Letters to the Editor

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ORCHESTRATING ENVIRONMENTAL RESEARCH AND ASSESSMENT FOR REMEDIATION[1]

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To the Editor:

The interfaces between science, assessment, and policy have come to the forefront of national attention recently as the result of problems related to pollution and environmental remediation, habitat modification and fragmentation, and endangered and invading species. Issues at these interfaces were recently summarized for the National Acid Precipitation Assessment Program (NAPAP) by Levin (1992) and reviewed as a case study (Cowling 1992, Loucks 1992, Russell 1992, Schindler 1992). More than half a billion ($>0.5 \times 10^9$) dollars were invested in NAPAP over more than a decade and thousands of researchers were involved. Due to the magnitude of the program and its role at the science/policy interface, Levin (1992) posed the question "Is NAPAP a model for future studies?" Although opinions on the success of the program varied greatly (Cowling 1992, Loucks 1992, Russell 1992, Schindler 1992), several common lessons emerged from the papers. We thought it appropriate to ask if these lessons are being applied to another ongoing large-scale environmental program: the remediation of contaminated sites in the U.S. Department of Energy (DOE) nuclear weapons complex.

For nearly a half-century, materials and components for nuclear weapons have been produced at facilities now operated by DOE. Vast quantities of toxic waste, including hazardous chemicals and radionuclides, were generated in the process and resulted in extensive environmental contamination (Congress of the U.S. 1991). To address these contaminant problems, DOE prepared a Five-Year Plan in 1989, updated in 1990 and 1991, outlining its goals, strategies, and specific programs for assessment and cleanup of contaminated sites (U.S. Department of Energy 1991). The plan calls for $>30 \times 10^9$ dollars in expenditures on environmental restoration and waste management from fiscal years 1993 through 1997. Yet this is only the initial phase of an anticipated 30 yr of remediation efforts that could cost 10^9–10^{11} dollars, although neither DOE nor any other agency has been able to prepare a reliable cost estimate (Congress of the U.S. 1991). Although the fraction of this funding that will be directly applied to risk assessment and supporting research is uncertain, the magnitude of the project urges an evaluation of the present status of DOE efforts in light of the NAPAP lessons.

The recent emphasis by DOE on environmental restoration is being driven by state and federal regulations. Pertinent federal acts include the National Environmental Policy Act (NEPA), the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA). Regulatory costs are leading to calls for ensuring a sound scientific basis for decision-making (Abelson 1993). Most of the regulations require an assessment of the risks to human health and to ecosystems associated with management alternatives prior to any corrective action (Harwell 1989, Bartell et al. 1992, Suter 1993). These risk assessments provide the fulcrum between science and policy. They are the interface at which predictive capability about ecological processes and contaminant kinetics can be applied to aid in resolving environmental problems and managing risk at these sites.

In Fig. 1 we present our perspective of the role science should play in a risk management problem. We find this perspective generally consistent with comments of Levin (1992), Russell (1992), Cowling (1992), and Loucks (1992), based on their experience with NAPAP. There are three major factors to be considered in evaluating a cleanup scenario: (1) scientific and technical input, (2) regulatory constraints, and (3) political, economic, and social input. These factors must initially be considered in concert to define the overall problem and specify the management options or cleanup scenarios to be evaluated. Subsequently, a risk assessment for each scenario should be driven by scientific and technical input and should be relatively independent of regulatory, political, economic, and social considerations except when necessary to clarify a scenario (Fig. 1A). The best risk management decision is obtained by considering the results from the risk assessments in conjunction with the regulatory, political, social, and economic factors and then comparing results from the scenarios (Fig. 1B). Technical input is required to help interpret the assessments and their inherent uncertainties. The scientific community must also be aware of the time constraints associated with mandated regulatory processes. These basic concepts apply not only to DOE environmental restoration and NAPAP, but also to a variety of other environmental problems including Environmental Protection Agency Superfund sites (Travis and Doty 1989), wetlands protection, and sustainable development.

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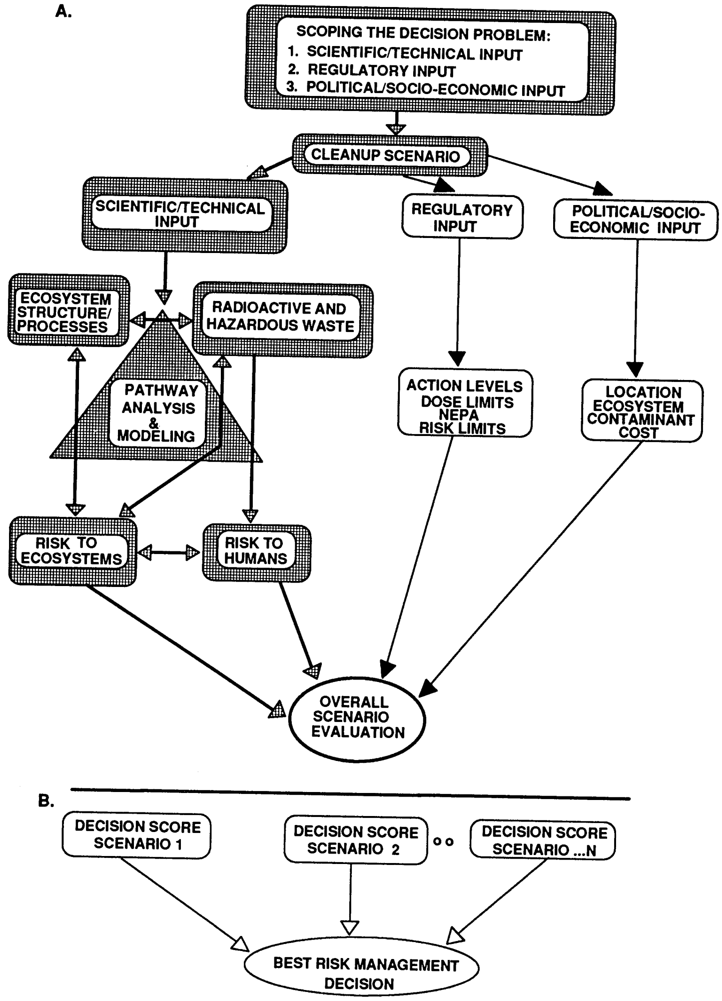

FIG. 1. (A) Processes included in a risk management decision, divided into (1) scientific and technical, (2) regulatory, and (3) political, social, and economic inputs. Activities directly involving science and technology are shaded. All types of input are required to define the problem and alternative mitigation or "cleanup" scenarios. Once a cleanup scenario is defined, risk assessment for humans and/or ecosystems and their components should proceed independently of regulatory and political, social, and economic factors. All factors are then reintegrated for an overall scenario evaluation. (B) Comparison of multiple scenarios is required to obtain the best risk management decision.

One of the most fundamental lessons from NAPAP is that objectives must be clearly spelled out early in the assessment (Cowling 1992, Levin 1992, Loucks 1992, Russell 1992). Based on recent reviews of the DOE Environmental Restoration program (National Research Council 1989, ACNFS 1991, Congress of the U.S. 1991) it is our opinion that DOE could address this issue in a more effective manner. Despite recommendations from the National Research Council (1989), of which Whicker was a member, that DOE should use "consistent risk assessment methodologies to bring scientific information into decisions regarding extent of site characterization, cleanup, cleanup methodologies, and priorities for environmental restoration," as of November 1991, DOE had yet to adopt a cleanup policy with specific, clear objectives (ACNFS 1991). An important function of clearly defined objectives is to prioritize data requirements and pertinent research needs for the assessment so that, as Cowling (1992) highlighted, research and assessment can be parallel activities with continuous feedback. The National Research Council (1989) concluded that additional research in the fields of hydrogeology and ecology as they relate to risk assessment is necessary to guide restoration activities in a timely manner; further prioritization hinges on a more focused problem statement. Thus, it appears that the DOE environmental restoration program needs to integrate better the various factors in the first step of risk management ("Scoping the decision problem" in Fig. 1A).

Another lesson from NAPAP is the importance of peer review throughout the scientific evaluation phase, including publication of a significant amount of research in peer-reviewed journals in a timely fashion

(Levin 1992, Russell 1992, Schindler 1992). Certainly the communication problem in risk management cannot be solved by peer review alone; Levin (1992), Russell (1992), and Cowling (1992) all stressed the important role of careful communication. Nonetheless, peer review is a critical component of risk management if scientific credibility is to be linked to the remediation process. With few exceptions (e.g., Whicker et al. 1990*b*) there are practically no peer-reviewed journal articles on risk to human or environmental endpoints resulting from environmental contaminants at DOE facilities. Alarmingly, published research in the field of radioecology, one of the most pertinent fields for such assessments, has decreased dramatically in the U.S. during the last decade, largely, we believe, because of altered DOE priorities and reduced funding for environmental research. There is currently little support for long-term, problem-directed research on the fate and effects of most environmental contaminants. We believe that such research could make future environmental cleanup decisions more sound and help prevent costly, unnecessary remediation.

A final NAPAP lesson for consideration that was highlighted by Levin (1992) is that the risk associated with remediation alternatives should be included in any assessment. This lesson is especially pertinent to DOE environmental restoration efforts and is the one we are most concerned about. The vast majority of contaminants at DOE sites consist of low concentrations of radioactivity and trace amounts of hazardous chemicals that are sequestered in terrestrial soils and aquatic sediments (Watters et al. 1980, Whicker et al. 1990*b*, Riley and Zachara 1992). One of the major remediation options being considered is physical removal of the soils and sediments (Congress of the U.S. 1991, U.S. Department of Energy 1991). This obviously requires virtual destruction of the contaminated ecosystem and the availability of a new site licensed to dispose of the contaminated materials that are removed. Clearly the risks associated with any remediation should be weighed against the risks of not remediating in a program of "environmental restoration." There is great potential for remedial activities that buy little if any reduction of risk to human health to result in significantly increased environmental impact. This same issue has been raised by Travis and Doty (1989) with respect to the Superfund program. Thus, decision-makers need information that allows clear comparison of the risks associated with and without implementation of remediation.

We fear that the lack of consistent, sound assessment procedures and supporting research that incorporates our best science into the decision-making process may lead to a great deal of cleanup that is unnecessary from the standpoint of actual risk to human health or environmental endpoints. The uncertainties inherent in most assessments remain quite large (Hoffman and Gardner 1983, Harwell and Harwell 1989, Blaylock 1990, Whicker et al. 1990*a*, Köhler et al. 1991, Sundblad 1991, Higley 1992), predominantly because our scientific knowledge on the transport and biological effects of many contaminants is insufficient for accurate and reliable predictions. Extreme conservatism in acceptable risk ranges in conjunction with large assessment uncertainties promotes a great deal of caution in setting standards and criteria for environmental remediation. Thus, $\gg 10^9$ dollars may be wasted by unnecessary cleanup and large tracts of ecologically valuable refugia may be lost (National Research Council 1989). Several other authors have raised these issues (McGuire 1989, Abelson 1990, 1992, Zeckhauser and Viscusi 1990), yet these problems do not appear to be appreciated by the general public, many regulators, and most decision-makers. DOE should avoid following the path of the Superfund program to date, in which there has been little correlation between risk levels and decisions to remediate (Travis and Doty 1989). Compounding the problem further is the growing political and economic pressure around DOE sites to maintain jobs and economic activity despite major cutbacks in the defense mission (Hickox 1992, Pasternak and Cary 1992) and the general perception that remediation is a "good thing" with no negative environmental costs. Certainly all of these factors may influence cleanup decisions; nonetheless it is critical that the risk assessment be driven by clear objectives and subsequently be conducted independently of these factors if the scientific and technical input into the decision-making is to be useful and uncompromised.

In conclusion, we believe that DOE, the U.S. taxpayer, and the environment would all benefit from a change in course that addresses the lessons from NAPAP. Some foresight is needed to define clear objectives and focused, supporting research. Schindler (1992: 129) complained that the lesson that "throwing a lot of money at science does not buy instant answers or instant excellence seems to be a hard one for bureaucrats and politicians to learn." We would add that throwing large amounts of money at areas with low levels of contamination without building a base of scientific knowledge is likely to compound our problems of economic debt and environmental degradation. We hope that pointing out the overlapping issues between NAPAP and DOE environmental restoration will make ecologists and others in the scientific community better placed for their role in "policy-relevant research and research-relevant policymaking" (Levin 1992:105). The environmental restoration program could benefit greatly from additional input from those in the fields of applied ecology.

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David D. Breshears
Environmental Science Group
Mail Stop J495
Los Alamos National Laboratory
Los Alamos, New Mexico 87545 USA
(current address)
Department of Radiological
Health Sciences
Colorado State University
Fort Collins, Colorado 80523 USA

F. Ward Whicker
Savannah River Ecology Laboratory
Drawer E
Aiken, South Carolina 29802 USA
Department of Radiological
Health Sciences
Colorado State University
Fort Collins, Colorado 80523 USA
(current address)

Thomas E. Hakonson
Environmental Science Group
Mail Stop J495
Los Alamos National Laboratory
Los Alamos, New Mexico 87545 USA

Note added in proof: An updated version of the DOE Environmental Restoration and Waste Management Five-Year Plan (DOE/S-00097P) was published January 1993 for Fiscal Years 1994 to 1998 and was unavailable to us at the time we submitted our revised letter. The 1993 version of the report largely acknowledges the issues we have raised. Addressing these issues remains a challenge before DOE and an opportunity for applied ecologists to place predictive science within the framework of risk assessment.