Barriers to Implementing Risk-Based Decision Making for the Department of Energy's Weapons Complex Cleanup Program

by

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ABSTRACT

The Office of Environmental Management (EM) is responsible for cleaning up the contamination and waste across the Department of Energy's (DOE) nuclear weapons complex. The costs associated with effort are enormous; the current annual budget for EM hovers around six billion dollars and is expected to increase in the coming years as the program advances from characterization to remediation. Congress has warned that there will not be an endless source of funding and that risk-based priorities should be established for cleanup.

DOE has not adopted a formal prioritization strategy. Remediation decisions, and the costs associated with those decisions, are currently driven by compliance agreements negotiated between DOE, the states, and the Environmental Protection Agency (EPA). Risk-based prioritization (placing priority on activities that will reduce the most risk to human health and the environment) has been gaining attention as a rational method for allocating funds with limited resources. This thesis assesses the managerial, institutional and political barriers to adopting a risk-based approach for setting remediation priorities; and recommends an alternative strategy for framing the program's objectives and measures for progress.

My analysis concludes that many of the key barriers to adopting a risk-based approach, which include the divergent perceptions of risk between the public and risk practitioners, parochial interests served by avoiding such an approach, and institutional deficiencies in the collection of risk information, are beyond DOE's influence to overcome, especially if the Department remains committed to an open and participatory decision-making process. As part of my recommendations, I suggest that DOE adopt a strategy for measuring cleanup performance, not by risk reduction, but by the successful remediation of land to a level appropriate for a designated future land use.

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CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CRA	Comparative risk analysis
D&D	Decontamination and decommissioning
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EM	Office of Environmental Management
EPA	U.S. Environmental Protection Agency
ER	Office of Environmental Restoration
ERPS	Environmental Restoration Priority System
FFA	Federal Facility Agreement
FFCA	Federal Facility Compliance Act
FY	Fiscal year
HRS	Hazard Ranking System
HQ	DOE headquarters
IAG	Interagency Agreement
MUA	Multi-attribute utility analysis
NAS	National Academy of Sciences
NEPA	National Environmental Policy Act
NRC	National Research Council
OMB	Office of Management and Budget
ppm	Parts per million
RCRA	Resource Conservation and Recovery Act
SAR	Safety Analysis Report
SSAB	Site-specific advisory boards
TPA	Tri-party Agreement

1 Introduction

1.1 Environmental Management Cleanup Program

Since the Manhattan Project, established during World War II, the Department of Energy (DOE) and its predecessor agencies[1] have been engaged in the monumental task of the research, development and testing of nuclear weapons. The enormous infrastructure of chemical processing and metal manufacturing plants, laboratories, nuclear reactors, and testing grounds established to support this mission has come to be known as the "weapons complex." At the peak of production during the Cold War, this complex consisted of 16 major facilities, including vast reservations of land in the states of Nevada, Idaho, Washington, and South Carolina, and now encompasses 2.3 million acres of land and 120 million square feet of buildings (DOE, 1995a). And though it was recognized early that weapons production would bring about a legacy of serious environmental contamination and waste management problems,[2] the imperatives of the nuclear arms race demanded that production, and not the environment, be given first priority.

In 1989 the Office of Environmental Management (EM) was established to consolidate the waste management and environmental remediation activities of various DOE programs under one organizational structure. The creation of the EM program occurred at a time during which nuclear weapons production was falling off dramatically for several well-known reasons. Key facilities in the production process were temporarily shut down for safety and maintenance decisions, and the resumption of operations at those facilities became increasingly less certain with decisions to significantly scale back the nuclear arsenal. EM became the landlord for those facilities no longer needed for weapons production.

The technical, planning, and institutional challenges facing the Office of Environmental Management are daunting. Many of the weapons complex facilities were constructed

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[1] The Atomic Energy Commission (1946 - 1975) and the Energy Research and Development Administration (1975 - 1977).

[2] Shortly after the establishment of the Atomic Energy Commission in 1946, its Safety and Industrial Health Advisory Board reported that the "disposal of contaminated waste in present quantities and by present methods...if continued for decades, presents the gravest of problems." (DOE, 1995a, p. 4)

prior to the development of major environmental controls, and are now found to be out of compliance with applicable environmental regulations. The complex has approximately 4,000 contaminated sites which include unique radiation hazards, unprecedented volumes of contaminated water and soil, and a vast number of contaminated structures awaiting decontamination, decommissioning and dismantlement (DOE, 1993; DOE, 1995a).

The primary mission of the EM program, as envisioned by the current administration, is to protect human health and the environment. In order to accomplish this mission, the present Assistant Secretary for Environmental Management has established the following six major goals (DOE, 1994a):

1. Manage and eliminate urgent risks and threats.
2. Provide a safe workplace that is free from fatalities and serious accidents, and continuously reduces injuries and adverse health effects.
3. Change the system so that it is under control managerially and financially.
4. Demonstrate tangible, outcome-oriented results.
5. Focus the technology development program on DOE's major Environmental Management issues.
6. Develop stronger partnerships between DOE and its stakeholders.[3]

In part, these goals were established to address a perceived need to stop doing "business as usual." Critics from both within and outside of the agency felt that the EM program has in the past been operating with inadequate risk information, inefficient and ineffective remediation technologies, poor project definition and management, and rigid compliance agreements imposed as a result of a lack of credibility (DOE, 1994a).

The Environmental Management mission is comprised of four major activities: nuclear materials and facility stabilization, environmental restoration, waste management, and technology development (see Box 1). While the tendency is to label the EM program as simply "cleanup", in reality it encompasses the management of complex facilities and requisite support responsibilities, including health and safety compliance measures, facility maintenance, and plant system upgrades.

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[3] The term "stakeholders" refers to the general public, Indian tribes, regulators, citizen's organizations, and state and local governments. The increasing use of this term reflects DOE's focus on being open and responsive to those who are impacted by and otherwise concerned about agency decisions.

Box 1. Four Major Tasks of the Environmental Management Program.

Nuclear Materials and Facilities Stabilization – Consisting of the most urgent and high-risk activities, this task involves stabilizing and maintaining a large number of nuclear materials and facilities which are no longer necessary for the production of nuclear weapons. Stabilization of the sensitive nuclear materials is necessary to prevent leaks, explosions, theft, terrorist attack, or avoidable radiation exposures. Because many of the facilities are more than 40 years old and have begun to deteriorate, they must be stabilized to protect the safety of cleanup workers prior to undertaking activities for decontamination and decommissioning.

Environmental Restoration – Tasks necessary for remedial action encompass discovery of site contamination, site characterization, analysis of cleanup alternatives, and selection of a remedy. Examples of remediation activities are stabilizing contaminated soil; pumping and treating groundwater; decontaminating, decommissioning, and demolishing process buildings, nuclear reactors, and chemical separation plants; and exhuming sludge and buried drums of waste. In many cases no safe or effective technology is available to address the contamination problem. Environmental restoration activities are accomplished through negotiated cleanup agreements into which DOE has entered with the EPA and host states. These agreements are tailored to the specific conditions at each site, including the properties and magnitude of contamination in the environmental media.

Waste Management – This task involves the minimizing, treating, storing, and disposing of wastes generated by ongoing activities at active facilities, as well as those wastes generated by the decontamination and decommissioning of surplus facilities. Among the numerous factors that increase the complexity of this task are the requirement to treat the hazardous component of mixed hazardous and radioactive waste; the uncertainty in both the nature and volume of waste generated by restoration activities; the impact of new regulatory requirements; and the need to define treatment requirements and develop acceptable treatment facilities.

Technology Development – This task seeks to develop, test, and demonstrate affordable and effective solutions to the numerous technical problems facing the Environmental Management program. In developing innovative technologies, ideas are sought from sources in the private sector, universities and other government agencies, in addition to relying on traditional sources of expertise at the DOE national laboratories.

(DOE, 1995a; DOE, 1992a)

The costs associated with this effort are enormous; the current annual budget for EM hovers around six billion dollars and is expected to increase in the coming years. Initial estimates predicted that the annual EM budget would increase to well over $10 billion by the year 2000, as the program proceeds from a characterization and assessment phase toward the more costly work of remediating contaminated sites and treating waste. Estimates of projected growth must account for costs of handling new volumes

of waste generated by remediation activities and the decontamination and decommissioning of surplus facilities.

DOE managers are struggling with the possibility that, given the present course of action, the costs of remediating the weapons complex will soon exceed what Congress is willing to pay. The first signs of trouble appeared with the passage of the Deficit Reduction Act of 1993. This Act established federal spending caps such that budgets for federal programs will be required to remain level or be allowed to increase only at a small rate, rather than at the higher rate initially estimated for the Environmental Management program. Funding constraints became even more imminent with significant budget cuts proposed by President Clinton in January, 1995. As part of the proposed cuts in federal spending, the Department of Energy is facing reductions of $10.6 billion over the next four years, with $4.4 billion targeted for the EM program. These proposed cuts, which will impact the 1997 budget cycle and beyond, are expected to cause a $17 billion funding gap between available dollars and compliance costs over the next five years (Grumbly, 1995a). This issue has raised a great deal of concern among stakeholders who fear that DOE will be unable to meet legally binding and statutorily driven commitments for cleaning up the complex.

DOE is responding to its bleak fiscal outlook by taking measures to reduce costs through increased efficiency and productivity. Such measures, which include reductions in indirect and overhead labor costs, contract reform, privatization, and streamlining, are expected to achieve over $9 billion in savings (Grumbly, 1995a). Yet, these projected savings fall well short of eliminating the impending funding shortfall (see Figure 1-1).

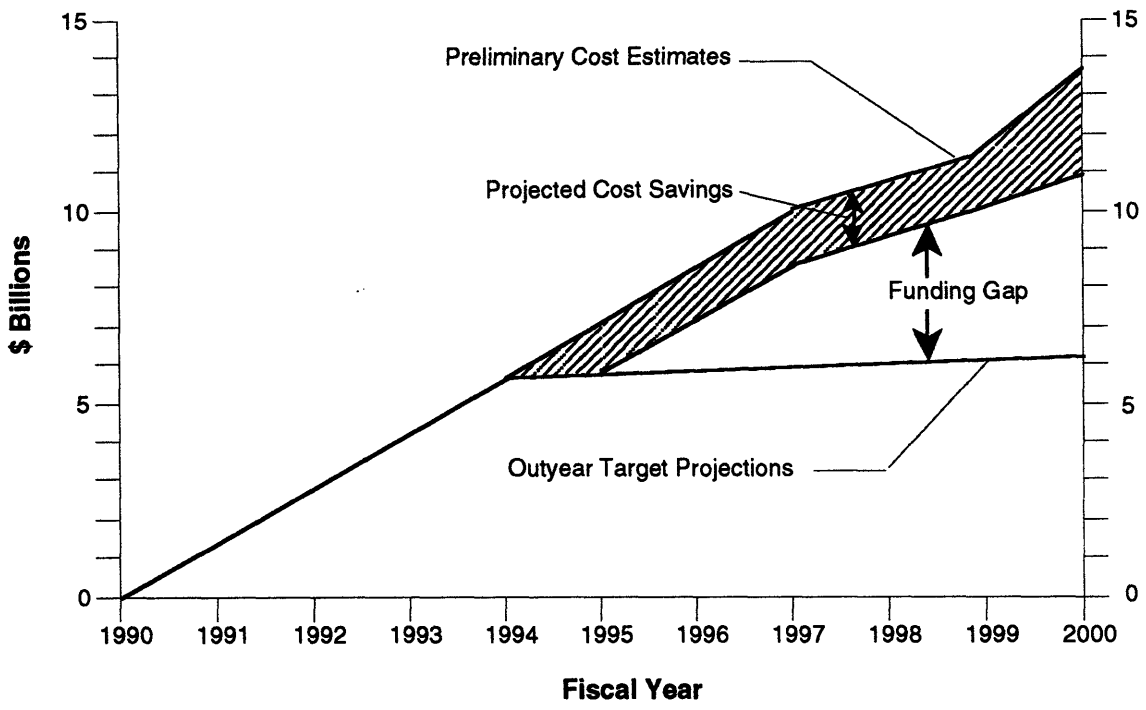

Figure 1-1. Illustration of impending funding shortfalls for the EM program. Preliminary annual cost estimates reflect the "business as usual" approach. Revised outyear target projections for available funding conform to the more stringent funding levels imposed by reductions in federal spending. In spite of managerial efforts to reduce costs and improve efficiency, significant funding shortfalls appear likely. This figure has been used by the current EM administration in numerous settings, in part to demonstrate the need for renegotiating compliance agreements and other cost saving measures.

1.2 Need for Prioritization

There is a strong possibility that DOE may be requested to develop a strategy which explicitly addresses risk reduction for prioritizing cleanup activities. Consider the following language introduced in the U.S. House of Representative's Conference Report 103-292 (October 14, 1993) for budget appropriations:

> The conferees wish to reiterate concerns raised by both the House and Senate with respect to the overall cost of environmental cleanup actions that the Department has committed to perform under existing compliance agreements. While committed to providing adequate funding for necessary cleanup activities around the country, the conferees emphasize that there will not be an endless source of funding for this program with significant increases in the outyears. ...
>
> The conferees agree that the Department needs to develop a mechanism for establishing priorities among competing cleanup requirements. Toward this end, the Department is directed to review compliance agreements and to submit ... a report ... evaluating the risks to the public health and safety posed by the conditions at weapons complex facilities that are addressed by compliance agreement requirements. (HR, 1993)

Risk-based prioritization (placing priority on activities that will reduce the most risk to human health and the environment) has been gaining attention as an important element of a rational approach for allocating limited remediation funds (CBO, 1994; NRC, 1994a; NRC, 1994d). DOE has not adopted a formal prioritization strategy. The pace of remedial actions, and the costs associated with those actions, are currently driven by compliance agreements negotiated between DOE, the host states, and the local EPA regions. Many of these agreements, which establish milestones (actions and associated timetables) for complying with environmental regulations, were negotiated at a time when the Department's mission was transitioning from production to cleanup and without an adequate understanding of the scope and scale of the problems at hand. Further, the majority of agreements fail to address broader policy issues of future land use planning and economic development of sites,[4] both of which directly impact desired levels of cleanup and associated risks.

That the Department of Energy needs to address prioritization of its massive cleanup program is a notion with which many observers would agree. Merely having the program

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[4] Land use planning seeks to identify stakeholder-preferred future use options at each site. Economic development planning enables communities to reuse surplus facilities and technologies

driven by rigid compliance agreements and constraints posed by numerous environmental regulations seems to be sacrificing an opportunity for guiding the program with sound policy and management. Compliance agreements provide a mechanism for establishing local priorities for reducing risk. And while they may be appropriate for intra-site priority-setting, they do not allow for inter-site comparisons of hazards to inform a rational distribution of funds *among* sites.

1.3 Public Role in Remediation Choices

In part due to DOE's efforts in improving public participation in remediation decisions and a growing demand by the public that tax dollars be used more responsibly by federal decision makers, some local citizens are calling for improved quality of risk information, and rational use of that information, in selecting cleanup options. Through forums such as site-specific advisory boards (SSABs) and other citizen working groups established at most sites to actively involve representatives of the local community in the cleanup decision-making process, members of affected communities are achieving improved access to information regarding site conditions, leading to an increased awareness of environmental and health effects of contamination and a recognition of the complexity and scientific uncertainty surrounding many decisions at sites (FFER, 1993). One result of improved dissemination of information is that DOE managers and EPA regulators are having to work with a public which demands dialogue on serious, and indeed tough, issues that warrant thoughtful debate. Such dialogue can lead to surprising revelations about how stakeholders view risk reduction associated with cleanup decisions.

For example, a recent public meeting to gather comments on DOE's proposed $69 million plan to clean the East Fork Poplar Creek of mercury contamination discharged from the Oak Ridge Y-12 plant drew over 200 attendees. The plan consists of excavating about 54,000 cubic yards of soil containing at least 180 parts per million (ppm) of mercury and trucking it to a Y-12 disposal site. The majority of comments offered at this meeting criticized the plan as a waste of taxpayer money and considered the conservative approach for determining the cleanup standard for mercury an example of "excessive conservatism" to protect the public from seemingly minor risks (KNS, 1995; OR, 1995a).

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to minimize the economic impact of DOE downsizing. The ultimate use of a site can be a major determinant in establishing acceptable risk and remediation levels.

At issue was the applicability of the risk assessments used to determine the cleanup level. Some argued that the actual risk to human health would be far less than estimated because the risk assessments were based on animal studies that tested response to mercury chloride, which is 3 million times more soluble than the mercury sulfide form commonly found in the floodplain (KNS, 1995). One resident proposed raising the cleanup level for mercury from 180 to 1,200 ppm. The EPA representative reasoned that "we can't be sure what is safe so we are going way beyond a normal standard of safety," consistent with EPA's policy of erring on the side of caution (OR, 1995a). Other residents argued that the excavation would cause more harm than good for the affected wildlife and would unnecessarily destroy the aesthetic value of the creek. In the words of one resident whose property abuts the creek:

> No one eats the dirt. No one fishes in the stream. No one swims in the stream and I have never seen anyone wading or playing in the water. No one eats any of the rats, mice, snakes, turtles, geese, moles, groundhogs, rabbits, squirrels, deer, herons, skunks, sparrows, finches, chickadees, grackles, crows, ravens, hawks, robins, titmice, bluejays, cardinals, grossbeaks, cowbirds, wrens, nuthatches, woodpeckers, etc., etc., that are present. ... We are opposed to having the trees cut, the soil removed and the stream disturbed. This would be an unnecessary expenditure of the government's – our – money. (OR, 1995b)

Although this example is perhaps unusual as an instance where a community is calling for less action rather than more, it should serve to inform decision makers that in some instances the desire to cleanup has overtaken the desires of those whom these efforts are intended to protect. Further, while this example does not directly speak to the issue of risk-based prioritization, it does illustrate several important points regarding the quality and use of risk information in cleanup decision-making.

- Members of the affected public are willing to engage in discussion on the technical merits of proposed remediation activities, and not merely the emotional aspects as many critics of public participation would suggest.
- Stakeholders are not simply interested in cleaning up at all costs. The public wants to be assured that environmental remediation funds are being used wisely and that their values are incorporated into cleanup decisions.
- Until there are significant improvements in risk assessment methodologies, there will frequently be a great deal of uncertainty in estimates of risks to human health. The manner by which this uncertainty is accommodated in cleanup standards (i.e., conservatively) may not reflect the wishes of the affected community.
- Reductions in health risks may not adequately balance the increased harm to the environment resulting from remediating to human health standards. Stakeholders desire rational cleanup standards that reflect future land-use plans that they have had a role in defining.

1.4 Organization of Thesis

The Environmental Management program faces major policy and management decisions about how to prioritize its environmental restoration activities. Given the current and future budget constraints, the EM cannot attempt to address all risks simultaneously. In spite of widespread support for DOE to adopt a risk-based approach to establish program priorities, including senior-level support from within the Department, DOE has not been able to formulate a workable strategy for doing so. This thesis examines the current framework for decision-making, as well as an unsuccessful prior attempt to set environmental restoration priorities, in order to answer the following questions:

1. What are the major managerial, institutional and political barriers to adopting a risk-based approach for setting remediation priorities?
2. To what extent are these barriers within the Departments ability to overcome?
3. How should the Department proceed to address the need to rationally allocate limited funds for completing its mission?

Chapter 2 reviews the existing framework for decision making. Environmental restoration priorities are dictated in large part by compliance agreements negotiated on a site-by-site basis to establish enforceable schedules for remedial actions, as well as by other environmental regulatory drivers. In this chapter, I describe the manner by which the prioritization of cleanup activities is constrained to these drivers through the budget process. I also describe how key deficiencies in compliance agreements impede progress toward the development of a more rational basis for allocating limited resources for cleanup.

Chapter 3 begins with an overview of risk assessment and risk management principles. Much of the controversy in using risk information to inform priority setting stems from disagreement or misunderstanding on the roles of science, judgment, and public concerns in risk analysis. I describe three risk-based tools which have been gaining acceptance for developing risk-based priorities: risk-ranking models, comparative risk analysis, and multiattribute utility analysis. Each has strengths and weaknesses that render them appropriate to support different types of decisions. I then recount a prior attempt by EM to use one of these tools to establish program priorities and identify the major criticisms that led to the abandonment of this tool. The chapter concludes with examples of conflicting influences that continue to frustrate DOE's efforts to manage the EM program in a publicly acceptable manner; on one side, a committee representing states, regulators and other stakeholders is explicitly opposing priority setting based on

inter-site comparisons of risk, while on the other side, Congress is urging the Department to adopt a cost-benefit approach as a means to prioritize its limited resources to address the most serious and cost-effective risks first.

Chapter 4 presents an analysis of the key barriers to risk-based decision making that EM is struggling to address in its pursuit of a rational approach for allocating limited resources. I begin with an assessment of the factors that influence public perception of the unique hazards posed by the weapons complex. Because DOE has committed to improving stakeholder participation in shaping the decisions that affect them, it is important that the management recognize the factors that influence risk perception and understand the limitations in bridging divergent views on risk. Next, I identify some of the deficiencies in the type and quality of risk data that limit its usefulness in informing broader risk-based decisions. And finally, I examine the political barriers that work to keep DOE bound to the present system of having legally enforceable, site-specific agreements drive the pace of remediation.

In Chapter 5, I explain why the barriers to a national risk-based approach for priority setting are beyond DOE's influence to overcome, especially if the Department remains committed to an open and participatory decision-making process. Given the short time frame in which the Department is expected to demonstrate progress in its environmental program, I contend that DOE should shift its efforts from a risk-based approach to a more tractable framework. As part of my recommendations, I suggest that DOE adopt a strategy for measuring cleanup performance, not by risk reduction, but by the successful remediation of land to a level appropriate for a designated future land use. Priorities for environmental restoration should be established consistent with such a performance-based goal.

2 EM Framework for Decision-Making

2.1 Current Framework

A formal framework for explicitly prioritizing cleanup activities across the complex does not exist. Any prioritization that occurs is part of the overall budget formulation process for EM. As such, the decisions to support activities for waste management or environmental remediation are driven primarily by the need to comply with formal agreements negotiated between DOE, the local EPA region, and responsible state agencies, as well as by other environmental regulatory drivers (see Figure 2-1). Box 2 (see below) provides descriptions of the major environmental drivers which impact budget allocation. The following description of the budget formulation process illustrates the manner by which the prioritization of cleanup activities is constrained to these drivers.

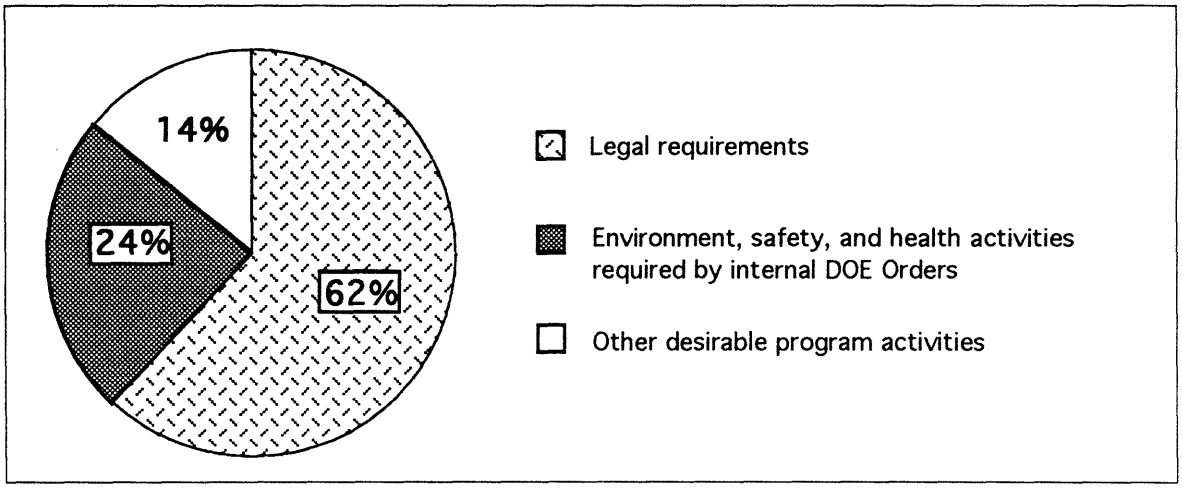

Figure 2-1. Estimates for FY 1994 budget allocation for the Office of Environmental Management. The majority of funded activities are legally driven. (DOE, 1993)

Box 2. Enforceable Agreements and Regulatory Drivers

Federal statutes and regulations – DOE activities are governed by a number of laws and regulations that are enforced by other Federal agencies and State and local regulators.

- National Environmental Policy Act (NEPA), which requires that environmental impact statements be prepared for actions that may significantly affect the quality of the human environment.
- Resource Conservation and Recovery Act (RCRA), which provides the framework for managing solid and hazardous wastes produced from ongoing activities.
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as Superfund), which sets the ground rules for cleaning up releases of hazardous substances at closed or abandoned sites.
- Federal Facility Compliance Act (FFCA), which was enacted in 1992 specifically to address problems related to the treatment of hazardous waste generated or stored at Federal facilities by directing such facilities to comply with RCRA requirements.

Other applicable regulations include the Clean Water Act, Clean Air Act, Occupational Safety and Health Act,[5] Atomic Energy Act, Safe Drinking Water Act, and the Toxic Substances Control Act.

Compliance agreements – DOE has entered into facility-specific agreements with EPA and state regulatory agencies which address the actions necessary to achieve compliance with CERCLA requirements and may also address RCRA corrective actions. These agreements are legally binding and establish specific milestones for completion of program activities.

Court orders/consent decrees – These are court-ordered actions to bring facilities into compliance with RCRA requirements. Failure to meet such actions can result in immediate fines.

State or local statutes or regulations – Most states have enacted legislation similar to Federal environmental statutes. In many instances state and local regulating agencies are permitted to require more stringent standards than those provided for in Federal statutes.

Agreements in principle – These are non-contractual (handshake) agreements between DOE and states to provide funding or other support for certain actions desired by the state (e.g., provide funding to establish a governor's task force to track remediation progress at a site). Agreements in principle have been established with 13 states to date.

(DOE, 1993; Harris, 1995a)

[5] Although DOE retains oversight over its worker health and safety programs, it has committed itself to meeting the Occupational Safety and Health Administration guidelines.

The DOE budgeting and appropriation process for securing funding for its hazardous waste remediation projects involves development of a cleanup program budget by EM; integration of the EM budget into the overall DOE budget; submittal of the DOE budget to the Office of Management and Budget (OMB, the Presidential office for the budget); and review and approval (or disapproval) by Congress (DOE, 1991a). The budget planning for each fiscal year in the three-year Federal budget process begins two years before the year in which the budget is actually executed. Figure 2-2 identifies the major phases of the FY 1997 budget planning process.

The instructions to DOE headquarters and field personnel for putting together a budget request are delivered through budget formulation guidance and are revised regularly to focus on the Environmental Management program's highest priorities. Responding to the constrained fiscal environment that the Department faces today, the EM budget guidance for fiscal year (FY) 1997 addresses the need to achieve compliance in a cost effective manner while still supporting the six major program goals previously mentioned. As directed in the FY97 budget formulation guidance, EM must base its budget requests upon the principle of risk reduction and the explicit requirements of enforceable agreements and Federal laws (DOE, 1994b). Additionally, the current guidance stresses the need to reduce costs of doing business, to improve productivity

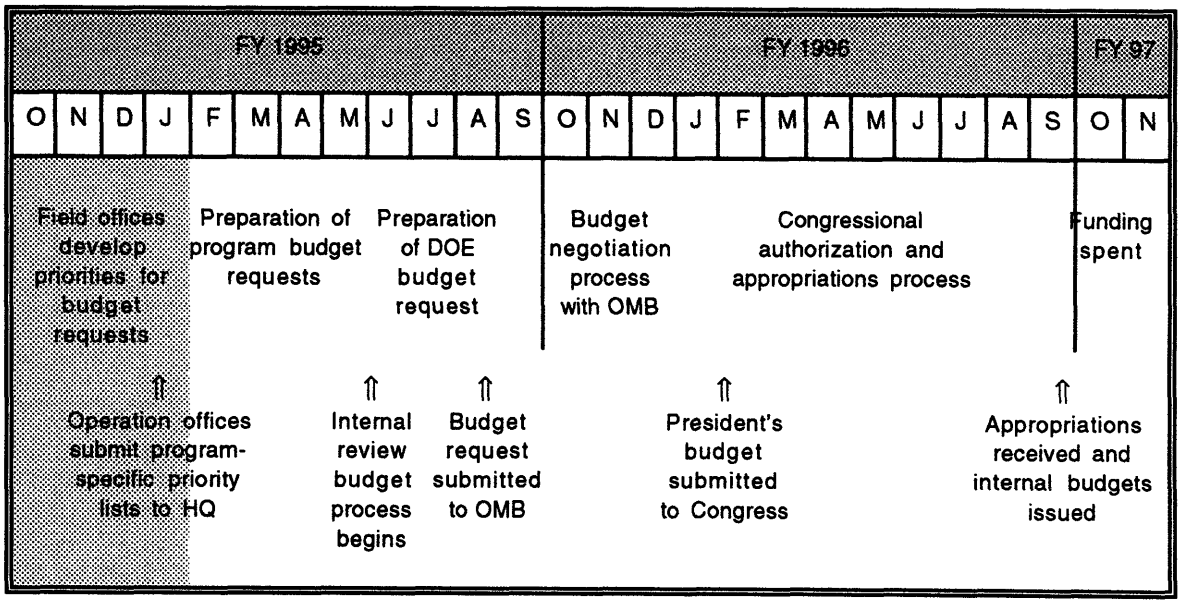

Figure 2-2. DOE budget process for FY 1997. The shaded region identifies the period for stakeholder involvement in establishing cleanup priorities at sites. (Adapted from DOE, 1991b; DOE 1994b)

and efficiency, and to strengthen credibility to stakeholders, regulators, and Congress. These goals are intended to minimize to the extent possible the impending funding shortfall and to maintain support from Congress. However, the degree to which DOE can achieve these goals is under serious debate.

In the first phase of budget formulation, each operations office develops a prioritized list of activities which defines a proposed program. Priority lists provide useful information for estimating the impact of cutting or adding funding to programs and are used to defend and justify program budget requests during internal EM budget negotiations. Although the specific methodologies and criteria to be used in developing priority lists are left to the discretion of each operations office, they are directed to observe minimum guidelines in establishing those priorities (DOE, 1994b), which include:

- Activities of the highest priority (for example, those addressing immediate risk to human health and the environment) should be included in the program first.
- The proposed program should maximize compliance with legal, environmental, safety, and health requirements at all levels of funding. Should projected funding levels have legal or compliance implications, discussions with regulators should begin immediately to identify and discuss such implications and develop acceptable proposals that acknowledge funding constraints.
- The proposed program should be prioritized with a focus on the guiding principles, particularly the six goals of the Environmental Management program.
- Prioritization procedures should seek to involve regulators and all interested stakeholders, such that their priorities are given consideration.

Though these guidelines encourage input from interested stakeholders, the opportunity for this input is quite limited. Field offices have approximately four months to develop the priority list for a site, during which time consultation with the public can occur. However, because the majority of funded activities are prescribed by compliance agreements and other legal drivers, the opportunity for community concerns to impact the selection of activities for funding is minimal. Once field office priority lists are sent up to the operations office, which may be responsible for the management of several field sites, the majority of adjustments to priorities occurs between the operations offices and headquarters.

The extent to which funding for activities may be reallocated among sites or between programs (i.e., Environmental Restoration, Waste Management), both during the budget formulation process and after the budget has been appropriated, depends a great deal on how those activities are grouped for funding. DOE allocates its budget by programs,

so that the focus is on the type of activity being conducted rather that on the site where the work is being done. Program-based funding is subsequently distributed among sites. During the budget planning process, field managers are permitted to shift proposed funding across programs to efficiently address priorities. However, once the President's budget has been presented to Congress, shifts in proposed funding across programs require Headquarters approval and the submittal of a budget amendment, which can be a lengthy process entailing several months.

The program-based funding structure poses several obstacles to fostering an efficient strategy for reducing risks at sites in situations where funding is less than anticipated or where new information leads to a shift in priorities. Under a program-based structure, regulators and stakeholders tend to look outside the site for additional funds rather than attempting to achieve an optimum balance among priorities within the site (Grumbly, 1995a). Further, managers have little flexibility to reallocate funds within a site to achieve economies or to address emerging requirements without first going through the formal reprogramming process.

One solution being considered by the current EM administration is the possibility of appropriating funds by site, rather than major programs (Grumbly, 1995a). Allocation of the budget by site, which requires Congressional approval, could allow flexibility for each site to engage regulators and stakeholders in a collaborative process for establishing cleanup priorities during times when constrained funding conflicts with previously established commitments for environmental restoration activities. Congress recently rejected a proposal for site-based budgeting, in part because it would politicize budget process by enabling better-represented sites to lobby for more funds.

In summary, in formulating the budget for environmental restoration and waste management, and thereby setting priorities, the opportunity for public involvement in setting those priorities is limited. Further, because most of the EM budget is allocated to meet the milestones established in site-specific enforceable agreements (Grumbly, 1993), little flexibility exists on part of managers to ensure a logical reduction of risks across the complex. The next section describes the purpose of compliance agreements and identifies some of their key shortcomings with respect to risk-based decision-making.

2.2 Compliance Agreements

Compliance agreements have become, in effect, an implicit priority setting mechanism. These agreements commit DOE to remediating specific sites at a specified pace and are often inflexible toward emerging changes in the program that may call for a different set of priorities. Most agreements were negotiated prior to the development of future land use strategies for sites. Further, many agreements fail to adequately consider changes in program scope, such as the need to devote resources for decontamination and decommissioning surplus facilities. Yet perhaps the most problematic issue, but one that will be addressed later in this thesis, is that compliance agreements bind the Department to a cleanup protocol that might have more to do with what the individual state government requires than with the relative risk of the site (NRC, 1994d). Accordingly, as a de facto priority system, compliance agreements pose several impediments for managing the cleanup program in the face of budget constraints.

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requires that Federal agencies responsible for specific hazardous waste sites enter into compliance agreements with the EPA and host states to clean up the sites. These agreements, also known as interagency agreements (IAGs) or tri-party (TPAs) agreements[6], establish enforceable schedules for remedial actions, as well as provide a mechanism for minimizing litigation. Because of the frequent use of agreements, DOE and EPA have developed model provisions for incorporation into agreements; these provisions generally reflect agreement between DOE and EPA on policy matters (DOE, 1991). Site-specific aspects, which include setting forth schedules and milestones, are established as part of the negotiation process among the three parties. Table 2-1 lists some of the major provisions of the DOE/EPA model, including those for funding, schedule and milestone development, and penalties for non-compliance. Site-specific agreements may deviate from some of these provisions and typically address additional topics, including a framework for public participation and the bases for modifying an agreement.

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[6] Yet another name for a compliance agreement is a Federal Facility Agreement (FFA). This name is a source of confusion in that it is commonly thought to be affiliated with the Federal Facility Compliance Act (FFCA). However, the FFCA specifically addresses federal facility compliance with RCRA waste generation and storage requirements, whereas FFAs specifically address remedial actions under CERCLA and *may* integrate site investigation and remediation requirements under NEPA and RCRA, as well.

Many of the programmatic deficiencies now recognized in the compliance agreements, including "unrealistic" schedules, can be attributed to the adversarial and pressured circumstances surrounding the negotiation of these agreements at a time when DOE was focused primarily on meeting weapons production schedules (GAO, 1995). Until the late 1980's DOE's regulators had no effective means to ensure the Department's commitment to environmental issues. When pressure from federal and state regulators and the public began mounting, DOE officials, worried that environmental compliance issues would impact production, entered into agreements without ensuring that the Department could meet either their funding requirements or schedules (GAO, 1995).

For example, the Hanford Reservation tri-party agreement[7] established hundreds of milestones which were to be completed over 30 years, including some milestones, such as removing radioactive tritium from groundwater, which were not even thought to be technically feasible (GAO, 1995). Perhaps even more unrealistic is the agreement signed for Rocky Flats following a raid in 1989 where agents spent three weeks searching for evidence of environmental mismanagement. The prevailing circumstances after the FBI raid left little leverage available for negotiation. DOE subsequently accepted an agreement with very restrictive schedules and deadlines, including over 250 enforceable milestones through the year 2002 (MMES, 1994). And because there were no provisions for schedule adjustment, a failure to meet one near-term milestone could trigger a flurry of continuing missed milestones far into the future.

2.2.1 Commitments to long-term milestones

Early in the program the Office of Environmental Management committed to a 30-year goal for cleaning up the 1989 inventory of inactive sites. This goal was consistent with recommendations by the State and Tribal Government Working Group that DOE establish a specific end point for completing necessary remediation and restoration activities (DOE, 1993). Experience gained from managing the program since 1989 has caused many to question the feasibility of this target, given that the problems are larger and more intractable than most people previously predicted. Problematic issues include (Wagoner, 1993):

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[7] Signed in 1989, this was Department of Energy's first compliance agreement (GAO, 1995).

Table 2-1. Major provisions of the DOE/EPA model for a FFA compliance agreement. (Adapted from MMES, 1994)

Topic	EPA/DOE FFA Model Provisions
Funding	• DOE shall take all necessary steps and make efforts to obtain timely funding to meet its obligations. • DOE will include in its annual report to Congress specific cost estimates and budgetary proposals associated with this agreement. • If appropriate funds are not available to fulfill DOE obligations under this agreement, EPA and the state reserve the right to initiate other actions which would be appropriate, absent the agreement.
Schedule/Milestone Development and Scope	• Schedule and milestones provisions are to be site-specific. • Timetables or deadlines associated with development, implementation, and completion of the remedial investigation/feasibility study is enforceable pursuant to Section 310 of CERCLA, any violation of such timetables or deadlines will be subject to civil penalties under Section 310(c) and 109 of CERCLA. • All terms and conditions of this agreement that relates to interim or final remedial actions, including timetables and deadlines, will be enforceable pursuant to Section 310(c) of CERCLA.
Public Participation	• Listed in the model table of contents with no specific provisions.
CERCLA/RCRA Integration	• EPA and DOE, based on the remedial action selected, implemented and completed, shall deem to be protective of human health and the environment, and will obviate the need for further corrective action under RCRA. RCRA shall be considered an applicable or relevant and appropriate requirement pursuant to CERCLA. • If a permit is issued to DOE for on-going hazardous waste management activities, EPA shall reference and incorporate any appropriate provisions, including appropriate schedules, into such permit and will be reviewed under the provisions of CERCLA.
Penalties for Non-Compliance	• If DOE fails to submit a primary document to EPA pursuant to the appropriate timetable or deadline, or fails to comply with a term or condition which relates to an interim or final remedial action, EPA may assess a stipulated penalty against DOE, not to exceed $5,000 for the first week and $10,000 for each additional week. • Upon determining that DOE has failed, EPA shall notify DOE in writing, DOE shall have 15 days to invoke dispute resolution of whether the failure did occur. No assessment of a stipulated penalty shall be final until the conclusion of dispute resolution procedures. • Stipulated penalties shall be payable to the Hazardous Substances Response Trust Fund. • This part shall not affect DOE's ability to obtain an extension of a timetable, deadline or schedule. • No officer or employee of DOE can be held personally liable for payment of any FFA penalty.

1. In many cases no effective long-term technologies exist to clean up hazardous and nuclear waste sites;

2. Even if a technology exists, DOE often lacks clear cleanup standards. Such standards are necessary for developing new technologies or applying existing technologies; and

3. Even with technologies and standards, there are far too many sites requiring attention to take action simultaneously to meet all cleanup demands.

These same issues impact the pace set forth in compliance agreements. Many compliance agreements specify long-term milestones, including targets for reaching records of decision that specify the technology for achieving a remedial action. Some agreements include milestones extending through 2005 to 2018 (MMES, 1994). Although the schedules developed in existing agreements were based on the best information available at the time, experience and knowledge gained from conducting interim remedial actions and site investigations have provided an incentive for modifying those schedules. It is now recognized that in some cases cleanups can be accelerated ahead of schedule by taking interim actions before all planned site investigations are complete, and in other cases investigations have revealed that the problem is larger, more complex, or simply different than originally expected (Wagoner, 1993). For example, certain problems lack permanent, effective technical solutions, and may be better handled by stabilizing the situation and investing in problem-specific research.

In negotiating these agreements, DOE fully expected that if unrealistic schedules seemed likely to result in missed milestones, then changes would be made. With the exception of the Rocky Flats Plant Interagency Agreement, most agreements include provisions for periodic review and adjustment of milestones based on new information or changed circumstances. In practice, however, compliance agreements have been difficult to modify. Given the Department's history of resistance to environmental regulation, many regulators have been reluctant to renegotiate, seeing such requests as evidence of mismanagement rather than as legitimate responses to new information about site conditions or improved understanding of technological limitations (DOE, 1995b).

2.2.2 Inadequate Consideration of Future Land Use Planning

Land use planning, which aids in answering the question "How clean is clean?" by deciding "Clean for what use?," should be a critical element in supporting remediation decisions. Potential future uses for a site could fall within one of the six following

categories (DOE, 1994d), each of which would likely result in a different level of acceptable risk and degree of remediation:

- Industrial/commercial – including research and development facilities, offices, manufacturing plants, utility systems, and waste management facilities.
- Residential – including permanent and temporary housing, dormitories.
- Agricultural – including farming, grazing, and aquaculture.
- Recreational – including passive and active uses.
- Native American – including traditional, cultural, and religious uses.
- Open space/wilderness – including protected wildlife and critical habitats, scenic vistas.

In addition to the above categories, land can also be designated as restricted use, which necessitates the use of institutional controls to limit access for human activity.[8] Restricted land uses may include waste disposal sites or sites which cannot be remediated to risk levels associated with unrestricted use. Whether a site is designated for restricted or unrestricted use has a large impact on the remediation methodology selected and the resulting volumes of wastes generated from the remedial action. Consider for example a pocket of contaminated soil. For a restricted land use scenario, the remediation strategy may be to contain the problem by placing an impermeable cap over the contaminated soil to prevent further spread of contamination. A containment strategy would require institutional controls to prevent human intrusion into the contaminated media. Whereas, if the site were designated for an unrestricted future land use scenario, a remediation strategy to achieve appropriate levels of residual risk may call for the removal and treatment of the contaminated soil. A removal remediation strategy, while not requiring the use of institutional controls, would result in significantly larger volumes of remediation-generated waste than a containment strategy.

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[8] At Federal facilities, institutional controls are frequently used for controlling public access or limiting the activities of on-site personnel in order to reduce exposure to hazardous substances which may have been released (DOE, 1992b). Examples of institutional controls include fences, security patrols and guard posts, deed restrictions, and warning notices.

Compliance agreements often require decisions about future land use before remediation goals can be established (see Figure 2-3). The majority of agreements, along with their schedules for conducting risk assessments as part of the remedial investigation phase, were negotiated prior to identifying future land use options at sites. In some cases where no clear decisions have been made on future land use, land use is assumed to be immediate unrestricted use for the purpose of risk assessments (Wagoner, 1993). Because future use scenarios establish a framework for the identification of exposure pathways and guide the estimations for contaminant uptake by human and ecological receptors, the lack of a reasonable future use scenario could lead to conservative risk assessment assumptions, calling for greater levels of cleanup than desired or necessary. A notable exception is a recent modification to the Hanford Tri-party Agreement, which established several new milestones that reflect the priorities of stakeholders, including early release of large uncontaminated areas, and priority cleanup of areas adjacent to the Columbia River (MMES, 1994).

2.2.3 Not Responsive to Changes in Scope

With the restructuring of the former Soviet Union and the attendant shift in DOE responsibilities, the Environmental Management program is anticipating major growth in both size and scope with the decontamination and decommissioning (D&D) of surplus

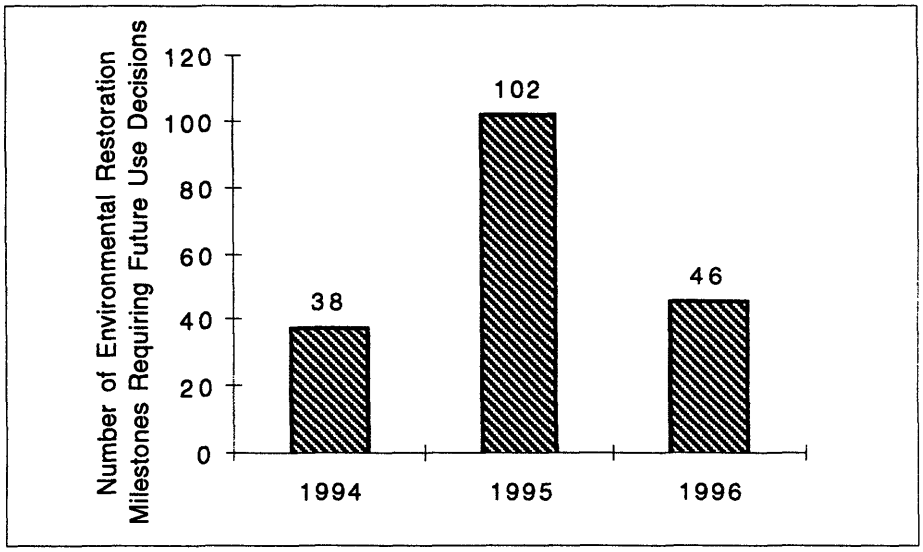

Figure 2-3 The number of environmental remediation milestones requiring future use decisions through 1996. (DOE, 1994d)

facilities pursuant to decisions to phase out and consolidate operations. Facilities that were formerly managed by the Office of Defense Programs and which are no longer needed for production are being turned over to EM for remediation and D&D.

Issues pertaining to decontamination and decommissioning are not addressed in the model provisions or in most existing compliance agreements. This situation has resulted in the potential for D&D activities to impact the schedule for completing other remediation milestones. Because D&D entails decisions relating to levels of cleanup and the potential for reuse of existing structures, and is an integral aspect of preparing sites for future uses, it is reasonable to expect that compliance agreements establish provisions for incorporating D&D milestones in schedules, as well as addressing their potential to impact those schedules. D&D milestones may accompany or complement milestones for other environmental restoration and waste management activities, thereby ensuring a coordinated, systematic approach for conducting all phases of cleanup and releasing areas for future uses as early as possible (MMES, 1994).

A second issue that has the potential to impact scope and schedule is the disposal of waste generated by cleanup activities. As the number of remedial actions increases over the next few years, large volumes of secondary wastes generated from these activities will require treatment. The volumes of waste generated will, in turn, depend on the level of remediation chosen. Many of these wastes lack effective treatment technologies. Without the early planning for on-site or off-site disposal of this remediation-derived waste, compliance agreement remedial action milestones could be delayed until such a disposal facility is identified (MMES, 1994).

The compliance agreement for the Oak Ridge Reservation has perhaps the best provisions in terms of being responsive to change in scope, in that milestones are negotiated for the current year after funding appropriations are known. Assistant Secretary Grumbly is proposing that problematic compliance agreements be renegotiated to adopt a two- or three-year rolling milestone approach to provide needed flexibility for responding to changes in scope (Grumbly, 1995a and 1995c). The shorter-term milestones would be reviewed and adjusted annually to reflect changes in scope, site priorities and available funding. Longer-term milestones could be included as guidelines rather than enforceable actions.

3 Methodologies for Risk-Based Prioritization

3.1 Uncertainties and Controversy in Assessing Risk

The methods for estimating risk to human health have been evolving steadily over the last few decades, and although these methods are fairly well developed, the use of risk assessment is still controversial. The techniques for estimating environmental risk are less developed. The science and metrics to assess ecological damage, in terms of species loss and impact on local ecosystems, have not been subject to as extensive debate as issues associated with human health risks. However, because remediating contaminated sites to human health standards can lead to severe ecological impacts (e.g. removing the top three inches of soil contaminated with plutonium over an expansive area), risk management approaches are needed to assist decision makers in understanding the potential tradeoffs between harm to human health and the harm to the environment.

According to the 1983 National Research Council (NRC) report, *Risk Assessment in the Federal Government: Managing the Process*,[9] quantitative risk assessments should consist of the following four elements (see Figure 3-1):

1. *Hazard identification* is the process of identifying contaminants that are suspected to pose health hazards, quantifying the concentrations at which they are present in the environment, and evaluating the types of hazards to human health that might result from exposure. Information for this step is usually derived from monitoring data and epidemiological animal studies.

2. *Dose-response assessment* is the process of characterizing the quantitative relation between an administered or received dose of a contaminant and the incidence of an adverse health effect (cancer, birth defect, chronic damage to organs, etc.). Because most toxicity tests are performed using high doses to animal subjects, the dose-response assessment must consider methods for extrapolating animal toxicity data to humans and extrapolating high doses to lower exposure rates that humans are likely to experience. This step may also include an assessment of variations in response, including differences in susceptibility between young and old people and differences among those who may be more sensitive to exposure (e.g. asthmatics).

3. *Exposure assessment* involves determining the size and nature of the population that might be exposed to the contaminants, identifying the routes through which exposure

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[9] This report, also known as the Red Book, had a major influence on the practice of risk assessment and provided the framework and many of the definitions used throughout the environmental health risk assessment community today. Many of the recommendations in this report have been implemented by EPA and other regulatory agencies.

can occur, and estimating the magnitude, duration and timing of the doses that people might receive as a result of their exposure.

4. *Risk characterization* is the integration of the information from the first three steps that results in a quantitative estimate of the magnitude and likelihood of health hazards expressed in an exposed population and should include a discussion of the uncertainties associated with these risk estimates.

Risk assessment is a multifaceted process that relies on a wide assortment of data, analytical methods, and assumptions. The complexity of this process often necessitates the use of risk assessment models, which provide risk estimates by representing mathematically the physical processes of the release of the agent of concern, exposures, and dose-response (ADA, 1993). Default options and assumptions, which are based on general scientific knowledge and policy judgment, are employed when the correct scientific model is unknown or uncertain. An assumption may be the scenario used to define a maximally exposed individual as part of an exposure assessment (e.g., a child ingesting 10 grams of contaminated soil a day). A default option may be the decision to treat risks additively when assessing risks associated with exposures to mixtures of chemicals or how to scale animal-test results to humans. Typical outputs of risk assessment models include the probability of fatality for the maximally exposed individual, expected numbers of fatalities in the population, and probability distributions describing uncertainties over health consequences.

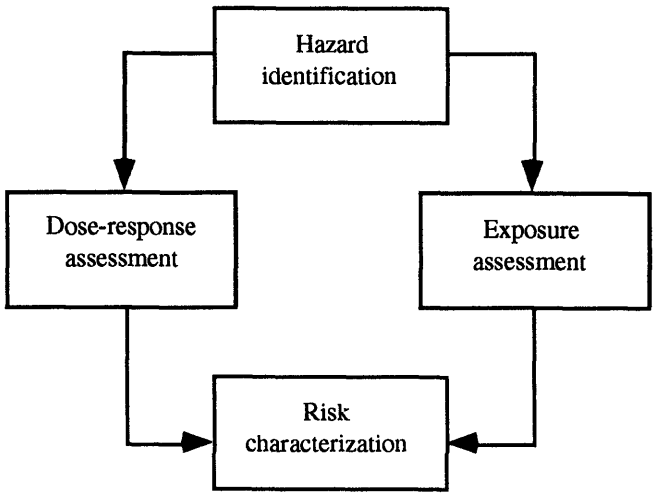

Figure 3-1. Four steps of a quantitative risk assessment.

The role of assumptions in human health risk assessments and the uncertainties associated with risk assessment results have been a target of frequent criticisms. The National Research Council identified several of these criticisms in the report, *Science and Judgment in Risk Assessment* (1994c, p. 2-15):

- Some critics claim that the default options used by EPA (i.e., the science-policy components of risk assessment) are excessively "conservative" or are not consistent with current scientific knowledge. The cumulative and combined effect of the many conservative default options might yield results that seriously overstate actual risks.
- Some feel that uncertainties in the results of risk assessments are inadequately described. Risks are most often reported as "point estimates," single numbers that admit to no uncertainty. Large uncertainties are often overlooked, and descriptions of risk as "upper bounds" can be misleading and simplistic.
- Some believe that we do not have sufficient knowledge to make risk estimates. In addition, some believe that a risk assessor can make risk calculations come out high or low, depending on what answer is desired. Thus, some people believe that credible risk assessments might be impossible to obtain with the existing state of science and risk-assessment institutions.

Risk management is the process by which risk assessment results are integrated with other information to make decisions about the need for and extent of risk reduction (NRC, 1994c). Within the realm of risk management, conflicts often arise over how information from risk assessments is used. Those in the regulated community may feel that risks are overstated because of conservative assumptions built in to standard risk assessment techniques, whereas concerned citizens may believe that assessments based on exposure to one chemical at a time grossly underestimate risks (Masters, 1991). Some analysts believe that the failure to pay sufficient attention to the results of risk assessment has resulted in misplaced priorities and regulatory actions that are driven by social forces rather than science, and yet others feel that risk assessment has been given too much weight, especially in light of its methodological limitations and inability to account for features of risk, such as voluntariness and fear (NRC, 1994c). The 1983 NRC report recommended that a clear distinction between risk assessment and risk management should be maintained and that risk assessments should be undertaken with attention to the contexts in which those assessments are used. Such a distinction should serve to explicitly separate the policy choices from the science, however this approach has proven to be problematic to practice. Many of the science assumptions made in the risk assessment process are in fact policy decisions. When policy choices are effectively hidden in a complex risk assessment process, members of the public become concerned that estimates of risk to not adequately reflect their concerns and values.

The addition of public concerns and policy choices to risk assessment renders the process of using risk to inform remedial action decisions as being dynamic and somewhat controversial. NRC (1994a) recommends that risk managers view the decision-making process as actually consisting of four different processes occurring simultaneously (see Figure 3-2). By recognizing and anticipating the interplay between risk assessment, risk management, public participation, and public policy decisions, risk managers at the Department of Energy can improve communication among the various parties and strengthen the public's confidence in DOE's ability to perform credible risk assessments. Such credibility will be shown to play a major role in the acceptability of using risk to set remediation and funding priorities.

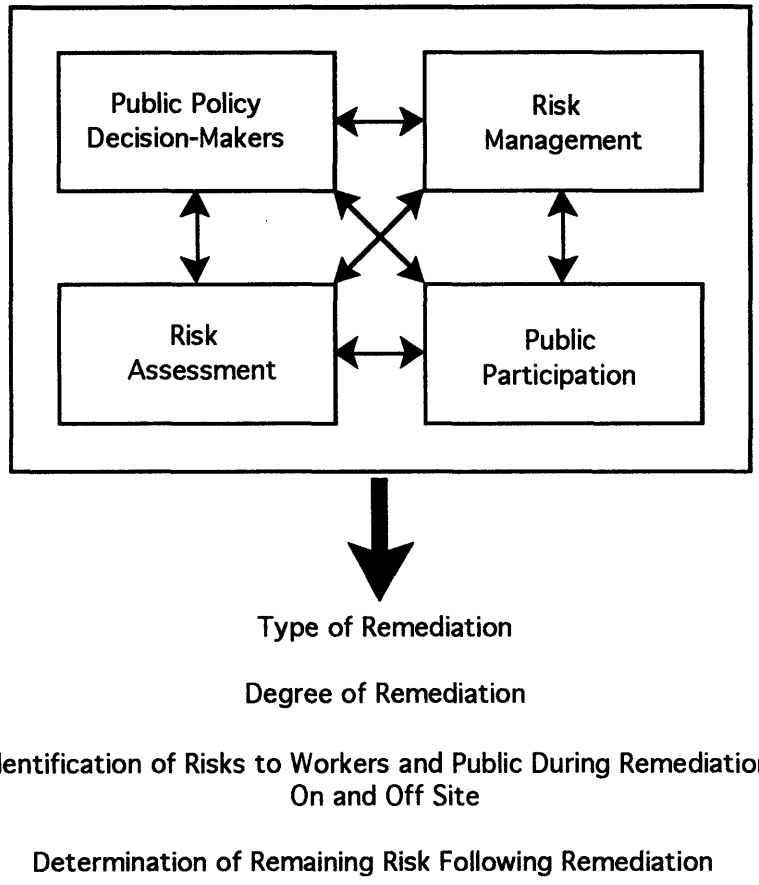

Figure 3-2. Four major factors that influence remedial action decisions are risk assessment, risk management, public participation, and public policy decisions. Each requires information from the others, and each needs to provide information to the others. (NRC, 1994a)

3.2 Use of Risk in Setting Priorities

Large-scale site remediation programs must consider several competing factors for allocating resources and setting priorities. In addition to the reduction of risk, managers of remediation programs must consider the economic viability, technological feasibility, and social equity of various alternatives. Many have identified the need to utilize a scientifically based system for setting priorities in a large scale site remediation program. The National Research Council, in its report *Ranking Hazardous-Waste Sites for Remedial Action* (1994d), contends that the purpose of such systems should be to "provide a consistent and scientifically based framework to catalog and compare potential risks to aid in resource allocation, to evaluate progress, and to serve as the basis for communication with affected parties."

Risk assessment models cannot by themselves be used as a priority-setting tools to support funding decisions (ADA, 1993). Because risk assessment models account only for considerations of risk, a prioritized ranking of sites based on such models would fail to consider other important factors, such as the cost or availability of clean-up technologies. Risk assessments are generally used to support a specific decision (e.g., what clean-up remedy to use, what will be the residual risk after remediation). The information to support broader risk management decisions and priority-setting are not provided by risk assessment alone. For example, risk assessment cannot inform on the relative risk posed by one site compared to another. Risk assessments generate risk numbers. How these numbers should be used to prioritize and compare different kinds of risk with different levels of uncertainty is an issue yet to be resolved by the risk management community. Several approaches for using risk to inform priority-setting include risk-ranking models, comparative risk analysis, and multi-attribute utility analysis. Each of these tools has its strengths and weaknesses and accordingly are appropriate to support different types of management decisions.

3.2.1 Risk-Ranking Models

Unlike risk assessment models which produce absolute measures of risk, risk-ranking models are used to provide relative measures of risk, usually on a unitless, numeric scale. Risk-ranking models incorporate factors judged to influence the magnitude of risk, rather than incorporating the more precise features of risk assessment models (ADA, 1993). And, whereas risk assessments to characterize large sites can be prohibitively expensive to perform, the more general inputs to risk-ranking models are relatively easy

to obtain. For example, inputs to a risk-ranking model for hazardous waste sites might include characteristics of waste present, characteristics of the target population or environment, and the likelihood of release or exposure.

A well-known example of a risk-ranking model is the Hazard Ranking System (HRS) used by EPA for screening hazardous waste sites to determine whether they pose enough of a risk to be included on the National Priority List for Superfund remediation. Rather than using the detailed models for estimating contaminant release, fate and transport, and dose response that comprise risk assessment models, the HRS uses simple analytical algorithms, which incorporate mechanistic factors, empirical relationships, and subjective judgment, to compute an overall score (NRC, 1994d). HRS scores, like most risk-ranking results, are only meaningful as a basis for comparison and have no apparent significance in terms of an absolute level of environmental or human health risk. Some have proposed that HRS scores be used as a general mechanism for quantifying risks from hazardous waste sites and measuring the risk reduction achieved in subsequent remediation (NRC, 1994d). However, extending results from risk-ranking models beyond their designed purpose is questionable at best.

Risk-ranking models are deficient in two key respects to inform priority-setting decisions for DOE's cleanup program. Because risk-ranking models are intended to assess relative degrees of risk among sites, they typically do not account for the uncertainties inherent in inputs that rely on judgment and empirical approximations (ADA, 1993). A significant portion of the current environmental restoration budget is being spent on characterization studies; such studies are motivated by the need to reduce uncertainty in risk estimates, and not risk itself. Further, risk-ranking models do not incorporate factors that are unrelated to risk, such as the availability of appropriate remediation technologies.

3.2.2 Comparative Risk Analysis

Comparative risk analysis (CRA) is a formal process for ranking various risks, which is being adopted by many state and tribal governments as a priority-setting tool to focus the long-term direction and allocation of resources of environmental programs. Comparative risk analysis is generally used to attain an understanding of the relative importance of risks which encompass diverse problem areas (e.g., global, local, industrial, ecological) and for which information available to assess those risks may be fairly poor. Projects typically enlist experts from many technical disciplines in order to

address the technical issues, as well as lay people from diverse backgrounds in order to provide legitimacy to the process of tackling value-laden issues.

A typical CRA project follows six basic steps (Minard, 1994):

1. define and analyze the risks posed by the environmental problems facing the jurisdiction;
2. rank the risks in order of their severity;
3. select priorities for particular attention; set goals for risk reduction;
4. propose, analyze, and compare strategies to achieve those goals;
5. implement the most promising strategies; and
6. monitor results and adjust policies or budgets accordingly; start over.

Because of the breadth of comparative risk projects, in terms of the area, population, and number and variety of hazards considered, such analyses are necessarily less detailed than risk-ranking projects that compare similar types of hazards. CRA projects typically focus on a limited number of contaminants and exposure scenarios that clearly dominate others in the magnitude of potential risks (EPA, 1993). As such, the assessment of risks in a comparative risk project often rely on sweeping generalizations to produce estimates on pollution levels and exposures, and about how people or ecosystems respond to those exposures (Minard, 1994). Yet because CRA is intended to be a subjective, participatory process, the recognized strength of comparative risk projects is not in the scientific basis for the ranking of risks, but rather in its aim to blend public concerns with scientific data and professional judgment to inform policy decisions.

One of the criticisms of using comparative risk analysis as a prioritization tool is that the resulting ranking of risks could be construed as implying that those activities producing the greatest risk reduction, or risk reduction per dollar of cost, be funded from the top down until all available funds are exhausted (ADA, 1993). Such an approach, which confuses rankings of risks with rankings of priorities, would effectively eliminate funding for low-risk projects for a given level of available funds. However, there is no evidence that CRA projects undertaken thus far have undermined the capacity or willingness to continue addressing low-risk problems (Minard, 1994). It is generally recognized that priorities must be established within the institutional, social, political technological, and economic realities that pose constraints on proposed risk

management strategies (EPA, 1993). As such, rankings have served to target budget cuts in order to minimize their impacts on successful programs and to clarify or illuminate high-risk problems that have previously been given little attention.

3.2.3 Multiattribute Utility Analysis

Multiattribute utility analysis (MUA) is a formal decision-aiding methodology that enables consideration of competing objectives in a decision problem. Problem objectives can reflect a variety of performance measures such as controlling costs, reducing risk and responding to regulatory and public concerns. Different decision options (e.g. various funding allocation scenarios) can be formally evaluated against the objectives (e.g., minimizing cost, maximizing regulatory compliance) using performance measures (e.g., total expenditures, missed milestones). The key to MUA is the ability to combine the various performance measures into a single measure of benefit using a multiattribute utility function. This mathematical function uses weights to represent the policy tradeoffs decision-makers face in determining the relative importance of each objective criterion. Unlike the risk-ranking methods which derive relative (ordinal) scores for ranking, MUA produces a cardinal score which corresponds to a real measure of benefit. And as risk-based priority-setting tool, MUA is markedly different than risk-ranking models and comparative risk assessment because it can be used to rank solutions as opposed to ranking problems. (NRC, 1994d; de Neufville, 1990)

3.3 Environmental Restoration Priority System

The Environmental Restoration Priority System (ERPS) was a decision support tool developed to assist in the allocation of the environmental restoration budget among programs and sites. The development of this tool arose in response to recommendations by several parties[10] that DOE establish a risk-based priority system in order to reduce risks to public health and environment and to use public resources wisely and effectively (ADA, 1993). Although the ERPS model was deemed "state of the art" and "well-designed, technically competent, and appropriate to its purpose" by an independent technical review team (TRG, 1991), the use of this model generated a great deal of

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[10] Parties recommending that DOE establish a risk-based priority system included the House Armed Services Committee in 1988, the Senate Committee on Appropriations in 1990, the National Governors' Association and National Association of Attorneys General in 1990, and the Office of Management and Budget in 1991. (ADA, 1993)

controversy among stakeholders. The model was eventually shelved by DOE because it was felt that several contentious issues could not be resolved.

As part of developing the ERPS system, DOE considered three priority-setting systems as strong candidates for further development: a site-ranking system, a project ranking system, and a funding allocation system. A site-ranking system requires quantitative estimates of factors relevant to judging urgency, such as the level of potential health risks associated with each site, the effectiveness of current technologies for remediating the site, and the incremental risks to workers caused by the remediation. Such estimates would be combined into an overall measure of health risk urgency, and sites would be funded in order of most urgent risks first. A project-ranking system ranks projects according to their benefit-to-cost ratios, which are determined by a multiattribute utility analysis using defined environmental restoration objectives. Projects are then funded in order of benefit-to-cost ratios until total funds are exhausted. A funding allocation system is similar to a project-ranking system, with the exception that benefit-versus-cost curves are developed for each facility, which are then optimized to determine the funding allocation among facilities which maximizes total benefits for a specified total cost. Advantages and disadvantages of each of the proposed priority-setting systems are summarized in Table 3-1.

The funding allocation approach was selected, in part, because it accounts for interdependencies among activities at sites, it permits the incorporation of local priorities and regulations in activity rankings, and it is compatible with DOE headquarters and Field Office roles for developing budget requirements, and thus more likely to be acceptable to field personnel (ADA, 1993).

The Environmental Restoration Priority System consists of three technical components:[11] a multiattribute utility model for evaluating the benefit of cleanup activities, a decision-analytic, value-of-information calculation for estimating the benefits associated with conducting studies for reducing uncertainty, and a combinatorial optimization routine for calculating efficient allocations of funds across facilities. The multiattribute utility model utilizes a utility function which was formally elicited from policy-level DOE managers and reflects the objectives and values underlying the ER program. The environmental restoration objectives incorporated into ERPS are:

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[11] The following description of ERPS is primarily drawn from the "Priority System Technical Overview," (ADA, 1993).

Table 3-1. Comparison of three alternative priority systems. (ADA, 1993, Table 2)

Option	Advantages	Disadvantages
Site-Ranking System	• relatively simple inputs and no criteria weighting required • maximizes management flexibility • rankings will be relatively easy to communicate to DOE and stakeholders	• only accounts for one attribute (health risk) • does not adequately account for effectiveness of solutions • provides inadequate help with budgeting decisions
Project-Ranking System	• accounts for multiple objectives • intuitive unit of analysis • can be modified to allow for partial funding options	• possible that no projects for a facility would be funded • does not account for possible project dependencies • input requirements are vast • may produce rankings that are inconsistent with local priorities
Funding Allocation System	• accounts for multiple objectives, partial funding options, and project dependencies • local priorities can be reflected in field office budget cases - consistent with current HQ/Field management structure • outputs useful in explaining budget requests as well as in allocating funds	• non-intuitive decision unit - ultimate dependence on activities is not necessarily clear • may constrain management flexibility • subject to charge that portfolios contain "fluff"

- Minimize health and safety risks,
- Minimize risks to the natural environment,
- Minimize adverse socio-economic impacts,
- Maximize reductions in uncertainty (applicable to characterization studies), and
- Maximize responsiveness to regulations.

These objectives represent the tradeoffs managers face in budgeting decisions. The basic inputs to the ERPS system are scores and weights associated with each of the objectives, which are used to obtain an estimate of the total benefits. Scores indicate estimated consequences of implementing each possible funding case at each facility (e.g., level of health risk, impact to the natural environment, impact on ability to comply with regulations). Weights (see Table 3-2) represent policy judgments about how much

society should willingly spend to avoid different types of adverse impacts, and about the relative value of making improvements with respect to one objective as opposed to another (e.g., reducing health risks versus responding to regulations).

In the first phase of ERPS implementation, field office program managers screen cleanup activities into one of three priority classes, according to the urgency of the problem that each activity addresses. Emergency and time-critical activities receive top priority and are assured of being funded. The remainder of activities are then ranked and grouped into several alternative cases, each of which can be conducted for a different level of cost. Each case is then evaluated according to how well it meets various ER objectives, using a scoring process. These scores ultimately determine the benefit of each case and the facility's ability to compete for funds. A curve is developed for each facility that indicates how the level of estimated benefit achieved at that facility depends on the amount of funding allocated to the facility. Finally, an optimization process determines how to allocate any total budget among the various facilities to obtain the greatest total level of benefit. Although the system could be used to recommend an optimal funding

Table 3-2. Weights assigned to the five objectives in the Environmental Restoration Priority System to reflect trade-offs between achievement of benefits. (Jenni, 1994)

Objective Criterion	Relative Weight	Value Tradeoff Judgment
Health risk	36%	$5 million per health effect avoided $200 to eliminate a 10^{-1} risk to maximally exposed individual
Environmental risk	13%	$400 million to eliminate the highest level of impact
Socioeconomic impact	9.5%	$300 million to eliminate the highest level of impact
Regulatory responsiveness	9.5%	$300 million to eliminate the highest level of impact
Uncertainty reduction	32%	Implied by weight on health risk and value-of-information calculation
Total	100%	
Other value judgments:		
Risk urgency/timing		– 5% discount rate applied to future benefits
Remaining and future costs		– 10% discount rate applied to future costs

level in terms of benefits and costs, DOE announced that the system would be used only to recommend funding allocations for a given total budget.

An independent technical review team praised technical aspects of the ERPS system and expressed the following benefits in using this tool (TRG, 1991):

- The system is well-designed, technically competent, appropriate to its purpose.
- Multiattribute utility is the best approach to complex prioritization problems; a formal, quantitative system is preferable to an informal qualitative system.
- It allows replication of results, reduces subjectivity, and can help offset the lobbying and "earmarking " that will inevitably occur in a political environment.

However, the technical review group identified several workability issues that it felt were not adequately addressed by the ERPS developers. These issue included:

- Inadequate explanation of the role of the priority system to existing agreements with local governments and enforcement agencies, since in principle, external agreements can only make the system less effective (i.e., will constrain budgets to less than optimal allocations).
- Inadequate framework for public participation to ensure credibility. In the current process, each field office develops its own budget cases and scores its own sites, and only then are defended in a public setting.

As part of their conclusions, the technical review group recommended that the model be used as a point of departure for informing decisions and not as a substitute for use of considered judgment. Further the group recommended that the system be used to prioritize cleanup efforts, but not for determining the size of the total budget allocated to that task. As such, ERPS could enable DOE and the Congress to review the overall costs and benefits of the program, including those posed by regulatory requirements and compliance agreements.

In keeping with the agency's desire to open up its decision-making process to public scrutiny, the ERPS design team consulted with a Priority System External Review Group (ERG) during model development and implementation for the FY92 and FY93 budget formulation exercises. The ERG included representatives from affected states, Indian Tribes, national-level governmental organizations, public interest groups and the EPA. Some of these members were or had been involved in the negotiation of compliance agreements at DOE sites. From the beginning of their involvement, the group expressed little enthusiasm for the effort and questioned the need for a priority system, since in the

opinion of many members, compliance agreements should serve as the sole basis for funding decisions (Jenni, 1991).

Consistent with the technical review group's concerns about ERPS implementation, the objections posed by the ERG and others were related less to the technical quality of the model, but rather how the model was to be used. Reasons for opposing the priority system included (Jenni, 1991):

- The unstated intent of the system is to provide DOE with a justification for not seeking adequate funds to comply with compliance agreements.
- The system is unnecessarily complex; this complexity prevents meaningful public participation because it can not be understood by members of the general public.
- The priority system could be "gamed" to achieve the desired outcome (e.g., maximizing funding for a certain facility).

A technical concern raised in several comments on the proposed use of ERPS was the quality of the input data. Because many of the risk inputs are based on professional judgment, and not on risk assessment data, some feared that a lack of minimum data requirements, analytical rigor, and basic guidance about estimating risk would severely limit the comparability of the model results (EPA, 1991; STGWG, 1991).

3.4 FFER Committee Recommendations for Funding Allocation

A significant voice of opposition toward a national risk-based prioritization strategy was delivered through the Federal Facilities Environmental Restoration (FFER) Dialogue Committee. This committee was established by EPA to develop consensus policy recommendations for improving the decision-making process to ensure that clean-up decisions reflect the priorities and concerns of all stakeholders. It consisted of representatives from several federal agencies involved in environmental restoration activities at federal facilities including EPA, DOE, Department of Defense (DOD) and others. The committee also included representatives from national and local environmental, citizen, and labor organizations; tribal governments and Native American organizations; and state governments.

The FFER Dialogue Committee published an Interim Report, also known as the Keystone Report, which included consensus recommendations for improving stakeholder involvement in key environmental restoration decisions, improving consultation on funding decisions, and setting priorities in the event of funding shortfalls.

This committee explicitly opposed a priority-setting system, such as ERPS, for several reasons. On consideration of its technical merits, the Committee felt that (FFER, 1993):

1. Existing data and science are currently inadequate to determine objective consensus clean-up priorities;

2. Factors other than environmental and human health risk deserve consideration in allocating clean-up resources;

3. Broadly acceptable and objective methods for evaluating some of the criteria relevant to the allocation of clean-up priorities do not currently exist, and, in some cases, may never exist and may even be inappropriate; and

4. Regardless of any party's opinion about the quality of available data and science, it is appropriate in a democracy to allow a variety of affected interests to provide input on decisions that affect them.

The FFER Dialogue Committee, recognizing that it may not always be possible to adhere to legally binding commitments in the face of funding shortfalls and strongly opposed to the evolving risk-based prioritization model being developed by Environmental Management, proposed a proportionate reduction strategy for allocating limited funds. This option, called the "fair share" allocation process, is to be implemented in the following manner (FFER, 1993):

- DOE must request a budget level sufficient to meet all regulatory commitments.

- If Congress appropriates less than what DOE requested for its remediation programs, then shortfalls would be shared proportionately among the sites. For example, if the amount approved by Congress is 90% of the agency request, then each site should receive 90% of the amount requested for that site.

- If any reduction seems likely to result in conflict with legal obligations, then DOE may seek changes in the scope or schedule of cleanup activities. Regulators would, presumably, renegotiate agreements and forego punitive enforcement actions as long as the Department made good-faith efforts to follow the fair-share allocation process.

In effect, this process forestalls any sort of priority setting; a proportionate reduction in funding would be imposed regardless of resulting marginal costs to efficiency. For example, a 10% reduction in funding at a smaller site might result in the delay of several remedial actions, whereas the reduction could be absorbed at a larger site with little impact. The "fair share" process effectively rules out inter-site comparisons for priority-setting. While the committee did not preclude the use of risk assessment in the envisioned process of resource allocation, they were concerned that reduction of risks to health and the environment might lessen the focus on other important factors (e.g.,

cultural values and socioeconomic impacts) and be used to avoid meeting the requirement of agreements negotiated with states (NRC, 1994a). Although the Keystone report was endorsed by the Secretary of Energy, DOE did not explicitly agree to adopt the "fair share" allocation process.

3.5 Congressional Push for Risk-benefit Analysis

Risk analysis and comparative risk assessment have recently enjoyed heightened interest in Congress as a rational and defensible means for resolving difficult budgetary choices related to environmental regulation. More than a dozen bills addressing risk analysis were introduced in the 103rd Congress, which concluded in November 1994 (Davies, 1995). Among these were:

- An amendment (introduced by Senator Bennett Johnston, D-Louisiana) which would have required that EPA conduct a risk analysis for each of its regulations and compare the intended risk reduction to both the cost of the proposed regulation and to other types of risks.
- An act (introduced by Senator Daniel Moynihan, D-New York) which would have required the EPA to establish a Committee on Relative Risks to identify and rank the greatest environmental risks to human health, welfare, and ecological resources, as well as a Committee on Environmental Benefits to provide expert advice on estimating the quantitative benefits of reducing risks; develop guidelines to ensure consistency and technical quality in risk assessments; establish a research program on environmental risk assessment; and create an Interagency Panel on Risk Assessment and Reduction to coordinate federal efforts.

Much of the proposed legislation was in response to the belief that environmental regulations are not directing resources to the most pressing problems, and that this misdirection of effort is due in part to the public's inability to compare targeted risks to those they commonly accept (Graham, 1994). The Johnston amendment, while similar to the cost-benefit requirements already called for by a Clinton administration executive order,[12] would additionally require that regulated risks be compared with other risks in order to provide a measure of perspective. The Moynihan bill was aimed at improving the quality and visibility of risk assessment and emphasized comparative risk analysis of the problems addressed by different EPA programs. With the exception of a version of the Johnston amendment that was attached to a U.S. Department of Agriculture reorganization bill, no other risk legislation passed (Davies, 1995). Many of the risk-related issues raised in the 103rd session of Congress continue to be addressed, and

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[12] Executive Order 12866.

indeed intensified, by Republican members of 104th Congress as part of their "Contract with America."

Much of the debate on risk assessment and cost-benefit analysis is currently being directed toward DOE's environmental restoration program in the form of "The Department of Energy Risk Management Act of 1995." Introduced as a means to compel the Department to "prioritize resources to address the most serious and most cost-effective risks first," the bill contains the following elements (Murkowski, 1995):

- Outlines a prescriptive approach for conducting risk assessments – which EM criticizes as being too focused on health impacts from exposure to environmental toxins without adequate consideration to nuclear safety risks, birth defects or immediate health effects and as failing to incorporate risks to workers and the environment during remediation (Grumbly, 1995b).

- Requires the Secretary to review and revise risk assessments if significant new information or methodologies become available – which causes concern about EM's ability to implement decisions that involve major actions, such as building waste treatment facilities (Grumbly, 1995b).

- Provides for the public to petition the Secretary for review of particular risk assessments not to their liking – which could cause significant delays in actual cleanup work (Grumbly, 1995b).

4 Barriers

The desire for managers to use risk considerations to guide programmatic decisions is evident throughout the Environmental Management program. That the principle of addressing urgent risks first is the first of six major program goals illustrates the imperative that the present administration of EM places on this issue. Yet experience derived from previous attempts of using a risk-based strategy to prioritize cleanup decisions has shown that several obstacles impede the use of risk information in management decisions. A risk management approach to decision-making must address several barriers to implementation, these barriers being both political and technical in nature. Nevertheless, pressure continues from Congress and other budget oversight groups for incorporating risk considerations to guide Department actions in the face of funding constraints (GAO, 1995).

While much of the discussion in this thesis has focused on environmental restoration and waste management program activities, these same issues impact decontamination and decommissioning (D&D) activities, as well:

> Optimal D&D strategies for some sites and facilities could involve a risk management approach in which some actions are taken early while others are deferred until a more permanent and effective solution could be implemented. However, difficulties in applying this approach arise from the lack of consensus on how to evaluate relative risks or determine acceptable risks, the tendencies for facilities to degrade over time, and the lack of public trust in interim risk management versus final resolutions. (DOE, 1994c)

Recognizing the need for a fundamental re-evaluation of the EM program, Assistant Secretary Thomas Grumbly asked the National Academy of Sciences (NAS) to assess whether a risk-based approach to evaluating the consequences of alternative remedial actions is feasible and desirable. As part of the Academy's response to this request, it conducted a workshop to solicit views from citizen advocacy groups, regulators, labor organizations, and other stakeholder representatives on how the EM program has operated and in what manner should scientific information on environmental and health risk should be used in decision making. The results from this workshop, as well as further deliberations by the Academy, were published by the National Research Council in *Building Consensus Through Risk Assessment and Management* (NRC, 1994a). In this report the committee identified several guidelines in using risk assessment for evaluating future outcomes at DOE weapons complex sites, including:

- Risk assessment is feasible, even when limited information is available, if the purpose and limitations of the risk assessment are well defined.
- Risk assessment can provide effective comparisons of outcomes and cost-effectiveness for possible future actions.
- Risk assessment must include public involvement in all of its aspects, including the planning of the process and the definition of the scope of risk assessment. Public involvement can thus become "... an important element of consensus-building for remediation."
- Risk assessment "... is a highly desirable component of the remediation decision-making process," but decision-making should also consider political, social, religious, financial, and technological factors.
- Risk assessment, properly used, provides for systematic data collection, uncertainty analysis, and result presentation. Yet limitations to risk assessment should be understood by DOE and stakeholders.

NAS also identified as an obstacle to implementing a risk-based approach that the use of risk assessment to set priorities for remediation is viewed by some as a process without adequate opportunity for public input. Table 4-1 lists a number of risk-related concerns identified by stakeholders regarding cleanup efforts at the Idaho National Engineering Laboratory. As this table shows, input from the public can reveal a broad range of concerns which extend well beyond the traditional issues considered by risk assessment practitioners, including issues of equity, socioeconomic impact, and distrust of responsible agencies. Members of the general public regard risks in a broader social context which includes environmental, social, political, and ethical considerations (Dooley, 1987). A priority-setting process that fails to adequately address these broader concerns will be viewed with skepticism.

4.1 Risk Perception and the Public Role

By committing to a path of stakeholder involvement, DOE has opened up its decision-making processes to public scrutiny. As such, the Department must be prepared to be responsive to the way the public perceives the unique risks associated with the cleanup program. Unlike other large-scale site remediation efforts, such as those being conducted under the Superfund Program or the Department of Defense, the Department of Energy's program is unique in having to manage enormous quantities of radioactive waste and contamination. Research has shown that the public perceives risks associated with radioactivity and nuclear programs quite differently than the experts who manage those risks.

Table 4-1. A summary of risk concerns, as well as related cost and public involvement issues, identified by members of the public and local tribes regarding the Idaho National Engineering Laboratory (CERE, 1995).

RISK ISSUES	COST AND PUBLIC INVOLVEMENT ISSUES
Method and Approach	*Cost Issues*
Approach	Allocation of funding
– fragmentation of site for purpose of assessment	– priority setting
– methodology	– role of State and Local agencies
Comprehensiveness of risk assessment	Labor/union issues
Models used	Regulations
	– cost of enforcement
Data and Assumptions	Remediation
Cultural/historic/spiritual resources, consideration of	– cost of
Data	– funding for, adequacy of
– qualitative, adequacy of	
– quantitative, quality and quantity of	*Public Involvement/Relations/Outreach Issues*
Ecological risks, evaluation of	Distrust of DOE
– species monitored, selection of	Public involvement
Economic risks, evaluation of	– comment period, insufficient
Groundwater risks, evaluation of	– personal cost and time for adequate participation
Health risks, evaluation of	– document accessibility
– future, due to present contamination/storage	– meeting logistics, inconvenient
– to residents	– information provided, insufficient/inaccurate
– to tribes, traditional uses of natural resources	Public outreach/mass media
– to workers	– coverage/outreach, inadequate or overwhelming
	– representation of site, inaccurate/incomplete info
Results and Interpretation	
Compounds of potential concern	
Risks, determination of	
Uncertainty, characterization of	
Remediation	
Land use, suitability of remediation practices for	
Milestones, pace of meeting	
Remediation practices	
– choice of	
– risks of	
Standards	
– selection, basis of	
– will proposed remediation meet	
Technologies considered	
Waste, disposal/storage/treatment/transportation of	

Regulators define human health risk in terms of the likelihood of adverse impacts occurring to individuals or populations (e.g., a 1 in one million lifetime risk of a fatal cancer, or the number probable deaths per 100,000 people) and find it useful to think in terms of "acceptable risks" or "below regulatory concern" as part risk analysis and policy decisions. Research related to individual attitudes about risk has consistently shown that individuals care about other dimensions of risk besides sheer statistical magnitude

(Portney, 1992). These other dimensions include fairness, distribution of benefits, alternatives which could lead to risk avoidance, control over risks, and voluntariness in assuming the risk (Covello, 1988). Because risk acceptability is primarily a matter of judging the results of quantitative risk assessment calculations in terms of explicit risk-benefit criteria, establishing an acceptable level means making choices about values and social mechanisms. Thus, the general public's criteria for judging acceptable levels of risk will necessarily be different from the technical criteria employed by the "experts."

Several studies were conducted to determine minimum acceptable distances that people would be willing to live to a hazardous facility, as part of the impact assessment for the Yucca Mountain repository. This metric is used as a measure of acceptable risk since risks to health from waste disposal facilities are believed to increase in closer proximity to those facilities. The larger the percent of people willing to live or work closer to a particular facility, the more acceptable that facility tends to be in terms of perceived risk. The results of these studies consistently ranked underground nuclear waste disposal facilities as being the least acceptable, followed by toxic chemical disposal facilities and nuclear power plants. These were also facilities characterized by high catastrophic consequences and high dread (Mushkatel, 1990). Table 4-2 shows the minimum distance to six hazardous facilities that would be acceptable for 70 percent of the urban population. It is interesting to note that nuclear power plants, for which there is some familiarity with catastrophic consequences (Chernobyl), are more acceptable than a nuclear waste repository, for which the public has far less experience.

Table 4-2. The minimum acceptable distance such that 70 percent of the population would be willing to live or work from various hazardous facilities based on health and safety considerations (Mushkatel, 1990).

Facility	*Minimum Acceptable Distance (Miles)*
Nuclear Waste Repository	500
Chemical Waste Disposal Site	425
Nuclear Power Plant	150
Pesticide Plant	85
Oil Refinery	75
Landfill	20

It is perhaps enticing for risk managers to discount the apparent failure for the public's capacity to make rational decisions on risk-related matters. However, this approach may be short-sighted. Psychologist Paul Slovic warns:

> Since even well-informed laypeople have difficulty judging risks accurately, it is tempting to conclude that the public should be removed from the risk assessment process. Such action would seem to be misguided on several counts. First, we have no assurance that experts' judgments are immune to biases once they are forced to go beyond hard data. ... Second, in many if not most cases, effective hazard management requires the cooperation of a large body of laypeople. These people must agree to do without some things and accept substitutes for others; they must vote sensibly on ballot measures and for legislators who will serve them as surrogate hazard managers; they must obey safety rules and use the legal system responsibly. Even if the experts were much better judges of risk than laypeople, giving experts an exclusive franchise for hazard management would mean substituting short-term efficiency for the long-term effort needed to create an informed citizenry. (As excerpted in Ruckelshaus, 1985)

The disparity between the public and expert valuation of risk has prompted social scientists to examine the ways in which different groups of people characterize and perceive risk. Perhaps the most notable and frequently cited is the work by Paul Slovic, et al. (1985), which examines the cognitive dimensions of risk that extend beyond the simple concept of risk as merely a quantitative measure of the conditional probabilities of hazard consequences. This work was based on studies in which participants rated a given set of hazards (e.g., disease from smoking, automobile accidents) against a range of risk characteristics which have been hypothesized to influence risk perception (e.g., to what extent are these hazards controllable, familiar, dreaded, or fatal). Participants were also asked to indicate the degree of risk reduction and regulation they desired. Through a correlation analysis, these risk characteristics were grouped into two broad categories of dreaded risks and unknown risks (see Figure 4-1). A plot of the hazards into a "factor space" defined by a spectrum of the degree to which risks are dreaded or unknown illustrates how the different groups characterized the risks associated with those hazards (see Figure 4-2).

The strikingly isolated position of the nuclear related hazards, including nuclear waste, weapons testing, and nuclear reactor accidents, indicates the extent to which their associated characteristics of risks differ in relation to other hazardous activities; they are generally perceived as being risks that are both exceptionally unknown and dreaded. Unlike many hazards, radiation cannot be seen, smelled or felt; people sense that they have little control over their exposure to radiation. Further, the level of knowledge about the likelihood of health effects from radiation and the technologies associated with

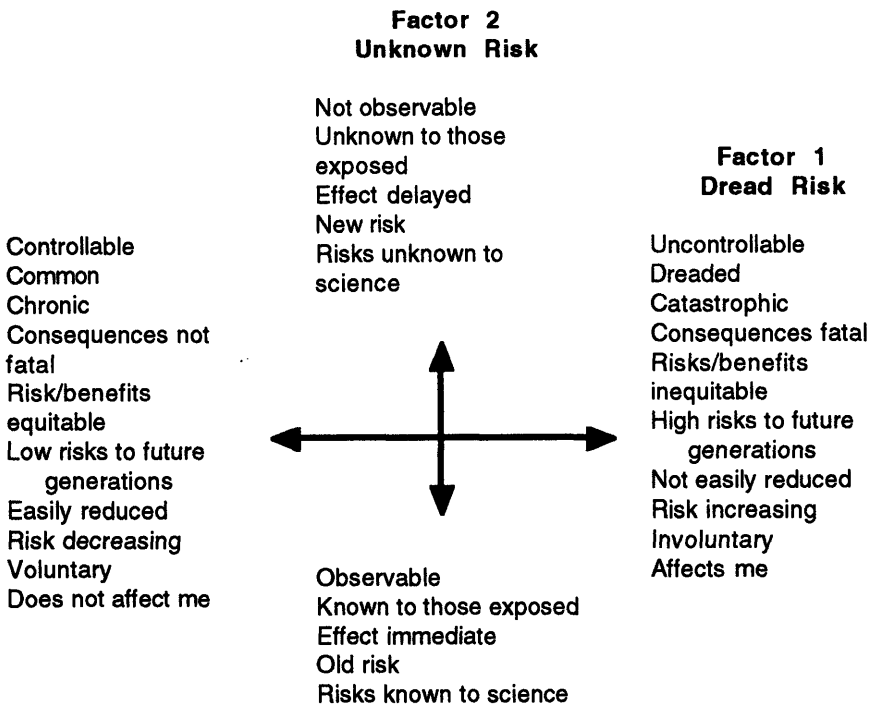

Figure 4-1. Two-factor space for identifying a spectrum of risk characteristics associated with hazards. Factor 1 represents characteristics of dreaded risks and Factor 2 represents those of unknown risks. (Adapted from Slovic, 1985, Figure 2)

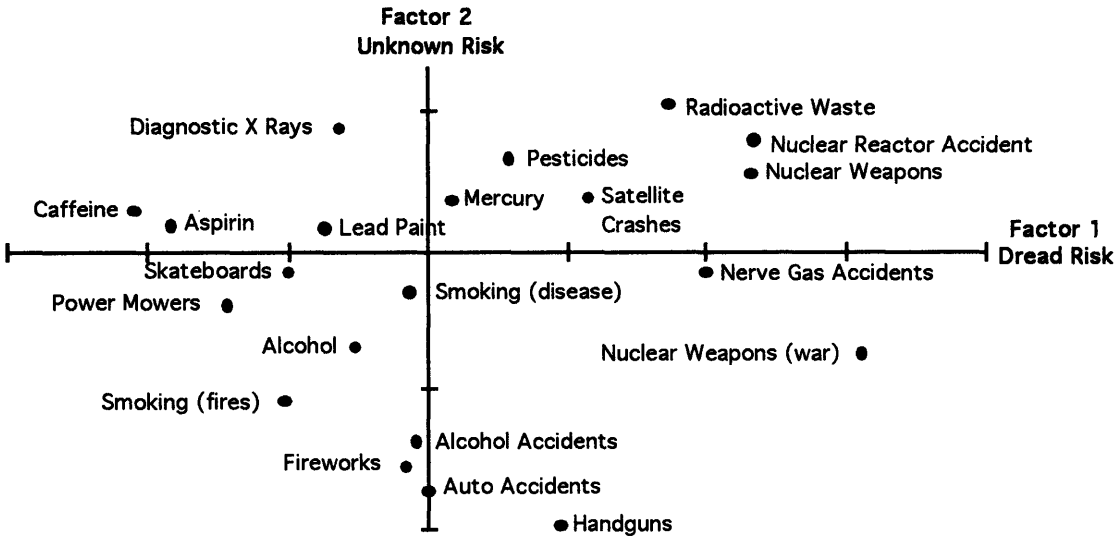

Figure 4-2. A plot of various hazards along axes representing the degree to which those hazards are dreaded (Factor 1) and unknown (Factor 2). Nuclear-related hazards are shown to be both exceptionally dreaded and unknown. (Adapted from Slovic, 1985, Figure 3)

nuclear power and nuclear waste management are quite low among the public. In a study of socioeconomic aspects of nuclear waste repository siting, the National Research Council (1984) found that public groups do not distinguish clearly between the risks of nuclear weapons and those of nuclear power plants, and that although the extent to which fear over nuclear weapons enters into attitudes on nuclear waste is difficult to measure, it is undoubtedly an element in the formation of public opinion. It is likely that people associate radioactive waste with cancer, a particularly dreaded form of illness and death. Concern of catastrophic accidents in nuclear power plants seems to add to those fears.

As part of their conclusions Slovic, et al. (1985) asserted that "people's strong fears of nuclear power and their political opposition to it are not irrational but can be understood as a logical consequence of their concerns about considerations such as equity, catastrophic potential, and the safety of future generations." Another important observation is that the cognitive dimensions of the extent to which risks are unknown and dreaded are not immediately apparent in the data generated by traditional risk assessments, yet these are factors which strongly influence the public's perception of risk. This work also determined that the desire for regulatory stringency was highly correlated with dreaded risks regardless of low mortality estimates, and not with risks that result in much higher mortality yet are not dreaded (e.g., alcoholic beverages, automobile accidents, and smoking).

The divergence of perceptions between technical experts and the general public of the level of risk associated with a particular activity has been coined the social amplification of risk (Kasperson, 1988). In general, this amplification is viewed by some as risk being overestimated, overemphasized and overplayed, particularly in contrast to the traditional model which presumes that individuals make consistent decisions over time in order to maximize their utility by evaluating choices of what matters to them and comparing probabilities of expected outcomes. Instead, an accumulating body of evidence, including the work by Slovic, has shown that people do not make consistent risk decisions. Risk managers and those engaged in public policy decision making should attempt to recognize those factors which lead to differing risk perceptions in order to engage in more meaningful dialogue with concerned members of the public.

Cognitive theory attempts to explain distortions and differences in risk perception by identifying heuristics (rules of thumb) and biases (consistent errors in judgment that characterize decision-making under uncertainty) that are frequently observed (Cantor,

1994; Hornstein, 1992). Some heuristics relevant to perceptions of hazardous and nuclear waste include:

- *Calibration and Overconfidence.* People are often over- or underconfident regarding their judgments depending on the difficulty of the assessment. For moderate or extremely difficult assessments, people with general knowledge are often overconfident. Overconfidence means that people believe their judgments to be more accurate than they are about assessing risks, even if this confidence cannot be supported by statistical evidence.

- *Availability.* This heuristic is expressed by tendency of people to weight the probability of an event by the ease with which some relevant information comes to mind; other information, although relevant, is ignored simply because it does not come to mind easily. For example, people may overestimate the risk posed by commercial nuclear power plants because sensational but statistically unlikely events, like the Three Mile Island and Chernobyl accidents, are readily available through the media whereas histories of plant safety data are not.

- *Adjustment and Anchoring.* People may anchor a risk judgment to some starting point in an assessment, so that even after learning they have based probability estimates on faulty information they continue to be influenced by the earlier estimate. This heuristic has important implications about the effectiveness of risk communication programs for the remediation of nuclear and hazardous waste sites.

Cantor offered some general guidelines for understanding public responses to highly complex risks, such as those associated with the remediation of hazardous waste facilities:

- People simplify.
- It is difficult to change people's minds once they are made up.
- People remember what they see.
- People cannot readily detect omissions in statistical evidence.
- People disagree more about the definition of risk than about the magnitude.
- People have difficulty sorting through risk disputes.
- People have difficulty evaluating expertise.

These heuristics and biases in risk perception tend to confound communication between experts, regulators, and the general public. A public information meeting which merely presents data on the magnitude of potential risks to health and safety is inadequate to satisfy the public's concerns. Such information must be framed to address the social values that contribute to the public's estimation of risks, which include dread of uncontrollable consequences, issues of equity, socioeconomic concerns, and distrust of

responsible agencies. Because public communication programs have historically failed to address these values, the siting of nuclear waste repositories has met with significant opposition, both locally and among the general public. And although the social response of having a new hazardous facility sited is necessarily different than the issues posed by existing facilities slated for remediation, it is likely that public participation efforts will confront similar problems in communicating risk unless the broader social elements of risk are addressed.

4.2 Public Distrust of DOE

The perceived quality of risk information depends a great deal on the credibility of the persons responsible for performing the risk assessment. The Department of Energy has a significant credibility problem with the public. In a national survey a clear majority of those surveyed indicated that they did not trust the Department to readily disclose serious problems regarding its nuclear waste programs (see Table 4-3). This lack of credibility stems in part from decades of not fully disclosing contamination releases and accidents at its weapons production facilities and an from operating in secrecy with little external oversight. And, in spite of recent agency efforts to open up DOE operations to public scrutiny, trust-building is hampered by attention-grabbing headlines like "Files Show U.S. Deception in 1950's Radiation Tests" (WP, 1995).

Lack of trust also impacts the way public feels about the sincerity of DOE to consider their input in decision making. In comments offered at the NRC workshop, Joe King, the City Manager of Richland, Washington, expressed the concern that community members may regard DOE as merely "going through the motions" of complying with public participation requirements set forth in various statutes and DOE orders. Mr. King made this statement regarding what he considers to be the largest barrier hampering DOE's efforts to build public confidence in EM's cleanup program:

> I think one of the main reasons why we are having such a hard time is that we will not, as the public, forgive your predecessors for their actions over the past 40 years. The credibility is so low, the antagonism level so high, that you do not have a clean slate to work from. (NRC, 1994b)

It is important to consider such statements in the context of community support for the DOE presence. Public attitudes shift dramatically from one DOE facility to the next. In Richland and its surrounding communities (population of 155,000), which grew to support the large Hanford facility located in a remote part of Washington state, seven

Table 4-3. National survey responses to the statement: "The U.S. Department of Energy can be trusted to provide prompt and full disclosure of any accidents or serious problems with their nuclear waste management programs." (Flynn, 1990)

Response	*Number*	*Percent*
Strongly Disagree	393	47.6
Somewhat Disagree	169	20.5
Neither Agree nor Disagree	50	6.1
Somewhat Agree	149	18.1
Strongly Agree	44	5.3
Don't Know	20	2.4
TOTAL	825	100.0

out of every ten households are employed at the facility (NRC, 1994b). It is one of several "atomic energy communities" in which members were generally supportive of the DOE mission. Nevertheless, with the mission change from production to cleanup and the discovery of contamination that is spreading from site boundaries, public support has shifted to that of skepticism and distrust of DOE's ability to safeguard the community's welfare.

Other facilities operated in a much less supportive and knowing environment during the peak years of weapons production, making public outreach efforts that much more difficult to foster in this new era of openness. For example, the mission of the Rocky Flats plutonium processing plant, which is located between the cities of Denver, Boulder, and Golden in the Colorado Rocky Mountain foothills, was vague to a majority of residents in surrounding communities. Although this facility employed over 9,000 workers, it was not a principal employer, in comparison to more remote facilities whose local economies were strongly linked to the DOE presence. As a result, when Rocky Flats was raided by the Federal Bureau of Investigations (FBI) in 1989 in response to allegations of safety and environmental violations, negative media coverage reinforced a public sentiment toward the plant that was generally adversarial and distrustful.

Many recognize the importance of trust in gaining public acceptance and consensus in risk management and priority setting (NRC, 1994a; NRC, 1994d). According to some,

the acceptance of any risk is more dependent on public confidence in the management of risk than on quantitative estimates of risk.

Mike McCloskey of the Sierra Club asserts that EPA and other risk assessment practitioners use the word risk to divert attention away from the severity of the nation's environmental problems:

> Use of this terminology is part of a broader effort to obscure the role of judgment and values in pollution control and make it sound like it can be addressed solely in terms of a 'scientific process.' However, the terminology both sounds convincing and acts to exclude the interested public. This emphasis on 'scientific process' also is designed to raise the threshold for action – with a demand for absolute proof before anything is done. (McCloskey, 1994)

4.3 Applicability of Risk Data

An institutional barrier to risk-based priority-setting is the quality of risk data available to support decision models, either quantitative or qualitative. Much of the quantitative risk data available to decision makers has been generated to support specific regulatory actions (such as CERCLA, NEPA) or DOE orders. Because such risk assessments are often performed to support very specific decisions and are subject to differing constraints and assumptions, risk information resulting from these assessments may not be appropriate for comparisons or amenable to informing broader risk-based decisions.

For example, at the Hanford Reservation, DOE and its contractors are responsible for generating and using fifteen different safety and risk-related reporting documents which add up to literally tens of thousands of pages of documentation (Blush, 1995). Each type of assessment or report is focused on an individual facility, program or project. No methodology exists for combining assessments of risk for different facilities with different levels of uncertainty into a collective assessment of risk for the entire site. Further, there is no accepted methodology or practice to identify the most significant data gaps that would hinder a site from attaining a sufficiently complete understanding of risk necessary for an integrated site-wide assessment.

Data integration from various assessments can be suspect due to the various types of assumptions that underpin those assessments. Consider two types of risk assessment frequently performed as part of regulatory requirements, baseline risk assessments and safety analysis reports:

- Baseline Risk Assessments - used to evaluate the potential threat to human health and the environment in the absence of any remedial actions. As such, it provides the basis for determining whether remedial action is necessary and the extent of cleanup needed to reduce potential risk levels to within EPA's acceptable range under CERCLA. (DOE, 1992b)

- Facility Safety Analysis Reports (SARs) - defined under DOE Order 5480.23 as "the combination of information relating to the control of hazards at a nuclear facility (including design, engineering analyses, and administrative controls) upon which DOE depends for its conclusion that activities at the facility can be conducted safely." The analyses of the safety bases shall include management, design, construction, operation and engineering characteristics necessary to protect the public, workers, and the environment (CERE, 1995).

Each assessment is used to support a very different decision and accordingly each has a different procedure allowing different types of assumptions. For example, when conducting a baseline risk assessment for CERCLA remedial investigation and feasibility studies, an assessor may not factor in the use of institutional controls. Conversely, institutional controls are central to the assessment of risk in a safety analysis report. Because institutional controls have a large impact on possible exposure scenarios, an estimate of risk resulting from a baseline risk assessment will be more conservative than an assessment which may incorporate factors believed to reduce exposure to the hazard being considered. While each type of assessment may be appropriate to its intended use, the comparability of results from different risk assessment vehicles is uncertain at best.

Some have criticized the lack of consistency in the preparation of risk assessments:

> DOE has not established any directives to ensure that DOE contractors and subcontractors follow consistent procedures for collecting environmental samples, analyzing data, or choosing among inference assumptions as risk assessments are developed throughout the Weapons Complex. Therefore, it is likely to be difficult, if not impossible, to compare risk estimates either within or among sites. (OTA, 1991, p. 103)

Some sites are taking initiatives to address the issue of ensuring conformity among the various risk assessments performed at their sites. For example, the management at Rocky Flats Plant is developing a risk assessment policy document to ensure consistency among risk assessments by providing uniform guidance assumptions to ensure compatible site-specific information. As Rocky Flats began this effort, it became quickly evident to those responsible for assessing the then present situation, that risk managers from around the site had little communication with each other. Similar types of risk assessments for hazards within the same general vicinity had, as inputs, different

assumptions for standard features such as annual rainfall and exposure scenarios for the maximally exposed individual. This is but one example of inconsistency among risk assessments that undermines confidence in the science.

4.4 Funding Allocation and Legal Agreements

A risk-based priority system should suit its political context. Critics of the Environmental Restoration Priority System felt that the tool was being developed to assist DOE in the unstated goal of seeking justification for failing to adhere to its legally binding commitments. Concern that the model would recommend funding allocations insufficient for meeting legally binding commitments proved to be the major contentious issue that led to the demise of the ERPS model. State representatives were suspicious that 1) the model would be used to justify a total budget request that would be less than that needed to meet DOE's negotiated agreements, and 2) the model would demonstrate a rationale for shifting resources away from facilities in their state (Jenni, 1994).

Sensitivity analyses performed on the ERPS model to investigate the impact of regulatory requirements on funding needs demonstrated that both total funding requirements and allocations among sites were very sensitive to the weight assigned to regulatory compliance (Jenni, 1994). These analyses showed that in order to achieve maximum possible regulatory compliance, necessary funding levels were typically estimated to be about 50% greater than funding levels actually chosen. Yet with zero weight on regulatory compliance (implying no value to complying with regulations that produce no additional health, environmental, socioeconomic, or cost-reducing benefit), optimal funding levels were typically about one-third of chosen levels. In other words, this model seems to show that rigid compliance with all regulatory requirements and legally binding agreements may conflict with DOE's stated goal of protecting public health and safety.

Although such a finding can be instructive to law makers, it nevertheless places an uncomfortable burden on those who would question the prudence and effectiveness of environmental regulations and legal agreements. In an independent technical review of the ERPS system, the review panel reported that the demonstration of the high costs of regulatory compliance was an important finding of this system and that this lesson should be transmitted to policy makers and other users of the system's output (TRG, 1991). The review panel also noted that,

> If regulatory compliance does cost this much without providing benefits, then the regulations should presumably be revised. ... Such revisions would not necessarily reduce expenditure, but would definitely turn regulation in a more profitable direction. ... This system will help us allocate funds more efficiently within the constraints of the present rules. In addition it can point out where the budgetary processes and regulations of the present system cause us to sacrifice significant amounts of value. The people who designed this system are not responsible for raising these issues. But it would be a tragic waste if we went through all this effort and did not point out deficiencies in the present system to executive branch and congressional personnel. (TRG, 1991, p. 22)

These findings are not inconsistent with the current criticisms of environmental regulation today. The *New York Times* recently reported an announcement by ranking members of the Senate Energy Committee (Senators Frank H. Murkowski and J. Bennet Johnson) that they are seeking changes to legislation[13] that underpin the compliance agreements which drive much of DOE's remediation efforts. They specifically cited the cleanup of the Hanford Nuclear Reservation as a program that "could not achieve its goals under any conceivable budget or timetable" (NYT, 1995). The Senators issued a report written by two former DOE senior officials that blamed the failure of Hanford's cleanup program on the tri-party agreement. The authors of this report asserted that,

> Congress will be able to fund the [tri-party agreement] only if it is willing to forgo appropriating money for other needs that almost certainly have a higher national priority. ... Many of the schedules in the [tri-party agreement] are unworkable, disjunctive, lack scientific and technical merit, undermine any sense of accountability, and most importantly, are having an overall negative effect on worker and public health and safety. (Blush, 1995)

State authorities were particularly critical of DOE's efforts to perform risk-based prioritization on a complex wide scale. In joint comments to DOE on the proposed use of ERPS, members of the State and Tribal Government Working Group (STGWG) and the Attorneys General of fifteen states asserted that DOE's proposed use of the prioritization model would undermine negotiated agreements and other laws that the environmental restoration program, and recommended that DOE abandon its use. Instead, this group advocated prioritizing cleanup activities on a site-by-site within the existing framework.

> Each DOE facility has its own priorities established in accordance with the best judgment of the DOE officials and state and EPA regulators who are most familiar with the site. Instead of unilaterally revising these priorities, DOE

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[13] Among the laws that the two senators said would have to be rewritten are CERCLA and RCRA.

> should simply comply with its legal obligation to request sufficient funds to carry out the activities required in each agreement or permit to which it is subject. (STGWG, 1991)

State authorities demonstrate an apparently inconsistent stance with regard to their own desire to prioritize risk-reducing activities imposed by environmental regulations. In a major policy statement by the National Governors Association on the issue of the proliferation of underfunded and inflexible environmental regulations that often "exceed the financial and technical capabilities of the governing agencies" and "preclude the intelligent application of resources to problems," the NGA urged EPA to "... set risk-based priorities for environmental protection. EPA should target its efforts to reducing the most serious remaining risks to the environment and public health." (NGA, 1993)[14] With regards to risk legislation from a national perspective, states desire a more rational regulatory framework within which to allocate resources for reducing risks, but turn a deaf ear to DOE's desire for the same.

Such an irrational stance can be attributed to the rational pursuit of officially unreasonable objectives (Fischhoff, 1981). Apparently, the states' resolve to hold DOE to negotiated compliance agreements is motivated less by a concern for reducing risks, but rather in safeguarding their share of the limited Federal funds for cleaning up DOE sites. Thus, the question of how to prioritize cleanup activities is concomitant to the problem definition, funding versus efficacy. It is not unlike asking an individual who is opposed to increased energy consumption about which energy source to adopt or where to site proposed facilities. Answers to these narrower questions provide a de facto answer to the broader question of growth (Fischhoff, 1981). It is not surprising that the ERPS model generated as much controversy and opposition as it did.

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[14] As excerpted in (CMA, 1994).

5 Conclusions and Recommendations

The Department of Energy's weapons complex cleanup program has reached an impasse. DOE is in the unfortunate position of having committed to legally enforceable agreements that are driving the program at a pace and cost which Congress is not willing to fund. The agreements have created a dynamic in which an emphasis on meeting milestones has discouraged a strategic focus at many sites; scarce resources are being spent to demonstrate a willingness to meet legal commitments even when those expenditures do not advance the Department's environmental goals (GAO, 1995). Further, the site-specific nature of the agreements have impaired the Department's ability to strategically target its resources across sites. While compliance agreements do not directly dictate levels of remediation to be achieved,[15] they may require DOE to select remedial actions today for problems which presently lack technically or economically feasible solutions.

From an allocation perspective, as illustrated in Figure 5-1, there is little incentive for stakeholders (e.g., state and local regulators, public interest groups) to wear a corporate hat and voluntarily choose levels of remediation at their sites that reflect national priorities and resources. Local representatives will promote parochial interests by pushing for the highest (and most costly) levels of remediation. Of course, we do not know the shape of the remediation cost-benefit curve, and the 'economically feasible' level of remediation is a fuzzy band politically established in the federal budget process. But it is clear that some process is needed to bring local expectations in line with federal resources. Congress and others continue to call for a risk-based approach to shape DOE's cleanup program priorities. The current administration of the Office of Environmental Management is struggling to adopt a risk-based approach to decision making, however it has not articulated a clear strategy for doing so.

Clearly, any endeavor to bring EM program expenditures in line with federal funding levels will depend on successfully renegotiating compliance agreements to be sufficiently flexible and responsive to budget constraints and changes in scope. This is an underlying premise of the conclusions and recommendations that follow.

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[15] Recall that compliance agreements do not specify remedial actions, but establish the schedules for reaching remedial action decisions, among other things.

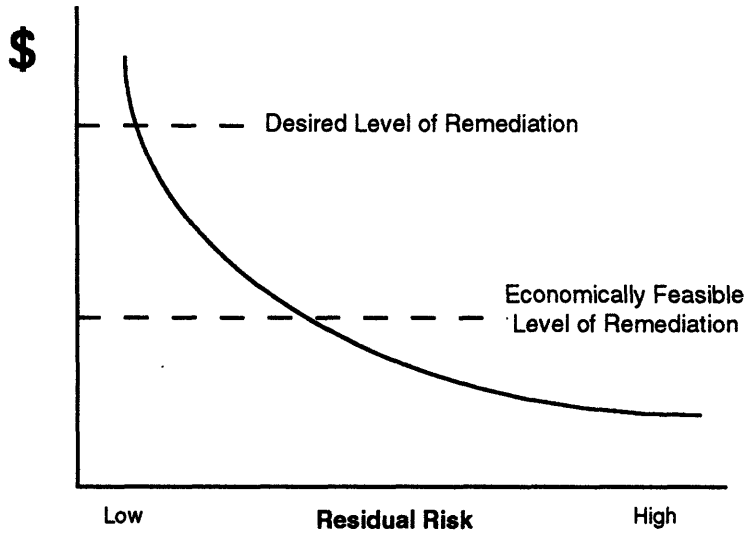

Figure 5-1. Disparity between local levels of desired remediation and a federal willingness to pay.

5.1 A Clear, National Strategy is Needed

The Government Accounting Office (GAO) recently issued a report that evaluates impediments to progress in cleaning up the weapons complex (GAO, 1995). This report identified "unrealistic agreements" signed with regulators as being a major obstacle toward progress, in part because they focus too much of EM's attention into setting priorities for individual sites and not enough on setting priorities for the weapons complex as a whole. Given the increasing pressure on the federal budget, GAO recommends that DOE adopt a national risk-based cleanup strategy, one which would enable DOE and its regulators to set priorities *across* as well as within sites.

In a response to the GAO report, DOE asserted that,

> ... a national risk-based priority setting system was as desirable as it was impractical. Certainly an analytical tool that objectively compared risk among sites could inform the allocation of budgets between sites and would "rationalize" the Environmental Management (EM) program. Unfortunately, limitations on the science of risk assessment, lack of adequate data, and imperatives of binding legal agreements with states reduce the practicality of such a "top down" system. (Grumbly, 1994)

This apparently alludes to EM's prior difficulty in implementing the Environmental Restoration Priority System. There is a reluctance on part of the current administration

to raise again the issue of a national priority setting strategy. However, in the same letter responding to the GAO report, DOE states that, "Our cleanup budget will need to be built with the help of regulators and stakeholders to focus on activities that achieve the greatest risk prevention and risk reduction per dollar spent." This language, if taken as a goal rather than a simple slogan, implies a somewhat rigorous system to impose a cost-benefit basis for managing program decisions. The result of achieving maximum reduction of risk per dollar spent can not come about by accident, nor can the simple ranking of problems at sites result in optimal program expenditures without inter-site comparisons.

In follow-up comments to DOE's remarks, the Government Accounting Office rejected DOE's claim that a national strategy incorporating risk as one of its criteria for decision-making is impractical. "Although we recognize that such a strategy requires difficult choices and introduces controversy into a complicated decision-making process, it is necessary, given expected shortfalls in the federal budget" (GAO, 1995). GAO acknowledged that a national priority-setting strategy can be adopted only if DOE succeeds in renegotiating compliance agreements to achieve sufficient flexibility. However, obstacles to a national strategy extend beyond inflexible agreements; the political opposition to such a strategy would interfere with DOE's commitment to seeking stakeholder input and, when possible, consensus. My view is that if the Department were able to manage the program autonomously, it would still avoid introducing a risk-based prioritization scheme that establishes national priorities out of a reluctance to further damage credibility.

5.1.1 Current Strategies are Insufficient

The Department of Energy claims to be a leader in risk-based priority setting (DOE, 1995c), yet it has not to date formulated a mechanism for integrating risk information into a process for establishing priorities among competing environmental management requirements. DOE is currently undergoing a major effort to characterize the risks at sites in response to the Congressional language (HR, 1993) introduced in Chapter 1 of this thesis. This is essentially a qualitative evaluation of the risks and public concerns arising from conditions covered by compliance agreements. DOE is expected to develop a framework for environmental management decision making that will enable it to balance competing cleanup requirements with limited federal funds, although DOE has not specified how this information will be used to guide cleanup priorities.

Recently proposed plans for establishing program priorities are essentially unchanged from the current budget-based paradigm. Assistant Secretary Grumbly announced, at the National Governor's Association meeting in February of this year, a "bottoms up" prioritization process, by which states would have greater involvement in setting site-specific budget priorities through the existing budget formulation process and would have an opportunity to review the national budget prior to DOE's final decisions (DOE, 1995a). This approach was proposed in response to concerns raised by state officials who fear that emerging fiscal constraints will jeopardize the Department's commitment to compliance agreements. A recent letter signed by the attorneys general for twenty-one states indicated that they are opposed to a headquarters-based "centralized priority system" that determines schedules and priorities (DOE, 1995a; DOE, 1995c).

The strategy of addressing urgent risks first is not adequate for the prioritization environmental restoration projects. In response to Assistant Secretary Grumbly's directive to address urgent risks first, the Office of Environmental Restoration prepared a study based on qualitative and quantitative risk estimates to identify those sites targeted for environmental restoration which are believed to pose the highest risk to the public, workers, and the environment. This study (DOE, 1994e) determined that at 43 of the 45 sites considered, radiological or hazardous material currently pose some risk or are expected to pose risks within five years to the public and/or workers. However, with the exception of the one identified "urgent risk" site and six sites for which exposures are uncertain, public and worker exposures to hazards at those sites continue to be maintained below established regulatory limits. That the one site identified as an urgent risk was the East Fork Poplar Creek site at Oak Ridge Reservation illustrates a shortcoming in using urgent risk as a criterion for prioritizing cleanup efforts.[16] Public desire for remedial action embodies more than merely reducing risk to human health standards; their concerns extend to impacts on the ecology and other environmental values.

While the goal of addressing urgent risks first appears prudent and publicly acceptable, it does little to assist in the problem of formulating a coherent strategy for prioritizing environmental restoration program activities. There are very few "urgent" risks posed

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[16] Recall from Chapter 1 of this thesis, the local community opposed proposed efforts to remediate the creek because they felt that risk estimates were conservative and that the cleanup action would unnecessarily destroy the aesthetic value of the creek and harm wildlife.

by contaminated soil and water that threaten the public and workers.[17] The most pressing problems are those risks posed by deteriorating facilities, degrading waste storage containers, and unstable waste forms, such as plutonium residues and the volatile mixtures of chemicals and high-level wastes stored in million-gallon tanks at Hanford. The levels of risk present at most sites being considered for environmental restoration are significant more in terms of establishing the level of remediation required for regulatory compliance than for describing a level of harm posed to the public. So how should risk inform the prioritization of cleanup activities if not by urgency?

5.1.2 Serious Barriers to a Risk-based Approach

The Department's posturing as a user of risk-based strategies to guide its cleanup program is perhaps in response to the current Congressional attention devoted to risk-benefit analysis as a rational means for allocating resources to environmental problems. While cost effectiveness, getting the most bang for the buck, may be an appropriate goal for managing the EM program, this thesis has demonstrated some of the reasons why risk reduction may be an unworkable metric for measuring program successes and why a risk-based approach to prioritizing program activities is problematic.

Risk is a Divisive Issue

- Lay people and risk practitioners evaluate risks differently.
- DOE lacks the credibility requisite for building stakeholder confidence in risk-based priority setting.
- Intricacies of risk assessment provide fertile ground for those intent on blocking consensus or progress on risk-based issues. Political constituencies may use risk concerns to place other non-risk demands on public authorities to serve a very different agenda (e.g., states intent on maintaining a healthy level of available funds, citizens who are opposed to nuclear weapons program intent on blocking any progress by DOE).

Inadequate Tools for DOE's Needs

- Risks are generally assessed in isolation from one another (e.g., individual facilities, projects, activities) using fundamentally different methods. There are no established methodologies for evaluating the collective risk of a site or to identify significant gaps in risk data.

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[17] Preliminary results from the current effort to characterize risks at the sites indicate that the risks posed by contaminated media are to a large extent either low or contained through institutional controls (Harris, 1995b).

- Comparative risk assessment is useful in broad comparisons of dissimilar hazards with large uncertainties in order to inform environmental policy decisions, and is not appropriate for a detailed ranking of problems suitable for prioritization of EM's activities.

- Multiattribute utility analysis calls for a quantization of values and tradeoffs that invite controversy and would best be defined locally.

5.2 Define a New Measure for Progress

The Department of Energy needs to articulate a clear vision for the Environmental Management program. The current administration identifies the primary mission of the EM program as "protecting human health and the environment" (DOE, 1994a). But the program is, in truth, far more than this. As the weapons complex consolidates its reduced nuclear weapons production operations into fewer facilities, the true challenge will be in remediating surplus facilities, where possible, and putting those lands and resources back into the national inventory for public and private uses. It is this aspect of the program that should define the program, not the esoteric goal of reducing risks.

Risk reduction as a programmatic goal has proven to be a divisive issue, and it is unlikely that programs for public communication and involvement will bring about consensus. John Atcheson, chief of the EPA's Prevention Integration Branch, had this to say about recommendations to educate the public in the complexities of risk assessment:

> This asks the public to respond to a process, not a problem. And it is a process couched in negative exponents and other trappings of science. One that has proven notoriously difficult to communicate. We are, in effect, saying to the public, 'Trust us, we know what's best for you.' (Atcheson, 1991).

The problem posed to the public should be how to *remediate sites to an appropriate endpoint* that is protective of human health and the environment. Remediating sites for future uses that the public has had a role in defining is a goal that can engage stakeholders in a way that reducing risk can not.

DOE needs to resolve land-use determinations at its sites. Land use decisions provide a basis for cleanup standards, which in turn dictate a required level of remediation. As discussed in Chapter 2, the remedial strategy selected has a significant impact on the volume of secondary waste that will be generated from remediation. DOE recently published results of a study to estimate the long-range costs and schedules to complete the Environmental Management program. The results of this study, presented in the Baseline Environmental Management Report (DOE, 1995b) demonstrated that

assumptions for future land use posed the *largest* potential cost impact on overall costs of the cleanup program (see Box 3).

The Office of Environmental Management has only recently undertaken the task of establishing future land use plans at the sites, and to date only the Hanford Reservation has succeeded in making significant progress toward identifying preferred future use options in conjunction with its stakeholders. For the most part, future land use determinations continue to be viewed as one the long-term decisions facing the Department, not as an urgent task to be addressed in the near future (Grumbly, 1995b).

A strategic focus on land use can result in an outcome-oriented approach that the Department needs to demonstrate progress in its cleanup program. A land use-based strategy may include such elements as:

- focusing on completing remedial actions that are tractable today, not necessarily those that pose the greatest risk.
- developing incentives to stakeholders for selecting feasible land use scenarios.

Risk information will certainly play a prominent role in informing cleanup decisions, but the barriers to using a risk-based approach for establishing program priorities are too intractable to be resolved in the near future.

Box 3. Impact of Land Use Assumptions on Total Projected Environmental Costs

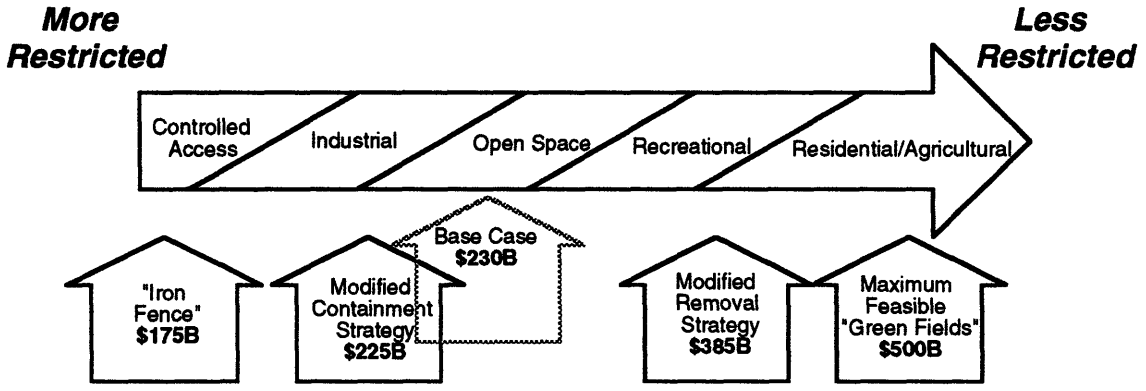
The Office of Environmental Management recently released its first annual Baseline Environmental Management Report, which provides life-cycle cost estimates, tentative schedules, and projected activities necessary to complete the EM program (DOE, 1995b). Among its findings were that land use decisions had the most dramatic impact on projected cost estimates.

Below is a graphical representation of the land use continuum, which ranges from completely restricted or controlled access to completely unrestricted or residential use. The "base case" estimate was built on site-specific assumptions regarding future land uses at each installation, which range from restricted to unrestricted use. Four alternative scenarios were evaluated against the base case, each representing land use mixes that are either more or less restricted than the base case.

"Iron Fence" assumes all contaminated sites will be treated for most restricted uses, by containing rather than treating or removing contamination.

"Green Fields" assumes aggressive removal strategies for unrestricted use for all release sites where technologies are available, including exhumation of contaminated soil and demolition of buildings with all contaminated media removed from the site.

Modified Containment and Modified Removal strategies represent varying degrees of contamination contained versus contamination removed corresponding to different degrees of land use restriction.



Answer: It was Colonel Mustard in the conservatory with the rope.

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