Peer Review of the U.S. Department of Energy's Use of Risk in its Prioritization Process

December 15, 1999

Peer Review Committee
of the
Consortium for Risk Evaluation
with Stakeholder Participation

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2. Executive Summary

At the request of the Management Board of the Consortium for Risk Evaluation with Stakeholder Participation (CRESP), the Consortium's Peer Review Committee reviewed the recent history of the use of risk analysis by the United States Department of Energy (DOE) in prioritizing and sequencing its environmental management activities. Because an in-depth review of the subject was precluded by time constraints, the Committee confined itself to a policy review, with guidance that could be helpful at the senior management level.

The principal findings resulting from the review can be summarized as follows:

1) In pursuit of the primary goal of DOE's environmental management program, which is the protection of human health and the environment, it is essential that risk be used as a criterion for priority setting and action.
2) DOE's use of a risk-based approach for the purpose has been mandated by Congress and recommended repeatedly by external advisors, recognizing that DOE must also consider other important programmatic objectives, including compliance with pertinent laws and regulations, minimization of socioeconomic, cultural, and land-use impacts, and the cost-effectiveness of alternative remediation options.
3) In recent years, DOE has found none of the various approaches it has explored for prioritizing its environmental management activities to be entirely satisfactory for the purpose, but each approach has been abandoned before it could develop adequately, owing largely to lack of confidence in the approach by DOE and site personnel, and/or lack of support for it by other stakeholders;

4) Although DOE's different approaches have varied in specific strengths and weaknesses, their shortcomings -- including those of the "Risk Profiles" described earlier this year -- have commonly included:

- Inadequacies in the input data used for ranking a given environmental management activity;
- Inadequate documentation of the basis for the rank assigned to a given activity;
- Inconsistencies in scoring practices among sites;
- Failure to relate a given activity to the specific environmental objective it was intended to address;
- Inadequacies in the assessment of risks to health and the environment;
- Insufficient clarity and transparency in the ranking process; and
- Lack of adequate credibility and acceptability of the process to in-house personnel, contractors, and/or other concerned stakeholders.

5) From review of the experience to date, it is concluded that the use of risk as a criterion for action in DOE's environmental management decision making is not only essential, but feasible and practical, given appropriate commitment and effort.

Recommendations for improving the process include the following:

1) DOE should develop and implement appropriate strategies for responsible interim and long-term stewardship, based on sound principles of risk assessment and risk management.

2) To this end, DOE should establish a process, either inside or outside the Department, for developing a risk evaluation methodology appropriate for meeting the near-term and long-term challenges to be addressed, and one that would allow the methodology to be adequately pilot-tested before it is applied across the complex.

3) DOE should take steps to ensure that:

- the methodology is consistent across the different sites, in order that the resulting priorities may be transparent and coherent;
- the process is community-based and accomplished locally, site-by-site, with the relevant personnel and other stakeholders adequately involved at all stages in its planning, development, and implementation; and
- . opportunities are provided for adequate consideration of the variations in risk parameters that may be necessitated by differences in the long-term values of different communities.

4) Specific risk-related issues that deserve increased attention in the future include:

- The need for a more integrated approach to risk assessment than one that would suffice for compliance purposes alone at sites containing multiple sources of contamination;
- The need to include exposure evaluation as a key step in any risk assessment;
- The need to assess the potential impacts of remediating activities themselves on the health of involved workers;
- The need to consider risks associated with chemical hazards, as well as radiation hazards;

- The need to address ecological risks;
- The need to evaluate potential socio-economic, cultural, and land-use impacts;
- The need for risk assessments to be documented appropriately and to be made as transparent as is feasible in every case;
- the need, particularly in complex assessments, for the Department and its contractors to provide clear summaries of the potential exposure pathways and hazardous agents in question, in order that the risk assessments may be more reviewable, credible, and useful in priority setting.

5) The forging of the needed approach ought to be carried out at the level of well-defined environmental management projects, yet take site geography and stakeholders' cultures into account.

6) The development of the needed approach also ought to build on the positive aspects and limitations of earlier efforts, and it should be given enough time and resources to be carefully evaluated before being implemented broadly.

3. Introduction

This report evaluates the evolving uses of risk as a basis for priority setting by the DOE Office of Environmental Management (EM) in its environmental management and budget formulation processes. The evaluation was conducted by the Peer Review Committee of CRESP, which was charged by the CRESP Management Board to review the recent history of the consideration of risk in the DOE decision process and to outline actions to be recommended to DOE for developing the data and analytical framework needed to deal effectively with the environmental problems it faces.

To assist in the evaluation, the Committee formed a subcommittee, which included additional members chosen for their recognized expertise in the relevant scientific and technical disciplines (Table 1). In addition, it sought pertinent information through interviews with a number of key DOE officials, state and federal regulators, site personnel, and other stakeholders. Since the CRESP Management Board had requested that the entire task be completed within three months, the Committee could not perform an exhaustive evaluation and confined itself to policy matters.

The report that follows briefly reviews the nature of DOE's environmental management problems, DOE's need for a sound method of prioritizing its activities in addressing the problems, the strengths and weaknesses of DOE's uses of risk evaluations in its recent approaches to priority-setting, and recommended steps for improving DOE's use of risk in future decision making.

4. The DOE-EM Decision Problem

4.A. Hazardous Nature of Wastes at DOE Sites

The nuclear technology and weapons development activities pursued by DOE and its predecessors (AEC and ERDA) during the past 50 years have given rise to large quantities of radioactive and chemical wastes. These include millions of tons of radioactive mine and mill tailings, millions of gallons of radioactive and chemical wastes, and millions of pieces of contaminated equipment, clothing, and other items. Included among the different waste materials that may be present at a given site are radionuclides and toxic chemicals which can be highly hazardous to human health and the environment (DOE/BEMR, 1995).

The safe management of such wastes has been complicated by the fact that they have been produced at more than 130 mines, laboratories, chemical plants, machine shops, nuclear reactors, and test sites, scattered among 30 states and territories. As a result, thousands of potentially hazardous substance release sites are now known to exist within the nuclear weapons complex (hundreds at some of the larger DOE reservations).

Management of the wastes produced by the past and ongoing activities requires decisions on a broad range of problems, including long-term health, safety, and neighborhood concerns, potential impacts on the environment, the threat to national security through nuclear proliferation, and the limitations imposed by knowledge gaps and by regulatory and budgetary constraints. In view of the enormity and urgency of the task, Congress advised DOE to develop a risk-based approach for prioritizing and sequencing the relevant environmental management

activities; i.e., "to estimate the risk addressed by cleanup requirements on the basis of the best scientific evidence available", without necessarily performing an "exhaustive, formal risk assessment" on each of the thousands of cleanup activities required by compliance agreements (HR, 1993).

A risk-based approach for prioritizing DOE's environmental management activities has also been endorsed by a National Research Council study, which concluded that its use would be feasible and successful, provided that its purposes and limitations were clearly defined, the public was involved in the process sufficiently early and fully, and that the approach gave adequate consideration to the full range of cultural, socioeconomic, historical, religious, and political concerns of interested stakeholders (NAS/NRC, 1994). DOE has consistently received similar advice about the importance of risk tools for its decision making from a variety of advisors, regulators, congressional overseers, and others throughout the decade. In addition, it has been suggested that risk is not only a concept to be used in guiding priority setting but also in evaluating the effectiveness of alternative ways of achieving project goals. Given such recommendations, it is appropriate that EM has pursued evolving efforts to develop and implement an effective risk-based decision system, recognizing that risk is but one of the many factors to be considered in setting management and budget priorities.

4. B. Multiplicity of Program Objectives

Selection among alternative risk management options is complicated for EM by the multiplicity of objectives that need to be addressed. Thus, although EM's primary goal is the protection of human health and the environment, its environmental management strategies must be tailored to meet other important programmatic objectives as well, as indicated in the following.

i). Control of Risks to Human Health and the Environment

The radioactive and chemical wastes, and the contaminated soil, surface water, ground water, equipment, and facilities left by DOE's nuclear technology and weapons development pose serious potential threats to human health and the environment. The health impacts that can be caused by exposure to such agents range from acutely lethal injuries to cancer, heritable diseases, and other chronic disorders that may not appear until years or decades after exposure (Mettler and Upton, 1995). The risks vary widely, however, depending on the nature and quantity of the hazardous agent in question and the levels of current and/or potential exposure to the agent.

In assessing the risks of such effects at a given site, the degree or complexity of assessment that is needed will depend on the purpose for which the assessment is needed, the availability of pertinent data, and other factors. In every assessment, however; the following need to be addressed at some level of detail: 1) hazard identification (determination of the identities, locations, and physicochemical states of the potentially hazardous physical and/or chemical agents that may be present at the site); 2) exposure assessment (analysis of the pathways of exposure to the agents in question, the number of people who may be exposed, the likelihood and

levels of their exposure, and the age and sex distribution of the exposed population); 3) dose-response evaluation (consideration of how the risk to a given individual may vary in relation to his or her level of exposure); and 4) risk characterization (estimation of the number of people who may be affected in the population at risk, the likelihood that they may be affected, and the types of effects that they may experience as a result).

Because health effects are not produced unless susceptible receptors are exposed to the hazardous agents in question, appropriate isolation and/or containment of the agents can suffice to eliminate the associated risks. In those situations where it is not feasible to avoid exposure completely, compliance with contemporary exposure limits will suffice to prevent the production of acute effects, since these occur only at high-dose levels (ICRP, 1991). Present dose limits cannot be assumed to afford complete protection against the carcinogenic and genetic effects of cumulative exposures, however, since these effects may have no thresholds (ICRP, 1991). For public health purposes, therefore, any level of exposure to radiation and/or certain of the chemicals that are present at DOE sites is generally presumed to involve some corresponding risks of genetic and carcinogenic effects. Although the magnitude of such risks cannot be estimated with precision, owing to uncertainties in the relevant exposure parameters and dose-response relationships, the potential risks should, nevertheless, receive appropriate consideration in formulating the priorities for any pertinent environmental management decisions. Such risk analyses are important not only for identifying and assessing the risks that may exist at a given site but also for comparing the alternative risk management options that may be applicable and for determining if and when a given remediation task may be considered to have been satisfactorily accomplished.

The large quantities of radionuclides and toxic chemicals that are present in unprecedented volumes of contaminated water, soil, facilities, and equipment at many sites in the nuclear weapons complex pose potential risks to the surrounding environment as well as to the health of exposed populations. To protect the environment and its ecosystems against such hazards requires: 1) the stabilization and containment of the toxic agents, to prevent the impacts that could result from their uncontrolled release into the surrounding air, soil, surface water, and ground water; 2) appropriate decommissioning and decontamination of surplus facilities and equipment; 3) the removal and safe disposition of any hazardous materials; and 4) long-term surveillance and monitoring of remediated facilities and sites to ensure their continuing safety.

The associated management problems are daunting, complicated not only by the quantities of hazardous materials to be dealt with but by two other factors as well. The first is the fact that some of the materials are destined to remain hazardous for thousands of years because of their content of long-lived radionuclides, whereas others (with which the long-lived radionuclides are often mixed) decay rapidly and thus represent a hazard for a shorter time than is of concern in most risk management contexts. The second is the fact that with many radionuclides, treatment to significantly reduce or detoxify the materials is not possible, so that the management of such materials requires isolating and securing them effectively for an indefinitely long period. In many instances, there are also limitations in our ability to assess the potential long-term impacts on the environment, as well as limitations in the available environmental management technologies and resources. In addition, the life cycle costs of the environmental problems attributable to past and future nuclear weapons activities are very high, having been projected to exceed $150 billion in constant 1995 dollars (DOE/BEMR, 1995). Because of all of these

factors, it is not surprising that opinions on the priority and level of cleanup required at a given site often differ among those concerned.

In many instances past operations have involved releases of hazardous materials that have contaminated soil and water, so that exposure to such soil and water must be managed to avoid undue risk to the public. This may involve the substitution of a safe water supply to avoid use of contaminated ground water, and it often involves monitoring to track the concentrations and locations of contaminants. Similarly, current levels of contamination will limit future public and tribal uses of the land at many sites. In such cases, a risk-informed approach is needed to assess the need for, and effectiveness of, control and remediation measures.

Also, although DOE has an obligation to bring its facilities into full compliance with relevant environmental regulations, such compliance can be achieved only over time. The decision problem is to allocate available funds most effectively, given the alternative scenarios for remediation that may be possible. DOE has tried to develop and use risk-based tools to help identify priorities for deciding what problems deserve to be addressed immediately and what problems are less urgent. Some of the ranking systems discussed below, such as the Environmental Restoration Priority System (ERPS), included measures to distinguish between situations where the future costs for remediation would increase significantly with inaction, in comparison to situations where the future costs would either remain constant or actually decrease with time.

ii. Compliance with Regulatory and Legal Requirements

DOE's environmental management activities must be conducted in accordance with applicable laws, regulations, and agreements. The principal environmental laws specifying how cleanup is to be performed at weapons sites are the Resource Conservation and Recovery Act (RCRA) as amended; the Atomic Energy Act of 1954, as amended; the Federal Facility Compliance Act of 1992; and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, which mandates that ARARS (applicable or relevant and appropriate requirements of federal and state environmental laws) must be taken into account In addition, for sites undergoing CERCLA cleanup, DOE is required to enter into agreements with EPA on how the cleanup is to be carried out. Furthermore, states have joined in such agreements as well, making them tripartite compliance agreements. Activities at such sites are also subject to DOE's own rules, the requirements of the Clean Water Act, Occupational Safety and Health Administration (OSHA) standards, recommendations from the Defense Nuclear Facility Safety Board, as well as recommendations from the Environmental Management Advisory Board, the National Research Council, and other agencies.

In addition, DOE's facilities for the disposal of high-level radioactive waste and spent nuclear fuel are regulated by the Nuclear Regulatory Commission, under regulations implementing standards promulgated by EPA. Some of the various federal and state regulatory constraints involve their own particular risk evaluation processes, numerical concentration limits, standards, priorities, and compliance schedules, all of which are required by law to be met. Most, but not all, of these regulations explicitly use risk as a criterion not only of action but also to guide risk management practice. The fact that the specific guidance for risk reduction and management

differs dramatically among the various regulatory mechanisms that are overseen by diverse authorities complicates DOE's task of devising an effective risk-based approach for selecting among alternative management activities and for properly sequencing such activities.

In some cases, the regulations were developed specifically to handle the kinds of hazardous materials that are found only at DOE sites or in specific non-DOE contexts. In other cases, the laws were developed to address contaminants in contexts that are ubiquitous, not only in industrial settings but in society generally. The task of tailoring appropriate risk management activities and priorities to the special problems of DOE sites, cited above, (i.e., nature of contaminants and contaminant mixes, distribution of contaminants over radically different sized facilities, and unusual temporal characteristics of the hazards at the sites) must be a focused and concerted effort. It will involve facilitated cooperation with regulators (cooperation we believe to be forthcoming) and also initiative and consistent follow-through from DOE at both headquarters and facility levels. Thus, a robust risk data system that can best support cost-effective remedial actions and minimize the long-term burdens is needed at DOE sites (Dhmmer et al, 1998).

iii. Achievement of Mortgage Reduction

"Mortgage reduction" is the term used by DOE to describe efforts to lower the long-term cost to the government of owning and managing DOE properties. Each property owned by DOE and under EM control requires active management to some degree. That management includes maintenance of security, provision of fire and other protection, provision of utilities, and routine maintenance and repair of facilities such as buildings and storage facilities. If hazardous or radioactive materials are present, provision of controls to avoid exposure is also required. All of these activities require an administrative infrastructure in addition to operation and maintenance. These "housekeeping" tasks incur costs that are nearly the same whether the facility is shut down, in standby, or operating, so long as the facility requires special care and is in DOE hands, and the associated costs form a substantial portion of today's EM budget.

The initial focus of EM managers was largely on understanding the conditions at facilities across the country and setting a path to ensure compliance with environmental laws and regulations. Thus it concentrated principally on the active treatment, storage, and disposal of waste and on environmental remediation and monitoring, as opposed to activities such as the decontamination and decommissioning of unused buildings, site maintenance, and security activities, which are usually not covered by legal requirements. Attention to the latter types of activities was drawn by budgetary pressure for mortgage reduction; i.e., when the EM budget rose from $2.2 billion in FY90 to $6 billion four years later, largely as a result of the commencement of cleanup activities, Congress and OMB took notice and began pressuring DOE to flatten its budget projections

Risks to health and the environment constitute both a direct and an indirect element in mortgage reduction activities. On the direct side, so long as operation and maintenance are required and/or hazardous or radioactive contamination exists, facilities are subject to activities that place workers, and sometimes the public, at risk. Conversely, eliminating surplus facilities and preparing them for release to other activities also brings risks, largely to site workers, but also to the public. Buildings must be decontaminated and sometimes dismantled, hazardous and radioactive wastes and materials removed or sequestered, and environmental media remediated. Materials and wastes may need to be transported to other DOE sites or to commercial treatment or disposal facilities. These are inherently risky activities, even without consideration of the hazardous and/or radioactive contamination that may be present.

The direct-risk-reduction effects of preparing facilities for release from special care are seldom the motivation for mortgage reduction activities. Usually, the motivation is to save DOE resources on a life-cycle basis. This is where the indirect effect of risk on mortgage reduction comes into play. The resources saved will: 1) allow more resources to be devoted to other risk reduction activities over time, 2)allow high-priority risk reduction activities to be conducted earlier, and 3) cushion possible future budget reductions. An essential element in this evaluation, of course, is the life-cycle assessment of risks to workers and the public, which must be based on a methodology that is effective for the purpose and consistent across sites. Viewed in this context, expenditures on mortgage reduction activities can be considered justifiable investments insofar as their "rate of return" exceeds that which could be gained from alternative expenditures..

Expenditures on mortgage reduction activities that meet the positive net return test (on both resource and risk terms) are thus at the center of a risk-reduction strategy for EM. While the allocation of resources to mortgage reduction may itself incur risks and may delay other actions, it will ultimately enable more and faster reduction of overall risk, and more rapid completion of EM's mission. Since the achievement of mortgage reduction is, therefore, an integral element in EM's program, appropriate allocation of resources to the task, and effective selection of targets to obtain the highest possible return, are key requirements if EM is to accomplish its mission expeditiously.

iv. Minimization of Mission Impact

At the time that various risk-based approaches to deal with the environmental problems of the DOE complex were first proposed, DOE's primary mission was still the production of nuclear weapons. Now, however, the primary mission of the DOE EM organization is to bring the system into a state that is safe, compliant with environmental regulations, and consistent with commitments made to the affected states and tribes. At present, therefore, there is generally no conflict between EM's mission and the management and mitigation of risks to the public.

Activities at some sites, however, are married to ongoing missions that continue to generate new wastes and involve security requirements. For example, although the United States ceased production of plutonium and new nuclear weapons years ago, DOE must still maintain a large complex in support of the nuclear weapons Stockpile Stewardship program. This program, which requires the replacement of weapons that are removed from the stockpile for examination, involves classified work and produces some hazardous waste. Likewise, DOE's support of the

U.S. program for disposition of plutonium from nuclear weapons to be destroyed under the arms control agreements involves the ongoing production of some hazardous waste.

4.C. Need for Prioritization of the Department of Energy's Remediation Activities for Maximal Value Added.

The Department of Energy has been given a Herculean set of tasks to accomplish in cleaning up the country's nuclear weapons complex. In fact, this task, when completed, will rank among the largest public works projects ever undertaken. Even so, since resources are limited, DOE must decide what to do first, what can be put off until later, and what need never be done at all.

Therefore, EM's goal must be to obtain the greatest possible benefit to the nation from the resources allocated to it. This means that it must do those things first that have the greatest incremental value. Moreover, to obtain the resources needed to accomplish its tasks it must communicate successfully to the Congress that it is indeed achieving this end.

The first and most important task is to decide what actions have the most incremental value. This is difficult to do because actions must generally respond to short-term conditions and at the same time be properly chosen and sequenced to serve long-term goals, and be coordinated with other diverse actions taking place throughout the large cleanup enterprise. Furthermore, in setting these priorities, two complexities must be kept in mind. First, the tasks are dispersed in numerous sites around the nation; each managed separately and each having to respond to local,

as well as national, concerns. Second, control over the ordering of tasks and the allocation of resources to them is shared with discrete regulatory authorities at each of the locations.

It turns out that despite the large numbers of absolute dollars being spent in the remediation program, the discretionary resources available to the Department are substantially limited. First, the costs of maintaining the facilities in a safe and secure state are enormous and must take precedence. Second, long-term projects are underway, and the benefits of these ongoing efforts will be realized only when incremental expenditures to complete them are made. Finally, certain activities are linked; to obtain maximal benefit from some, others must be performed. All of such expenditures are largely fixed in the short-term and sometimes intermediate-term, and they cannot be varied if the effort is to be responsible and effective. However, all are variable over the long-term, which makes planning based on priorities both possible and essential. It is for this reason that the major planning effort of EM will be most credible when it links short-term gains and set-backs to an ever-more consistent and credible picture of the long-term stewardship task that is emerging. Thus, it will gain general public acceptance only if its risk evaluations are seen to be increasingly stable and verifiable.

In order that the threats to human health and the environment can be addressed most effectively with the limited resources that are available for the purpose, the system for prioritizing the relevant management activities should distinguish among the differences in strategies that are needed for addressing future "high-risk," "intermediate-risk," and "low-risk" situations. Hence the system should recognize that those "high-risk" situations in which the barriers to exposure are expected to deteriorate within a decade in the absence of remediation deserve higher priority than those in which the hazards can be stabilized through interim management. It should also

recognize that among situations in the "low-risk" category, those in which the landlord costs are higher than the remediation costs may deserve a higher priority for remediation than would otherwise be the case. Finally, the system should recognize that situations in the "intermediate-risk" category call for a "rolling stewardship", which relies on hazard stabilization, surveillance, and monitoring, with an observation period long enough to permit consideration of transition options, waste dynamics, social perceptions, maintenance costs, the development of new management technologies, and the potential need to shift the priority on the basis of updated analysis (CRESP, 1996).

Given the necessity and practicality of setting budget priorities to fund the remediation efforts that are required, there must be a clearly stated goal commensurate with such expenditures. We would suggest that the goal should be to minimize the present environmental burden of the nuclear weapons complex, which consists of two parts: first, the potential harm to human health and the environment that may be caused by the hazardous wastes it contains; and second, the loss of the alternative benefits that the resources devoted to lessening this harm could otherwise be used to produce. Reduced to its essentials, then, the prioritization problem faced by the DOE is to optimize between environmental and health risk reduction, on the one hand, and the costs of achieving it on the other, with both integrated over time. Although it may not be possible to determine optimal solutions precisely, of course, even rough quantification or qualitative assessments can be sufficient for guiding decisions at the coarse-screen level required.

As discussed previously, there are some complexities in implementing this holistic view. First is the necessity to conduct business efficiently and expeditiously. In this regard the dispersed nature of the sites where activities take place, and the discrete management and local influence to which

each responds, becomes important in prioritization. Funds cannot be shifted from site to site like a hockey puck on ice in response to short-term shifts in risk reduction payoffs without incurring substantial efficiency penalties. Stability of site operations is essential for long-term operational efficiency, planning, and project sequencing, for obvious reasons. Furthermore, incentives for effective and efficient management and operations may be jeopardized if success in reducing risks is rewarded by a decrease in future budgets.

There is another constraint as well. Decisions on what is to be done are shared with local regulatory authorities and other stakeholders. Actions therefore must be responsive to broader local concerns, including stable employment and useable, functional land-use planning. Priorities must of necessity, then, balance national and local needs.

The implication of all this is that for the Department of Energy to succeed as the national program manager it first must have a clear vision of its mission in order to guide its decisions and approach. It must then have a firm and complete, but not necessarily precise, grasp of the risk reduction opportunities available and of their incremental costs, with both properly considered over time. This will provide a basis for establishing national and site-specific priorities for action, and the ability to demonstrate the loss to the national well-being if those priorities are not followed. Thus armed, DOE can balance the advantages of increased attention to shorter-term, high-payoff activities against the advantages of more effective performance on other activities at the discrete sites. Further, it can negotiate with local authorities over local versus national priorities from the position of strength provided by a clear understanding of the impacts and implications of the choices. Finally, DOE can communicate effectively the implications of choices to participants in negotiations, to others who will be affected, to site

personnel where the work is done, to Congress, and to the public. But none of the steps toward making the DOE process both more transparent and explicable can occur unless or until DOE has put in place credible information to support the decisions discussed above. Irrespective of where one turns in seeking to improve DOE's decision making and relationships with its stakeholders, the need for project-based risk information emerges as a priority.

To summarize: It is essential that the Department of Energy set priorities for its remediation activities. These priorities must meet the goal of minimizing the burden of the legacy of the nuclear weapons complex. One essential element for setting these priorities is to understand how much risk can be reduced, at what incremental cost, from each alternative risk-management action. Priorities must also, however, take into account operational efficiency, incentives, and shared control of decisions with local stakeholders.

4D. Need for Institutional, Public, and Political Support in Prioritizing Management and Budget Decisions:

In selecting among alternative environmental management options, EM must consider the interests and needs of the many different groups and individuals who may be directly or indirectly affected by a given environmental management decision. In the context of EM's environmental management mission, therefore, the programmatic objectives are multiple and diverse, including protection of the health and safety of site personnel; protection of the health and safety of the public; protection of the environment; protection of cultural and/or religious resources in areas that may be impacted; protection of land-use values and future land use

options in affected areas; prevention of adverse economic impacts on affected populations; compliance with pertinent legal and regulatory requirements; and accomplishment of the intended management task as expeditiously and cost-effectively as possible. Within any one of these categories, moreover, the objective in question cannot be characterized adequately without being defined more narrowly and precisely; e.g., risks to the health of workers may be expressed in terms of the relevant annual risks, lifetime risks, relative risks, absolute risks, risks to the average individual, risks to the maximally exposed individual, risks to the exposed population, attributable risks, etc. (e.g., Upton, 1992).

The various issues to be considered also include the potential incompatibility of risk-based priority setting approaches with applicable compliance agreements; the potential value of risk-based methods in exploring the feasibility, cost, and timing of alternative strategies for achieving remediation for various future site uses; and the exploration of different stewardship options in situations where cleanup is not feasible with current technology or except at unreasonable cost.

Each of the above issues must receive careful consideration and be weighted appropriately in the formulation of environmental management decisions by EM if it is to sustain the institutional, public, and political support needed to accomplish its mission. Although EM has endeavored to address the relevant health and environmental risks explicitly in various multi-attribute prioritization approaches it has pursued for the purpose in recent years, a methodology adequate for the purpose remains to be developed and implemented. The strengths and weaknesses of the uses of risk that EM has made in its evolving approaches are discussed below.

5. Strengths and Weaknesses of DOE's Successive Efforts to Develop and Implement a Risk-Based Prioritization System for Decision Making

5.A. Program Optimization System

The Program Optimization System (POS) was developed by DOE in 1988, in direct response to a congressional directive that DOE establish a priority system for the application of funds for environmental restoration. The organizational unit responsible for POS development was the Defense Programs unit, which had responsibility at that time for cleanup activities at nuclear weapons facilities.

A major problem of the POS was the resistance it elicited by its radical recommendations regarding the allocation of funds across facilities. For example, its most controversial recommendation was for a 50 percent cut in funding for the Hanford site. Other problems included the inability of the POS to account for the value of studies to reduce uncertainties. For these and other reasons, the POS had little impact on actual DOE budget allocations for environmental restoration, in spite of the strong support for the system among some DOE decision-makers. One of the reasons for this support was that the process provided a channel for detailed documentation regarding cleanup problems and for program information to flow from the field to DOE headquarters.

5. B. Environmental Restoration Priority System

During 1989 - 1990, the POS evolved into the Environmental Restoration Priority System (ERPS), through the efforts of the same design team that had developed the POS. The ERPS differed from the POS, in three major respects: 1) it included activity screening, information analysis, and criteria regarding socio-economics; 2) it was not limited to the facilities within DOE Defense Programs; and 3) it had been planned for use as an external tool, with outside involvement. In comparison to the POS, the ERPS was designed to provide a more complex decision model, especially concerning the value to DOE of the uncertainty reductions that would occur through site characterization activities. Although ERPS was designed to operate with any specified set of values and trade-offs, it was used with values, including those based on risk analysis, which were elicited from DOE managers. This fact, coupled with the complexity of the model, gave it a lack of transparency that was troubling to stakeholders. In addition, the internal structure of ERPS required that impacts be viewed in a trade-off analysis, which was equivalent to converting all effects into costs. This philosophical approach was particularly controversial with respect to regulatory compliance, where many observers noted that DOE must obey the letter of the law.

Despite the technical improvements that were added to ERPS and its praise by independent reviewers, it was viewed suspiciously by stakeholders as a tool for making allocation decisions across sites (Jenni et al, 1995). In essence, therefore, DOE headquarters decided not to apply ERPS because of stakeholder opposition, although similar decision support systems have since been adopted for use at various DOE sites, as discussed below.

5.C. Risk Data Sheet Scoring System

In 1995, in formulating its FY 1998 budget, EM used a standardized form, the Risk Data Sheet (RDS), for rating its environmental management activities. Entries on this form were used to record the scores assigned to a given activity on the basis of its importance in addressing each of the following program objectives:

1) Public health and safety;
2) Site personnel health and safety;
3) Environmental protection;
4) Compliance with pertinent laws and regulations;
5) Mission impact;
6) Mortgage reduction; and
7) Avoidance of adverse social, cultural, and economic impacts.

By explicitly linking risk with program planning and budget formulation, the RDS represented a creditable advance in DOE's evolution of a risk-based approach for prioritizing its environmental management activities. The system was not, however, without problems.

A basic problem with the system stemmed from the fact that it tended to obscure the primary purpose of any given activity, since the RDS typically failed to indicate the relationship of a particular activity to its intended environmental management objective. In some instances, moreover, multiple RDS's were used in combination to address a single objective, whereas in other instances a single RDS was used to address multiple objectives. As a result, the system did not enable the potential advantages of alternate environmental management strategies to be evaluated adequately. Also, a given activity was assessed only on the basis of a one-year time

horizon, so that its effectiveness over a longer period could not be judged.

Additional problems with the system included marked inconsistencies across the different DOE sites in the scoring of a given type of activity; severe limitations in the data available for use in the scoring process; inadequate documentation of the basis for scores that were assigned; insufficient attention to chemical, as opposed to radiation hazards; inadequate assessment of ecological risks, transportation risks, and potential impacts on future land-use options; lack of clarity and transparency in the scoring process; and inadequate involvement of stakeholders at all stages in the process (CRESP, 1996).

Many of the above issues were addressed in the RDS system that was emerging in 1997 for the 1999 budget. In particular, EM officials gave careful attention to the development of a system that aggressively sought to incorporate past, present, and future risks, and to give more specificity to ecological risks. As the system was being put into place, however, the focus shifted to the year 2006 as the planning template, and RDSs were supplanted by projects as the units of analysis. As a result, the amended approach to the RDSs was never actually tested in the field.

5.D. Project Baseline Summaries (PBSs)

The 2006 Plan Guidance, prepared by the DOE Headquarters to assist the Field in implementing the National 2006 Plan, provided detailed instructions for completing Project Baseline Summaries (PBSs) as a basic part of the annual Integrated Planning, Accountability, and Budgeting System (DOE, 1997). From the Fall of 1997, each Operations/Field Office has been required to submit to DOE Headquarters a PBS for every one of its approved 2006 Plan projects. The PBS is generally to include a detailed summary of the project's scope, schedule and cost baseline, life-cycle metrics, annual performance targets, financial history, budget, and other information such as data on risk, safety, and health (DOE, 1997,1998). In the PBS, which is intended to serve as the major management tool for each of the 2006 Plan projects, risk is to be considered in setting priorities at and across the sites, sequencing project work, measuring progress, and showing that EM is addressing the most urgent risks first. Project managers are required to perform a qualitative evaluation of the risks to workers, the public, and the environment associated with each project, following a screening evaluation to determine the need and appropriate level of detail for the risk evaluation. The project's risk evaluation is also intended to build upon previous evaluations and to address the interests and concerns of regulators, stakeholders, and Tribal Nations. For each applicable risk category (public, worker, environment), the level of risk is defined by the intersection of two qualitatively assessed parameters (i.e., impact and likelihood), and the risk is classified as *Urgent (U)*, *High (H)*, *Medium (M)*, *Low (L)*, or *Not Applicable (NA).*

Although the 2006 Plan Guidance states that "Tracking risk information will demonstrate how dollars spent on cleanup efforts work to reduce overall risk and further the mission of EM", it is

not clear how this can be accomplished with the qualitative definitions of risk that are proposed. Furthermore, the assessments of risk, as defined in the plan, do not require adequate evaluation of the exposure of receptor(s) of concern and of the toxicity of constituent(s) of concern, which are of fundamental importance to any risk characterization. While the approach can be construed as an improvement over previous approaches in some respects, it lacks critical information necessary for evaluating risk, and it oversimplifies risk characterization. Also, without a clearer and more transparent definition of the basis for classifying risks, and the consistent application of the process across all projects and sites, it will be difficult, if not impossible, to track project progress adequately and to make the process credible and acceptable to stakeholders. Also, the PBS is clearly a tool that is most useful for comparing projects within a given site alone, where there is a reasonable hope that the ratings will be consistent and consistently coordinated with stakeholders.

5.E. Accelerated Cleanup: Paths to Closure

The DOE report "Accelerated Cleanup: Paths to Closure" (DOE, 1998) represented DOE's response to Congress' concern with the large magnitude of the projected cleanup costs. The key goals of the strategy that was presented in the report were: (1) to plan from the top down on what could be achieved within a realistic funding level; and (2) to achieve some early successes, so that Congress would have confidence that the environmental problems at most DOE sites would be resolved within less than a decade.

To date (Fall, 1999), the plan presented in the report has been largely followed, and the new DOE EM organization chart reflects the distinction between the few sites that may require greater, and perhaps longer, attention (e.g., Hanford, Savannah River, and Idaho), and the many other sites and facilities where the goal is closure within the coming decade.

The report appears to have been written to advocate and justify a new budget approach, in which the programs at each DOE site were subdivided into individual projects, many of which were intended for completion by the year 2006. Altogether some 353 such projects were identified at the various sites, the combined cost of which (through 2070) was estimated to approximate $147B (1998 $). The report stresses, however, that it is only a management tool and that:

- "Paths to Closure is not a budget or a decision document."
- "Paths to Closure gives EM the management tools needed to understand impacts on life-cycle costs and closure date schedules."
- "Paths to Closure gives EM, its stakeholders, regulators, and Tribal Nations, and the Congress the management tools we need to understand the consequences of our choices - the effects on life-cycle costs and closure date schedules of alternative near-term and outyear budget scenarios."

The report focuses almost entirely on costs and schedules, and the term "risk", as defined therein, is not the risk of harm to health or to the environment, as in most other risk analyses, but the risk of missing cost or schedule targets. The latter, so-called "programmatic risk" is defined as the risk to cost, schedule, and technical performance resulting from the failure to complete a given activity on schedule. Three categories of programmatic risk are defined: 1) Technology (do we have the technology to do our work?); 2) Scope (do we know how much work there is to do?);

and 3) Intersite Dependency (do we know how and where we plan to store, treat, and dispose of material and waste?). Thus, although specific technological needs are identified for each project, there is no specific reference in the report to reduction of risks to health and the environment.

"Paths to Closure" appears to have been based on the assumption that risks to health and the environment are already incorporated into the planning of projects and need not be mentioned or are unimportant, or that introducing traditional risk concepts could weaken the appeal for constant funding. Traditional risk analysis would raise such questions as:

- Do we know what are the more significant health and environment risks?
- Are the resources targeted to reducing these risks?
- Should EM look at risks across the whole complex and allocate funds according to a risk reduction metric?

It is significant that none of these questions was addressed in "Paths to Closure"

5.F. Site Risk Profiles

The "Risk Profiles" represent the latest in a series of annual efforts by DOE's EM program to summarize and communicate present, planned, and end-state risk information. They are presented in a draft report entitled, "Results and Status of Environmental Management Site Risk Profiles. Public Hazard Management at Ten DOE Field Offices. Working Papers", dated March 22, 1999. This report, from the Center for Risk Excellence (CRE), resulted from a collaborative effort by CRE, the ten DOE field offices, and the Office of Science and Risk Policy to characterize the risks addressed by activities of the EM program (CRE, 1999)..

According to the report, the approach utilized in the preparation of the "Risk Profiles" departs significantly from previous efforts to collect and communicate risk information in several respects; namely,

- It involved collaboration with site personnel to gain access to site data and viewpoints outside the budget process.
- It provided documentation of current and future public health risks, including determination of the change in risk resulting from completion of site EM hazard management actions.
- It presented results at the site level, and not merely at the project level.

The report cautions that the Risk Profiles are not to be construed as detailed assessments of site risks but are to serve as a communication tool for documenting the status, progress, and endpoints of EM activities in terms of hazard and risk. The five stated objectives of the Risk Profiles are:

- To provide broad site-level risk information.
- To make effective use of existing data from the sites.
- To present clear information to a variety of audiences, in support of the budget process and in response to outside requests for summary risk information.
- To develop and follow an objective and repeatable evaluation of EM progress over time.
- To seek and incorporate extensive site and stakeholder input.

CRE requested an independent review of the report by the Consortium for Risk Evaluation and Stakeholder Participation (CRESP). The resulting review, dated May 19, 1999, was limited in its

scope, focusing on the adequacy of the Profiles to meet their stated objectives and suggesting some key areas for improvement (Goldstein and Powers, 1999). The major points in the analysis, confirmed in the present review, are that the report, in general, does not meet its stated objectives, and, especially, that it should be construed as a *hazard* profile rather than a *risk* profile report. The latter criticism is based on the finding that although the report presents detailed information about the volumes and type of waste products present at each site, essential information for evaluating the associated risks (e.g., receptors of concern, applicable and relevant potential exposure pathways and scenarios, conceptual site models, estimates of existing levels of risk, estimates of changes in risk resulting from risk management activities) is not consistently and adequately documented.

The CRE report states explicitly the assumption that "hazard evaluations are an indicator of public risk" for EM activities; however, it also acknowledges that the relationship between hazards and risks is not a one-to-one relationship. Since the CRE report presents little exposure information, and no toxicity or potency information, risk estimates derived by linking exposure with toxicity cannot be constructed. Furthermore, the terms risk and hazard are used inconsistently and interchangeably in the report, causing confusion and ambiguity. Although each of the profiles contains graphs depicting relative change in site hazard (or risk) over time for each waste type, it is not clear how hazard or risk reductions are estimated and whether they are similarly calculated from one graph to the next. Hence the graphs do not answer the fundamental question of how and to what extent a given reduction in hazard corresponds to a reduction in risk; also, the concept of "relative time" that is used in the report makes chronological tracking of progress difficult. Finally, the report fails altogether to address ecological, occupational, or transportation risks.

In response to comments received from CRESP and other interested parties, CRE has developed a "Draft Retooling Plan" to address the comments and to improve the Risk Profiles so that they can serve as a useful communication tool (Young, 1999). CRE has also announced plans for a number of pilot projects to address issues omitted in the current version of the Risk Profiles, including evaluation of site-level occupational, ecological, and transportation risks, cultural risks, risk communication alternatives, programmatic risk profiles, and analysis of the role of risk in decision-making. CRE has also proposed that future versions of the Risk Profiles be designed so that they can be easily attached to, or incorporated in, future Paths to Closure documents (Young, 1999). It is too early to judge whether these plans will be carried out and, if so, whether they will have been implemented satisfactorily.

5.G. New Efforts to Link Risk Concepts with Regulatory Innovations: Integrator Operable Unit and Composite Analyses.

Although most of the statutes regulating DOE-EM cleanup efforts are risk-based, observers whose views were sought for this review see a gap between those EM activities which are needed to comply with the applicable environmental statutes/regulations and those which would be generated by a risk evaluation of the complex. In particular, the successful accomplishment of DOE's environmental management mission at large sites containing multiple sources of contamination will require that the interim measures necessitated by pertinent regulatory requirements be linked appropriately to the long-term goal of completing the overall cleanup process and assuring lasting protection against risks from any residual hazards that may remain at a given site. All involved parties, but especially DOE-EM officials and DOE's regulators,

know that source-by-source analysis and cleanup alone are not only extremely inefficient at large sites but may also fail to capture adequately the full scope of current and potential risks therein.

In the early years of the decade, the expectation that Congress would soon amend the several relevant hazardous waste statutes and related laws meant that little effort was made to utilize the existing authorities in ways that were more creative and would better fit the needs of the EM cleanup. But recent initiatives in several arenas in the Complex suggest that the tension, or mismatch, between risk and compliance may be partially addressed by seeking innovations in the application of the current legislation and regulations. The agreement reached between DOE, the State of Washington, and EPA in October 1998 explicitly called for a risk-based sequencing of activities under the Tripartite Agreement at the Hanford site; however, fulfilling such commitments operationally is challenging, to say the least. A single example in which this is being attempted is a major new initiative at the Savannah River Site (SRS), involving the active participation of DOE, EPA, and the State of South Carolina's Department of Health and Environmental Control (DHEC).

Using CERCLA authorities, the initiative is incorporating the existing source-by-source analyses of smaller operable units into 6 large areas comprising the whole of SRS, so that whole areas or surface water systems (called *Integrator Operable Units*) are evaluated together. The goal of the initiative is both to verify that key sources have been identified and to determine whether measures to prevent contaminant movement to receptors are adequate or need improvement; simultaneously, however, the initiative seeks to provide a basis for assessing when cleanup in large portions of the site is complete and no further action is required. While the review of multiple sources in large areas at SRS is proceeding under CERCLA, a second approach being

developed at SRS and elsewhere is designed to analyze the total exposures that might result from radionuclide release from multiple facilities in a particular area of a site. The latter approach is being developed to address regulations under the Defense Nuclear Facility Safety Board's recommendations that long-term forecasts capture all such exposures and not be done individually for a single source in isolation from other nearby sources. These new Composite Analyses are designed to fill the gap left by Performance Assessments that are made on individual facilities alone (Cook and Wilhite, 1999).

As an aid to making risk-based data and evaluation parts of regulatory coherence, it will be necessary, as these two new approaches to both restoration and waste management mature, to draw them together so that the full scope of risk protection for the geographical areas they are addressing can be coordinated in the cleanup and be made transparent to the stakeholders who may be affected.

A central challenge identified by this review of the use of risk analysis in DOE decision making is the necessity to draw directly into the effort those who regulate EM activities, not merely to find more effective methods for evaluating risks at sites in the complex but, simultaneously, to assure that the methods are endorsed by the regulators and that the methods and data are actually integrated into the relevant analyses and enforcement agreements. For several years, DOE has been committed to the DNFSB (DNFSB 94-2, Rev I, 4/96) to find a comprehensive environmental management systems approach for EM's activities. We encourage that this commitment be fully integrated with efforts to develop a method of risk evaluation appropriate for application to the sites and facilities in the nuclear weapons complex.

6. Problems Encountered and Lessons Learned

A) DOE's environmental management programs for the cleanup of chemical, radioactive, and other hazardous wastes call for virtually unprecedented efforts in terms of the required resources, duration, geography (some 30 states and Puerto Rico), numbers of potential release sites, large volumes and diverse nature of the wastes, and the many uncertainties inherent in the applicable technology and in the nuclear weapons complex itself.

B) The various wastes that have been produced and are now largely being stored, pending treatment and disposal, contain radioactivity and hazardous chemicals, often in combination. To treat and dispose of these materials involves a diversity of methodologies, some of which must sequester and isolate certain types of wastes for many thousands of years.

C) In some cases, the technology needed to ensure adequate control of the associated risks to workers, the public, and the environment is lacking, requiring the use of interim environmental management measures, pending the availability of satisfactory long-term solutions. In other cases, although the appropriate technology has existed and may have been applied, interpretation of the results of its application has been complicated by uncertainties about the adequacy of the relevant input data and/or risk assessments.

D) In striving to ensure the protection of human health and the environment, which is the principal goal of DOE's environmental management program, DOE's efforts have been complicated by the necessity to minimize any associated socioeconomic and cultural impacts, comply with all relevant statutes, regulations, and agreements, and accomplish remediation of

the contaminated sites and facilities as rapidly and economically as possible, without jeopardizing other DOE missions. Therefore, to utilize its resources most effectively in pursuing these diverse objectives, the program has had to prioritize its activities accordingly.

E) For priority-setting purposes, the program has explored a number of approaches in recent years for considering risk in ranking each of its major environmental management activities. As yet, however, the program has found none of the approaches to be entirely appropriate and useful.

F) The various priority-setting approaches pursued by the program have differed in specific strengths and weaknesses, but none has been given enough time to evolve adequately, owing largely to lack of a consistent vision in how to use risk for the purpose, lack of sufficient confidence in the approaches by in-house personnel, lack of the acceptability of the approaches to other stakeholders, and failure to integrate any such approaches into the decision process.

G) Common weaknesses of the different approaches, including those of the "Risk Profiles" described earlier this year, include inadequacies in the input data used for ranking a given environmental management activity; inadequate documentation of the basis for the rank assigned to a given activity; inconsistencies in scoring practices among sites; and failure to relate the scoring of a given activity to the specific environmental objective it was intended to address. Additional weaknesses include inadequacies in the assessment of risks to public health, risks to worker health, ecological risks, transportation risks, economic and cultural impacts, and potential impacts on future land-use options; insufficient consideration of chemical hazards, as opposed to radiation hazards; lack of clarity and transparency in the ranking process; lack of sufficient

credibility and acceptability of the process to in-house personnel, contractors, and/or other concerned stakeholders; and failure to balance the value of detailed program-oriented prioritization of projects on a site-by-site basis with the need for rational standards of comparison.

7. Recommendations for Future Improvements

A) To ensure that the potential risks to human health and the environment at sites in the nuclear weapons complex are addressed appropriately and in the most cost-effective manner, DOE should intensify its efforts to develop and implement a risk-based approach for prioritizing its environmental management activities, in keeping with previous recommendations from Congress, The National Research Council, the Environmental Management Advisory Board, and other advisory groups. It must make a commitment to a sustained effort that will be pilot-tested before being implemented across the complex. Any initiative should begin with an immersion in what has been done before and driven primarily by conceptual clarity about how to tie both current cleanup and stewardship to the new approach. Also, the legacy of failed prior efforts means that any new approach will necessarily have to overcome significant skepticism. The reality is that any program with EM's mission must make risk and risk concepts a guide to the selection and sequencing of alternative approaches for achieving its goals and eventually using risk reduction as a measure of progress.

B) Although none of the various risk-based priority-setting approaches explored in recent years has been found by DOE to be entirely successful, none has been pursued long enough to have developed adequately, and each of them has embodied promising features that deserve to be considered in shaping an effective approach for future use. DOE should, therefore, establish a process, either inside or outside the Department, for developing the risk methodology needed for meeting the near-term and long-term challenges to be addressed.

C) To the extent that the success of any priority-setting approach can be expected to depend on its credibility and acceptability to all concerned, DOE should: 1) take steps to make sure that the specific prioritization process is community-based and accomplished locally, site-by-site, so that priorities within each site are stressed adequately; 2) ensure that the key personnel and other stakeholders are adequately involved at all stages in the planning, development, and implementation of any approach that is contemplated; and 3) enhance the effectiveness with which the national prioritization process can be used to allocate resources among sites.

D) While the degree or complexity of risk assessment at a given site will depend on the availability of pertinent data, the purpose for which the assessment is needed, and other factors, the methodology employed across the different sites should be consistent, in order that DOE's overall priorities can be set in a fair and reasonable manner.

E) In the absence of a fully effective technology for addressing some of the risks confronting it at this time, DOE must be prepared to develop and implement an appropriate interim strategy for ensuring responsible stewardship for the tasks in question, pending the availability of suitable long-term solutions. To implement this strategy, a research and demonstration program focusing on the most critical needs for risk and mortgage reduction is recommended. Ideally, this program should be supported by a line item in the DOE budget that would be large enough to support the development of significant and demonstrably effective technological means of risk reduction. To develop the technology needed, multiple-year research proposals should be solicited from site contractors, National Laboratories, university investigators, and others, to whom the awards would be based on approval by an appropriate peer review panel.

F) Among specific risk-related issues deserving greater attention in DOE's future priority-setting efforts are: i) the need for a more holistic and integrated approach to risk assessment at sites containing multiple sources of contamination than may suffice for compliance purposes alone; ii) the importance of exposure evaluation as a key step in risk assessment; iii) the potential impacts of remediating activities on the health of involved workers; iv) risks associated with chemical hazards, as opposed to radiation hazards; v) transportation and ecological risks; vi) potential socio-economic, cultural, and land-use impacts; vi) the need for risk assessments to be documented appropriately and to be transparent of if they are to be maximally credible and useful in priority setting.

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Acknowledgement

The assistance of Lisa Bliss, Serap Erdal, Sylvia LaFerrara and Henrietta Owusu in the preparation of this report is gratefully acknowledged.