Final

**Technology and Risk Sciences Program
FY99 Annual Report**

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Technology and Risk Sciences Program Progress Report

1.0 Background

Developing innovative solutions for complex environmental problems requires integrating knowledge and the input from numerous scientific and technical disciplines. Data must be evaluated and communicated in a logical and understandable way to enhance its utility to a variety of audiences. The Entergy Spatial Analysis Research Laboratory (ESARL) was established in 1994 as a unit of the School of Public Health and Tropical Medicine, Tulane University Medical Center to respond to that challenge. Under the direction of Dr. James L. Regens, the Entergy Spatial Analysis Research Laboratory is committed, through its strategic planning to the establishment of internationally recognized research and educational programs. Over the last five years, ESARL has managed almost \$27 million in extramurally sponsored research funded by public and private sector clients. ESARL now maintains a diverse and growing research and development program that involves interdisciplinary teams and draws on experts from a variety of scientific and professional disciplines. The team's experience has allowed us to design an organization that fosters high-quality work performed on schedule and within budget. ESARL has developed a proven track record of conducting programs domestically and overseas.

ESARL provides a full range of state-of-the-art modeling, spatial analysis including [Geographical Information System (GIS)], and relational database management/integration capabilities to address complex environmental issues. ESARL utilizes computer hardware and software, logically structured databases, and spatial analysis expertise to create and evaluate risk scenarios, conduct predictive modeling, perform decision analysis, assess land use patterns, identify key uncertainties, delineate knowledge gaps, and evaluate technologies for environmental remediation.

To be successful in establishing and meeting realistic cleanup goals, DOE needs to develop a comprehensive understanding of the potential risks to human and ecological health at its sites as well as cost-efficient environmental management technologies so that cleanup activities can be appropriately directed. The Center for Risk Excellence (DOE/CH-CRE) is responsible for coordinating efforts to design and evaluate tools to support risk-based, cost-efficient environmental management to achieve this end. Under funding provided by Cooperative Agreement No. FC02-99CH110970, the Technology and Risk Sciences Program conducted by the Entergy Spatial Analysis Research Laboratory (ESARL) at Tulane University Medical Center is supporting the Center for Risk Excellence and DOE's mission. ESARL provides a university-based research and education program, incorporating peer-reviewed analyses, to identify, develop, evaluate, and communicate credible scientific information about significant risks and technology-based issues. The Technology and Risk Sciences Program is committed to expanding the knowledge base necessary to support the nation's environmental cleanup and policy agenda, and brings expertise and experience to bear in confronting the challenge of creating credible research, technology transfer, and educational programs that address environmental problems. TRSP's efforts help minimize risks, reduce costs, protect worker health and safety, create collaborative relationships with stakeholders and regulators, and focus technology development and deployment on cost and risk reduction. The scope of work under this cooperative agreement has built on the existing capabilities and high-value deliverables developed

through the Consortium for Environmental Risk Evaluation (CERE) under a prior cooperative agreement with DOE established in May 1994.

In conducting research and training projects, ESARL draws on the expertise of highly motivated faculty and staff with strong interdisciplinary backgrounds in statistics, modeling, spatial analysis, environmental remediation, geology, forestry, economics, engineering, policy analysis, and public outreach. ESARL faculty and staff have extensive experience conducting projects dealing with environmental restoration and waste management of radionuclides and hazardous chemicals, decontamination and decommissioning (D&D), demonstration and evaluation of environmental technologies, health and ecological risk assessment, occupational safety and health, spatial analysis (remote sensing/GIS/GPS), natural resources management, and environmental monitoring. Those projects have been conducted domestically and overseas for agencies of the U.S. Government, including the U.S. Department of Energy, National Institutes of Health, USDA Forest Service, and National Aeronautics and Space Administration, as well as commercial clients. Our experience and technical expertise allows ESARL's highly skilled faculty and staff to provide a full range of value-added project services. The following describes our FY99 projects conducted under Cooperative Agreement No. FC02-99CH110970. More details about ESARL's program are available on our web site: www.esarl.tulane.edu

2.0 Program Focus Areas and Accomplishments

In making the transition from weapons production to environmental restoration, DOE finds it needs to develop reliable means of defining and understanding health and environmental risks and of selecting technologies so that cleanup activities can be appropriately directed. Under the Technology and Risk Sciences Program, ESARL is focusing on activities in the areas of risk assessment methodologies and technology evaluation. These activities are contributing to DOE's effort by

- Designing mechanisms for filling data and risk assessment gaps
- Developing tools to integrate the evaluation of health and ecological risks into decision making
- Enhancing risk assessment infrastructure to expedite scientifically sound risk assessment
- Validating methods for risk assessment and technology evaluation
- Developing strategies and mechanisms for meaningful stakeholder involvement in the risk assessment, technology evaluation, and risk management processes

Through the Technology and Risk Sciences Project, ESARL continues to provide DOE with products that incorporate spatial analysis techniques in the risk assessment, communication, and management processes; design and evaluate methods for evaluating innovative environmental technologies; and collaborate and access technical information on risk assessment methodologies, including multimedia modeling and environmental technologies in Russia and the Ukraine. In addition, as a university-based

research and education program, ESARL is contributing to training and developing the skills of the next generation of scientists and environmental professionals.

Maintaining the technical and scientific quality of TRSP's work is essential for the Technology and Risk Science Program to help meet DOE's needs. All of the substantive efforts conducted under this cooperative agreement have been subjected to the review and guidance of an external review panel specifically selected for this program. Such external review is integral to designing, conducting, and providing an independent appraisal that will promote immediate scientific and public credibility and advance the ongoing national dialogue over environmental management at the weapons complex. It is a critical element of the QA/QC approach and provides a continuing review of the work product by peers from all of the relevant disciplines. Members of the independent science advisory committee have expertise in risk assessment, occupational health and safety, risk communication, environmental engineering, modeling, and environmental management.

TRSP SCIENCE ADVISORY COMMITTEE

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2.1 Risk Assessment Methodologies

The development and application of methods for health and ecological risk assessment represents one of the key ways to link an understanding of the dynamics of pollutant transport and fate within and across environmental media to the effects on human health or ecological receptors as the basis for risk management.

2.1.1 Risk-based Science and Technology Integration Project

The reduction of near-term risks and long-term management of residual risks associated with contaminated sites within the nuclear weapons complex is a major challenge facing the U.S. Department of Energy's Environmental Management Program. Numerous individual projects ranging from decommissioning nuclear reactors and other facilities to management of waste storage and disposal areas (i.e., underground tanks and past burial or discharge areas) and contaminants that have moved into and through the soil to groundwater and surface water have been proposed. Providing the analytical basis necessary to generate reliable estimates of risk as well as evaluate the effectiveness of remediation alternatives to support credible decision-making is a key driver for DOE's Environmental Management Science and Technology (S&T) program. Tulane University Medical Center, in collaboration with the Medical University of South Carolina and Argonne National Laboratory, participated in the Hanford Groundwater/Vadose Zone Integration Project and developed an integrated conceptual approach for identifying risk-based S&T requirements to support site decisions and assess long-term stewardship strategies.

Risk-Based Science and Technology Matrix

The approach developed a three-dimensional matrix as a device for identifying risk-based S&T information requirements and research priorities. The x-axis of the matrix is comprised of potential receptors and impacted resources. The y-axis is comprised of analytical elements that shape risk-based S&T needs. The z-axis of the matrix is comprised of the major contaminants and sources of exposure that define the hazards and potential for risk. Information obtained through a review of available data and documents combined with expert judgment was used to define the content of the cells in the matrix. Completion of the matrix produced an integrated risk-based S&T agenda reflecting key information gaps or uncertainties about potential risks to human health, the environment, cultural/social resources, and economic resources from contaminants at DOE sites. The requirement for developing tools to effectively communicate risks (y-axis) to human health (x-axis) from contamination impacting the vadose zone (z-axis) provides an example of the results of using this

approach to develop a risk-based S&T agenda.

This approach can be used to set a risk-based science and technology agenda for remediation and long-term stewardship. It also can help define uncertainties in existing knowledge. Identifying risk science and technology activities that address significant data gaps and uncertainties and then reducing those gaps and uncertainties by focusing S&T resources is central to producing reliable assessments of risk that support credible decision making. This approach was used to identify risk elements of the Hanford Groundwater/Vadose Zone Integration Plan's S&T Road Map. Because many significant risk issues cut across the nuclear weapons complex, the analysis has complex-wide utility for DOE's environmental management program.

Accomplishments

- Regens, J.L., P.L. Wilkey, R.E. Zimmerman, D.G. Hodges, L.C. Mohr, and G. Fleming, "A Risk-Based Approach for Setting an Environmental Science and Technology Agenda for the U.S. Department of Energy Nuclear Weapons," *Environmental Science and Pollution Research* (forthcoming).
- J.L. Regens, L.C. Mohr, P.L. Wilkey, E. Zimmermen, D.G. Hodges, G. Fleming, An Integrated Conceptual Approach to Setting a Risk-based Science and Technology Agenda, Tulane University Medical Center, Entergy Spatial Analysis Research Laboratory, New Orleans, LA , Report prepared for the U.S. Department of Energy Center for Risk Excellence, May 1999.
- P.L. Wilkey, J.L. Regens, D.G. Hodges, E. Zimmerman, G. Fleming, L.C. Mohr, Risk Science and Technology Element of the Applied Science and Technology Plan for the Hanford Groundwater/Vadose Zone Integration Project, Tulane University Medical Center, Entergy Spatial Analysis Research Laboratory, New Orleans, LA , Report prepared for the U.S. Department of Energy Center for Risk Excellence, February 1999.
- P.L. Wilkey, J.L. Regens, D.G. Hodges, E. Zimmerman, G. Fleming, L.C. Mohr, Risk Science and Technology Technical Report for the Hanford GW/VZ Integration Project, Tulane University Medical Center, Entergy Spatial Analysis Research Laboratory, New Orleans, LA , Report prepared for the U.S. Department of Energy Center for Risk Excellence, January 1999.
- J.L. Regens, D.G. Hodges, P.L. Wilkey, R.E. Zimmerman, L.C. Mohr, G. Flemming, "A Risk-Based Approach for Evaluating Science and Technology Priorities for Environmental Management at the U.S. Department of Energy Nuclear Weapons Complex," Proceedings of the 2nd ISTC/SAC Seminar, "Large Scale Area Remediation," Snezhinsk, Russia, 1999.
- Dr. Regens presented results of work supporting the Hanford Groundwater/Vadose Zone Project at the "International Symposium on Society and Resource Management" in Brisbane, Australia in July 1999. He was also invited to meet with officials of Australia's

Department of Environment and Heritage to discuss U.S. and Australian strategies for integrated resource management and long-term stewardship.

2.1.2 Risk Analysis and Visualization

Criteria for Multimedia Model Selection

Identifying the most significant risks to the public, workers, and the environment as DOE remediates its sites is a complex challenge. Computer-based multimedia models are key analytical tools for assessing potential present day as well as future human and ecological exposure to environmental contaminants. Multimedia models organize and summarize available knowledge about environmental settings, contaminant sources, pollutant transport through multiple media, and exposure pathways to estimate relative risk. These models can be used to (1) predict the movement of potentially toxic materials; (2) determine the exposure an individual might receive in a lifetime; and (3) estimate the health risk from that exposure. Our research team compared the performance and similarity of results of three major multimedia models—MEPAS, RESRAD, and MMSOILS—in two case studies using actual release site data from Oak Ridge National Laboratory and the Rocky Flats Environmental Technology Site.

**Rocky Flats, CO Conceptual Site Model:
VOCs in Groundwater and Air**

Building on the results of our multimedia model comparison effort, the Technology and Risk Sciences Program is integrating geographical information systems and multimedia modeling (using Access and Visual Basic programs) to develop an ArcView site characterization interface that allows the user to interactively visualize/characterize a waste site and view the results of a RESRAD run in ArcView. Earlier versions of multimedia models have traditionally lacked a visual component, a link between a Geographic Information Systems (GIS) and risk analysis. Integrating multimedia modeling into a GIS environment will allow for 1) incorporating spatial analysis techniques into the risk assessment, communication, and management process and 2) developing and applying methods that utilize GIS and other spatial analysis techniques to identify the distribution of contaminants and receptors and assess multipathway exposure patterns on a spatial and temporal basis. The prototype GIS interface will be used with RESRAD version 5.82, a multimedia model developed by Argonne National Laboratory. Through the proposed interface, the user can input parameters (e.g., contaminants, soil types); visualize spatially-related site characteristics (e.g., contaminant plumes); perform RESRAD analyses; and display results based on contaminants of concern, transport and exposure pathways, medium, and time.

Accomplishments

- *Designed PC-based demonstration version of preliminary graphics and database management modules*
- J.L. Regens, K.R. Obenshain, C.C. Travis, M. Clauberg. "Applying Multimedia Modeling to Karst Systems: Comparing MEPAS, MMSOILS, and RESRAD," *Environmental Geosciences* 1999; 6(3), pp. 115-122.
- C.C. Travis, K.R. Obenshain, J.L. Regens, C.G. Whipple. "Limitations of Multimedia

Interface windows (Arcview 3.0a, Microsoft Access 97, RESRAD version 5.82)

Models for Use in Environmental Decision Making," *Environmental Monitoring and Assessment* (forthcoming).

- J.L. Regens, C.C. Travis, K.R. Obenshain, C.G. Whipple, J.T. Gunter, V. Miller, et al. Multimedia Modeling and Risk Assessment. The Medical University of South Carolina Press, 1999.
- M. Clauberg and J.L. Regens, "Comparison of Multi-Media Model Results of the Consortium for Environmental Risk Evaluation," in A. Troge, ed., *Proceedings of the Concerted Action for Contaminated Sites in the European Union International Workshop on Risk Assessment Models and Risk Management for Contaminated Sites* (Berlin, Germany: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 1998), pp.121-131.
- Regens James L., Karen R. Obenshain, Curtis Travis, James T. Gunter, Vincent Miller. 1999. *Multimedia modeling of environmental restoration risks at Rocky Flats*. Presented at: Waste Management 99. Tucson, Arizona. February 28 – March 4, 1999.
- M. Clauberg and J.L. Regens, "Comparison of Multi-Media Model Results of the Consortium for Environmental Risk Evaluation," presented at the European Commission International Workshop on Risk Assessment Models and Risk Management for Contaminated Sites, Berlin, Germany, April 23-24, 1998.

2.2 Technology Evaluation

Environmental managers confront the challenge of making decisions to select and deploy remediation technologies to address a variety of problems. These choices are increasingly more complex because a greater variety of contamination problems are being defined and innovative technologies are becoming available as potential alternatives to existing technologies. Managers are further challenged because they are compelled to integrate information about relative risk into their considerations of remedial actions and also are required to balance information about technology performance and risk with fixed or limited budgetary resources and regulatory constraints. In addition, information about the concerns of stakeholders, as well as their meaningful involvement in the larger decision process, influences the ultimate technology selection and deployment decision. Environmental managers need better tools to help them assemble and synthesize information to design and implement risk-based, cost-effective environmental management decisions about remediation priorities and alternatives. Our research team has conducted a series of projects to develop decision support tools that help meet this important DOE need.

2.2.1 Project Screening Approach for Office of Science and Technology Peer Review

Evaluating technologies in terms of their capabilities for meeting remediation end points and long-term stewardship options is a major requirement of the U.S. Department of Energy's Environmental Management Program. The ability to conduct timely, independent peer review of Office of Science and Technology (OST) projects is a key element in meeting this requirement. However because of

conditions of constrained funding and time, there is a backlog of OST projects which never have been subjected to an external, independent peer review. Under the direction of the Director of the Center for Risk Excellence, who is the Peer Review Coordinator, a team consisting of personnel from the Center for Risk Excellence, ESARL, and Argonne National Laboratory was formed to develop a formal, pre-screening process that would identify OST projects which would benefit most from such a review prior to implementing an extensive peer review by the American Society of Mechanical Engineers.

Project Screening Relationship to Peer Review

The project screening approach developed provides an integrated decision support tool for assembling, synthesizing, and communicating information needed to support the allocation of limited peer review assets. It is a defensible, transparent, reproducible system designed to produce the greatest benefit from the application of limited peer review resources for OST projects. The project screening approach provides a mechanism for screening individual projects based on the quantitative criteria of total DOE investment in FY99 dollars, relevancy to DOE needs, and availability to meet schedule requirements. The three criteria are defined as follows:

- **Investment**—funding provided by DOE EM from the project inception through FY99 inclusive, allowing for the capture of possible gap funding and/or cost sharing by OST and other EM offices
- **Relevancy**—the degree to which a technology responds to one or more priority needs identified by a focus area
- **Availability**—whether the technology is scheduled for implementation prior to or when required as identified in the Needs Management System

Project Screening Approach Criteria

Measures for each criterion were computed through associated indicators (DOE funding, relevance index, and schedule status, respectively).

The project screening approach provides a consistent appraisal of OST technology projects. The output generated by the project screening approach supports FA managers' identification of new or continuing active projects that maximize benefits from the application of limited peer review resources. The screening approach integrates information about project status into the overall peer review process while maintaining existing responsibilities.

The initial application of the project screening approach concentrated on active technology projects managed by the Focus Areas. The output from the project screening approach will be used to support FA managers' recommendations of projects for peer review in the FY 2000 peer review cycle.

Process Flowchart for the Project Screening Approach

Accomplishments

- P.L. Wilkey, J.L. Regens, M.C. Dionisio, E. Zimmerman, Project Screening Approach for the Office of Science and Technology Peer Review Program, DOE/CH/CRE-3-1999, Center for Risk Excellence, September 1999.
- J.L. Regens et al, "A Project Screening Approach to Prioritizing Environmental Management Technology Review," to be presented at Waste Management 00, Tucson, Arizona, February 27-March 2, 2000.

2.2.2 U.S.-Russian Initiatives for Environmental Remediation

The Russian Federation confronts significant scientific and technical challenges in terms of developing cost-efficient, risk-based strategies to utilize environmental technologies for cleanup and long-term stewardship at the Russian Federation nuclear weapons complex. The end of the Cold War and the ensuing collapse of the Soviet Union has created unique opportunities for scientists and engineers in the former Soviet nuclear weapons complex to collaborate in developing, evaluating, and commercializing promising environmental technologies and risk assessment methodologies. ESARL, in collaboration with Argonne National Laboratory, is participating in U.S.-Russian projects which will foster such opportunities for mutually beneficial collaboration. These projects support the U.S. Government's cooperative threat reduction program. Support for Russian participation is provided by the International Science and Technology Center (ISTC), including Project #787 which focuses on designing and developing new polyfunctional compounds for remediation of radionuclide, heavy metal, and organic contamination.

December 1998 Meeting at Tulane University Medical Center

ESARL has established relationships and enjoys ongoing cooperation with a number of key Russian government institutions, including the Ministry of Russian Federation for Atomic Energy (Minatom), the Kurchatov Institute, the Russian Federal Nuclear Research Center (Chelyabinsk-70), Nuklide, and the Medical Radiological Scientific Center of the Russian Academy of Medical Sciences. For example, we are collaborating with the Russian Federal Nuclear Center on projects related to innovative technologies for disposing of radioactive waste and risk assessment of sites that compose the Russian nuclear weapons complex. We have established a basis for scientific and technical cooperation with the Russian Academy of Sciences (Far East Branch) which is involved in the development and deployment of innovative technology for disposing of liquid radioactive waste generated by the Russian Navy's Pacific Fleet. Additionally, we established a working relationship with the Ukrainian Center of Radiation Medicine in Kiev. Dr. Regens also is a scientific collaborator on an International Scientific and Technical Center project (Project #KR-072) focusing on the identification of spatial distribution of radioactive and heavy metals tailing storage sites in Northern Kyrgyzstan. Project objectives include measuring the total gamma radioactivity and the content of heavy metals.

Activities for this initiative include a series of small group, interactive workshops coupled with scientific exchanges to (1) identify and access Russian innovative technologies, (2) review the state-of-the-art for risk assessment, and (3) improve understanding of the technical and scientific infrastructure requirements to support long-term stewardship. Workshop locations alternate between the U.S. and Russia. Workshops have been held at Tulane University Medical Center in New Orleans, LA, USA; Argonne National Laboratory in Chicago, IL, USA; and in Snezhinsk, Russia.

Accomplishments

- J.L. Regens, D.G. Hodges, P.L. Wilkey, R.E. Zimmerman, L.C. Mohr, G. Flemming, "A Risk-Based Approach for Evaluating Science and Technology Priorities for Environmental Management at the U.S. Department of Energy Nuclear Weapons Complex," presented at the 2nd ISTC/SAC Seminar on Large Scale Area Remediation sponsored by the Russian Federal Nuclear Center, Institute in Technical Physics (RFNC-VNIITF), Snezhinsk, Russia, June 1999.
- Zimmerman J.L. Regens, P.L. Wilkey, "Multiparametric Tool for Evaluation of the Development and Deployment of Innovative Remediation Technologies," presented at the 2nd ISTC/SAC Seminar on Large Scale Area Remediation sponsored by the Russian Federal Nuclear Center, Institute in Technical Physics (RFNC-VNIITF), Snezhinsk, Russia, June 1999.
- Researchers from Tulane University Medical Center; Argonne National Laboratory; IVA-Ural State Economic University; and the Russian Nuclear Research Center, Institute of Technical Physics met in Chicago in February 1999 and November 1999. The joint collaborative effort produced an invention disclosure for a wide-spectrum chemical analyzer that can detect, measure, and differentiate metals in aqueous phase and volatile organics in gaseous phase.

- ESARL hosted a two-day workshop for senior Russian scientists, led by Academician Evgeny Avrorin, Scientific Director of the Russian Federal Nuclear Center-Zababakhin Institute of Technical Physics (VNIITF), and representatives of Argonne National Laboratory and the U.S. Department of Energy in December 1998.
- Dr. Regens has presented Guest Seminars on strategies for radioactive waste management and risk assessment at a number of Russian institutes, including the RCC Kurchatov Institute, the All-Russian Research Institute of Chemical Technology, and the Zelinsky Institute of the Russian Academy of Sciences.
- Dr. Regens was invited to participate in the 3rd International Conference on Ecology and Development of the Russian Northwest Region, sponsored by the International Academy of Ecology, Man and Nature Protection Services; RF Ministry of Atomic Energy, RF Ministry for Emergency Situations; and the Russian Academy of Sciences.

2.2.3 Tools for Evaluating Environmental Technology

ESARL led a university-national laboratory-consulting firm team in developing a Technology Evaluation Framework to identify and compare information about conventional and innovative technologies for environmental remediation. The Technology Evaluation Framework provides a standardized process that allows environmental managers to integrate the diverse factors that influence the selection and deployment of environmental technologies. Eight measurable criteria with specific indicators are employed to assess the capability of a technology or suite of technologies to address environmental restoration problems on a site-specific basis.

Technology Evaluation Framework Criteria

The Technology Evaluation Framework does not employ a series of preassigned weights for each of the criteria. Instead, it represents a flexible approach, allowing trade-offs among the eight criteria on the basis of site-specific needs, such as temporal or physical constraints, schedule demands, and funding profiles. Environmental managers can use the Technology Evaluation Framework to assess the effectiveness of individual technologies or remedial alternatives, which may consist of various technologies or suites of technologies, in meeting site-specific goals. The Technology Evaluation Framework enables environmental managers to identify and systematically compare information about the ability of innovative and conventional technologies to meet remediation goals for their site. The completed Framework provides the environmental manager with a documented, reproducible evaluation, which can be updated as new information becomes available.

Environmental Technology Evaluation Data Sheet: Site X - Groundwater Treatment

TECHNOLOGY A	TECHNOLOGY B	TECHNOLOGY C
Details regarding technology deployment	Details regarding technology deployment	Details regarding technology deployment

Criteria and Indicators	Technology A	Technology B	Technology C
Technical Performance			MEDIUM
Effectiveness			
Implementability			
Reliability			
Life-Cycle Cost			
M&I Cost	\$450,000	\$300,000	\$253,000
Capital Cost	\$3,001,000	\$2,847,000	\$914,000
OGM Cost	\$5,076,000	\$2,153,000	\$3,232,000
Total Cost	\$8,527,000	\$5,300,000	\$4,399,000
Process Residuals	IN PROCESS LOW	IN PROCESS LOW	IN PROCESS LOW
System Capacity			MEDIUM
Research Feasibility			
Permitting Experience			
Permit Modifications			
Risk			
Relative Risk Reduction		MEDIUM	MEDIUM
Exposure Risk			
Transportation Risk	MEDIUM		
Site Safety Risk			
Future Use	Technology C	Technology B	Technology A
Future Land Use	Technology C	Technology B	Technology A
Natural Resource Damages			
Natural Resource Damage Mitigation			
Stakeholder Concerns			
Performance	NO	NO	NO
Cost	NO	NO	NO
Risk	YES	YES	YES
Process Residuals	YES	NO	NO
Natural Resource Damages	YES	YES	YES
Environmental Justice	NO	NO	NO
Total Issues	YES	YES	YES

NOTE: For those indicators that are color-coded, green indicates the technology has a desirable rating for that attribute, yellow indicates a medium rating, and orange indicates an undesirable rating.

Example of Environmental Technology Evaluation Data Sheet

The pilot application of the Framework utilized data from three DOE and one DoD installation to evaluate technologies for containment and treatment of soil and groundwater contaminated by TCE. Although the Framework was developed for DOE, it has far-ranging potential for application as a management tool in the private sector and for other federal facilities.

In addition, ESARL co-sponsored the "Development and Application of Environmental Technologies for Federal Facilities Cleanup: Issues and Opportunities for Indian Tribes" workshop organized by the International Institutes for Indigenous Resource Management. Additional co-sponsors included the Council of Energy Resource Tribes; the U.S. Environmental Protection Agency, Office of Federal Facilities Restoration and Reuse and Office of Solid Waste, Emergency Response; the U.S. Department of Energy, Center for Risk Excellence; and the National Indian Business Association. The facilitated workshop brought together Tribal Council members, attorneys, natural and cultural resource specialists and environmental protection professionals to 1) help tribal professional staff and decision makers gain and understanding of characterization, remediation, and monitoring technologies; 2) provide tribal professional staff and decision makers with the tools they need to knowingly and intelligently participate in technology selection decisions; 3) help federal facility managers, regulators, and technology developers appreciate the wide range of tribal interests that can be affected by technology development and deployment decisions; 4) help federal facility managers and regulators understand the legal drivers that require consideration of tribal interests in technology development and deployment decisions; and 5) spur tribal-federal-private partnerships around the planning, research, development, testing, and fabrication of environmental technologies. At the workshop, interest was expressed in using the Technology Evaluation Framework, or a modification of it, for assisting Tribal governments in participating in technology development and deployment decisions.

Accomplishments

- James L. Regens, Patrick L. Wilkey, Eugene A. Hughes, Donald G. Hodges, Anthony Q. Armstrong, Linda Kelley, Eric Zimmerman, and Al J. Unione. "An Integrated Framework for Environmental Technology Evaluation" Prabhu Dayal, ed., Innovative Remediation Technologies (forthcoming).
- Regens, J.L., R.E. Zimmerman, P.L. Wilkey, D.G. Hodges, A.Q. Armstrong, and L. Kelley. "Evaluating Environmental Technology for Meeting Remediation End Points and Long-Term Stewardship Options," *Environmental Science and Pollution Research* (forthcoming).
- J.L. Regens, "Tools for Evaluating Environmental Management Technologies" presented at the Development and Application of Environmental Technologies for Federal Facilities Cleanup: Issues and Opportunities for Indian Tribes Workshop sponsored by the International Institutes for Indigenous Resource Management et al, Denver, December 1999.
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- J.L. Regens, D.G. Hodges, L. Kelley, T.A. Sands. "Site Remediation Technologies," *The Military Engineer* 1999; 91(601), pp. 57-58.
- J.L. Regens, D.G. Hodges, P.L. Wilkey, L. Kelley, E. Zimmerman, A.Q. Armstrong, L. Kelley, et al. "Integrated Framework for Evaluating Subsurface Contamination Remediation Technologies," *Environmental Geosciences* 1999; 6(2), pp. 82-87.
- Regens, J.L., D.G. Hodges, P.L. Wilkey, E. Zimmerman, A.Q. Armstrong, L. Kelley, T.A. Hall, and E.A. Hughes, "Screening Technologies for Soil and Groundwater Remediation," *Soil & Groundwater Cleanup* 1999; pp. 24-27.
- J.L. Regens, D.G. Hodges, P.L. Wilkey, L. Kelley, A.Q. Armstrong, R.E. Zimmerman, et al. An Integrated Framework for Environmental Technology Evaluation. The Medical University of South Carolina Press, 1999.
- J.L. Regens, D.G. Hodges, P. Wilkey, L. Kelley, A. Armstrong, E. Zimmerman, T.A. Hall, and E.A. Hughes, "Integrated Framework for Assessment of Site Remediation Options," presented at the Waste Management 98 Symposium, Tucson, March 1-5, 1998.

2.3 Training and Education in Environmental Health Sciences

Research universities are uniquely positioned to play a significant role in building the fundamental knowledge base necessary to support the nation's environmental clean up and policy agenda by training the next generation of scientists and environmental professionals. Through advanced education and research in such fields as health sciences, ecology, and environmental engineering, they potentially represent a major source of intellectual talent for meeting the challenge of making risk-based decisions grounded in credible, technical information.

Transforming that potential into a reality will require society to sustain active investment in supporting research and educational activities. That investment in fundamental research and training is important for several reasons. First, developing a credible scientific and technical base for remedial actions and long-term stewardship rests on improving existing knowledge and understanding. Second, DOE and its stakeholders are likely to enhance their ability to set priorities and make tradeoffs among alternatives as DOE becomes better informed about the public's concern and stakeholders become more capable of making informed judgements on probable risks. Third, the workforce of trained professionals necessary to design and implement programs will come from the current generation of students and junior faculty. Providing opportunities for junior faculty and graduate students to apply their academic training to real world projects is critical to sustaining and enhancing the knowledge base and pool of professionals that will be needed to develop and implement effective solutions to complex and often contentious problems.

Through its cooperative agreements with DOE, ESARL, as a unit in the School of Public Health and Tropical Medicine at Tulane University Medical School, has participated in training professionals to meet those needs. Using an interdisciplinary approach to environmental health sciences, ESARL provides opportunities to develop an in-depth understanding of the principles and application of analytical skills for risk assessment and environmental remediation. The Technology and Risk Science Program has used Tulane University as the integrating entity for a nation-wide initiative, bringing together nationally recognized experts from universities, national laboratories, and the private sector to address focused tasks. Tulane University has formed partnerships to focus the best technical minds on DOE's environmental problems, while utilizing high levels of quality control and review so as to ensure scientifically credible conclusions. Through these partnerships, ESARL has provided opportunities for graduate students and junior faculty to develop collaborative and mentoring relationships with professionals nation-wide, and even internationally.

ESARL has supported 3 post-doctoral fellows and 31 doctoral and master's candidates. In addition, ESARL has published numerous books, peer-reviewed articles, and presented research results at national and international professional conferences. (See Section 4.0.)

3.0 Path Forward

Our activities in FY99 demonstrate a strong and continuing record of research productivity. ESARL has been successful in maintaining a high level of publication in peer review journals, collaboration with national laboratories and other academic institutions, and mentoring of graduate students and post-doctoral fellows. The partnership with DOE's Center for Risk Excellence has been instrumental in sustaining our success.

The primary goal in FY00 is to enhance our contributions to developing and applying credible scientific approaches with meaningful stakeholder involvement, to assess technology performance, evaluate risks, estimate life cycle costs, and analyze public concerns linked to the cleanup of the DOE nuclear weapons complex. ESARL envisions expanding collaboration with national laboratories as a crucial step in meeting this goal. For example, we are exploring working with Los Alamos National Laboratory to use that site for the pilot application of the risk analysis and visualization model. ESARL similarly is building on our existing relationship with Argonne National Laboratory to leverage opportunities for joint work in the area of technology evaluation and application. We also anticipate continuing to work with CRE to design tools and methodologies that support EM's decision making process. Given our unique and well-established relationships, ESARL also anticipates ongoing collaboration with senior scientific and technical counterparts in the Russian Federation in the areas of risk assessment and technology evaluation.

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