United States
Environmental
Protection Agency

Science Advisory
Board (A-101)

EPA-SAB-EEC-93-008
April 1993

EPA

AN SAB REPORT: REVIEW OF THE UNDERGROUND STORAGE TANK RESEARCH PROGRAM

REVIEW OF THE OFFICE OF RESEARCH AND DEVELOPMENT UNDERGROUND STORAGE TANK RESEARCH PROGRAM

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

EPA-SAB-EEC-93-008

OFFICE OF THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

April 15, 1993

Honorable Carol M. Browner
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Subject: Science Advisory Board Review of the Underground Storage Tank Research Program

Dear Ms. Browner:

The Science Advisory Board (SAB) is pleased to submit its report on the review of the Office of Research and Development's (ORD) May 1992 draft document entitled "Underground Storage Tank Research Program, Volumes I and II." This report resulted from a review meeting on June 29 and 30, 1992 by the Underground Storage Tank Research Subcommittee (USTRS) of the SAB's Environmental Engineering Committee (EEC). The USTRS also received supplements containing a Volume III document of the Risk Reduction Engineering Laboratory (RREL) of Edison, NJ and an overview document of the Environmental Monitoring Support Laboratory (EMSL) of Las Vegas, NV. It is significant to note that, other than an earlier review on the UST release simulation model (See EPA-SAB-EEC-88-029, April 15, 1988), this is the first truly comprehensive review of the UST research program since its inception nearly seven years ago. Consequently, this SAB report is more detailed than is typical of research-in-progress reviews.

Several million underground storage tanks (USTs) containing petroleum products and hazardous chemicals have been installed nationwide. National surveys have revealed that several hundred thousand of these tanks have either been abandoned, exceeded their useful lives, or are leaking, thus posing potential serious threats to surface and ground waters. Therefore, it is evident that the ORD research on USTs takes on major national significance in terms of improvements in UST leak detection, reporting, monitoring, guidance for site

assessment and corrective actions, tank closures at sites where leaks have occurred and standards for installation and monitoring of new tanks.

The staffs of both ORD laboratories are to be commended for preparing and presenting thorough and well-conceived documents. Based on an evaluation focused on technology and its transfer to the user community, including research on leak prevention, detection, monitoring and remediation, the major findings and recommendations of the Subcommittee are as follows:

1) It was apparent from the documents and supplemental information that the organization and decision processes used to identify broad areas of research focus were deliberate and productive. Clarification of the criteria used to select research areas in preference to others of promise, such as bioremediation or Ground-Penetrating Radar (GPR), is recommended. Moreover, the Subcommittee endorses the continuation of a proactive research approach which encourages development and application of innovative technologies.

2) Past emphasis on applied research should be continued. The applied research program being conducted is scientifically sound and of value to the user community. Overall good basic and applied science is being practiced by both external researchers and EPA/ORD personnel, and the selection of projects is generally appropriate. Moreover, the Subcommittee recognizes that the Risk Reduction Engineering Laboratory (RREL) in Edison has historically concentrated on internal leak detection, and more recently on corrective action technology evaluation, while the Environmental Monitoring Systems Laboratory (EMSL) in Las Vegas has mainly concentrated on applied monitoring research, including external leak detection, and more recently on site investigation techniques and measurements to support in situ remediation technologies. Both the RREL-Edison and the EMSL-Las Vegas laboratories need to participate in the conduct of more research to improve the understanding of basic concepts, contaminant dynamics, and other governing factors affecting fate and transport in the subsurface environment, including the properties of petroleum and hazardous products, the mechanisms affecting movement and disposition, and the behavior of non-aqueous phase liquids (NAPLs) on the water table surface under fluctuating water table conditions. To maximize the benefits of this initiative, coordinated planning of the respective research agenda and technology transfer programs between RREL and EMSL is recommended.

3) The investments by the ORD EMSL and RREL laboratories in research facilities, such as the UST Test Facility and Large Experimental Aquifer Program (LEAP) for UST issues, have been timely and appropriate. Continued utilization of these facilities for basic and applied research is highly recommended by the Subcommittee. These unique facilities provide a special capability to investigate new and improved techniques for assessing and evaluating the structural integrity of UST systems, fate and transport processes and remediation technologies.

4) In view of the ORD emphasis on rapid, real-time site assessment, the Subcommittee recommends that there needs to be a more systematic and thorough investigation into non-invasive site investigation techniques. Although fast characterization was highlighted, the methods developed or described were more traditional, slower, and invasive. Other currently used methods, including GPR, together with further development of the LOCI conceptual model for data interpretation, could make significant contributions to progress in site assessment.

5) One of the products of the research agenda was the use of passive acoustic systems for locating leaks in UST pipelines. The Subcommittee recognizes that there is a need to demonstrate the effectiveness of signal processing in various noisy conditions as well as under clayey or heterogenous conditions in order to establish the limits of the technique, its sensitivity and resolution, and circumstances under which the technique is applicable.

6) Development of the RREL LOCI conceptual model as a teaching, demonstration, and remedial guidance tool is commendable. The Subcommittee recommends that it be publicized and made available, not only within the program, but to other Agency programs (e.g., Superfund) and state and local units of government.

7) A greater emphasis on prevention as an ethic is advocated by the Subcommittee. Specifically, the corrosion protection retrofit research proposed for 1994-95 should be initiated as soon as possible, and the certification program for tank testers should be expanded to those providing tank specifications and installations. This information will be very important to tank owners that will be replacing or retrofitting tanks based on the 1998 deadline.

8) The Subcommittee recommends that a field performance database be developed and made available to program users to aid in determining the

effectiveness of "real-world" systems. For instance, past research has attempted to improve understanding of liquid and vapor transport in the subsurface, and has provided a basis for evaluation of UST leak detection equipment, including both internal and external leak detection devices. Field studies of cleanup technologies at actual UST sites should be conducted to improve the design and application of existing techniques, as well as to encourage development and use of innovative technologies. Moreover, the magnitude and effects of risks posed to ground water by UST hydrocarbon residuals after remediation need to be established and compared to those associated with the relatively few National Priorities List (NPL) sites.

9) A fractured rock research program area has been proposed with results to be delivered in 1996. The Subcommittee recommends that preliminary research efforts should focus on locating some of the many fractured rock remediations currently or soon to be underway, so that additional monitoring instrumentation required for research purposes could be installed and appropriate field data collected. Such an approach is consistent with the EPA "open windows" policy and can be used to develop projects to address limitations uncovered in current remediations.

10) The Subcommittee recognizes that users can benefit and derive value from completed research only if they are informed, trained and made aware of results in a timely manner. Therefore, it is of utmost importance that a central coordination and support of conferences, seminars and workshops, as well as training, be provided and funded as a separate project item.

11) It is recommended that an expanded technology transfer program be established between RREL and EMSL, and that the results of the respective research programs be published in authoritative, broad-based, widely recognized and peer-reviewed journals so that maximum benefit from the collective research initiatives can be realized.

These recommendations are made with the view that this is a first evaluation of an important research area, and in anticipation that the research program will be thereby guided and enhanced. We are pleased to have had an opportunity to conduct this review and to be of service to the Agency, and look forward to your response to the findings in this report.

Sincerely,

Dr. Raymond C. Loehr, Chair
Executive Committee
Science Advisory Board

Mr. Richard A. Conway, Chair
Environmental Engineering Committee
Science Advisory Board

Dr. Frederick G. Pohland, Chair
Underground Storage Tank Research
Subcommittee
Environmental Engineering Committee
Science Advisory Board

NOTICE

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ABSTRACT

The Underground Storage Tank Research Subcommittee (USTRS) of the Environmental Engineering Subcommittee (EEC) of the Environmental Protection Agency's (EPA) Science Advisory Board (SAB) has prepared a report on the Agency's underground storage tank (UST) research program. The USTRS met on June 29 and 30, 1992 and reviewed the Agency's UST research-in-progress, as well as plans for future UST-related research.

The USTRS found that the Risk Reduction Engineering Research Laboratory (RREL) at Edison, NJ and the Environmental Monitoring and Support Laboratory (EMSL) at Las Vegas, NV prepared and presented thorough and well-conceived documents. The USTRS commented on broad research topics, as well as specific projects, pointing out other areas of promise, such as bioremediation and ground-penetrating radar, and cited the need for more research on the basic concepts of contaminant dynamics and other factors affecting fate and transport in the subsurface environment, the properties of petroleum products, and the behavior of non-aqueous phase liquids (NAPLs). The USTRS commended the development and use of the LOCI conceptual model as a teaching or demonstration tool, and recommended its wider application, especially in state and local government and other agency programs.

The USTRS cited, among a number of other recommendations, the need for coordination and more systematic technology transfer activities between the laboratories, development of more non-invasive real-time site assessment techniques, emphasis on corrosion retrofit research and leak prevention, and identification and evaluation of currently practiced as well as new and improved cleanup technologies. These recommendations were made toward the entire UST research effort, in an effort to improve an already well-designed program in an important research area.

Key Words: Underground Storage Tanks (UST), UST research, leaking UST

U.S. ENVIRONMENTAL PROTECTION AGENCY
Science Advisory Board
Environmental Engineering Committee
Underground Storage Tank Research Subcommittee

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1. EXECUTIVE SUMMARY

On June 29 and 30, 1992, the Underground Storage Tank Review Subcommittee (USTRS) of the U.S. Environmental Protection Agency's (EPA's) Science Advisory Board (SAB) Environmental Engineering Committee (EEC) met to conduct a review of the Office of Research and Development (ORD) Underground Storage Tank (UST) Research Program, which was developed in conjunction with the Office of Underground Storage Tanks (OUST). The Subcommittee reviewed a two-volume set of documents entitled "Underground Storage Tank Research Program" (See Appendix A; References 1 and 2), and presentations (See Appendix A; References 3 and 4) by U.S. EPA RREL-Edison staff and EMSL-LV staff and extramural researchers funded by cooperative agreements. At the meeting, the Subcommittee presented a general debriefing to Agency staff concerning its findings. This report to the U.S. EPA Administrator completes the review process.

In general, the USTRS commends the Office of Underground Storage Tanks, the Risk Reduction Engineering Laboratory of Edison, NJ, and the Environmental Monitoring Systems Laboratory of Las Vegas, NV for thorough and well-conceived documents of their respective research programs. The two-volume set of documents and two volumes of supporting information were considered by the Subcommittee to be extremely useful in its review. The follow-up staff presentations were designed to further expand on selected project efforts and underlying science. It is significant to note that, other than an earlier review on the UST release simulation model (See Appendix A; Reference 12), this is the first truly comprehensive review of the UST research program since its inception nearly seven years ago. Consequently, this SAB report is more detailed than is typical of research-in-progress reviews. Specific findings and recommendations are as follows:

a) It was apparent from the documents and supplemental information that the organization and decision processes used to identify broad areas of research focus were deliberate and productive. Clarification of the criteria used to select research areas in preference to others of promise, such as bioremediation (See Appendix A; Reference 11) or Ground-Penetrating Radar (GPR), is recommended. Moreover, the Subcommittee endorses a continuation of a proactive research approach which encourages continued development and application of innovative technologies.

b) Past emphasis on applied research should be continued. The Subcommittee recognizes that this applied research program being conducted is scientifically sound, and the resultant information is of value to the user community. Overall good basic and applied science is being practiced by both external researchers and EPA/ORD personnel, and the selection of projects is generally appropriate. Moreover, the Subcommittee recognizes that the Risk Reduction Engineering Laboratory (RREL) in Edison has historically concentrated on internal leak detection, and more recently on corrective action technology evaluation, while the Environmental Monitoring Systems Laboratory (EMSL) in Las Vegas has mainly concentrated on applied monitoring research, including external leak detection, and more recently on site investigation techniques and measurements to support in situ remediation technologies. Both the RREL-Edison and the EMSL-Las Vegas Laboratories need to participate in the conduct of more research to improve the understanding of basic concepts, contaminant dynamics, and other governing factors affecting fate and transport in the subsurface environment, including the properties of petroleum and hazardous products, the mechanisms affecting their movement and disposition, and the behavior of non-aqueous phase liquids (NAPLs) on the water table surface under fluctuating water table conditions. Advantage should be taken of site characterization and remediation work already completed or in progress, and a comprehensive effort to communicate the current state-of-technology to the user community needs to be provided.

c) The investments by the ORD EMSL and RREL laboratories in research facilities, such as the UST Test Facility and the Large Experimental Aquifer Program (LEAP), for UST issues have been timely and appropriate. Continued utilization of these facilities for basic and applied research is highly recommended. These unique facilities provide a special capability to investigate new and improved techniques for assessing and evaluating the structural integrity of

UST systems, fate and transport processes, and remediation technologies.[1]

d) In view of the ORD emphasis on rapid, real-time site assessment, and with due cognizance of limited resources, identification of the best performing technologies and associated standard protocol requirements should be coupled with a more systematic and thorough investigation into the realities of non-invasive site investigation techniques. Although fast characterization was highlighted, the methods developed or described were more traditional, slower, and invasive. Of the other known geophysical methods that meet these criteria, Ground-Penetrating Radar (GPR) has, in the view of the Subcommittee, some potential for making a contribution to solving the site assessment problem. Likewise, development of the RREL LOCI conceptual model is important for the interpretation of radar data.

e) One of the products of the research agenda was the use of passive acoustic systems for locating leaks in UST pipelines. The Subcommittee recognizes that there is a need to demonstrate effectiveness of signal processing in various noisy conditions, as well as under clayey or heterogenous conditions, in order to establish the limits of the technique, its sensitivity and resolution, and circumstances under which the technique is applicable.

f) Development of the RREL LOCI conceptual model as a teaching, demonstration, and remedial guidance tool is commendable. The Subcommittee recommends that it be publicized and made available not only within the program, but disseminated in an understandable and usable form to state and local units of government. It may also be valuable to other Agency programs (e.g., Superfund) as a teaching, demonstration or diagnostic tool.

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[1] EMSL-LV sponsored the construction of the OGI model aquifers, while RREL-Edison sponsored the construction and operation of the UST test facility. Three years ago, EMSL could not support research at the OGI facility. Accordingly, RREL has solely funded and directed the research at the OGI aquifers for the past three years under a cooperative agreement (RREL Project Description C-23).

g) The RREL and EMSL research programs appear to be pursuing efforts to estimate spill volume both before and during corrective action. Projected studies on passive degradation, soil vapor extraction/air sparging and improved hydrocarbon recovery reflect an accurate assessment of remediation research priorities. To maximize the benefits and resources allocations associated with these efforts, they need to be coordinated between the two laboratories.

h) A greater emphasis on prevention as an ethic is advocated by the Subcommittee. Specifically, the corrosion protection retrofit research proposed for 1994-95 should be initiated as soon as possible, and the certification program for tank testers should be expanded to those providing tank specification and installations. This information will be very important to tank owners that will be replacing or retrofitting tanks based on the 1998 deadline.

i) Past research has greatly improved understanding of liquid and vapor transport in the subsurface, and provides an excellent basis for evaluation of UST leak detection equipment. A field performance database should be developed and made available to program users to aid in determining the effectiveness of "real-world" systems, including both internal and external leak detection devices. Field studies of cleanup technologies at actual UST sites should be conducted to improve design and application of existing techniques, as well as to encourage the use of innovative technologies. Moreover, the magnitude and effects of risks posed to groundwater by UST hydrocarbon residuals after remediation need to be established and compared to those associated with the relatively few NPL sites.

j) A fractured rock research program area has been proposed with results to be delivered in 1996. Preliminary research efforts should focus on locating some of the many fractured rock remediations currently or soon to be underway, so that additional monitoring instrumentation required for research purposes could be installed and appropriate field data collected. Such an approach is consistent with the EPA "open windows" policy (See Appendix A; Reference 15) and can be used to develop projects to address limitations uncovered in current remediations.

k) Specific projects evaluating natural bioremediation, bioventing, SVE, and air sparging are timely and should provide useful information. However, the research should emphasize the effects of soil heterogeneities through the understanding of fundamental phenomena and hydrologic properties that limit success, and should be linked to and perhaps leveraged by complementary initiatives elsewhere.

l) In the briefings to the Subcommittee, both the RREL and EMSL researchers identified different user groups for technology transfer activities, although both laboratories identified the universe of target audiences (See Appendix A; Reference 1, Figure 4-1). The Subcommittee recognizes that users can benefit and derive value from completed research only if they are informed, trained and made aware of results in a timely manner. Therefore, it is of utmost importance that central coordination and support of conferences, seminars and workshops, as well as training, be provided and funded as a separate project item. The Agency should identify and help organize the user community in as systematic a manner as possible by promoting and/or funding the establishment of groups similar to the EPA-funded National Roundtable of State Waste Reduction Programs.

These recommendations are made with the view that this is a first evaluation of a well-designed program in an important research area, and in anticipation that the research program will be thereby guided and enhanced. The Subcommittee considers this program to be very important to the mission and responsibilities of the Agency.

2. INTRODUCTION

2.1 Background

Several million underground storage tanks (USTs) containing petroleum products as well as hazardous chemicals have been installed nationwide. National surveys have revealed that several hundred thousand of these tanks have either been abandoned, exceeded their useful lives, or are leaking, thus posing potential serious threats to surface and ground waters, public health and the environment in general. As a result of these findings, the 1984 Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA) mandated that the U.S. Environmental Protection Agency (EPA) regulate USTs. The Act required EPA to develop and implement a new regulatory program including; registration of existing and new tanks, requirements for UST leak detection and reporting, guidance for site assessment where leaks have occurred, initiation of corrective action and/or tank closure at those sites, and development of standards for installation and monitoring of new tanks.

After the passage of HSWA, the EPA established the Office of Underground Storage Tanks (OUST) to develop regulations and carry out the Act's mandate. The OUST was also assigned administration of the Leaking Underground Storage Tank (LUST) Trust Fund, mandated by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and funded by a tax on motor fuels to pay for corrective actions at sites where no financially viable responsible party could be identified. Aside from its regulatory role, the OUST has committed resources to supplying technical information and services as well as supporting innovations in system design, site investigation, and corrective action. In these efforts, the OUST has relied on the Office of Research and Development (ORD) for research in both technical application issues and as a support to rule-making. Research responsibilities have been shared by the Risk Reduction Engineering Laboratory (RREL) in Edison, NJ and the Environmental Monitoring Systems Laboratory (EMSL) in Las Vegas, NV. Associated research has an intended focus on UST leak detection and monitoring, leak prevention and corrective action technologies.

It is significant to note that very little research to date has focused on leak prevention. Initial research focused largely on leak detection because of the need to develop regulations, and then shifted to corrective action in order to address the many contaminated sites that were identified once the regulations take effect.

2.2 Environmental Engineering Committee Review of the UST Research Program

The Office of Environmental Engineering and Technology Demonstration (OEETD) requested that the Environmental Engineering Committee (EEC) of the Science Advisory Board (SAB) conduct a review of the ORD UST Research Program. The request for review was of the scientific adequacy of the UST Research Program as represented by a two-volume report prepared by RREL and EMSL entitled "Underground Storage Tank Research Program," (See Appendix A; References 1 and 2). These two volumes were transmitted to the EEC on May 20, 1992.

On June 29 and 30, 1992, the EEC Underground Storage Tank Research Subcommittee (USTRS) met in Washington, D.C. to consult with representatives from the OUST, RREL, and EMSL in review of the above documents. The USTRS consisted of EEC members, consultants, and a Designated Federal Official from the SAB. The USTRS listened to overview and technical presentations by the OUST, RREL, and EMSL staffs and the EMSL extramural researchers (See Appendix A; References 3 and 4 for staff presentation materials), discussed the extensive research documentation, and provided a verbal synopsis of findings and recommendations to Agency staff before adjourning. This report is a compilation of the major findings and recommendations of the USTRS, and responds to the original charge to USTRS posed by the OEETD, namely:

a) Are the research projects and programs in support of the OUST's regulatory needs being conducted in a scientifically sound manner? Are we doing good science?

b) Is the selection of research projects appropriate, considering resource constraints?

c) Does the current and planned research adequately address scientific and technical gaps that currently exist?

d) Are there scientific or technical areas not presently being addressed that should be included?

The response of the USTRS in this report consists of general comments concerning the overall assessment of the research program based on the

documentation and commentary of past, current and future research provided. This report represents a general consensus of the views and conclusions of the USTRS concerning the issues placed before the Subcommittee, as well as specific comments on the adequacy of the research program and the documents reviewed by the Subcommittee.

The Subcommittee wishes to alert the reader of this report that the four questions raised in the charge are answered in the text of this report in a general manner appropriate to an overall program review, rather than an incisive critique focused on the science basis behind individual projects. That is, the Subcommittee commented primarily on the adequacy, soundness and direction of the overall research strategy, and coincidentally on some individual projects as examples were presented to illustrate a particular thrust. Indeed, the manner in which the projects were presented in the documents, as well as the content and approach of the ORD staff presentations, directed the Subcommittee to critique the overall program strategy. While the ORD review documents contained individual project write-ups for examination by the Subcommittee, to fairly judge the fundamental technical basis, rationale and science behind the individual projects would have required more documentation, scrutiny and review time than was available in the time allotted for the planned two-day review period.

3. COMMENTS ON CURRENT UST RESEARCH PROGRAM

3.1 General Comments

The resource materials and documents made available to the Underground Storage Tank Research Subcommittee (USTRS) were thorough and well-conceived, and provided a revealing and thought-provoking basis for review of the research program. In addition, the new information provided by a few researchers holding cooperative agreements with EMSL was useful, but time constraints did not allow for an in-depth review of these or other specific projects. Hence, this latter feature of the overall UST program could not be thoroughly scrutinized.

It was apparent from the documents and supplemental materials that the organization and decision-making processes used to identify areas of research focus were deliberate and productive. However, clarification of the basis (i.e., criteria for selection) used to choose areas in preference to others of promise, e.g., bioremediation or ground-penetrating radar, is recommended. These decisions were likely directed by resource constraints and an apparent need to appropriately accommodate regulatory and programmatic priorities. The respective laboratories and the OUST, however, have adopted a proactive research approach which encourages continued development and application of innovative technologies.

Because of the Agency policy to integrate pollution prevention as an ethic throughout its activities (See Appendix A; References 6 through 9), the USTRS concluded there is a need for added emphasis on pollution prevention in the UST research program, consistent with the recent memorandum from the EPA Deputy Administrator to EPA personnel (See Appendix A; Reference 13). A program to certify tank testers is in place, and could be a complementary element of an overall pollution prevention initiative. However, it could also be expanded to those who provide tank specifications and install tanks.

Past research has identified several problem areas, for example, the need for an inventory of the nature and locations of leaks. Development of, or recommendations for, solutions to these problems needs to be aggressively pursued. The ORD staff, along with other researchers outside the Agency, should discuss how to develop research, how to leverage projects, and how others who seek to become involved in future research and demonstration projects and other applications would be able to most productively participate in this information exchange. The contractors would discuss what they have learned, especially issues

which may fall outside the specific tasks. Potential future subcontractors, contractors and recipients of cooperative agreements or other vehicles of support should be invited to participate. These groups in turn would facilitate the technology transfer initiative.

Past research has also emphasized technology development more than scientific discovery. The Subcommittee recognizes that the RREL-Edison Laboratory is an engineering laboratory which has concentrated on internal leak detection, and more recently on evaluating corrective action technologies, while the EMSL-Las Vegas Laboratory has concentrated on external leak detection methods and more recently on applied monitoring research, perhaps driven by a perceived as well as a real need to quickly transfer results to target users. Such an approach tends to emphasize applied science rather than investigative science. While the users need tools to be responsive to regulatory requirements, more needs to be done to develop or improve understanding of basic concepts, contaminant dynamics and other governing factors affecting fate and transport. Such an initiative should be coordinated with other activities, i.e., the EPA laboratories at Ada, OK and Athens, GA, as well as the U.S. Army Vicksberg Research Center and the various university Research Centers conducting similar basic research, in order to avoid redundancy.

Both the EMSL and RREL appear to be pursuing efforts to estimate spill volume before and during corrective action, and this work needs to be coordinated. In addition, it is very important that the planned field tests of corrective actions, i.e., the model aquifer and field tests of soil vapor extraction (SVE) corrective actions (Projects C-23 and C-24, Appendix A; References 1 and 2) be carried out. Mathematical models and conceptual evaluations of these technologies in the laboratory alone are insufficient, and despite current funding limitations, "real-world" studies need to be conducted. The laboratories were correct to begin to focus on SVE, air sparging and bioventing activities, because these techniques are currently in use, are not well understood, and a much better determination of the important controlling factors must be developed. There is also a need to expand controlling factors research to other in situ methods, such as bioremediation, as well as to continue to pursue ex situ methods where circumstances dictate their application.

The research approach at the two laboratories has been quite different. RREL largely has used a contractual extramural support approach, supplemented by expert workshops to gather existing information and science, and with a focus

on changing the state-of-the-art of leak detection nationwide. This allowed RREL to cover a wide range of leak detection issues and problems responsive to the stated needs of the target audience. While this research approach has served as a catalyst for useful applications such as tank and pipe leak detection methods development, it has not actively promoted or engaged the program in new fundamental science and/or its advancement, beyond on-site contractor identification and evaluation of variables impacting and controlling leak detection technology. EMSL has focused on monitoring as its mission and has aggressively employed cooperative agreements with universities. Although development is also emphasized, some new science with relevance to UST monitoring issues has also been sponsored. It was not evident in the documentation or during the presentations whether these efforts have been sufficiently exposed through the peer-review process in broad-based, authoritative and widely recognized publications (an issue applicable to both laboratory programs to some extent), although some effort toward external publication has been made. Hence, a greater emphasis should be given to publication in authoritative peer-reviewed journals so that the benefits of such external scrutiny and endorsement can be fully realized.

3.2 RREL Site Assessment

The investments in research facilities, specifically the UST Test Facility and the Large Experimental Aquifer Program (LEAP), for investigating UST issues have been timely and appropriate. Research and development progress has been greatly enhanced by the availability of these facilities. These facilities should continue to be used for fundamental research into contaminant behavior and dynamics and their controlling factors.

The historical focus of RREL on internal leak detection has been well placed, and has resulted in development of appropriate standards and technology. This emphasis continues to evolve and is being expanded appropriately to include leak location and testing of tank integrity.

One of the important products of the research agenda was the use of passive acoustic systems for locating leaks in UST and pipelines. However, there is a need to demonstrate effectiveness of signal processing in various noisy conditions, in order to establish the limits of the technique, its sensitivity, its resolution, and under what circumstances the technique will be applicable. This effort should be extended to field conditions, especially in heterogeneous or clayey media, and beyond the sand/gravel conditions used during development. This

research could also be considered an example with pollution prevention ramifications, if improvements in system design or recommendations for upgrading requirements (such as in Projects C-1 and C-13, Appendix A; References 1 and 2) were forthcoming as problem areas are defined.

The development of the LOCI conceptual model (referred throughout the text as LOCI) is one of the areas where an effort has been made to embrace underlying concepts and their didactic value in remedy selection. There may be some merit in expanding this further, perhaps by using other source materials, such as included in the ORD transport models or the SAB reports on leachability (See Appendix A; Reference 10), bioremediation (See Appendix A; Reference 11), or pollution prevention (See Appendix A; References 8 and 9). Such an extension would need to more thoroughly address matrix heterogeneity, spatial variability, and the issue of fractured rock settings. There is also a need to emphasize characterization of alternative fuels, contaminant behavior and transport, and constituent reactivity.

The intent of RREL research on site assessment "to develop a better understanding of the location and movement of a contaminant in the subsurface environment ..." encompasses more fundamental and broader issues than just leak detection. Therefore a broader approach to the overall research and development effort would encourage more complete understanding of the subsurface environment, the properties of petroleum, chemical products and hazardous chemicals, and the mechanisms affecting the movement and disposition of hydrocarbons and hazardous chemicals in the subsurface. This broader approach is critical to the selection of remedial technologies and the monitoring of corrective actions at UST sites. Site characterization is considered central to all the other activities leading to final remediation and closures, and the UST research at RREL should extend its focus beyond the leak detection mission, coordinating it with other Agency laboratories as well as research initiatives outside the Agency.

3.3 RREL Corrective Action

Again, the LOCI conceptual model is good and appears to be useful in corrective action analysis. While guidance is available to users, the guidance needs to be more systematically developed to make it more field sensitive, as well as to help in estimating the amount or percent of contaminant in each locus under actual field conditions in a variety of soil matrices, i.e., where the bulk of the contaminant resides and how that knowledge can aid in remedy selection. While

industry and the Agency's CERCLA removal and remediation, RCRA corrective action and other programs are directed with an abundance of guidance, there is a lack of consistent opinion among the various programs, especially with respect to guidance on acceptable levels of risk. Moreover, selection of appropriate corrective action requires sufficient understanding of basic underlying scientific principles and description of the subsurface environment. For instance, there is little guidance for remediation based upon scientific principles governing the behavior of hydrocarbon constituents in the subsurface environment. Researchers need to see how the LOCI conceptual model holds up in the field. Therefore, although implied in the general approach, it appears that the role of aquifer heterogeneities has not been given sufficient scrutiny.

Another research area needing attention is the behavior of non-aqueous phase liquids (NAPLs) on the water table surface, and what happens when the water table fluctuates. Correspondingly, there is a need for better corrective action strategies at sites requiring remediation. This in turn is limited by the need to know the location and concentration of the contamination and its vertical and horizontal dimensions. Concomitantly, this reinforces the need for research in development of real-time and innovative monitoring methods for effective site characterization.

3.4 EMSL Site Assessment/Corrective Action

The EMSL-Las Vegas program consists of development of monitoring/site assessment in support of corrective action, and its overall strategy and feedback in the research and development plan is considered appropriate. However, the major site investigation techniques are limited, and should have been listed with the associated advantages and disadvantages. From this should have emerged available techniques and a strategy on how they can be improved. There was an impression that EMSL chose techniques with which they were familiar and did not plan much geophysical work.

In view of ORD emphasis on rapid real-time site assessment, and recognizing that the EMSL-LV program has listed on-going research projects that include monitoring technologies focusing on both rapid site assessment and non-invasive techniques, there needs to be a systematic and thorough evaluation of these and other rapid site assessment and non-invasive site investigative techniques. Although the need for fast characterization was highlighted, the methods developed or described to the Subcommittee were more traditional,

slower, and invasive, and other geophysical methods such as Ground-Penetrating Radar (GPR) for mapping the shallow subsurface were not highlighted and should receive commensurate attention. The Subcommittee further notes that commercially available GPR and bioremediation (See Appendix A; Reference 11) techniques have been evaluated only generally for use in resolution of the UST problem. Both technologies have not been specifically designed for the UST problem, and thus did not fully meet the expectations of the evaluators. In addition, no effort was made to determine the reasons why the techniques did or did not work. For instance, with today's GPR technology, the direct detection of contaminated subsurface soil may not be possible. Yet, of the known geophysical methods that meet these criteria, GPR has, in the view of the Subcommittee, some potential for making a contribution to solving the site assessment problem. Likewise, development of the RREL LOCI conceptual model is important for the interpretation of radar data, and a Time Domain Reflectometry (TDR) dipstick could also be developed to measure soil moisture content with depth and to detect contamination location.

Development of methods like the dipstick technique are not science, but are practical uses of technology. Similarly, various monitoring methods as represented by the work at the University of Connecticut (U-CONN) were considered good overall, although there is a need to move toward protocols and emphasis on real-time, fast identification of site conditions to shorten response time. A hierarchy could be developed to determine various techniques that could be applied as complexity of the problem varies. The techniques need to be evaluated in various media, with emphasis on issues such as making available easy-to-use and well-studied tools for the screening of sites. Some of the products developed in the research meet this need, however, there appears to be no systematic attempt to seek out and develop other tools, outside of the expertise of present cooperators.

The ORD staff needs to address the issue of safeguarding the continuity and progress of research initiatives, with assurances that results and their further interpretation are not lost as a consequence of possible personnel turnover. This could be provided by developing strategies that ensure timely and effective utilization of research results and guidance for planning future work. For example, both the OGI and U-CONN projects indicated formation of dissolved groundwater plume layers, which illustrate the importance of multi-level sampling at UST sites in order to accurately observe aqueous phase concentration. Water table fluctuations have been observed to spread products and trap them by capillary forces; hydrophobic gravel pack material has been favorably tested for

improving the performance of monitoring or production wells, and preliminary results indicate that vapor composition can be used to distinguish between a free-phase or aqueous-phase vapor source. The value of such findings should be clearly established and used to foster coordinated continuation efforts in a focused manner and consonant with the respective missions of the participating laboratories.

4. COMMENTS ON FUTURE RESEARCH PROGRAM

4.1 General Comments

Ground water protection research related to UST has historically been dominated by EPA's successful program to develop detection technology. Part of the RREL-Edison research resources, possibly augmented by EMSL-Las Vegas support, should focus on field studies to determine the causes of failures of UST systems installed since 1988. Technologies proposed for secondary containment should also be evaluated to validate performance claims. In addition, the corrosion protection retrofit research proposed for Fiscal Year (FY) 1994-1995 periods should be initiated as soon as possible. Results from this initiative will be very important to tank owners who will be replacing or retrofitting tanks based on the 1998 deadline.

Although some alliances with other agencies (e.g., DOD/USAF) have been established through Interagency Agreements (IAGs), many additional opportunities exist for cooperative research. For instance, the Air Force is initiating considerable numbers of bioventing remediation projects within the 1992 and 1993 time frame. Both laboratories should expand and explore opportunities to benefit from such complementary activities on a continuum. Formal communication links for tracking the current and projected activities of the variety of public and private groups currently engaged in UST-related research (e.g., DOD, DOE, API, EPRI, NSF, the various EPA Hazardous Waste Research Centers (HWRC), and the numerous academic "institutes" that have been formed during the last several years) should be established and sustained. Such linkages could provide numerous opportunities to discuss mutual objectives, progress and potential cooperation in research efforts.

It appears that most past activities of RREL-Edison have dealt with above ground or enclosed systems. The Subcommittee recognizes that RREL has expertise in both in situ and ex situ treatment of contaminated soil, and has major research programs currently in place under RCRA and Superfund at Edison and in Cincinnati. However, if RREL intends to increasingly focus on subsurface processes, e.g., SVE, air sparging and bioventing research, there should be close interaction and cooperation with EMSL-Las Vegas to take advantage of their contractors and in-house expertise in dealing with the complexities of subsurface systems.

Current research to develop new technologies (e.g., in the areas of leak detection or field analytical methods) should be extended to establish protocols for evaluating the performance of new technologies developed by the private sector, as well as to compare the performance of commonly used technologies. Such information would be extremely valuable to users of these technologies, and may serve to guide and prioritize future research and development initiatives.

A topic not addressed by either laboratory, but one that could serve as a valuable resource to the user community, is the physical and chemical properties of petroleum products. These products are very complex organic mixtures, and many involved in this field still do not have a basic understanding of fuel composition and basic physical and chemical properties (e.g., solubility, volatility and biodegradability). Therefore, there is a need to develop a user-friendly compendium of this kind of information.

While mention was made of the ability to "piggy-back" on Superfund-related research, it is not clear exactly how UST-related needs will be addressed by this process, or how this information will be made available to the user community. Wherever practical, it would be beneficial for Superfund research to address petroleum hydrocarbons, and for that information to be somehow extracted and summarized from research reports. (It should be noted that the RREL and EMSL research related to Superfund is complicated in terms of extending to petroleum hydrocarbons due to the statutory exemption for petroleum products). A similar emphasis on above-ground storage tanks is appropriate and, although the topic of above-ground storage tanks was not explicitly included in the charge to the Subcommittee, such a focused review is also advocated for this element of the respective research initiatives.

4.2 Future RREL Research

Continued utilization of the UST test facility and the LEAP facility at the Oregon Graduate Institute of Science and Technology (OGI, also OGIT) for basic and applied research is highly recommended. These unique facilities provide special capabilities to investigate new and improved techniques for assessing and evaluating the structural integrity of UST systems, fate and transport processes, and remediation technologies. Projected studies on passive degradation, air sparging, soil venting and improved hydrocarbon recovery reflect an appropriate assessment of remediation research priorities. Since RREL-Edison has supported and proposed investigations in some of these areas, it will be important to

carefully synchronize the respective research initiatives to maximize effective use of available resources. Future research utilizing the UST test facility in leak detection and location, in developing innovative technologies, and focusing on above-ground storage tanks is considered appropriate and recommended by the Subcommittee.

Currently the RREL-Edison corrective action research program is focused on evaluating performance of remediation technologies in a relatively research-oriented environment. Although research at some field sites is performed, evaluations of systems that have been installed for non-research remediations are lacking and are necessary for ultimate technology development. Hence, to determine actual performance, the current approach should be modified to include more evaluations of data from "real-world" applications of technology. Such "real-world" remediations and evaluations would help establish factors limiting or assuring success. Complementary field data need to be accessed and can be obtained by integrating cooperative efforts with other EPA programs such as Superfund, with corresponding state regulatory agencies, or with industry.

Ideally, the overall goal of the UST research program should be to provide more than just performance data. Information must be developed that can be used to educate the general public as to just what to expect from remediation technologies, i.e., how long the remediation will take, how clean the site will be after completion, and what will be the relative change in the magnitude of site risk. The public is a stakeholder in the results of UST remediation, yet they are rarely objectively informed about the actual limitations of remedial technologies. Hence, they react accordingly and often very conservatively, and regulatory agencies may then mandate remediation targets beyond the capabilities of the remediation technique. (As indicated subsequently, none of the proposed technology transfer activities were targeted at the general public.)

Specific projects evaluating natural degradation, bioventing, SVE, and air sparging are timely and should provide useful information. However, the research should also emphasize the effects of soil heterogeneities through the understanding of fundamental phenomena and hydrologic properties that limit success, and should be linked to and perhaps leveraged by complementary initiatives elsewhere.

Research proposed for design and optimization of free-phase hydrocarbon recovery systems will also provide useful information. The deliverables should be structured to allow the remediation project manager to design a recovery system,

predict system and matrix response, and optimize system performance based on field data. This research, or any other, should not be used to develop general remediation system performance curves that are intended to be universally used for compliance or enforcement purposes; any evaluation of system performance should be based on site-specific information.

As emphasized in the SAB "Reducing Risk" report (See Appendix A; Reference 14), research should be initiated to determine the effects of and risk posed to groundwater by the hydrocarbon residuals remaining after remediation, using such techniques as air sparging, soil vapor recovery, or biodegradation. These residuals will be dominated by the long-chain hydrocarbons and may be only partially mobile. Therefore, remediation may be incomplete, with a potential residual threat to health and the environment.

A fractured rock research program has been proposed with results to be delivered in 1996. Many fractured rock remediations will be initiated within this time frame. Techniques such as hydraulic fracturing and horizontal drilling will be implemented by UST and Superfund responsible parties. Therefore, preliminary research efforts in this area should focus on locating these projects, installing additional monitoring instrumentation required for research purposes, and collecting field data. These results can then be used to develop customized projects that address limitations detected in the preliminary research. Such an "open windows" approach is advocated in the EPA "Safeguarding the Future" report (See Appendix A; Reference 15), and will ensure recognition and effective use of other research and development initiatives.

Research has also been proposed to evaluate, at the laboratory and pilot-scale levels, the applicability of existing remediation technologies for remediation of oxygenate-based fuels. The American Petroleum Institute (API) has already completed laboratory-scale biodegradation and field-scale fate and transport studies of Methyl-t-Butyl Ether (MTBE) and methanol, treatability of oxygenate fuels additives using classical water treatment methods, and the potential for co-solvency effects of oxygenate fuel additives on volatile aromatic compounds in gasoline. Although the Agency indicates an awareness of this research, further evaluation of the results of this research would be beneficial to the initiation of any alternative fuels research program.

The research being proposed to evaluate ex situ treatment of contaminated soils using "biopiles," a modification of traditional landfarming techniques, is

already a fairly mature remedial technology. There are many examples of successful treatment of coarse-textured soils contaminated by gasoline or middle distillate fuels. Therefore, research in the area should focus on the applicability of these techniques to fine-textured soils and specifically on the physical destruction of aggregates. The Subcommittee recognizes that factors which affect the kinetics associated with the process may need to be better defined and understood and that design and operational data, especially for high boiling point hydrocarbons and fine soils, needs more documentation. Moreover, potential atmospheric releases and impacts should be included in any such research initiative.

Finally, a client feedback group could be established to monitor proposed and ongoing research. It should include U.S. EPA personnel, state regulatory officials, and academic and industrial representatives. They could assist in the review of proposed and ongoing research, and help determine whether the intended research goals will promote results that satisfy the needs of the user community.

4.3 Future EMSL Research

Past research at the EMSL-LV facility has improved understanding of liquid and vapor transport in the subsurface, and provides a good basis for evaluation of UST leak monitoring equipment. However, there are no current plans to develop a field performance database that could determine the effectiveness of "real-world" systems. This is an immediate research need, given the rapidly approaching compliance date (Dec. 1993) for UST Leak Detection.

The Lab-in-a-Bag methodology has been proven to be a useful site assessment tool; the rare example of a rigorously validated on-site technique. However, there are a number of other widely used field methods, and several emerging techniques whose performance is unknown. It would be beneficial to develop such performance data to help regulators and consultants assess the quality of information they provide.

5. TECHNOLOGY TRANSFER

Given the considerable number of UST sites currently being evaluated, and the likelihood that these numbers will at least double in the next few years, it is extremely important to make a substantial effort to ensure that useable results from UST research are placed into the hands of the user community as quickly as possible. This will raise the level of technical understanding of field personnel who can most benefit from this information. It would be beneficial to summarize the current state-of-the-knowledge through a variety of media outlets (books, videos, training materials, workshops). It would also be useful to prepare an analysis of the relative risk currently posed by the many UST sites that are commonly found in urban and suburban areas versus that posed by the few NPL sites. Moreover, the Agency should evaluate the current allocation of EPA research funding to determine whether some changes in funding allocations are merited to improve and accelerate technology transfer.

5.1 Findings and Recommendations for Technology Transfer

To appropriately review the RREL-Edison, NJ and EMSL-Las Vegas, NV activities, it is necessary to establish a benchmark for technology transfer. For purposes here, technology transfer should be a systematic, two-way interactive process which determines the audience for the research results and selects the appropriate mode of getting the relevant information to that audience or portion thereof. Accordingly, a technology transfer plan should be prepared for each type of project, instead of attempting to apply a suite of tools randomly for any and all projects.

It was noted that both RREL-Edison and EMSL-LV apparently have different methods of achieving their stated goals for UST technology transfer. By applying total quality management (TQM) principles currently advocated by the Agency, and working with the OUST program office, an effort should be made to consolidate and/or coordinate these goals and procedures. This approach would also be useful to guide how the different groups implement technology transfer in their respective research programs, and how this should change as future programs change.

Some specific recommendations are as follows:

a) In the briefings to the Subcommittee, both the RREL and EMSL personnel identified different user groups for technology transfer activities, although both laboratories identified a universe of target audiences (See Appendix A; - Reference 1, Figure 4-1). The Agency should identify and help organize the user community in a more systematic manner by promoting and/or funding the establishment of groups similar to the EPA-funded startup of the National Roundtable of State Waste Reduction Programs. Such an UST user group could consist of state and federal regulatory personnel, university-based groups, the regulated community and other public outreach or nongovernmental organizations who are "stakeholders" in UST issues. It could coordinate training and information transfer particularly useful to the constituency represented, and provide feedback to EPA on the overall effectiveness of its activities. Programs such as train-the-trainer efforts would make information more available to larger audiences.

b) Efforts to develop focus groups on specific technologies should go beyond simply inviting identified experts to a meeting. Experts from "competing" technologies should also be invited to obtain a better perspective of associated limitations of technology applications. Perhaps such meetings could be better publicized to elicit a broader range of input. The U.S. Department of Energy (DOE) holds a "technology fair" where inventors pay to have their ideas seen by the investor community, and can win prizes to further develop the technology (i.e., grants, etc.). Commercialization of these technologies is a goal which could be assisted by working with the EPA-funded National Environmental Technology Applications Corporation (NETAC), and considering an UST program similar to EPA's Superfund Innovative Technology Evaluation (SITE) and Waste Reduction Innovative Technology Evaluation (WRITE) programs. Some means of evaluating the utility of the technologies developed in the program is also needed, i.e., a means of learning from failures can also be derived from this activity.

c) There is a need to utilize feedback to assist in measuring the effectiveness of technology transfer efforts. Development of objective

measures of success is also essential, as has been pointed out in earlier reviews by the SAB which focused on pollution prevention (See, in particular, Appendix A; References 8 and 9).

d) There is a need to provide better information transfer, within the UST program. This could be accomplished by establishing an OUST/EMSL/RREL working group which would be responsible for determining how these and other entities could work more effectively together in determining common goals and objectives, and establishing priorities and assigning responsibility. While controls need to be instituted to assure objective technology assessments, other working groups to be convened by this EPA group would consist of representatives of universities involved in the cooperative agreements or grants, and extramural "mission" contractors.

e) Technology transfer between different professional specialties may assist in the measurement and detection of leaks. There has been research on natural gas and potable water leaks which may be applicable in the UST programs in progress. The work on acoustical detection is common to each of these areas. The search for other applicable technologies may be assisted by investigating activities of other similar fields.

f) There is a need to get standards and specifications for USTs to the practitioners in the field. Participation in the activities of the American Society for Testing and Materials (ASTM) is one such vehicle which is being pursued. In addition, UST results could be included in technical resource documents and distributed widely to the user community.

5.2 RREL-Edison Technology Transfer Activities

The goal of the RREL technology transfer program is to "communicate research results to the appropriate end-users in an effective, efficient and timely manner." End-users identified by the RREL-Edison research staff are the scientific community, regulators, engineering consultants/contractors, equipment manufacturers and tank owners/operators. Past and present efforts by RREL-Edison personnel have sought to match research products to the needs and skills of target audiences, and to use a variety of technology transfer tools. A more

recent approach involves end-users in the planning and progress of research efforts. Tools for implementing the approaches include publications, conferences/workshops/training, state/regional assistance, computerized information systems, cooperative and interagency agreements developed under the auspices of the Federal Technology Transfer Act (FTTA).

It is projected that technology transfer activities will represent, on average, 15% of each project funds. However, it is difficult for the Subcommittee to determine the effectiveness of the past and present activities based upon the information presented. Accordingly, the appropriateness of the budget invested in technology transfer activities is not certain.

A coordinated, well documented and measurable technology transfer plan is needed. The stated approach of the plan presented is well conceived, but does not appear to be integrated into the present projects. An additional component needed for completeness of the plan is an effort to provide for continuous feedback from the appropriate user of the technology being developed, e.g., product evaluation, as well as a way to objectively measure the success of these efforts. Additionally, the RREL computerized information systems should be continued in a focused manner, targeted to user groups who could most benefit from these services.

5.3 EMSL-LV Technology Transfer Activities

The mission of the EMSL-LV technology transfer program is to make research results available to those who can benefit from their application. In the briefing to the Subcommittee, the EMSL-LV research staff saw as their audience three primary groups: a) federal, regional and state UST staff (i.e., the regulators); b) consultants and contractors who provide leak detection, site investigation and corrective action technologies; and c) the regulated community, primarily industry (this includes the manufacturers and tank owners/operators).

The approach of the EMSL-LV research staff to technology transfer has been to: a) build new research capability and resource centers at universities; b) sponsor development of standard methods for UST investigation and remediation; c) sponsor development of new tools for commercialization; and d) participate in outreach activities. The tools that the EMSL-LV research staff have used to implement its technology transfer program include: a) cooperative agreements with researchers at selected universities; b) interagency agreements with the U.S. Air Force (USAF) and the U.S. Geological Survey (USGS); c) consensus standards

through ASTM Committee D-18 on soil and rock (principally Subcommittee D18.21 on Ground Water and Vadose Zone Investigations) and E-50 (particularly the Subcommittee on Storage Tanks); d) patents for devices or methods developed under EMSL-sponsored research projects; e) papers presented at professional meetings, published in peer-reviewed journals and disseminated through their "Tank Issue Papers" service; f) sponsorship of symposia or conferences; and g) presentation of workshops and training courses, some in cooperation with the OUST. No details on the individual activities were provided to the SAB, but the program listing is considered impressive.

The EMSL-LV research staff appears to have identified its major audience, but secondary and other important audiences, for example, equipment manufacturers and researchers at institutions not already participating in their programs have not been fully addressed. More emphasis could be placed on other tools that may be effective in getting the message out, including sponsorship of method guidance documents for regulatory personnel, news releases in trade and professional publications, and participation in the available electronic databases (e.g., ATTIC [Alternative Treatment Technology Information Center], COLIS [Computerized On-Line Information System], or VISITT [Vendor Information System for Innovative Treatment Technology]). Use of expert technical assistance teams, which could provide assistance to regulators, would also be a valuable technology transfer tool for EMSL to consider.

The EMSL-LV research staff appears to have targeted many of its audience groups, but it is difficult to assess the effectiveness of technology transfer efforts without a recognizable feedback process, as well as objective measures of success, which apparently are not built into the process. Objective methods of measuring the impact of EMSL's technology transfer efforts is particularly essential. It was also unclear how many budgeted resources are actually devoted to technology transfer. Therefore, it is suggested that an appropriate amount of each project budget be allocated to technology transfer, and that a project-specific plan for technology transfer be outlined, evaluated and implemented.

APPENDIX A: REFERENCES CITED

1) U.S. EPA, "Underground Storage Tank Research Program," Volume I - Report, Prepared by the U.S.EPA's Risk Reduction Engineering Laboratory and Environmental Monitoring Systems Laboratory - LV, Office of Research and Development, May 1992

2) U.S. EPA, "Underground Storage Tank Research Program," Volume II - Appendices, Prepared by the U.S.EPA's Risk Reduction Engineering Laboratory and Environmental Monitoring Systems Laboratory - LV, Office of Research and Development, May 1992

3) U.S. EPA, "Underground Storage Tank Research Program," Volume III - RREL Presentation Supplement, Prepared by the U.S.EPA's Risk Reduction Engineering Laboratory, Office of Research and Development, June 1992

4) U.S. EPA, "ORD EMSL-LV Overview," Prepared by the EMSL-LV Staff for presentation by Dr. Gene Meier, Acting Deputy Director, EMSL-LV (and others), as Agenda Item III.B, June 1992

5) U.S. EPA/ORD/RREL, "Assessing UST Corrective Action Technology: A Scientific Evaluation of the Mobility and Degradability of Organic Contaminants in Subsurface Environments", (Prepared under Contract Number 68-03-3409) by Camp, Dresser and McKee, Inc.) USEPA Risk Reduction Engineering Laboratory, Edison, New Jersey. (EPA/600/2-91/053), September 1991

6) U.S. EPA, "EPA...Preserving Our Future Today," Strategic Direction for the U.S. Environmental Protection Agency, April 1991

7) U.S. EPA, "EPA...Preserving Our Future Today," U.S. Environmental Protection Agency Strategic Plan, Draft IIb, October 17, 1991

8) U.S. EPA/SAB, "Review of the ORD Draft Pollution Prevention Research Plan: Report to Congress," Pollution Prevention Subcommittee of the Environmental Engineering Committee (EPA-SAB-EEC-89-037), September 1989

APPENDIX A: REFERENCES CITED (CONTINUED)

9) U.S. EPA/SAB, "Review of ORD's Draft Pollution Prevention Research Strategic Plan," Pollution Prevention Subcommittee of the Environmental Engineering Committee (EPA-SAB-EEC-LTR-92-007), April 21, 1992

10) U.S. EPA/SAB, "Leachability Phenomena: Recommendations and Rationale for Analysis of Contaminant Release," Leachability Subcommittee of the Environmental Engineering Committee (EPA-SAB-EEC-92-003), October 29, 1991

11) U.S. EPA/SAB, "Review of the Office of Research and Development Bioremediation Research Program Strategy," Bioremediation Research Review Subcommittee of the Environmental Engineering Committee (EPA-SAB-EEC-92-026), September 1992

12) U.S. EPA/SAB, "Review of the Underground Storage Tank (UST) Release Simulation Model", UST Subcommittee of the Environmental Engineering Committee (EPA-SAB-EEC-88-029), April 15, 1988

13) U.S. EPA, Memorandum entitled, "EPA Definition of 'Pollution Prevention,'" from F. Henry Habicht II, Deputy Administrator, to all EPA Personnel, May 28, 1992

14) U.S. EPA/SAB, "Reducing Risk: Setting Priorities and Strategies for Environmental Protection", the Report of the SAB's Relative Risk Reduction Strategies Committee, (EPA-SAB-EC-90-021), September 25, 1990

15) U.S. EPA, Expert Panel on the Role of Science at EPA (Loehr, Goldstein, Nerode and Risser), "Safeguarding the Future: Credible Science, Credible Decisions", (EPA/600/9-91-050), March 1992.

APPENDIX B: GLOSSARY OF TERMS AND ACRONYMS

AEERL	AIR AND ENERGY ENGINEERING RESEARCH LABORATORY (U.S. EPA)
AIA	AMERICAN INSTITUTE OF ARCHITECTS
API	AMERICAN PETROLEUM INSTITUTE
ASTM	AMERICAN SOCIETY FOR TESTING AND MATERIALS
ATTIC	ALTERNATIVE TREATMENT TECHNOLOGY INFORMATION CENTER (AN EPA NATIONAL DATA SYSTEM)
CERCLA	COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION AND LIABILITY ACT
COLIS	COMPUTERIZED ON-LINE INFORMATION SYSTEM
D-18.21	ASTM SUBCOMMITTEE ON GROUND-WATER AND VADOSE ZONE INVESTIGATION
DOD	U.S. DEPARTMENT OF DEFENSE
DOE	U.S. DEPARTMENT OF ENERGY
E-50	AMERICAN SOCIETY FOR TESTING AND MATERIALS, SUBCOMMITTEE ON UNDERGROUND STORAGE TANKS
EDISON	EDISON, NEW JERSEY
EEC	ENVIRONMENTAL ENGINEERING COMMITTEE (SAB/EPA, ALSO REFERRED TO AS "THE COMMITTEE")
EMSL	ENVIRONMENTAL MONITORING SYSTEMS LABORATORY, OFFICE OF RESEARCH AND DEVELOPMENT (U.S.EPA)
EPA	U.S. ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA, or "THE AGENCY")
EPRI	ELECTRIC POWER RESEARCH INSTITUTE
FTTA	FEDERAL TECHNOLOGY TRANSFER ACT
FY	FISCAL YEAR
GA	GEORGIA
GPR	GROUND-PENETRATING RADAR
HSWA	HAZARDOUS AND SOLID WASTE AMENDMENTS, (A PART OF THE REAUTHORIZATION OF RCRA)
HWRC	HAZARDOUS WASTE RESEARCH CENTER, U.S. EPA
IAG	INTERAGENCY AGREEMENT
LEAP	LARGE EXPERIMENTAL AQUIFER PROGRAM
LNAPL	LIGHT NON-AQUEOUS PHASE LIQUID

APPENDIX B: GLOSSARY OF TERMS AND ACRONYMS (CONTINUED)

LOCI	A CONCEPTUAL MODEL FOR LEAKING UNDERGROUND STORAGE TANKS, WHICH CONTAINS 13 LOCI, OR CONDITIONS WHICH DEFINE THE KNOWN UNIVERSE OF CONDITIONS FOR DEALING WITH CONTAMINANTS IN A SOIL, AIR, WATER, OR OTHER MATRIX
LUST	LEAKING UNDERGROUND STORAGE TANK
LV	LAS VEGAS, NEVADA
MTBE	METHYL-T-BUTYL ETHER
NAPL	NON-AQUEOUS PHASE LIQUID
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NC	NORTH CAROLINA
NETAC	NATIONAL ENVIRONMENTAL TECHNOLOGY APPLICATIONS CORPORATION
NJ	NEW JERSEY
NPL	NATIONAL PRIORITIES LIST
NSF	NATIONAL SCIENCE FOUNDATION
NV	NEVADA
OEETD	OFFICE OF ENVIRONMENTAL ENGINEERING AND TECHNOLOGY DEMONSTRATION, OFFICE OF RESEARCH AND DEVELOPMENT (U.S. EPA)
OGI	OREGON GRADUATE INSTITUTE OF SCIENCE AND TECHNOLOGY (See also OGIT)
OGIT	OREGON GRADUATE INSTITUTE OF SCIENCE AND TECHNOLOGY
OK	OKLAHOMA
OPPT	OFFICE OF POLLUTION PREVENTION AND TOXICS (U.S. EPA)
ORD	OFFICE OF RESEARCH AND DEVELOPMENT (U.S. EPA)
OSWER	OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE (U.S. EPA)
OUST	OFFICE OF UNDERGROUND STORAGE TANKS (U.S. EPA/OSWER)
RCRA	RESOURCE CONSERVATION AND RECOVERY ACT
RREL	RISK REDUCTION ENGINEERING LABORATORY, OFFICE OF RESEARCH AND DEVELOPMENT (U.S. EPA)
RTP	RESEARCH TRIANGLE PARK
SAB	SCIENCE ADVISORY BOARD (U.S. EPA)
SARA	SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT
SITE	SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION
SVE	SOIL VAPOR EXTRACTION

APPENDIX B: GLOSSARY OF TERMS AND ACRONYMS (CONTINUED)

TDR	TIME DOMAIN REFLECTOMETRY
TQM	TOTAL QUALITY MANAGEMENT
U-CONN	UNIVERSITY OF CONNECTICUT
USAF	UNITED STATES AIR FORCE
USGS	UNITED STATES GEOLOGICAL SURVEY
UST	UNDERGROUND STORAGE TANK
USTRS	UNDERGROUND STORAGE TANK RESEARCH SUBCOMMITTEE (EEC/SAB/EPA, ALSO REFERRED TO AS "THE SUBCOMMITTEE")
U.S.	UNITED STATES
VISITT	VENDOR INFORMATION SYSTEM FOR INNOVATIVE TREATMENT TECHNOLOGY
VOCS	VOLATILE ORGANIC COMPOUNDS
WRITE	WASTE REDUCTION INNOVATIVE TECHNOLOGY EVALUATION

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