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Unexploded Ordnance Cleanup Costs

Implications of Alternative Protocols

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RAND CORPORATION

This research in the public interest was supported by RAND, using discretionary funds made possible by the generosity of RAND's donors, the fees earned on client-funded research, and independent research and development (IR&D) funds provided by the Department of Defense.

Library of Congress Cataloging-in-Publication Data

MacDonald, Jacqueline.
Unexploded ordnance cleanup costs : implications of alternative protocols / Jacqueline MacDonald, Carmen Mendez.
p. cm.
"MG-244."
Includes bibliographical references.
ISBN 0-8330-3774-9 (pbk.)
1. Explosive ordnance disposal—United States—Costs. 2. Unexploded ordnance—Environmental aspects—United States. I. Mendez, Carmen, 1977– II. Title.

UF860.M33 2005
355.4—dc22

2005006110

Published 2005 by the RAND Corporation
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201 North Craig Street, Suite 202, Pittsburgh, PA 15213-1516
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Summary

Military downsizing has resulted in the closure of numerous military bases that once hosted military training and weapons testing activities. Ultimate plans call for many of these former range areas to be transferred or sold to civilians—either to other government agencies or to private landowners. The presence of unexploded ordnance (UXO)—bombs, grenades, rockets, and other munitions that have been primed and launched but failed to detonate—has interfered with efforts to transfer and sell this land because of the potential hazards it poses to civilians. All types of ordnance have a failure rate, ranging from a few percent to 30 percent. As a result, unexploded munitions that could still detonate at some future time are inevitably present on any land where the military has trained with or tested weapons.

The research presented in this monograph explores issues related to the cost of cleaning up UXO.[1] The analysis illustrates that the costs to search for and excavate UXO can vary by orders of magnitude depending upon the process used and the clearance requirements. Since final agreements on these processes and requirements have not been reached at many UXO sites, the estimates of total cleanup costs remain speculative.

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[1] Throughout this monograph, we use the terms "UXO cleanup," "UXO clearance," "UXO remediation," and "UXO response" interchangeably. In each case, we mean the set of steps taken to reduce the UXO hazard. We realize that at many sites, even after extensive efforts are made to search for and excavate UXO, complete cleanup may not be achieved, and some UXO may remain.

Previous Estimates of UXO Cleanup Costs

In response to requests from Congress, the Department of Defense (DoD) has generated several estimates of the costs it expects to incur in cleaning up UXO at closed or closing domestic military installations in the coming years. These estimates have produced varying results. Some have predicted that costs will total $8 billion, while others project costs of up to $140 billion. The discrepancies in the estimates are due to a lack of complete data on the locations and characteristics of UXO sites, a lack of standard cost-estimation procedures, and a lack of agreement on what cleanup processes will ultimately be required.

DoD is compiling a comprehensive inventory of UXO sites that will contain information necessary for cost estimation. It has also been working on standardizing the cost-estimation process for planning purposes. But even with complete data and a reliable, standard cost-estimation tool, forecasting the total costs may not be possible without further information about what UXO cleanup protocol is satisfactory to protect the public health for different land uses. Without knowing what steps will be taken during UXO cleanup, and the extent of the search for UXO that will be required, it is impossible to forecast costs accurately.

Controversy over UXO Remediation Standards

Currently, there are no enforceable standards for UXO cleanup. Although the DoD Explosives Safety Board (DDESB) released guidelines tying future land use to recommended clearance depth (see Table S.1), these guidelines are not binding. Rather, DoD's directive for UXO clearance, entitled "DoD Ammunition and Explosives Safety Standards," states that the "preferred method to determine remediation depths is to use site-specific information." Thus at each new site, DoD must negotiate a clearance depth with the environmental regulators, state and local officials, and involved citizens. In the absence of

Table S.1
DoD Explosives Safety Board Guidelines for Clearing UXO Sites

Planned End Use	Default Removal Depth
Unrestricted (commercial, residential, construction, subsurface recreational, utility)	10 feet
Public access (farming, agriculture, surface recreational, vehicle parking, surface supply storage)	4 feet
Limited public access (livestock grazing, wildlife preserve)	1 foot
Not yet determined	Surface
Like use	Not applicable

SOURCE: DoD Explosives Safety Board (1999).

enforceable standards, reaching agreement on clearance requirements at each individual site is a time-consuming process.

In addition to disagreeing on clearance depth requirements, DoD, the Environmental Protection Agency (EPA), and state environmental regulatory agencies have been unable to reach consensus on how the search should be conducted. The only available tools for finding UXO are metal detectors, which signal the location of all buried metal, not just UXO but also harmless shrapnel, rocks containing natural iron, coins, cans, and other metallic items. Usually, contractors conduct an initial survey to map the locations of buried metal on a computer database. They then analyze the data to determine which items are most likely to be UXO and return to the site to resurvey with metal detectors and dig up suspicious items. Once this process is completed, there is still some risk that UXO not found by the metal detectors or not flagged for excavation will remain buried.

As a result of the risk of some UXO remaining, the involved parties cannot agree on what set of steps should be taken to ensure that the land is safe for reuse. Suggested protocols range from clearing only the UXO on the ground surface, to surveying the affected area once using the scan-map-scan-dig approach described above, to conducting multiple surveys over the same area or portions of it, to digging up and sifting all the soil. DoD has contended that the latter approach is too costly, while at some installations environmental regulators have contended that the other approaches may not provide an adequate guarantee of public safety (see Chapter Three). For example, at one installation the lead state environmental regulator told us that the state would like DoD to guarantee that the top several feet of soil in areas slated for residential development are 100 percent free of UXO. To provide this guarantee, the state would like DoD to excavate the entire area one foot at a time, with metal detector searches conducted prior to each new one-foot excavation. DoD has rejected this proposal as too costly.

The RACER Cost-Estimation Tool

For this study, we wanted to explore how changes in UXO cleanup protocols (clearance depth, number of surveys with a metal detector, and amount of excavation) could affect costs. To do so, we needed a cost-estimation tool. We chose the software package "Remedial Action Cost Engineering Requirements" (RACER). This software is widely used by DoD to estimate the costs of a range of environmental remediation activities. It includes a module, developed in conjunction with the U.S. Army Corps of Engineers, for estimating UXO cleanup costs.

To better understand the strengths and limitations of RACER and how it might bias the outcomes of our cost computations, we conducted a sensitivity analysis. Its purpose was to identify which input variables have the greatest impact on UXO cleanup cost, according to RACER. As well, we wanted to assess whether RACER included all the potential cost factors we thought were important.

The sensitivity analysis revealed that the input variables that have the most significant influence on cost are total acreage, number of UXO and other metal items per acre, and amount of vegetation that must be cleared before UXO surveys can begin. This was as we expected. However, we also identified some limitations:

- **The extra costs of increasing clearance depth are not well represented.** Most important, RACER does not fully account for the increased costs that may be incurred when greater clearance depths are required. RACER's cost estimates are nearly constant with changes in depth. We were able to devise a RACER implementation strategy (described below) that could partly overcome this deficiency.

- **Soil effects are not considered.** RACER does not account for the effects of soil type on costs. The effort involved in searching for and excavating UXO may vary depending on whether the soil is loose sand or hard-packed clay, and on whether or not it contains a high level of natural iron (which can interfere with the performance of the detection equipment). RACER does not provide a means for estimating the effects of soil type on cost.
- **No option is provided to modify the vegetation removal process.** RACER assumes that the effort required for vegetation removal is the same regardless of the terrain. It offers no capability to specify if the vegetation will be removed by controlled burning, with machinery, or manually.
- **Performance rates are not adjusted to reflect changes in excavation equipment.** RACER assumes that backhoes will be used for all excavation. But personnel at installations with UXO told us that much excavation is done manually, with shovels. RACER allows users to remove the cost of renting backhoes, but it does not accordingly adjust the time or number of personnel required for excavation.
- **Default density values are questionable.** RACER uses default values to estimate UXO density (number of UXOs per unit of land area) based on range type. When site-specific data are available, the user can override the default density values. In the absence of site-specific data, however, RACER's default density estimates are unlikely to be accurate because they do not account for the length of time the range was in use, the amount of ordnance fired, or whether there were changes in the range's use over time.

Despite these limitations, we were able to adapt RACER for our cost analysis, as described below.

Case Study: How UXO Clearance Requirements Affect Costs

Our primary purpose in conducting this study was to consider how changing the processes required for UXO cleanup might affect costs. To explore this question, we analyzed the costs of three different potential UXO cleanup strategies using data from an actual military installation. The installation asked that we keep the name of the site confidential, so we refer to it as Site A. Site A is a former multipurpose military training range that contains about 7,000 acres of rolling, wooded terrain. We chose Site A because a large amount of data on UXO density, topographic characteristics, and vegetation density is available for it.

At Site A, as at many UXO sites, the military and the state cannot agree on what UXO cleanup processes should be used. We analyzed the costs of two of the proposals put forward—one by the military and one by the state—and of a third alternative that represents a compromise.

- Protocol 1, preferred by the military, involves surveying the entire area with metal detectors and then digging up every metal anomaly to a depth of one, two, or four feet. The state objects to this protocol, contending that metal detectors might miss some UXO.
- Protocol 2, suggested by the state for areas that will be developed for residential uses, would involve excavating all the soil in affected areas and sifting it to remove any UXO. Under this proposal, the excavation would proceed in one-foot depth increments, and the ground would be surveyed with a metal detector before each excavation to reduce risks to workers. The military has contended that this approach would be too costly.
- Protocol 3, the possible compromise, would involve carrying out protocol 1 and then surveying the entire area again with a metal detector to locate UXO missed on the first search. More than two surveys might be needed to ensure that as much UXO as possible is located. This protocol would not guarantee that all

UXO has been found, because some items might not be detected at all due to their size, depth, and orientation, but it still could increase the probability of detection.

Our cost analysis probed the financial implications of choosing one or the other of these strategies. Table S.2 summarizes the results for the first two protocols. Table S.3 shows the results for the third protocol. For the third protocol, we assumed a four-foot clearance depth, meaning that search crews would dig up to four feet deep wherever their equipment indicated that UXO might be present. For the others, we calculated costs for four different clearance depths. Figure S.1 summarizes the costs for all the protocols and all the variations within each protocol.

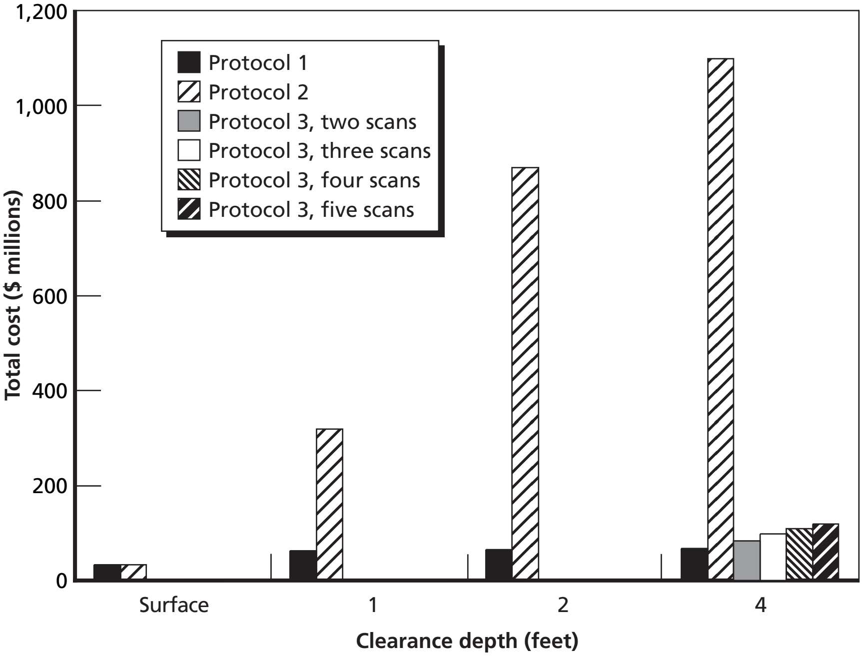
Table S.2
Summary of Costs of Protocols 1 and 2

Depth	Protocol 1 Total Cost ($ Millions)	Protocol 2 Total Cost ($ Millions)
Surface	35	35
1 foot	63	320
2 feet	64	590
4 feet	67	1,100

Table S.3
Summary of Costs of Protocol 3

Number of Full-Site Surveys with Metal Detector (Four-Foot Search Depth)	Total Cost ($ Millions)
1	67
2	84
3	98
4	110
5	120

Figure S.1
Cost Differences Among Alternative UXO Cleanup Protocols at Case Study Site



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As Figure S.1 illustrates, the cost differences among the alternatives are very large. The most expensive alternative (protocol 2, with excavation to four feet) would cost DoD $1.1 billion if implemented across all of Site A. This option is more than 30 times as expensive as the least costly alternative (protocol 1 with surface clearance only), which would cost $35 million. The compromise approach of conducting multiple searches with metal detectors without completely excavating the soil would cost $84 million if the entire site were scanned twice and $120 million if it were scanned five times. The total cost of surveying the entire site five times is about one-tenth that required for the excavation and sifting approach.

The budgetary implications of these findings are significant. For example, the entire budget available in fiscal year 2004 for cleaning up all types of environmental contamination at all Army installations closed since the end of the Cold War was $57 million. The cost of cleaning up Site A to any depth below the surface—even using the least costly protocol—exceeds this entire annual budget, which is intended to cover many other installations and kinds of environmental contaminants.

Recommendations for Improving Cost Estimation

Changes in cost estimation and budgeting are needed to allow DoD to effectively plan how it will resolve the UXO problem. In particular, we recommend the following steps.

1. DoD should continue its efforts to develop a uniform strategy for UXO cleanup cost estimation. A feasible way to reach this goal is to modify RACER's OE [ordnance and explosives] Removal Action Module and to establish a standardized RACER implementation method.
2. DoD should work with its contractors to improve RACER's ability to estimate UXO cleanup costs. In particular, RACER needs the following additional capabilities:
   - accurate calculation of cost estimates for different search depth requirements, considering the vertical distribution of UXO;
   - consideration of how soil type affects costs;
   - inclusion of the length of time a range was used for different weapons activities in the calculation of default values for anomaly density;
   - an option to select the method for vegetation clearance (manual, mechanical, or controlled burn) and to choose the method for ordnance excavation (backhoes or shovels); and
   - an option to disable the automatic return to default settings when changes are made to the "Removal Area" tab.

3. DoD and its contractors should conduct an exercise to calibrate and validate the modified RACER OE Removal Module. Once initial modifications are completed, the OE Removal Module should be validated by checking it against actual cost data for a variety of different types of UXO sites. Then it should be modified again as necessary to correct additional limitations identified in the validation process.

Recommendations for Improving Government Management of UXO Sites

Due to the multiple limitations and challenges associated with UXO remediation efforts, solving the UXO problem involves more than a simple decision to clean up the land. No existing technology can guarantee that all UXO has been located, and as a result, regulators and the military have had difficulty agreeing on what UXO clearance process is sufficient to protect the public. The federal government should prepare a plan for developing baseline UXO clearance standards to end the stalemates that have arisen at many installations among regulators, community members, and the military. In particular, we recommend the following actions.

1. The federal government should designate an executive agency (the Army Corps of Engineers, EPA, or both) to develop baseline standards for UXO clearance. The standards should be tied to future land use and should be flexible enough to account for unique situations but broad enough to recognize the many similarities across sites. A risk assessment algorithm that considers site characteristics (UXO density, depth, and others) and future land uses could be created to guide the decisionmaking process. Sites that deviate significantly from any such classification of site characteristics could be addressed on a case-by-case basis. At a minimum, the standards should specify the search depth required for different land uses. The standards should also

include provisions for periodic reinspection of any sites where some UXO items may have been left behind.

2. The federal government should establish a publicly accessible database of UXO accidents in the United States. As the database matures, the information it contains could be used to update UXO clearance standards. The database should include all domestic UXO incidents, both those that involve explosive ordnance disposal contractors and military personnel and those that involve civilians. It should also include incidents that occur off of military property, such as when UXO is transported from a military installation and causes harm elsewhere. Such a database would provide valuable new information to support estimates of the costs and risks of domestic UXO. The Army Corps of Engineers recently compiled data on UXO incidents involving civilians. However, the data are incomplete because only about half of the known UXO sites were included, and incidents involving military personnel were excluded.
3. The federal government should consider the funding implications of different choices about "how clean is clean enough" for UXO remediation. As shown in this document, UXO clearance can be very costly, and variations in the cleanup protocol can significantly affect the expense of the operation. Given the many uncertainties in calculating UXO cleanup costs, as described in this monograph, new studies would be required to assess how different UXO clearance standards affect costs.