regional Baseline Wells constitute a diverse array of accessible wells in a variety of geologic and contaminant settings.	222-S Shielded Cells or PNNL Shielded Cells can receive actual tank wastes for demonstration of treatment methods. PNNL Radiological Laboratories can handle low activity tank wastes and radioactive simulants for demonstration of treatment methods.

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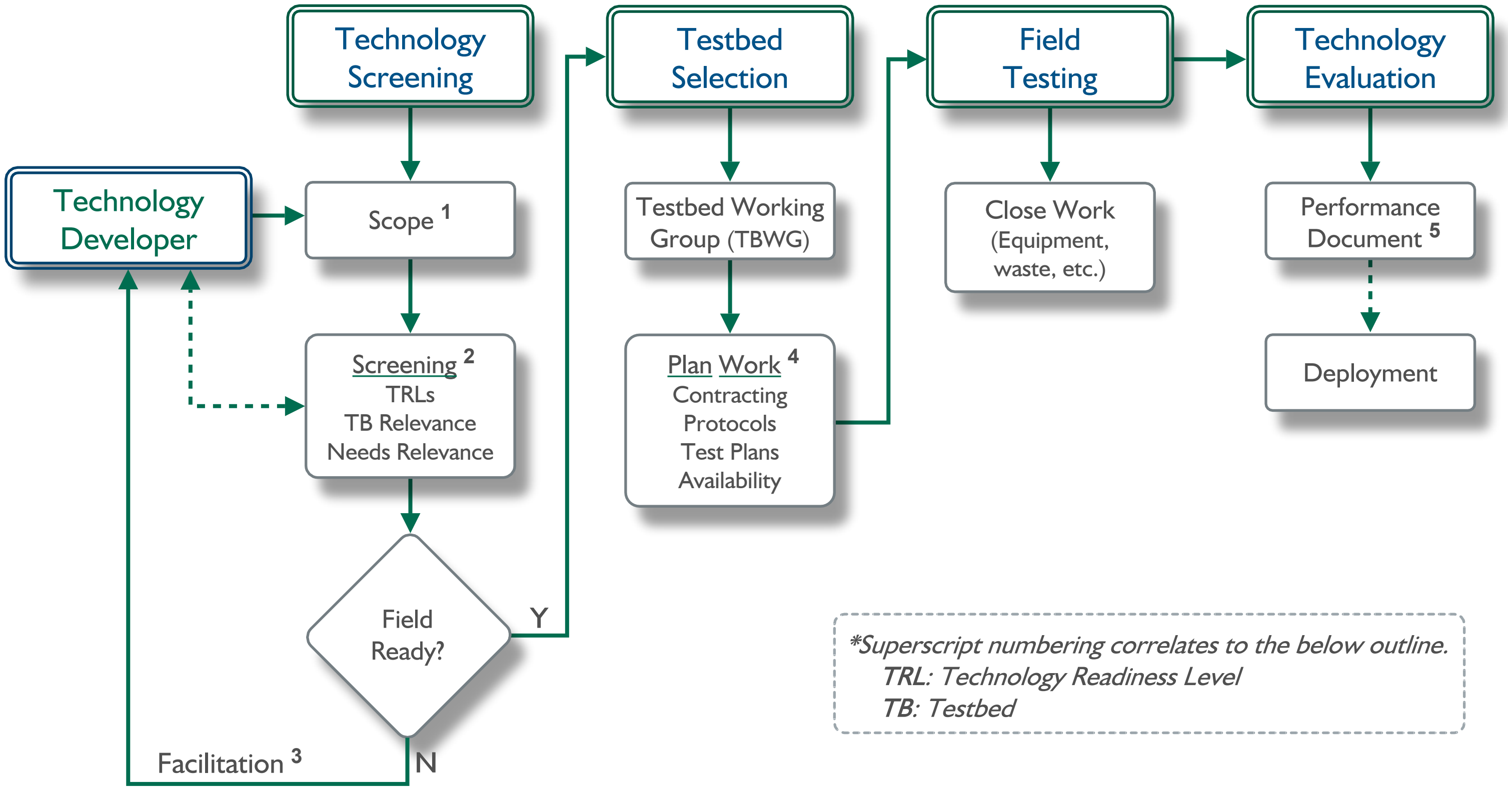
Testbed Technology Process



1. Scope from Technology Developer (TD)
   - Technology description
     - -What does it do?
     - -What processes are used?
   - Technology application to Environmental Management needs
   - Technology developer's TRL estimate
   - Description of relevant baseline technology(s)
   - Testbed requirements / description of anticipated field deployment protocol

2. Testbed Working Group Screening Protocol
   - Technology /Environmental Management needs relevance
   - TRLs (4-7) [risk/benefit]
   - Technology / Testbed relevance
   - Cost / Contracting

3. Facilitation – Provide technical assistance to advance technology to field-ready status
   - Identify personnel
   - Funding / Contracting

4. Plan Work
   - Contracting / funding (hands on work?)
   - Personnel and resources availability
   - Task Technical Plans and QA Plans (evaluation criteria)
   - Hazards analysis and controls (physical, chemical, radiological)
   - Regulatory approvals, NEPA, waste mitigation / disposal

5. Performance Document
   - Performance and cost compared to baseline technology
   - Technology Readiness Level
   - Deployment opportunities (site specific)

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