

LETTER TO THE EDITOR

Letter to the Editor on A National Strategy for Vadose Zone Science and Technology

We would like to make your readers aware of the recently completed Department of Energy's (DOE's) National Roadmap for Vadose Zone Science and Technology, DOE/ID10871. This Roadmap was published in August 2001 at <http://www.inel.gov/vadosezone> (U.S. Department of Energy, 2001). Together with DOE's Subsurface Contaminant Focus Area Vadose Zone Science and Technology Solutions (Looney and Falta, 2000), the Roadmap represents an important step in developing a national science program necessary to implement, fund, and coordinate interdisciplinary research into vadose zone fluid flow and contaminant transport and fate.

A team of scientists from a spectrum of federal agencies, national laboratories, universities, and the private sector identified key areas of research necessary to improve our ability to predict and monitor vadose zone flow and transport. These categories include proposed research to: reveal the fundamental nature of complex processes and their interactions at various scales, develop sensors for characterization and monitoring, and enhance our computational capabilities to predict behavior and performance. Significant emphasis was placed on delineating laboratory and field research programs dealing with both porous and fractured media. Moving existing research and recent technology developments into common practice was identified as an important priority for early implementation.

The Roadmap outlines a long-term program that also has short-term potential benefits that cut across multiple federal and state agencies subsurface needs. Within DOE, the vadose zone research effort has the potential to benefit some of the ongoing environmental restoration projects as well as stewardship efforts. The broad scope of the research needs identified is applicable to many other programs, including the U.S. Environmental Protection Agency, Department of Defense, U.S. Department of Agriculture, and U.S. Geological Survey, among others.

In 1998, the National Academy of Science was asked by DOE to identify the most critical contamination problems within their complex of legacy sites, and to recommend a long-term basic research program to address the subsurface challenges. The report issued from the National Research Council (National Research Council, 2000) identified significant knowledge gaps that are impeding the Department's ability to clean up, stabilize, or contain subsurface contamination. The Roadmap is a significant step in developing a response to closing those gaps in the vadose zone.

The natural processes that occur in the vadose zone do not respect the traditional disciplinary divisions between geology, hydrology, soil science, chemistry, and biology. Realistically there must be a multidisciplinary character to what is being discovered, described, monitored and modeled in the vadose zone. To provide a complete picture of this interconnected system, researchers will need to interweave theory (understanding), characterization and measurement (factual description), and prediction and integration (numerical modeling)

across their traditional areas of expertise. The ultimate goal is to build a framework integrating geologic, hydrologic, chemical, and biologic properties and processes to allow scientists to quantitatively describe specific vadose zone environments. Their research will naturally fall into the following areas of understanding basic processes and obtaining basic data as identified in the Roadmap: Physical Description of Flow and Transport Processes, Chemical Transformations, Microbiology, Colloidal Formation and Transport, Multiphase Flow and Transport, and Unstable Processes.

It will be a long, gradual process before researchers can simulate and visualize the vadose zone of a contaminated site as an integrated system. Computations will be needed to interpret and reconcile data that was collected at different instrument support scales, collected over varying time periods, and collected at different spatial scales. For this task, a new and different set of tools will be needed which will help scientists transcend their customary disciplinary boundaries in gaining a systems perspective by combining the basics such as: Understanding Coupled Systems, Scaling Issues, Estimating and Reducing Uncertainty, Improving Site Monitoring Systems, and Integrating and Validating Site-Wide Models.

When funded, results of the research activities outlined above will be improvements in our understanding and our capability to monitor and model the fate and transport of subsurface contaminants. To pursue these activities effectively and achieve the anticipated results within reasonable time horizons, researchers need capabilities and facilities that do not yet exist. Some of these are unlikely to become available without concerted attention and directed resources. Others will become available much sooner, and provide a more powerful boost toward achieving major results, if they are developed systematically rather than emerging haphazardly. Key elements of infrastructure and supporting capability as discussed in the Roadmap include: A National Virtual Library, Sensor Instrumentation, Sensor Networks, Testing Facilities, The Problem-Solving Environment, Advanced Numerical Algorithms, and Highpower Computing Capability.

The technical content of the Roadmap is captured in 61 activities, most of which have associated tasks and status points within a time horizon of approximately 25 years. The details of the Roadmap activities provide the basis for selecting alternative research and development initiatives at any of the DOE sites—providing the basis for the development of a program plan for implementation.

Many of the near-term results expected for both the research and infrastructure activities share a common theme: moving the state of the art to the state of practice. This means getting the current knowledge and capabilities already existing in the vadose zone research communities into operational use at the nation's priority sites of vadose zone contamination. One benefit is that these tasks "pick the low-hanging fruit", providing quick returns because much of the research investment has already been made. A less obvious benefit is that concerted effort to get new knowledge and technical capability into practice will bring researchers and solution-oriented problem owners into continuing and close interaction.

For the mid term, the Roadmap outcomes of greatest significance are likely to be the cumulative advances in monitoring

systems for contaminated vadose zone sites. A sound and efficient monitoring program is critical at major sites during environmental cleanup and afterward, throughout any period of stewardship required by residual contamination on-site. The state of practice has been to monitor the groundwater at and around the site, rather than monitoring the vadose zone. However, for many sites where contaminants are at some distance from the water table, waiting until contaminants appear in the groundwater is less desirable than monitoring the vadose zone. If remediation can remove or isolate source terms and halt plumes while they are still in the vadose zone, groundwater contamination can be prevented. In addition, the effectiveness of the remediation is often greatly enhanced, and the cost significantly reduced, compared with groundwater remediation alternatives.

Many of the long-term results anticipated from the roadmap activities will provide better tools for supporting site-wide assessments and decisions on environmental cleanup and stewardship. Models and data gathering will undoubtedly improve incrementally in the near and mid term. However, after a decade or so of pursuing the Roadmap's activities, a quantitative leap forward (step change) is expected in the ability to visualize, quickly and accurately, the current and projected future states of site-wide vadose zone systems. These projections, which will carry levels of certainty and sensitivity unattainable at present, should help build the confidence of regulators and the public.

We invite the vadose zone research community to read,

understand, and support the implementation of the National Roadmap for Vadose Zone Science and Technology as a national research priority under a well-funded multi-agency research and development program.

Received 8 Nov. 2001

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- U.S. Department of Energy. 2001. A national roadmap for vadose zone science & technology understanding, monitoring, and predicting contaminant fate and transport in the unsaturated zone. Revision 0.0. DOE/ID-10871. Available on-line at <http://www.inel.gov/vadosezone> (verified 12 June 2002).