Office of Science
Notice 02-03

Environmental Management Science Program (EMSP): Research Related to Subsurface Contamination in the Vadose and Saturated Zones

Department of Energy

Office of Science Financial Assistance Program Notice 02-03; Environmental Management Science Program (EMSP): Research Related to Subsurface Contamination in the Vadose and Saturated Zones

AGENCY: U.S. Department of Energy

ACTION: Notice inviting grant applications.

SUMMARY: The Offices of Science (SC) and Environmental Management (EM), U.S. Department of Energy (DOE), hereby announce their interest in receiving grant applications to support specifically innovative, fundamental research to investigate DOE subsurface contamination in the vadose and saturated zones.

DATES: The deadline for receipt of formal applications is 4:30 P.M., E.S.T., Wednesday, March 27, 2002, in order to be accepted for merit review and to permit timely consideration for award in Fiscal Year 2002.

ADDRESSES: Applications must be sent to: U.S. Department of Energy, Office of Science, Grants and Contracts Division, SC-64, 19901 Germantown Road, Germantown, MD 20874-1290, Attn: Program Notice 02-03. This address must be used when submitting applications by U.S. Postal Service Express Mail, any commercial mail delivery service, or when hand carried by the applicant.

FOR FURTHER INFORMATION CONTACT: Dr. Roland F. Hirsch, SC-73, Mail Stop F-237, Medical Sciences Division, Office of Biological and Environmental Research, Office of Science, U.S. Department of Energy, 19901 Germantown Road, Germantown, MD 20874-1290, telephone: (301) 903-9009, facsimile: (301) 903-0567, E-mail: roland.hirsch@science.doe.gov, or Mr. Mark Gilbertson, Office of Science and Technology, Office of Environmental Management, 1000 Independence Avenue, SW, Washington, D.C. 20585, telephone: (202) 586-7150, facsimile: (202) 596-1492, E-mail: mark.gilbertson@em.doe.gov. The full text of Program Notice 02-03 is available via the Internet using the following web site address: http://www.science.doe.gov/production/grants/grants.html.

SUPPLEMENTARY INFORMATION: The Office of Environmental Management, in partnership with the Office of Science, sponsors the Environmental Management Science Program (EMSP) to fulfill DOE's continuing commitment to the cleanup of DOE's environmental legacy. The program was initiated in Fiscal Year 1996, to (1) address long-term technical issues crucial to the EM mission, and (2) provide EM with near-term fundamental data critical to the advancement of technologies that are under development, but not yet at full scale nor implemented. Proposed basic research under this notice should contribute to environmental management activities that would decrease risk for the public and workers, provide opportunities for major cost reductions, reduce time required to achieve EM's mission goals, and, in general, should address problems that are considered intractable without new knowledge.

This program is designed to inspire breakthroughs in areas critical to the EM mission through basic research and will be managed in partnership with SC. The Office of Science's procedures, as set forth in the Office of Science Merit Review System, as published in the Federal Register, March 11, 1991, Vol. 56, No. 47, pages 10244-10246, will be used for merit review of applications submitted in response to this notice.

Subsequent to the formal scientific merit review, applications that are judged to be scientifically meritorious will be evaluated by DOE for relevance to the objectives of the Environmental Management Science Program. Additional information can be obtained about the general program at: http://emsp.em.doe.gov.

PURPOSE

Over the past 50 years, the United States created an industrial complex to develop, test, manufacture, and maintain nuclear weapons for national security purposes. The production and testing of nuclear weapons created a legacy of significant environmental contamination, ranging from uranium mining and milling, waste disposal, and radionuclide migration in ground water and soil. In 1995, the 104th Congress authorized creation of the Environmental Management Science Program (EMSP) to develop a long term, basic science infrastructure to focus on the environmental cleanup effort DOE began formally in 1989. To address the largest environmental cleanup program in the world, from a cost perspective, EMSP has the following objectives:

- Provide scientific knowledge that will revolutionize technologies and cleanup approaches to significantly reduce future costs, schedules, and risks
- "Bridge the gap" between broad fundamental research that has wide-ranging applicability, such as that performed in DOE's Office of Science and needs-driven applied technology development that is conducted in EM's Office of Science and Technology
- Focus the Nation's science infrastructure on critical DOE environmental management problems

Since 1996, the Program has held six competitions and has awarded over $290 million in funding to 361 research projects. A breakdown of the EMSP awards by year is as follows:

- 1996 and 1997: 202 awards totaling $160 million targeted at a broad spectrum of basic science cleanup and waste management issues
- 1998: 33 awards totaling $30 million focused on high-level radioactive waste and decontamination and decommissioning issues

- 1999: 39 awards totaling $30 million fostered basic research in the areas of vadose zone contamination and low dose radiation
- 2000: 42 awards totaling $30 million in research renewals for 1996 and 1997 funded projects
- 2001: 45 awards totaling $39 million focused on additional high-level radioactive waste and decontamination and decommissioning issues

REPRESENTATIVE RESEARCH AREAS

Basic research is solicited in all areas of science with the potential for addressing problems in subsurface contamination and transport processes in the vadose and saturated zones. Processes and problems in the vadose zone constitute important subjects of concern to the Department's Environmental Management Program. Relevant scientific disciplines include, but are not limited to: geological sciences (including geochemistry, geophysics, hydrogeologic flow and transport modeling, process modeling, and hydrologic field-studies), plant sciences (including mechanisms of contaminant uptake, concentration, sequestration, and phytoremediation), chemical sciences (including fundamental interfacial chemistry, computational chemistry, actinide chemistry, and analytical chemistry and instrumentation), engineering sciences (including control systems and optimization, diagnostics, transport processes, fracture mechanics, and bioengineering), materials science (including other novel materials-related strategies), and bioremediation (including biogeochemistry; microbial science related to ex situ treatment of metals, radionuclides, and organics; and in situ treatment of organics). The Natural and Accelerated Bioremediation Research (NABIR) program in the Office of Biological and Environmental Research, Office of Science, may issue a Notice related to in situ treatment of metals and radionuclides during FY 2002. Research projects relating to this area should be submitted to NABIR rather than to EMSP. Additional information about the NABIR program can be found at: http://www.lbl.gov/NABIR/.

PROJECT RENEWALS

Lead Principal Investigators of record for Projects funded under Office of Science Notice 99-06, Environmental Management Science Program: Research Related to Subsurface Contamination, are eligible to submit renewal applications under this solicitation.

PROGRAM FUNDING

It is anticipated that up to a total of $4,000,000 of Fiscal Year 2002, funds will be available for new and renewal EMSP awards resulting from this Notice. Multiple-year funding of grant awards is anticipated, contingent upon the availability of appropriated funds. Award sizes are expected to be on the order of $100,000-$300,000 per year for total project costs for a typical three-year grant. Collaborative projects involving several research groups or more than one institution may receive larger awards if merited. The program will be competitive and offered to investigators in universities or other institutions of higher education, other non-profit or for-profit organizations, non-Federal agencies or entities, or unaffiliated individuals. DOE reserves the right to fund in whole or part any or none of the applications received in response to this Notice. A parallel announcement with a similar potential total amount of funds will be issued to DOE Federally Funded Research and Development Centers (FFRDCs). All projects will be evaluated using the same criteria, regardless of the submitting institution. Additionally, relevant innovative basic research pertaining to other sites will be considered.

COLLABORATION AND TRAINING

Applicants to the EMSP are strongly encouraged to collaborate with researchers in other institutions, such as universities, industry, non-profit organizations, federal laboratories and FFRDCs, including the DOE National Laboratories, where appropriate, and to incorporate cost sharing and/or consortia wherever feasible.

Applicants are also encouraged to provide training opportunities, including student involvement, in applications submitted to EMSP.

APPLICATION FORMAT

Applicants are expected to use the following format in addition to following instructions in the Office of Science Application Guide. Applications must be written in English, with all budgets in U.S. dollars.

- Office of Science Face Page (DOE F 4650.2 (10-91))
- Application classification sheet (a plain sheet of paper with one selection from the list of scientific fields listed in the Application Categories Section)
- Table of Contents
- Project Abstract (no more than one page)
- Budgets for each year and a summary budget page for the entire project period (using DOE F-4620.1)
- Budget Explanation. Applicants are requested to include in the travel budget funds to attend: (1) an initial research kick-off meeting; (2) for each year, to attend either the National EMSP Workshop, or a Focus Area-specific Mid-Year Review; and (3) one or more extended visits (1 to 2 weeks in duration) to a cleanup site by either the Principal Investigator, or a senior staff member, or collaborator
- Budgets and Budget explanation for each collaborative subproject, if any
- Project Narrative (recommended length is no more than 20 pages; multi-investigator collaborative projects may use more pages if necessary up to a total of 40 pages)
- Goals
- Significance of Project to the EM Mission
- Background
- Research Plan
- Preliminary Studies (if applicable)
- Research Design and Methodologies
- Literature Cited
- Collaborative Arrangements (if applicable)
- Biographical Sketches (limit 2 pages per senior investigator)
- Description of Facilities and Resources
- Current and Pending Support for each senior investigator

APPLICATION CATEGORIES

In order to properly classify each application for evaluation and review, the documents must indicate the applicant's preferred scientific research field, selected from the following list.

Field of Scientific Research:

1. Actinide Chemistry
2. Analytical Chemistry and Instrumentation
3. Bioremediation
4. Engineering Sciences
5. Geochemistry
6. Geophysics
7. Hydrogeology
8. Interfacial Chemistry
9. Materials Science
10. Plant Science
11. Other

APPLICATION EVALUATION AND SELECTION

Scientific Merit

The program will support the most scientifically meritorious and relevant work, regardless of the institution. Formal applications will be subjected to scientific merit review (peer review) and will be evaluated against the following evaluation criteria listed in descending order of importance as codified at 10 CFR 605.10(d).

1. Scientific and/or Technical Merit of the Project
2. Appropriateness of the Proposed Method or Approach
3. Competency of Applicant's Personnel and Adequacy of Proposed Resources
4. Reasonableness and Appropriateness of the Proposed Budget

External peer reviewers are selected with regard to both their scientific expertise and the absence of conflict-of-interest issues. Non-federal reviewers may be used, and submission of an application constitutes agreement that this is acceptable to the investigator(s) and the submitting institution.

RELEVANCE TO MISSION

Researchers are encouraged to demonstrate a linkage between their research projects and significant contamination problems at DOE sites. Researchers can establish this linkage in a variety of ways, for example, by elucidating the scientific problems to be addressed by the proposed research and explaining how the solution of these problems could improve remediation capabilities. Of course, given the nature of basic research, there will not always be a clear pathway between research results and application to site remediation.

Subsequent to the formal scientific merit review, applications which are judged to be scientifically meritorious will be evaluated by DOE for relevance to the objectives of EMSP. DOE shall also consider, as part of the evaluation, program policy factors such as an appropriate

balance among the program areas, including research already in progress. Past research solicitations, abstracts, and research reports of projects funded under EMSP can be viewed at: http://emsp.em.doe.gov/researcher.htm.

APPLICATION GUIDE AND FORMS

Information about the development, submission of applications, eligibility, limitations, evaluation, the selection process, and other policies and procedures may be found in 10 CFR Part 605, and in the Application Guide for the Office of Science Financial Assistance Program. Electronic access to the Guide and required forms is made available via the World Wide Web at: http://www.science.doe.gov/production/grants/grants.html. DOE is under no obligation to pay for any costs associated with the preparation or submission of applications if an award is made.

SUBSURFACE CONTAMINATION RESEARCH NEEDS

This research Notice has been developed for Fiscal Year 2002, with the primary objective of providing continuity in scientific knowledge that will revolutionize technologies and clean-up approaches for solving DOE's most complex environmental problems. An overview of EMSP vadose and saturated zone research needs is summarized in this section based on the National Academy of Sciences, National Research Council (NRC) report published in 2000 titled "Research Needs in Subsurface Science." NRC recommendations for basic research focus in four areas:

- Location and characterization of subsurface contaminants and characterization of the subsurface
- Conceptual modeling
- Containment and stabilization
- Monitoring and validation

More detailed explanations of the nature and extent of environmental contamination throughout the DOE Complex, particularly at the six largest Field Offices, and reference web sites, can be found in the background section of this Notice. Interested investigators are referred to three web sites that provide information regarding subsurface contamination across the DOE Complex:

- Subsurface Contamination Focus Area (SCFA) at: http://www.envnet.org/scfa/ provides new science technologies, approaches, and technical assistance to address soil and water pollution, reducing the risk and cost of cleanup and stewardship. Researchers are invited to review the SCFA Product Lines and Technical Targets; the later is under development to strategically guide research and technology products to end-users. A few of the critical research areas included in the Technical Targets are: characterizing and monitoring the lateral and vertical extent of dense nonaqueous phase liquids (DNAPLs) transport; reactive materials for barrier systems that maintain permeability over time; biogeochemical processes leading to the mobilization/immobilization of the contaminants in soils and sediments, as well as the those factors controlling their bioavailability; and monitored natural attenuation processes and validation strategies.
- Idaho National Engineering and Environmental Laboratory lead an effort to develop a National Roadmap for Vadose Zone Science and Technology described at:

http://www.inel.gov/vadosezone/ to improve vadose zone characterization and to monitor and simulate subsurface contamination fate and transport, integrating the saturated zone.

- Idaho National Engineering and Environmental Laboratory's (INEEL) role as EM's Lead Lab is to ensure the integration of critical new science, technology, and programmatic solutions for cleanup and long term stewardship, described at: http://www.inel.gov/environment/em-lead.shtml.

There are about 6.4 billion cubic meters of contaminated soil, groundwater, and other environmental media at the DOE sites. Contaminants of concern across the Complex broadly include: radionuclides, metals, and dense nonaqueous phase liquids (DNAPLs). More specifically, key chemicals by group are:

- Radionuclides: plutonium, strontium-90, cesium-137, isotopes of uranium, trituim, thorium, technecium-99, radium, and iodine-129.
- Metals: lead, chromium VI, mercury, zinc, beryllium, arsenic, cadmium, and copper.
- DNAPLs: carbon tetrachloride, trichloroethylene, dichloroethylene, tetrachloroethylene, chloroform, dichloromethane, and polychlorinated biphenyls.

The life cycle costs for the Office of Environmental Management cleanup program have been estimated to be $147 billion between 1997 and 2070 (DOE 1998a). During this period of time, the EMSP research results can make a significant impact on reducing risks, costs, and cleanup schedules.

Details of the programs of the Office of Environmental Management and the technologies currently under development or in use by the Environmental Management Program can be found at: http://www.em.doe.gov and at the extensive links contained therein. The programs and technologies should be used to obtain a better understanding of the missions and challenges in environmental management in DOE when considering areas of research to be proposed.

Location and Characterization of Subsurface Contaminants and Characterization of the Subsurface

The challenges of locating and characterizing subsurface contamination are magnified by the wide range of contaminant types; the wide variety of geological and hydrological conditions across the DOE complex; and the wide range of spatial resolutions at which this contamination must be located and characterized, from widely dispersed contamination in groundwater plumes to small isolated hot spots in waste burial grounds. Basic research is needed to support the development of the following capabilities to locate and characterize contamination in the subsurface and to characterize subsurface properties at the scales that control contaminant fate and transport behavior:

- Improved capabilities for characterizing the physical, chemical, and biological properties of the subsurface.
- Improved capabilities for characterizing physical, chemical, and biological heterogeneity, especially at the scales that control contaminant fate and transport behavior. Approaches that allow the identification and measurement of the heterogeneity features that control contaminant fate and transport to be obtained directly (i.e., without having to perform a detailed characterization of the subsurface) are especially needed.

- Improved capabilities for measuring contaminant migration and system properties that control contaminant movement.
- Methods to integrate data collected at different spatial and temporal scales to better estimate contaminant and subsurface properties and processes.
- Methods to integrate such data into conceptual models.

Conceptual Modeling

Existing conceptual and predictive models have often proven ineffective for understanding and predicting contaminant movement, especially at sites that have thick vadose (unsaturated) zones or complex subsurface characteristics. Accurate conceptualizations are essential for understanding the long-term fate of contaminants in the subsurface and the selection and application of appropriate corrective actions. Basic research explicitly focused on fundamental approaches and assumptions underlying conceptual model development could produce a toolbox of methodologies that are applicable to contaminated sites both inside and outside the DOE complex. This research should focus on the following topics:

- New observational and experimental approaches and tools for developing conceptual models that apply to complex subsurface environments, including such phenomena as colloidal transport and biologic activity.
- New approaches for incorporating geological, hydrological, chemical, and biological subsurface heterogeneity into conceptual model formulations at scales that dominate flow and transport behavior.
- Development of coupled-process models through experimental studies at variable scales and complexities that account for the interacting physical, chemical, and biological processes that govern contaminant fate and transport behavior.
- Methods to integrate process knowledge from small-scale tests and observations into model formulations, including methods for incorporating qualitative geological information from surface and near-surface observations into conceptual model formulations.
- Methods to measure and predict the scale dependency of parameter values.
- Approaches for establishing bounds on the accuracy of parameters and conceptual model estimates from field and experimental data.

The research needs outlined above call for more hypothesis-driven experimental approaches that address how to integrate the understanding of system behavior. This research will require expertise from a wide range of disciplines and must be conducted at scales ranging from the laboratory bench top to contaminated field sites. Moreover, to have long-term relevance to the DOE cleanup mission, this research must be focused on the kinds of subsurface environments and contamination problems commonly encountered at major DOE sites.

Containment and Stabilization

There has been an increasing emphasis on, and acceptance of, waste containment and stabilization in recent years, both in DOE and by regulatory agencies. Decreasing cleanup budgets, evaluations that show containment is a low-risk choice for some problems, and recognition that some contamination cannot be remediated either with current technologies or conceivable new technologies are responsible for this change in philosophy. However, at some

sites, containment and stabilization may be an interim measure and has its own set of associated technical problems. There is little understanding of the long-term performance of containment and stabilization systems, and there is a general absence of robust and cost-effective methods to validate that such systems are installed properly or that they can provide effective long-term protection.

The construction of stabilization and containment systems is properly within the province of applied technology development. However, basic research focused on the following topics will be needed to support this technology development effort:

- The mechanisms and kinetics of chemically and biologically mediated reactions that can be applied to new stabilization and containment approaches (e.g., reactions that can extend the use of reactive barriers to a greater range of contaminant types found at DOE sites) or that can be used to understand the long-term reversibility of chemical and biological stabilization methods.
- The physical, chemical, and biological reactions that occur among contaminants, soils, and barrier components so that more compatible and durable materials for containment and stabilization systems can be developed.
- The fluid transport behavior in conventional barrier systems, for example, understanding water infiltration into layered systems, including infiltration under partially saturated conditions and under the influences of capillary, chemical, electrical, and thermal gradients can be used to support the design of more effective infiltration barrier systems.
- The development of methods for assessing the long-term durability of containment and stabilization systems.

Monitoring and Validation

Monitoring and validation are necessary at both the front and the back ends of the site remediation process. At the front end, monitoring and validation are used to support the development of conceptual and predictive models of subsurface and contaminant behavior. At the back end, monitoring and validation are used to demonstrate the effectiveness of efforts to remove, treat, or especially to contain contamination and to gain regulatory acceptance for such corrective actions. Moreover, such monitoring and validation efforts can also improve the understanding of the contaminant fate and transport processes and can be used to recalibrate and revise conceptual and predictive models— important elements of the model building process.

The ability to monitor and validate is essential to the successful application of any corrective action to a subsurface contamination problem and regulatory acceptance of that action. However, the knowledge and technology bases to support these activities are not fully developed and are receiving little attention in EM's science and technology programs.

Many of the research opportunities for monitoring and validation have been covered in the research emphases discussed above. Basic research is needed on the following topics:

- Development of methods for designing monitoring systems to detect both current conditions and changes in system behaviors. These methods may involve the application of conceptual, mathematical, and statistical models to determine the types and locations of observation systems and prediction of the spatial and temporal resolutions at which observations need to be made.

- Development of validation processes. The research questions include (1) understanding what a representation of system behavior means and how to judge when a model provides an accurate representation of a system behavior—the model may give the right answers for the wrong reasons and thus may not be a good predictive tool; and (2) how to validate the future performance of the model or system behavior based on present-day measurements.
- Data for model validation. Determining the key measurements that are required to validate models and system behaviors, the spatial and temporal resolutions at which such measurements must be obtained, and the extent to which surrogate data (e.g., data from lab-scale testing facilities) can be used in validation efforts.
- Research to support the development of methods to monitor fluid and gaseous fluxes through the unsaturated zone, and for differentiating diurnal and seasonal changes from longer-term secular changes. These methods may involve both direct (e.g., in situ sensors) and indirect (e.g., using plants and animals) measurements over long time periods, particularly for harsh chemical environments characteristic of some DOE sites. This research should support the development of both the physical instrumentation and measurement techniques. The latter includes measurement strategies and data analysis (including statistical) approaches.

BACKGROUND

The DOE has a 50-year legacy of environmental problems resulting from the production of nuclear weapons. Migration of some groundwater plumes threaten local and regional water sources, and in some cases, have adversely impacted off-site resources. The Department is responsible for the remediation of numerous landfills at facilities. These landfills are estimated to contain over three million cubic meters of radioactive and hazardous buried waste, some of which has migrated to the surrounding soils and groundwater. Currently available cleanup technologies are inadequate or unacceptable due to excessive costs, increased risks, long schedules, or the production of secondary waste streams.

Much of the defense-related contamination within the Department (the Complex has over 100 sites) occurs at six of the largest sites, as summarized below: Hanford, Washington; Idaho National Engineering and Environmental Laboratory (INEEL); Nevada Test Site (NTS); Oak Ridge Reservation (ORR), Tennessee; Rocky Flats Environmental Technology Site, Colorado, and Savannah River Site (SRS), South Carolina.

<u>Hanford Site, Washington</u>

Located in southeastern Washington State, Hanford encompasses 1450 square kilometers (km2). From 1940 to 1989, nuclear weapons production took place, leaving several production reactors, chemical separations plants, and solid and liquid storage sites. The unsaturated, or vadose zone, on the central plateau area is 60-90 meters (m) thick. Here, several trillion liters of contaminated water and supernatant liquid were discharged or gravity-settled via, basins, cribs, trenches, tanks, etc., causing ground water and soil contamination from radionuclides (primarily, tritium, uranium, cesium-137, strontium-90, technecium-99, and iodine-129), metals (e.g. chromium), and DNAPLs (e.g. carbon tetrachloride). Prior to the 1990s, it was thought that the sorption capabilities of the soil in the vadose zone would limit migration of radionuclides; however, recent conceptual and mathematical models indicate more rapid migration potential to the groundwater.

The DOE created the Groundwater/Vadose Zone Integration Project, described at: http://www.bhi-erc.com/projects/vadose to coordinate cleanup activities at Hanford. A number of projects were awarded in the 1999 EMSP Vadose Zone research call that were highly relevant to science needs at the Hanford site. DOE/Richland has identified important, current scientific issues for research that are not being addressed by others at the Hanford site, or within the current EMSP program. Resolution of these issues would advance the state of remediation and site closure at Hanford and other DOE sites as well. These scientific issues may be found in a briefing document at: http://www.bhi-erc.com/projects/vadose/sandt/stdocs.htm. A 2001 report by the National Academy of Sciences and the National Research Council, titled "Science and Technology for Environmental Cleanup at Hanford" presents the successes and improvement areas of the science and technology program in the Hanford cleanup. Interested investigators are also referred to the Fiscal Year 2001, Subsurface Contaminations Technology Needs list at: http://www.pnl.gov/stcg/fy01needs/ss/index.stm for a detailed description of site research needs.

Idaho National Engineering and Environmental Laboratory

Located west of Idaho Falls, Idaho, INEEL occupies 2,300 km2 of semi-arid desert along the northern margin of the Eastern Snake River Plain. The site was established as a building, testing, and operating station for various types of nuclear reactors and propulsion systems. Spent fuel from the naval reactor program is also managed there. Low levels of plutonium have been found in ground water beneath the Radioactive Waste Management Complex (RWMC)–a disposal site that received low-level and transuranic waste beginning in 1952. Pit 9, a trench within the RWMC, received an estimated 7,100 m3 of sludge and solids contaminated with plutonium and americium. Similar to Hanford, at the time, the thick (60-240 m) unsaturated zone of volcanic strata was thought to impede contaminant migration to the underlying aquifers. Estimates today indicate travel times of tens of years, as opposed to estimates made in the 1950s and 1960s of thousand-year travel times. Interested investigators are referred to the INEEL Science and Technology Needs list at: http://www.inel.gov/st-needs for a detailed description of fundamental science studies that will assist, accelerate, or reduce the cost of cleanup.

Nevada Test Site

The NTS became the primary location for atmospheric and underground nuclear testing in 1951. The Test Site occupies 3,500 km2 of land in southern Nevada, north of Las Vegas about 143 km. Surface and shallow soil are contaminated with americium, plutonium and depleted uranium, and with metals from nuclear detonations, safety test shots, and rocket engine testing. Underground nuclear testing resulted in over 300 million curies of subsurface contamination including, tritium, plutonium, uranium, cesium, strontium, and other fission products. Tritium plumes have been detected from testing locations because this radionuclide is very mobile in the water phase. Plutonium, once thought to be relatively immobile in groundwater due to low solubilities and strong sorption on mineral surfaces, was detected 1.3 km down gradient of the Benham test on Pahute Mesa, in a 600-m-deep monitoring well. The plutonium was detected on colloids, leaving open the question of the contribution of colloidal transport of plutonium versus the prompt injection effects of the detonation blast. Basic research in the mechanical and geochemical transport of plutonium is warranted. Other site-specific technology needs can be found at: http://www.nv.doe.gov/programs/envmgmt/blackmtn/TDSTCGTechnologyNeeds.htm.

Oak Ridge Reservation

Located about 10 km west of Knoxville, Tennessee, ORR was built originally to produce and chemically separate plutonium. Later, ORR produced isotopes and conducted isotopic and hazardous constituents research. ORR has three main facilities: the Oak Ridge National Laboratory supported plutonium production research and development, and the Y-12 and K-25 Plants produced highly enriched uranium via magnetic separation and gaseous diffusion, respectively. Wastes from these activities were placed in burial grounds, that have subsequently caused soil and water contamination in the Melton Valley Watershed, including strontium-90, tritium, cesium-137, and cobalt-60. Seepage from flooding of the waste trenches caused downgradient migration of radionuclides. The sediments behind White Oak Dam are significantly contaminated with radionuclides; White Oak Creek drains Melton Valley and the surface water contains tritium. Basic research is needed to better locate and characterize contamination hot spots in the burial grounds, as well as to improve the site conceptual and mathematical models, which include fractured-bedrock flow and karst hydrology. Containment systems, such as caps and barriers, and performance monitoring of engineered systems will be constructed under the cleanup program to verify and validate long-term performance and model results. Investigators are referred to the Technology Needs Database at: http://www.em.doe.gov/techneed to review Oak Ridge's needs list in the areas of characterization, treatment, storage, and disposal of hazardous and radioactive wastes.

Rocky Flats

Rocky Flats Environmental Technology Site is located on the western side of Denver, Colorado, and encompasses 140 hectares. Operations ceased in 1989 after years of fabrication and components assembly for nuclear weapons production. Materials used in these activities included plutonium and enriched uranium metals and oxides. Poor storage and disposal practices resulted in surface and groundwater contamination on and offsite, principally, soil contamination with americium, plutonium, and uranium. Cleanup and closure actions include removal and stabilization of contaminated media, construction of caps and barriers, and long term monitoring and surveillance. Investigators are referred to the Rocky flats website at: http://www.aimsi.com/rockyflats/ to review science and technology needs, as well as related information.

Savannah River Site

The SRS was established in 1950 near Aiken, South Carolina, to produce radioactive isotopes for use in nuclear weapons production. Encompassing 800 km2, the Site contains production reactors, chemical processing plants, and solid and liquid waste storage facilities. The Burial Ground Complex in the central part of SRS received low- and intermediate-level radioactive and mixed waste from 1952-1995. The source term of the waste is somewhat uncertain, and has leaked to groundwater creating plumes of hazardous chemicals, metals, and radionuclides. Closure of the Complex will include removal or stabilization of highly contaminated zones, an engineered and layered cover, possibly consisting of synthetic material, and long term monitoring and surveillance.

A persistent DNAPL plume of 140 hectares is associated with a manufacturing area in the northern portion of the site. From the 1950s to the 1980s, wastewater from fuel and target manufacturing seeped into the ground via an overflow basin, releasing solvents and heavy metals to the environment. A pump and treat system at the down gradient end of the plume controls spreading, 400 monitoring wells are used to collect data for surveillance and modeling. Site engineers and scientists continue to look for new technologies and methods to better characterize, describe, and remediate the plume and its source(s). Investigators are referred to the SRS website at: http://www.srs.gov/general/scitech/scitech.htm to review science and technology needs, as well as related information.

REFERENCES

Note: World Wide Web locations of these documents are provided where possible. For those without access to the World Wide Web, hard copies of these references may be obtained by writing Mark A. Gilbertson at the address listed in the FOR FURTHER INFORMATION CONTACT section.

DOE. 2001. A National Roadmap for the Vadose Zone Science & Technology. http://www.inel.gov/vadosezone/

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DOE. 1998b. Report to Congress on the U.S. Department of Energy's Environmental Management Science Program - April 1998. http://emsp.em.doe.gov/products.htm#rep

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National Research Council. 2001a. A Strategic Vision for Department of Energy Quality of Research and Development. National Academy Press, Washington, D.C. http://www.nap.edu/browse.html

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National Research Council. 2000. Research Needs in Subsurface Science, U.S. Department of Energy's Environmental Management Science Program. National Academy Press, Washington, DC. http://www.nap.edu/browse.html

National Research Council. 1997. Building an Environmental Management Science Program: Final Assessment. National Academy Press, Washington, D.C. http://www.nap.edu/browse.html

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Richland Environmental Restoration Project, Groundwater/Vadose Zone Integration Project http://www.bhi-erc.com/projects/vadose/

The Catalog of Federal Domestic Assistance Number for this program is 81.049, and the solicitation control number is ERFAP 10 CFR Part 605.

John Rodney Clark
Associate Director of Science
for Resource Management

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