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LANL Environmental Restoration Site Ranking System

System Description

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The basic structure of the LANL Environmental Restoration (ER) Site Ranking System and its use are described in this document. A related document, Instructions for Generating Inputs for the LANL ER Site Ranking System, contains detailed descriptions of the methods by which necessary inputs for the system will be generated.

INTRODUCTION

LANL has long recognized the need to provide a consistent basis for comparing the risks and other adverse consequences associated with the various waste problems at the Lab. The LANL ER Site Ranking System is being developed to help address this need. The specific purpose of the system is to help improve, defend, and explain prioritization decisions at the Potential Release Site (PRS) and Operable Unit (OU) level.

The precise relationship of the Site Ranking System to the planning and overall budget processes is yet to be determined, as the system is still evolving. Generally speaking, the Site Ranking System will be used as a decision aid. That is, the system will be used to aid in the planning and budgetary decision-making process. It will never be used alone to make decisions. Like all models, the system can provide only a partial and approximate accounting of the factors important to budget and planning decisions. Decision makers at LANL will have to consider factors outside of the formal system when making final choices. Some of these other factors are regulatory requirements, DOE policy, and public concern. The main value of the site ranking system, therefore, is not the precise numbers it generates, but rather the general insights it provides.

A schematic of the role envisioned for the system is provided in Figure 1 below.

Figure 1. Role of the LANL ER Site Ranking System

As illustrated, the system is designed to evaluate selected attributes of various waste problems at the Laboratory in terms of cleanup objectives specified by LANL decision makers. The output of the system is a ranked list of problems which can then be used as one input to the decision making process.

DESIGN CHOICES

Three primary types of system were considered: a site or problem ranking system, a project prioritization system, and a funding allocation system. Table 1 illustrates the system types considered and their respective strengths and weaknesses.

	Site Ranking System	Project Prioritization System	Funding Allocation System
Key Outputs	"Worst first" Site ranking	Prioritized list of projects	Recommended funding allocations
Distinguishing characteristics	Scores and ranks sites according to the importance of solving the site's problems	Provides "yes/no" project approval based on B/C ratios	Identifies funding allocations that produce most benefit for least cost
Relative strength	Least constraining, simplest to implement, simplest to collect inputs	Intuitive decision unit (projects)	Most logically complete and responsive to decision making needs
Relative Weakness	Ignores effectiveness, feasibility of technologies for addressing the site; provides no basis for funding decisions	Ignores project interdependencies; potentially constraining	Less intuitive; potentially constraining

Table 1. System types considered

A site ranking system was chosen for two reasons. First, it was decided that there is much less information available on potential project cost and effectiveness than there is on the extent of waste problems. This makes the additional data collected by project-based systems (project prioritization and funding allocation systems) on project cost and effectiveness less useful. Second, there are approximately 2000 SWMUs, and having to design and score potential work for even a significant proportion of these would be a huge task.

The "waste unit," typically a potential release site (PRS), was chosen as the ranking unit for the system, and the scope of the system was chosen to include all

PRs at the lab. It was decided that the ranking needed to make differentiations at the level of individual PRs in order to support detailed decisions on the phasing of characterization and remediation work. However, it was decided that the data should be collected in such a way that it can be aggregated both to the OU level to support ranking of OUs and to the facility level in order to provide inputs to the Headquarters level DOE Priority System.

The methodology chosen for evaluating waste units in the Ranking System is known as Multiattribute Utility Analysis (MUA). MUA is a systematic set of procedures that seeks to model decision-maker preferences rigorously. MUA is especially designed for evaluating and comparing alternatives according to multiple criteria (thus the term "multiattribute"). The major advantage of the MUA method is that it provides a means for evaluating the various waste units in a way that is theoretically sound and consistent with decision maker values. The major disadvantage is that the method is more complex than less formal methods. Figure 2 illustrates the key steps of the MUA process.

Figure 2. The MUA process

SYSTEM USE

The Site Ranking System is intended to be applied in a three-step process:

1. Identifying, grouping, and scoring waste units
2. Quality assurance
3. Analysis of results

The first step is described in detail in the Scoring Instructions document. First, Operable Unit Project Leaders (OUPLs) identify all waste concerns under their jurisdiction. Next, OUPLs group waste concerns into waste units. Finally, OUPLs score each of the waste units according to a set of pre-specified criteria. In the quality assurance step, the scores assigned by OUPLs are reviewed by a panel of experts to assure quality and consistency. In the analysis step, the scores assigned for each waste unit are combined to obtain an overall evaluation of the waste unit. Then the overall evaluations for each waste unit are assembled to produce a ranked list. At the same time, waste unit scores are aggregated to the OU level and a list ranking OUs is developed. The rankings can then be used by LANL, DOE, and regulatory managers and the public to aid in decision-making.

SYSTEM DESCRIPTION

In order to rank waste units consistently and equitably, LANL developed a formal set of criteria and a process for measuring performance against each criterion. The Scoring Instructions document provides details on how performance is measured. This document provides only an overview. The criteria identified by LANL and included in the System are illustrated in Figure 3 below.

Figure 3. Criteria considered by the Ranking System

Figure 3 illustrates the six criteria assumed to contribute to the importance of addressing a waste unit in a timely manner. It is important that the waste unit be addressed in a timely manner if it poses a health risk to either workers or the public, if it poses a risk to the environment, or if it causes some adverse socioeconomic impact on surrounding communities. Similarly, if the cost of addressing the waste unit is escalating over time, then it should be addressed sooner rather than later. Finally, if the characteristics of a waste unit are highly uncertain, such that there is a chance that it poses significant risk, then there is significant value to resolving the uncertainties about the waste unit, and this increases the importance of addressing the waste unit soon.

In order to provide a consistent basis for ranking, the Scoring Instructions document provides one or more quantitative performance scales for applying the criteria. Each performance scale is defined so that OUPs can score a waste unit by assigning a number. The scales go from one (best) to three (worst). The meaning of each number on each scale is carefully defined, with examples, to help keep the scoring consistent. The scales used to apply each criterion are explained below. Details on each scale can be found in the Scoring Instructions document.

Health Risk Scales

The risks to public and worker health posed by a waste unit are each quantified in terms of four measures (four scales in the Scoring Instructions document), as illustrated in Figure 4. The measures are Risk Source Hazard, Exposure Timing, Exposure Efficiency, and Population at Risk. Risk Source Hazard is a measure of the hazard posed by the risk source at a waste unit based solely on the type and quantity of the substances present. It thus does not depend on the likelihood of exposures or size of nearby populations. Exposure Efficiency measures the efficiency with people may be exposed to the hazard, taking into account potential for transport and likely exposure pathways. Population at Risk measures the size of the population that is likely to be exposed to the risk source. Finally, Exposure Timing measures when exposures are likely to occur.

Figure 4. Scales for measuring health risk

The Ranking System assumes that Risk Source Hazard, Exposure Efficiency, and Population at Risk are multiplicative in health risks. That is, if the quantity or toxicity of the risk source is doubled (i.e., the Risk Source Hazard measure is doubled), then the health risk is doubled. Likewise, if the level of exposure to exposed populations is doubled (i.e., the Exposure Efficiency measure is doubled), then the

health risk is doubled. Finally, if the size of the population potentially exposed at a particular level is doubled, then the health risk is doubled. The product of Risk Source Hazard, Exposure Efficiency, and Population at Risk is proportional to the expected number of health effects at the time when exposures occur.

The Ranking System also includes an Exposure Timing measure so that current health effects can be valued differently from health effects in the distant future. This allows the system to measure the importance of addressing waste units with current or near-term exposures promptly. The model applies a 5% discount rate to health effects in the future, using the Exposure Timing measure to determine the time at which health effects begin occurring.

Environmental Risk Scales

The risk to the environment posed by a waste unit is quantified in terms of two measures, as illustrated in Figure 5. The measures are Environmental Resources at Risk and Impact on Resources. Environmental Resources at Risk is a measure of the sensitivity and value of the environmental resources that could potentially be impacted by the waste unit. Impact on Resources is a measure of the seriousness of the impact on the resources identified as being at risk.

Figure 5. Scales for measuring environmental risk

The Ranking System uses the product of Environmental Resources at Risk and Impact on Resources as a measure of the degree of impact that the waste unit has on the environment.

Socioeconomic Impact Scales

The socioeconomic impact that a waste unit has on surrounding communities is quantified in terms of two measures, as illustrated in Figure 6. The measures are Public Concern and Fraction of Problem. Public Concern measures the degree of public concern about and/or the dollar amount of economic losses attributed to some problem of which the waste unit is a part. Fraction of Problem measures what fraction of the entire problem is attributable to the specific waste unit.

Figure 6. Scales for measuring socioeconomic impact

The Ranking System uses the product of Public Concern and Fraction of Problem as a measure of the degree of socioeconomic impact that the waste unit has on surrounding communities.

Cost Escalation Scales

The degree of cost escalation at a waste unit is quantified in terms of two measures, as illustrated in Figure 7. The measures are Remediation Cost and Degradation Rate. Remediation Cost is a rough estimate of the cost to completely remediate the problem at the waste unit. Degradation Rate is an estimate of the percent increase in cost if work on the waste unit is delayed.

Figure 7. Scales for measuring cost escalation

The Ranking System uses the product of Remediation Cost and Degradation Rate as a measure of the importance of addressing the waste unit quickly due to cost escalation. Specifically, it measures the cost of a delay in remediation.

Value of Resolving Uncertainty

For most waste units, there is some degree of uncertainty about the risks posed by the waste unit and the potential cost to remediate the waste unit. If the risks are virtually certain to be very small and the costs are virtually certain to be very large, then there it is virtually certain that the waste unit should not be remediated on the basis of risk alone. In such a case, there is little to be gained from resolving the minor uncertainties

about cost and risk. However, if both cost and risk are highly uncertain, such that it is possible that costs are high while risks are low, but it is also possible that costs are low while risks are high, then it is unclear whether the waste unit should be remediated or not. There is then some value to resolving the uncertainties about risk and cost, so that the proper decision can be made with regard to remediation. Figure 8 illustrates this situation by showing probability distributions on risk and cost in which for which it is likely that remediation cost will exceed the expected value to be gained by removing the risk (represented by the non-shaded regions under the distributions). However, since the distributions overlap, there is some likelihood that risk will be high enough to justify the cost of remediation (the shaded area of overlap between the distributions).

Figure 8. Logic underlying value of resolving uncertainty

The Ranking System employs Value of Information Theory to provide a formal mechanism for measuring the importance of resolving uncertainties regarding a waste unit prior to making a decision of whether or not to remediate.

Calculation of Importance of Addressing a Waste Unit

The above sections explain how the Ranking System calculates measures of the importance of addressing a waste unit based on the six criteria. To calculate the total importance of addressing a waste unit, the six criteria measures are combined as illustrated in Figure 9.

Figure 9. Calculating a measure of importance for a waste unit

Figure 9 represents what is formally known as a “multiattribute utility function.” This is a mathematical formula that aggregates scores to obtain an overall measure of the importance of addressing a waste unit. The formula reflects value judgements about both the relative desirability of different scores on each scale and the relative importance of the different criteria. Provided that the criteria (e.g., Public Health Risk) can be shown to meet certain independence conditions (related to the way a person values the interactions between different criteria), the multiattribute utility function for quantifying benefits may be expressed as a weighted sum of the measures of importance for each criterion.

The weighting factors employed in the Ranking System essentially account for the relative significance of worst-case scores on one criterion versus worst-case scores on another. Weighting factors are necessarily value judgements, and are typically a source of controversy in systems such as this one. However, these value judgements must be made, either explicitly or implicitly, in any decision-making process that involves multiple objectives. The explicitness of weighting factors in this system helps assure consistency in the evaluation of numerous waste units.

The weighting factors used in this system were chosen by LANL management through a formal elicitation process and their basis is illustrated in Table 2 below. The weighting factors are consistent with those used in the system LANL has developed to prioritize Tiger Team action plans. They are also largely consistent with the Priority System employed by DOE HQ to help allocate funding across DOE installations, the

only significant difference being that the LANL system places greater value on environmental impacts.

Worker Health Risk	\$2.5M / statistical fatality averted, 5% discount rate
Public Health Risk	\$5M / statistical fatality averted, 5% discount rate
Environmental Risk	\$25M/averted destruction of resource equivalent to a wetland
Socioeconomic Impacts	Worst case public concern equivalent to \$10M economic impact
Cost Escalation	Five year delay, 10% discount rate

Table 2. Basis for weighting the criteria

PLAN FOR DEVELOPMENT AND USE OF SYSTEM

The development of the system is proceeding in several phases. First, the system was pilot tested with a number of Operable Unit Project Leaders providing inputs for only a few PRSs each. The system has been revised as a result of this experience and is scheduled for an initial full-scale application at the end of this year. It is envisioned that the system will possibly be revised further as a result of this application and will continue to be applied in future years to evaluate newly identified PRSs and to reevaluate PRSs based on new information.

Pilot Test

The system was pilot tested in April and was deemed by participants to accurately summarize the relevant characteristics of the problems that they scored and to produce an intuitive ranking of waste units. The ranking produced as a result of the

pilot test is illustrated in Figure 10 below. Waste units were grouped into four classes according to importance as designated by the lines above the bars.

Figure 10. Ranking of waste units from pilot test application

Pilot-test participants were able to provide system inputs, but were concerned about the time required to do so. In response to their concern, the current system described herein is a simplification of that used for the pilot test. Participants were also concerned about the consistency of scores assigned across scorers. In response to this concern, a Quality Assurance program is being devised which will mandate that scores be reviewed by experts at the Lab before being considered final.

Initial Full-Scale Application

It is intended that scores be collected as input to the system for all of LANL's PRSs by the beginning of 1993. The system will then produce a ranking of waste units according to importance analogous to that illustrated in Figure 10 above. The ranking would then be reviewed and the Ranking System possibly adjusted to address any problems identified in the first full-scale application. A tentative schedule for the application is as follows:

<u>Date</u>	<u>Event/Task</u>
November 27	Distribute scoring instructions
December 1	Conduct training
December 2 - 15	Preliminary scoring
December 16	Preliminary scores due
December 16 - 18	QA sessions
December 21 - January 8	Final scoring
January 8	Final scores due
January 11 - 29	Analyze results/possible score revisions
January 29	Present initial results
Month of February	LANL review of initial results/possible revisions
February 26	Present preliminary results/preliminary report
Month of March	Outside review of results/final report
April and beyond	Possible extensions to ranking system; future applications

Future Applications

It is expected that the first application of the system will be useful in providing information to LANL decision-makers about the problems across the Lab. However, it is also expected that this application will help us identify aspects of the system that can be improved to enhance the quality and applicability of system outputs. In addition, the state of information about problems at the Lab is not static. Thus, the system may continue to be applied in future years to evaluate newly identified PRSs and to reevaluate PRSs for which additional information has been found, with the system being revised as necessary to provide the highest quality information possible to the decision-making process.

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LANL ER SITE RANKING SYSTEM

SCORING INSTRUCTIONS

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INTRODUCTION

This document provides instructions and examples for generating inputs (scores and supporting information) for the LANL ER Site Ranking System. Bring any problems or confusion that arise as you attempt to use this document to the attention of the team responsible for developing the ranking system. The team will provide additional guidance, as necessary, to augment these instructions.

Who Should Generate Scores?

Scores should be generated by a team of individuals established for the purpose and including appropriate OUPs. Although this document refers to a "scorer" as the source of scores, scores should be generated by team members according to their areas of expertise and under the final approval of the OUP.

Scales and Tables

The appendices contain the scales and tables to be used in the scoring process and the two forms to be used to document and submit scores and related information. These forms are the Waste Unit Information Form (WUI Form) and the Scoring Form, illustrated in Figure 1.

The WUI Form is a complex document with multiple sections. It includes a header section, a table with several columns and rows, and a large section with multiple sub-sections and tables. The form is designed to capture detailed information about waste units.

(a) WUI Form

The Scoring Form is a table with a large number of rows and columns. It is designed for recording scores for various waste units. The table has a header section and a main body with many rows for data entry.

(b) Scoring Form

Figure 1. Forms (Provided in Appendix A) for Documenting and Submitting Scores

OVERVIEW OF THE SCORING PROCESS

There are five steps:

1. Identify waste units to be scored.

Waste units are the basic ranking units for the system. Waste units are typically potential release sites (PRSs) but may be aggregates or subunits of PRSs.

2. Group waste units of similar types.

If the OU contains multiple waste units of a similar type (e.g., several outfalls), group waste units by type.

3. Select one waste unit from each group for scoring.

To reduce the scoring effort, only a single waste unit from each group typically needs to be scored in detail.

4. Score each selected waste unit.

Scoring a waste unit requires (1) specifying a risk concern (conceptual risk model) for the waste unit, (2) assigning risk scores based on the risk concern, and (3) assigning non-risk scores.

5. Assign scores to the remaining waste units in each group.

Assigning scores to the other waste units in a group requires making scoring adjustments to account for differences among the waste units in the group.

STEP 1: IDENTIFY WASTE UNITS TO BE SCORED

Define waste units as the smallest (most disaggregated) waste problems that can be independently identified, scored, and ranked. The waste unit will typically be a Potential Release Site (PRS). However, in some cases it may be necessary for the scorer to define a waste unit for scoring that is larger or smaller than a PRS.

Combine PRSs into a larger waste unit for scoring if:

- Contaminants from PRSs are intermingled so that the PRSs cannot be physically distinguished; OR,
- It is physically impossible (not merely inefficient) to remediate one PRS without disturbing the others to the extent that they must also be remediated. Similarly, PRSs should be combined if it is physically impossible to characterize one PRS without fully characterizing the others.

Break a PRS into smaller waste units for scoring if:

- The PRS contains distinct waste problems that could be characterized and remediated individually; AND,
- The problems can be distinguished in terms of the risks that they pose.

Physically separate areas of contamination should normally be considered separate waste units.

Make as many copies of the WUI Form as there are waste units. Define each waste unit for scoring by completing Part A on a copy of the form.

Example

OU 2222 contains 15 PRSs in two Technical Areas (TA 77 and 78). The PRSs are SWMUs and subSWMUs of three types:

<u>SWMU or SubSWMU #</u>	<u>Type</u>
77-001	Outfall
77-002	Outfall
77-003	Material disposal area
77-004	Material disposal area
77-005a	Sump
77-005b	Sump
77-005c	Sump
77-005d	Sump
78-001	Sump
78-002	Sump
78-003	Sump

(continued on next page)

78-004	Sump
78-005	Sump
78-006	Sump
78-007	Sump

The two outfalls enter a ditch in close proximity and the wastes have become intermingled. Therefore, the outfalls are combined into a single waste unit. The other SWMUs and subSWMUs are physically distinguishable and are treated as separate waste units. A WUI Form is prepared as follows for each of the resulting 14 waste units (one combined outfall, two material disposal areas, and eleven sumps).

Outfalls (Combined Into Single Waste Unit)

Name(s) of Scorer(s):		JOHN DOE		OU#:	2222	TA#:	77
A Describe the Waste Unit:		OUTFALLS					
Check appropriate box for the Waste Unit type:		Storage:	MDA:	Filling Site:	Sep. Tank:	Waste Line:	Sump:
							Outfall: X
List the PRS number(s) that constitute(s) this Waste Unit:		77-001		77-002			
If you are grouping PRSs, state your reasoning:		WASTES INTERMINGLED					
Check the PRS type:		HSWA-SWMU:	X	RCRA-SWMU:	Area of Concern:	Check the waste type:	
						Non-rad. waste:	Rad. waste:
						Mixed waste:	X

Material Disposal Areas (2 Waste Units)

Name(s) of Scorer(s):		JOHN DOE		OU#:	2222	TA#:	77
A Describe the Waste Unit:		MATERIAL DISPOSAL AREA					
Check appropriate box for the Waste Unit type:		Storage:	MDA:	Filling Site:	Sep. Tank:	Waste Line:	Sump:
			X				Outfall:
List the PRS number(s) that constitute(s) this Waste Unit:		77-003					
If you are grouping PRSs, state your reasoning:							
Check the PRS type:		HSWA-SWMU:	X	RCRA-SWMU:	Area of Concern:	Check the waste type:	
						Non-rad. waste:	Rad. waste:
						Mixed waste:	X

Sumps (11 Waste Units)

Name(s) of Scorer(s):		JOHN DOE		OU#:	2222	TA#:	77
A Describe the Waste Unit:		SUMP					
Check appropriate box for the Waste Unit type:		Storage:	MDA:	Filling Site:	Sep. Tank:	Waste Line:	Sump:
							X
List the PRS number(s) that constitute(s) this Waste Unit:		77-005a					
If you are grouping PRSs, state your reasoning:							
Check the PRS type:		HSWA-SWMU:	RCRA-SWMU:	X	Area of Concern:	Check the waste type:	
						Non-rad. waste:	Rad. waste:
						Mixed waste:	X

STEP 2: GROUP WASTE UNITS OF SIMILAR TYPES

If the OU contains multiple waste units of a similar type, effort may be reduced if waste units are grouped and only a single unit from each group is selected for detailed scoring. Scores for other waste units in the group may be obtained by making adjustments in scores to account for any differences among units within the group.

To qualify for grouping, waste units should be of the same type (e.g., all outfalls, all pipes and septic tanks, all surface deposition areas, etc.) and their risk concerns should be identical or nearly so. Having the same risk concern means that the same type of risk agents are present (e.g., all waste units in the group contain mostly plutonium contaminated soil), the mechanisms by which people might be exposed are the same (e.g., transport through storm runoff is the mechanism of concern for all of the waste units), and the populations potentially at risk are the same or similar (e.g., all waste units in the group pose a potential risk to people living or working in the same local area). Do not group waste units for scoring if they differ so significantly that it is easier to score the units separately than to make the adjustments in scores necessary to account for the differences.

Example

The sumps in OU 2222 are all physically similar and the scorer observes that the risk concerns associated with each are identical--release of residual toxic chemicals (HEs) under heavy precipitation or flood conditions. Based on this similarity, the scorer groups the sumps for scoring.

The material disposal areas are similar, but involve different risk concerns. In the case of 77-003, toxic chemicals previously stored at the site are known to have leached underground. Underground transport of these chemicals is the major risk concern for 77-003. In the case of 77-004, the major risk concern is plutonium contaminated soil. Because of these differences, the scorer does not to group the material disposal areas.

Based on the above reasoning, the scorer defines four groups, three of which consist of a single waste unit:

- Group 1: The outfalls (single waste unit consisting of 77-001 and 77-002)
- Group 2: The chemical material disposal area (77-003)
- Group 3: The plutonium material disposal area (77-004)
- Group 4: The sumps (77-005a through d plus 78-001 through 7)

STEP 3: SELECT ONE WASTE UNIT FROM EACH GROUP FOR SCORING

For convenience, a waste unit may be selected that is particularly familiar or well-known to the scorer.

Example

The first three groups each consist of a single waste unit each. From the group of sumps, the scorer chooses 77-005a, which is more familiar to the scorer and likely to contain the most waste. Thus, four waste units must be scored:

1. 77-001/002 (the outfalls)
2. 77-003 (chemical material disposal area)
3. 77-004 (plutonium material disposal area)
4. 77-005a (one of the sumps)

STEP 4: SCORE EACH SELECTED WASTE UNIT

Figure 2 illustrates the measures that must be scored for each waste unit and shows how they are related. As indicated, scores must be assigned both to risk measures and to measures that do not relate to risk. Before scores are assigned to risk measures, a risk concern must be identified.

Figure 2. Site Ranking System Measures and Aggregation Logic

Step 4.1: Identify The Most Significant Risk Concern For Each Selected Waste Unit

To specify a risk concern for a waste unit, you must identify:

1. A risk agent associated with the waste unit,
2. A potential exposure pathway, and
3. A population at risk.

The above three specifications define a risk concern (i.e., a conceptual risk model). From the various risk concerns that could be defined for a waste unit, select one that provides the strongest motivation for addressing the site expeditiously. Important considerations include (1) the toxicity or hazard associated with the risk agent, (2) how likely and how soon exposures might occur, (3) the nature of potential health effects, and (4) the size of the population at risk. Specify the selected risk concerns by completing Part B of the WUI Form for each waste unit that you intend to individually score.

If no risk concern for a waste unit can be identified, signify this by leaving the required entries in Part B of the WUI Form blank.

If several risk concerns are identified and it is not clear which one is most significant, then the top two or three concerns should be reported and scored as separate waste units. In this case, provide multiple versions of the WUI Form for the waste unit, each with a distinct specified risk concern. Distinguish the submissions by adding "RC#" to the waste unit number entered in Part A of the WUI Form. For example, waste unit 77-006 would become 77-006RC1, 77-006RC2, etc. Try to minimize the number of risk concerns that require separate scoring.

Example 1) Known Risk Agent, Future Exposure through Unlikely Event

Sump 77-005 a) is known to contain silver. No current exposures are occurring. Exposures could occur in the future if unauthorized individuals attempt to remove and recover the silver.

I. Identify the most significant risk concern for the Waste Unit by specifying a risk agent, potential exposure pathway, and population at risk. Indicate your choices by providing entries or checking the appropriate boxes below.			
Risk Agent		II. Potential Exposure Pathway	
a) If the risk agent posing the greatest risk is known, specify it: (See Table 1 for examples).		a) Are exposures occurring now, e.g., because of on-site exposure, or because releases to the accessible environment have already occurred? Yes ☐ No ☒ If yes, go to d); if no, go to b) or c).	
Silver		d) Is the exposure scenario likely to result in long-term (chronic) exposures, or short-term (acute) exposures? Chronic ☐ Acute ☒	
b) If the most significant risk agent is unknown, specify the type:		e) Describe the potential exposure pathway:	
Radionuclides ☐ VOCs ☐ Semi-volatile organic compounds ☐ Heavy metals ☐ High explosives ☐ Toxic chemicals ☐ Other (specify below) ☐		Inhalation of contaminated dust? ☐ Ingestion of contaminated substances, e.g., soil, drinking water, produce? ☐ Dermal contact with contaminant, e.g., handling contaminated material? ☒ External radiation exposure? ☐ Other? (specify below) ☐	
c) Or will maximum exposures occur in the future as a result of some initiating event such as:		f) Is the population at risk:	
Excavation? ☐ Explosion? ☐ Fire? ☐ Containment failure? ☐ Rain/Flood? ☐ Other? (specify below) ☒		Maintenance workers ☐ Road workers ☐ Construction workers ☐ Workers on lunch break ☐ Resident workers ☐ Nearby residents ☐ Joggers/hikers/bikers ☐ Park visitors ☐ Campers ☐ Playing children ☐ Picnic party ☐ Trespassers ☒ People driving on nearby roads ☐ Farmers/gardeners ☐ Hunters/fishers ☐ Homesteaders ☐ Other (specify below) ☐	
		Forced entry	

(continued on next page)

Example 2) Unknown Risk Agent, Future Exposure through Gradual Waste Transport

Chemicals from material disposal area 77-003 have leached underground and may be moving off site. No mechanism for exposing workers can be identified. Members of the public may be exposed if concentrations reach a nearby canyon creek. No concentrations have yet been measured in the creek, so any exposures would occur in the future.

R Identify the most significant risk concern for the Waste Unit by specifying a risk agent, potential exposure pathway, and population at risk. Indicate your choices by providing entries or checking the appropriate boxes below.			
I. Risk Agent		II. Potential Exposure Pathway	
a) If the risk agent posing the greatest risk is known, specify it: (See Table 1 for examples).		a) Are exposures occurring now, e.g., because of on-site exposure, or because releases to the accessible environment have already occurred?	
		Yes ☐ No ☒ If yes, go to d); if no, go to b) or c).	
b) If the most significant risk agent is unknown, specify the type:		b) Or will maximum exposures occur in the future because of a gradual release due to:	
Radionuclides VOCs Semi-volatile organic compounds Heavy metals High explosives Toxic chemicals Other: (specify below)		Underground transport? ☒ Erosion? ☐ Other?: (specify below)	
		c) Or will maximum exposures occur in the future as a result of some initiating event such as:	
		Excavation? ☐ Explosion? ☐ Fire? ☐ Containment failure? ☐ Rain/Flood? ☐ Other?: (specify below)	
		d) Is the exposure scenario likely to result in long-term (chronic) exposures, or short-term (acute) exposures? Chronic ☐ Acute ☒	
		e) Describe the potential exposure pathway:	
		Inhalation of contaminated dust? ☐ Ingestion of contaminated substances, e.g., soil, drinking water, produce? ☒ Dermal contact with contaminant, e.g., handling contaminated material? ☐ External radiation exposure? ☐ Other?: (specify below)	
		f) Is the population at risk:	
		Maintenance workers Road workers Construction workers Workers on lunch break Resident workers Nearby residents Joggers/bikers/bikers Park visitors Campers Playing children Picnic party Trespassers People driving on nearby roads Farmers/gardeners Hunters/fishers Homesteaders Other: (specify below)	
		X	

Step 4.2: Assign Risk Scores

Assign risk scores for each waste unit according to the risk concern(s) that you identified for that unit.

How to Assign Scores

Risk scores should be assigned using the scoring scales that are provided in Appendix B for each measure. Scores for up to eight measures may be required (see Figure 2, page 6). For simplicity, all scoring scales consist of four levels labeled 0, 1, 2, and 3. In general, 0=zero (i.e., none), 1=low, 2=medium, and 3=high. Detailed descriptions have been provided to tailor and more clearly define the levels for each scale. Read the descriptions associated with each score on a scale and select the score whose descriptions, on balance, seem most appropriate. Your scores should represent best professional judgment. If there is uncertainty, best-judgment scores should represent median estimates (i.e., estimates such that actual values are equally likely to be above or below).

Assign noninteger scores (e.g., 2.7) if you feel that the situation you are scoring fits between the descriptions provided. Interpolation tables are provided for most scales to facilitate the assignment of noninteger scores. If you wish to interpolate a noninteger score for a measure for which no interpolation table is provided, be sure to account for the logarithmic nature of scales and the change in the measure implied by a unit change in score. For example, to interpolate noninteger scores for risk source hazard, note that a one unit change in score implies a three-order-of-magnitude change in the measure of hazard. The table below indicates how interpolations should be conducted in this case:

Interpolation Aid for Magnitude of Hazard Score			
Measure	Score	Measure	Score
y	m	1000x	n + 1.0
0.5y	m - 0.1	500x	n + 0.9
0.1y	m - 0.3	100x	n + 0.7
0.05y	m - 0.4	50x	n + 0.6
0.01y	m - 0.7	10x	n + 0.3
0.002y	m - 0.9	2x	n + 0.1
0.001y	m - 1.0	x	n

For example, if the measure (e.g., quantity of hazardous waste) is half the value specified for an integer score, subtract 0.1 units from the score; if it is one-tenth the value, subtract 0.3 units from the score, etc. Similarly, if the measure is twice the value specified for an integer score, add 0.1 units to the score; if it is ten times the value, add 0.3 units, etc.

Hazard of The Risk Source

Risk source hazard scores must be assigned for each waste unit for which a risk concern was identified in Part B of the WUI Form. If no risk concern was identified, skip to the section on Environmental Risk (page 16).

Hazard scores should be based on the risk agent identified on the WUI Form as the most significant risk concern. The hazard score depends on the type and quantity of the specified risk agent. It does not depend on the likelihood of exposures or the availability of a population at risk.

If the risk agent of concern is a toxic chemical, use Table 1A to assign a score based on the estimated quantity of the risk agent present. If the risk agent is soil contaminated with a radionuclide, use Table 1B. If the risk is a physical hazard (e.g., fire, explosion), rather than a toxic hazard or radiation, use Table 1C to assign a score. If the risk agent is unknown or not listed in the previous tables, use Table 1D to assign a score. If there is no information available to support any judgment of hazard whatsoever (i.e., it is impossible to use any of the tables), assign a hazard score of 1 and be sure to assign a risk uncertainty score of 3 (page 17). Report scores on the scoring form under "Health Risk: Risk Source Hazard."

Example 1) Known Chemical Risk Agent that Appears in Table 1A

The risk agent for the risk concern is PCB. According to available records, at least 10 pounds of PCB were disposed of at this site. However, the records are sketchy, so the scorer estimates that the actual amount of PCB disposed of was probably several times larger. The scorer's best judgment is that the actual amount of PCB is approximately 30 pounds. In Table 1A, the score for 10 pounds of PCB is 1.4 while the score for 100 pounds of PCB is 1.8. Recognizing the logarithmic nature of the scale and the fact that 30 pounds is geometrically about halfway between 10 pounds and 100 pounds, the scorer assigns a score of 1.6 (halfway between 1.4 and 1.8).

Example 2) Known Risk Agent that Appears in Table 1A

The risk agent for the risk concern is radioactive soil. The scorer estimates that the soil is contaminated with Plutonium 239 at a level of roughly 100 pi C/gram and that there are approximately 50 tons of soil so contaminated. According to Table 1B the hazard score is 1.8.

Example 3) Unknown Risk Agent

Unknown toxic chemicals are present in the outfall. The scorer believes that they may pose moderate danger. Using Table 1D, the scorer assigns a score of 2.0 because the corresponding description in the table applies:

- Worst-case exposure scenarios lasting one hour (e.g., inhalation or ingestion of contaminated soil) would almost certainly cause moderate reversible health effects.

(continued on next page)

Name(s) of Scorer(s): JOHN DOE										OU#: 2222			
WASTE UNIT	HEALTH RISK					ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT		REMEDIATION COST		COST ESCALATION
	Risk Source Hazard	Exposure Potential				Env.1 Resources	Impact on Env.1 Resources		Public Concern	Fraction of Problem	Best Judgment	Cost Uncertainty	
		Timing	Level	Duration	Population								
77-001/2	2.0												

Table 1A
 Chemical Hazard of the Risk Source

Table 1B
 Radiological Hazard of the Risk Source

Table 1C
 Physical Hazard of the Risk Source

Table 1D
 Alternative Table

• Use Table 1D if risk agent is unknown or does not appear in Table 1A, B, or C.

Exposure Potential

Four scales are used to measure exposure potential. The first indicates when exposures may occur. The second measures the level of potential exposures taking into account the exposure pathway. The third measures the duration of potential exposures. The fourth measures the size of the population at risk. Assign scores for all four measures for each waste unit before scoring the next waste unit.

Exposure Timing

Use Tables 2A and 2B to select a score for exposure timing. Table 2B is more useful if you wish to assign a noninteger score.

Assign a score of 3 if exposures are occurring now. Assign a lower score if exposures are likely to occur in the future. Exposures may be more likely to occur in the future because:

1. Physical or procedural barriers that limit exposure will, over time, become ineffective,
2. Previously released risk agents are slowly migrating to more accessible portions of the environment (e.g., underground transport), OR
3. Exposures require an initiating event that is unlikely to occur in the near future, but may eventually occur.

In cases (1) and (2) above, assign timing scores based on an estimate of how soon exposures are likely to occur. In case (3), assign timing scores based on the estimated annual probability of the required event. Report scores on the scoring form under "Health Risk: Exposure Potential: Timing."

Example 1) Exposures Delayed by Physical Barriers

Toxic chemicals are slowly moving underground. The scorer estimates that contaminants will not reach areas accessible to people for 25 years. Using the second column of Table 2B, an exposure timing score of 1.0 is assigned.

Example 2) Exposures Requiring an Unlikely Event

If suspended in the atmosphere, plutonium particulates in contaminated soil could harm workers. High concentrations of suspended particulates might be produced by a fire. The scorer estimates that a fire has occurred in the vicinity roughly once every 50 years. The scorer also estimates that there is a 50/50 chance that such an event would produce significant exposures to workers. The annual probability of an event producing significant exposures is, therefore, $0.02 \times 0.5 = 0.01$. Using the first column of Table 2B, an exposure timing score of 0.4 is assigned.

Name(s) of Scorer(s): JOHN DOE										OU#:		2222	
WASTE UNIT	HEALTH RISK					ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT		REMEDIATION COST		COST ESCALATION
	Risk Source Hazard	Exposure Potential				Env'l Resources	Impact on Env'l Resources		Public Concern	Fraction of Problem	Best Judgment	Cost Uncertainty	
		Timing	Level	Duration	Population								
77-004	2.0	1.0

Table 2A
Exposure
Timing

Table 2B
Exposure
Timing

- Use Table 2B to interpolate noninteger scores.
- If an initiating event is required, base the timing score on the annual probability of the event.

Exposure Level

Use Tables 3A and 3B to indicate how high exposures are likely to be when risks are at or near their peak. Exposure level is expressed relative to a “worst case” chronic environmental exposure scenario. The worst-case chronic environmental exposure scenario is, in effect, the highest level of exposure that could realistically occur, assuming that any required initiating events occur and individuals at risk take no steps for self-protection, but taking into account estimated quantities and concentrations and the physical properties of the hazard (e.g., solubility, volatility, propensity for bioaccumulation, rate of degradation, etc.). The worst-case exposure scenario is the exposure scenario that would be used in a conservative risk assessment to compute maximum individual risk. For example, if the risk agent is contaminated soil, the worst-case exposure scenario assumes:

- A residence established over the site.
- Plant foods are grown in the area of concern and irrigated with potentially contaminated surface water.

- Plant ingestion, soil ingestion, and dust inhalation rates are as specified in EPA risk assessment guidance documents.

To assign a score, consider the descriptions in Table 3A and determine which description or descriptions are most appropriate. If exposures are chronic, you should assign a score of 2 or less. (A score of 2 corresponds to the “worst case” chronic environmental exposure scenario.) If exposures are acute, they may occur at levels above the chronic “worst case,” so you may assign a score above 2 in this case. If you believe that the waste unit you are scoring lies between two descriptions in Table 3A, use Table 3B to estimate noninteger scores based on interpolation. If the risk source is a physical hazard (i.e., you scored risk source hazard using Table 1C), assign a score of 2.0 for exposure level. Report the results on the scoring form under “Health Risk: Exposure Potential: Level.”

Example 1) Chronic Exposures

VOCs from the waste unit may produce chronic low-level exposures to workers in a nearby building. The scorer estimates that concentrations are approximately 100 times lower in the building than what would be consistent with a worst-case chronic exposure scenario (residence established over the site). Using Table 3B, an Exposure Level score of 1.3 is assigned.

Example 2) Acute Exposures

A fire may temporarily suspend high concentrations of plutonium particulates. Workers would then be exposed to high concentrations of the contaminant during evacuation or fire-fighting activities. These levels are expected to be approximately equivalent to what would occur under a worst-case chronic exposure scenario. Using Table 3A, an Exposure Level score of 2.0 is assigned.

Example 3) Repeated Low-Level Exposures

Hikers who regularly pass through an area to which runoff from the waste unit drains may experience significant exposures after heavy rains. The scorer judges that the rate of exposure under such circumstances is roughly 10^{-3} of the rate that would result from a worst-case environmental exposure scenario. According to Table 3A, a score of 1.0 is assigned.

Name(s) of Scorer(s): JOHN DOE										OU#: 2222			
WASTE UNIT	HEALTH RISK					ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT		REMEDATION COST		COST ESCALATION
	Risk Source Hazard	Exposure Potential				Env.1 Resources	Impact on Env.1 Resources		Public Concern	Fraction of Problem	Best Judgment	Cost Uncertainty	
		Timing	Level	Duration	Population								
77-004	2.0	1.0	1.0

Table 3A
Exposure
Level

Table 3B
Exposure
Level

- Use Table 3B to interpolate noninteger scores.

Exposure Duration

Use Table 4 to indicate how long/frequent exposures are likely to be. To assign a score, determine what fraction of the year exposures would occur to an average member of the exposed population at levels consistent with your exposure level score. If exposures are chronic, you should assign a score from the lower shaded part of Table 4. If exposures are acute, you should assign a score from the upper part of the table. If the risk source is a physical hazard (i.e., you scored risk source hazard using Table 1C), assign a score of 3.0 for exposure duration. Report the results on the scoring form under "Health Risk: Exposure Potential: Duration."

Example 1) Chronic Exposures

VOCs from the waste unit are likely to be producing chronic exposures to workers in a nearby building. The scorer estimates that exposures at this level only occur during the eight hour work days (one-third of the day) between Monday and Friday (five-sevenths of all days) and only when the wind speed is relatively high (one-fourth of the time) for a total of approximately one-seventeenth of the year. Using the equation in the footnote to Table 4, an Exposure Duration score of 2.6 is assigned.

Example 2) Acute Exposures

A fire may temporarily suspend high concentrations of plutonium particulates. Workers might then be exposed during evacuation or fire-fighting activities. The scorer estimates that the average worker would be exposed at such high levels for approximately 2 hours. Using Table 4, an Exposure Duration score of 1.8 is assigned.

Example 3) Repeated Low-Level Exposures

Hikers who regularly pass through an area to which runoff from the waste unit drains may experience exposures after heavy rains. The scorer judges that exposures are likely to occur only after heavy rains (one-tenth of the year), that exposures will last for approximately one hour during each hike (the estimated time to traverse the potentially contaminated area) and that the exposed population of hikers hikes through the area no more than 50 times per year (5 times after heavy rains). Thus, the average hiker is exposed for approximately 5 hours per year. According to Table 4, a score of 1.9 is assigned.

Name(s) of Scorer(s): JOHN DOE											OU#:	2222	
WASTE UNIT	HEALTH RISK					ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT		REMEDIATION COST		COST ESCALATION
	Risk Source Hazard	Exposure Potential				Env'l Resources	Impact on Env'l Resources		Public Concern	Fraction of Problem	Best Judgment	Cost Uncertainty	
		Timing	Level	Duration	Population								
77-004	2.0	1.0	1.0	1.9

Table 4
Exposure
Duration

Population at Risk

Use Table 5 to assign scores reflecting the size of the population potentially at risk. Report the results on the scoring form under "Health Risk: Exposure Potential: Population."

Example

The scorer estimates that roughly two people are exposed per year at levels consistent with the exposure efficiency and duration scores. According to Table 5, a score of 0.5 is assigned.

Name(s) of Scorer(s): JOHN DOE										OU#:	2222		
WASTE UNIT	HEALTH RISK					ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT		REMEDIATION COST		COST ESCALATION
	Risk Source Hazard	Exposure Potential				Env.'1 Resources	Impact on Env.'1 Resources		Public Concern	Fraction of Problem	Best Judgment	Cost Uncertainty	
		Timing	Level	Duration	Population								
77-004	2.0	1.0	1.0	1.9	0.5

Table 5
Population
at Risk

Environmental Risk

Two scales are used to measure environmental risk. The first measures the types of environmental resources that could be adversely impacted. The second measures the likely magnitude of the impact on these resources.

Table 6 lists sensitive environmental resources in the vicinity of the Laboratory. Identify each instance of a resource that is potentially at risk due to the waste unit. In the absence of better information, assume that any resource within 4 miles of measured contamination from the waste unit is at risk. Sum the scores associated with each instance of a resource potentially at risk. Report summed scores on the Scoring Form under "Env.'1 Resources."

Use Table 7 to assign a score indicating the level of waste unit impact on the sensitive environmental resources that you identified above. Report scores on the scoring form under "Impact on Env.'1 Resources."

Example

The scorer determines that there are sensitive plants and animals in the vicinity of the waste unit and that within 4 miles there are habitats for the Jemez Salamander and the Spotted Owl. Based on Table 6, an environmental resources score of $1+4+4=9$ is assigned. Although an impact of the waste unit on these resources is possible, there is no evidence of a decrease in environmental quality to date. It is reasoned that environmental exposures would, at worst, produce only minor, temporary impacts. According to Table 7, an environmental impact score of 1.0 is assigned.

Name(s) of Scorer(s): JOHN DOE											OU#:		2222	
WASTE UNIT	HEALTH RISK					ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT		REMEDIATION COST		COST ESCALATION	
	Risk Source Hazard	Exposure Potential				Env.1 Resources	Impact on Env.1 Resources		Public Concern	Fraction of Problem	Best Judgment	Cost Uncertainty		
		Timing	Level	Duration	Population									
77-004	2.0	1.0	1.0	1.9	0.5	9	1.0

<u>Table 6</u> Environmental Resources at Risk	<u>Table 7</u> Impact on Environmental Resources
---	---

Risk Uncertainty

Use Table 8 to indicate your uncertainty over your risk estimates. The table is designed to obtain an order of magnitude judgment regarding how much higher risks could be (a 99% confidence level). Consider risk to be the total of health risk plus environmental risk. Be sure to take into account uncertainties in the magnitude of the source term, exposure level and duration, and population at risk. Report scores on the scoring form under "Risk Uncertainty."

Example

The scorer estimates that there is a possible scenario (1 in 100 chance) wherein the quantity of the source term could be one order of magnitude higher than the best judgment estimate, exposure efficiency could be two orders of magnitude higher, and population at risk could be one order of magnitude higher. The scorer therefore reasons that total uncertainty is roughly $1 + 2 + 1 = 4$ orders of magnitude. According to Table 8, a score of 2.0 is assigned.

(continued on next page)

Name(s) of Scorer(s): JOHN DOE										OU#: 2222			
WASTE UNIT	HEALTH RISK					ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT		REMEDICATION COST		COST ESCALATION
	Risk Source Hazard	Exposure Potential			Env.1 Resources	Impact on Env.1 Resources	Public Concern		Fraction of Problem	Best Judgment	Cost Uncertainty		
		Timing	Level	Duration								Population	
77-004	2.0	1.0	1.0	1.9	0.5	9	1.0	2.0

Table 8
Risk
Uncertainty

Step 4.3: Assign Non-Risk Scores

Up to five separate non-risk scores may be required for each waste unit (see Figure 2, page 6):

1. Public concern and economic impact to the community
2. Fraction of the source of public concern
3. Estimated cost of remediation
4. Cost uncertainty
5. Cost escalation rate

Socioeconomic Impacts

Socioeconomic impacts include public concern and economic impacts to the community. Scoring requires accounting for the fraction of the public concern that should be attributed to the waste unit. The fraction of public concern is important because the public may be concerned about the waste unit directly, perceive it to be part of a larger waste problem of special concern (e.g., Acid Canyon, TA49), or perceive it only vaguely as part of the total ER waste problem posed by the Laboratory.

Use Table 9 to provide a score indicating the level of any public concern directed at any problem of which the waste unit is a part. Use Table 10A to provide a score indicating the fraction of the problem attributed to the waste unit. Use Table 10B to assign noninteger scores based on interpolation. Report scores on the scoring form under "Public Concern" and "Fraction of Problem," respectively.

Example

The area in the canyon to which runoff drains is popularly called "Radioactive Creek." Negative news stories appear several times per year in newspapers serving communities in the surrounding area, and there have been a couple of stories in national news magazines. According to Table 9, a score of 2.0 is assigned to the level of public concern. The waste unit is not the only source of potential radioactive contamination in the creek. Because it is a relatively small contributor (roughly 10%), a score of 2.0 is assigned to the fraction of the problem attributed to the waste unit, based on Table 10B.

Name(s) of Scorer(s): JOHN DOE										OU#:		2222	
WASTE UNIT	HEALTH RISK					ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT		REMEDIATION COST		COST ESCALATION
	Risk Source Hazard	Exposure Potential				Env.1 Resources	Impact on Env.1 Resources		Public Concern	Fraction of Problem	Best Judgment	Cost Uncertainty	
		Timing	Level	Duration	Population								
77-004	2.0	1.0	1.0	1.9	0.5	9	10	20	20	20

Estimated Cost of Remediation

Table 11 provides remediation cost scores for alternative remediation approaches. Use this table to generate a best-judgment score for the cost of remediation at the waste unit. If indirect costs (e.g., costs of evacuation, lost resources, etc.) are estimated to be a significant proportion of the total cost of remediation, the score should be adjusted for these costs using the cost adjustment equation given in the second footnote to Table 11. All costs should be expressed in 1992 dollars. Use a 10 percent discount rate to express future costs in 1992 dollars. If your best judgment is that two or more of the remediation approaches listed in Table 11 will be necessary to address the waste unit (e.g., a septic tank will be removed and a soil cap put in place), find scores for each of the necessary approaches and combine them using the score combining equation given in the third footnote to Table 11.

Example

The scorer's best judgment is that remediation will consist of removing 100 cubic yards of soil. According to Table 11, the score corresponding to removing 100 cubic yards of radioactive soil is 0.7.

Name(s) of Scorer(s): JOHN DOE										OU#:	2222		
WASTE UNIT	HEALTH RISK					ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT		REMEDIATION COST		COST ESCALATION
	Risk Source Hazard	Exposure Potential				Env.1 Resources	Impact on Env.1 Resources		Public Concern	Fraction of Problem	Best Judgment	Cost Uncertainty	
		Timing	Level	Duration	Population								
77-004	2.0	1.0	1.0	1.9	0.5	9	1.0	2.0	2.0	2.0	0.7

Table 11
Remediation
Approaches
and Costs

Cost Uncertainty

Use Table 12 to indicate the level of current uncertainty over remediation cost. The table is designed to obtain an order of magnitude judgment regarding how much higher than your best judgment estimate remediation cost could be (99% confidence level). Be sure to take into account the magnitude of uncertainties in both the type of remediation necessary and in the cost of that remediation. Report scores on the scoring form under "Cost Uncertainty."

Example

The scorer estimates that there is a possible scenario (1 in 100 chance) wherein as much as 1,000 cubic yards of soil (10 times the best-judgment estimate) would need to be removed and wherein costs would be 10 times higher per cubic yard since much of the additional excavation would have to be done in difficult terrain. Thus, the scorer reasons that cost could possibly (1 chance in 100) be $10 \times 10 = 100$ times higher than the best-judgment estimate. According to Table 12, the appropriate cost uncertainty score is 1.0.

Name(s) of Scorer(s): JOHN DOE											OU#:	2222		
WASTE UNIT	HEALTH RISK					ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT		REMEDATION COST		COST ESCALATION	
	Risk Source Hazard	Exposure Potential				Env.1 Resources	Impact on Env.1 Resources		Public Concern	Fraction of Problem	Best Judgment	Cost Uncertainty		
		Timing	Level	Duration	Population									
77-004	2.0	1.0	1.0	1.9	0.5	9	1.0	2.0	2.0	2.0	0.7	1.0

Table 12
Estimated
Remediation
Cost

Cost Escalation

Use Table 13 to indicate whether and at what rate remediation costs would escalate as a result of delay. Costs may escalate, for example, because of site deterioration. What increase, if any, in the total cost of remediation would result from a delay of 5 years? Assume no change in the cost-effectiveness of cleanup technology and ignore any cost increases associated with normal inflation. Report scores on the scoring form under "Cost Escalation."

Example

The scorer does not believe that a delay would significantly increase the costs. Accordingly, Table 13 indicates that a cost escalation score of 0.0 should be assigned.

Name(s) of Scorer(s): JOHN DOE											OU#:	2222		
WASTE UNIT	HEALTH RISK					ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT		REMEDATION COST		COST ESCALATION	
	Risk Source Hazard	Exposure Potential				Env.1 Resources	Impact on Env.1 Resources		Public Concern	Fraction of Problem	Best Judgment	Cost Uncertainty		
		Timing	Level	Duration	Population									
77-004	2.0	1.0	1.0	1.9	0.5	9	1.0	2.0	2.0	2.0	0.7	1.0	0.0

Table 13
Cost
Escalation

STEP 5: ASSIGN SCORES TO THE REMAINING WASTE UNITS IN EACH GROUP

The last step of the scoring process is to assign scores to the remaining waste units in each group by adjusting the scores assigned to the single group member that was already scored. Consider each measure, one at a time. If there is no discernible difference with regard to that measure between the scored waste unit and another member of the group, assign the same score. Otherwise, make small adjustments to the scores as needed based on their differences. Document the scores for the remaining waste units on the Scoring Form.

EXAMPLE

Scores must be assigned to the remaining 10 sumps based on the scores assigned to the selected sump, 77-005a. The scorer observes that the sumps are identical in all respects except the quantity of waste that they are likely to contain. Therefore, the scorer assigns the same scores for all measures except risk source hazard. To adjust hazard scores, the scorer notes that:

- The remaining sumps in TA 77 (77-005b-d) are slightly smaller than the sump that was scored (77-005a), and probably received smaller amounts of HEs.
- The sumps in TA 78 are likely to contain lower quantities of HE because a previous effort was undertaken to remove wastes from these sumps.

Based on these considerations, the scorer ranks the sumps into three categories:

Category 1 (highest hazard):	77-005a
Category 2 (next highest hazard):	77-005b-d
Category 3 (lowest hazard):	78-001-7

Waste unit 77-005a was assigned a hazard score of 2.0 (moderate hazard). To obtain hazard scores for the other waste units, the scorer reasons that the waste units in Category 2 are roughly half as hazardous as Category 1, and the waste units in Category 3 are one-tenth as hazardous as Category 1. Recognizing the lognormal nature of the scales and using the interpolation aid (page 10), the scorer assigns hazard scores as follows:

Category 1:	2.0
Category 2:	1.9
Category 3:	1.7

(continued on next page)

Completed Scoring Form

SCORING FORM

Name(s) of Scorer(s): JOHN DOE										OU#: 2222			
WASTE UNIT	HEALTH RISK					ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT		REMEDIATION COST		COST ESCALATION
	Risk Source Hazard	Exposure Potential			Env.1 Resources	Impact on Env.1 Resources	Public Concern		Fraction of Problem	Best Judgment	Cost Uncertainty		
		Timing	Level	Duration								Population	
77-001/2	1.0	3.0	2.0	2.5	1.2	9	1.0	2.0	1.0	3.0	2.0	2.0	0.0
77-003	2.0	1.0	2.0	1.0	0.8	9	1.0	2.0	0.0	0.0	0.5	1.4	0.0
77-004	2.0	1.0	1.0	1.9	0.5	9	1.0	2.0	2.0	2.0	0.7	1.0	0.0
77-005a	2.0	1.0	1.0	1.0	2.0	9	1.0	3.0	1.0	3.0	1.0	2.0	0.0
77-005b	1.9	*	*	*	*	*	*	*	*	*	*	*	*
77-005c	*	*	*	*	*	*	*	*	*	*	*	*	*
77-005d	*	*	*	*	*	*	*	*	*	*	*	*	*
78-001	1.7	*	*	*	*	*	*	*	*	*	*	*	*
78-002	*	*	*	*	*	*	*	*	*	*	*	*	*
78-003	*	*	*	*	*	*	*	*	*	*	*	*	*
78-004	*	*	*	*	*	*	*	*	*	*	*	*	*
78-005	*	*	*	*	*	*	*	*	*	*	*	*	*
78-006	*	*	*	*	*	*	*	*	*	*	*	*	*
78-007	*	*	*	*	*	*	*	*	*	*	*	*	*

Glossary

Acute exposure. An exposure which extends for a relatively short amount of time (less than 40 hours per year).

Chronic exposure. An exposure to a waste unit's risk agents which is repeated or continuous in duration (greater than 40 hours per year).

Cost escalation. A measure of the rate at which remediation costs would escalate as a result of a five-year delay in addressing the waste unit.

Economic impacts. A measure of the economic losses claimed to be attributable to the waste unit.

Exposure mechanism. The means whereby contaminants from a waste unit are exposed to a population, including both the means of transport to the population (where relevant) and the pathway of exposure for the population.

Exposure potential. A measure of the efficiency of exposure pathways. Exposure potential accounts for the time at which exposures are likely to begin occurring, the fraction of the year during which the population at risk is exposed to a waste unit's risk agents, the level of exposure relative to worst case exposure levels, and the size of the population potentially at risk.

Exposure timing. A measure of when exposures to the risk agent from a waste unit are expected to be at or near their peak, based either on the transport rate of risk agents or the expected time to occurrence of some risk initiating event.

Hazard at the risk source. A measure of the hazard posed by the risk agent at a waste unit based on the type and quantity of contaminants. Likelihood of exposure to the risk agent and the availability and size of a population at risk are irrelevant to this measure.

Initiating event. An event which triggers an increase in the potential for exposure to a waste unit's risk agents (e.g., flood, fire, earthquake).

Potential for exposure. A measure of the magnitude of potential exposures to the risk agent from a waste unit. Measured in terms of the likely timing of exposures, efficiency of exposures, and the size of the population at risk.

Public concern. A measure of the psychological impact of the waste unit on people in surrounding communities, measured in terms of publicity of and attention paid to the waste unit's problems.

Risk agent. Fundamental agents for health and environmental risks, including hazardous chemicals and radioactive materials. A specific contaminant associated with the waste unit. The risk agent chosen for scoring is typically that contaminant which poses the most significant risk of all those associated with the waste unit.

Risk Concern. A conceptual risk model. A scenario by which adverse health effects might occur as a result of a waste unit. The scenario is defined in terms of a risk agent, an exposure mechanism, and a population potentially at risk.

Scoring Form. The form used to document and submit quantitative scores. Scores for up to twelve waste units may be reported on a single scoring form. Make copies of the form if more waste units must be scored.

Waste unit. The unit of analysis for the ER Problem Ranking System. Waste units are defined to represent the smallest (most disaggregated) waste problems that can be independently identified, scored, and ranked.

Worst-case exposure. The highest level of exposure to the risk agent that could reasonably occur, taking into account estimated quantities and concentrations, and assuming a worst case exposure pathway (e.g., inhalation, ingestion, or immersion), taking into account the form and nature of the risk agent (e.g., solubility, volatility, propensity for bioaccumulation, rate of degradation, etc.). This would be the scenario used in a conservative risk assessment to calculate maximum individual risk at the site.

WUI Form. Waste Unit Information Form - the form used to describe a single waste unit and its risk concerns. The WUI Form is used to document and submit qualitative information.

**APPENDICES TO LANL ER PRIORITIZATION
SYSTEM SCORING INSTRUCTIONS**

FORMS AND TABLES USED FOR SCORING

APPENDIX A

**FORMS TO BE USED IN
REPORTING SCORES**

WASTE UNIT INFORMATION (WUI) FORM

Name(s) of Scorer(s):

OU#:

TA#:

A. Describe the Waste Unit:

Check appropriate box
for the Waste Unit type:

Storage

MDA

Firing Site

Sep. Tank

Waste Line

Sump

Outfall

Canyons

Other (specify)

List the PRS number(s) that constitute(s) this Waste Unit:

If you are grouping PRSs, state your reasoning:

Check the PRS type:

HWSA-SWMU

RCRA-SWMU

Area of Concern

Check the waste type:

Non-rad. waste

Rad. waste

Mixed waste

B. Identify the most significant risk concern for the Waste Unit by specifying a risk agent, potential exposure pathway, and population at risk.

Indicate your choices by providing entries or checking the appropriate boxes below.

I. Risk Agent

a) If the risk agent posing the greatest risk is known, specify it:
(See Table 1 for examples).

b) If the most significant risk agent is unknown, specify the type:

Radionuclides

VOCs

Semi-volatile organic compounds

Heavy metals

High explosives

Toxic chemicals

Other (specify below)

II. Exposure Potential

a) Are exposures occurring now, e.g., because of on-site exposure, or because releases to the accessible environment have already occurred?

Yes ☐No ☐

If yes, go to d), if no, go to b) or c).

b) Or will maximum exposures occur in the future because of a gradual release due to:

Underground transport?

Erosion?

Other? (specify below)

c) Or will maximum exposures occur in the future as a result of some initiating event such as:

Excavation?

Explosion?

Fire?

Containment failure?

Rain/Flood?

Other? (specify below)

d) Is the exposure scenario likely to result in long-term (chronic) exposures, or short-term (acute) exposures?

Chronic ☐Acute ☐

e) Describe the potential exposure pathway:

Inhalation of contaminated dust?

Ingestion of contaminated substances, e.g., soil, drinking water, produce?

Dermal contact with contaminant, e.g., handling contaminated material?

External radiation

exposure?

Other? (specify below)

f) Is the population at risk:

Maintenance workers

Road workers

Construction workers

Workers on lunch break

Resident workers

Nearby residents

Joggers/hikers/bikers

Park visitors

Campers

Playing children

Picnic party

Trespassers

People driving on nearby roads

Farmers/gardeners

Hunters/fishers

Homesteaders

Other (specify below)

C. Remediation Options

Best Judgment Approach

Pessimistic (High Cost) Approach

Identify and describe possible remediation approaches for the Waste Unit:

SCORING FORM

Name(s) of Scorer(s):		OU#:	
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WASTE UNIT	HEALTH RISK					ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT		REMEDIATION COST		COST ESCALATION
	Risk Source Hazard	Exposure Potential				Env.'l Resources	Impact on Env.'l Resources		Public Concern	Fraction of Problem	Best Judgment	Cost Uncertainty	
		Timing	Level	Duration	Population								

[illegible][illegible][illegible][illegible][illegible][illegible][illegible][illegible][illegible][illegible][illegible][illegible][illegible][illegible]

APPENDIX B

SCORING SCALES AND TABLES

Table 1A. CHEMICAL HAZARD OF THE RISK SOURCE

Use the following table to assign scores for the hazard of the risk source if the risk agent of concern is a toxic chemical. Select scores according to the type and quantity of the risk agent specified as the most significant risk concern.

When estimating the quantity of risk agents, exclude from your total any quantities that could not possibly produce exposures (e.g., any quantities for which containment can be guaranteed). If the risk agent is a contaminant mixed with soil, water, or other nonhazardous agent, estimates of quantity referred to in the table apply only to the contaminant itself. To obtain an estimate of total quantity, multiply the estimated average concentration of the risk agent by the total amount of material that is contaminated with it.

		Quantity									
		gallons	0.01	0.1	1	10	100	1,000	10,000	100,000	1.00E+06
		cubic yards			0.005	0.05	0.5	5	50	500	5,000
		tons	0.00	0	0.005	0.05	0.5	5	50	500	5,000
		drums			0.02	0.2	2	20	200	2,000	20,000
lbs	0.1	1	10	100	1,000	10,000	100,000	1.00E+06	1.00E+07		
Chemical	Toxicity										
1,1-dichloroethane	10	0.3	0.6	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
1,1-dichloroethene	100	1.3	1.6	1.6	1.9	2.3	2.6	2.9			
1,1,1-trichloroethane	10	0.2	0.5	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
1,1,2-trichloroethane	1000	0.9	1.2	1.4	1.8	2.1	2.4	2.8			
1,1,2,2-tetrachloroethane	10	1.0	1.3	1.3	1.6	2.0	2.3	2.6	3.0		
1,2-dichlorobenzene	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
1,2-dichloroethane	1000	1.4	1.7	1.7	2.1	2.4	2.7				
1,2-dichloroethene (total)	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	2.5	
1,2-dichloropropane	10000	1.1	1.4	1.8	2.1	2.4	2.8	2.6	2.9		
1,2,4-trichlorobenzene	1000	0.8	1.1	1.4	1.8	2.1	2.4	2.8			
1,3-DNB (dinitrobenzene)	10000	1.1	1.4	1.8	2.1	2.4	2.8				
1,3,5-TNB (trinitrobenzene)	10000	1.1	1.4	1.8	2.1	2.4	2.8				
1,4-dichlorobenzene	10	0.4	0.7	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
2-butanone (methyl ethyl ketone)	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
2-chloronaphthalene			0.2	0.2	0.6	0.9	1.2	1.6	1.9	2.2	
2-chlorophenol	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
2-methylphenol (o-cresol)	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
2-methylphenol (p-cresol)			0.3	0.3	0.6	1.0	1.3	1.6	2.0	2.3	
2-nitroaniline (O-nitroaniline)		0.9	1.3	1.3	1.6	1.9	2.3	2.6	2.9		
2,2-oxybis (1-chloropropane)		0.5	0.8	0.8	1.2	1.5	1.8	2.2	2.5	2.8	
2,4-DNT (dinitrotoluene)	100	1.2	1.5	1.5	1.8	2.2	2.5	2.8			
2,4-dichlorophenol	1000	0.8	1.1	1.4	1.8	2.1	2.4	2.8			
2,4-dinitrotoluene	1000	1.1	1.4	1.4	1.8	2.1	2.4	2.8			
2,4-dinitrophenol	1000	0.8	1.1	1.4	1.8	2.1	2.4	2.8			
2,4-dimethylphenol	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
2,4,5-trichlorophenol			0.2	0.2	0.5	0.9	1.2	1.5	1.9	2.2	
2,4,6-trichlorophenol	100	0.6	0.9	1.1	1.4	1.8	2.1	2.4	2.8		

Table 1A. CHEMICAL HAZARD OF THE RISK SOURCE (Continued)

		Quantity								
	gallons	0.01	0.1	1	10	100	1,000	10,000	100,000	1.00E+06
	cubic yards			0.005	0.05	0.5	5	50	500	5,000
	tons	0.00	0	0.005	0.05	0.5	5	50	500	5,000
	drums			0.02	0.2	2	20	200	2,000	20,000
	lbs	0.1	1	10	100	1,000	10,000	100,000	1.00E+06	1.00E+07
Chemical	Toxicity									
2,6-DNT (dinitrotoluene)	10000	1.2	1.5	1.8	2.1	2.4	2.8			
3,3-dichlorobenzidine	1000	1.1	1.4	1.4	1.8	2.1	2.4	2.8		
4-chloro-3-methylphenol (p-chloro-m-cresol)	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
4-chloroaniline	1000	0.8	1.1	1.4	1.8	2.1	2.4	2.8	2.3	2.7
4-methyl-2-pentanone	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
4-methylene chloride		0.9	1.3	1.3	1.6	1.9	2.3	2.6	2.9	
4-methylphenol (p-cresol)	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
acenaphthene	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
acetone	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
acetonitrile	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
alcohols	1		0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4
aldrin	10000	1.1	1.4	1.8	2.1	2.4	2.8			
ammonia	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
anthracene	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
antimony	10000	1.1	1.4	1.8	2.1	2.4	2.8			
arsenic	10000	1.3	1.6	1.8	2.1	2.4	2.8	3.0		
asbestos	10000	1.1	1.4	1.8	2.1	2.4	2.8			
barium	10000	1.1	1.4	1.8	2.1	2.4	2.8			
barium nitrate (soluble barium)	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
benzene	100	1.2	1.6	1.6	1.9	2.2	2.6	2.9		
benzo(a)pyrene	10000	1.5	1.8	1.8	2.2	2.5	2.8			
benzoic acid	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
benzyl alcohol	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
beryllium	10000	1.4	1.8	1.8	2.1	2.4	2.8			
bis-(2-chloroethyl) ether	1000	1.5	1.8	1.8	2.1	2.5	2.8			
bis-(2-chloroisopropyl) ether	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
bis-2-(ethylexyl)phthalate	100	0.6	0.9	1.1	1.4	1.8	2.1	2.4	2.8	
bromodichloromethane	100	0.9	1.3	1.3	1.6	1.9	2.3	2.6	2.9	
bromoform	100	0.5	0.9	1.1	1.4	1.8	2.1	2.4	2.8	
bromomethane	1000	1.3	1.6	1.6	2.0	2.3	2.6	3.0		
butyl benzyl phthalate	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
cadmium	10000	1.1	1.4	1.8	2.1	2.4	2.8			
carbazole		0.7	1.0	1.0	1.3	1.7	2.0	2.3	2.7	3.0
carbon disulfide	100	0.9	1.2	1.2	1.6	1.9	2.2	2.6	2.9	
carbon tetrachloride	1000	1.4	1.7	1.7	2.1	2.4	2.7			
chlordane	10000	1.1	1.4	1.8	2.1	2.4	2.8			
chlorobenzene	100	0.6	0.9	1.1	1.4	1.8	2.1	2.4	2.8	
chloroethane	1	0.0	0.3	0.4	0.8	1.1	1.4	1.8	2.1	2.4
chloroform	100	1.4	1.7	1.7	2.1	2.4	2.7			
chloromethane	10	0.9	1.2	1.2	1.6	1.9	2.2	2.6	2.9	
chromium IV	10000	1.1	1.4	1.8	2.1	2.4	2.8			

Table 1A. CHEMICAL HAZARD OF THE RISK SOURCE (Continued)

		Quantity									
		gallons	0.01	0.1	1	10	100	1,000	10,000	100,000	1.00E+06
		cubic yards			0.005	0.05	0.5	5	50	500	5,000
		tons	0.00	0	0.005	0.05	0.5	5	50	500	5,000
		drums			0.02	0.2	2	20	200	2,000	20,000
lbs	0.1	1	10	100	1,000	10,000	100,000	1.00E+06	1.00E+07		
Chemical	Toxicity										
cis-1,3-dichloropropene	10000	1.4	1.8	1.8	2.1	2.4	2.8				
cobalt	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
copper	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
cyanide	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
cyanogen	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
DDT	1000	0.8	1.1	1.4	1.8	2.1	2.4	2.8			
di-n-butylphthalate	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
di-n-octyl phthalate	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
dibromochloromethane	100	0.5	0.9	1.1	1.4	1.8	2.1	2.4	2.8		
dichlorodifluoromethane (F-12)	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
dieldrin	10000	1.1	1.4	1.8	2.1	2.4	2.8				
diethylphthalate	1		0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	
dimethyl phthalate	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
DPA (diphenylamine)	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
endrin	10000	1.1	1.4	1.8	2.1	2.4	2.8				
ethanol	1		0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	
ethyl benzene	1	0.0	0.3	0.4	0.8	1.1	1.4	1.8	2.1	2.4	
ethylene glycol (antifreeze)	1		0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	
fluoranthene	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
fluorene	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
fluorine	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
formaldehyde	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
freon	1		0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	
heptachlor	1000	0.8	1.1	1.4	1.8	2.1	2.4	2.8			
hexachlorobenzene	1000	1.3	1.6	1.6	2.0	2.3	2.6	3.0			
hexachlorobutadiene	1000	0.8	1.1	1.4	1.8	2.1	2.4	2.8			
hexachlorocyclopentadiene	10000	1.1	1.4	1.8	2.1	2.4	2.8				
hexachloroethane	1000	0.8	1.1	1.4	1.8	2.1	2.4	2.8			
HMX (cyclotetramethylenetetranitramine)	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
hydrazine	10000	1.1	1.4	1.8	2.1	2.4	2.8				
hydrochloric acid	1000	0.8	1.1	1.4	1.8	2.1	2.4	2.8			
hydrofluoric acid	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
hydrogen cyanide	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
isopentane	1		0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	
isophorone	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
lead	10000	1.1	1.4	1.8	2.1	2.4	2.8				
lindane (hexachlorocyclohexane, gamma)	10000	1.1	1.4	1.8	2.1	2.4	2.8				
manganese	10000	1.1	1.4	1.8	2.1	2.4	2.8				
mercury	10000	1.1	1.4	1.8	2.1	2.4	2.8				
methanol	1		0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	
methylene chloride	10	0.9	1.3	1.3	1.6	1.9	2.3	2.6	2.9		

Table 1A. CHEMICAL HAZARD OF THE RISK SOURCE (Continued)

		Quantity								
	gallons	0.01	0.1	1	10	100	1,000	10,000	100,000	1.00E+06
	cubic yards			0.005	0.05	0.5	5	50	500	5,000
	tons	0.00	0	0.005	0.05	0.5	5	50	500	5,000
	drums			0.02	0.2	2	20	200	2,000	20,000
	lbs	0.1	1	10	100	1,000	10,000	100,000	1.00E+06	1.00E+07
Chemical	Toxicity									
N-nitrosodiphenylamine	10	0.5	0.8	0.8	1.1	1.5	1.8	2.1	2.5	2.8
N-nitroso-di-N-dipropylamine	10000	1.5	1.8	1.8	2.2	2.5	2.8			
naphthalene	1000	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
nickel	10000	1.1	1.4	1.8	2.1	2.4	2.8			
nitrate	1		0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4
nitric acid	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
nitrobenzene	1000	0.9	1.3	1.4	1.8	2.1	2.4	2.8		
parathion	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
PCB	10000	1.1	1.4	1.8	2.1	2.4	2.8			
PETN	1000	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
PCB	10000	1.1	1.4	1.8	2.1	2.4	2.8			
PETN (pentaerythritol tetranitrate)	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
pentachlorophenol	100	0.9	1.3	1.3	1.6	1.9	2.3	2.6	2.9	
phenol	1		0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4
pyrene	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
RDX (trimethylenetrinitramine)	1000	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
selenium	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
silver	1000	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
strychnine	10000	1.1	1.4	1.8	2.1	2.4	2.8			
styrene	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
sulfuric acid	1000	0.8	1.1	1.4	1.8	2.1	2.4	2.8		
tetrachloroethene	100	0.9	1.3	1.3	1.6	1.9	2.3	2.6	2.9	
tetrachloroethylene	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
tetrahydrofuran (THF)	1		0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4
tetryl (N-methoxy-N,2,4,6-tetranitrobenzeneamine)	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
thallium	10000	1.1	1.4	1.8	2.1	2.4	2.8	2.6	2.9	
tin	1		0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4
TNT (trinitro toluene)	10000	1.1	1.4	1.8	2.1	2.4	2.8			
toluene	10	0.2	0.5	0.8	1.1	1.4	1.8	2.1	2.4	2.8
trans-1,3-dichloropropene	10000	1.1	1.4	1.8	2.1	2.4	2.8			
trichloroethene	10	1.0	1.3	1.3	1.7	2.0	2.3	2.7	3.0	
trichloroethylene	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
trichlorofluoromethane	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
uranium	10000	1.1	1.4	1.8	2.1	2.4	2.8			
vanadium	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	
vinyl acetate	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
vinyl chloride	1000	1.8	2.1	2.1	2.5	2.8				
warfarin	10000	1.1	1.4	1.8	2.1	2.4	2.8			
xylene	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
zinc	10	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8
zirconium	100	0.4	0.8	1.1	1.4	1.8	2.1	2.4	2.8	

Table 1B. RADIOLOGICAL HAZARD OF THE RISK SOURCE

Use the following table to assign scores for the hazard of the risk source if the risk agent of concern is radioactive soil. Select scores according to the type of contaminant, the level of contamination, and the quantity of soil so contaminated.

	Quantity								
	cubic yards	0	0.05	0.5	5.0	50	500	5,000	50,000
	tons	0.00	0	0.05	0.5	5.0	50	5,000	50,000
	drums		0	0.2	2	20	200	2,000	20,000
	lbs	1.0	10	100	1,000	10,000	100,000	1,000,000	1.00E+08
Radionuclide, Concentration									
Am-241, 10 pCi/g			0.2	0.5	0.8	1.2	1.5	1.8	2.5
Am-241, 100 pCi/g		0.2	0.5	0.8	1.2	1.5	1.8	2.2	2.8
Am-241, 1000 pCi/g		0.5	0.8	1.2	1.5	1.8	2.2	2.5	2.8
C-14, 10e5 pCi/g			0.1	0.4	0.7	1.1	1.4	1.7	2.4
C-14, 10e6 pCi/g		0.1	0.4	0.7	1.1	1.4	1.7	2.1	2.7
C-14, 10e7 pCi/g		0.4	0.7	1.1	1.4	1.7	2.1	2.4	2.7
Co-57, 10 pCi/g				0.1	0.4	0.7	1.1	1.4	2.1
Co-57, 100 pCi/g			0.1	0.4	0.7	1.1	1.4	1.7	2.4
Co-57, 1000 pCi/g		0.1	0.4	0.7	1.1	1.4	1.7	2.1	2.7
Co-60, 1 pCi/g				0.3	0.6	1.0	1.3	1.6	2.3
Co-60, 10 pCi/g			0.3	0.6	1.0	1.3	1.6	2.0	2.6
Co-60, 100 pCi/g		0.3	0.6	1.0	1.3	1.6	2.0	2.3	3.0
Cs-134, 1 pCi/g				0.2	0.5	0.8	1.2	1.5	2.2
Cs-134, 10 pCi/g			0.2	0.5	0.8	1.2	1.5	1.8	2.5
Cs-134, 100 pCi/g		0.2	0.5	0.8	1.2	1.5	1.8	2.2	2.8
Cs-137, 1 pCi/g				0.1	0.4	0.7	1.1	1.4	2.1
Cs-137, 10 pCi/g			0.1	0.4	0.7	1.1	1.4	1.7	2.4
Cs-137, 100 pCi/g		0.1	0.4	0.7	1.1	1.4	1.7	2.1	2.7
H-3, 10e7 pCi/g			0.2	0.5	0.9	1.2	1.5	1.9	2.5
H-3, 10e8 pCi/g		0.2	0.5	0.9	1.2	1.5	1.9	2.2	2.9
H-3, 10e9 pCi/g		0.5	0.9	1.2	1.5	1.9	2.2	2.5	2.9
I-129, 10 pCi/g				0.1	0.4	0.7	1.1	1.4	2.1
I-129, 100 pCi/g			0.1	0.4	0.7	1.1	1.4	1.7	2.4
I-129, 1000 pCi/g		0.1	0.4	0.7	1.1	1.4	1.7	2.1	2.7
Mn-54, 1 pCi/g				0.1	0.4	0.8	1.1	1.4	2.1
Mn-54, 10 pCi/g			0.1	0.4	0.8	1.1	1.4	1.8	2.4
Mn-54, 100 pCi/g		0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.8
Na-22, 1 pCi/g				0.2	0.6	0.9	1.2	1.6	2.2
Na-22, 10 pCi/g			0.2	0.6	0.9	1.2	1.6	1.9	2.6
Na-22, 100 pCi/g		0.2	0.6	0.9	1.2	1.6	1.9	2.2	2.9
Pu-238, 10 pCi/g			0.1	0.5	0.8	1.1	1.5	1.8	2.5
Pu-238, 100 pCi/g		0.1	0.5	0.8	1.1	1.5	1.8	2.1	2.8
Pu-238, 1000 pCi/g		0.5	0.8	1.1	1.5	1.8	2.1	2.5	2.8
Pu-239, 10 pCi/g			0.1	0.5	0.8	1.1	1.5	1.8	2.5
Pu-239, 100 pCi/g		0.1	0.5	0.8	1.1	1.5	1.8	2.1	2.8
Pu-239, 1000 pCi/g		0.5	0.8	1.1	1.5	1.8	2.1	2.5	2.8
Ra-226, 1pCi/g				0.3	0.7	1.0	1.3	1.7	2.3

Table 1B. RADIOLOGICAL HAZARD OF THE RISK SOURCE (Continued)

	Quantity								
	cubic yards	0	0.05	0.5	5.0	50	500	5,000	50,000
	tons	0.00	0	0.05	0.5	5.0	50	5,000	50,000
	drums		0	0.2	2	20	200	2,000	20,000
	lbs	1.0	10	100	1,000	10,000	100,000	1,000,000	1.00E+08
Radionuclide, Concentration									
Ra-226, 10 pCi/g			0.3	0.7	1.0	1.3	1.7	2.0	2.3
Ra-226, 100 pCi/g		0.3	0.7	1.0	1.3	1.7	2.0	2.3	2.7
Ru-106, 10 pCi/g				0.2	0.5	0.9	1.2	1.5	1.9
Ru-106, 100 pCi/g			0.2	0.5	0.9	1.2	1.5	1.9	2.2
Ru-106, 1000 pCi/g		0.2	0.5	0.9	1.2	1.5	1.9	2.2	2.5
Sr-90, 10 pCi/g				0.3	0.6	1.0	1.3	1.6	2.0
Sr-90, 100 pCi/g			0.3	0.6	1.0	1.3	1.6	2.0	2.3
Sr-90, 1000 pCi/g		0.3	0.6	1.0	1.3	1.6	2.0	2.3	2.6
Th-232, 1pCi/g				0.3	0.6	1.0	1.3	1.6	2.0
Th-232, 10 pCi/g			0.3	0.6	1.0	1.3	1.6	2.0	2.3
Th-232, 100 pCi/g		0.3	0.6	1.0	1.3	1.6	2.0	2.3	2.6
U-233, 100 pCi/g			0.3	0.6	1.0	1.3	1.6	2.0	2.3
U-233, 1000 pCi/g		0.3	0.6	1.0	1.3	1.6	2.0	2.3	2.6
U-233, 10000 pCi/g		0.6	1.0	1.3	1.6	2.0	2.3	2.6	3.0
U-235, 10 pCi/g				0.2	0.5	0.9	1.2	1.5	1.9
U-235, 100 pCi/g			0.2	0.5	0.9	1.2	1.5	1.9	2.2
U-235, 1000 pCi/g		0.2	0.5	0.9	1.2	1.5	1.9	2.2	2.5
U-238, 10 pCi/g			0.0	0.4	0.7	1.0	1.4	1.7	2.0
U-238, 100 pCi/g		0.0	0.4	0.7	1.0	1.4	1.7	2.0	2.4
U-238, 1000 pCi/g		0.4	0.7	1.0	1.4	1.7	2.0	2.4	2.7

Table 1C. PHYSICAL HAZARD OF THE RISK SOURCE

Use the following table to assign scores for the hazard of the risk source if the risk agent of concern is a physical hazard (e.g., fire or explosion). Select scores according to the associated descriptions.

0	The risk source poses virtually no danger.
	<ul style="list-style-type: none"> • The physical characteristics of the risk agents are such that accidents harmful to humans could occur only under the most unusual conditions (e.g., sabotage, deliberate effort to harm oneself). • Examples of risk agents qualifying for this score include clean fill, building debris that is unlikely to pose a fire hazard, and light scrap without sharp edges.
1	The risk source poses low danger.
	<ul style="list-style-type: none"> • Contaminated areas can be safely entered and could be characterized and remediated by workers wearing minimal protective clothing (e.g., field clothes). • Contact with the hazards on the site could easily produce minor injuries (e.g., cuts and bruises) and could potentially result in moderate injuries (e.g., burns, broken bones). However, life-threatening accidents are virtually impossible (10^{-8} probability)
2	The risk source poses moderate danger.
	<ul style="list-style-type: none"> • Contaminated areas could be characterized and remediated only with extreme care — full protective clothing would be required and special measures would need to be instituted to reduce the risk of explosion or fire. • Unprotected contact with the hazards on the site could easily produce moderate injuries (e.g., significant burns, broken bones). Death is unlikely (10^{-5} probability).
3	The risk source poses high danger.
	<ul style="list-style-type: none"> • Contaminated areas could be characterized and remediated only by workers using specialized protective clothing and equipment designed to protect against extreme fire, explosion, or other physical hazard. • Unprotected contact with the hazards on the site would almost certainly cause injury of sufficient severity to threaten life (e.g., 1 chance in 100 of death) or product permanent physical impairment or disfigurement.

Table 1D. HAZARD OF THE RISK SOURCE (ALTERNATIVE TABLE)

Use this scale to assign risk hazard scores when the most significant risk agent is unknown or does not appear in Tables 1A, B, or C.

0	The risk source poses virtually no danger.
	<ul style="list-style-type: none"> The type and quantity of risk agent is such that harmful effects to humans could occur only under the most unusual conditions (e.g., deliberate effort to obtain overwhelming dosage). Examples of risk agents qualifying for this score include building debris, scrap metal, and clean fill.
1	The risk source poses low danger.
	<ul style="list-style-type: none"> Contaminated areas can be safely entered and could be characterized and remediated by workers wearing minimal protective clothing (e.g., ordinary field clothes). If exposed to the risk agent under a worst-case environmental exposure scenario,* an acute exposure (one hour) would likely cause only minor effects (e.g., skin irritation) that are reversible following termination of exposure. Chronic or frequently repeated worst-case environmental exposure scenarios extending over a year would likely produce minor, reversible effects, or rarely, produce irreversible effects. In any case, such exposures would almost certainly not be life-threatening (10^{-6} probability).
2	The risk source poses moderate danger.
	<ul style="list-style-type: none"> Contaminated areas could be characterized and remediated only with extreme care — full protective clothing would be required, including self-contained breathing apparatus, rubber gloves, boots, and bands around the legs, arms, and waist. If exposed to the risk agent under a worst-case environmental exposure scenario, an acute exposure (one hour) would almost certainly cause subjects to experience moderate reversible health effects and could possibly produce irreversible effects as well. Death is unlikely (10^{-5} probability). Chronic or frequently repeated worst-case environmental exposure scenarios extending over a year would likely produce reversible effects and could produce irreversible, life-threatening effects (10^{-3} probability).
3	The risk source poses high danger.
	<ul style="list-style-type: none"> Contaminated areas could be characterized and remediated only by workers wearing special protective equipment designed to protect against the specific risk agents present. If exposed to the risk agent under a worst-case environmental exposure scenario, an acute exposure (one hour) would almost certainly cause injury of sufficient severity to threaten life (e.g., 1 chance in 100 of death) or produce permanent physical impairment or disfigurement. Chronic or frequently repeated worst-case environmental exposure scenarios extended over a year would almost certainly produce life-threatening effects.

* By “worst-case environmental exposure scenario” we mean the scenario that would be used in conservative risk assessment to calculate maximum individual risk at the site. This is the highest level of exposure that could realistically occur, taking into account estimated quantities and concentrations and the physical properties of the hazard (e.g., solubility, volatility, propensity for bioaccumulation, rate of degradation, etc.). Conceptually, it is the maximum exposure that could occur to an individual who takes no steps for self protection (due to ignorance of the danger posed) and is extremely unlucky (the collection of chance events that occur turn out to maximize the potential for exposure).

Table 2A. EXPOSURE TIMING

Use this table to assign scores indicating how soon exposures are expected to occur. If exposures are being delayed due to slow transport mechanisms, base your scores on how much longer (in years) transport to the population is likely to take. If exposures require an initiating event, pick your scores according to your estimate of the annual probability of occurrence of the event. Use Table 2B to interpolate noninteger scores.

0	Risks will not occur during the period of institutional control.
	<ul style="list-style-type: none"> • There are no credible pathways by which people might be exposed. • Physical or institutional control is completely effective. • So long as this control is maintained, there can be no exposures.
1	Roughly twenty-five years, because transport mechanisms are extremely slow and/or initiating events are extremely unlikely.
	<ul style="list-style-type: none"> • Of exposures requiring an initiating event, there is roughly one chance in 3 of it occurring within 100 years (annual probability of occurrence of roughly 1 in 30). • Atmospheric transport during this time period is not credible due to the conditions of containment or the physical properties of the risk agent and the extreme unlikelihood of mechanisms for obtaining atmospheric suspension (e.g., nonvolatile, well-consolidated solids, no physical traffic, protection from winds). • Overland transport is exceedingly unlikely, for example, because of sound waste containment, insusceptibility to burrowing animals, low or negative average slope and intervening areas of higher elevation between the waste unit and areas accessible to the population at risk. The risk agent may be in the form of consolidated or stabilized solids and/or containment is provided through nonpermeable compatible liner, sealed and sound containers, covered piles, and/or leachate collection system. • Unsaturated flow is the only mechanism by which populations might ultimately be exposed and contaminants are unlikely to reach groundwater. • Food chain exposure is impossible due to the physical and chemical properties of the risk agent and lack of potentially contaminated edible plants or animals.

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Table 2A. EXPOSURE TIMING (continued)

2	Roughly five years, because transport mechanisms are moderately slow.
	<ul style="list-style-type: none"> • If exposures require an initiating event, the annual probability of occurrence is roughly 1 in 10. • Atmospheric transport in this time period is not credible due to the conditions of containment or the physical properties of the risk agent and the extreme unlikelihood of mechanisms for obtaining atmospheric suspension (e.g., well-consolidated, no physical traffic, protection from winds). • Overland transport is unlikely, for example, because of reasonably sound waste containment, and only moderate average slope to downhill surface water accessible to the population at risk. The risk agent may be in the form of unstabilized, unconsolidated solids with containment provided through moderately permeable liner with leachate collection system, uncovered piles, or a landfill surface that precludes ponding. • Food chain exposure is unlikely due to the physical and chemical properties of the risk agent and lack of edible plants or animals.
3	Within one year, because transport mechanisms are extremely rapid or because of current possibility of exposure to site visitors.
	<ul style="list-style-type: none"> • If exposures require an initiating event, the annual probability of occurrence is roughly 50%. • Atmospheric transport is credible due to containment inadequacies and the physical properties of the risk agent (e.g., fine powder or gas) or the likelihood of mechanisms for obtaining atmospheric suspension (e.g., contamination of unconsolidated soil, denuded surface conditions, and ground traffic). • Overland transport is likely, for example, because the risk agent is a liquid or sludge or is highly soluble; containment is inadequate (e.g., leaking containers, unsound diking, no liner, uncovered unstabilized piles); and high average slope with nearby downhill surface water accessible to the population at risk. • Transport to groundwater is imminent, as plumes are nearing groundwater. • Exposures to the population at risk require no transport of contaminants (e.g., because the waste unit's risk agents are currently accessible).

Table 2B. EXPOSURE TIMING (NONINTEGER SCORES)

Use this table to assign scores indicating how soon exposures are expected to occur. If exposures require an initiating event, pick your scores according to your estimate of the annual probability of occurrence of the event (Column 1). If exposures are being delayed due to slow transport mechanisms, base your score on how much longer (in years) transport to the population at risk will take (Column 2).

Annual Probability (P)	Years (X)	Score (Y)*
Less than or equal to 0.5%	Greater than or equal to 125	0.0
	100	0.1
	90	0.2
	80	0.3
1%	70	0.4
	60	0.5
	50	0.6
	40	0.7
2%	35	0.8
	30	0.9
3%	25	1.0
	20	1.1
4%	15	1.3
5%	13	1.4
	12	1.5
6%	11	1.5
	10	1.6
7%	9	1.6
8%	8	1.7
9%	7	1.8
10%	6	1.9
	5	2.0
15%	4	2.1
20%	3	2.3
30%	2	2.6
Greater than or equal to 50%	Less than or equal to 1	3.0

* Interpolate using:

$$X = \frac{\log 0.5}{\log(1-P)}, \text{ where } P \text{ is expressed as a fraction}$$

$$Y = 3 - \frac{\log X}{\log 5}$$

Table 3A. EXPOSURE LEVEL

Use this scale to assign scores for exposure level. **Assign a score of 2 if the risk is posed by some physical hazard (i.e., you scored risk source hazard using Table 1C).** Otherwise, assign scores based on the estimated average magnitude of exposures per unit time compared to a “worst-case” chronic environmental exposure scenario (see footnote to Table 1D). A score of 2 corresponds to an exposure rate at the level of the “worst-case” chronic exposure scenario. Note that for acute exposures, the rate of exposure may be in excess of that for a “worst-case” chronic exposure, and thus a score above 2 may be assigned. Assume that point in time at which exposures are estimated to peak (as indicated by your exposure timing score). Use Table 3B to interpolate noninteger scores.

0	The characteristics of the risk agent, containment, and local environment ensure that there is virtually no potential for exposures, either now or in the foreseeable future.
1	The characteristics of the risk agent and local environment ensure that will be exposed to only minute fractions of the waste unit’s risk agents per year of exposure.
	<ul style="list-style-type: none"> • Exposure rates are likely to be on the order of 10^{-3} of the “worst-case chronic environmental exposure scenario” because: <ul style="list-style-type: none"> - Adequate controls ensure no direct exposures to the risk agents contained at the waste unit, and migration of risk agents out of controlled areas is extremely inefficient or highly unlikely. - For example, the most significant risk agents may be in the form of a consolidated or stabilized solid, and/or containment is reliable (e.g., nonpermeable compatible liner with leachate collection system, sealed and sound containers, covered piles, or uncovered but stabilized waste). - If the primary transport mechanism is transport to groundwater, the contaminant release site is a long distance from the water table and the contaminant is well-retarded by the soil structure so that the contaminant concentration will be extremely dilute before reaching groundwater and the rate of transport into groundwater will be very slow. - If the primary transport mechanism is overland transport, there is a low average slope and intervening areas of higher elevation that decrease contaminant concentration and slow the transport of contaminants to downhill surface water accessible to the population at risk (e.g., lake or stream).

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Table 3A. EXPOSURE LEVEL (continued)

2	<p>The characteristics of the risk agent and local environment are such that people will be exposed to moderate to large fractions of the waste unit's risk agents per year of exposure.</p>
	<ul style="list-style-type: none"> • Exposure rates are likely to be roughly equal to the “worst-case chronic environmental exposure scenario” because: <ul style="list-style-type: none"> - Controls preventing direct exposures to contaminants contained at the waste unit will be ineffective or nonexistent, or migration of risk agents out of controlled areas will be efficient. - For example, the significant risk agents may be in the form of a liquid, sludge, gas, powder, or fine material with inadequate or deteriorating containment (e.g., leaking containers, unsound diking, no liner, uncovered piles, unconsolidated contaminated surface soils). - If the primary transport mechanism is to groundwater, distance to nearest well, recreational surface water, or population is relatively short; underground transport may be rapid (e.g., transport through connected fractures); and the contaminant is highly soluble and not well-retarded by the soil structure. - If the primary transport mechanism is overland transport, there is a high average slope and nearby (e.g., 1000 feet) downslope surface water accessible to the population at risk (e.g., lake or stream).
3	<p>The characteristics of the risk agent and local environment are such that people will be exposed to moderate-to-large fractions of the waste unit's risk agents per day of exposure.</p>
	<ul style="list-style-type: none"> • Exposure rates are likely to be roughly 3 orders of magnitude greater than the “worst-case chronic environmental exposure scenario” because: <ul style="list-style-type: none"> - The envisioned exposure scenario involves high level acute exposures. For the duration of the exposure, contaminants are present in the environment at the highest concentration levels consistent with the quantity of contaminant and there are no barriers preventing direct exposures to the contaminant at these concentrations. - For example, the significant risk agents may be in the form of a gas, powder, or fine material that has been suspended in the air at very high concentrations due to some acute event (e.g., an explosion) or the risk agents may be present in high concentrations in soil or water and the envisioned exposure scenario may result in acute dermal contact (e.g., falling into a pool of highly contaminated water) or ingestion (e.g., a child eating soil).

Table 3B. EXPOSURE LEVEL (NONINTEGER SCORES)

Use this scale to assign noninteger scores for worker exposure level. **Assign a score of 2 if the risk is posed by some physical hazard (i.e., you scored risk source hazard using Table 1C).** Otherwise, assign scores based on the estimated average magnitude of exposures per unit time compared to a “worst-case” chronic environmental exposure scenario (see footnote to Table 1D). A score of 2 corresponds to an exposure rate at the level of the “worst-case” chronic exposure scenario. Note that for acute exposures, the rate of exposure may be in excess of that for a “worst-case” chronic exposure, and thus a score above 2 may be assigned. Assume that point in time at which exposures are estimated to peak (as indicated by your exposure timing score). Read the descriptions for scores of 0, 1, 2, and 3 in Table 3A before attempting to interpolate between these scores.

EXPOSURE EFFICIENCY Fraction/Multiple of Worst Case (X)	Score (Y)*
1e-6 or less	0.0
1e-5	0.3
1e-4	0.7
1e-3	1.0
1e-2	1.3
1e-1	1.7
1 (equal to worst case chronic exposure rate)	2.0
1e+1	2.3
1e+2	2.7
1e+3	3.0

* Interpolate using:

$$Y = \frac{\log X}{3} + 2$$

Table 4. EXPOSURE DURATION

Use this scale to assign scores for exposure duration. **Assign a score of 3 if the risk is posed by a physical hazard (i.e., you scored risk source hazard using Table 1C).** Otherwise, assign scores based on the fraction of time (e.g., hours per year) that exposures will occur at the level indicated by your exposure efficiency score for an average exposed individual. Assume that point in time at which exposures are estimated to be at or near their peak (as indicated by your exposure timing score). Note that chronic exposures are typically defined to be exposures with a duration of 80 hours or more per year. Thus, if you indicated a chronic exposure scenario on the WUI Form, your duration score should come from the lower shaded portion of the table, while if you indicated an acute exposure scenario, your duration score should come from the upper portion of the table.

EXPOSURE DURATION Length of Exposure Per Year (X)		Score (Y)*
A c u t e	≤ 1/10 second	0.0
	1 second	0.5
	5 seconds	0.7
	10 seconds	0.8
	15 seconds	0.9
	30 seconds	1.0
	1 minute	1.1
	5 minutes	1.3
	10 minutes	1.4
	20 minutes	1.5
	30 minutes	1.6
	1 hour	1.7
	2 hours	1.8
	5 hours	1.9
	10 hours	2.0
	1 day (24 hours)	2.1
	2 days	2.2
	5 days	2.4
C h r o n i c	10 days	2.5
	1 month	2.6
	2 months	2.7
	3 months	2.8
	6 months	2.9
	Continuous	3.0

* Interpolate using:

$$Y = \frac{\log X}{3} + 3 \quad \text{where X is expressed as a fraction of a year}$$

Table 5. POPULATION AT RISK

Use this scale to assign scores for the size of the population at risk. Choose the size of population to be consistent with your answers on previous scales. That is, provide your best-judgment as to how many people will be exposed at the levels indicated by your exposure efficiency score to the risk agent indicated by your risk source hazard score at the time or as a result of the event indicated by your timing score.

Population (X)	Score (Y)*
0	0.0
1	0.3
2	0.5
3	0.6
4	0.7
5	0.8
7	0.8
10	0.9
20	1.1
30	1.2
40	1.3
50	1.4
70	1.5
100	1.6
200	1.8
300	1.9
400	1.9
500	2.0
700	2.1
1,000	2.2
2,000	2.4
3,000	2.5
4,000	2.6
5,000	2.6
7,000	2.7
10,000	2.8
20,000	3.0

* Interpolate using:

$$Y = \frac{\log(X / 12.5)}{\log 40} + 1$$

Table 6. ENVIRONMENTAL RESOURCES AT RISK

Use this table to identify which sensitive environmental resources are at risk from the waste unit. In the absence of better information, assume that any resource within four miles of measured contamination is at risk. Sum the scores for the identified resources to obtain a total Environmental Resources at Risk score.

Sensitive Resource	Score
Plants and animals not listed below	1
San Ildefonso Hunting Lands	2
Jemez Salamander Habitat	4
Spotted Owl Habitat	4
Grama Grass Cactus	6
Bald Eagle Habitat	6
Wetlands in Pajarito Canyon	6
Peregrine Habitat	6
Bandelier National Monument	8
Bandelier Wilderness Area	8

Table 7. IMPACT ON ENVIRONMENTAL RESOURCES

Use this scale to assign scores for the impact of the waste unit on the sensitive environmental resources that you identified in Table 6. If you estimate that different scores will be impacted differently, your score should reflect the average impact across the resources you identified.

0	The waste unit poses no threat to the environment.
	<ul style="list-style-type: none"> • The nature of risk agents and environmental pathways precludes exposures to sensitive environmental resources.
1	The waste unit poses a very low threat to the environment.
	<ul style="list-style-type: none"> • The nature of risk agents and environmental pathways are such that there is no credible scenario by which for exposures to sensitive environmental resources could cause toxic effects. • There are no observations indicating any decrease in environmental quality as a result of the waste unit.
2	The waste unit poses a moderate threat to the environment.
	<ul style="list-style-type: none"> • The nature of risk agents and environmental pathways are such that likely scenarios for exposing sensitive environmental resources would result in moderate levels of impact that may affect the local abundance of a sensitive species or damage valued (but not unique) historical properties. • Observations indicate that environmental quality may already have decreased as a result of the waste unit. • Action to prevent further damage will probably be needed in less than 20 years to avoid irreversible damage.
3	The waste unit poses a very high threat to the environment.
	<ul style="list-style-type: none"> • The nature of risk agents and environmental pathways are such that likely scenarios for exposing sensitive environmental resources would result in widespread and severe damage to sensitive species or destruction of unique historical properties. • Observations indicate that environmental quality has significantly or rapidly decreased over time. • Action to prevent further damage will probably be needed in less than 5 years to avoid irreversible damage.

Table 8. RISK UNCERTAINTY

Actual risks (including health and environmental risk) may be less than, about the same as, or greater than those implied by the best-judgment estimates measured in the previous scales. The scale below is designed to enable you to express a judgment regarding how much greater actual risks could turn out to be, taking into account the magnitude of existing uncertainties and the degree to which best-judgment estimates may be conservative. Choose the statement below that best reflects your professional opinion.*

0	The upside uncertainty is very low.
	<ul style="list-style-type: none"> Waste volumes; contaminant identities; contaminant concentrations and release potential; site characteristics that may affect fate, transport, and persistence of contaminants; potential exposure pathways; and potential receptors at risk (abbreviated as source terms, pathways, and receptors below) have already been well-established, and the level of risk is clearly defined or bounded. Actual risks may end up being significantly below the best-judgment estimate, but it is very unlikely that they will come out significantly higher.
1	The upside uncertainty is moderate.
	<ul style="list-style-type: none"> Current risk judgments represent only an educated guess. Source terms, pathways, and receptors at risk are highly uncertain and potentially much greater than current estimates. Actual risks could possibly (1 chance in 100) end up being up to 100 times (two orders of magnitude) higher than the best-judgment estimate.
2	The upside uncertainty is high.
	<ul style="list-style-type: none"> Current risk judgments are highly uncertain. Source terms, pathways, and receptors at risk are largely unknown. Actual risks could possibly (1 chance in 100) end up being up to 10,000 times (four orders of magnitude) higher than the best-judgment estimate.
3	The upside uncertainty is very high.
	<ul style="list-style-type: none"> Current risk judgments have no basis whatsoever. Source terms, pathways, and receptors at risk are almost totally unknown. Actual risks could possibly (1 chance in 100) end up being up to 1,000,000 or more times (six orders of magnitude) higher than the best-judgment estimate.

* Because the scale is logarithmic with two orders of magnitude change per unit change in score, if uncertainty is such that actual risks could be 1, 3, or 5 orders of magnitude higher than the best judgment, assign a score of 0.5, 1.5, or 2.5, respectively.

Table 9. LEVEL OF PUBLIC CONCERN

Consider the smallest waste problem differentiated and recognized by the public that includes the waste unit. Use this scale to assign a score that indicates how much public concern there is about this problem.

0	The problem of which the waste unit is a part generates no incremental public concern.
	<ul style="list-style-type: none"> • People are not aware of the waste unit or any problem definition that includes the waste unit other than the Laboratory as a whole. • People are aware of a distinct problem definition including the waste unit, but don't have any concern about the specific problem incremental to their concern about the Laboratory as a whole.
1	The problem of which the waste unit is a part generates little incremental public concern.
	<ul style="list-style-type: none"> • Some small fraction of area residents are aware of the problem, but even among these residents, the problem is not a major concern. • Claimed economic impacts on the community or to the Laboratory are on the order of \$1,000 total.
2	The problem of which the waste unit is a part generates moderate public concern.
	<ul style="list-style-type: none"> • There are occasional (several times per year) negative news stories about the problem in the media serving the localized communities within the surrounding area. • Claimed economic impacts on the community are roughly \$100,000 total or \$10,000 annually.
3	The problem of which the waste unit is a part generates very high public concern.
	<ul style="list-style-type: none"> • There is frequent (greater than monthly) negative news coverage in Santa Fe and Albuquerque and occasional news stories in national media about the problem and there have been small-scale protests. • Local referenda related to the problem are likely and state officials are getting involved. • Claimed economic impacts on the community are on the order of \$10 million or more total, or \$1 million annually.

Table 10A. FRACTION OF THE PROBLEM ATTRIBUTED TO WASTE UNIT

Use this scale to indicate what fraction of the waste problem, as you defined it for Table 9, should be attributed to the waste unit. Table 10B provides a basis for assigning noninteger scores based on interpolation.

0	The public is not aware of the waste unit and does not associate it with any specific problems about which they have concern. From the public perspective, it is merely part of the total LANL ER problem.
1	The waste unit is a very small fraction (roughly 1%) of the problem perceived by the public.
2	The waste unit is a moderate fraction (roughly 10%) of the problem perceived by the public.
3	The waste unit is specifically identified in the mind of the public as the problem of concern.

**Table 10B. FRACTION OF THE PROBLEM ATTRIBUTED TO WASTE UNIT
(NONINTEGER SCORES)**

Use this table to assign noninteger scores for the percent of the problem, as you defined it in Table 11, that should be attributed to the waste unit.

Percent (X)	Score (Y)*
Less than or equal to 0.1%	0.0
0.2%	0.3
0.3%	0.5
0.4%	0.6
0.5%	0.7
0.6%	0.8
0.7%	0.9
1%	1.0
2%	1.3
3%	1.5
4%	1.6
5%	1.7
6%	1.8
7%	1.9
10%	2.0
20%	2.3
30%	2.5
40%	2.6
50%	2.7
60%	2.8
70%	2.9
100%	3.0

* Interpolate using:

$Y = 3 + \log(X)$, where X is expressed as a fraction

Table 11. Matrix for Determining Remediation Cost Scores *

Remediation Approach	Quantity					Assumptions
Soil Excavation	10 cy	100 cy	1000 cy	10000 cy	100000 cy	- Includes disposal charges
radioactive	0.2	0.7	1.2	1.7	2.2	- Includes filling of excavated site
mixed waste	0.6	1.1	1.6	2.1	2.6	
hazardous waste	0.5	1.0	1.5	2.0	2.5	
Septic Tank Removal	10 cy	100 cy	1000 cy	10000 cy	100000 cy	- Includes disposal charges for tank and contents
radioactive	0.6	1.1	1.6	2.1	2.6	
mixed waste	0.9	1.4	1.9	2.4	2.9	
hazardous waste	0.9	1.4	1.9	2.4	2.9	
Soil Cap	10 sf	100 sf	1000 sf	10000 sf	100000 sf	- Remediation approach conforms to regulatory specifications
radioactive	0.1	0.6	1.1	1.6	2.1	
mixed waste	0.5	1.0	1.5	2.0	2.5	
hazardous waste	0.4	0.9	1.4	1.9	2.4	
Removal of Inactive Firing Site	10 sf	100 sf	1000 sf	10000 sf	100000 sf	- Includes disposal charges
radioactive	0	0.3	0.8	1.3	1.8	- Removal of 6 inch layer
mixed waste	0.2	0.7	1.2	1.7	2.2	
hazardous waste	0.1	0.6	1.1	1.6	2.1	
Removal of Outfall	10 sf	100 sf	1000 sf	10000 sf	100000 sf	- Includes disposal charges
radioactive	0	0.5	1.0	1.5	2.0	- Removal of 1 ft layer
mixed waste	0.3	0.8	1.3	1.8	2.3	
hazardous waste	0.2	0.7	1.2	1.7	2.2	
Removal of Drain Line	10 ft	100 ft	1000 ft	10000 ft		- Includes disposal charges for pipe and dirt
radioactive	1.0	1.5	2.0	2.5		- Line is 6 ft deep
mixed waste	1.3	1.8	2.3	2.8		- Contamination removed 2 ft below line
hazardous waste	1.3	1.8	2.3	2.8		
Fence Material Disposal Area	100 ft	1000 ft	10000 ft			- 10 ft high
radioactive	1.3	1.8	2.3			- Includes posts and gate
mixed waste	1.3	1.8	2.3			- Includes installment of monitoring systems
hazardous waste	1.3	1.8	2.3			

*

A score of 1 in this table corresponds to approximately \$10,000, a score of 2 corresponds to approximately \$1,000,000, a score of 3 corresponds to \$100,000,000 and higher.

Cost Adjustment Equation:

To obtain a score that reflects incremental costs in addition to a score obtained in the table, use the following equation:

$$y = \frac{\log(\text{cost} + 10^{(2\text{score}+2)})}{2} - 1$$
Score Combination Equation:

To obtain a combined score if more than one remediation alternative is needed, use the following equation:

$$y = \frac{\log(10^{2\text{score}_1} + 10^{2\text{score}_2} + \dots + 10^{2\text{score}_n})}{2}$$
Cost Conversion Equation:

To obtain a score if you have a current cost estimate for the remediation approach, use the following equation:

$$y = \frac{\log(\text{cost})}{2} - 1$$

Table 12. COST UNCERTAINTY

Actual remediation cost may turn out to be less than, about the same as, or greater than that implied by the best-judgment estimate measured in the previous scale. The scale below is designed to enable you to express a judgment regarding how much greater actual costs could turn out to be, taking into account the magnitude of existing uncertainties in both the type of remediation necessary and in the cost of that remediation. Choose the statement below that best reflects your professional opinion.*

0	The upside uncertainty is very low.
	<ul style="list-style-type: none"> • There is a single remediation approach that is known to be appropriate, or if there are several possible approaches that may be necessary, they are all comparable in terms of cost. • Characteristics of the waste problem that may affect remediation cost (e.g., waste volumes, contaminant identities and characteristics, and site characteristics) are well-known. • Actual costs may end up being significantly below the best-judgment estimate, but it is very unlikely that they will come out significantly higher.
1	The upside uncertainty is moderate.
	<ul style="list-style-type: none"> • There are several possible remediation approaches that may be necessary, and they differ in cost. • Current judgments about characteristics of the waste problem that may affect remediation cost (e.g., waste volumes, contaminant identities and characteristics, and site characteristics) are uncertain. • Actual costs could possibly (1 chance in 100) end up being up to 100 times (two orders of magnitude) higher than the best-judgment estimate.
2	The upside uncertainty is high.
	<ul style="list-style-type: none"> • There is very little information available to indicate what type of remediation will be necessary, and a number of remediation approaches with radically different costs could conceivably be required. • Current judgments about characteristics of the waste problem that may affect remediation cost (e.g., waste volumes, contaminant identities and characteristics, and site characteristics) are highly uncertain. • Actual costs could possibly (1 chance in 100) end up being up to 10,000 times (four orders of magnitude) higher than the best-judgment estimate.
3	The upside uncertainty is very high.
	<ul style="list-style-type: none"> • There is no basis for determining what remediation approach will be necessary. Virtually any remediation approach could conceivably be required, and it is very difficult to establish an upper bound on what the cost of remediation will be. • Current judgments about characteristics of the waste problem that may affect remediation cost (e.g., waste volumes, contaminant identities and characteristics, and site characteristics) are almost totally unknown. • Actual costs could possibly (1 chance in 100) end up being up to 1,000,000 times (six orders of magnitude) higher than the best-judgment estimate.

* Because the scale is logarithmic with two orders of magnitude change per unit change in score, if uncertainty is such that actual risks could be 1, 3, or 5 orders of magnitude higher than the best judgment, assign a score of 0.5, 1.5, or 2.5, respectively.

LANL ER SITE RANKING SYSTEM BRIEFING

March 15, 1993

LANL

Lars Soholt

**Applied Decision Analysis
2710 Sand Hill Road
Menlo Park, CA 94025**

Lee Merkhofer
Mike Voth
Antje Kann

LANL ER SITE RANKING SYSTEM BRIEFING

March 16, 1993

LANL

Lars Soholt

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Agenda

- Project Objectives and Intended System Role
- History of System Development
- Model Overview
- Application Overview
- The Scoring Process

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Project Objectives

Develop a formal system for aiding LANL environmental restoration decisions. The system should help:

- Improve LANL prioritization and scheduling decisions
- Defend LANL decisions to EPA and others
- Assist OUPs by providing information and analyses useful for planning

The Intended Role of the System is:

- To aid decisions, but not replace the decision making process
- To generate insights and permit analysis of “what if” questions
- To help explain the factors that logically influence decision making

The System May Be Useful in a Variety of Contexts

- Help determine where work can be slowed in the event of a funding shortfall and where work should be accelerated in the event of a funding surplus
- Help identify potential adverse impacts (e.g., worker risks, socioeconomic impacts) requiring mitigation
- Help identify sites to consider for no further actions
- Help develop inputs for the HQ Priority System that will allow LANL to compete effectively in the competition for funds
- Risk and risk timing information may facilitate the negotiation and renegotiation of cleanup schedules

Agenda

- Project Objectives and Intended System Role
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Assumptions Guided the Selection of a System Methodology

- The system should account for risk, but should also address other factors important to decision making
- In the absence of hard data, the system should be capable of relying on professional judgment for input
- The system should be accurate and logically defensible (e.g., pass technical peer review)
- The system should be no more complex than necessary

A Deliberate Process Was Used to Obtain a System Design

- Factors important to decision making were identified
- Alternative approaches were evaluated and a preferred approach identified
- An initial implementation was developed and tested
- A revised design was implemented

Factors Identified as Important for Decision Making

- Regulatory requirements
- Health risks to the public
- Health risks to workers
- Risks to the natural environment
- Socioeconomic impacts on the surrounding communities
- Level of existing uncertainties
- Costs

A Site Ranking System Approach Was Chosen

- Options considered included:
 - Site ranking system
 - Activity prioritization system
 - Budget allocation system
- Site ranking was chosen because:
 - It is the least complex approach and can be expanded to a more complicated system design if necessary
 - Site rankings based on risk and other factors were anticipated to be useful to decision making

Multiattribute Utility Analysis (MUA) Was Chosen to Provide Maximum System Defensibility

Recent Independent Peer Reviews of DOE systems based on MUA:

- *National Academy of Sciences Board on Radioactive Waste Management:*

“The use of the multiattribute utility method is appropriate... While recognizing that there is no single, generally accepted procedure for integrating technical, economic, environmental, socioeconomic, and health and safety issues..., the Board believes that the multiattribute utility method used by DOE is a satisfactory and appropriate decision aiding tool.”

- *Independent Technical Review Group:*

“The (DOE ER Priority) system is well-designed, technically competent, appropriate to its purpose, and ready for use.... The key to the system’s design is its explicit acceptance of multiattribute utility as the best approach to such complex prioritization problems. The tool fits the problem very well.”

Some Standard References for MUA

- von Neumann, J., and O. Morgenstern, "Theory of Games and Economic Behavior," 2nd edition, Princeton University Press, Princeton, New Jersey (1947).
- Luce, R. D., and H. Raiffa, "Games and Decisions," Wiley, New York (1957).
- Raiffa, H., "Decision Analysis," Addison-Wesley, Reading, Massachusetts (1968).
- Keeney, R. L., and H. Raiffa, "Decisions with Multiple Objectives," Wiley, New York (1976).
- Von Winterfeldt, D., and W. Edwards, "Decision Analysis and Behavioral Research," Cambridge University Press, New York (1986).

The MUA Process Involves Four Steps

1. Develop a list of objectives
2. Organize objectives into a hierarchy
3. Specify performance measures for indicating the degree to which alternatives achieve objectives
4. Specify a utility function for aggregating performance measures and indicating the overall achievement of objectives

$$U = W_1 U_1(X_1) + W_2 U_2(X_2) + W_3 U_3(X_3) + W_4 U_4(X_4)$$

Six Major Objectives Are Used to Measure Importance

Key Features of System

- Considers full range of site characteristics important to setting priorities
- Provides consistent means for developing and documenting OUPL professional judgments important to prioritizing cleanup work
- Explicitly captures uncertainty in a logically defensible way (probability distributions)
- Separates technical inputs from value judgments, helping to focus disagreements and thereby build understanding and consensus

A Pilot Test was Conducted

- Five OUPLs generated scores for 18 sites in face-to-face meetings with system developers
- Sites were chosen to span a variety of site types (MDAs, Firing Sites, Septic Tanks, Waste Lines, Outfalls, etc.) and waste types (radioactive, non-radioactive, mixed)
- Pilot test participants provided feedback on the technical details of the system and on the scoring process as they generated scores
- Participants judged reasonableness of pilot test results

Pilot Test Conclusions

- Participants
 - were able to provide system inputs
 - felt inputs represented "the right questions"
 - thought overall rankings seemed reasonable
 - were concerned about repeatability of scores
 - were concerned about time required to score
- System results are not overly sensitive to errors in scores/weights
- Useful improvements and simplifications in system design were identified

Ranking of Waste Units in Pilot Test

A Review of the System was Conducted

- OUPLs who did not participate in the Pilot Test and other Laboratory personnel were given a detailed briefing.
- System was revised according to reviewer suggestions.

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Health Risk is Calculated from Five Measures

Logic for Quantifying Health Risk

I) Estimate level of risk

II) Incorporate timing and uncertainty in risk

Environmental Risk is Calculated from Three Measures

Logic for Quantifying Environmental Risk

Resources at Risk Score	
Spotted Owl Habitat	2
Bald Eagle Habitat	3
<hr/>	
Sum	5

X

Impact on Resources
<ul style="list-style-type: none"> • No possibility of exposures • • • Widespread and severe damage is likely

Risk Uncertainty
<p>How much is known about this risk concern?</p> <p>Is there a 1% chance risks could be:</p> <ul style="list-style-type: none"> -- 10 times higher -- 100 times higher ...

Socioeconomic Impact is Calculated from Two Measures

Logic for Quantifying Socioeconomic Impact

Cost Escalation is Calculated from Three Measures

Logic for Quantifying Cost Escalation

Cost of Remediation and Uncertainty

X

Escalation Rate

1%	-	Real cost increases only slightly over 5 years
100%	-	Real cost doubles over 5 years

Value of Resolving Uncertainty is Calculated from Three Measures

Logic for Quantifying Value of Resolving Uncertainty

Probability distributions on risk and cost are used to calculate the benefits of resolving risk and cost uncertainty according to standard Value of Information Theory

The Measures for Each Objective Must be Combined into a Single Measure of the Importance of Addressing a Waste Unit

The Measures are Combined Using Weights Which Represent Value Judgments About the Relative Importance of the Criteria

MEASURES

Worker Health

Public Health

Environment

Socioeconomics

Site Degradation

Risk Uncertainty

WEIGHTS

W 1

W 2

W 3

W 4

W 5

W 6

Basis for Weighting the Objectives

Worker Health Risk	\$2.5M / statistical fatality averted, 5% discount rate
Public Health Risk	\$5M / statistical fatality averted, 5% discount rate
Environmental Risk	\$25M/averted destruction of resource equivalent to a wetland
Socioeconomic Impacts	Worst case public concern equivalent to \$10M economic impact
Cost Escalation	10% discount rate applied to future cost increases

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Application will be Conducted in Six Steps

Scoring Assistance Sessions:

System developers help OU Scorers begin scoring PRSs

Preliminary Scoring:

OU Scorers score all PRSs

Quality Assurance Sessions:

OU Scorers meet to discuss rationale for their scores

Final Scoring:

OU Scorers make changes in scores according to suggestions from Quality Assurance sessions

Analysis & Presentation of Results:

Ranking of PRSs and other outputs produced based on scores; results discussed and reviewed

Scoring Assistance Sessions

January 6-8

PRS	Description
1000	_____
1001	_____
1002	_____
1003	_____
1004	_____
1005	_____
.	.
.	.

- A set of 3-5 PRSs to score should be identified in advance
 - PRSs chosen should span the variety of OU waste problems and should include the PRSs deemed hardest to score
-
- OU Scorers meet individually with system developers to score these PRSs
 - Hands-on experience will clarify the scoring process, preparing OU Scorers to score their remaining PRSs

Preliminary Scoring

January 11-28

- A set of scores will be assigned to each PRS or group of PRSs according to the Scoring Instructions
- OU Scorers should work in consultation with any relevant OU or Lab experts so that scores represent the best available information
- Lab experts and system developers will be available by phone to answer questions
- Scores for all PRSs are due January 29

Scoring Instructions

PRS	Scores				
1001	2	2	0	1	...
1002	1	1	0	1	...
1003	3	2	1	1	...
1004	2	1	2	0	...
1005	2	1	3	3	...
.	.	.	.	.	.
.	.	.	.	.	.

Quality Assurance Sessions

February 2-4

- Several OU Scorers will meet at each of three one-day meetings
- A preliminary ranking of PRSs will be presented and discussed
- PRSs that rank higher or lower than expected will be highlighted

RANKING						
PRS	Importance	Scores				
1005	I	2	1	3	3	...
1003	I	3	2	1	1	...
1001	II	2	2	1	0	...
1004	II	2	1	2	0	...
.	.	.	.	.	.	.
.	.	.	.	.	.	.

- OU Scorers will be asked to explain the rationale behind scores for highlighted PRSs
- Any problems with or inconsistencies in scoring will be identified and corrections will be suggested

Final Scoring

February 5-18

- OU Scorers will make scoring changes as suggested at Quality Assurance sessions
- System developers and Lab experts will be available to assist in finalizing scores
- Final scores for all PRSs are due February 19

PRS	Scores				
1001	2	2	0	1	...
1002	1	1	0	1	...
1003	2 ²	2	1	1	...
1004	2	1	2	0	...
1005	2	1	3	3	...
.	.	.	.	.	.
.	.	.	.	.	.

Analysis and Presentation of Results February 22-March 9

- Scores for each waste unit are combined to provide a measure of importance for addressing the waste unit

- By logically aggregating and categorizing results, the system can produce various outputs

- A results presentation on March 9 will give OU Scorers a chance to review System results before the final application report is written

Agenda

- Project Objectives and Intended System Role
- History of System Development
- Model Overview
- Application Overview
- **The Scoring Process**

There are Five Steps in the Scoring Process

1. Identify waste units to be scored
2. Group waste units of similar types
3. Select one waste unit from each group to score
4. Score each selected waste unit
5. Assign scores to the remaining waste unit in each group

Step 1: Identify Waste Units to be Scored

- Generally, a waste unit is a single PRS. In some cases, a waste unit will consist of several PRSs, according to Rules of Aggregation.

Step 1: Identify Waste Units to be Scored (continued)

- Rules for Aggregation Were Developed to Clarify the Definition of a Waste Unit

A waste concern is defined to be the smallest (most disaggregated) waste problem that can be independently identified

- Generally, a PRS (i.e., HSWA-SWMU, RCRA SWMU, AOC, or area-wide contamination)

Waste concerns should be grouped into a waste unit if:

- Contaminants are intermingled and no longer distinguishable.
- Waste concerns cannot be remediated separately.
- Waste concerns cannot be characterized separately.

Waste concerns should NOT be grouped if:

- There is any doubt that one of the above justifications for grouping apply, e.g., if waste concerns are spatially separated.

Steps 2-3: Group Similar Waste Units, Select One to Score

- Scoring is simplified if similar waste units are grouped and only a single waste unit from each group is scored in detail
- Other waste units in each group can be scored by adjusting the scores assigned to this waste unit

Guidelines for grouping:

- Waste units are of same type
- Same risk concern
 - Risk agents
 - Exposure mechanisms
 - Populations at risk
- Do not group if two waste units are so different that its easier to score separately

Step 4: Score Each Selected Waste Unit

- OU Scorers assign scores to each waste unit by estimating how bad problems at the waste unit are according to specific criteria
- A scoring manual provides an objective basis for assigned scores for each criterion

Scoring Manual

Scoring Scale

Scoring Form

PRS #	Health	Env	Unc	Soc	Degr
#	2	3	1	2	2
#	1	1	2	1	1
#					
#					
#					
#					

Scores are Assigned for Six Major Objectives

Public and Worker Health Risk are Scored Similarly

Identify the Most Significant Public and Worker Health Risk Concerns for the Waste Unit

1. What is the risk agent?
2. Are exposures occurring now or in the future?
3. Does exposure require some unlikely initiating event?
4. What is the exposure pathway?
5. What population is at risk?

This information should be recorded on the Waste Unit Information form for both Workers and the Public

A WASTE UNIT INFORMATION (WU) FORM															Name of Owner: JOHN DOE		OU# 2222		TAX# 77	
B Describe the Waste Unit: MATERIAL DISPOSAL AREA																				
Check appropriate box for the Waste Unit type:															Storage: ☐ NDA ☐ Spill Tank ☐ Waste Line ☐ Dump ☐ Outfall ☐ Canyon ☐ Other (specify):					
List the PDS number(s) that constitute(s) this Waste Unit: 77-003																				
If you are grouping PDSs, state your reasoning:																				
Check the PDS type: HSWA-SWMB ☐ RCRA-SWMB ☐ Area of Concern ☐															Non-hazard waste ☐		Radioactive waste ☐		Mixed waste ☐	
Identify the most significant risk concern for the Waste Unit by specifying a risk agent, exposure timing, exposure pathway, and population at risk. Indicate your choices by providing entries or checking the appropriate boxes below. (W = workers; P = public)																				
III. Exposure Timing																				
Is the exposure scenario likely to result in long-term (chronic) exposures, or short-term (acute) exposures?															Chronic ☐ Acute ☒					
If chronic, describe the potential exposure pathway:																				
Chronic inhalation of contaminated dust? ☐															W ☐ P ☐					
Chronic ingestion of contaminated substances, e.g., soil, drinking water, produce? ☐															W ☐ P ☐					
Chronic dermal contact with contaminant, e.g., handling contaminated material? ☐															W ☐ P ☐					
Chronic low-level external radiation exposure? ☐															W ☐ P ☐					
Other? (specify below):																				
IV. Population at Risk																				
Is the population at risk?															W ☐ P ☐					
Maintenance workers ☐																				
Road workers ☐																				
Construction workers ☐																				
Workers on light break ☐																				
Resident workers ☐																				
Nearby residents ☐																				
Joggers/bikers ☐																				
Park visitors ☐																				
Caretakers ☐																				
Playing children ☐																				
Benevolence ☐																				
Trepanners ☒																				
People drinking on nearby roads ☐																				
Farmers/ign. dependents ☐																				
Hunters/fishers ☐																				
Horned animals ☐																				
Other? (specify below):																				
W ☐ P ☐																				
V. Forced Entry																				
Is there a forced entry? ☐															W ☐ P ☐					
If yes, specify the type of forced entry:																				
Radiation ☐																				
VOCs ☐																				
Semi-volatile org. compounds ☐																				
Heavy metals ☐																				
High explosives ☐																				
Toxic chemicals ☐																				
Other? (specify below):																				
W ☐ P ☐																				

Health Risk is Calculated from Five Measures

Score Risk Source Hazard

- Depends on type and quantity of the specified risk agent
- Does not depend on likelihood of exposures or population at risk

If the risk agent is . . .

Known, chemical

Known, radionuclide

Known, physical

Unknown or not listed on other tables

Use Table . . .

1A (5A for Public)

1B (5B for Public)

1C (5C for Public)

1D (5D for Public)

Scoring Risk Source Hazard - Example A

The risk agent for the risk concern is soil contaminated with Plutonium-239. The scorer estimates that the soil is contaminated at a level of roughly 200 pCi/gram and that there are approximately 50 tons of soil so contaminated. According to Table 1B (see entry under "Pu-239"), the hazard score is 2.0.

Table 1B. HAZARD OF THE RISK SOURCE - WORKERS (Continued)

		Quantity								
gallons	0.01	0.1	1	10	100	1,000	10,000	100,000	1.00E+06	
cubic yards			0.005	0.05	0.5	5	50	500	5,000	
tons			0.005	0.05	0.5	5	50	500	5,000	
drums			0.02	0.2	2	20	200	2,000	20,000	
lbs	0.1	1	10	100	1,000	10,000	100,000	1.00E+06	1.00E+07	
Chemical	Toxicity									
...										
Pu-238, soil contaminated at 2200 pCi/g		0.3	0.7	1.0	1.3	1.7	2.0	2.3	2.7	3.0
Pu-239, soil contaminated at 20 pCi/g				0.3	0.7	1.0	1.3	1.7	2.0	2.3
Pu-239, soil contaminated at 200 pCi/g			0.3	0.7	1.0	1.3	1.7	2.0	2.3	2.7
Pu-239, soil contaminated at 2000 pCi/g		0.3	0.7	1.0	1.3	1.7	2.0	2.3	2.7	3.0
...										
U-238, soil contaminated at 4800 pCi/g		0.3	0.7	1.0	1.3	1.7	2.0	2.3	2.7	3.0

SCORING FORM		Name of Scorer: JOHN DOE								CUE: 2222				
WASTE UNIT	HEALTH RISK								ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIO-IMPACT	REMEDICATION COST	COST ESC
	Worker Risk				Public Risk				Env. Impact on Env. Resour.		Public Concern	Fraction of Problem	Best Judgment	Cost Uncertainty
	Risk Source		Exposure Potential		Risk Source		Exposure Potential		Env. Resour.					
	Hazard	Timing	Efficiency	Population	Hazard	Timing	Efficiency	Population	Resour.	Resour.				
77-001/2	(2.0)

Scoring Risk Source Hazard - Example B

The Potential Release Site is a medium-sized material disposal area (MDA). The scorer knows that a multitude of different chemicals have been disposed of on this site. Occasionally, smells arise on the site that suggest the presence of volatile organic compounds (VOCs). In addition, some high explosive (HEs) are suspected to be contained in the soil. Since the scorer is uncertain about both quantity and type of the risk agent, Table 1D is the appropriate scoring tool. After reading the descriptions associated with scores 2 and 3, the scorer decides that a score of 2.5 is appropriate since an acute exposure of an hour could result in irreversible health effects, but not necessarily threaten life.

Table 1D. HAZARD OF THE RISK SOURCE - WORKERS (ALTERNATIVE TABLE)

	not be life-threatening (10^{-6} probability).
2	The risk source poses moderate danger.
	<ul style="list-style-type: none"> Contaminated areas could be characterized and remediated only with extreme care - full protective clothing would be required, including self-contained breathing apparatus, rubber gloves, boots, and bands around the legs, arms, and waist.
	<ul style="list-style-type: none"> If exposed to the risk agent under a worst-case environmental exposure scenario, an acute exposure (one hour) would almost certainly cause subjects to experience moderate reversible health effects and could possibly produce irreversible effects as well. Death is unlikely (10^{-5} probability).
	<ul style="list-style-type: none"> Chronic or frequently repeated worst-case environmental exposure scenarios extending over a year would likely produce reversible effects and could produce irreversible, life-threatening effects (10^{-3} probability).
3	The risk source poses high danger.
	<ul style="list-style-type: none"> Contaminated areas could be characterized and remediated only by workers wearing special protective equipment designed to protect against the specific risk agents present.
	<ul style="list-style-type: none"> If exposed to the risk agent under a worst-case environmental exposure scenario, an acute exposure (one hour) would almost certainly cause injury of sufficient severity to threaten life (e.g., 1 chance in 100 of death) or produce permanent physical impairment or disfigurement.
	<ul style="list-style-type: none"> Chronic or frequently repeated worst-case environmental exposure scenarios extended over a year would almost certainly produce life-threatening effects.

*By "worst-case environmental exposure scenario" we mean the scenario that would be used in conservative risk assessment to calculate maximum individual risk at the site. This is the highest level of exposure that could realistically occur, taking into account estimated quantities and concentrations and the physical properties of the hazard (e.g., solubility, volatility, propensity for bioaccumulation, rate of degradation, etc.). Conceptually, it is the maximum exposure that could occur to an individual who takes no steps for self protection (due to ignorance of the danger posed) and is extremely unlucky (the collection of chance events is such as to maximize the potential for exposure).

Score Exposure Timing

- Measures the amount of time before exposures are expected to occur
- Allows the model to put more weight on more imminent risks
- Timing score is based on one of two phenomena:
 - Exposures are delayed due to slow transport
 - Exposures require some unlikely initiating event

If you wish to . . .

Assign a rough score according to qualitative descriptors

Assign a score between the qualitative descriptors provided

Use Table . . .

2A (6A for Public)

2B (6B for Public)

Scoring Exposure Timing - Example A

Most of the radioactive materials are several feet below ground. The scorer estimates that erosion may make contaminants accessible to workers in approximately 25 years. Using the second column of Table 2A, an exposure timing score of 1.0 is assigned.

Table 2A. WORKER EXPOSURE TIMING

Use this table to assign scores indicating how soon exposures to workers are expected to occur. If exposures are being delayed due to slow transport mechanisms, base your scores on how much longer (in years) transport to the worker population is likely to take. If exposures require an initiating event, pick your scores according to your estimate of the probability of occurrence of the event. Use Table 2B to interpolate noninteger scores.

0	Risks will not occur during the period of institutional control. <ul style="list-style-type: none"> There are no credible pathways by which workers might be exposed. Physical or institutional control is completely effective. So long as this control is maintained, there can be no exposures to workers.
1	Roughly twenty-five years, because transport mechanisms are extremely slow and/or initiating events are extremely unlikely. <ul style="list-style-type: none"> If exposures require an initiating event, there is roughly one chance in 3 of it occurring within 100 years (annual probability of occurrence of roughly 1 in 30). If exposures to workers require transport or erosion, these processes are extremely slow and are unlikely to result in exposures within twenty-five years.
2	Roughly five years, because transport mechanisms are moderately slow. <ul style="list-style-type: none"> If exposures require an initiating event, the annual probability of occurrence is

SCORING FORM										Name of Scorer		JOHN DOE		CU#		2222	
WASTE UNIT	HEALTH RISK								ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT	REMEDIALTION COST		COST ESC.		
	Worker Risk				Public Risk												
	Risk Source		Exposure Potential		Risk Source		Exposure Potential		Env. Impact			Fraction of Public Concern	Estimated Problem	Best Judgment	Cost Uncertainty		
	Hazard	Timing	Efficiency	Population	Hazard	Timing	Efficiency	Population	Resour.	Resour.							
77-004	2.0	1.0

Scoring Exposure Timing - Example B

The potential release site is a sump in which heavy metals have been found at high concentrations. There are no exposures occurring, and the scorer judges that exposures would only occur if the sump overflowed. This would require the unlikely event of a flash flood. The scorer estimates that the probability of a flash flood is about 5% per year, since only one flash flood has been recorded in the past twenty years. Therefore, a score of 1.4 is assigned from Table 2B.

Table 2B. WORKER EXPOSURE TIMING (NONINTEGER SCORES)

Annual Probability (P)	Years (X)	Score (Y)*
Less than or equal to 0.5%	Greater than or equal to 125	0.0
	100	0.1
	90	0.2
	80	0.3
1%	70	0.4
	60	0.5
	50	0.6
	40	0.7
2%	35	0.8
	30	0.9
3%	25	1.0
	20	1.1
4%	15	1.3
5%	13	1.4
	12	1.5
6%	11	1.5

...

Score Exposure Efficiency

- Measures how severe exposures are likely to be when risks are at or near their peak
- Measured relative to a “worst-case” exposure scenario involving constant exposure at worst-case levels
- Scored either of two ways:
 - **Acute:** exposures are at worst-case levels for less than 40 hours per year
 - **Chronic:** exposures are virtually continuous but are at less than worst case levels

If you wish to . . .

Assign a rough score according
according to qualitative descriptors

Assign a score between the
qualitative descriptors provided

Use Table . . .

3A (7A for Public)

3B (7B for Public)

Scoring Exposure Efficiency - Example A

The material disposal area described above is located approximately 300 feet from a building in which workers spend several hours per day. These workers have recorded instances in the past where they could smell some fumes that were attributed to the MDA. However, the wind generally blows away from the building towards the MDA. Therefore, exposure levels are assumed to be only 1/100 as bad as the worst case scenario. The scorer assigns a score of 2 from Table 3A.

Table 3A. WORKER EXPOSURE EFFICIENCY

	and sound containers, covered piles, or uncovered but stabilized waste).
2	The characteristics of the risk agent and local environment are such that workers will be exposed to only very small quantities or fractions of the waste unit's risk agents per year.
	<ul style="list-style-type: none"> If exposures are acute, a typical exposed worker will be exposed at significant (worst-case) levels for a duration of about one hour per year or per event. If exposures are chronic (more than 40 hrs/yr), exposure levels are likely to be on the order of 10^{-2} of the "worst-case environmental exposure scenario" because: <ul style="list-style-type: none"> Although not fully reliable, controls discourage direct exposures to contaminants contained at the waste unit, and migration of risk agents out of controlled areas is inefficient or unlikely. For example, the significant risk agent may be a moderately consolidated solid, or containment of the risk agent appears reasonably sound (e.g., moderately permeable liner without leachate collection system, uncovered piles with unstable waste, landfill surface that precludes ponding).

(continued on next page)

SCORING FORM										Name of Scorer: JOHN DOE		ID# 2222		
WASTE UNIT	HEALTH RISK								ENVIRONMENTAL RISK		SOCIO-IMPACT		REMEDICATION COST	
	Worker Risk				Public Risk				UNCERTAIN		IMPACT		COST	
	Risk Source	Exposure Potential	Risk Source	Exposure Potential	Env. Impact	TAINTY	Public Concern	Fraction of Problem	Best Judg. mnt	Cost Uncertainty				
	Hazard	Timing	Efficiency	Population	Hazard	Timing	Efficiency	Population	Resour.	Resour.				
77-003	2.0	1.0	2.0

Scoring Exposure Efficiency - Example B

Even once the radioactive materials are potentially accessible to workers, exposures are likely to be rare due to the remote location of the site. Workers may be exposed for up to one hour per year during routine surveillance. Using the second column of Table 3B, an exposure efficiency score of 2.0 is assigned.

Table 3B. WORKER EXPOSURE EFFICIENCY (NONINTEGER SCORES)

CHRONIC EXPOSURES Fraction of Worst Case (X1)	ACUTE EXPOSURES Duration (X2)	Score (Y)*
Less than or equal to 1E-06		0.0
3.00E-06	1 second	0.2
1.00E-05		0.5
2.00E-05	5 seconds	0.6
3.00E-05	10 seconds	0.7
5.00E-05	15 seconds	0.9
1.00E-04	30 seconds	1.0
2.00E-04	1 minute	1.2
4.00E-04	2 minutes	1.3
1.00E-03	5 minutes	1.5
2.00E-03	10 minutes	1.6
3.00E-03	15 minutes	1.7
4.00E-03	20 minutes	1.8
6.00E-03	30 minutes	1.9
1.00E-02	1 hour	2.0
...		
0.5	40 hours+	2.9
1.0		3.0

Score Population at Risk

- Measures the number of people who may be exposed annually at the levels indicated by exposure efficiency scores when risk is at its peak
- Use Table 4 (8 for public)

Scoring Population at Risk - Example A

The scorer estimates that roughly two workers will be exposed per year. According to Table 4, a score of 0.8 is assigned.

Table 4. WORKER POPULATION AT RISK

Population (X)	Score (Y)*
0	0
1	0.6
2	0.8
3	1
4	1.1
5	1.1
7	1.2
10	1.3
20	1.5
...	
2,000	2.9
3,000	3

SCORING FORM										Name of Scorer: JOHN DOE										COW: 2222														
WASTE UNIT															HEALTH RISK										ENVIRONMENTAL RISK		RISK UNCERTAINTY		SOCIO-IMPACT		REMEDIATION COST		COST ESC.	
															Worker Risk					Public Risk					Env. Impact			Resource	Resource	Public Concern		Problem		Best Judgment
Risk Source Hazard					Exposure Potential Timing Efficiency Population					Risk Source Hazard Timing Efficiency Population					Env. Impact Resource			Resource	Public Concern		Problem		Best Judgment		Cost Uncertainty									
77-003					2.0 1.0 2.0 0.8

Scoring Population at Risk - Example B

The scorer knows that a work force of exactly 15 people is active in the building located near the MDA. Since no score is provided for 15 people, the scorer decided to use the interpolation aide provided at the bottom of the table:

$$y = \frac{\log(9 \cdot 15)}{\log 30} = 1.44$$

Since only one decimal place is required, the scorer assigns a score of 1.4.

Table 4. WORKER POPULATION AT RISK

. . .	
1,000	2.7
2,000	2.9
3,000	3.0

*Interpolate using:

$$Y = \frac{\log(9X)}{\log 30}$$

Environmental Risk is Calculated from Three Measures

Score Environmental Resources at Risk

- Identify environmental resources *potentially* at risk from the waste unit
- Assume resources within 4 miles qualify, unless better information is available

Table 9. ENVIRONMENTAL RESOURCES AT RISK

Sensitive Resource	Score
Plants and animals not listed below	1
San Ildefonso Hunting Lands	2
Jemez Salamander Habitat	4
Spotted Owl Habitat	4
Grama Grass Cactus	6
Bald Eagle Habitat	6
Wetlands in Pajarito Canyon	6
Peregrine Habitat	6
Bandelier National Monument	8
Bandelier Wilderness Area	8

$$4 + 6 = 10$$

- Use Table 9 to identify resources
- Sum individual resource scores to obtain total resources at risk score

Scoring Environmental Resources at Risk

The scorer determines that there are sensitive plants and animals in the vicinity of the waste unit and that within 4 miles there are habitats for the Jemez Salamander and the Spotted Owl. Based on Table 9, an environmental resources score of 1+4+4=9 is assigned.

Table 9. ENVIRONMENTAL RESOURCES AT RISK

Sensitive Resource	Score
Plants and animals not listed below	1
San Ildefonso Hunting Lands	2
Jemez Salamander Habitat	4
Spotted Owl Habitat	4
Grama Grass Cactus	6
Bald Eagle Habitat	6
Wetlands in Pajarito Canyon	6
Peregrine Habitat	6
Bandelier National Monument	8
Bandelier Wilderness Area	8

SCORING FORM				Name of Scorer: JOHN DOE				CU#: 2222							
WASTE UNIT	HEALTH RISK								ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIOECONOMIC IMPACT	REMEDIAL COST	COST EST.	
	Worker Risk				Public Risk				Env. Resour.	Impact on Env. Resour.	TAINTY	Public Condem.	Fraction of Problem	Est. Cost	Cost Uncertainty
	Risk Source Hazard	Exposure Potential	Risk Source Hazard	Exposure Potential											
	Timing	Efficiency	Population	Timing	Efficiency	Population									
77-003	2.0	1.0	2.0	0.8	1.9	3.0	1.0	1.6	9

Score Impact on Environmental Resources

- Measures the extent of impact of the waste unit on the identified resources
- If different resources are impacted differently, assigned score should reflect the average impact
- Use Table 10

Scoring Impact on Environmental Resources

Although an impact of the waste unit on these resources is possible, there is no evidence of a decrease in environmental quality to date. It is reasoned that environmental exposures would, at worst, produce only minor, temporary impacts. According to Table 10, an environmental impact score of 1.0 is assigned.

Table 10. IMPACT ON ENVIRONMENTAL RESOURCES

0	The waste unit poses no threat to the environment.
*	The nature of risk agents and environmental pathways precludes exposures to sensitive environmental resources.
1	The waste unit poses a very low threat to the environment.
*	The nature of risk agents and environmental pathways are such that there is no credible scenario by which for exposures to sensitive environmental resources could cause toxic effects.
*	There are no observations indicating any decrease in environmental quality as a result of the waste unit.
3	The waste unit poses a very high threat to the environment.
*	The nature of risk agents and environmental pathways are such that likely scenarios for exposing sensitive environmental resources would result in widespread and severe damage to sensitive species or destruction of unique historical properties.
*	Observations indicate that environmental quality has significantly or rapidly decreased over time.
*	Action to prevent further damage will probably be needed in less than 5 years to avoid irreversible damage.

SCORING FORM				Name of Scorer: JOHN DOE				CU#: 2222						
WASTE UNIT	HEALTH RISK								ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIO-IMPACT	REMEDIATION COST	COST ESC.
	Worker Risk				Public Risk				Env. Impact Resource	Impact on Env. Resource	Public Concern	Remed. Problem	Best Judgment	Cost Uncertainty
	Risk Source	Exposure Potential			Risk Source	Exposure Potential								
	Hazard	Timing	Efficiency	Population	Hazard	Timing	Efficiency	Population						
77-004	2.0	1.0	2.0	0.8	1.9	3.0	1.0	1.6	9	1.0

Score Risk Uncertainty

- Measures uncertainty in public and worker health risk as well as in environmental risk
- Think of current knowledge about risks as a probability distribution
- How high above your best judgment of site risks is the level at which you can be 99% sure that risks are no higher
- Be sure to consider all sources of uncertainty:
 - Source term constituents and quantity
 - Exposure efficiency
 - Populations at risk
 - Impacts on environmental resources
- Use Table 11

Scoring Risk Uncertainty - Example A

The scorer estimates that there is a possible scenario (1 in 100 chance) wherein the quantity of the source term could be one order of magnitude higher than the best judgment estimate, exposure efficiency could be two orders of magnitude higher, and population at risk could be one order of magnitude higher. The scorer therefore reasons that total uncertainty is roughly $1+2+1=4$ orders of magnitude. According to Table 11, a score of 2.0 is assigned.

Table 11. RISK UNCERTAINTY

0	The upside uncertainty is very low.
	<ul style="list-style-type: none"> Waste volumes; contaminant identities; contaminant concentrations and release potential; site characteristics that may affect fate, transport, and persistence of contaminants; potential exposure pathways; and potential receptors at risk (abbreviated as source terms, pathways, and receptors below) have already been well-established, and the level of risk is clearly defined or bounded. Actual risks may end up being significantly below the best-judgment estimate, but it is very unlikely that they will come out significantly higher.
2	The upside uncertainty is high.
	<ul style="list-style-type: none"> Current risk judgments are highly uncertain. Source terms, pathways, and receptors at risk are largely unknown. Actual risks could possibly (1 chance in 100) end up being up to 10,000 times (four orders of magnitude) higher than the best-judgment estimate.
3	The upside uncertainty is very high.
	<ul style="list-style-type: none"> Current risk judgments have no basis whatsoever. Source terms, pathways, and receptors at risk are almost totally unknown. Actual risks could possibly (1 chance in 100) end up being up to 1,000,000 or more times (six orders of magnitude) higher than the best-judgment estimate.

SCORING FORM										Name of Scorer: JOHN DOE		CU# 2222				
WASTE UNIT	HEALTH RISK								ENVIRONMENTAL RISK		RISK UNCER TAINTY	SOCIO IMPACT		REMEDIATION COST		COST ESC.
	Worker Risk				Public Risk											
	Exposure Potential		Risk		Exposure Potential		Risk		Impact			Fraction		Best		
	Source	Hazard	Timing	Efficiency	Population	Source	Hazard	Timing	Efficiency	Population		Env. Receptor	on Env. Receptor	Public Concern	of Problems	
77-003	2.0	1.0	2.0	0.8	1.9	3.0	1.0	1.6	9	1.0	2.0

Scoring Risk Uncertainty - Example B

The scorer is uncertain about the magnitude of hazard at the MDA, but judges that all other scores are not unlikely to be any higher than his best judgment estimates. The scorer reasons that there is some chance a score of 3 would apply rather than the best judgment risk source hazard score of 2. The scorer recognizes that a score of 3 on the hazard scale is 1000 times worse than a score of 2. Thus, he should assign a risk uncertainty score between 1 and 2. Recognizing the logarithmic nature of the risk uncertainty scale, the scorer assigns a score of 1.5.

Table 11. RISK UNCERTAINTY

0	The upside uncertainty is very low.
*	Waste volumes; contaminant identities; contaminant concentrations and release potential; site characteristics that may affect fate, transport, and persistence of contaminants; potential exposure pathways; and potential receptors at risk (abbreviated as source terms, pathways, and receptors below) have already been well-established, and the level of risk is clearly defined or bounded.
*	Actual risks may end up being significantly below the best-judgment estimate, but it is very unlikely that they will come out significantly higher.
...	
2	The upside uncertainty is high.
*	Current risk judgments are highly uncertain. Source terms, pathways, and receptors at risk are largely unknown.
*	Actual risks could possibly (1 chance in 100) end up being up to 10,000 times (four orders of magnitude) higher than the best-judgment estimate.
3	The upside uncertainty is very high.
*	Current risk judgments have no basis whatsoever. Source terms, pathways, and receptors at risk are almost totally unknown.
*	Actual risks could possibly (1 chance in 100) end up being up to 1,000,000 or more times (six orders of magnitude) higher than the best-judgment estimate.

Table to be redone

Socioeconomic Impact is Calculated from Two Measures

Score Level of Public Concern

- Measures public concern in terms of:
 - Public awareness
 - Public actions
 - Claimed economic losses
- Score based on the smallest problem recognized by the public that includes the waste unit
- Use Table 12

Scoring Level of Public Concern

The area in the canyon to which runoff from the waste unit drains is popularly called "Radioactive Creek." Negative news stories appear several times per year in newspapers serving communities in the surrounding area. There have been occasional stories in Albuquerque papers. According to Table 12, a score of 2.5 is assigned to the level of public concern.

Table 12. LEVEL OF PUBLIC CONCERN

0	The problem of which the waste unit is a part generates no incremental public concern.
	<ul style="list-style-type: none"> People are not aware of the waste unit or any problem definition that includes the waste unit other than the Laboratory as a whole. People are aware of a distinct problem definition including the waste unit, but don't have any concern about the specific problem incremental to their concern about the Laboratory as a whole.
2	The problem of which the waste unit is a part generates moderate public concern.
	<ul style="list-style-type: none"> There are occasional (several times per year) negative news stories about the problem in the media serving the localized communities within the surrounding area. Claimed economic impacts on the community are roughly \$100,000 total or \$10,000 annually.
3	The problem of which the waste unit is a part generates very high public concern.
	<ul style="list-style-type: none"> There is frequent (greater than monthly) negative news coverage in Santa Fe and Albuquerque and occasional news stories in national media about the problem and there have been small-scale protests. Local referenda related to the problem are likely and state officials are getting involved. Claimed economic impacts on the community are on the order of \$10 million or more total, or \$1 million annually.

SCORING FORM										Name of Scorer: JOHN DOE		CU#: 2222	
WASTE UNIT	HEALTH RISK								ENVIRONMENTAL RISK	RISK UNCERTAINTY	SOCIO-IMPACT	REMEDICATION COST	COST ESC.
	Worker Risk				Public Risk								
	Risk Source Hazard	Exposure Potential	Risk Source Hazard	Exposure Potential	Risk Source Hazard	Exposure Potential	Risk Source Hazard	Exposure Potential					
77-004	2.0	1.0	2.0	0.8	1.9	3.0	1.0	1.6	9	1.0	2.0	2.0

Score Fraction of Problem

- Measures what fraction of the problem recognized by the public this waste unit represents

If you wish to . . .

Assign a rough score

Interpolate between rough scores

Use Table . . .

13A

13B

Scoring Fraction of Problem - Example A

The waste unit is not the only source of radioactive contamination in the creek. Five waste units are part of the problem covered in the news stories. However, one of the other waste units is causing most of the concern. Because the waste unit is a relatively small contributor (roughly 10%), a score of 2.0 is assigned to the fraction of the problem attributed to the waste unit, based on Table 13A.

Table 13A. FRACTION OF PROBLEM ATTRIBUTED TO WASTE UNIT

0	The public is not aware of the waste unit and does not associate it with any specific problems about which they have concern. From the public perspective, it is merely part of the total LANL ER problem.
1	The waste unit is a very small fraction (roughly 1%) of the problem perceived by the public.
②	The waste unit is a moderate fraction (roughly 10%) of the problem perceived by the public.
3	The waste unit is specifically identified in the mind of the public as the problem of concern.

SCORING FORM														Name of Scorer		JOHN DOE		OU#		2222	
WASTE UNIT	HEALTH RISK								ENVIRONMENTAL RISK		RISK UNCERTAINTY	SOCIO-IMPACT	REMEDIATION COST		COST ESC.						
	Worker Risk				Public Risk				Env. Impact on Env. Resour.	Reactive	Public Concern	Fraction of Problem	Best Management	Cost Uncertainty							
	Risk Source Hazard	Exposure Potential	Risk Source Hazard	Exposure Potential																	
	Timing	Efficiency	Population	Population																	
77-004	2.0	1.0	2.0	0.8	1.9	3.0	1.0	1.6	9	1.0	2.0	2.0	②.0

Scoring Fraction of Problem - Example B

The waste unit is one of three sites that are undifferentiated in news coverage. All three sites are considered to contribute equally (1/3) to the perceived problem. The scorer assigns a score of 2.5 using Table 13B.

**Table 13B. FRACTION OF THE PROBLEM ATTRIBUTED TO WASTE UNIT
(NONINTEGER SCORES)**

Use this table to assign noninteger scores for the percent of the problem, as you defined it in Table 11, that should be attributed to the waste unit.

Percent (X)	Score (Y)*
Less than or equal to 0.1%	0.0
0.20%	0.3
0.30%	0.5
0.40%	0.6
0.60%	0.8
0.70%	0.9
1%	1.0
2%	1.3
3%	1.5
4%	1.6
5%	1.7
6%	1.8
7%	1.9
10%	2.0
20%	2.3
30%	2.5
40%	2.6
50%	2.7
60%	2.8
70%	2.9
100%	3.0

*Interpolate using:

$$Y = 3 + \log(X), \text{ where } X \text{ is expressed as a fraction}$$

Cost Escalation is Calculated from Three Measures

Score Remediation Cost

- Measures estimated total cost of remediating the site
- Requires best-judgment estimates of:
 - Remediation approach
 - Physical scope of remediation effort
- Use Table 14

Scoring Remediation Cost

The scorer's best judgment is that it will be necessary to remove 100 cubic yards of soil. According to Table 14, the score corresponding to removing 100 cubic yards of radioactive soil is 0.7.

Table 14. MATRIX FOR DETERMINING REMEDIATION COST SCORE*

Remediation Approach	Quantity				
	10 cy	100 cy	1000 cy	10000 cy	100000 cy
Soil Excavation					
radioactive	0.2	0.7	1.2	1.7	2.2
mixed waste	0.6	1.1	1.6	2.1	2.6
hazardous waste	0.5	1.0	1.5	2.0	2.5
Septic Tank Removal					
radioactive	0.6	1.1	1.6	2.1	2.6
mixed waste	0.9	1.4	1.9	2.4	2.9
hazardous waste	0.9	1.4	1.9	2.4	2.9
Soil Cap					
	10 sf	100 sf	1000 sf	10000 sf	100000 sf

SCORING FORM										Name of Scorer: JOHN DOE		OU#: 2222								
WASTE UNIT	HEALTH RISK								ENVIRONMENTAL RISK		RISK UNCERTAINTY		SOCIO-IMPACT		REMEDIATION COST		COST ESC.			
	Worker Risk				Public Risk				Impact		TAINTY		Public Concern		Fraction of Problem		Best Judgment		Order of Priority	
	Risk Source	Exposure Potential	Risk Source	Exposure Potential	Env. Resour.	Impact on Env. Resour.	Public Concern	Fraction of Problem	Best Judgment	Order of Priority										
	Hazard	Timing	Efficiency	Population	Hazard	Timing	Efficiency	Population	Resour.	Resour.	Concern	Problem	Judgment	Priority						
77-004	2.0	1.0	2.0	0.8	1.9	3.0	1.0	1.6	9	1.0	2.0	2.0	2.0	0.7

Scoring Remediation Cost - Example B

A monitoring well will be installed. A cost estimate of \$50,000 has already been obtained from an engineering firm. The scorer uses the cost conversion equation at the bottom of the cost table to convert the cost estimate into a score.

$$y = \frac{\log(50,000)}{2} - 1 = 1.3$$

Table 14. MATRIX FOR DETERMINING REMEDIATION COST SCORE*

...

* A score of 1 in this table corresponds to approximately \$10,000, a score of 2 corresponds to approximately \$1,000,000, a score of 3 corresponds to \$100,000,000 and higher.

Cost Adjustment Equation:

To obtain a score that reflects incremental costs in addition to a score obtained in the table, use the following equation:

$$y' = \frac{\log(\text{cost} + 10^{(2\text{score}+2)})}{2} - 1$$

Score Combination Equation:

To obtain a combined score if more than one remediation alternative is needed, use the following equation:

$$y' = \frac{\log(10^{2\text{score}_1} + 10^{2\text{score}_2} + \dots + 10^{2\text{score}_n})}{2}$$

Cost Conversion Equation:

To obtain a score if you have a current cost estimate for the remediation approach, use the following equation:

$$y = \frac{\log(\text{cost})}{2} - 1$$

Score Cost Uncertainty

- Measures uncertainty in the ultimate total cost of remediation
- Analogous to scoring risk uncertainty
- How much higher would your cost estimate have to go to be 99% sure that the eventual cost will be no higher
- Be sure to consider all sources of uncertainty:
 - Remedial approach
 - Physical scope of remediation
- Use Table 15

Scoring Cost Uncertainty

The scorer estimates that there is a possible scenario (1 in 100 chance) wherein as much as 1,000 cubic yards of soil (10 times the best-judgment estimate) would need to be removed and wherein costs would be 10 times higher per cubic yard since much of the additional excavation would have to be done in difficult terrain. Thus, the scorer reasons that cost could possibly (1 chance in 100) be $10 \times 10 = 100$ times higher than the best-judgment estimate. According to Table 15, the appropriate cost uncertainty score is 1.0.

Table 15. COST UNCERTAINTY

0	The upside uncertainty is very low.
*	There is a single remediation approach that is known to be appropriate, or if there are several possible approaches that may be necessary, they are all comparable in terms of cost.
*	Characteristics of the waste problem that may affect remediation cost (e.g., waste volumes, contaminant identities and characteristics, and site characteristics) are well-known.
*	Actual costs may end up being significantly below the best-judgment estimate, but it is very unlikely that they will come out significantly higher.
1	The upside uncertainty is moderate.
*	There are several possible remediation approaches that may be necessary, and they differ in cost.
*	Current judgments about characteristics of the waste problem that may affect remediation cost (e.g., waste volumes, contaminant identities and characteristics, and site characteristics) are uncertain.
*	Actual costs could possibly (1 chance in 100) end up being up to 100 times (two orders of magnitude) higher than the best-judgment estimate.

SCORING FORM										Name of Scorer: JOHN DOE		ID#: 2222					
WASTE UNIT:	HEALTH RISK								ENVIRONMENTAL RISK		RISK UNCERTAINTY		SOCIO IMPACT		REMEDIATION COST		COST ESC
	Worker Risk				Public Risk				Risk		Risk		Risk		Risk		
	Risk Source	Exposure Potential	Risk Source	Exposure Potential	Env. Impact	Impact on Env.	Public Concern	Fraction of Problem	Best Judgment	Cost Under Judgment							
Hazard	Timing	Efficiency	Population	Hazard	Timing	Efficiency	Population	Resource	Resource	Concern	Problem	ment	Under Judgment				
77-004	2.0	1.0	2.0	0.8	1.9	3.0	1.0	1.6	9	1.0	2.0	2.0	2.0	0.7	1.0

Score Cost Escalation

- Measures the rate at which costs may increase due to a 5 year delay in work on the waste unit
 - Consider site deterioration
 - Consider any other factors which may make the site more difficult to remediate if delayed
 - Ignore normal inflation
- Use Table 16

The scorer does not believe that a delay would significantly increase the cost of remediation. Accordingly, Table 16 indicates that a cost escalation score of 0.0 should be assigned.

Percent Increase(X)	Score (Y)
Less than or equal to 1%	0.0
2%	0.6
3%	0.8
4%	1.0
5%	1.1
7%	1.3
8%	1.4
9%	1.5
10%	1.6
15%	1.8
20%	2.0
25%	2.1
30%	2.3
40%	2.4
50%	2.6
70%	2.8
80%	2.9
Greater than or equal to 100%	3.0

Value of Resolving Uncertainty is Calculated from Three Measures Requiring No Additional Scores

Step 5. Assign Scores to the Remaining Waste Units in Each Group

- Adjust scores assigned to the representative waste unit to obtain scores for every other unit in the group
- Consider one measure at a time
 - If there are differences among group members in this measure, make adjustments
 - If not, assign same score to all members and go on to the next measure