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NATURAL RESOURCE RISK AND COST MANAGEMENT IN ENVIRONMENTAL RESTORATION: DEMONSTRATION PROJECT AT THE SAVANNAH RIVER SITE

INTRODUCTION

The U.S. Department of Energy (DOE) is both a trustee for the natural resources present on its properties and the lead response agency under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). As such, DOE is addressing the destruction or loss of those resources caused by releases of hazardous substances from its facilities (DOE 1991) and collecting data to be used in determining the extent of contamination at its facilities, estimating risks to human health and the environment, and selecting appropriate remedial actions. The remedial investigation/feasibility study (RI/FS) process is used to investigate sites and select remedial actions. A Natural Resource Damage Assessment (NRDA) process may be used to determine whether natural resources have also been injured by the released hazardous substances and to calculate compensatory monetary damages to be used to restore the natural resources.

Because the RI/FS and NRDA processes share some common purposes and procedures, the RCRA/CERCLA Division of the DOE Office of Environmental Policy and Assistance (EH-413) has developed an approach for integrating the NRDA and RI/FS processes to improve environmental remediation decisions, reduce costs, and achieve more rapid restoration of natural resource services using the following rationale. (Note: A complete description of the NRDA process is beyond the scope of this paper. The reader should consult the U. S. Department of the Interior's (DOI's) regulations at 43 CFR 11 and Sharples et al. 1993 for complete details.) An NRDA is usually not conducted until after a Record of Decision (ROD) has been issued in a CERCLA action, i.e., when a remedy has been selected and the degree of residual injury to natural resources can be more precisely determined. But for large, complex sites like the DOE reservations, it is not unlikely that starting the collection of data for NRDA purposes after the issuance of a ROD might require several years of additional effort beyond the RI/FS. Because DOE is both a lead response agency and a natural resource trustee, DOE has the opportunity to integrate the RI/FS and NRDA processes so that data suitable for both can be collected during the RI/FS. Integrating in this way can increase the cost-effectiveness of environmental restoration activities in two ways. First, expanding the RI/FS data collection effort to accommodate NRDA concerns can minimize the need for repeated sampling of the same resources. Second, considering the relationships between remedial action alternatives and natural resource damages provides an opportunity to select remedial actions that minimize or avoid natural resource damages and reduce the total costs of remediation plus restoration.

In FY 1994, the Savannah River Site (SRS) was chosen to serve as a demonstration site for testing the integrated NRDA framework and demonstrating how NRDA concerns might be integrated into the environmental restoration activities of an actual site that is characteristically large and complex. The demonstration project (1) provided a means to illustrate the use of complex analyses using real information on the specific natural resources of the SRS; (2) served as a vehicle for reinforcing and expanding the SRS staff's understanding of the links between the

NRDA and RI/FS processes; (3) provided a forum for the discussion of strategic issues with SRS personnel; and (4) allowed the refining and elaboration of DOE guidance by benchmarking the theoretical process using real information and issues.

A more comprehensive discussion of the project is available in the report "NRDA Guidance Implementation Project: Savannah River Site," which is available from the authors.

INTEGRATING THE ECOLOGICAL RISK ASSESSMENT AND INJURY DETERMINATION STEPS

The integration of the NRDA injury determination with the ecological risk assessment (ERA) required in the RI/FS is made possible by the development of conceptual models, an example of which is illustrated here for selected portions of the SRS. The conceptual model identifies the potential linkages between releases of hazardous substances, pathways of exposure, receptor natural resources, and potential injuries to the natural resources due to these exposures. Development of the SRS example was based on intensive discussions with the SRS staff. These discussions helped identify sources of available data for SRS, as well as areas of data gaps/needs.

Technical Approach - Complex sites, such as DOE facilities, usually contain many different sources and types of contamination. Implementation of CERCLA at such sites usually involves identification of discrete sites or groups of closely-related OUs that (1) contain the same or similar contamination and (2) can be treated using the same technology. Independent RIs, risk assessments, and FSs are performed for each OU. Although convenient from an engineering perspective, independent investigation of individual OUs can be illogical from an ERA perspective because the ecological receptors at risk from contamination are often exposed to contamination from multiple sources.

The first steps in the NRDA process involve identification of "resources of concern" to natural resource trustees. The purpose of this list is to eliminate resources that are not injured and to focus efforts on resources that the trustees think are important, either due to their rarity, economic value, or general value to the public. This list serves as a starting point for the purposes of identifying NRDA concerns at DOE facilities and may be modified as circumstances require. The resources identified are functionally equivalent to the "assessment end points" (Suter 1993; EPA 1992) in CERCLA ERAs. Once resources of concern are identified, the conceptual model that links the resources of concern to the known or suspected sites of contamination needs to be developed. According to EPA's *Framework for Ecological Risk Assessment*, the conceptual model "describes how a given stressor might affect the ecological components in the environment" and "describes the relationships among the assessment and measurement end points, the data required, and the methodologies that will be used to analyze the data." In short, the conceptual model provides the framework for designing an assessment and interpreting the results.

For the integrated approach discussed here, two levels of conceptual models are needed. A site-level model displays the relationships between the various OUs present at the site and the various

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resources potentially affected by contaminants from those OUs. The site-level model identifies the specific resources potentially affected by each OU so that appropriate information can be gathered during OU-specific field studies (e.g., contaminant concentrations in vegetation grazed by deer moving through the site). The site-level model also facilitates identification of all of the OUs potentially affecting each resource, so that studies of resource condition can be focused on the most exposed resources and locations.

OU-level models identify the specific pathways by which resources could be affected by each contaminant source. A generic conceptual model of a lake or stream containing contaminated sediment, for example, would graphically represent the environmental pathways by which fish, birds, and mammals might be exposed to migrating contaminants. The exposure pathways identified in the conceptual model provide a guide to selection of (1) the specific types of field data required for the assessment and (2) the spatial locations from which measurements are needed. The conceptual model can also be used to identify the types of service losses and potential damages that may require investigation. Creation of the conceptual model should also allow trustees to determine what data exist and who on the site created and has access to the data. Typical types of data useful for injury determination include (1) concentrations of contaminants in environmental media, (2) contaminant body burdens in natural resource species or in organisms important as food for those species, (3) other evidence of injury to natural resource species (deformations, biomarker responses, or other data specified in NRDA regulations), and (4) abundance or use of the resources that could be used for determining service losses.

The spatial distributions of natural resources have an important influence on the design of data collection programs needed for injury determination. Resources such as soil and vegetation are permanently fixed in space. Small mammals often occupy home ranges that are small compared to the size of a typical OU. Most of the data required to support injury determination in location-specific resources can be obtained from OU-level studies. Large, mobile animals such as deer, migratory waterfowl, and anadromous fish migrate over long distances and can be exposed to contaminants from multiple OUs. Injury assessments for wide-ranging species require watershed-level or facility-wide studies to determine habitat distribution/use patterns, spatial distributions of contaminant exposure, and the contributions of different OUs to total resource exposure. Much of this information may already exist. Compliance-related environmental monitoring programs and reservation management programs typically collect information on aquatic ecosystems, vegetation, soils, wildlife, and endangered species. Geographic information systems that can summarize these data in resource maps either exist or are being developed at many DOE facilities.

Once a conceptual model is developed, the next step for the technical analyst is to survey all of the existing data for a reservation and determine whether gaps exist. Once the data have been obtained, a variety of techniques are available for quantifying the relationships between contaminant exposures and resource injuries (e.g., Bartell et al. 1992; Suter 1993). For the most part, these are the same methods used to quantify exposures and effects for CERCLA ERAs.

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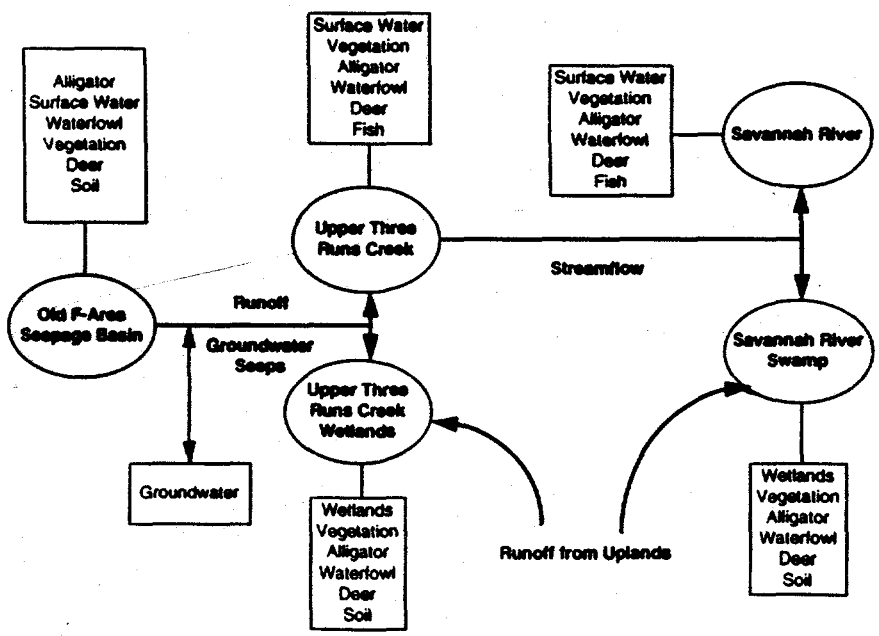
Potential Natural Resource Injuries at SRS - Numerous studies at the SRS have documented releases of radionuclides and hazardous chemicals to groundwater, surface water, and soils and sediments. The most common contaminants include chlorinated volatile organics (e.g., trichloroethylene, tetrachloroethylene), heavy metals (lead, mercury, antimony, chromium, cadmium, aluminum, manganese, and zinc), radionuclides (radium, tritium, ^{137}Cs, ^{238}U, ^{235}U), and other contaminants, such as sulfates and nitrates. In addition, some studies have determined that contaminants such as mercury and various radionulcides are present in or have affected the biota. Evidence for genotoxic effects has been noted in ducks, fish, and turtles.

Development of Conceptual Model and Data Needs - A single watershed and a single contamination source were to chosen to illustrate the approach to model development. The old F-area seepage basin is contaminated with radionuclides, heavy metals, and trichloroethylene. Contamination of groundwater beneath the basin has been confirmed; groundwater seeps and surface runoff may have entered Upper Three Runs Creek. Contaminated water or sediment from the seep could have been transported to the Savannah River Swamp and the Savannah River.

Figure 1 represents the conceptual model of the Upper Three Runs Creek watershed. The eight natural resources listed were selected because they are all present within the watershed potentially affected by the old F-area seepage basin and there are relatively clear links to service losses for each of them. Documented exposure pathways link the basin to groundwater, surface streams, and riparian wetlands within the Upper Three Runs Creek watershed. At the lower end of the creek, the Savannah River Swamp and the Savannah River bordering SRS provide the lower boundary of the study area. OU-level studies at the basin should provide information sufficient to assess injuries to biota present in the basin and to quantify off-basin contaminant movement.

Fig. 1. Conceptual model of Upper Three Runs Creek.



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To apply the integrated approach recommended here, the next step would be to evaluate existing data for gaps and then develop a sampling and analysis plan to collect critical information needed to complete the injury determination. Once alternatives for restoration of the old F-area seepage basin were identified, potential injuries, service losses, and assessable damages could be evaluated against each alternative and included as a consideration in the remedy selection process.

QUANTIFYING NATURAL RESOURCE SERVICES

People place value on natural resources because of the services they provide, such as timber harvesting, irrigation, and outdoor recreation. In general, natural resource services can be grouped into two categories. "Direct-use services" are services provided by resources to humans that involve physical or visual contact with a resource, e.g., fishing. "Passive-use services" are services provided by a resource to humans or to other resources that do not involve physical or visual contact with humans, e.g., providing habitat for fish and wildlife. Table 1 lists services typically provided by natural resources such as the ones found on SRS. When a resource is injured and the services provided by the injured resource are reduced, society suffers an economic loss.

Table 1. Typical natural resource services associated with resources found on the Savannah River Site

	Surface water	Ground water	Wetlands	Terrestrial biota
Use services	Recreation Fishing Drinking water Irrigation Industrial Scientific survey	Drinking water Irrigation Industrial Recreation (caving) Scientific survey	Recreation Fishing Scientific survey	Timber Trapping/hunting Recreational camping, etc. Scientific survey
Nonuse services	Fish and wildlife habitat Groundwater recharge Thermal/pollutant sink	Option/bequest Filtration of water Habitat	Fish and wildlife habitat Groundwater recharge Thermal/pollutant sink Groundwater discharge Flood flow alteration Sediment stabilization Nutrient removal/transformation Production export Wildlife diversity/abundance Aquatic diversity/abundance Uniqueness or aesthetic	Ecosystem balance Genetic CO_2 sink Pollutant filtration/sink Habitat Flood control Existence value

Economists use a variety of data sources to measure losses of natural resource services. Examples of types of data that can be used to measure direct-use services include park visitation or timber harvest rates; creel surveys and license data; and estimates of future conditions by "experts".

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Such data are typically available in public documents or can be readily obtained by conducting surveys or consulting local experts. The measurement of passive-use services usually requires data that characterize the ecological conditions of a resource. Examples of sources for such data are published reports or scientific documentation on the condition of biota or the quality of groundwater, and "expert" estimates of future and past conditions. The baseline service level is the level of natural resource services that would be expected in the absence of the hazardous substance release that caused an injury. Post-release conditions are be compared to baseline levels in order to evaluate service losses. Baseline service levels can be estimated using a control area or a reference area. In either case, ecological differences between the injured and control or reference area are assumed to be attributable to the release.

For the old F-area seepage basin at SRS, four types of services were selected for an exercise to illustrate the handling of the major types of resources of concern: (1) direct-use services provided by trees,(2) direct-use services provided by fish, (3) passive-use services provided by alligators, and passive-use services provided by groundwater. Since trees are harvested for timber at SRS, trees represent resources that provide a commercial service. Fish were selected as a resource that provides direct-use recreational services. Alligators are a threatened species in much of the southeast and were selected to represent threatened and endangered species that provide passive-use services. Lastly, groundwater represents a nonbiological resource that provides passive-use services. For each resource and associated service type, primary data needs and potential data sources were identified.

DAMAGE DETERMINATION

The first step in determining natural resource damages is to estimate the per unit value of resource services. Economists can sometimes use a market approach to estimate the value of resource products, but for most resources, a nonmarket approach, where the value of the resource is determined by unit of use, such as per fishing trip, must be used. Some resources do not provide any direct-use services and, therefore, can only be valued in a hypothetical setting.

Once the resource is valued, the value of the lost services over time can be calculated. Measuring the value of lost services over time presents some difficulty because the service effects of restoration must be considered. All damages must be estimated in their net present value, so the timing of future restoration activities becomes an important determinant of damages. Once the expected restoration action is decided and the timing of future damages is calculated, the present value of all past damages is added to the present value of all future damages to arrive at total damages.

Using the old F-area seepage basin example, the four natural resource services discussed above were used to illustrate the valuing services. Since timber is traded or sold in a market, a market value approach could be used to value the loss of services provided by timber. First, the per unit market value of timber would be determined using timber market data such as sales receipts. Next, the per unit value of timber would be multiplied by the quantity of timber that was lost

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because of injury. This product would equal the value of the lost direct-use services provided by commercially harvested trees near the old F-area seepage basin, which would be the basis for damages to timber. Since fish in the adjacent reach of the Savannah River are not commercially harvested, a market-based approach could not be used to value lost angling services. Instead, a nonmarket approach would be required to estimate the "consumer surplus" associated with fishing. (The difference between what people are willing to pay and what they actually pay for a service or commodity is known as consumer surplus.) First, using a nonmarket valuation method such as a random utility model, the consumer surplus per user day would be calculated. Next the value of a user day would be multiplied by the number of user days that had been lost as a result of releases from the old F-area seepage basin. This product would equal the value of the lost angling days and would serve as the basis for damages to fish and fishing.

For both alligators and groundwater, there are no associated direct-use services at this site; therefore, potential service losses would come from a decline in passive-use services. A nonmarket approach would be required to estimate the reduction in consumer surplus resulting from a decline in passive-use services. The only possible valuation method would be a contingent valuation model (CVM) study. Using a CVM survey, the average consumer surplus per household for the passive use services provided by alligators and groundwater would be estimated. Based on the estimated consumer surplus and the estimated decline in services, the reduction in consumer surplus attributable to the decline in passive-use services would be estimated. The estimated decline in consumer surplus would constitute the natural resource damages associated with the decline in services provided by alligators and groundwater.

Total damages equal the sum of restoration costs, compensable value, and assessment costs. Restoration costs are the engineering, operation and maintenance costs associated with returning natural resource services to baseline levels sooner than natural recovery. Suppose a hazardous substance release kills the fish in a stream. Restoration costs would include the cost of restocking the stream with fish. Compensable value is the value of the lost fishing services prior to the restoration of fishing services to baseline. Assessment costs are the costs associated with determining restoration costs and compensable value.

Estimating Total Damages - To estimate total damages, the future compensable values and restoration costs must be predicted, both of which are a function of the restoration alternative selected. Compensable value and restoration costs are usually inversely related. As restoration alternatives become more intensive the costs increase, yet at the same time services return to baseline more quickly, reducing lost services and reducing compensable value. This trade-off between increased restoration costs (cost) and decreased compensable value (benefit) should be analyzed in order to minimize total damages. Table 2 presents an example of this trade-off. All three restoration alternatives have the same cost in this hypothetical example. However, Alternative A reduces compensable values the most, followed by Alternative C, and then Alternative B. Overall, Alternative A reduces natural resource damages by $10 million. Alternative C has no effect on natural resource damages, because its reduction in compensable values is the same as its cost. Finally, Alternative B actually increases natural resource damages, because its costs are greater than the resulting reduction in compensable values.

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Table 2. Hypothetical example of the effect of various restoration alternatives on natural resource damages

	Restoration alternatives		
	A ($\$10^6$)	B ($\$10^6$)	C ($\$10^6$)
Restoration costs	10	10	10
Change in compensable value	-20	-5	-10
Net effect of restoration on natural resource damages	-10	+5	0

Selecting Restoration Alternatives - DOI lists ten factors that trustees should consider when selecting restoration alternatives: (1) technical feasibility, (2) relationship of expected costs to expected benefits, (3) cost-effectiveness, (4) results of response actions, (5)potential for additional injury resulting from restoration actions, (6) natural recovery period, (7)ability of the resource to recover with or without alternative actions, (8) acquisition of equivalent land when restoration, rehabilitation, or replacement are not possible, (9) potential effects on human health and safety, and (10) consistency with applicable laws and policies. The NRDA regulations do not prioritize these criteria, nor do they require compliance by trustees.

To minimize total natural resource damages, we recommend the following procedure for selecting restoration actions at DOE sites:

1. Identify "relevant" restoration alternatives, which are both technically feasible (DOI Factor 1) and consistent with applicable laws and policies (DOI Factor 10).

2. Of these "relevant" alternatives, select the most cost-effective alternative (DOI Factor 3) or the alternative providing the greatest net benefit (DOI Factor 2), taking into account the remaining six factors.

INTEGRATING THE RI/FS AND NRDA PROCESSES

Goals Of Integration - By integrating the RI/FS and NRDA processes, DOE hopes to achieve three goals, all of which should help reduce overall response and restoration costs. The first goal is to incorporate NRDA data considerations into the RI/FS to make data collection for both processes more efficient. The second is to incorporate natural resource damage considerations into the selection of remedial actions, so that the best remedial action can be selected. The third is for DOE to obtain "irreversible/irretrievable" liability exclusions in instances where the selected remedial actions are expected to increase natural resource damages.

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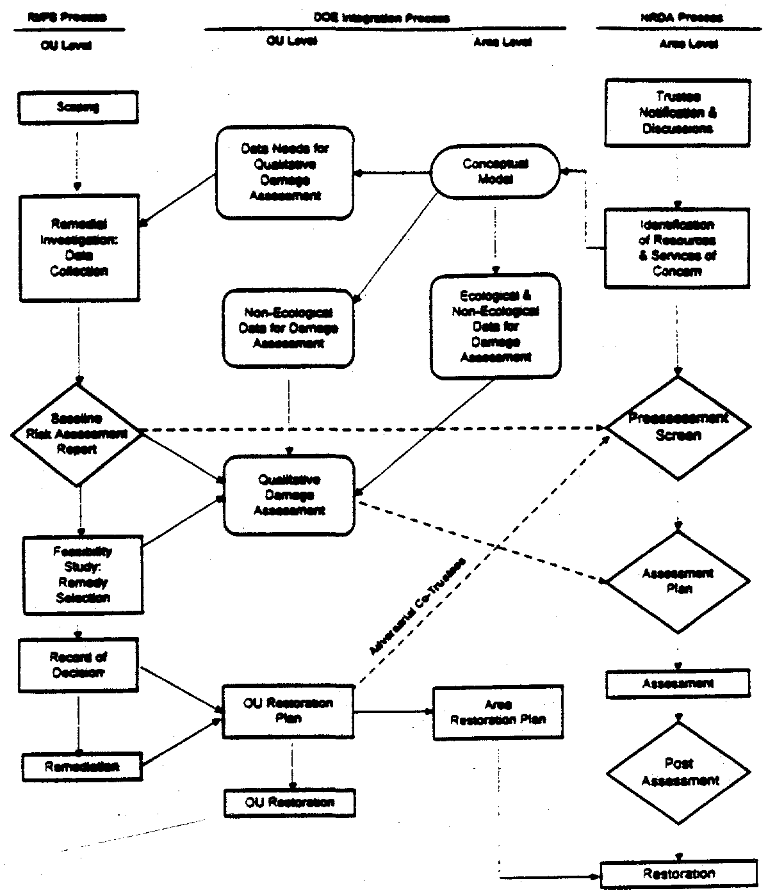
General Model for Process Integration - Both the RI/FS and NRDA processes have well-defined steps. (The requirements and procedures of NRDA have been summarized in DOE, 1993, and Sharples et al. 1993.) Figure 2 is a flowchart illustrating the major steps in the two processes and indicating the linkages between them. RI/FS steps, at the left, are completed at the OU level. The components of a standard NRDA, at the right, are completed at the sitewide, or "area" level. To integrate the two processes, each must be timed appropriately and some intermediate steps taken to coordinate data collection efforts. These intermediate steps are indicated in the middle of the flowchart under the heading DOE Integration Process. Some of these integration steps are completed at the OU level and some are completed at the area level.

Fig. 2. Flowchart for integrating RI/FS and NRDA processes.



It should be emphasized that Fig. 2 contains a great deal of information on the timing of the steps in an integrated process under ideal conditions. For example, early contact with the cotrustees is strongly recommended to afford the opportunity for trustee concerns to influence the design of data collection during the RI. Failure to allow trustee participation in the design of data

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collection may mean that some aspects of the RI will have to be revised by adding new efforts after work is already under way, or, even worse, that some data may have to be collected in a separate effort after the RI is finished. The timing of other steps may, however, have much greater flexibility. Ideally, NRDA data needs should be integrated into the RI data collection effort from the outset. Disconnects in timing, lack of funds, or other reasons may, however, produce difficulties, with the result that some NRDA data may have to be gathered outside of the CERCLA framework in a separate effort. One of the key elements of the proposed approach is the influence of NRDA concerns on the evaluation and selection of remedial alternatives in the FS. Where no attempt is being made to integrate, remedy evaluation and selection are based solely on EPA criteria and do not include any consideration of natural resource damages. When integrating, the cost of each remedial action alternative, which is one of EPA's nine criteria, should be broadened to include an estimate of natural resource damages related to that alternative. We refer to this broader view of remedial action costs as their "life-cycle" cost, because it includes the natural resource damage impacts of the remedial actions in addition to their capital, operating, and maintenance costs. Since natural resource damages are partially determined by the "residual" injuries to natural resources following remediation, life-cycle cost is the appropriate measure of remedial action cost. Other things being equal, the public interest would be best served by selecting the remedial action that results in the lowest life-cycle cost, because this remedial action will minimize the combined cost of the remedial action and the resulting natural resource damages.

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