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Vol. 3

Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities

Appendices C-H

Final Report

U.S. Nuclear Regulatory Commission

Office of Nuclear Regulatory Research

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ABSTRACT

The action being considered in this Final Generic Environmental Impact Statement (GEIS) is an amendment to the Nuclear Regulatory Commission's (NRC) regulations in 10 CFR Part 20 to include radiological criteria for decommissioning of lands and structures at nuclear facilities. Under the National Environmental Policy Act (NEPA), all Federal agencies must consider the effect of their actions on the environment. To fulfill NRC's responsibilities under NEPA, the Commission is preparing this GEIS which analyzes alternative courses of action and the costs and impacts associated with those alternatives.

In preparing the final GEIS, the following approach was taken: (1) a listing was developed of regulatory alternatives for establishing radiological criteria for decommissioning; (2) for each alternative, a detailed analysis and comparison of incremental impacts, both radiological and nonradiological, to workers, members of the public, and the environment, and costs were performed; and (3) based on the analysis of impacts and costs, conclusions on radiological criteria for decommissioning were provided. Contained in the GEIS are results and conclusions related to achieving, as an objective of decommissioning ALARA, reduction to preexisting background, the radiological criterion for unrestricted use, decommissioning ALARA analysis for soils and structures containing contamination, restricted use and alternative analysis for special site-specific situations and groundwater cleanup. In its analyses, the final GEIS includes consideration of comments made on the draft GEIS (NUREG-1496, August 1994) during the public comment period.

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APPENDIX C

C.1 Introduction

Decommissioning is currently defined in the Commission's regulations as removing a facility safely from service and reducing residual radioactivity to a level that permits release of the property for unrestricted use and termination of license. Criteria and practices are described in several NRC guidance documents which have been used for a number of years. The NRC is in the process of conducting a rulemaking to establish radiological criteria for the decommissioning of NRC-licensed facilities. According to the requirements of NEPA and of the Commission's regulations in 10 CFR Part 51, the planned rulemaking needs to be accompanied by an Environmental Impact Statement (EIS) which analyzes costs and impacts associated with rulemaking alternatives.

C.1.1 GEIS Scope

To fulfill the NRC's responsibilities under NEPA, the Commission is preparing this Generic Environmental Impact Statement (GEIS) to analyze alternative courses of action and the costs and impacts associated with those alternatives. Because of the variety of NRC-licensed facilities eventually requiring decommissioning, the GEIS uses reference facilities in analyzing impacts and costs associated with regulatory alternatives. The reference facilities analyzed in the GEIS are discussed below as are the regulatory alternatives being evaluated.

C.1.1.1 Reference Facilities

The proposed amendment to 10 CFR Part 20 to include radiological criteria for termination of licenses would be applicable to almost all of the facilities and sites that the NRC licenses, including both fuel-cycle facilities and non-fuel-cycle material licensees. Fuel-cycle facilities include, among others, commercial nuclear power plants, nonpower (research and test) reactors, fuel fabrication plants, uranium mill facilities, and independent spent fuel storage facilities. The reference fuel-cycle facilities analyzed in the EIS include a reference commercial nuclear power plant and a reference fuel fabrication plant.

Non-fuel-cycle material licensees include universities, medical institutions, radioactive source manufacturers, and companies that use radioisotopes for industrial purposes. Over 75% of the NRC's materials licensees use either sealed radioactive sources or small amounts of short-lived radioactive materials. Decommissioning of these facilities should be relatively inexpensive and of short duration because there is usually little or no residual radioactive contamination to be cleaned up and disposed. Of the remaining 25% of licensees, a small number (e.g., radioactive source manufacturers, radiopharmaceutical producers, and radioactive ore processors) conduct operations which could produce substantial radioactive contamination during the life of the facilities. The reference non-fuel-cycle material licensees analyzed in the EIS include a sealed source manufacturer and a rare metal extraction plant.

C.1.1.2 Decommissioning/Remediation Alternatives

The costs and impacts of decommissioning NRC-licensed facilities will be heavily dependent upon the residual radioactivity criteria that the licensee must meet to allow release of the facility for other uses. Additionally, these criteria will be dependent upon how the facility will be used after decommissioning is complete and the facility is released for reuse. While the GEIS is evaluating five different regulatory alternatives (Chapter 2 of Volume 1) for establishing radiological criteria for decommissioning, the two alternative land-use scenarios distinguishing the analyses reported in this appendix are as follows:

- Unrestricted Land-Use: No restrictions are placed on the use of the facility after it is released. This scenario assumes that a family takes up residence on the site and farms the land. Analytically what this means is that the residential farm family is exposed to residual radioactivity via all potential pathways (i.e., external, inhalation, soil, drinking water, agriculture (irrigation), and aquatic).

- Restricted Land-Use: Use of the facility after decommissioning is restricted to industrial uses. This scenario assumes that decontaminated buildings are reoccupied by workers and that a farm family would take up residence outside the site boundary. Analytically what this means is that the occupational worker can be exposed to residual radioactivity from the following pathways: external, inhalation, soil, and aquatic.

Each of the reference facilities described previously is evaluated for each of these alternatives. In addition, the reference commercial nuclear power plant is evaluated for each alternative under two scenarios: 1) decommissioning activities commence immediately after reactor shutdown and 2) decommissioning activities begin after a 50-year SAFSTOR period. Other sensitivity analyses are also performed for the various reference facilities.

C.1.2 Purpose of This Appendix

An assessment of the life-cycle costs and impacts (environmental, ecological, and human health effects) of alternatives is required for any EIS. The purpose of this appendix is to describe only the methodology developed for estimating the costs associated with cleaning, removal, and disposal of contaminated concrete and soil for each of the EIS alternatives. The methodologies for estimating costs associated with other decommissioning activities, including radiation surveys before, during, and after decommissioning, are discussed in Appendix D. Also, the methodologies used to estimate the environmental, ecological, and human health effects associated with each of the alternatives are discussed in Appendix B.

C.1.3 Analytical Approach

The major high-cost decommissioning activities include cleaning, removal, and disposal of contaminated concrete and soil (and potentially groundwater). However, the cost of these activities is very sensitive to regulation-based residual cleanup levels, or residual radioactivity criteria, that must be met. Estimating decommissioning costs for alternate residual radioactivity criteria is difficult because of problems in making a generic evaluation of contamination levels on and within concrete and soil surfaces (including accounting for contamination within cracks in the concrete and hot spots) and because of uncertainties regarding the amount of dose reduction achieved by concrete and soil removal techniques.

The approach taken in this study was to develop generic models for estimating the following:

- the volume of contaminated concrete requiring removal from building interior floors and walls for alternate residual dose levels to the building occupants after completion of decommissioning,

- the volume of contaminated soil requiring excavation for alternative residual dose levels to the residential farmer after completion of decommissioning, and

- the labor requirements, occupational doses, and costs associated with removal/excavation of contaminated concrete/soil and treatment, transportation, and disposal of the resulting waste volume.

The models, originally developed for the GEIS, were based on technical work previously performed by PNNL for the NRC and documented in a series of reports on the technology, safety, and costs of decommissioning fuel-cycle and non-fuel-cycle nuclear facilities (Smith 1978; Konzek 1982a, 1982b, 1995; Murphy 1981; Elder 1980a, 1980b, 1981; Short 1989). Also utilized in the development of the methodology was PNNL technical expertise on residual radionuclide contamination within and around nuclear power plants (Abel 1986; Robertson 1989, 1991). These models are discussed in Appendix C of the draft GEIS (NRC 1994) (for completeness, Appendix C of the draft GEIS is included here as Attachment D).

Subsequently, the NRC received a number of public comments questioning the soil contaminant distribution methodology utilized in the draft GEIS. The essence of these comments was that the draft GEIS methodology, in some instances, significantly underestimates the "real world" volume of contaminated soil requiring remediation during decommissioning of nuclear facilities. In response to these comments, NRC and PNNL staff reviewed data on contamination submitted by the commenters, compared it with available data on radionuclide distributions in contaminated soil including that in the draft GEIS, and verified and/or modified, as appropriate, the analyses of the reference facilities. This final GEIS thus considers additional soil contamination data. In response to these comments and the results of the data review, the analyses of the reference facilities were modified to include "real world" scenarios for the nuclear power plant, uranium fuel fabrication plant, sealed source manufacturer, and rare metal extraction plant. It should be noted that these "real world" scenarios represent extreme contamination cases and not the typical situation but are valuable in providing an upper bound to the problem.

C.1.4 Appendix Organization

The remainder of this appendix is organized as follows:

- Section 2: provides a brief summary of the results of the decommissioning/remediation analyses,

- Section 3: provides a discussion of the public comments received on the draft GEIS, response to those comments, and modifications made to the analyses for the final GEIS,

- Section 4: provides a description of each of the reference facilities being evaluated in the GEIS,

- Section 5: provides a description of the methodology developed to estimate radionuclide contamination levels in contaminated soil at the reference facilities,

- Section 6: provides a description of the methodology developed for estimating the costs of removal/excavation of contaminated concrete/soil, treatment, transportation, and disposal of resulting low-level radioactive waste volumes,

- Section 7: provides the results of the decommissioning analyses,

- Section 8: provides a cursory examination of possible groundwater remediation,

- Section 9: provides a list of references utilized in developing the analytical methodologies.

Attachments A, B, C, and D provide additional information on assumptions and detailed results of the decommissioning analysis, and Attachment E provides detailed groundwater information.

C.2 Summary of Results

The intent of this section of the appendix is to provide a brief summary and overview of the costs, labor requirements, and occupational doses associated with decontaminating contaminated facilities to alternate residual dose criteria. The purpose of these analyses has not been to estimate the total magnitude of each of these figures-of-merit, but to estimate only those portions of each parameter that are sensitive to different residual cleanup levels. Therefore, the results presented here show the incremental/differential remediation costs and occupational doses between alternate residual cleanup levels, not total decommissioning/remediation costs at each residual cleanup level.

Table 2.1 provides a matrix identifying each of the baseline and sensitivity cases evaluated in the GEIS. As the table indicates, both an unrestricted and a restricted land-use scenario, as described in Section 1.1.2, are evaluated for each reference facility. The Baseline decommissioning scenario assumes that D&D begins immediately after shutdown while the 50-Year SAFSTOR scenario assumes that D&D begins 50 years after shutdown. In order to assess the potential benefits/costs associated with minimizing the generation of LLW requiring disposal, both a Soil Wash scenario, that assumes that soil is cleaned via immersion and agitation within an aqueous decontamination solution, and a Direct Disposal scenario, that assumes any excavated contaminated soil is sent directly to disposal without any decontamination, are evaluated for each case.

Each of these scenarios is, in turn, evaluated for different assumed average levels of contamination in the soil. These different levels are labeled H for high, M for medium, and L for low. Depending upon the type of contamination, the medium level assumes an average concentration of contaminant in the soil that is three to six times greater than the concentration assumed for the low contamination level. The high level assumes an average concentration of contaminant in the soil that is two to five times greater than the concentration assumed for the medium contamination level.

Finally, the reference nuclear power reactor site, uranium fuel fabrication plant, sealed source manufacturer, and rare metals extraction plant are each evaluated assuming two different sources of contamination in the soil. Each reference facility is evaluated assuming contamination is deposited upon the surface of the soil, such as via windblown contaminated dust. This analysis assumes that the primary mechanism driving contaminant migration deeper into the soil column is diffusion. The methodology for this analysis was originally developed for the draft GEIS and is discussed in NRC, 1994.

The second scenario for the reference nuclear power reactor site and the sealed source manufacturer assumes that soil contamination was primarily the result of a spill and/or leak of contaminated solution into the soil column that provided a gravitational-driven source of contamination. The second scenario for the reference uranium fuel fabrication plant and rare metals extraction plant assumes that soil contamination is primarily the result of mixing clean soil with contaminated soil and also potentially using this mixture as landfill material on the site. These "real world" scenarios were developed for the final GEIS based on public comments received on the draft GEIS analyses (see Sections 1.3 and 3). A discussion of the methodology developed for these "real world" scenarios is provided in Section 5.

A summary of the results for each of the identified scenarios follows. For a discussion and presentation of the detailed results, refer to Section 7 and Attachment C.

C.2.1 Reference Nuclear Power Plant

The baseline decommissioning evaluation of the reference nuclear power plant included decontamination of the reactor bioshield concrete and other contaminated concrete surfaces and remediation of soil on the site contaminated by infrequent surface deposition where there is no mechanism other than diffusion downward into the soil column over time. The contaminated soil was evaluated two different ways: 1) the contaminated soil was disposed of directly into a disposal facility and 2) the contaminated soil was first treated with a soil-cleaning technology to remove contaminants followed by disposal of the contaminated soil remaining after cleaning. These cases were evaluated for both the restricted and unrestricted land-use scenarios. Each of these scenarios was also reevaluated assuming the power reactor is not decommissioned until 50 years after shutdown (i.e., 50-Year SAFSTOR). A second set of scenarios was evaluated that assumed that soil was contaminated as a result of leaks and/or spills of contaminated liquids where the contamination is driven into the soil at a faster rate than diffusion and percolates downward into the soil column over time.

A summary of the analyses evaluating the decontamination of the reactor bioshield and other contaminated floors and walls is provided in Tables 2.1.1 and 2.1.2 for the bioshield (via drill and blast) and other concrete surfaces (via scabbling), respectively. Both of these tables show that there is a definite occupational dose advantage to waiting 50 years prior to decommissioning a nuclear power plant (although doses incurred during the long-term surveillance and maintenance period of the plant have not been estimated in these analyses).

The incremental costs of decommissioning the bioshield are not dependent upon when decommissioning occurs. However, there is a significant total decommissioning cost advantage to waiting 50 years before beginning decommissioning (since the bioshield is primarily contaminated with the relatively short-lived activation product Co-60). While this conclusion is not obvious from just looking at the incremental costs reported in Table 2.1.1, it can be reached by comparing the total costs reported in Tables 7.3.1 and 7.3.5 in Section 7.3.

Finally, the cost advantage of waiting 50 years to decommission the bioshield is somewhat offset by the increased costs of waiting 50 years to decontaminate other contaminated walls and surfaces. As Table 2.1.2 indicates, immediate decontamination of the walls and floors to a residual dose rate of 10.4 mrem/y will cost about $3 million (assuming a disposal cost of $350/ft^3) while waiting 50 years to decontaminate will increase this cost to about $4 million (residual dose rate of 9.5 mrem/y). These costs increase in this case due to the fact that the contamination in the walls/floors is assumed to include Cs-137 in addition to Co-60 (so a 50-year decay period does not provide the same benefit as if just Co-60 were present), and the longer time period provides an opportunity for deeper penetration of the radionuclides into the concrete.

A summary of the results of remediating the contaminated soil at the reference nuclear power plant, assuming deposition of contamination on the soil surface, is provided in Tables 2.1.3 through 2.1.6 for the immediate D&D scenario and Tables 2.1.7 through 2.1.10 for the 50-Year SAFSTOR scenario. Similar results are provided in Tables 2.1.11 through 2.1.18 for the same scenarios but assuming that soil contamination is the result of a spill and/or leak of contaminated liquids.

The results in each of these tables are provided for three different assumed contamination levels (high, medium, and low) in the soil and for three different soil disposal costs ($10, $50, and $350 per ft^3). A general observation of the results presented in these tables is that, depending upon what the regulatory requirement is for radioactive exposure from residual contamination left in the soil, remediation may or may not be required. This is demonstrated in the low contamination case in Table 2.1.3 where soil remediation would not be required unless the residual dose rate were set at a level of 3 mrem/y or lower.

Another general observation supported by the results in these tables is that the incremental cost of soil remediation increases with each unit (1 mrem/y) reduction in the required residual dose level. In other words, the cost of reducing the residual contamination in the soil by 1 mrem/y is significantly higher if the reduction is from 10 to 9 mrem/y than it is if the reduction is from 100 to 99 mrem/y. This is due to the general nature of how contaminants are distributed in the soil column where the majority of the contaminant is near the surface of the soil column and which trails off significantly with depth (i.e., significantly more soil volume requires remediation to remove the last one curie of activity than it takes to remove the first one curie of activity).

A comparison of the results of the soil washing scenarios with the corresponding direct disposal of soil scenarios, such as Tables 2.1.3 and 2.1.4, indicates that the higher the disposal cost, the greater the incentive to clean the soil to reduce the volume requiring disposal. At a disposal cost of $350 per ft^3, the results indicate that it is always more cost effective (both total and incremental) to clean the soil to reduce the volume requiring disposal. On the other hand, at a disposal cost of only $10 per ft^3, it is generally more cost effective to ship the excavated soil directly to disposal.

Another conclusion drawn from the results provided in the tables is that remediation requirements are reduced in the restricted land-use scenario when compared to the unrestricted land-use scenario (i.e., the residual dose level at which remediation would be required is lower, as are generally the total and incremental costs of remediation, under a restricted land-use scenario); compare Tables 2.1.3 and 2.1.5 as an example. This is to be expected since there are fewer exposure pathways assumed in the restricted land-use scenarios (i.e., there are restrictions and controls on the use of the land) than are assumed in the unrestricted land-use scenarios.

By delaying decommissioning of the reference nuclear power plant for 50 years (i.e., allowing radionuclide decay and contaminant dispersion in the soil to "naturally" remediate the soil), the total cost of decommissioning can potentially be significantly reduced. As with the restricted and unrestricted land-use comparison discussed above, a 50-year delay in remediation can significantly lower the residual dose level where remediation would even be required (compare Tables 2.1.3 and 2.1.7 as an example). Again, these analyses did not include the costs associated with long-term monitoring and surveillance. However, if the required residual dose level were set sufficiently low (i.e., at 3 mrem/y in Table 2.1.7, high contamination case, as an example), the cost of soil remediation under the 50-Year SAFSTOR scenario would be considerably higher than if the reactor site were immediately decommissioned. This is due to giving the contaminant plume an additional 50 years to migrate deeper into the soil column, thereby requiring greater soil volumes to be remediated.

Finally, the above conclusions are also consistent with the results of the "real world" scenarios provided in Tables 2.1.11 through 2.1.18. The difference in the results in these tables and those for the "baseline" scenarios in Tables 2.1.3 through 2.1.10 is that the incremental and total costs, soil volumes being remediated, and occupational doses to workers are higher across the board in the "real world" scenarios. This is because the "real world" scenarios were developed, in response to public comments on the draft GEIS, to be a bounding representation of the extent of contamination that might be expected to require remediation during decommissioning of a nuclear power plant.

C.2.2 Reference Uranium Fuel Fabrication Plant

The baseline decommissioning evaluation of the reference uranium fuel fabrication plant included decontamination of contaminated concrete surfaces and remediation of soil contaminated by infrequent surface deposition where there is no mechanism other than diffusion downward into the soil column over time on the site. The contaminated soil was evaluated two different ways: 1) the contaminated soil was disposed of directly into a disposal facility and 2) the contaminated soil was first treated with a soil-cleaning technology to remove contaminants followed by disposal of the contaminated soil remaining after cleaning. These cases were evaluated for both the restricted and unrestricted land-use scenarios. Also, the second set of scenarios was evaluated assuming the soil contamination on the site was the result of mixing/landfilling with contaminated soil and/or slag.

Decontamination of the concrete surfaces was determined to require only one layer (0.3175 cm) of concrete be removed due to the very slow diffusion of uranium through concrete. This translates into a total concrete volume requiring disposal of 288 m^3, a concrete disposal cost of \$1.89 million, a total occupational dose of 7 person-rem, and a residual dose rate of just 1.4×10^{-10} mrem/y.

A summary of the results of remediating the contaminated soil at the reference uranium fuel fabrication plant is provided in Tables 2.2.1 through 2.2.4 for the windblown deposition of contamination scenarios and Tables 2.2.5 through 2.2.8 for the mixing/landfilling scenarios. The same general trends and conclusions discussed previously for remediation of contaminated soil at the reference nuclear power plant apply to the results for the reference uranium fuel fabrication plant and therefore will not be repeated here. Soil remediation costs and occupational doses incurred during remediation of the soil are shown to be significantly higher across the board for the uranium fuel fabrication plant than for the nuclear power plant due to the much larger volumes of soil requiring remediation at these types of facilities.

C.2.3 Reference Sealed Source Manufacturer

The baseline decommissioning evaluation of the reference sealed source manufacturer, in which the soil is assumed to be contaminated by infrequent surface deposition where there is no mechanism other than diffusion downward into the soil column over time, is the same as that described for the two reference facilities already discussed previously. Specifically, the analyses included scenarios where contaminated soil was both treated via soil washing and direct disposed without treatment and scenarios in which both the restricted and unrestricted land-use scenarios were evaluated. A second set of "real world" scenarios was evaluated that assumed that the soil contamination at the site was the result of a leak and/or spill of contaminated liquids where the contamination is driven into the soil at a faster rate than diffusion. Finally, as with the previous facilities, contaminated concrete on structures was removed in 0.3175 cm layers via scabbling.

The estimated requirements for decontamination of the concrete surfaces of this reference facility are summarized in Table 2.3.1. Minimal concrete removal is assumed to be required at these types of facilities.

A summary of the results of remediating the contaminated soil at the reference sealed source manufacturer is provided in Tables 2.3.2 through 2.3.5 for the "baseline" scenarios and Tables 2.3.6 through 2.3.9 for the leak/spill scenarios. The same general trends and conclusions discussed previously for remediation of contaminated soil at the reference nuclear power plant apply to the results for the reference sealed source manufacturer and therefore will not be repeated here. Soil remediation costs and occupational doses incurred during remediation of the soil are shown to be lower across the board than for either the uranium fuel fabrication plant or the nuclear power plant. These types of facilities are assumed to not have significant volumes of contaminated soil requiring remediation during decommissioning.

C.2.4 Reference Rare Metal Extraction Plant

The scenarios evaluated for the reference rare metal extraction plant are the same as those evaluated for the reference uranium fuel fabrication plant, although the radionuclide contaminants and other specific data used in the analyses were obviously different. Specifically, both soil washing and direct disposal of contaminated soil were evaluated for both the restricted and unrestricted land-use scenarios. Also, each of these scenarios was evaluated for both a "baseline" scenario, where soil is assumed to be contaminated by infrequent surface deposition where there is no mechanism other than diffusion downward into the soil column over time and a "real world" scenario, where soil contamination is assumed to be the result of landfilling with contaminated soil and/or slag.

Decontamination of the concrete surfaces was determined to require just two layers (0.635 cm) of concrete be removed due to the very slow diffusion of thorium through concrete. This translates into a total concrete volume requiring disposal of 176 m^3, a concrete disposal cost of $2.28 million, a total occupational dose of 8.6 person-rem, and a residual dose rate of 0.023 mrem/y.

A major difference between this reference facility and the others is that this site is assumed to have a 7,000-m^3 slag pile requiring remediation. The slag pile, therefore, is the major source of contaminated soil requiring remediation at this site. Since the slag cannot be effectively washed, it requires direct disposal.

A summary of the results of remediating the contaminated soil at the reference rare metal extraction plant is provided in Tables 2.4.1 through 2.4.4 for the baseline scenarios and Tables 2.4.5 through 2.4.8 for the mixing/landfilling scenarios. The same general trends and conclusions discussed previously for remediation of contaminated soil at the reference nuclear power plant apply to the results for the reference rare metal extraction plant and therefore will not be repeated here. It should be noted that the total costs of remediating this site include those costs associated with remediating the slag pile (which is significant and is reported in Tables 7.6.2 through 7.6.5 in Section 7.6). However, since the requirements for remediation of the slag pile do not vary by residual dose level or contamination level, and since Tables 2.4.1 through 2.4.8 only report incremental soil volumes, occupational doses, and costs for remediating soil, these tables do not reflect the remediation requirements associated with the slag pile.

Also, the definition of the restricted land-use scenario for this reference site is different than for any of the other reference sites. Restricted land-use for the other reference facilities was based on limitation/controls that affectively eliminated some potential pathways for exposure. While this is also true for the reference rare metal extraction plant, restricted land-use also means the slag pile will not be remediated and disposed of offsite but will be left onsite and used as a disposal facility for other contaminated soil produced during remediation. Therefore, for the restricted land-use scenarios, there is no cost associated with the disposal of the slag pile or contaminated soil. However, costs are estimated for stabilizing the slag pile in place (although costs associated with long-term monitoring and surveillance are not included). Since there are no disposal costs in the results of the restricted land-use scenarios, the estimated costs for these scenarios are considerably less than for the corresponding unrestricted land-use scenarios.

Table C.2.1. GEIS Scenario Matrix

Reference Facility	Unrestricted Land-Use												Restricted Land-Use											
	Baseline						50-Year SAFSTOR						Baseline						50-Year SAFSTOR					
	Soil Wash			Direct Disposal			Soil Wash			Direct Disposal			Soil Wash			Direct Disposal			Soil Wash			Direct Disposal		
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
PWR Power Reactor Site																								
- Deposition on Soil Surface	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
- Spill/Leak	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Uranium Fuel Fabrication Plant																								
- Deposition on Soil Surface	X	X	X	X	X	X							X	X	X	X	X	X						
- Mixing/Landfilling	X	X	X	X	X	X							X	X	X	X	X	X						
Sealed Source Manufacturer																								
- Deposition on Soil Surface	X	X	X	X	X	X							X	X	X	X	X	X						
- Spill/Leak	X	X	X	X	X	X							X	X	X	X	X	X						
Rare Metals Extraction Plant																								
- Deposition on Soil Surface	X	X	X	X	X	X							X	X	X	X	X	X						
- Mixing/Landfilling	X	X	X	X	X	X							X	X	X	X	X	X						

Table 2.1.1. Incremental Costs and Occupational Dose for Decontamination of the Reference Nuclear Power Plant Bioshield

Decommissioning Soon After Shutdown										
					$50/ft^3 Disposal Cost			$350/ft^3 Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Concrete Volume (m^3)	Cumulative Concrete Volume (m^3)	Incremental Occupational Dose (person-rem)	Cumulative Occupational Dose (person-rem)	Incremental Concrete Disposal Cost ($ millions)	Cumulative Concrete Disposal Cost ($ millions)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Concrete Disposal Cost ($ millions)	Cumulative Concrete Disposal Cost ($ millions)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
100-60	16	16	6.3	6.3	0.14	0.14	4	0.32	0.32	8
60-30	22	38	0.1	6.4	0.05	0.19	2	0.28	0.60	9
30-25	5	43	0.0	6.4	0.01	0.20	2	0.07	0.67	14
25-15	16	60	0.3	6.7	0.04	0.25	4	0.21	0.88	21
15-10	16	76	0.0	6.7	0.03	0.28	7	0.21	1.09	41
10-3	41	117	6.7	13.4	0.21	0.49	29	0.64	1.72	91
3-0.3	87	204	7.4	20.8	0.32	0.80	117	1.24	2.96	458
0.3-0.03	90	294	7.7	28.4	0.33	1.13	1,204	1.28	4.24	4,726

50-Year SAFSTOR										
					$50/ft^3 Disposal Cost			$350/ft^3 Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Concrete Volume (m^3)	Cumulative Concrete Volume (m^3)	Incremental Occupational Dose (person-rem)	Cumulative Occupational Dose (person-rem)	Incremental Concrete Disposal Cost ($ millions)	Cumulative Concrete Disposal Cost ($ millions)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Concrete Disposal Cost ($ millions)	Cumulative Concrete Disposal Cost ($ millions)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
100-60	14	14	0.00	0.00	0.03	0.03	1	0.17	0.17	4
60-30	22	35	0.00	0.00	0.05	0.08	2	0.28	0.45	9
30-25	3	38	0.00	0.00	0.01	0.08	1	0.04	0.49	7
25-15	16	54	0.00	0.00	0.04	0.12	4	0.21	0.70	21
15-10	11	65	0.01	0.01	0.13	0.25	25	0.24	0.94	48
10-3	35	101	0.00	0.01	0.08	0.33	11	0.45	1.39	65
3-0.3	73	174	0.00	0.01	0.27	0.59	100	1.05	2.44	387
0.3-0.03	79	253	0.01	0.02	0.29	0.88	1,056	1.12	3.56	4,148

Table C.2.1.2. Summary of Costs and Occupational Dose for Decontamination of the Reference Nuclear Power Plant Floors/Walls

	Decommissioning Soon After Shutdown					50-Year SAFSTOR				
Concrete Thickness Removed (cm)	Residual Dose Rate (mrem/y)	Concrete Volume Requiring Disposal (m^3)	Occupational Dose (person-rem)	$50/ft³ Disposal Building D&D Cost ($ millions)	$350/ft³ Disposal Building D&D Cost ($ millions)	Residual Dose Rate (mrem/yr)	Concrete Volume Requiring Disposal (m^3)	Occupational Dose (person-rem)	$50/ft³ Disposal Building D&D Cost ($ millions)	$350/ft³ Disposal Building D&D Cost ($ millions)
0.3175	36,000	90	2.4	0.6	1.5	535	90	0.003	0.6	1.5
0.6350	4,100	104	3.8	1.0	2.1	376	104	0.005	1.0	2.1
0.9525	220	116	5.2	1.3	2.6	210	116	0.007	1.3	2.6
1.2700	10.4	129	6.6	1.7	3.1	94	129	0.009	1.7	3.1
1.5875	0.28	142	8.0	2.1	3.6	33	142	0.011	2.1	3.6
1.9050	0.0035	155	9.4	2.4	4.1	9.5	155	0.013	2.4	4.1
2.2225	<0.003	168	10.8	2.8	4.6	2.2	168	0.015	2.8	4.6
2.5400	<0.003	181	12.2	3.2	5.1	0.39	181	0.017	3.2	5.1
2.8575	---	---	---	---	---	0.056	194	0.056	3.5	5.6
3.1750	---	---	---	---	---	0.006	207	0.006	3.9	6.1

Table 2.1.3. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Deposition on Soil Surface, with Soil Washing)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	10	10	2	2	6.6	7	0.16	14.4	14	0.36	56.6	57	1.42
60-30	10	20	2	4	6.3	13	0.21	12.6	27	0.42	53.5	110	1.78
30-25	2	22	0	4	1.6	15	0.32	3.2	30	0.65	13.7	124	2.73
25-15	6	28	1	5	3.9	18	0.39	7.8	38	0.78	32.8	157	3.28
15-10	5	33	1	6	3.6	22	0.72	8.5	47	1.70	31.8	188	6.35
10-3	28	61	5	11	18.4	40	2.63	38.0	85	5.43	156.6	345	22.38
3-0.3	66	128	12	23	43.6	84	16.14	89.5	174	33.16	370.5	715	137.21
0.3-0.03	33	161	6	29	25.8	110	95.64	44.6	219	165.26	184.6	900	683.76
Medium													
100-60	18	18	3	3	50.2	50	1.26	59.4	59	1.49	137.2	137	3.43
60-30	15	34	3	6	10.2	60	0.34	21.6	81	0.72	87.0	224	2.90
30-25	3	36	0	7	1.7	62	0.35	3.4	84	0.69	14.6	239	2.91
25-15	7	43	1	8	4.5	67	0.45	9.0	93	0.90	38.1	277	3.81
15-10	5	48	1	9	3.3	70	0.65	6.5	100	1.30	27.6	304	5.52
10-3	13	61	2	11	8.5	78	1.22	18.3	118	2.62	73.3	378	10.48
3-0.3	61	123	11	22	40.3	119	14.94	83.0	201	30.75	343.0	721	127.02
0.3-0.03	44	167	8	30	29.0	148	107.32	60.4	262	223.71	247.1	968	915.31
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	27	27	5	5	56.0	56	8.00	71.0	71	10.14	185.9	186	26.56
3-0.3	35	62	6	11	23.0	79	8.52	48.5	119	17.97	196.8	383	72.91
0.3-0.03	77	139	14	25	50.5	130	187.03	104.6	224	387.50	430.1	813	1,592.86

Table 2.1.4. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Deposition on Soil Surface, Direct Disposal of Soil)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	10	10	2	2	5.9	6	0.15	23.5	23	0.59	129.0	129	3.23
60-30	10	20	2	3	5.7	12	0.19	22.7	46	0.76	124.9	254	4.16
30-25	2	22	0	4	1.4	13	0.29	5.5	52	1.09	31.5	285	6.31
25-15	6	28	1	5	3.5	16	0.35	13.1	65	1.31	75.8	361	7.58
15-10	5	33	1	5	3.2	20	0.65	13.5	78	2.70	71.6	433	14.33
10-3	28	61	5	10	20.6	40	2.94	64.8	143	9.26	361.4	794	51.62
3-0.3	66	128	11	21	43.1	83	15.96	155.2	298	57.47	857.5	1,652	317.59
0.3-0.03	33	161	5	26	19.4	103	71.96	78.7	377	291.34	428.6	2,080	1,587.58
Medium													
100-60	18	18	3	3	14.9	15	0.37	43.4	43	1.08	237.7	238	5.94
60-30	15	34	3	5	9.1	24	0.30	37.0	80	1.23	200.6	438	6.69
30-25	3	36	0	6	1.5	26	0.31	5.8	86	1.17	33.6	472	6.73
25-15	7	43	1	7	4.0	30	0.40	15.2	101	1.52	87.9	560	8.79
15-10	5	48	1	8	2.9	32	0.59	12.4	114	2.48	65.1	625	13.02
10-3	13	61	2	10	7.6	40	1.09	30.2	144	4.31	167.7	793	23.95
3-0.3	61	123	10	20	40.2	80	14.88	144.2	288	53.39	794.0	1,587	294.06
0.3-0.03	44	167	7	27	30.0	110	111.17	103.2	391	382.06	570.0	2,157	2,111.08
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	27	27	4	4	20.1	20	2.86	64.2	64	9.17	351.5	352	50.22
3-0.3	35	62	6	10	20.6	41	7.62	81.7	146	30.26	452.5	804	167.60
0.3-0.03	77	139	12	23	49.3	90	182.47	179.8	326	666.00	993.4	1,798	3,679.40

Table 2.1.5. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Deposition on Soil Surface, with Soil Washing)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	12	12	2	2	46.0	46	9.21	51.1	51	10.21	101.7	102	20.34
10-3	27	39	5	7	17.6	64	2.51	36.3	87	5.19	149.6	251	21.37
3-0.3	23	62	4	11	15.2	79	5.63	31.6	119	11.72	129.6	381	48.01
0.3-0.03	18	79	3	14	11.6	90	43.01	23.1	142	85.73	98.0	479	362.91
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	28	28	5	5	56.4	56	8.05	72.9	73	10.42	190.1	190	27.15
3-0.3	28	56	5	10	18.6	75	6.90	38.4	111	14.24	158.4	348	58.68
0.3-0.03	18	74	3	13	11.6	87	43.11	23.2	135	85.93	98.2	447	363.77
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	17	17	3	3	49.4	49	18.31	57.8	58	21.43	130.4	130	48.30
0.3-0.03	35	52	6	9	22.8	72	84.28	46.7	105	172.88	193.3	324	716.00

Table 2.1.6. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Deposition on Soil Surface, Direct Disposal of Soil)

					$10/ft^3 Disposal Cost			$50/ft^3 Disposal Cost			$350/ft^3 Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	12	12	2	2	11.1	11	2.23	29.2	29	5.84	155.8	156	31.16
10-3	27	39	4	6	15.7	27	2.25	62.0	91	8.86	345.1	501	49.30
3-0.3	23	62	4	10	13.6	40	5.04	54.0	145	20.00	299.0	800	110.75
0.3-0.03	18	79	3	13	14.5	55	53.66	41.9	187	155.07	229.0	1,029	848.05
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	28	28	4	4	20.4	20	2.91	65.3	65	9.33	358.1	358	51.16
3-0.3	28	56	5	9	16.7	37	6.17	66.9	132	24.76	366.9	725	135.88
0.3-0.03	18	74	3	12	14.5	52	53.75	40.6	173	150.51	228.2	953	845.12
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	17	17	3	3	14.2	14	5.25	40.7	41	15.06	222.1	222	82.25
0.3-0.03	35	52	6	8	20.4	35	75.38	80.8	121	299.34	447.4	670	1,657.15

Table 2.1.7. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Deposition on Soil Surface, with Soil Washing, 50-Year SAFSTOR)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	21	21	4	4	51.9	52	7.41	62.7	63	8.96	151.0	151	21.57
3-0.3	392	413	70	74	265.9	318	98.48	533.5	596	197.59	2,194.2	2,345	812.68
0.3-0.03	75	487	13	87	49.1	367	181.96	100.6	697	372.49	417.2	2,762	1,545.16
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	106	106	19	19	108.0	108	39.98	178.5	178	66.09	628.1	628	232.65
0.3-0.03	342	448	61	80	232.9	341	862.57	465.1	644	1,722.46	1,913.1	2,541	7,085.65
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
0.3-0.03	373	373	67	67	291.6	292	1,080.11	541.4	541	2,005.33	2,122.0	2,122	7,859.14

Table 2.1.8. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Deposition on Soil Surface, Direct Disposal of Soil, 50-Year SAFSTOR)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	21	21	3	3	16.4	16	2.34	48.9	49	6.99	269.6	270	38.51
3-0.3	392	413	63	67	251.0	267	92.96	918.0	967	340.00	5,069.9	5,339	1,877.72
0.3-0.03	75	487	12	79	48.0	315	177.94	175.2	1,142	648.88	966.8	6,306	3,580.57
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	106	106	17	17	70.6	71	26.15	248.9	249	92.19	1,373.1	1,373	508.56
0.3-0.03	342	448	55	73	221.5	292	820.27	801.2	1,050	2,967.54	4,421.4	5,795	16,375.53
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
0.3-0.03	373	373	60	60	244.0	244	903.55	874.6	875	3,239.36	4,826.0	4,826	17,873.90

Table 2.1.9. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Deposition on Soil Surface, with Soil Washing, 50-Year SAFSTOR)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
0.3-0.03	44	44	8	8	66.8	67	247.57	93.9	94	347.61	278.6	279	1,031.71
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
0.3-0.03	24	24	4	4	53.9	54	199.57	66.7	67	247.05	167.9	168	621.85
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
0.3-0.03	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2.1.10. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Deposition on Soil Surface, Direct Disposal of Soil, 50-Year SAFSTOR)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
0.3-0.03	44	44	7	7	29.7	30	110.13	103.4	103	383.03	565.2	565	2,093.26
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
0.3-0.03	24	24	4	4	18.1	18	67.20	57.0	57	211.13	310.0	310	1,148.12
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
0.3-0.03	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2.1.11. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Spill/Leak, with Soil Washing)

Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	$10/ft³ Disposal Cost: Incremental Cost ($K)	$10/ft³ Disposal Cost: Cumulative Cost ($K)	$10/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$50/ft³ Disposal Cost: Incremental Cost ($K)	$50/ft³ Disposal Cost: Cumulative Cost ($K)	$50/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$350/ft³ Disposal Cost: Incremental Cost ($K)	$350/ft³ Disposal Cost: Cumulative Cost ($K)	$350/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	16	16	3	3	10.6	11	0.27	21.1	21	0.53	89.5	89	2.24
60-30	34	50	6	9	22.1	33	0.74	45.3	66	1.51	187.5	277	6.25
30-25	10	59	2	11	6.3	39	1.26	13.9	80	2.78	54.5	332	10.90
25-15	26	86	5	15	17.3	56	1.73	35.8	116	3.58	147.3	479	14.73
15-10	21	107	4	19	14.1	70	2.81	28.0	144	5.61	118.7	597	23.74
10-3	71	178	13	32	50.7	121	7.25	96.9	241	13.85	397.5	995	56.79
3-0.3	144	322	26	58	94.7	216	35.06	195.3	436	72.33	805.3	1,800	298.26
0.3-0.03	123	445	22	80	85.3	301	315.81	168.4	605	623.72	691.5	2,492	2,561.15
Medium													
100-60	16	16	3	3	10.6	11	0.27	21.1	21	0.53	89.4	89	2.24
60-30	21	37	4	7	14.0	25	0.47	29.2	50	0.97	119.1	209	3.97
30-25	7	45	1	8	4.9	29	0.97	9.7	60	1.93	41.0	250	8.19
25-15	26	70	5	13	16.9	46	1.69	34.9	95	3.49	143.6	393	14.36
15-10	21	91	4	16	13.9	60	2.78	29.0	124	5.80	118.5	512	23.70
10-3	62	153	11	27	40.6	101	5.80	83.6	207	11.94	345.3	857	49.33
3-0.3	141	294	25	53	96.9	198	35.89	192.9	400	71.45	791.0	1,648	292.97
0.3-0.03	131	425	23	76	89.9	288	333.04	176.4	577	653.15	729.4	2,377	2,701.63
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	3	3	0.5	0.5	39.9	40	7.98	38.8	39	7.76	49.8	50	9.97
10-3	29	31	5	6	18.9	59	2.70	38.9	78	5.56	160.6	210	22.94
3-0.3	112	143	20	26	73.4	132	27.19	151.6	229	56.16	624.8	835	231.42
0.3-0.03	150	293	27	52	102.7	235	380.28	203.1	432.5	752.22	838.4	1,674	3,105.13

Table 2.1.12. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Spill/Leak, Direct Disposal of Soil)

Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	$10/ft³ Disposal Cost: Incremental Cost ($K)	$10/ft³ Disposal Cost: Cumulative Cost ($K)	$10/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$50/ft³ Disposal Cost: Incremental Cost ($K)	$50/ft³ Disposal Cost: Cumulative Cost ($K)	$50/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$350/ft³ Disposal Cost: Incremental Cost ($K)	$350/ft³ Disposal Cost: Cumulative Cost ($K)	$350/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	16	16	3	3	9.5	9	0.24	38.5	38	0.96	209.4	209	5.23
60-30	34	50	5	8	23.8	33	0.79	78.5	117	2.62	434.1	643	14.47
30-25	10	59	2	10	5.6	39	1.13	21.3	138	4.26	122.8	766	24.55
25-15	26	86	4	14	15.5	54	1.55	62.4	201	6.24	341.1	1,107	34.11
15-10	21	107	3	17	12.6	67	2.52	50.2	251	10.03	276.8	1,384	55.35
10-3	71	178	11	29	45.8	113	6.55	165.5	416	23.64	917.0	2,301	131.00
3-0.3	144	322	23	52	92.9	206	34.39	338.2	755	125.27	1,863.3	4,164	690.11
0.3-0.03	123	445	20	72	80.8	286	299.26	288.7	1,043	1,069.26	1,596.5	5,761	5,912.83
Medium													
100-60	16	16	3	3	9.5	9	0.24	37.1	37	0.93	207.9	208	5.20
60-30	21	37	3	6	12.5	22	0.42	49.8	87	1.66	274.8	483	9.16
30-25	7	45	1	7	4.3	26	0.87	17.7	105	3.54	95.9	579	19.18
25-15	26	70	4	11	19.2	45	1.92	59.6	164	5.96	331.2	910	33.12
15-10	21	91	3	15	12.4	58	2.48	49.5	214	9.91	273.3	1,183	54.65
10-3	62	153	10	25	40.4	98	5.78	145.1	359	20.73	799.4	1,982	114.21
3-0.3	141	294	23	48	91.2	190	33.78	330.6	690	122.46	1,825.9	3,808	676.25
0.3-0.03	131	425	21	69	85.0	275	314.67	305.7	995	1,132.36	1,688.5	5,497	6,253.54
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	3	3	0.4	0.4	5.6	6	1.13	7.1	7	1.42	34.6	35	6.93
10-3	29	31	5	5	16.9	23	2.41	66.4	73	9.48	370.5	405	52.93
3-0.3	112	143	18	23	73.9	96	27.36	262.5	336	97.24	1,445.5	1,851	535.37
0.3-0.03	150	293	24	47	96.4	193	356.93	350.1	686	1,296.81	1,938.4	3,789	7,179.09

Table 2.1.13. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Spill/Leak, with Soil Washing)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	0.2	0.2	0.03	0.03	38.30	38.30	1.277	35.64	35.64	1.188	36.38	36.38	1.213
30-25	1	1	0.2	0.3	0.87	39.16	0.173	1.72	37.36	0.345	7.30	43.68	1.460
25-15	4	5	1	1	2.3	42	0.23	4.7	42	0.47	19.8	63	1.98
15-10	11	16	2	3	7.2	49	1.43	14.3	56	2.86	60.5	124	12.09
10-3	44	60	8	11	28.8	77	4.12	60.1	116	8.59	245.9	370	35.12
3-0.3	116	176	21	32	76.5	154	28.32	157.7	274	58.42	650.6	1,020	240.96
0.3-0.03	114	290	20	52	78.8	233	291.86	154.2	428	571.07	635.6	1,656	2,354.14
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	3	3	0.5	0.5	39.9	40	7.98	38.9	39	7.77	50.0	50	10.00
10-3	29	32	5	6	19.1	59	2.73	39.5	78	5.64	162.8	213	23.26
3-0.3	109	141	20	25	71.6	131	26.54	148.1	226	54.85	609.8	823	225.87
0.3-0.03	114	255	20	46	79.0	210	292.60	154.6	381	572.55	637.3	1,460	2,360.38
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	21	21	4	4	51.8	52	19.20	62.6	63	23.19	150.6	151	55.77
0.3-0.03	101	122	18	22	66.5	118	246.43	137.9	201	510.78	566.7	717	2,098.91

Table 2.1.14. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Spill/Leak, Direct Disposal of Soil)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	0.2	0.2	0.03	0.03	4.20	4.20	0.140	1.71	1.71	0.057	3.58	3.58	0.119
30-25	1	1	0.2	0.2	0.77	4.98	0.15	2.92	4.64	0.58	16.86	20.44	3.37
25-15	4	5	1	1	2.1	7	0.21	7.9	13	0.79	45.6	66	4.56
15-10	11	16	2	3	6.4	13	1.28	25.5	38	5.10	141.0	207	28.19
10-3	44	60	7	10	25.8	39	3.68	102.6	141	14.66	567.0	774	81.01
3-0.3	116	176	19	29	76.6	116	28.37	272.9	414	101.06	1,505.0	2,279	557.41
0.3-0.03	114	290	18	47	75.0	191	277.84	265.5	679	983.46	1,469.1	3,748	5,441.12
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	3	3	0.4	0.4	5.6	6	1.13	7.2	7	1.43	35.0	35	7.00
10-3	29	32	5	5	17.1	23	2.45	67.3	74	9.61	375.7	411	53.67
3-0.3	109	141	18	23	68.2	91	25.25	255.2	330	94.53	1,409.6	1,820	522.07
0.3-0.03	114	255	18	41	75.2	166	278.50	267.5	597	990.87	1,474.3	3,295	5,460.45
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	21	21	3	3	16.3	16	6.04	48.7	49	18.06	268.7	269	99.51
0.3-0.03	101	122	16	20	63.6	80	235.60	238.0	287	881.31	1,309.9	1,579	4,851.61

Table 2.1.15. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Spill/Leak, with Soil Washing, 50-Year SAFSTOR)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	19	19	3	3	50.6	51	10.13	60.23	60	12.05	140.49	140	28.10
10-3	36	55	6	10	23.8	74	3.39	50.0	110	7.14	203.2	344	29.02
3-0.3	173	228	31	41	117.9	192	43.68	234.8	345	86.98	968.5	1,312	358.69
0.3-0.03	224	453	40	81	151.6	344	561.66	304.7	650	1,128.45	1,255.6	2,568	4,650.30
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	14	14	2	2	47.18	47	6.74	53.35	53	7.62	111.36	111	15.91
3-0.3	98	112	18	20	64.4	112	23.87	133.73	187	49.53	549.02	660	203.34
0.3-0.03	218	329	39	59	147.1	259	544.90	295.66	483	1,095.04	1,217.39	1,878	4,508.85
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	33	33	6	6	60.0	60	22.22	80.21	80	29.71	220.79	221	81.77
0.3-0.03	124	157	22	28	81.6	142	302.19	167.92	248	621.92	693.74	915	2,569.41

Table 2.1.16. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Spill/Leak, Direct Disposal of Soil, 50-Year SAFSTOR)

Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	$10/ft³ Disposal Cost: Incremental Cost ($K)	$10/ft³ Disposal Cost: Cumulative Cost ($K)	$10/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$50/ft³ Disposal Cost: Incremental Cost ($K)	$50/ft³ Disposal Cost: Cumulative Cost ($K)	$50/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$350/ft³ Disposal Cost: Incremental Cost ($K)	$350/ft³ Disposal Cost: Cumulative Cost ($K)	$350/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	19	19	3	3	15.2	15	3.05	44.7	45	8.94	245.4	245	49.07
10-3	36	55	6	9	21.3	36	3.04	85.6	130	12.22	468.4	714	66.92
3-0.3	173	228	28	37	114.1	151	42.27	404.3	535	149.75	2,238.4	2,952	829.03
0.3-0.03	224	453	36	73	144.3	295	534.34	526.1	1,061	1,948.63	2,903.4	5,856	10,753.24
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	14	14	2	2	12.2	12	1.74	33.0	33	4.72	178.1	178	25.44
3-0.3	98	112	16	18	61.7	74	22.87	229.5	263	85.02	1,267.8	1,446	469.54
0.3-0.03	218	329	35	53	140.2	214	519.35	509.5	772	1,887.10	2,813.8	4,260	10,421.63
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	33	33	5	5	23.6	24	8.74	79.0	79	29.25	430.4	430	159.42
0.3-0.03	124	157	20	25	81.2	105	300.66	290.1	369	1,074.53	1,604.7	2,035	5,943.24

Table 2.1.17. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Spill/Leak, with Soil Washing, 50-Year SAFSTOR)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	41	41	7	7	64.87	64.87	24.026	89.92	89.92	33.305	261.92	261.92	97.006
0.3-0.03	142	183	25	33	97.5	162	361.09	192.8	283	713.97	794.7	1,057	2,943.22
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
0.3-0.03	87	87	16	16	95.49	95.49	353.684	153.61	153.61	568.933	522.97	522.97	1,936.916
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
0.3-0.03	20	20	4	4	51.06	51.06	189.100	61.07	61.07	226.176	144.04	144.04	533.476

Table 2.1.18. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Spill/Leak, Direct Disposal of Soil, 50-Year SAFSTOR)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	41	41	7	7	27.97	27.97	10.359	95.43	95.43	35.345	525.41	525.41	194.597
0.3-0.03	142	183	23	30	91.7	120	339.76	332.6	428	1,232.00	1,837.4	2,363	6,805.13
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
0.3-0.03	87	87	14	14	59.46	59.46	220.229	205.48	205.48	761.038	1,128.87	1,128.87	4,180.995
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
0.3-0.03	20	20	3	3	15.62	15.62	57.834	46.13	46.13	170.850	253.56	253.56	939.099

Table 2.2.1. **Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, Deposition on Soil Surface, with Soil Washing)**

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	133	133	24	24	87.2	87	2.18	180.5	180	4.51	742.7	743	18.57
60-30	156	289	28	52	107.0	194	3.57	213.0	393	7.10	875.9	1,619	29.20
30-25	37	327	7	58	24.6	219	4.92	50.4	444	10.08	209.1	1,828	41.82
25-15	100	426	18	76	69.7	288	6.97	136.0	580	13.60	558.4	2,386	55.84
15-10	76	502	14	90	49.7	338	9.93	102.9	683	20.59	422.9	2,809	84.59
10-3	201	703	36	126	140.5	479	20.08	273.0	956	39.01	1,125.9	3,935	160.85
3-0.3	326	1,029	58	184	218.2	697	80.80	442.5	1,398	163.91	1,822.1	5,757	674.85
0.3-0.03	289	1,317	52	236	198.0	895	733.48	392.9	1,791	1,455.37	1,616.4	7,373	5,986.67
Medium													
100-60	541	541	97	97	367.9	368	9.20	735.2	735	18.38	3,026.8	3,027	75.67
60-30	284	824	51	148	194.8	563	6.49	386.4	1,122	12.88	1,588.8	4,616	52.96
30-25	59	883	11	158	38.6	601	7.72	79.5	1,201	15.91	328.2	4,944	65.63
25-15	142	1,025	25	183	97.2	698	9.72	192.2	1,393	19.22	792.1	5,736	79.21
15-10	99	1,124	18	201	69.2	768	13.85	135.1	1,528	27.02	554.8	6,291	110.97
10-3	251	1,375	45	246	169.3	937	24.19	341.2	1,870	48.74	1,405.8	7,696	200.83
3-0.3	382	1,757	68	315	259.5	1,196	96.11	519.4	2,389	192.37	2,138.9	9,835	792.19
0.3-0.03	312	2,069	56	370	213.4	1,410	790.46	424.9	2,814	1,573.84	1,747.5	11,583	6,472.35
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	840	840	150	150	607.0	607	60.70	1,176.3	1,176	117.63	4,736.6	4,737	473.66
15-10	479	1,320	86	236	327.6	935	65.51	652.2	1,828	130.44	2,684.0	7,421	536.81
10-3	469	1,789	84	320	320.9	1,256	45.84	637.6	2,466	91.08	2,626.3	10,047	375.19
3-0.3	502	2,291	90	410	338.1	1,594	125.23	682.8	3,149	252.87	2,809.0	12,856	1,040.38
0.3-0.03	364	2,655	65	475	251.9	1,845	932.78	494.7	3,644	1,832.13	2,038.5	14,895	7,549.95

Table 2.2.2. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, Deposition on Soil Surface, Direct Disposal of Soil)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	133	133	21	21	86.2	86	2.16	310.5	311	7.76	1,716.0	1,716	42.90
60-30	156	289	25	47	100.2	186	3.34	367.3	678	12.24	2,024.7	3,741	67.49
30-25	37	327	6	53	22.0	208	4.40	87.1	765	17.43	483.8	4,224	96.77
25-15	100	426	16	69	66.8	275	6.68	233.3	998	23.33	1,289.5	5,514	128.95
15-10	76	502	12	81	48.5	324	9.70	177.0	1,175	35.39	976.9	6,491	195.39
10-3	201	703	33	114	130.7	454	18.67	472.1	1,647	67.45	2,604.4	9,095	372.05
3-0.3	326	1,029	53	167	207.9	662	76.99	762.7	2,410	282.47	4,211.6	13,307	1,559.83
0.3-0.03	289	1,317	47	213	186.2	849	689.63	675.6	3,086	2,502.16	3,734.2	17,041	13,830.43
Medium													
100-60	541	541	88	88	350.8	351	8.77	1,265.8	1,266	31.64	6,994.7	6,995	174.87
60-30	284	824	46	134	183.3	534	6.11	665.9	1,932	22.20	3,671.7	10,666	122.39
30-25	59	883	10	143	38.6	573	7.72	136.9	2,069	27.38	758.5	11,425	151.70
25-15	142	1,025	23	166	91.5	664	9.15	331.6	2,400	33.16	1,831.5	13,256	183.15
15-10	99	1,124	16	182	62.4	727	12.47	231.9	2,632	46.38	1,281.2	14,538	256.24
10-3	251	1,375	41	223	164.2	891	23.45	588.4	3,220	84.05	3,249.9	17,788	464.28
3-0.3	382	1,757	62	285	245.3	1,136	90.84	895.1	4,115	331.50	4,943.8	22,731	1,831.05
0.3-0.03	312	2,069	51	335	204.1	1,340	755.78	731.5	4,847	2,709.31	4,038.0	26,769	14,955.59
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	840	840	136	136	543.3	543	54.33	1,969.1	1,969	196.91	10,870.1	10,870	1,087.01
15-10	479	1,320	78	214	310.7	854	62.14	1,123.0	3,092	224.61	6,202.6	17,073	1,240.52
10-3	469	1,789	76	290	304.7	1,159	43.53	1,099.1	4,191	157.02	6,071.0	23,144	867.28
3-0.3	502	2,291	81	371	323.8	1,483	119.93	1,175.2	5,366	435.26	6,490.9	29,635	2,404.03
0.3-0.03	364	2,655	59	430	234.8	1,717	869.49	854.1	6,221	3,163.19	4,713.6	34,348	17,457.75

Table 2.2.3. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, Deposition on Soil Surface, with Soil Washing)

Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	$10/ft^3 Disposal Cost			$50/ft^3 Disposal Cost			$350/ft^3 Disposal Cost		
					Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	1,056	1,056	189	189	753.1	753	75.31	1,469.8	1,470	146.98	5,944.9	5,945	594.49
15-10	323	1,379	58	247	220.7	974	44.13	439.4	1,909	87.88	1,808.7	7,754	361.73
10-3	438	1,817	78	325	300.2	1,274	42.89	595.1	2,504	85.01	2,450.8	10,204	350.11
3-0.3	491	2,308	88	413	335.2	1,609	124.13	667.4	3,172	247.17	2,748.1	12,952	1,017.81
0.3-0.03	363	2,671	65	478	247.1	1,856	915.28	494.8	3,666	1,832.42	2,034.5	14,987	7,535.31
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	1,056	1,056	189	189	753.1	753	107.58	1,469.8	1,470	209.97	5,944.9	5,945	849.27
3-0.3	933	1,989	167	356	638.2	1,391	236.36	1,269.3	2,739	470.10	5,223.5	11,168	1,934.61
0.3-0.03	434	2,423	78	434	293.4	1,685	1,086.80	589.7	3,329	2,184.09	2,427.9	13,596	8,992.36
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	1,379	1,379	247	247	973.7	974	360.65	1,909.1	1,909	707.09	7,753.5	7,754	2,871.68
0.3-0.03	698	2,077	125	372	475.5	1,449	1,760.99	949.4	2,859	3,516.37	3,907.9	11,661	14,473.81

Table 2.2.4. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, Deposition on Soil Surface, Direct Disposal of Soil)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	1,056	1,056	171	171	682.6	683	68.26	2,475.0	2,475	247.50	13,662.8	13,663	1,366.28
15-10	323	1,379	52	223	210.5	893	42.11	756.0	3,231	151.20	4,179.2	17,842	835.84
10-3	438	1,817	71	294	282.1	1,175	40.31	1,026.8	4,258	146.68	5,666.0	23,508	809.42
3-0.3	491	2,308	80	374	317.5	1,493	117.59	1,150.0	5,408	425.93	6,351.8	29,860	2,352.54
0.3-0.03	363	2,671	59	433	234.2	1,727	867.42	850.6	6,258	3,150.46	4,700.1	34,560	17,407.69
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	1,056	1,056	171	171	682.6	683	97.51	2,475.0	2,475	353.57	13,662.8	13,663	1,951.82
3-0.3	933	1,989	151	322	606.2	1,289	224.52	2,184.8	4,660	809.17	12,070.2	25,733	4,470.45
0.3-0.03	434	2,423	70	393	279.7	1,569	1,036.01	1,016.3	5,676	3,764.07	5,611.9	31,345	20,784.73
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	1,379	1,379	223	223	893.1	893	330.79	3,231.0	3,231	1,196.65	17,842.0	17,842	6,608.14
0.3-0.03	698	2,077	113	337	451.6	1,345	1,672.61	1,636.5	4,867	6,061.07	9,032.8	26,875	33,454.67

Table 2.2.5. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, Mixing/Landfilling, with Soil Washing)

Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	$10/ft³ Disposal Cost: Incremental Cost ($K)	$10/ft³ Disposal Cost: Cumulative Cost ($K)	$10/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$50/ft³ Disposal Cost: Incremental Cost ($K)	$50/ft³ Disposal Cost: Cumulative Cost ($K)	$50/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$350/ft³ Disposal Cost: Incremental Cost ($K)	$350/ft³ Disposal Cost: Cumulative Cost ($K)	$350/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	996	996	178	178	679.8	680	16.99	1,353.6	1,354	33.84	5,576.0	5,576	139.40
60-30	3,492	4,488	625	803	1,811.3	2,491	60.38	4,180.5	5,534	139.35	18,977.4	24,553	632.58
30-25	765	5,253	137	940	423.8	2,915	84.76	943.8	6,478	188.75	4,183.8	28,737	836.75
25-15	1,985	7,238	355	1,296	1,102.9	4,018	110.29	2,450.9	8,929	245.09	10,863.6	39,601	1,086.36
15-10	1,864	9,102	334	1,629	1,038.3	5,056	207.67	2,300.6	11,229	460.13	10,200.1	49,801	2,040.02
10-3	5,228	14,330	936	2,565	2,904.4	7,960	414.91	6,455.0	17,684	922.14	28,608.1	78,409	4,086.88
3-0.3	9,492	23,821	1,699	4,264	5,279.0	13,240	1,955.20	11,718.5	29,403	4,340.20	51,942.6	130,352	19,238.00
0.3-0.03	9,663	33,484	1,730	5,994	5,370.2	18,610	19,889.56	11,929.4	41,332	44,182.80	52,878.3	183,230	195,845.61
Medium													
100-60	25	25	4	4	16.3	16	0.41	33.8	34	0.84	138.7	139	3.47
60-30	1,849	1,874	331	335	1,257.2	1,273	41.91	2,514.0	2,548	83.80	10,351.7	10,490	345.06
30-25	767	2,641	137	473	524.7	1,798	104.94	1,042.0	3,590	208.40	4,291.4	14,782	858.27
25-15	2,147	4,788	384	857	1,461.2	3,259	146.12	2,918.9	6,509	291.89	12,018.4	26,800	1,201.84
15-10	1,704	6,492	305	1,162	1,157.2	4,417	231.45	2,316.4	8,825	463.28	9,536.5	36,337	1,907.31
10-3	5,057	11,549	905	2,067	2,514.5	6,931	359.21	5,944.5	14,770	849.21	27,375.3	63,712	3,910.75
3-0.3	9,667	21,216	1,730	3,798	5,376.6	12,308	1,991.32	11,934.4	26,704	4,420.16	52,901.5	116,614	19,593.16
0.3-0.03	9,664	30,880	1,730	5,528	5,370.8	17,678	19,891.67	11,932.0	38,636	44,192.41	52,885.5	169,499	195,872.04
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	38	38	7	7	63.5	63	6.35	87.2	87	8.72	250.2	250	25.02
15-10	22	60	4	11	14.4	78	2.89	30.1	117	6.02	123.2	373	24.63
10-3	3,557	3,618	637	648	2,421.0	2,499	345.86	4,835.5	4,953	690.79	19,909.7	20,283	2,844.24
3-0.3	9,673	13,290	1,731	2,379	5,443.7	7,943	2,016.19	12,005.2	16,958	4,446.36	52,995.5	73,279	19,627.95
0.3-0.03	9,666	22,957	1,730	4,109	5,372.0	13,315	19,896.39	11,934.8	28,893	44,202.91	52,898.4	126,177	195,920.07

Table 2.2.6. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, Mixing/Landfilling, Direct Disposal of Soil)

Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	$10/ft³ Disposal Cost: Incremental Cost ($K)	$10/ft³ Disposal Cost: Cumulative Cost ($K)	$10/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$50/ft³ Disposal Cost: Incremental Cost ($K)	$50/ft³ Disposal Cost: Cumulative Cost ($K)	$50/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$350/ft³ Disposal Cost: Incremental Cost ($K)	$350/ft³ Disposal Cost: Cumulative Cost ($K)	$350/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	996	996	161	161	643.4	643	16.09	2,333.3	2,333	58.33	12,889.4	12,889	322.23
60-30	3,492	4,488	566	727	2,254.5	2,898	75.15	8,179.5	10,513	272.65	45,171.9	58,061	1,505.73
30-25	765	5,253	124	851	494.8	3,393	98.95	1,791.9	12,305	358.39	9,891.9	67,953	1,978.38
25-15	1,985	7,238	322	1,173	1,282.4	4,675	128.24	4,649.7	16,954	464.97	25,681.6	93,635	2,568.16
15-10	1,864	9,102	302	1,475	1,202.9	5,878	240.59	4,367.5	21,322	873.50	24,116.1	117,751	4,823.21
10-3	5,228	14,330	847	2,321	3,378.0	9,256	482.57	12,246.4	33,568	1,749.48	67,629.3	185,380	9,661.32
3-0.3	9,492	23,821	1,538	3,859	6,132.0	15,388	2,271.11	22,234.2	55,802	8,234.90	122,794.3	308,174	45,479.39
0.3-0.03	9,663	33,484	1,565	5,424	6,244.9	21,633	23,129.26	22,636.6	78,439	83,839.34	125,009.0	433,183	462,996.38
Medium													
100-60	25	25	4	4	14.6	15	0.36	57.7	58	1.44	320.0	320	8.00
60-30	1,849	1,874	300	304	1,198.5	1,213	39.95	4,332.5	4,390	144.42	23,926.7	24,247	797.56
30-25	767	2,641	124	428	492.0	1,705	98.39	1,796.8	6,187	359.37	9,920.2	34,167	1,984.04
25-15	2,147	4,788	348	776	1,390.0	3,095	139.00	5,029.5	11,216	502.95	27,778.3	61,945	2,777.83
15-10	1,704	6,492	276	1,052	1,100.5	4,195	220.09	3,991.6	15,208	798.32	22,041.9	83,987	4,408.38
10-3	5,057	11,549	819	1,871	3,265.4	7,461	466.49	11,846.6	27,055	1,692.37	65,423.6	149,411	9,346.23
3-0.3	9,667	21,216	1,566	3,437	6,247.4	13,708	2,313.86	22,646.1	49,701	8,387.45	125,063.9	274,475	46,319.95
0.3-0.03	9,664	30,880	1,566	5,003	6,241.4	19,950	23,116.41	22,639.0	72,340	83,848.15	125,022.8	399,497	463,047.24
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-		-
25-15	38	38	6	6	26.7	27	2.67	90.8	91	9.08	498.4	498	49.84
15-10	22	60	4	10	12.9	40	2.58	51.4	142	10.28	284.1	782	56.81
10-3	3,557	3,618	576	586	2,301.2	2,341	328.74	8,332.7	8,475	1,190.38	46,018.2	46,801	6,574.02
3-0.3	9,673	13,290	1,567	2,153	6,246.5	8,587	2,313.53	22,659.6	31,134	8,392.45	125,135.4	171,936	46,346.44
0.3-0.03	9,666	22,957	1,566	3,719	6,246.9	14,834	23,136.80	22,644.3	53,779	83,867.82	125,053.4	296,989	463,160.72

Table 2.2.7. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, Mixing/Landfilling, with Soil Washing)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	48	48	9	9	70.0	70	7.00	100.1	100	10.01	305.1	305	30.51
15-10	15	63	3	11	9.7	80	1.95	20.7	121	4.14	83.4	389	16.69
10-3	3,983	4,047	713	724	2,709.5	2,789	387.08	5,414.1	5,535	773.44	22,294.7	22,683	3,184.96
3-0.3	9,672	13,719	1,731	2,456	5,390.0	8,179	1,996.28	11,952.4	17,487	4,426.81	52,940.6	75,624	19,607.64
0.3-0.03	9,666	23,385	1,730	4,186	5,376.1	13,555	19,911.49	11,934.7	29,422	44,202.72	52,898.2	128,522	195,919.19
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	48	48	9	9	70.0	70	10.00	100.1	100	14.30	305.1	305	43.58
3-0.3	6,911	6,959	1,237	1,246	4,704.2	4,774	1,742.31	9,395.2	9,495	3,479.71	38,681.7	38,987	14,326.56
0.3-0.03	9,670	16,629	1,731	2,977	5,021.2	9,795	18,596.95	11,584.7	21,080	42,906.26	52,561.8	91,549	194,673.36
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	63	63	11	11	79.7	80	29.53	120.8	121	44.76	388.5	389	143.90
0.3-0.03	8,504	8,567	1,522	1,534	5,235.7	5,315	19,391.55	11,007.2	11,128	40,767.25	47,045.7	47,434	174,243.43

Table 2.2.8. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, Mixing/Landfilling, Direct Disposal of Soil)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	48	48	8	8	32.5	33	3.25	114.0	114	11.40	626.5	626	62.65
15-10	15	63	2	10	8.7	41	1.74	34.2	148	6.84	191.0	817	38.20
10-3	3,983	4,047	645	656	2,576.5	2,618	368.07	9,332.3	9,481	1,333.19	51,533.9	52,351	7,361.98
3-0.3	9,672	13,719	1,567	2,222	6,246.2	8,864	2,313.43	22,657.2	32,138	8,391.55	125,127.8	177,479	46,343.61
0.3-0.03	9,666	23,385	1,566	3,788	6,246.9	15,111	23,136.71	22,644.2	54,782	83,867.46	125,052.8	302,532	463,158.65
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	48	48	8	8	32.5	33	4.65	114.0	114	16.29	626.5	626	89.49
3-0.3	6,911	6,959	1,120	1,127	4,466.4	4,499	1,654.22	16,189.8	16,304	5,996.24	89,406.1	90,033	33,113.35
0.3-0.03	9,670	16,629	1,566	2,694	6,244.7	10,744	23,128.55	22,651.4	38,955	83,893.99	125,094.2	215,127	463,311.75
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	63	63	10	10	41.3	41	15.28	148.2	148	54.90	817.4	817	302.75
0.3-0.03	8,599	8,663	1,393	1,403	5,557.9	5,599	20,584.66	20,144.8	20,293	74,610.51	111,249.2	112,067	412,034.18

Table C.2.3.1. Summary of Costs and Occupational Dose for Decontamination of the Reference Sealed Source Manufacturer Floors/Walls

Concrete Depth Removed (cm)	Residual Dose Rate (mrem/y)	Concrete Volume Requiring Disposal (m^3)	Building D&D Cost ($ millions)	Occupational Dose (person-rem)
0.3175	485	2.7	0.048	0.081
0.6350	56	3.0	0.061	0.12
0.9525	3.0	3.3	0.075	0.16
1.2700	0.50	3.7	0.089	0.20
1.5875	0.004	4.0	0.103	0.25

Table 2.3.2. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, Deposition on Soil Surface, with Soil Washing)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	6	6	1	1	4.2	4	0.10	8.4	8	0.21	35.4	35	0.88
60-30	6	13	1	2	4.1	8	0.14	9.4	18	0.31	35.6	71	1.19
30-25	2	14	0	3	1.0	9	0.21	2.1	20	0.41	8.7	80	1.75
25-15	4	18	1	3	2.5	12	0.25	5.0	25	0.50	21.0	101	2.10
15-10	4	21	1	4	2.3	14	0.46	4.6	29	0.92	19.5	120	3.90
10-3	18	39	3	7	11.8	26	1.68	24.8	54	3.54	100.7	221	14.39
3-0.3	42	82	8	15	27.9	54	10.33	56.9	111	21.08	236.7	458	87.67
0.3-0.03	21	103	4	18	13.9	68	51.49	29.0	140	107.53	118.6	576	439.37
Medium													
100-60	12	12	2	2	45.9	46	1.15	50.8	51	1.27	100.5	101	2.51
60-30	10	22	2	4	6.5	52	0.22	13.0	64	0.43	54.9	155	1.83
30-25	2	23	0	4	1.1	54	0.22	2.2	66	0.44	9.3	165	1.86
25-15	4	28	1	5	2.9	56	0.29	7.1	73	0.71	25.7	190	2.57
15-10	3	31	1	6	2.1	58	0.42	4.2	77	0.83	17.7	208	3.53
10-3	8	39	1	7	5.5	64	0.78	10.9	88	1.56	46.1	254	6.58
3-0.3	39	78	7	14	25.8	90	9.56	52.8	141	19.55	219.1	473	81.16
0.3-0.03	28	107	5	19	18.5	108	68.68	38.3	179	141.80	157.8	631	584.43
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	17	17	3	3	49.6	50	7.09	58.2	58	8.31	131.7	132	18.82
3-0.3	22	40	4	7	14.7	64	5.46	30.7	89	11.36	125.6	257	46.52
0.3-0.03	49	89	9	16	32.3	97	119.70	67.1	156	248.39	275.4	533	1,019.82

Table 2.3.3. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, Deposition on Soil Surface, Direct Disposal of Soil)

Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	$10/ft³ Disposal Cost: Incremental Cost ($K)	$10/ft³ Disposal Cost: Cumulative Cost ($K)	$10/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$50/ft³ Disposal Cost: Incremental Cost ($K)	$50/ft³ Disposal Cost: Cumulative Cost ($K)	$50/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$350/ft³ Disposal Cost: Incremental Cost ($K)	$350/ft³ Disposal Cost: Cumulative Cost ($K)	$350/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	6	6	1	1	3.8	4	0.09	15.5	15	0.39	83.0	83	2.08
60-30	6	13	1	2	3.6	7	0.12	13.7	29	0.46	79.1	162	2.64
30-25	2	14	0	2	0.9	8	0.19	3.5	33	0.70	20.2	182	4.04
25-15	4	18	1	3	2.2	11	0.22	9.7	42	0.97	49.8	232	4.98
15-10	4	21	1	3	2.1	13	0.41	7.8	50	1.56	45.0	277	9.00
10-3	18	39	3	6	10.5	23	1.51	42.4	93	6.06	232.2	509	33.17
3-0.3	42	82	7	13	29.1	52	10.76	98.2	191	36.37	547.7	1,057	202.84
0.3-0.03	21	103	3	17	12.4	65	46.05	49.6	240	183.71	273.6	1,331	1,013.30
Medium													
100-60	12	12	2	2	11.0	11	0.28	28.7	29	0.72	153.1	153	3.83
60-30	10	22	2	4	5.8	17	0.19	22.0	51	0.73	126.7	280	4.22
30-25	2	23	0	4	1.0	18	0.20	5.1	56	1.01	22.9	303	4.57
25-15	4	28	1	4	2.6	20	0.26	9.8	65	0.98	56.3	359	5.63
15-10	3	31	1	5	1.9	22	0.37	7.1	73	1.41	40.8	400	8.16
10-3	8	39	1	6	4.9	27	0.70	19.8	92	2.82	107.8	507	15.40
3-0.3	39	78	6	13	27.2	54	10.07	92.5	185	34.25	508.3	1,016	188.28
0.3-0.03	28	107	5	17	16.6	71	61.43	65.3	250	241.77	364.1	1,380	1,348.34
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	17	17	3	3	14.3	14	2.04	41.2	41	5.89	225.1	225	32.16
3-0.3	22	40	4	6	13.2	27	4.88	52.4	94	19.41	289.7	515	107.30
0.3-0.03	49	89	8	14	33.0	60	122.25	115.8	209	428.79	636.5	1,151	2,357.37

Table 2.3.4. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, Deposition on Soil Surface, with Soil Washing)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	8	8	1	1	43.2	43	8.64	45.4	45	9.09	77.8	78	15.57
10-3	17	25	3	4	11.2	54	1.61	22.4	68	3.20	94.9	173	13.56
3-0.3	15	40	3	7	9.7	64	3.60	20.7	89	7.68	83.4	256	30.91
0.3-0.03	11	51	2	9	7.4	72	27.53	14.8	103	54.86	62.7	319	232.27
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	18	18	3	3	49.8	50	7.12	58.6	59	8.37	133.5	134	19.08
3-0.3	18	36	3	6	11.9	62	4.41	25.1	84	9.29	101.9	235	37.73
0.3-0.03	11	47	2	8	7.4	69	27.59	14.8	99	54.99	62.9	298	232.81
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	11	11	2	2	45.4	45	16.81	49.8	50	18.43	96.2	96	35.63
0.3-0.03	22	33	4	6	14.6	60	53.94	30.4	80	112.41	124.2	220	460.01

Table 2.3.5. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, Deposition on Soil Surface, Direct Disposal of Soil)

Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	\$10/ft³ Disposal Cost: Incremental Cost (\$K)	\$10/ft³ Disposal Cost: Cumulative Cost (\$K)	\$10/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate (\$K/mrem/yr)	\$50/ft³ Disposal Cost: Incremental Cost (\$K)	\$50/ft³ Disposal Cost: Cumulative Cost (\$K)	\$50/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate (\$K/mrem/yr)	\$350/ft³ Disposal Cost: Incremental Cost (\$K)	\$350/ft³ Disposal Cost: Cumulative Cost (\$K)	\$350/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate (\$K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	8	8	1	1	8.6	9	1.72	18.3	18	3.66	99.3	99	19.87
10-3	17	25	3	4	10.1	19	1.44	40.6	59	5.80	221.8	321	31.69
3-0.3	15	40	2	6	8.7	27	3.22	34.2	93	12.66	191.0	512	70.74
0.3-0.03	11	51	2	8	6.6	34	24.62	26.4	120	97.87	146.2	658	541.37
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	18	18	3	3	14.5	15	2.07	41.9	42	5.99	229.3	229	32.76
3-0.3	18	36	3	6	10.7	25	3.95	42.9	85	15.89	234.9	464	87.00
0.3-0.03	11	47	2	8	6.7	32	24.68	26.5	111	98.09	146.5	611	542.64
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	11	11	2	2	10.5	11	3.91	27.0	27	9.99	143.1	143	52.99
0.3-0.03	22	33	4	5	13.0	24	48.24	51.8	79	191.97	286.5	430	1,060.97

Table 2.3.6. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, Spill/Leak, with Soil Washing)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	17	17	3	3	11.0	11	0.27	23.2	23	0.58	93.7	94	2.34
60-30	46	63	8	11	30.3	41	1.01	63.0	86	2.10	258.1	352	8.60
30-25	13	76	2	14	8.8	50	1.77	17.6	104	3.52	74.6	426	14.91
25-15	38	114	7	20	24.8	75	2.48	50.8	155	5.08	210.9	637	21.09
15-10	30	144	5	26	19.7	95	3.95	42.0	197	8.40	169.2	806	33.84
10-3	89	233	16	42	62.9	158	8.99	121.3	318	17.32	500.5	1,307	71.50
3-0.3	172	405	31	73	117.1	275	43.37	233.2	551	86.37	961.5	2,268	356.10
0.3-0.03	172	577	31	103	117.1	392	433.63	234.5	785	868.36	962.6	3,231	3,565.09
Medium													
100-60	8	8	1	1	5.3	5	0.13	10.5	11	0.26	44.6	45	1.12
60-30	20	28	3	5	12.8	18	0.43	26.9	37	0.90	109.7	154	3.66
30-25	10	37	2	7	6.3	24	1.26	12.6	50	2.52	53.3	208	10.66
25-15	36	73	6	13	23.5	48	2.35	48.1	98	4.81	199.3	407	19.93
15-10	30	103	5	18	19.8	68	3.96	42.1	140	8.42	169.6	576	33.91
10-3	90	193	16	34	63.0	131	9.00	121.4	262	17.35	501.2	1,078	71.59
3-0.3	172	365	31	65	117.4	248	43.47	233.7	495	86.56	963.7	2,041	356.91
0.3-0.03	172	537	31	96	117.4	365	434.77	235.1	730	870.63	965.2	3,006	3,574.70
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	4	4	1	1	41.0	41	8.21	41.1	41	8.22	59.4	59	11.89
10-3	20	24	4	4	13.1	54	1.88	26.2	67	3.74	110.9	170	15.85
3-0.3	150	174	27	31	98.7	153	36.57	204.8	272	75.84	841.1	1,011	311.52
0.3-0.03	171	345	31	62	116.5	269	431.66	232.1	504	859.52	956.8	1,968	3,543.54

Table 2.3.7. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, Spill/Leak, Direct Disposal of Soil)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	17	17	3	3	9.8	10	0.24	39.6	40	0.99	216.1	216	5.40
60-30	46	63	7	10	31.2	41	1.04	107.5	147	3.58	595.3	811	19.84
30-25	13	76	2	12	7.9	49	1.58	31.2	178	6.23	173.6	985	34.71
25-15	38	114	6	18	22.2	71	2.22	89.2	268	8.92	489.3	1,474	48.93
15-10	30	144	5	23	21.8	93	4.35	70.6	338	14.13	388.7	1,863	77.73
10-3	89	233	14	38	56.7	150	8.10	209.3	547	29.90	1,157.4	3,020	165.34
3-0.3	172	405	28	66	113.4	263	41.99	402.9	950	149.20	2,223.6	5,244	823.55
0.3-0.03	172	577	28	93	109.3	372	404.64	402.8	1,353	1,491.70	2,223.0	7,467	8,233.51
Medium													
100-60	8	8	1	1	4.7	5	0.12	19.2	19	0.48	104.4	104	2.61
60-30	20	28	3	4	11.5	16	0.38	46.0	65	1.53	252.9	357	8.43
30-25	10	37	2	6	5.7	22	1.13	22.7	88	4.53	124.5	482	24.89
25-15	36	73	6	12	25.1	47	2.51	83.2	171	8.32	461.3	943	46.13
15-10	30	103	5	17	17.7	65	3.54	70.8	242	14.16	389.5	1,333	77.90
10-3	90	193	15	31	56.8	121	8.11	209.6	451	29.94	1,159.0	2,491	165.57
3-0.3	172	365	28	59	113.6	235	42.08	403.7	855	149.53	2,228.6	4,720	825.42
0.3-0.03	172	537	28	87	109.5	345	405.66	403.8	1,259	1,495.55	2,229.0	6,949	8,255.72
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	4	4	1	1	6.6	7	1.33	10.9	11	2.19	56.8	57	11.37
10-3	20	24	3	4	11.8	18	1.68	47.1	58	6.72	258.9	316	36.98
3-0.3	150	174	24	28	96.5	115	35.75	352.0	410	130.38	1,942.9	2,259	719.60
0.3-0.03	171	345	28	56	108.8	224	402.88	399.6	810	1,480.13	2,211.3	4,470	8,190.18

Table 2.3.8. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, Spill/Leak, with Soil Washing)

					\$10/ft^3 Disposal Cost			\$50/ft^3 Disposal Cost			\$350/ft^3 Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost (\$K)	Cumulative Cost (\$K)	Cost per Reduction in Residual Dose Rate (\$K/mrem/yr)	Incremental Cost (\$K)	Cumulative Cost (\$K)	Cost per Reduction in Residual Dose Rate (\$K/mrem/yr)	Incremental Cost (\$K)	Cumulative Cost (\$K)	Cost per Reduction in Residual Dose Rate (\$K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	0.3	0.3	0.1	0.1	38.37	38.37	1.279	35.79	35.79	1.193	37.03	37	1.234
30-25	2	2	0.4	0.4	1.44	39.82	0.288	2.87	39	0.575	12.17	49	2.433
25-15	6	8	1	2	3.9	44	0.39	7.8	46	0.78	32.9	82	3.29
15-10	6	14	1	3	3.9	48	0.77	7.7	54	1.54	32.7	115	6.54
10-3	46	60	8	11	30.0	78	4.29	62.4	117	8.92	255.8	371	36.54
3-0.3	170	230	30	41	115.9	194	42.94	230.9	347	85.51	951.7	1,322	352.48
0.3-0.03	171	401	31	72	116.7	310	432.15	232.3	580	860.50	957.9	2,280	3,547.70
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	4	4	1	1	41.1	41	8.21	41.1	41	8.23	59.7	60	11.94
10-3	20	25	4	4	13.2	54	1.89	26.4	68	3.77	111.8	171	15.96
3-0.3	153	177	27	32	104.4	159	38.67	207.9	275	76.98	854.2	1,026	316.38
0.3-0.03	172	349	31	62	112.9	272	418.09	232.9	508	862.75	960.4	1,986	3,557.22
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	17	17	3	3	49.4	49	18.29	57.7	58	21.37	129.8	130	48.09
0.3-0.03	133	150	24	27	87.5	137	324.19	181.1	239	670.68	745.2	875	2,759.94

Table 2.3.9. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, Spill/Leak, Direct Disposal of Soil)

					$10/ft³ Disposal Cost			$50/ft³ Disposal Cost			$350/ft³ Disposal Cost		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	0.3	0.3	0.05	0.05	4.27	4.27	0.142	1.97	1.97	0.066	5.08	5	0.169
30-25	2	2	0.4	0.4	1.29	5.56	0.258	4.87	6.84	0.974	28.10	33	5.620
25-15	6	8	1	1	3.5	9	0.35	13.2	20	1.32	76.1	109	7.61
15-10	6	14	1	2	3.5	13	0.69	14.4	34	2.88	76.8	186	15.37
10-3	46	60	7	10	26.8	39	3.83	106.6	141	15.23	589.9	776	84.28
3-0.3	170	230	28	37	112.3	152	41.61	398.9	540	147.75	2,201.0	2,977	815.19
0.3-0.03	171	401	28	65	108.9	261	403.32	400.1	940	1,481.79	2,213.9	5,191	8,199.78
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	4	4	1	1	6.7	7	1.34	11.0	11	2.21	57.4	57	11.49
10-3	20	25	3	4	11.8	19	1.69	47.4	58	6.77	260.8	318	37.25
3-0.3	153	177	25	29	97.9	116	36.26	357.3	416	132.32	1,973.2	2,291	730.81
0.3-0.03	172	349	28	56	109.2	226	404.33	402.4	818	1,490.51	2,221.2	4,513	8,226.68
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-	-	-	-	-	-	-
3-0.3	17	17	3	3	14.1	14	5.23	40.4	40	14.98	220.7	221	81.76
0.3-0.03	133	150	22	24	86.5	101	320.33	311.5	352	1,153.74	1,721.8	1,943	6,376.89

Table 2.4.1. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Unrestricted Land Use, Deposition on Soil Surface, with Soil Washing)

Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	$10/ft³ Disposal Cost: Incremental Cost ($K)	$10/ft³ Disposal Cost: Cumulative Cost ($K)	$10/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$50/ft³ Disposal Cost: Incremental Cost ($K)	$50/ft³ Disposal Cost: Cumulative Cost ($K)	$50/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$350/ft³ Disposal Cost: Incremental Cost ($K)	$350/ft³ Disposal Cost: Cumulative Cost ($K)	$350/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	35	35	6	6	27.2	27	0.68	47.3	47	1.18	196.0	196	4.90
60-30	26	61	5	11	17.3	44	0.58	35.8	83	1.19	147.3	343	4.91
30-25	4	66	1	12	2.9	47	0.58	5.7	89	1.15	24.3	368	4.87
25-15	9	75	2	13	5.8	53	0.58	12.8	102	1.28	50.0	418	5.00
15-10	4	79	1	14	2.9	56	0.58	5.7	107	1.15	24.3	442	4.87
10-3	63	142	11	25	41.4	97	5.92	85.2	193	12.17	352.1	794	50.30
3-0.3	34	176	6	32	22.5	120	8.33	46.2	239	17.09	191.1	985	70.77
0.3-0.03	87	263	16	47	61.5	181	227.94	119.8	359	443.68	490.0	1,475	1,814.83
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	50	50	9	9	71.0	71	2.37	102.2	102	3.41	313.8	314	10.46
30-25	9	59	2	11	5.8	77	1.15	11.5	114	2.30	48.7	362	9.73
25-15	18	76	3	14	11.5	88	1.15	24.3	138	2.43	98.6	461	9.86
15-10	9	85	2	15	5.8	94	1.15	11.5	149	2.30	48.7	510	9.73
10-3	34	119	6	21	22.2	116	3.17	46.9	196	6.70	189.9	700	27.13
3-0.3	68	187	12	34	45.0	161	16.66	92.3	289	34.19	382.2	1,082	141.55
0.3-0.03	80	267	14	48	56.8	218	210.45	109.1	398	403.91	448.8	1,531	1,662.31
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	15	15	3	3	43.8	44	4.38	54.9	55	5.49	117.8	118	11.78
15-10	29	44	5	8	23.3	67	4.66	39.6	95	7.93	163.5	281	32.70
10-3	41	85	7	15	26.9	94	3.84	55.0	149	7.85	228.4	510	32.63
3-0.3	84	169	15	30	55.5	150	20.56	115.9	265	42.94	473.7	983	175.44
0.3-0.03	47	216	8	39	34.8	184	128.81	62.5	328	231.38	260.2	1,244	963.65

Table 2.4.2. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Unrestricted Land Use, Deposition on Soil Surface, Direct Disposal of Soil)

Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	$10/ft³ Disposal Cost: Incremental Cost ($K)	$10/ft³ Disposal Cost: Cumulative Cost ($K)	$10/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$50/ft³ Disposal Cost: Incremental Cost ($K)	$50/ft³ Disposal Cost: Cumulative Cost ($K)	$50/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$350/ft³ Disposal Cost: Incremental Cost ($K)	$350/ft³ Disposal Cost: Cumulative Cost ($K)	$350/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	35	35	6	6	20.6	21	0.52	81.9	82	2.05	453.5	454	11.34
60-30	26	61	4	10	15.5	36	0.52	61.1	143	2.04	339.8	793	11.33
30-25	4	66	1	11	6.7	43	1.34	11.1	154	2.21	57.5	851	11.50
25-15	9	75	1	12	5.2	48	0.52	19.5	173	1.95	112.4	963	11.24
15-10	4	79	1	13	2.6	51	0.52	11.1	185	2.21	57.5	1,021	11.50
10-3	63	142	10	23	41.1	92	5.88	147.8	332	21.12	815.1	1,836	116.44
3-0.3	34	176	6	29	20.1	112	7.45	79.9	412	29.60	442.3	2,278	163.81
0.3-0.03	87	263	14	43	55.5	167	205.48	204.6	617	757.79	1,130.1	3,408	4,185.66
Medium													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	50	50	8	8	33.5	33	1.12	117.5	118	3.92	646.5	646	21.55
30-25	9	59	1	10	5.2	39	1.03	20.8	138	4.16	113.7	760	22.74
25-15	18	76	3	12	10.3	49	1.03	40.3	179	4.03	226.1	986	22.61
15-10	9	85	1	14	9.3	58	1.85	20.8	199	4.16	113.7	1,100	22.74
10-3	34	119	5	19	19.9	78	2.84	78.9	278	11.28	436.5	1,536	62.36
3-0.3	68	187	11	30	44.3	122	16.42	159.9	438	59.21	884.6	2,421	327.62
0.3-0.03	80	267	13	43	51.3	174	189.84	188.7	627	698.71	1,038.1	3,459	3,844.73
Low													
100-60	-	-	-	-	-	-	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-	-	-	-	-	-	-
25-15	15	15	2	2	12.8	13	1.28	35.6	36	3.56	193.0	193	19.30
15-10	29	44	5	7	17.2	30	3.44	67.6	103	13.51	377.3	570	75.45
10-3	41	85	7	14	28.2	58	4.02	96.2	199	13.74	529.8	1,100	75.68
3-0.3	84	169	14	27	53.8	112	19.91	198.1	397	73.36	1,092.5	2,192	404.61
0.3-0.03	47	216	8	35	27.4	139	101.63	108.9	506	403.37	603.2	2,796	2,234.06

Table 2.4.3. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, Deposition on Soil Surface, with Soil Washing)

					No Offsite Disposal		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-
10-3	42	42	8	8	56.9	57	8.13
3-0.3	65	107	12	20	35.6	92	13.18
0.3-0.03	79	186	14	34	43.1	136	159.52
Medium							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-
3-0.3	90	90	17	17	83.4	83	30.89
0.3-0.03	87	177	16	33	47.4	131	175.45
Low							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-
3-0.3	62	62	11	11	67.9	68	25.17
0.3-0.03	74	136	14	25	40.5	108	150.00

Table 2.4.4. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, Deposition on Soil Surface, Direct Disposal of Soil)

					No Offsite Disposal		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-
10-3	42	42	7	7	12.9	13	1.84
3-0.3	65	107	11	18	20.1	33	7.45
0.3-0.03	79	186	13	31	24.3	57	90.15
Medium							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-
3-0.3	90	90	15	15	27.9	28	10.32
0.3-0.03	87	177	15	30	26.8	55	99.15
Low							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-
3-0.3	62	62	10	10	19.1	19	7.09
0.3-0.03	74	136	13	23	22.9	42	84.77

Table 2.4.5. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Unrestricted Land Use, Mixing/Landfilling, with Soil Washing)

Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m³)	Cumulative Soil Volume (m³)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	$10/ft³ Disposal Cost: Incremental Cost ($K)	$10/ft³ Disposal Cost: Cumulative Cost ($K)	$10/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$50/ft³ Disposal Cost: Incremental Cost ($K)	$50/ft³ Disposal Cost: Cumulative Cost ($K)	$50/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)	$350/ft³ Disposal Cost: Incremental Cost ($K)	$350/ft³ Disposal Cost: Cumulative Cost ($K)	$350/ft³ Disposal Cost: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High													
100-60	402	402	72	72	272.8	273	6.82	547.3	547	13.68	2,252.9	2,253	56.32
60-30	545	948	98	170	371.0	644	12.37	741.4	1,289	24.71	3,053.1	5,306	101.77
30-25	143	1,091	26	195	98.4	742	19.68	195.9	1,485	39.18	803.6	6,110	160.73
25-15	402	1,493	72	267	272.3	1,015	27.23	545.0	2,030	54.50	2,247.3	8,357	224.73
15-10	319	1,812	57	324	217.8	1,232	43.56	433.7	2,463	86.74	1,784.5	10,141	356.91
10-3	948	2,760	170	494	643.9	1,876	91.98	1,288.8	3,752	184.12	5,306.2	15,448	758.03
3-0.3	1,811	4,570	324	818	1,231.5	3,108	456.12	2,461.6	6,214	911.72	10,134.2	25,582	3,753.40
0.3-0.03	1,812	6,382	324	1,142	819.7	3,928	3,036.02	2,045.4	8,259	7,575.62	9,724.5	35,306	36,016.76
Medium													
100-60	401	401	72	72	276.3	276	6.91	546.0	546	13.65	2,247.2	2,247	56.18
60-30	546	948	98	170	371.4	648	12.38	742.3	1,288	24.74	3,056.9	5,304	101.90
30-25	144	1,091	26	195	98.5	746	19.70	196.1	1,484	39.21	804.3	6,108	160.87
25-15	402	1,493	72	267	272.5	1,019	27.25	545.3	2,030	54.53	2,248.7	8,357	224.87
15-10	319	1,812	57	324	217.9	1,237	43.58	433.8	2,464	86.77	1,785.3	10,142	357.05
10-3	947	2,759	170	494	643.3	1,880	91.90	1,287.7	3,751	183.96	5,301.5	15,444	757.35
3-0.3	1,812	4,571	324	818	1,232.2	3,112	456.37	2,462.9	6,214	912.20	10,139.7	25,584	3,755.45
0.3-0.03	1,812	6,383	324	1,142	1,236.5	4,349	4,579.68	2,462.1	8,676	9,118.78	10,140.3	35,724	37,556.64
Low													
100-60	3	3	1	1	36.1	36	0.90	38.2	38	0.95	51.5	51	1.29
60-30	545	548	98	98	370.5	407	12.35	740.4	779	24.68	3,048.8	3,100	101.63
30-25	143	691	26	124	98.3	505	19.66	195.7	974	39.15	802.9	3,903	160.58
25-15	402	1,093	72	196	276.6	782	27.66	545.2	1,520	54.52	2,248.3	6,152	224.83
15-10	319	1,413	57	253	214.2	996	42.84	434.6	1,954	86.93	1,788.6	7,940	357.71
10-3	947	2,360	170	422	647.5	1,643	92.51	1,288.0	3,242	184.00	5,302.6	13,243	757.52
3-0.3	1,812	4,172	324	747	1,232.5	2,876	456.48	2,463.6	5,706	912.43	10,142.3	23,385	3,756.41
0.3-0.03	1,811	5,983	324	1,071	1,231.8	4,108	4,562.12	2,460.8	8,167	9,114.04	10,134.9	33,520	37,536.57

Table 2.4.6. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Unrestricted Land Use, Mixing/Landfilling, Direct Disposal of Soil)

Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	\$10/ft^3 Disposal Cost: Incremental Cost (\$K)	\$10/ft^3 Disposal Cost: Cumulative Cost (\$K)	\$10/ft^3 Disposal Cost: Cost per Reduction in Residual Dose Rate (\$K/mrem/yr)	\$50/ft^3 Disposal Cost: Incremental Cost (\$K)	\$50/ft^3 Disposal Cost: Cumulative Cost (\$K)	\$50/ft^3 Disposal Cost: Cost per Reduction in Residual Dose Rate (\$K/mrem/yr)	\$350/ft^3 Disposal Cost: Incremental Cost (\$K)	\$350/ft^3 Disposal Cost: Cumulative Cost (\$K)	\$350/ft^3 Disposal Cost: Cost per Reduction in Residual Dose Rate (\$K/mrem/yr)
High													
100-60	402	402	65	65	261.3	261	6.53	942.8	943	23.57	5,206.6	5,207	130.17
60-30	545	948	88	154	349.5	611	11.65	1,277.6	2,220	42.59	7,056.7	12,263	235.22
30-25	143	1,091	23	177	92.5	703	18.51	335.7	2,556	67.14	1,855.0	14,118	371.00
25-15	402	1,493	65	242	260.9	964	26.09	941.1	3,497	94.11	5,196.8	19,315	519.68
15-10	319	1,812	52	294	203.9	1,168	40.78	746.3	4,244	149.27	4,123.5	23,439	824.70
10-3	948	2,760	154	447	615.0	1,783	87.85	2,221.8	6,465	317.41	12,265.3	35,704	1,752.18
3-0.3	1,811	4,570	293	740	1,167.4	2,950	432.35	4,240.6	10,706	1,570.61	23,422.0	59,126	8,674.81
0.3-0.03	1,812	6,382	294	1,034	1,172.4	4,123	4,342.09	4,245.4	14,951	15,723.69	23,443.2	82,569	86,826.54
Medium													
100-60	401	401	65	65	260.7	261	6.52	940.5	941	23.51	5,193.5	5,194	129.84
60-30	546	948	88	154	354.0	615	11.80	1,279.2	2,220	42.64	7,065.6	12,259	235.52
30-25	144	1,091	23	177	92.6	707	18.52	336.0	2,556	67.20	1,856.7	14,116	371.33
25-15	402	1,493	65	242	256.9	964	25.69	941.7	3,497	94.17	5,200.1	19,316	520.01
15-10	319	1,812	52	294	208.1	1,172	41.61	746.6	4,244	149.32	4,125.1	23,441	825.03
10-3	947	2,759	153	447	610.4	1,783	87.19	2,218.6	6,463	316.95	12,253.1	35,694	1,750.44
3-0.3	1,812	4,571	293	740	1,172.0	2,955	434.09	4,244.2	10,707	1,571.92	23,436.1	59,130	8,680.03
0.3-0.03	1,812	6,383	294	1,034	1,168.1	4,123	4,326.45	4,244.9	14,952	15,721.97	23,440.5	82,571	86,816.61
Low													
100-60	3	3	1	1	1.8	2	0.05	8.3	8	0.21	41.5	42	1.04
60-30	545	548	88	89	353.2	355	11.77	1,275.9	1,284	42.53	7,046.9	7,088	234.90
30-25	143	691	23	112	92.5	447	18.49	335.4	1,620	67.08	1,853.4	8,942	370.68
25-15	402	1,093	65	177	261.0	708	26.10	941.5	2,561	94.15	5,199.1	14,141	519.91
15-10	319	1,413	52	229	204.3	913	40.86	747.9	3,309	149.59	4,132.8	18,274	826.55
10-3	947	2,360	153	382	614.6	1,527	87.80	2,219.1	5,528	317.01	12,255.7	30,529	1,750.82
3-0.3	1,812	4,172	294	676	1,168.2	2,696	432.67	4,245.2	9,773	1,572.30	23,442.1	53,971	8,682.25
0.3-0.03	1,811	5,983	293	969	1,171.7	3,867	4,339.50	4,241.4	14,015	15,709.04	23,426.6	77,398	86,765.36

Table 2.4.7. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, Mixing/Landfilling, with Soil Washing)

					No Offsite Disposal		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	117	117	21	21	97.8	98	9.78
15-10	319	435	58	80	173.9	272	34.77
10-3	947	1,383	174	254	516.9	789	73.85
3-0.3	1,811	3,194	333	586	988.4	1,777	366.07
0.3-0.03	1,812	5,006	333	919	988.6	2,766	3,661.52
Medium							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-
10-3	837	837	154	154	490.7	491	70.09
3-0.3	1,812	2,649	333	486	988.8	1,479	366.22
0.3-0.03	1,812	4,461	333	819	988.7	2,468	3,661.99
Low							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-
3-0.3	1,702	1,702	312	312	962.7	963	356.57
0.3-0.03	1,812	3,514	333	645	988.5	1,951	3,661.24

Table 2.4.8. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, Mixing/Landfilling, Direct Disposal of Soil)

					No Offsite Disposal		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	117	117	20	20	36.0	36	3.60
15-10	319	435	54	73	98.3	134	19.65
10-3	947	1,383	160	233	292.1	426	41.73
3-0.3	1,811	3,194	305	538	558.5	985	206.87
0.3-0.03	1,812	5,006	305	844	558.7	1,544	2,069.15
Medium							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-
10-3	837	837	141	141	258.0	258	36.86
3-0.3	1,812	2,649	305	446	558.8	817	206.95
0.3-0.03	1,812	4,461	305	752	558.7	1,376	2,069.41
Low							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-
3-0.3	1,702	1,702	287	287	524.8	525	194.37
0.3-0.03	1,812	3,514	305	592	558.6	1,083	2,068.99

Table 2.5.1. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Mill (Unrestricted Land Use, Deposition on Soil Surface, with Soil Washing)

Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	No Offsite Disposal: Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High							
100-60	11,594	11,594	2,075	2,075	4,555	4,555	114
60-30	13,672	25,265	2,447	4,522	5,372	9,927	179
30-25	3,272	28,538	586	5,108	1,286	11,213	257
25-15	8,712	37,250	1,559	6,668	3,423	14,636	342
15-10	6,599	43,849	1,181	7,849	2,593	17,229	519
10-3	17,589	61,437	3,148	10,997	6,911	24,140	987
3-0.3	28,450	89,887	5,092	16,090	11,178	35,318	4,140
0.3-0.03	25,230	115,118	4,516	20,606	9,914	45,232	36,717
Medium							
100-60	47,257	47,257	8,459	8,459	18,568	18,568	464
60-30	24,795	72,053	4,438	12,897	9,743	28,311	325
30-25	5,127	77,180	918	13,815	2,015	30,326	403
25-15	12,372	89,552	2,215	16,030	4,861	35,187	486
15-10	8,656	98,208	1,549	17,579	3,401	38,588	680
10-3	21,955	120,163	3,930	21,509	8,627	47,214	1,232
3-0.3	33,398	153,561	5,978	27,487	13,123	60,337	4,860
0.3-0.03	27,275	180,836	4,882	32,370	10,717	71,054	39,692
Low							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	73,423	73,423	13,143	13,143	29,399	29,399	2,940
15-10	41,901	115,324	7,500	20,643	16,464	45,863	3,293
10-3	41,012	156,337	7,341	27,984	16,115	61,977	2,302
3-0.3	43,849	200,186	7,849	35,833	17,229	79,206	6,381
0.3-0.03	31,837	232,023	5,699	41,532	12,509	91,716	46,331

Table 2.5.2. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Mill (Unrestricted Land Use, Deposition on Soil Surface, Direct Disposal of Soil)

					No Offsite Disposal		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High							
100-60	11,594	11,594	1,878	1,878	2,763	2,763	69
60-30	13,672	25,265	2,215	4,093	3,259	6,022	109
30-25	3,272	28,538	530	4,623	780	6,802	156
25-15	8,712	37,250	1,411	6,034	2,077	8,878	208
15-10	6,599	43,849	1,069	7,104	1,573	10,451	315
10-3	17,589	61,437	2,849	9,953	4,192	14,643	599
3-0.3	28,450	89,887	4,609	14.562	6,781	21,424	2,511
0.3-0.03	25,230	115,118	4,087	18,649	6,014	27,438	22,273
Medium							
100-60	47,257	47,257	7,656	7,656	11,264	11,264	282
60-30	24,795	72,053	4,017	11,673	5,910	17,173	197
30-25	5,127	77,180	831	12,503	1,222	18,396	244
25-15	12,372	89,552	2,004	14,507	2,949	21,344	295
15-10	8,656	98,208	1,402	15,910	2,063	23,407	413
10-3	21,955	120,163	3,557	19,466	5,233	28,640	748
3-0.3	33,398	153,561	5,410	24,877	7,960	36,601	2,948
0.3-0.03	27,275	180,836	4,41[illegible]	29,295	6,501	43,102	24,077
Low							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	73,423	73,423	11,895	11,895	17,500	17,500	1,750
15-10	41,901	115,324	6,788	18,683	9,987	27,487	1,997
10-3	41,012	156,337	6,644	25,327	9,775	37,262	1,396
3-0.3	43,849	200,186	7,104	32,430	10,451	47,713	3,871
0.3-0.03	31,837	232,023	5,158	37,588	7,588	55,302	28,105

Table 2.5.3. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Mill (Restricted Land Use, Deposition on Soil Surface, with Soil Washing)

					No Offsite Disposal		
Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	Incremental Cost ($K)	Cumulative Cost ($K)	Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	92,287	92,287	16,519	16,519	36,811	36,811	3,681
15-10	28,238	120,525	5,055	21,574	11,095	47,906	2,219
10-3	38,268	158,794	6,850	28,424	15,036	62,943	2,148
3-0.3	42,910	201,704	7,681	36,105	16,860	79,803	6,244
0.3-0.03	31,754	233,458	5,684	41,789	12,477	92,279	46,210
Medium							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-
10-3	92,287	92,287	16,519	16,519	36,811	36,811	5,259
3-0.3	81,545	173,832	14,596	31,116	32,040	68,851	11,867
0.3-0.03	37,909	211,741	6,786	37,902	14,895	83,746	55,167
Low							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-
3-0.3	120,525	120,525	21,574	21,574	47,906	47,906	17,743
0.3-0.03	61,011	181,537	10,921	32,495	23,973	71,879	88,787

Table 2.5.4. Incremental Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Mill (Restricted Land Use, Deposition on Soil Surface, Direct Disposal of Soil)

Reduction in Residual Dose Rate (mrem/yr)	Incremental Soil Volume (m^3)	Cumulative Soil Volume (m^3)	Incremental Occupational Dose (person-mrem)	Cumulative Occupational Dose (person-mrem)	No Offsite Disposal: Incremental Cost ($K)	No Offsite Disposal: Cumulative Cost ($K)	No Offsite Disposal: Cost per Reduction in Residual Dose Rate ($K/mrem/yr)
High							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	92,287	92,287	14,951	14,951	21,996	21,996	2,200
15-10	28,238	120,525	4,575	19,525	6,730	28,727	1,346
10-3	38,268	158,794	6,199	25,725	9,121	37,848	1,303
3-0.3	42,910	201,704	6,951	32,676	10,227	48,075	3,788
0.3-0.03	31,754	233,458	5,144	37,820	7,568	55,644	28,031
Medium							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-
10-3	92,287	92,287	14,951	14,951	21,996	21,996	3,142
3-0.3	81,545	173,832	13,210	28,161	19,436	41,432	7,198
0.3-0.03	37,909	211,741	6,141	34,302	9,035	50,467	33,464
Low							
100-60	-	-	-	-	-	-	-
60-30	-	-	-	-	-	-	-
30-25	-	-	-	-	-	-	-
25-15	-	-	-	-	-	-	-
15-10	-	-	-	-	-	-	-
10-3	-	-	-	-	-	-	-
3-0.3	120,525	120,525	19,525	19,525	28,727	28,727	10,640
0.3-0.03	61,011	181,537	9,884	29,409	14,542	43,269	53,859

C.3 Modifications to Analyses in Response to Public Comments

The NRC received a number of public comments questioning the soil contaminant distribution methodology utilized in the draft GEIS. The essence of these comments was that the draft GEIS methodology, in some instances, significantly underestimates the volume of contaminated soil requiring remediation during decommissioning of nuclear facilities. In response to these comments, NRC and PNNL staff reviewed data on contamination submitted by the commenters, compared it with available data on radionuclide distributions in contaminated soil including that in the draft GEIS, and verified and/or modified, as appropriate, the analyses of the reference facilities. This final GEIS thus considers additional soil contamination data. The following sections discuss specific public comments received relative to each of the draft GEIS reference facilities and any modifications to the reference facilities made in response to these comments.

C.3.1 Reference Nuclear Power Plant

C.3.1.1 Summary of Public Comments

Public comments received on the analysis of the reference nuclear power plant suggest that the diffusion, or "surface deposition," model utilized in the draft GEIS for estimating radioactively-contaminated soil volumes is not representative of "real world" situations. Specifically, it is suggested that the "surface deposition" model used for predicting radionuclide distributions in the soil column is too simple to adequately represent "real world" situations. Noted "real world" situations that the "surface deposition" model does not adequately represent were as follows:

- radionuclide deposition from airborne effluents released over the life of the plant,
- breaks that occur in underground pipelines that extend between buildings, between outdoor tanks and buildings, or between tanks and discharge points; furthermore, these leaks can occur several feet underground,
- seepage of slightly contaminated routine effluents from drain lines, from tank overflows, and from natural buildup of permitted effluent releases over years of operation, and
- mixing of contaminated and uncontaminated soil that occurs during remediation.

These possible sources of contamination suggest that areal variability can be much more pronounced than the uniformly-spread contamination assumed in the "surface deposition" model, contamination can be much deeper than predicted with the "surface deposition" model, and contaminated soil volumes predicted by the "surface deposition" model are too low compared to "real world" situations. Furthermore, a number of commenters indicated that soil volumes requiring removal can increase exponentially with decreasing dose criteria at levels below about 30 mrem/y.

One commenter acknowledged that the "surface deposition" model used in the draft GEIS may adequately represent situations where contamination results from discrete spills, such as around perimeters of tanks. This same commenter further indicated, however, that the other sources of contamination mentioned above would be more prevalent in the "real world."

Finally, with regard to building contamination, one commenter suggested that the volumes of activated and contaminated equipment and structures requiring D&D increase exponentially with decreasing dose rates below 500 mrem/y. More specifically, two commenters suggested that the costs of decontaminating activated concrete, in particular for some reactor designs where significant volumes of concrete (hundreds of thousands of cubic feet) become slightly activated, were not included in the draft GEIS.

C.3.1.2 Analyses Conducted in Response to Public Comments

The simple diffusion model developed to predict radionuclide distributions in contaminated soil for the draft GEIS was originally chosen over other more complex models because of the scarcity of "real world" data on radionuclide profiles in the soil column at nuclear power reactors from which to develop a generic, or composite, site description for analysis and the desire to develop a generic site that could be representative of the broad class of NRC licensees.

However, in the final GEIS, in order to be responsive to public comments, further PNNL review and analysis of available data (NRC, 1997), including that submitted by commenters, on the extent and depth of radioactive contamination in soil at commercial nuclear power plants was conducted. The major results of this review and analysis are as follows:

- Based on general site data and specific site area information, which generally came from decommissioning plans for commercial nuclear power reactors, the majority of the environs surrounding a power plant have such low concentrations of radionuclides that the dose to an onsite resident would be in the range of a few mrem/y (based on utilizing the dose conversion factors from the draft GEIS or this GEIS. However, there are isolated areas that appear to have higher levels of contamination. These higher levels for Co-60 (10-12 pCi/g) and Cs-137 (9-30 pCi/g) are comparable to the surface contamination levels assumed in the draft GEIS (i.e., 2-60 pCi/g and 1-20 pCi/g, respectively). These isolated areas of higher contamination also have areal extents (225 to 300 m^2) that are comparable to that assumed for the reference facility in the draft GEIS (i.e., 185 m^2).

- Many commercial nuclear power plants have had documented events that resulted in contaminated soil and requests for onsite burial of this contaminated soil (formerly 10 CFR Part 20.302 burials). Based on an analysis of data available on the contaminated soil from these events, the majority of the contaminated soil would result in doses in the range of a few mrem/y to the onsite resident (based on utilizing the dose conversion factors reported in Kennedy, 1992). Several of these events resulted in higher contamination levels which are comparable to the surface contamination levels assumed in the draft GEIS (e.g., Co-60 levels between 2 and 25 pCi/g up to a level of 200 pCi/g; Cs-137 levels between 4 and 15 pCi/g up to 80 pCi/g).

- Information on the volume of contaminated soil associated with individual events suggests that there may be instances where contaminated soil volumes are larger than predicted in the draft GEIS.

- Based on previous analyses performed for the NRC (Oak, 1980 and Tichlier, 1995), soil contamination resulting from airborne effluent deposition in general appears to result in contamination levels ($<$ 0.1 mrem/y) that are significantly below proposed release criteria and will not add noticeably to contamination levels resulting from other causes such as spills.

- There is very limited information on the distribution of radionuclide contamination with depth into the soil column or volume. Where data are available on radionuclide concentration with depth into the soil column, they are generally only for a sample taken from a single borehole (based on the limited data available and in Abel, 1986).

With regard to the building contamination model utilized in the draft GEIS, a simple diffusion model combined with "real world" data on measured radionuclide distributions in concrete at commercial nuclear power plants was developed for predicting the spread of radionuclides into concrete walls and floors and the reactor bioshield. In response to public comments received on this methodology, further PNNL review and analysis of available data (NRC, 1997), including that presented by the commenters on the extent and depth of radioactive contamination in concrete at commercial nuclear power plants, were conducted. The major results of the review and analysis are as follows:

- Based upon these new analyses and the analyses originally conducted for the draft GEIS (refer to Appendix C in NRC, 1994), measured radionuclide concentrations (between 10^{-1} and 10^{5} pCi/cm^3 for C-60 and between 10^{-2} and 10^{6} pCi/cm^3 for Cs-137) in concrete are comparable to the geometric mean (data from 7 nuclear power reactors) radionuclide distribution profiles assumed in the draft GEIS (between 10^{0} and 10^{4} pCi/cm^3 for C-60 and between 10^{0} and 10^{4} pCi/cm^3 for Cs-137).

- Based on data available in decommissioning plans and previous analyses done for the NRC (Konzek, 1990 and Konzek, 1995, Appendix M), the contaminated concrete volumes removed during D&D assumed in the draft GEIS (900-1,800 m^3) are in good agreement with the volumes generated or estimated by the commercial industry (800-1,500 m^3). Furthermore, comments received by industry experts on earlier NRC studies of the reference nuclear power plant indicate general agreement with the extent of radioactive contamination in concrete assumed in the draft GEIS.

- Analysis of recent data from the Trojan Nuclear Plant decommissioning project indicates higher than expected tritium contamination levels in the walls of the reactor containment building (Robertson, 1996). While the tritium levels are 2 to 3 orders of magnitude above background levels, the levels are still well below acceptable residual contamination criteria and therefore do not require aggressive decontamination using surface removal techniques. This is consistent with the assumptions in the draft GEIS regarding the extent of contamination in containment building walls/floors.

C.3.1.3 Analysis Modifications Made in Response to Public Comments

Based on the analysis of available "real world" data made in response to public comments received on the reference nuclear power station D&D analysis methodology in the draft GEIS, the following modifications were made to the analysis methodology for the final GEIS:

- The size of the contaminated soil site requiring remediation was increased from 185 m^2 (2,000 ft^2) in the draft GEIS to 280 m^2 (3,000 ft^2).

- A "real world" radionuclide profile with depth in soil model was developed based on data available on contaminated soil from Robertson (1986) at the Humboldt Bay Unit 3 Nuclear Power Plant. This contamination profile was taken from a soil core that was taken near a condensate storage tank where either a spill or underground leak of radioactive water had occurred.

The analysis methodology for the final GEIS included scenarios that evaluated remediation of a 280-m^2 (3,000-ft^2) contaminated soil site using both the "surface deposition" model from the draft GEIS and the new "spill/leak" model.

C.3.2 Reference Uranium Fuel Fabrication Plant

C.3.2.1 Summary of Public Comments

Public comments received on the analysis of the reference uranium fuel fabrication plant suggest that the diffusion, or "surface deposition," model utilized in the draft GEIS for estimating radioactively-contaminated soil volumes is not representative of "real world" situations. Specifically, comments suggested that

- the "surface deposition" model used for predicting radionuclide distributions in the soil column is too simple to adequately represent "real world" situations,

- that the volumes of contaminated soil estimated using the "surface deposition" model in the draft GEIS are too low and that volumes requiring removal in reality increase rapidly (even geometrically) with decreasing dose criteria; figures, without supporting data, submitted by commenters indicated that the volume of contaminated soil requiring remediation increased by a factor of 3 to 6 when the residual dose criteria are decreased from 100 to 15 mrem/y, and

- that the "surface deposition" model only results in significant levels of surface contamination, which is only representative of situations where contamination has resulted from windblown contaminated dust or spreading of contaminated topsoil; actual experience indicates that depths of contamination are considerably deeper due to a variety of site-specific waste management practices such as onsite burials of radioactive materials, leaks in underground radioactive liquid effluent systems, and mixing of contaminated soil with clean soil from previous site activities such as excavations for new building foundations.

No public comments were received on the building contamination model for the reference uranium fuel fabrication plant.

C.3.2.2 Analyses Conducted in Response to Public Comments

A review of available data on areal extent, depth, and volume of contaminated soil at uranium fuel fabrication plants was originally conducted for the draft GEIS. However, as with the reference nuclear power station discussed above, a simple diffusion model was developed to predict radionuclide distributions in contaminated soil for the draft GEIS rather than a more complex model, because of the scarcity of "real world" data on radionuclide profiles in the soil column at uranium fuel fabrication plants from which to develop a generic, or composite, site description for analysis. In response to public comments received, however, PNNL and NRC staff conducted a further review and analysis of available data (NRC, 1997), including that presented by the commenters, on the extent and depth of radioactive contamination in soil at uranium fuel fabrication plants. The major results of this review and analysis are as follows:

- Based on site-specific data for several uranium fuel fabrication plants, which generally came from decommissioning plans for NRC licensees, contaminated soil volumes and the areal extent of contaminated sites requiring remediation can be considerably higher than predicted in the draft GEIS. Specifically, the decommissioning of the Babcock and Wilcox fuel conversion plant in Apollo, Pennsylvania, resulted in 18,800 m^3 (665,000 ft^3) of contaminated soil having greater than 30 pCi/g of radioactive contamination being disposed of offsite (Carlson, 1994). The total area of contamination was estimated to be about 13,900 m^2 (150,000 ft^2).

- Leakage from liquid effluent systems (i.e., sewers) can substantially increase the depth of contamination into the soil column and the resulting volume of contaminated soil requiring remediation.

- There is very limited information on the distribution of radionuclide contamination with depth into the soil column or volume at uranium fuel fabrication plants. Data available on three DOE Formerly Utilized Sites Remedial Action Program (FUSRAP) uranium facilities indicate that the volume of contaminated soil requiring remediation increases by a factor of 3.4 to 14 when the residual criteria are decreased from 130 to 13 pCi/g (DOE, 1994a).

While no public comments were received specific to the building contamination model used for the reference uranium fuel fabrication plant, PNNL review and analysis of available data (NRC, 1997) were conducted. The results were that there are very few data available on radionuclide contamination levels and are much less sufficiently detailed to allow a comparison with the results of the model used in the draft GEIS.

C.3.2.3 Analysis Modifications Made in Response to Public Comments

Based on the analysis of available "real world" data made in response to public comments received on the reference uranium fuel fabrication plant D&D analysis methodology in the draft GEIS, the following modifications were made to the analysis methodology for the final GEIS:

- The size of the contaminated soil site requiring remediation was increased from 4,650 m^2 (50,000 ft^2) in the draft GEIS to 9,300 m^2 (100,000 ft^2).

- A "real world" radionuclide distribution in soil model was developed based on data available on contaminated soil at the Babcock and Wilcox Apollo Plant and the DOE FUSRAP uranium sites. This contamination profile was based on a DOE site where extensive landfilling and site grading occurred resulting in significant mixing of contaminated soil with clean soil.

The analysis methodology for the final GEIS included scenarios that evaluated remediation of a 9,300-m^2 (100,000-ft^2) contaminated soil site using both the "surface deposition" model from the draft GEIS and the "mixing/landfilling" model developed based on the public comments.

C.3.3 Reference Sealed Source Manufacturer

C.3.3.1 Summary of Public Comments

Only one specific public comment was received on the draft GEIS analysis of the reference sealed source manufacturer, which also used a diffusion, or "surface deposition," model for estimating radioactively-contaminated soil volumes. This commenter did not specifically question the "surface deposition" or building contamination models but rather made the general note that the selection of the reference facility (i.e., a sealed source manufacturer) does not adequately represent other types of non-fuel-cycle facilities, such as radiochemical and radiopharmaceutical manufacturing facilities. The commenter suggested that the impact of decommissioning on these types of facilities to the level of the proposed standard would be significant, yet was not considered as part of the impact analysis.

C.3.3.2 Analyses Conducted in Response to Public Comments

An analysis of NRC licensees classified as non-fuel-cycle facilities indicated that of the approximately 1,400 non-fuel-cycle licensees, 295 are sealed source manufacturers, 1,101 are broadly classified as R&D facilities (of which over 800 are academic, medical, and private laboratory-type facilities), and the remaining are rare earth extraction facilities. Generally, academic and medical facilities are issued licenses for the possession and use of radionuclides for teaching, training, and research. Previous NRC analyses of the D&D of these broad R&D types of facilities have not indicated significant soil contamination problems and the contaminated laboratories are generally relatively small, on the same order as the size of the reference sealed source manufacturer assumed in the draft GEIS (Murphy, 1981 and Short, 1989). The draft GEIS results for decontamination of the reference sealed source manufacturer building can easily be scaled to determine comparable results for larger buildings.

A review was made by PNNL and NRC staff of available literature on non-fuel-cycle nuclear facilities to identify available data (NRC, 1997) on areal extent, depth, and volume of contaminated soil at these types of facilities (Murphy, 1981; Short, 1989; NRC, 1993). While there were references to contaminated soil in a couple of instances, a site having contaminated soil was clearly the exception rather than the rule (in general, contamination is confined to localized areas inside the building). And even in those cases where contaminated soil was indicated to be present, there were no estimates of the areal extent, depth, or volume of contamination in the soil from which to base an analysis upon.

C.3.3.3 Analysis Modification Made in Response to Public Comments

The indication in the public comment that remediation requirements are significantly greater at other types of non-fuel-cycle nuclear facilities than sealed source manufacturers is not substantiated by the data available to NRC and PNNL staff. It therefore appears reasonable to conclude that the reference sealed source manufacturer facility assumed in the draft GEIS be retained as the reference facility.

However, as a sensitivity case, a "spill/leak" model was developed to represent potentially deeper contamination than would result from the "surface deposition" model used in the draft GEIS. The model used to represent this scenario was the same as was developed for the reference nuclear power plant "real world" scenario. The analysis methodology for the final

GEIS therefore included scenarios that evaluated remediation of a 465 m^2 (5,000 ft^2) contaminated soil site using both the "surface deposition" model from the draft GEIS and the "spill/leak" model developed based on public comments.

C.3.4 Reference Rare Metal Extraction Facility

C.3.4.1 Summary of Public Comments

Only one specific public comment was received on the draft GEIS analysis of the reference rare metal extraction facility, which also used a diffusion, or "surface deposition," model for estimating radioactively-contaminated soil volumes. The essence of the comment received was that the volumes of contaminated soil estimated as requiring remediation using the "surface deposition" model are underestimated and, consequently, the calculated soil remediation costs are underestimated. The commenter also suggested that soil volumes requiring remediation would increase appreciably as the residual dose criteria decrease, especially at low dose criteria.

C.3.4.2 Analyses Conducted in Response to Public Comments

A review of available data on areal extent, depth, and volume of contaminated soil at rare metal extraction facilities was originally conducted for the draft GEIS. However, as with the reference nuclear power station and uranium fuel fabrication plant discussed previously, a simple diffusion model was developed to predict radionuclide distributions in contaminated soil for the draft GEIS rather than a more complex model because of the scarcity of "real world" data on radionuclide profiles in the soil column at rare metal extraction facilities from which to develop a generic, or composite, site description for analysis.

Also, as discussed in the draft GEIS, the reference rare metal extraction facility is assumed to have a large 7,000-m^3 (250,000-ft^3) contaminated slag pile. However, this slag pile was not included in the draft GEIS analyses because the relatively high contamination levels associated with the slag pile (an average activity level of 1,250 pCi/g) meant that there would be no difference in remediation requirements for the alternative residual dose levels being considered in the GEIS (i.e., those less than 100 mrem/y). In other words, the impacts of remediating the slag pile would just subtract out when comparing the differences in remediation costs between two residual dose levels. Since the purpose of the GEIS analyses is to determine the differences in impacts between different residual dose levels and not to estimate the total costs of remediation, remediation of the slag pile was not included in the GEIS analyses (even though it would have added substantially to the total volume of contaminated soil requiring remediation).

In response to public comments received, however, PNNL and NRC staff conducted a further review and analysis of available data (NRC, 1997), including that submitted by commenters, on the extent and depth of radioactive contamination in soil at rare metal extraction facilities. The major results of this review and analysis are as follows:

- Based on site-specific data for several rare metal extraction facilities, which generally came from decommissioning plans for NRC licensees and from NRC, 1993, there are generally large volumes of contaminated slag piles associated with these types of facilities. Much of the contamination data available on these types of sites is for the slag piles, with very little contamination data, or estimates of contaminated volumes and/or areal extent, available on the soil.

- There is very limited information on the distribution of radionuclide contamination with depth into the soil column or volume at rare metal extraction facilities. Limited information on the Molycorp, Inc., rare metal ore processing facility in York, Pennsylvania, indicates that a total of 510 m^3 (18,000 ft^3) of Th-232-contaminated soil, with concentrations as high as 700 pCi/g, is estimated to require excavation and removal from the site during remediation. Approximately 100 m^3 (3,600 ft^3) of this volume is contaminated with Th-232 to levels greater than 70 pCi/g (NRC, 1993).

- Information from several of the sites evaluated indicated that thorium does not leach appreciably from the slag into the soil and that soil contamination is generally limited to the upper one to two feet of soil.

While no public comments were received specific to the building contamination model used for the reference rare metal extraction facility, PNNL review and analysis of available data (NRC, 1997) were conducted. The results were that there are very few data available on radionuclide contamination levels and are much less sufficiently detailed to allow a comparison with the results of the model used in the draft GEIS.

C.3.4.3 Analysis Modifications Made in Response to Public Comments

Based on the analysis of available "real world" data made in response to public comments received on the reference rare metal extraction facility D&D analysis methodology in the draft GEIS, the following modifications were made to the analysis methodology for the final GEIS:

- A 7,000-m^3 (250,000-ft^3) slag pile was included in the soil remediation analyses.

- A "real world" radionuclide distribution in soil model was developed based on data available on contaminated soil at the Molycorp, Inc., rare metal ore processing facility in York, Pennsylvania. This contamination profile was based on a very limited data set that required a number of "best engineering judgement" assumptions before the data could be developed into a model sufficient for analysis. The soil contamination was assumed to be the result of utilizing the slag as landfill, similar to past practices at the Molycorp, Inc., rare metal ore processing facility in Washington, Pennsylvania.

The analysis methodology for the final GEIS included scenarios that evaluated remediation of a 7,000-m^3 (250,000-ft^3) slag pile and a 9,300-m^2 (100,000-ft^2) contaminated soil site using both the "surface deposition" model from the draft GEIS and the new "mixing/landfilling" model developed based on public comments.

C.4 Characterization of Reference Facility Contamination

The NRC received a number of public comments questioning the soil contaminant distribution methodology utilized in the draft GEIS (refer to Section 3). The essence of these comments was that the draft GEIS methodology, in some instances, significantly underestimates the volume of contaminated soil requiring remediation during decommissioning of nuclear facilities. In response to these comments, NRC and PNNL staff reviewed information submitted and also conducted a literature search for information documenting the extent and depth of radioactive contamination at both NRC-licensed and DOE nuclear facilities. This literature search identified a number of "real world" situations where, as suggested by public comment, radioactively-contaminated soil volumes were significantly greater than had been estimated by the draft GEIS methodology. These "real world" data were subsequently analyzed and used to form the basis for modified reference facilities.

This chapter provides a brief physical description of the reference facilities being evaluated in the final GEIS. The descriptions include information such as the size of buildings and total site area, the extent and penetration of radioactive contamination on building surfaces from actual radiation surveys when available, and the extent and depth of radioactive contamination in the environment where "real world" data were available.

The descriptions of each of the reference facilities are based upon actual facilities licensed by the NRC or owned and regulated by the DOE. In some cases, insufficient information was available on any one facility to provide an adequate description for evaluation. In these cases, the reference facility description is actually a composite description of multiple facilities. While much of the reference facility descriptions include information originally presented in the draft GEIS (NRC, 1994), it is repeated here for completeness and clarity.

C.4.1 Reference Nuclear Power Reactor Station

The Trojan Nuclear Power Plant, located in Rainier, Oregon, was used as the representative 1095-MWe pressurized water reactor plant that is preparing for decontamination and decommissioning. Conceptual decommissioning of this plant has been reported in previous studies for the NRC (Smith et al., 1978; Konzek et al., 1995).

C.4.1.1 Description of Building Contamination

The extent of surface radionuclide contamination on floors of the various buildings of the reference PWR nuclear power station was estimated by reviewing detailed contamination survey maps supplied by the utility for contaminated areas of the station. The contamination surveys were conducted by taking smears of removable radioactive material from 100 cm^2 areas of floor surfaces. In a number of locations in the reactor containment building, contaminated walls were also surveyed for removable radioactive contamination. A summary of the contaminated surface areas is given in Table 4.1.1. As shown in the table, all of the floor surfaces in the reactor containment building (estimated area of about 1900 m^2) are assumed to be contaminated at levels which would require scabbling to reduce the contamination levels to acceptable residual concentrations.

Contamination penetrated into concrete below-grade floors in the Sodium Reactor Experiment Facility approximately 1/8 to 3/8 inches on the average and up to the full thickness of walls and floors where cracks and joints existed (Brengle, 1979). Angus et al. (1990) found that ^{137}Cs penetrated deeply into areas of surface porosity and cracks. Information on surface contamination of concrete in the Japan Power Demonstration Reactor (Yasunaka et al., 1987) indicated that most of the contamination penetrated less than 2 cm and only 15% penetrated up to 3 cm. In the liquid waste treatment building, the deepest penetration was up to 11 cm in the vicinity of cracks, but elsewhere it was less than 2 cm. Therefore, complete removal of concrete will likely be required in the vicinity of contaminated cracks. The perimeter of the concrete floors is assumed to contain 1500 m of cracks. Because contamination tends to penetrate rapidly into cracks, contaminated crack regions are expected to require complete removal.

The interior walls of certain locations within the reactor containment building also contain significant radionuclide contamination, particularly the upper and lower cavity areas surrounding the pressure vessel. Although summaries of wall contamination are not included in Table C.4.1.1, it is estimated that approximately 400 to 600 m^2 of wall area from these locations have been contaminated at levels ranging from about 1,000 to 60,000 pCi/100 cm^2. Other portions of the interior wall surfaces in the containment building may also be contaminated and require some type of decontamination.

Table C.4.1.1. Extent of Surface Radionuclide Contamination in the Reference PWR Nuclear Power Station[(a)]

Building	Approximate Floor Surface Area, ft^2	Estimated % of Floor Area Contaminated	Estimated Area Needing Cleanup, ft^2
Reactor Containment	20,400	100	20,400
Auxiliary (6 levels)	43,000	1-5	430 - 2,200
Fuel Building (5 levels)	53,800	1-5	540 - 2,690
Turbine Building	61,300 per level	0	0
Control Building	7,500 per level	0	0

(a) From Smith et al. 1978.

In addition to the widespread surface contamination of concrete and patchy areas of contamination associated with spills or high radiation areas where maintenance work was conducted, radioactive contamination is produced in-situ by neutron activation of concrete shields. Concrete areas subjected to neutron exposure within the plant are limited primarily to the bioshield and the sump area directly beneath the reactor vessel. Concrete core samples collected directly beneath the pressure vessel show the effects of both surface contamination and subsurface neutron activation of stable elements present in the concrete (Abel et al., 1986). The concentration of radionuclides, such as ^{60}Co, decreases rapidly (by approximately four orders of magnitude) with depth from the surface to about 2 cm beneath the surface. This concentration profile is attributed to diffusion of surface contamination. The radioisotopes produced by neutron activation extend much deeper (even feet) in nuclear reactors (Abel et al., 1986; Irving, 1980). The concentration may peak at depths where the neutron energy spectrum coincides with peaks in the capture cross section for the parent isotope. The subsurface contamination produced by neutron activation is too deep to be removed by surface scabbling and must be removed by procedures for concrete demolition.

The auxiliary and fuel buildings also have some areas of floor contamination but not nearly to the extent of that observed in the reactor containment building. It has been estimated, based on survey reports (Smith et al., 1978), that about 1 to 5% of the floor area (representing about 430 to 2,200 ft^2) in the auxiliary building has radioactive contamination levels in the range of 500 to 3,600 pCi/100 cm^2. The fuel handling building also has a small amount of floor contamination, estimated at approximately 540 to 2,690 ft^2, with contamination levels ranging from about 500 to 2,300 pCi/100 cm^2.

The other buildings, including the turbine building, the control building, radwaste handling warehouse, and the condenser building, generally do not have any measurable radioactive contamination on any surfaces.

Within the common variabilities of contamination levels in nuclear power plants, the analysis for a PWR reasonably estimates the contaminants and contamination levels for a BWR. Within these variabilities and considering the information shown in Table 4.1.2, the radioactive contamination in the various types of reactors appears to be similar. The primary difference is in the areas and volumes of the structures. Dry active waste (DAW) is a mixture of radioactively contaminated items typically generated at nuclear power stations (e.g., trash, protective clothing, gloves, equipment, tape, plastic sheeting and bags, etc.), and the radioactive material associated with DAW would be expected to be reasonably representative of that found on surface contaminated concrete. These measurements were made on over 100 DAW samples during a recent study conducted by Battelle for the Electric Power Research Institute to determine the industry-wide variability in the radionuclide composition of very low-level wastes generated at nuclear power stations (Robertson, et al. 1989).

C.4.1.2 Description of Soil Contamination

Available information on radionuclide contamination in soils at nuclear power plant sites indicates that this contamination is generally located in small patches of very low concentrations, that these patches are generally located within the security fences, and that they are generally at known spill sites. These locations were generally close to condensate or borated water storage tanks, effluent sampling points, or equipment maintenance and/or cleaning areas. Small areas of contaminated soils at most plants would require remedial action, such as excavation and disposal as low-level waste. Contaminated soil volumes are relatively low, generally in the tens of cubic meters (Abel et al., 1986). Additional volumes of contaminated soil might occur during decontamination and/or dismantling, as additional spills occur or covered areas (e.g., underneath spent fuel storage pools) are found to be contaminated.

Abel, et al. (1986) reported concentration ranges of a number of radionuclides measured in surface soils (to a depth of 4 cm) at six different nuclear power reactor plants. These reported radionuclide concentration ranges are reproduced in Table 4.1.3. Cobalt-60 was the largest contributor to radiation dose from radionuclides in soils at these plants. The highest levels of radionuclides found in "hot spots" (soil samples and holding pond sediments) consisted of ^{60}Co (up to 377 pCi/g) and ^{137}Cs (up to 91 pCi/g) (Abel et al., 1986).

Table C.4.1.2. Gamma-Emitting Radionuclide Distributions in Dry Active Waste (Robertson et al. 1989, 1991)

	Average % Composition of γ-Emitting Radionuclides		
Radionuclide	All PWR Stations[a]	All BWR Stations[b]	All Stations Combined[c]
^{60}Co	49 ± 34[d]	78 ± 2.6	61 ± 30
^{137}Cs	27 ± 22	11 ± 2.2	20 ± 18
^{134}Cs	8.6 ± 7.3	2.5 ± 1.2	6.1 ± 6.3
^{58}Co	9.8 ± 9.8	0.59 ± 0.43	6.7 ± 9.0
^{54}Mn	0.7 ± 0.5	6.4 ± 3.6	3.0 ± 3.6
^{106}Ru	2.4 ± 2.1	1.8 ± 0.4	2.1 ± 1.4
^{125}Sb	0.6 ± 0.3	0.69 ± 0.47	0.6 ± 0.4
^{95}Nb	2.4 ± 3.2	0.2 ± 0.09	1.8 ± 2.8
^{95}Zr	0.7 ± 0.5	-	0.7 ± 0.5
^{110m}Ag	0.3 ± 0.5	0.12	0.3 ± 0.4

(a) Includes 6 stations and 60 samples.
(b) Includes 4 stations and 42 samples.
(c) Includes 10 stations and 102 samples.
(d) ± values are the standard deviation (1σ).

Table 4.1.3. Concentration Ranges of Radionuclides in Contaminated Surface Soils (0-4 cm) from Radiation Controlled Areas (pCi/g) (Abel et al. 1986)

Radionuclide	Pathfinder[a]	Humboldt Bay[b]	Dresden[c]	Monticello[d]	Turkey Point[e]	Rancho Seco[f]
^{54}Mn	<0.005-0.06	0.45-5.5	0.02-0.23	<0.004-<0.02	0.03-0.34	<0.003-0.27
^{60}Co	<0.01-1.7	26-377	1.3-161	0.006-0.45	4.0-45	0.012-11
^{106}Ru	<0.1-0.36	<0.02-<0.05	<0.07-0.2	<0.07	<0.1-0.2	<0.03-<0.09
^{125}Sb	<0.02	<0.4-4.9	<0.03-<1	<0.03	<0.6-22	<0.006-0.75
^{134}Cs	<0.04-<0.01	1.5-6.1	<0.01-6.3	<0.004-0.16	0.28-5.5	0.01-0.95
^{137}Cs	0.15-2.9	25-91	0.49-260	0.068-2.1	1.7-11	0.05-4.9
^{144}Ce	<0.03-0.18	<0.3-1.3	<0.04-1.5	0.083-0.17	<0.05-0.27	<0.02
^{238}Pu	$3\text{-}41 \times 10^{-5}$	$8.2\text{-}170 \times 10^{-3}$	N.M.[g]	N.M.	N.M.	N.M.
$^{239\text{-}240}Pu$	$6\text{-}42 \times 10^{-4}$	$9.5\text{-}230 \times 10^{-3}$	N.M.	N.M.	N.M.	N.M.

(a) Fourteen soil samples

(b) Five soil samples

(c) Four soil samples; highest observed contamination was at a depth of 15-30 cm.

(d) Four soil samples

(e) Six soil samples

(f) Seven soil samples

(g) N.M. represents Not Measured

C.4.2 Reference Uranium Fuel Fabrication Plant

The reference uranium fuel fabrication plant is based upon General Electric Company's Facility located in Wilmington, North Carolina, which processes an average of 1,000 MTU/y. Conceptual decommissioning of this plant has been reported in a previous study for the NRC (Elder and Blahnik, 1980a). Buildings or site areas associated with the reference uranium fuel fabrication plant include:

- Processing buildings, which are typically two-story windowless structures of concrete and steel. Interior walls, typically of concrete block, divide the buildings into discrete operations areas that house each of the production steps.
- Onsite waste ponds containing calcium fluoride; calcium fluoride is a waste product that is produced by treating the fluoride wastes with $Ca(OH)_2$. The calcium fluoride is stored in waste ponds on the site.
- A total site area of 4.7×10^6 ft^2.

The reference facility is licensed by the NRC, is a major fabricator of nuclear fuel for commercial nuclear power plants, and is considered to have characteristics similar to other existing commercial uranium fabrication plants. Contamination of equipment and floors results during normal operations and, on at least one occasion, from a spill that caused uranium to penetrate through cracks in the concrete floor into soil beneath the fuel processing building.

The feed to the plant is slightly enriched uranium in the chemical form of UF_6. The plant uses two chemical processes for converting the UF_6 to UO_2. The primary method is a chemical process that reacts UF_6 with ammonia to form ammonium diuranate (ADU) precipitate and reduces and calcines the ADU to dry UO_2 powder. The second method involves direct conversion of the UF_6 to U_3O_8 to UO_2 powder in a reduction calciner. The UO_2 powder from each process is subsequently milled and pressed into pellets that are sintered and ground to size. The pellets are loaded into rods and sealed. The rods are assembled into fuel bundles ready for use in light water reactors.

Liquid waste streams containing uranium are kept separate to facilitate uranium recovery operations. They are classified as nitrate wastes, fluoride wastes, and radwastes. Uranium-bearing nitrate sludge is sent to an offsite contractor for uranium recovery. Calcium fluoride solids entrap uranium residuals in the waste from the UF_6 to UO_2 conversion process. CaF_2 solids are stored onsite for eventual reprocessing to recover the uranium residuals.

C.4.2.1 Description of Building Contamination

The reference fuel fabrication plant consists of five potentially contaminated buildings (Elder and Blahnik, 1980b). There are an average of two floors per building with a total floor space of approximately 235,000 ft^2 (about 22,000 m^2). Contamination incidents, as well as releases during normal operations, are assumed to have affected 50% of the surface of the process areas. The principal contaminant is uranium, and its concentration at the exposed surface after removal of the covering and after surface washing is 1 g U/m^2 (33 pCi/g of concrete). Therefore, approximately 11,000 m^2 are assumed to be contaminated to a level of 1 g U/m^2 (33 pCi/g of concrete) and require decontamination by surface removal.

Floor tiles cover 100% of the process area floors. Replacement of the floor tiles and linoleum coverings removes significant contamination. However, recontamination during operation requires floor tiles to be replaced annually for ALARA considerations. The tiles are also removed during normal decommissioning operations. Because of contaminant penetration through seams between tiles, it is assumed in Table 4.2.1 that 50% of the concrete floor has become contaminated[1]. The chemical area has a sealed concrete floor. It is assumed that 50% of the concrete floor surface under the seal is contaminated. Offices and change rooms have tiled or painted floors (Elder and Blahnik 1980a); it is assumed that the concrete surfaces below these surface coverings are not contaminated.

Table C.4.2.1. Distribution of Contaminated Concrete Floor Area in the Reference Uranium Fuel Fabrication Facility[a]

Location	Estimated Surface Area, ft^2	Estimated Area Contaminated, %	Contamination Level, pCi/cm^3
Fuel Manufacturing Building	208,000	50	73
Chemical Metallurgical Laboratory	8,300	40	73
Uranium Scrap Recovery Room	3,700	90	73
UO_2 Powder Warehouse	8,700	30	73
Contaminated Waste Incinerator	2,400	100	73
Fluoride and Nitrate Waste Treatment Plant	2,500	100	73
Boiler Steam House	1,100	0	0
Total	234,700	50	-

(a) (Elder and Blahnik 1980b)

Note: this assumption deviates from that made by Elder and Blahnik (1980) in that they assumed the concrete was not contaminated. Penetration and spread of contamination through seams between tiles is assumed in Table 4.2.1 to result in approximately 50% of the concrete floor becoming contaminated.

Elder and Blahnik (1980a) estimated the surface concentration of uranium on horizontal surfaces to be approximately 1 g U/m^2 (33 pCi U/g of concrete)[1]. Approximately 700 samples were taken from the main building block and brick walls at the Babcock and Wilcox plant located in Apollo, Pennsylvania. The majority of the wall contamination was <30 pCi U/g with some selective areas containing up to 2,000 pCi U/g (Haase et al. 1992). The characterization of surface contamination was complicated by the heterogeneous nature of the contamination and, in some areas, the number of overlying pours of concrete that were made to cover contaminated floor areas.

Measurements at the DOE Fernald facility have shown some floor regions with extreme uranium contamination approaching 10,000,000 dpm/100 cm^2 with an average maximum of 2,220,000 dpm/100 cm^2 (DOE 1992). These high levels are believed to be an upper bound.

The three uranium fuel fabrication facilities provide information on three levels of contamination: an estimated 33 pCi U/g for Wilmington, up to 2,000 pCi U/g measured for Apollo, and a maximum beta-gamma of nearly 16,000 pCi U/g for Fernald. These data were converted to dpm/100 cm^2 and resulted in values of 18,000 dpm/100 cm^2 (low); 1,100,000 dpm/100 cm^2 (medium); and 10,000,000 dpm/100 cm^2 (high). Based on the above discussion, the level of surface contamination after surface washing assumed for the reference uranium fuel fabrication facility is 18,000 dpm/100 cm^2.

Considerable documentation was reviewed (Elder and Blahnik, 1980a, 1980b; Babcock and Wilcox, 1992a, 1992b; Haase et al., 1992; and DOE, 1992) to locate information on the depth of penetration of uranium into concrete for use in the analyses. However, no experimental data were found.

C.4.2.2 Description of Soil Contamination

Although the General Electric Wilmington Plant is the reference nuclear fuel fabrication facility, more information on the condition of the soils at this type of facility was found for the Babcock and Wilcox Apollo plant. Also, considerable information on soil contamination was available for the Ventron Corporation plant located in Beverly, Massachusetts, which is a DOE Formerly Utilized Site Remedial Action Program (FUSRAP) site (DOE, 1994a).

The Babcock and Wilcox Apollo plant is a former nuclear fuel manufacturing site currently undergoing decontamination (Babcock and Wilcox, 1992a, 1992b). The fuel manufacturing operations were performed in one part of the facility, owned by Babcock and Wilcox, and located on the east side of the site in approximately one acre of roofed two-story buildings. Other parts of the complex included a parking lot (2.5 acres) and an "offsite area" (3 acres) which included a metals-processing complex, laundry, railroad spur, and equipment storage building.

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1 g U/m^2 = 0.7 x 10^6 pCi/m^2 x 0.472 pCi/g per pCi/cm^2 x 10^{-4} m^2/cm^2 = 33 pCi/g

Principal NRC-licensed manufacturing operations at the Apollo site included the manufacture of low- and high-enriched uranium oxide fuels for commercial nuclear power plants and for nuclear-powered naval ships. Nuclear fuel manufacturing commenced in the main building in 1957 and was terminated in 1983. The manufacturing process was the chemical conversion of uranium hexafluoride to uranium oxide powder. All operations were terminated in 1984.

Site soil has been estimated to be potentially contaminated above 30 pCi U/g, at depths ranging from near-surface to >25 feet. Uranium contamination concentrations of 24 - 300 pCi U/g were found beneath part of Building 3 and the east end of Building 4, at depths from 6 - 96 inches. The riverbank soils are also being characterized; three samples taken from near the plant exceeded 30 pCi U/g. All materials known to be contaminated in excess of 2,000 pCi/g were removed from the site prior to December 31, 1991. The median concentration of uranium in the soils is less than 200 pCi/g (NRC, 1993). A surface area of approximately 150,000 ft^2 is estimated to be contaminated to varying degrees with uranium. A total of 665,000 ft^3 of soil contaminated to greater than 30 pCi/g have been excavated and disposed of offsite at the Envirocare disposal facility (Carlson, 1994).

The Ventron Corporation plant formerly performed uranium work in three buildings for the Atomic Energy Commission (AEC) and requires remediation of thorium-contaminated soils and buildings. Preliminary information provided by the DOE on the estimated ratio of volumes of contaminated soil for different cleanup criteria is as follows (DOE, 1994a):

Cleanup Criteria (pCi/g)	Contaminated Soil Volume Ratio (relative to 130 pCi/g)
130	1
80	1.23
39	1.6
30	2.27
20	2.76
13	3.38
4	4.5

C.4.3 Reference Sealed Source Manufacturer

The sealed source manufacturing process is a hand operation that is carried out in buildings which contain a number of small laboratories, each of which is devoted to a specific process and/or isotope. The reference sealed source manufacturer is a laboratory which processes ^{137}Cs and ^{60}Co. Contaminated facilities associated with the reference sealed source manufacturer include:

- hot cells, fume hoods, workbenches, sinks

- laboratory floor and wall areas

- building areas used for storage of waste drums.

The situation for radiochemical and radiopharmaceutical manufacturers would be very similar to that of the sealed source manufacturer and is not examined further in this report.

Advanced Medical Systems, Inc. (AMS) is used as the reference sealed source manufacturer. It is a licensed non-fuel-cycle plant in Cleveland, Ohio, that manufactures ^{137}Cs and ^{60}Co capsule sources for use in medical teletherapy devices and radiography machines (NRC, 1993).

The AMS operations occupy about one quarter of an 8,000-ft^2 (ground floor) warehouse building. The remainder of the building is unused. The facility occupies portions of three floors in the warehouse. The first floor consists of an office area, an isotope shop area, a hot cell, a shielded work room, and a storage area. The second floor area houses a mechanical equipment room and an exhaust ventilation equipment room. A liquid waste handling room and the former liquid waste holdup tank room and dry waste storage area are located in the basement. Waste is stored in a locked room with roped areas on the south side of the warehouse area. The floor surface areas are estimated to be 6,000 ft^2 (assuming three floors). The indoor surface area of the walls (estimated at 10 ft high) is estimated to be 4,600 ft^2.

C.4.3.1 Description of Building Contamination

A 1985 survey by Oak Ridge Associated Universities (ORAU) found surface contamination in a hot cell, the ventilation system, the dry waste storage area, the liquid waste area, and the holding tank and its piping. No offsite contamination was found. However, some detectable activity (attributed to stack effluent releases) was found in sediments, soil, and vegetation in the southern portion of the AMS property. The ORAU survey showed contamination up to 1.51 x 10^6 dpm/100 cm^2 in the hot cell access port in the isotope shop area, an area normally expected to be highly contaminated. A water sample from the liquid waste room floor contained 1.75 x 10^5 pCi ^{60}Co/L. Sediment from the loading dock drain showed low but detectable levels of activity.

C.4.3.2 Description of Soil Contamination

The site area of the reference facility is estimated to be 40,000 ft^2. The contaminated area is estimated to be 5,000 ft^2, based on assumed stack effluent releases. Advanced Medical Systems, Inc., manufactures ^{60}Co and ^{137}Cs sources for medical use. A small amount of detectable activity has been found in site soil and was assumed to be due to stack effluent releases. Apart from this, the major route to soil contamination would be via liquid waste spills on building floors running off through floor-wall seams in the concrete. However, apart from some activity in sanitary sludges, there is no evidence of contamination outside the buildings from this source (NRC, 1993).

C.4.4 Reference Rare Metal Extraction Facility

Rare metal extraction facilities refine raw ore materials for the recovery of rare metals such as tantalum and niobium. The raw ores processed by these facilities can contain appreciable quantities of uranium and thorium that can then end up in waste tailings produced during the refining process.

The reference rare metal ore processor is the Molycorp, Inc., facility located in Washington, Pennsylvania. This plant occupies a 17-acre (740,000-ft^2) site and was used to produce a ferro-columbium alloy from a Brazilian ore from 1964 to 1970 (Martin, 1985). The ore contained licensable concentrations of thorium (1-1.5%), consequently a byproduct of the operation was a thorium-bearing slag. Contaminated facilities and areas associated with the reference rare metal extraction facility include:

- Buildings in which slag is processed and the rare metals are extracted. Significant building contamination from these operations is not expected.

- Settling ponds containing the tailings from the metal extraction process, including essentially all of the thorium and uranium present in the original raw ore. The pond is assumed to be unlined at the reference rare metal ore processor, although it may be lined at newer facilities.

- A 7,000-m^3 slag pile containing solid wastes from the extraction process.

C.4.4.1 Description of Building Contamination

The site contains a number of buildings, eight holding ponds, and a large slag pile. Building 34 has up to 90 dpm/100 cm^2 fixed alpha contamination, up to 8,680 dpm/100 cm^2 fixed beta contamination, and direct radiation levels up to 169 μR/hr. The source of direct radiation is suspected to be below the floor. The total area of floors is estimated to be 150,000 ft^2; 40% of this surface is estimated to be contaminated with thorium. The surface area of the walls is estimated to be 180,000 ft^2, of which 10% is estimated to be contaminated with thorium.

C.4.4.2 Description of Soil Contamination

Thorium-bearing slag and contaminated soil was previously collected and segregated in 1972. Some of this material was removed offsite at the time while the remainder was placed in a clay-capped pile on the property. Some of the slag was used as fill over portions of the site. The large slag pile is located on the southern part of the property and has an average activity level of 1,250 pCi/g (NRC, 1993). The slag pile is in a stabilized configuration in that it is covered with vegetation.

Thorium contaminant concentrations in the soil, throughout the site, range between 10 and 2,650 pCi/g and average 100-200 pCi/g. The area of contaminated soil is estimated to be 100,000 ft^2 based on the extensive handling and storing of ore and slag at the site. It is estimated that there is 1.1×10^5 kg of thorium onsite in the form of contaminated soils and slags.

While more detailed information on soil contamination at this facility is not available, another Molycorp, Inc., rare metal ore processing facility located in York, Pennsylvania, does have some specific information on thorium contamination in the soil. During remediation of this site, it is anticipated that a total of 18,000 ft^3 of soil contaminated primarily with thorium-232 will be excavated and removed offsite. Of this volume, approximately 3,600 ft^3 will contain up to 70 pCi/g of contamination. In addition, prior to soil excavation and removal activities in 1987, the site had soil with contamination levels up to 700 pCi/g of Th-232 (NRC, 1993).

C.5 Methodology for Estimating Contamination Levels

Evaluating the costs and impacts associated with remediating contaminated buildings and soils to different residual cleanup levels requires information on the level, extent, and depth of contaminants within the concrete structures requiring decontamination and in the soil column, respectively. Baseline models were developed for the draft GEIS (NRC, 1994) to provide the required contamination profiles needed for estimating the volume of contaminated soil requiring excavation and/or treatment for alternative residual dose levels. These baseline models were described in the draft GEIS and are not repeated here.

Public comments received on the draft GEIS expressed concern that the calculated contamination profiles considerably underestimated the depth of contamination penetration into the soil column as compared to "real world" data. This difference is to be expected given that the model used in the draft GEIS to calculate the radionuclide contamination profiles in the soil is a simple diffusion model most appropriately representative of contamination deposition on the surface of the soil from a thin blowing contaminated dust or a thin spreading of contaminated material. The "real world" data, on the other hand, reflect extreme conditions of spills and leaks of contaminated aqueous solutions and/or mixing and burial of contaminated material in soil that result in deeper zones of contamination than are predicted by the diffusion model where contaminant transport is assumed to be via diffusion only.

In response to these comments, contaminant distribution models for ^{60}Co, ^{137}Cs, uranium, and thorium were developed to represent available "real world" data. The models developed to represent these scenarios are discussed below. No new models were developed to estimate contaminant distributions in concrete for the final GEIS based on the discussion in Section C.3.1.2.

C.5.1 Cobalt- and Cesium-Contaminated Soil

Data available on the extent of radionuclide contamination in soil around nuclear power plants are sparse and generally not readily available. However, the NRC did conduct a study in the early 1980s in which a comprehensive sampling program was conducted at several operating and shutdown nuclear power plants for the purpose of assessing residual radionuclide compositions, distributions, and quantities (Abel, 1986). Data obtained from sampling and analyses conducted for this study were used to develop a "real world" model of soil contamination at nuclear power plants.

While considerable data were obtained on the levels of contamination in soil around the nuclear power plants investigated, very limited data on soil profiles were developed. Of that limited information, core samples taken near a condensate storage tank at the Humboldt Bay Nuclear Unit provided sufficient data to derive a concentration profile as a function of depth into the soil column representative of soil behavior at the facilities studied. These data are provided in Table 5.1.1 for Co-60 and Cs-137, the primary long-lived radionuclides of interest. As that table shows, the concentrations (pCi/g) of ^{60}Co and ^{137}Cs generally decrease with soil depth until a depth of 30 to 38 cm, at which point the concentrations begin to increase with depth. These increases are presumably caused by local conditions at this particular site or possibly by faulty sampling procedures. To do any kind of reasonable modeling, an assumption had to be made regarding the behavior of the concentration profile at depths beneath the available data. Three possibilities were identified:

- The concentration rises as indicated by the data until a depth around 44 cm (the limit of the data) is reached. The concentration then remains at this level until some unknown depth, at which point the concentration drops at some unknown rate.

- The concentration rises as indicated by the data until about 44 cm and then drops effectively to zero for depths greater than 44 cm.

- The rise in concentration below the 30 to 38 cm interval is peculiar to this soil. In the general case, for a "typical" soil, the concentration should fall monotonically with depth.

There are other possibilities, of course, but it was decided that the third option would be used in this study. In the development of the "real world" model, it was assumed that the upper 36 cm of the concentration data is representative of a "typical" soil and that beyond 36 cm the data would be extrapolated.

Upon examination of the general shape of the data in Table C.5.1.1, it was found that the decreasing portion of the concentration curves for ^{60}Co and ^{137}Cs could be fit rather well to a function, $C(x)$, having units of pCi/g, consisting of the sum of two decaying exponentials, i.e.,

$$C(x) = A_1 e^{-\lambda_1 x} + A_2 e^{-\lambda_2 x},$$

where $C(x)$ is the ^{60}Co or ^{137}Cs concentration (in pCi/g of soil) at a depth of x centimeters below the surface, and A_1, λ_1, A_2, and λ_2 are constants determined by a least squares curve-fitting procedure. The value for the constants derived from the least squares analysis is provided in Table C.5.1.2 for both ^{60}Co and ^{137}Cs.

The $C(x)$ functions for ^{60}Co and ^{137}Cs are assumed to represent the soil concentration distribution profiles at the time of reactor shutdown. Since exposure is primarily via beta/gamma radiation, the contact dose to individuals from this contamination is due to more than just the contamination in the layer of surface soil to which they are in contact. In order to compensate for this, it is conservatively assumed that all of the inventory of contaminant remaining in the soil column is evenly distributed in the top 15 cm of soil and that the dose rate from each layer of soil removed is from 1/15th of the total inventory. The residual dose rate after removal of x cm of soil is therefore calculated by integrating $C(x)$ over all x and dividing by 15 to obtain an average adjusted concentration in the soil, and then multiplying by the appropriate dose conversion factor (refer to Attachment A) as follows:

$$D(x) = \frac{dcf}{15}\left(\frac{A_1}{\lambda_1}e^{-\lambda_1 x} + \frac{A_2}{\lambda_2}e^{-\lambda_2 x}\right),$$

where $D(x)$ is the residual dose rate (in mrem/y) after x centimeters of soil have been removed, and *dcf* is the dose conversion factor (in mrem/y per pCi/g) for either ^{60}Co or ^{137}Cs.

The model developed for the above data is assumed to be representative of a site having a high surface contamination level since the data from the Humboldt Bay Nuclear Unit was at the high end of the data obtained from all of the nuclear power plants evaluated in the study referred to above (compare to data in Table C.4.1.3). Medium and low surface contamination level models were developed by assuming the same scaling relationships as were assumed for the baseline, or diffusion model, scenarios (i.e., contaminant concentrations in the medium case are assumed to be ½ and ¼ those in the high case for ^{60}Co and ^{137}Cs, respectively, and in the low case are assumed to be 1/30th and 1/20th that of the high case for ^{60}Co and ^{137}Cs, respectively). The model results for the unrestricted and restricted land-use scenarios are shown in Figures C.5.1.1 and C.5.1.2, respectively, for ^{60}Co and in Figures C.5.1.3 and C.5.1.4, respectively, for ^{137}Cs.

A composite case is presented for the same scenarios in Figures C.5.1.5 and C.5.1.6. The composite case is just the summation of the results for ^{60}Co and ^{137}Cs and are the results actually used in the analyses conducted for this study.

Figures C.5.1.7 through C.5.1.12 present the same results as discussed above for the scenarios where decommissioning is delayed for 50 years (i.e., SAFSTOR). In these cases, the results from the models above were input into the diffusion model, which is discussed in NRC, 1994. The diffusion model was used to simulate the 50-year SAFSTOR period by assuming that existing contamination migrated deeper into the soil column via diffusion only.

The calculated data underlying Figures C.5.1.1 through C.5.1.12 are provided in Attachment B.

C.5.2 Uranium-Contaminated Soil

The "real world" model for uranium-contaminated soil was developed from data available on the extent of soil contamination at the former Ventron Corporation plant located in Beverly, Massachusetts (refer to Section C.3.2). The volume of soil that would be expected to be excavated at this site for different residual cleanup levels is provided in Table 5.2.1 (DOE, 1994a). These data were extrapolated to the reference uranium fuel fabrication plant by normalizing to contaminated soil volume data available on the Babcock & Wilcox Apollo fuel fabrication plant. During remediation of this site, a total of 665,000 ft^3 of soil contaminated to greater than 30 pCi/g was excavated and disposed (Kingsley, 1994).

The total estimated soil volume requiring remediation was then calculated for each of the cleanup criteria shown in Table C.5.2.1. These volumes were converted to an estimated depth of contamination penetration into the soil column by assuming that the contamination was uniformly spread throughout an approximate contaminated surface area at the Apollo plant estimated at 200,000 ft^2. The residual dose rate corresponding to each of these soil depths was then determined by converting the cleanup criteria (pCi/g) in Table C.5.2.1 to dose rate (mrem/y) using the appropriate Dose Conversion Factor for uranium (refer to Attachment A).

A model to estimate residual dose rate as a function of the depth of contaminated soil remediated was developed by curve-fitting an exponential function to the above data, which is as follows:

$$D(x) = 232.5\, e^{(-0.02217x)} \qquad \text{(unrestricted land-use), and}$$

$$D(x) = 8.694\, e^{(-0.02217x)} \qquad \text{(restricted land-use),}$$

where $D(x)$ is the residual dose rate (in mrem/y) and x is the soil depth remediated (in cm). The model results are shown in Figures C.5.2.1 and C.5.2.2 for the unrestricted and restricted land-use scenarios, respectively.

The models developed for the above data are assumed to be representative of a site having a high surface contamination level since data available on the Apollo plant suggest that the median concentration of uranium throughout the entire contaminated soil volume is less than 200 pCi/g (NRC, 1993). Medium and low surface contamination level models were developed by assuming the same scaling relationships as were assumed for the baseline, or diffusion model, scenarios (i.e., contaminant concentrations in the medium case are assumed to be 1/5th those in the high case, and in the low case are assumed to be 3/100th that of the high case). The calculated data underlying Figures C.5.2.1 and C.5.2.2 are provided in Attachment B. For purposes of soil removal calculations in Attachment C (and in particular for Tables C.25 and C.26), the depth of soil removal necessary to attain the lower alternative dose criteria (30-0.03 mrem/y) was based on Attachment B. The depth of soil removal necessary to achieve the higher alternative dose criteria (100 and 60 mrem/y) was based on the data available rather than a calculated curve fit because they were a better representation.

C.5.3 Thorium-Contaminated Soil

Limited information was available relating to soil contamination profiles in terms of thorium concentrations as a function of depth of soil for rare metal extraction plants. Based on the very limited data available, however, the following broad conclusions can be made:

- the majority of the "large" contaminated volumes reported for these types of facilities are associated with thorium-contaminated slag piles or ponds and not contaminated soil,

- thorium-contaminated slag was not generally used for landfilling at these types of facilities (only one of 12 sites evaluated indicated that this had been done), and

- many of the sites evaluated reported that thorium does not leach appreciably from the slag into the soil and that soil contamination is generally limited to the upper 1 to 2 feet of soil.

Given the very limited data available, a somewhat crude "real world" model was developed based on data available on the Molycorp, Inc., rare metal ore processing facility located in York, Pennsylvania (refer to Section 3.4). Information on this site suggests that, during remediation, an estimated total of 18,000 ft^3 of soil contaminated primarily with thorium-232 will be excavated and removed offsite. Approximately 3,600 ft^3 of this volume contain up to 70 pCi/g of contamination. In addition, prior to soil excavation and removal activities in 1987, the site had soil with contamination levels up to 700 pCi/g of Th-232 (NRC, 1993).

By assuming that 700 pCi/g is the maximum concentration of Th-232 at the soil surface, that 18,000 ft^3 of contaminated soil correspond to a residual dose level of less than background, and that the contamination is spread uniformly over a surface area of 25,000 ft^2, Th-232 concentration, as a function of depth into the soil column, is derived. The residual dose rate corresponding to each of the calculated soil depths was then determined by converting the cleanup criteria (pCi/g) to dose rate (mrem/y) using the appropriate Dose Conversion Factor for thorium (refer to Attachment A).

A model to estimate residual dose rate as a function of the depth of contaminated soil remediated was developed by curve-fitting an exponential function to the above data, which is as follows:

$$D(x) = 200.8\ e^{(-0.1182x)} \quad \text{(unrestricted land-use), and}$$

$$D(x) = 8.701\ e^{(-0.1182x)} \quad \text{(restricted land-use),}$$

where $D(x)$ is the residual dose rate (in mrem/y) and x is the soil depth remediated (in cm). The model results are shown in Figures 5.3.1 and 5.3.2 for the unrestricted and restricted land-use scenarios, respectively.

The models developed for the above data are assumed to be representative of a site having a medium level of surface contamination since the peak thorium concentration of 700 pCi/g that this model is based on is considerably less than peak concentration levels identified for other similar sites (i.e., 2,650 pCi/g for the Molycorp-Washington site). High and low surface contamination level models were developed by assuming the same scaling relationships as were assumed for the baseline, or diffusion model, scenarios (i.e., contaminant concentrations in the high case are assumed to be twice those in the medium case, and in the low case are assumed to be 3/10th that of the medium case). The calculated data underlying Figures C.5.3.1 and C.5.3.2 are provided in Attachment B.

Table C.5.1.1. Concentration of ^{60}Co and ^{137}Cs in Soil at Humboldt Bay

Core Sample Number	Depth into Soil (cm)	^{60}Co Concentration (pCi/g)	^{137}Cs Concentration (pCi/g)
1	0-2	306	88.9
	2- 6	67.8	21.4
	6 - 10	15	4.88
	10 - 14	7.91	2.71
	14 - 18	8.3	2.36
	18 - 22	2.98	1.24
	22 - 26	0.109	<0.03
	26 - 30	2.31	0.526
	30 - 34	1.92	0.304
	34 - 38	2.16	0.238
	38 - 42	4.71	0.48
	42 - 46	8.55	0.742
	46 - 50	16.8	0.97
2	0 - 4	26	37.7
	4 - 8	34.7	50.6
	8 - 12	16.1	16.3
	12 - 18	4.3	5.32
	18 - 24	2.03	2.83
	24 - 28	0.75	1.25
	28 - 32	0.351	0.66
	32 - 36	3.33	0.32

Table C.5.1.2. Value for Parameters in the *C(x)* Model for ^{60}Co and ^{137}Cs

Parameter	^{60}Co	^{137}Cs
A_1	506.5	141.9
λ_1	0.5534	0.5317
A_2	15.74	5.95
λ_2	0.06217	0.07623

Table C.5.2.1. Estimated Contaminated Soil Volume Ratio at Different Cleanup Levels for the Ventron Corporation Plant

Cleanup Criteria (pCi/g)	Contaminated Soil Volume Ratio (relative to 130 pCi/g)
130	1
80	1.23
39	1.6
30	2.27
20	2.76
13	3.38
4	4.5

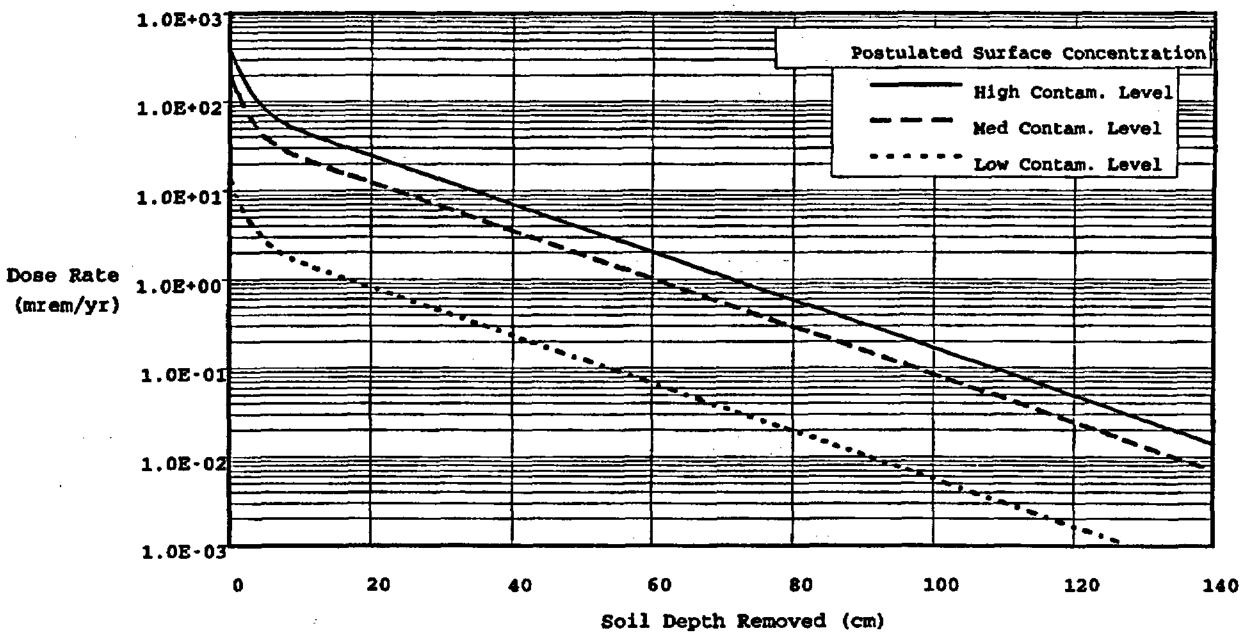

Figure C.5.1.1. Calculated Residual ^{60}Co Radiation Dose Rate as a Function of Soil Depth Removed (Spill/Leak Model, Unrestricted Land Use)

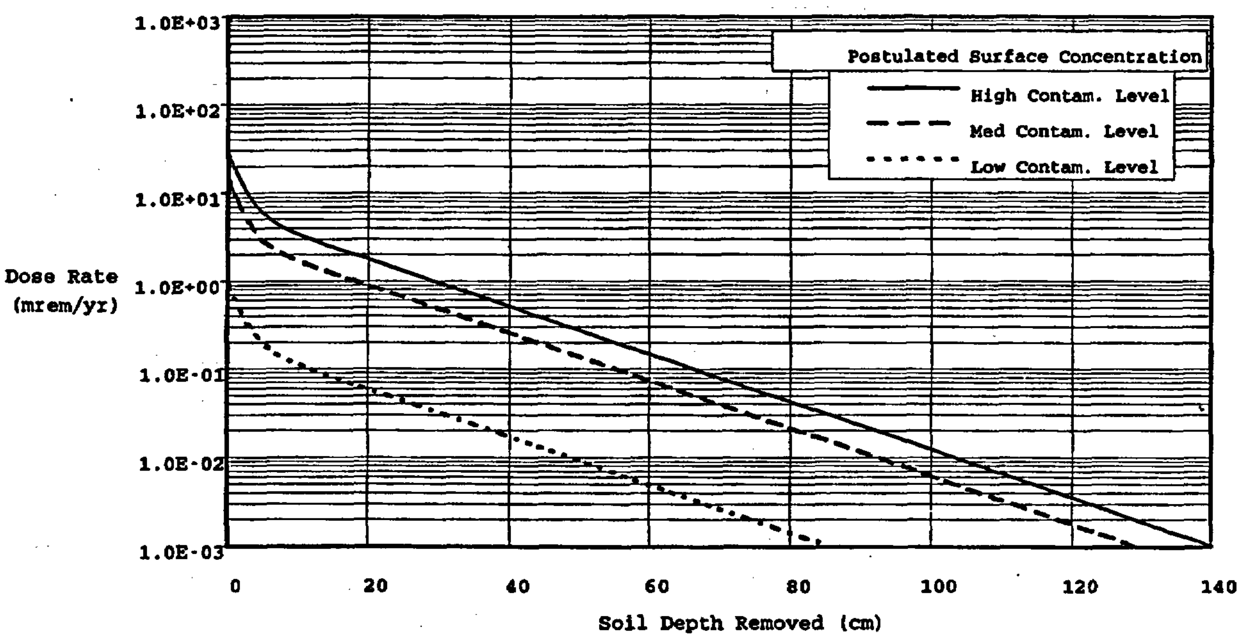

Figure C.5.1.2. Calculated Residual ^{60}Co Radiation Dose Rate as a Function of Soil Depth Removed (Spill/Leak Model, Restricted Land Use)

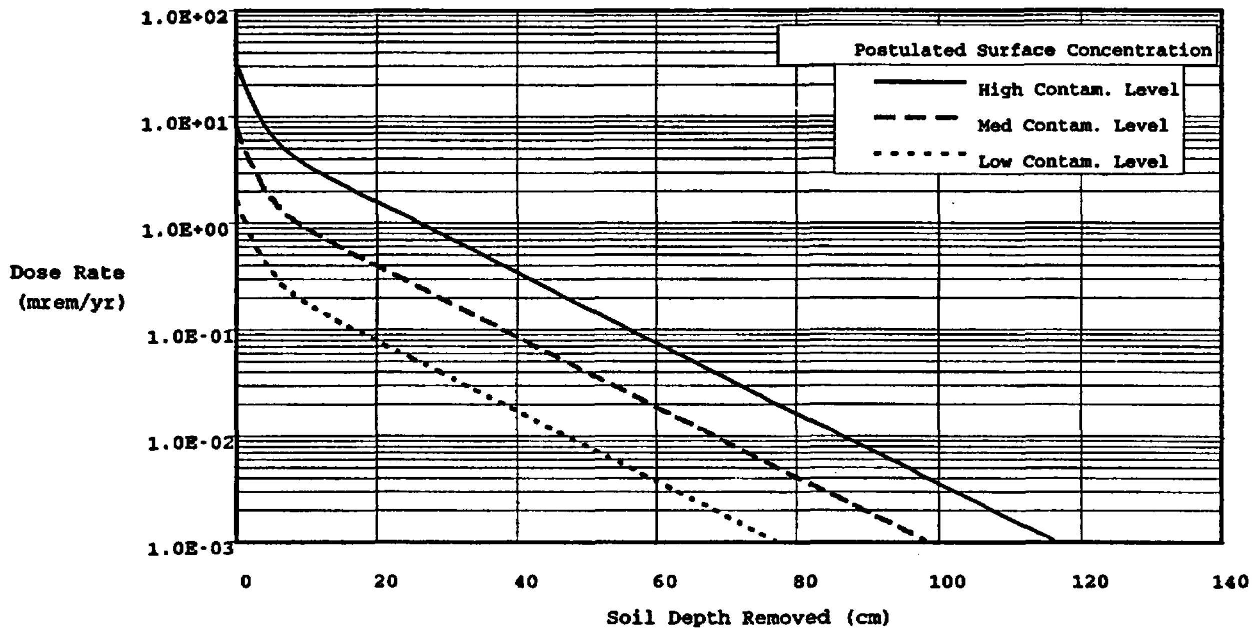

Figure C.5.1.3. Calculated Residual [137]Cs Radiation Dose Rate as a Function of Soil Depth Removed (Spill/Leak Model, Unrestricted Land Use)

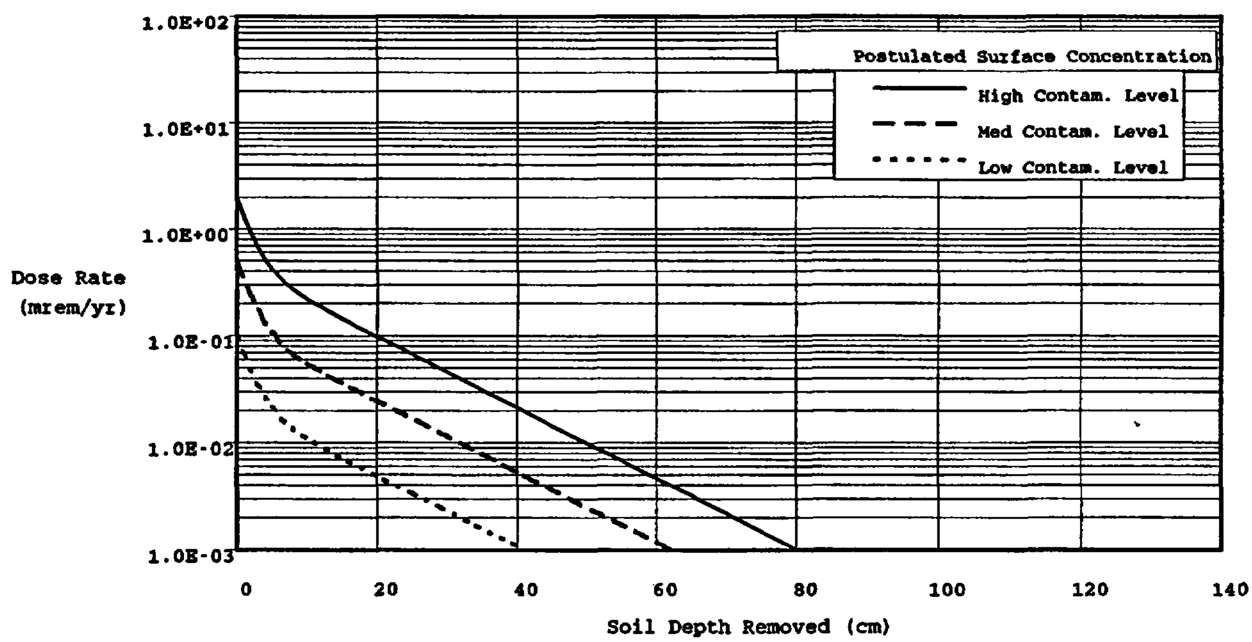

Figure C.5.1.4. Calculated Residual [137]Cs Radiation Dose Rate as a Function of Soil Depth Removed (Spill/Leak Model, Restricted Land Use)

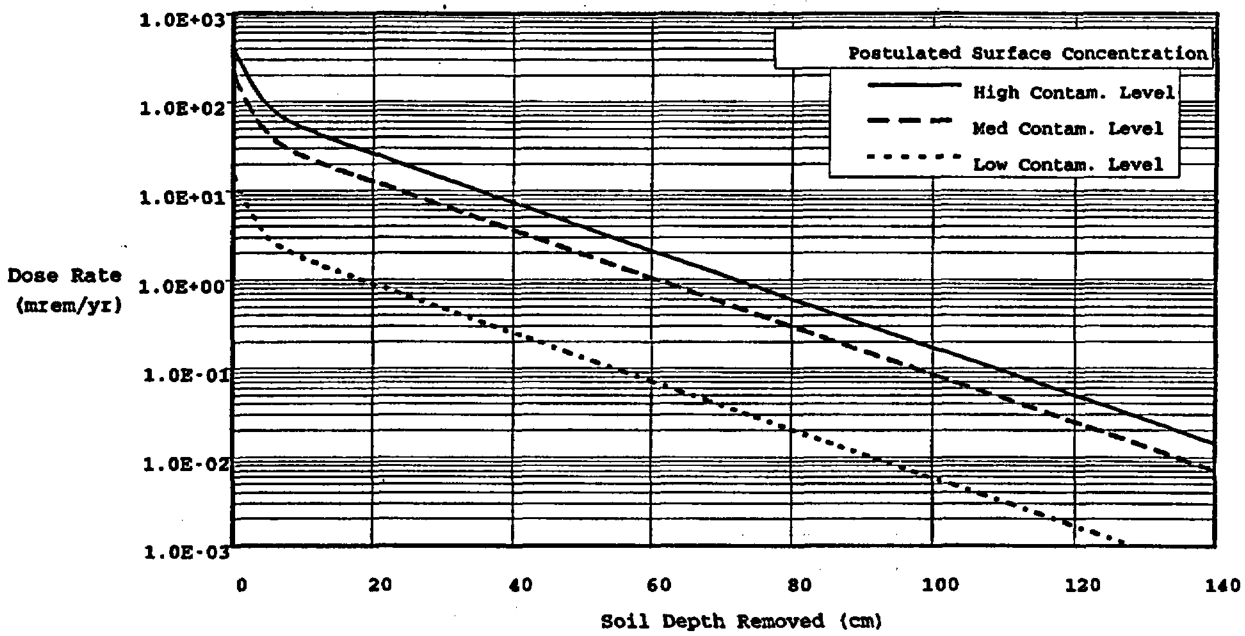

Figure C.5.1.5. Calculated Residual Composite ^{60}Co and ^{137}Cs Radiation Dose Rate as a Function of Soil Depth Removed (Spill/Leak Model, Unrestricted Land Use)

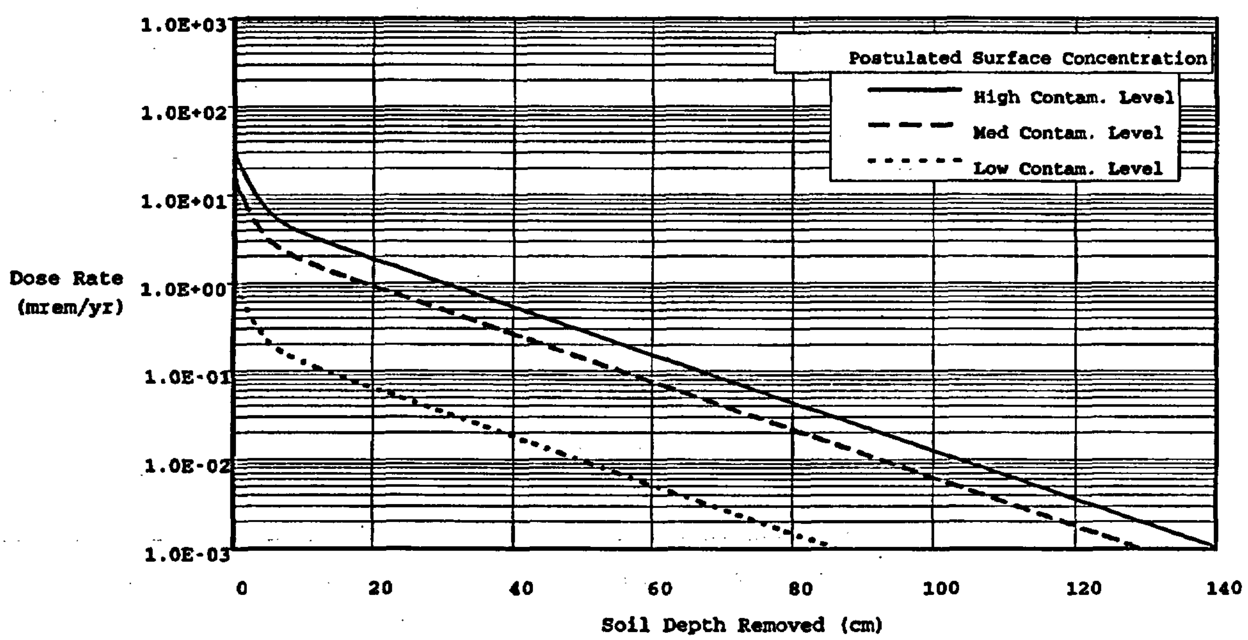

Figure C.5.1.6. Calculated Residual Composite ^{60}Co and ^{137}Cs Radiation Dose Rate as a Function of Soil Depth Removed (Spill/Leak Model, Restricted Land Use)

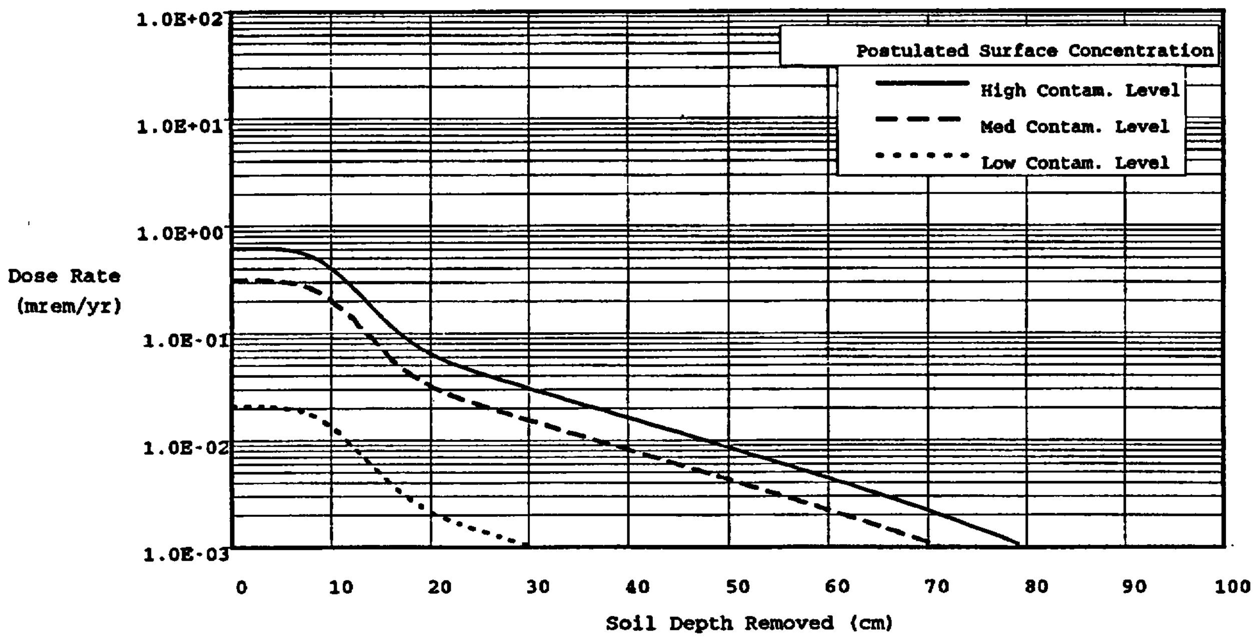

Figure C.5.1.7. Calculated Residual ^{60}Co Radiation Dose Rate as a Function of Soil Depth Removed (Spill/Leak Model, Unrestricted Land Use, 50-Year SAFSTOR)

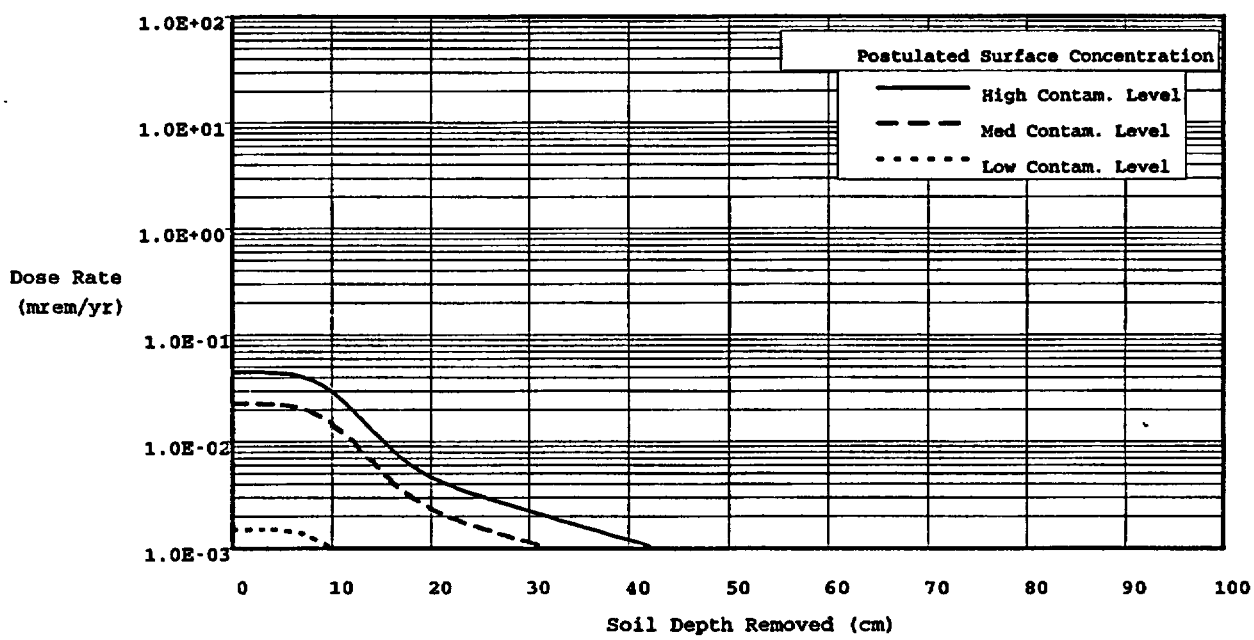

Figure C.5.1.8. Calculated Residual ^{60}Co Radiation Dose Rate as a Function of Soil Depth Removed (Spill/Leak Model, Restricted Land Use, 50-Year SAFSTOR)

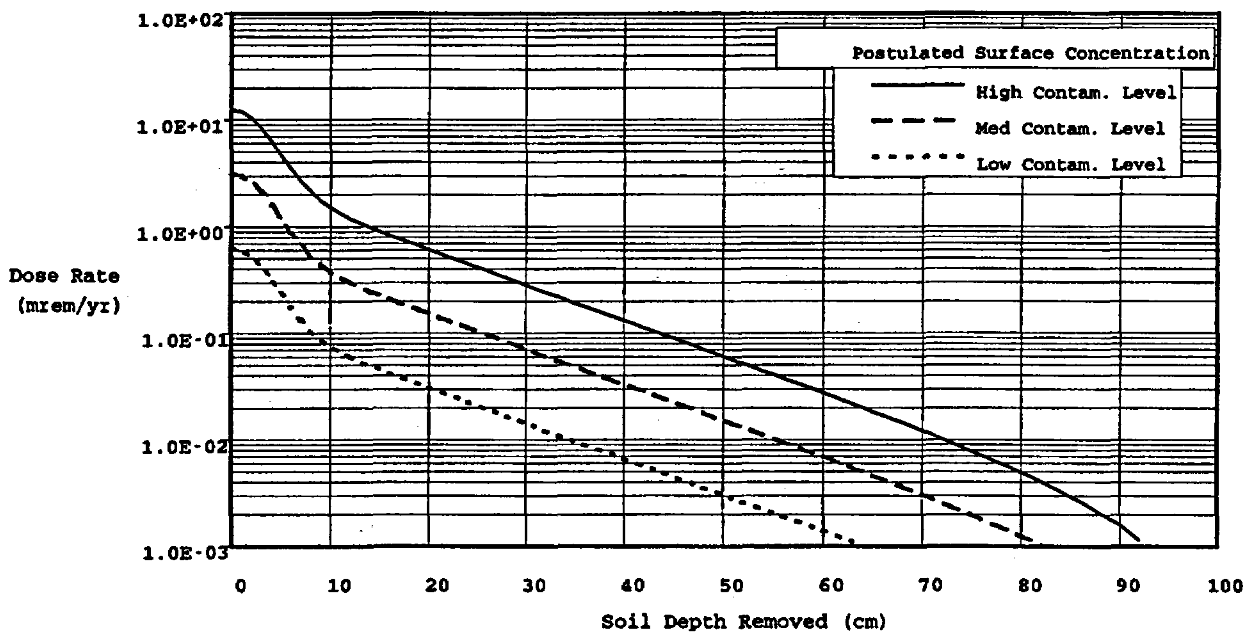

Figure C.5.1.9. Calculated Residual ^{137}Cs Radiation Dose Rate as a Function of Soil Depth Removed (Spill/Leak Model, Unrestricted Land Use, 50-Year SAFSTOR)

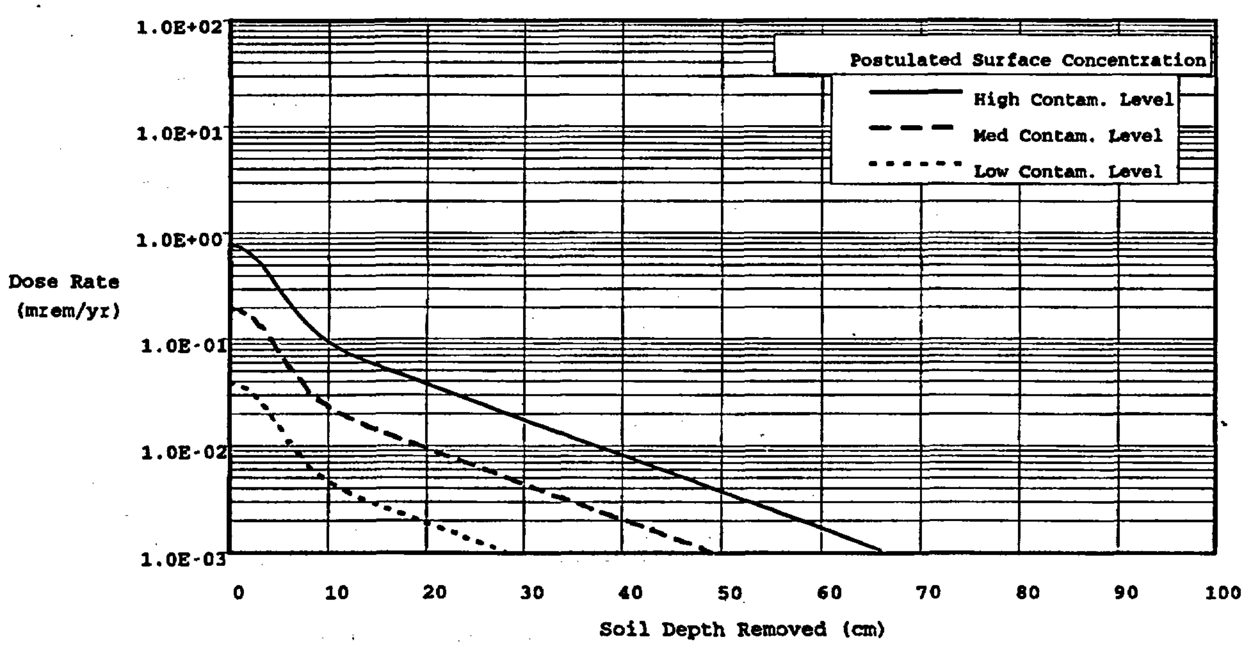

Figure C.5.1.10. Calculated Residual ^{137}Cs Radiation Dose Rate as a Function of Soil Depth Removed (Spill/Leak Model, Restricted Land Use, 50-Year SAFSTOR)

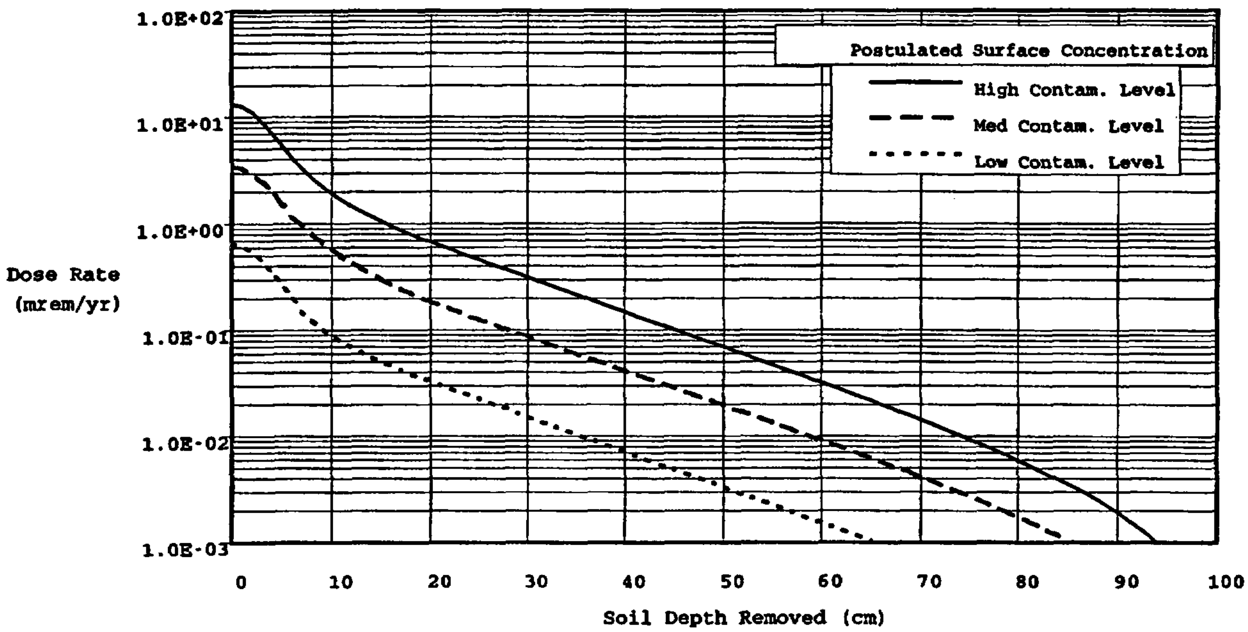

Figure C.5.1.11. Calculated Residual Composite ^{60}Co and ^{137}Cs Radiation Dose Rate as a Function of Soil Depth Removed (Spill/Leak Model, Unrestricted Land Use, 50-Year SAFSTOR)

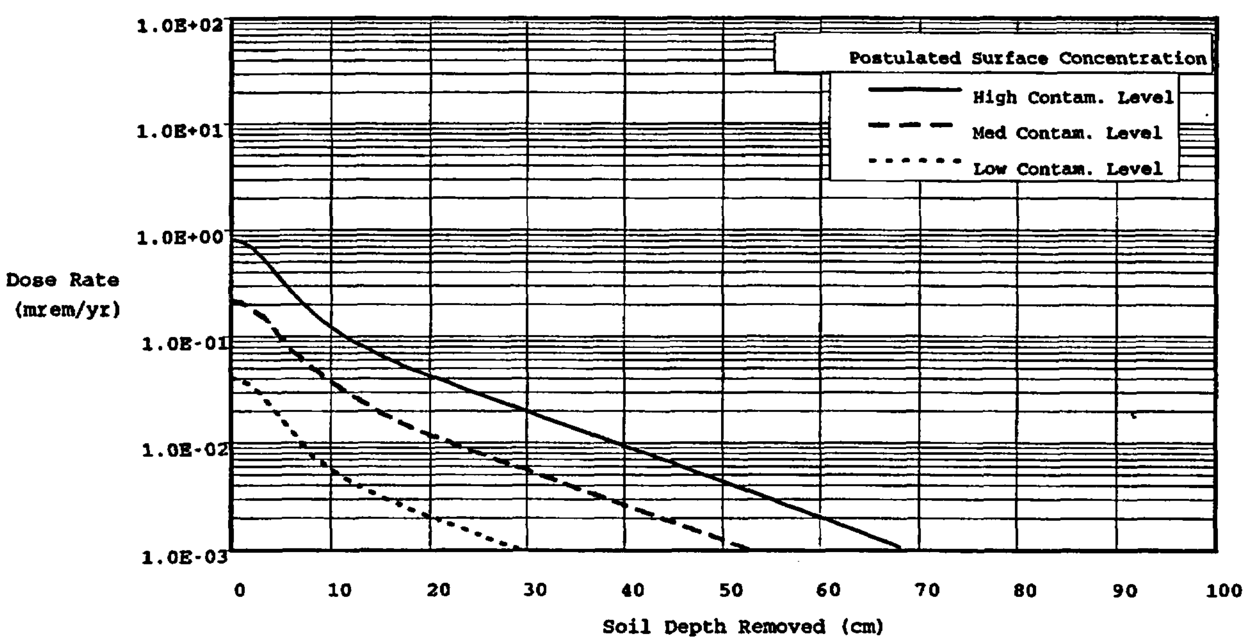

Figure C.5.1.12. Calculated Residual Composite ^{60}Co and ^{137}Cs Radiation Dose Rate as a Function of Soil Depth Removed (Spill/Leak Model, Restricted Land Use, 50-Year SAFSTOR)

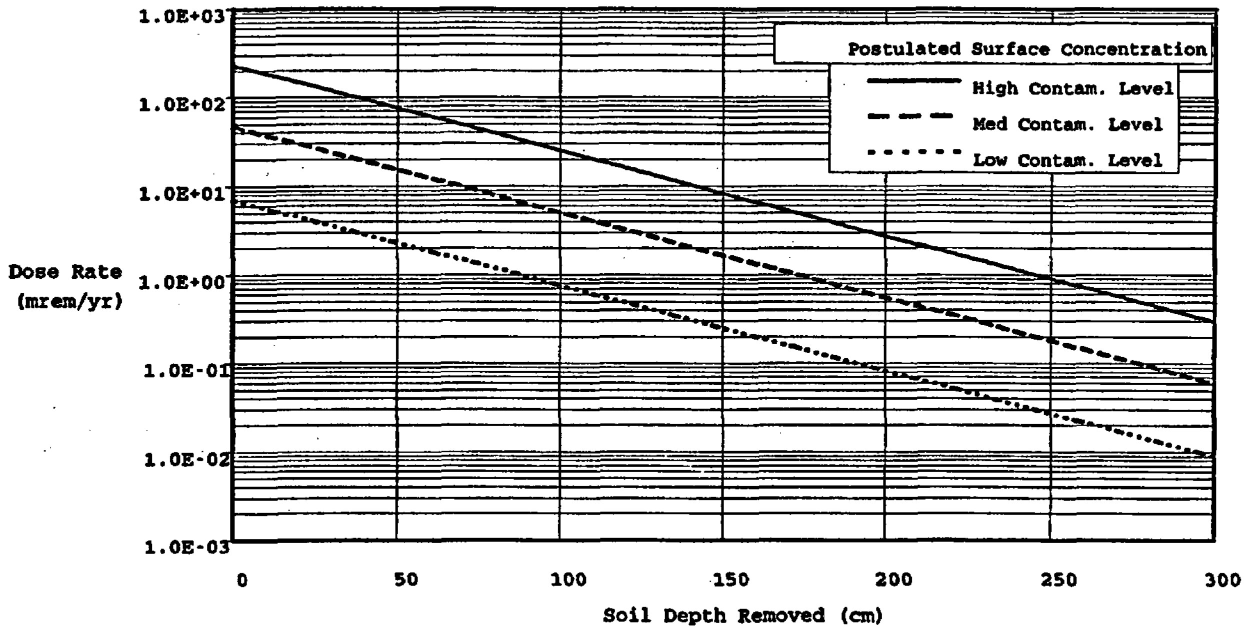

Figure C.5.2.1. Calculated Residual Uranium Radiation Dose Rate as a Function of Soil Depth Removed (Mixing/Landfilling Model, Unrestricted Land Use)

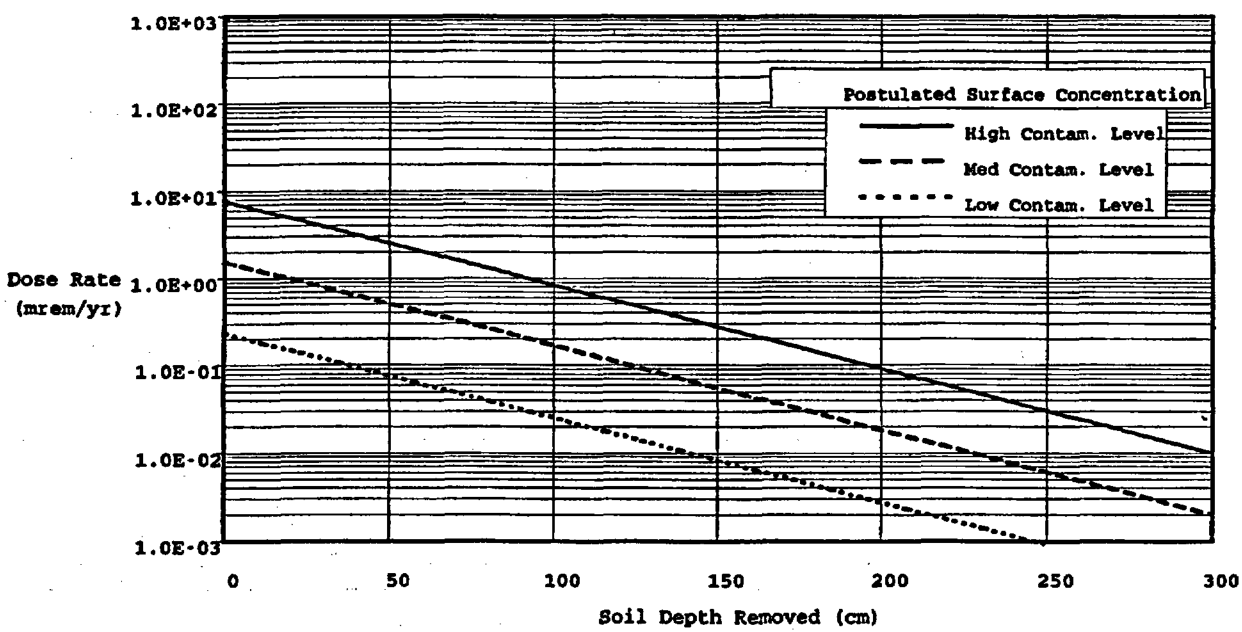

Figure C.5.2.2. Calculated Residual Uranium Radiation Dose Rate as a Function of Soil Depth Removed (Mixing/Landfilling Model, Restricted Land Use)

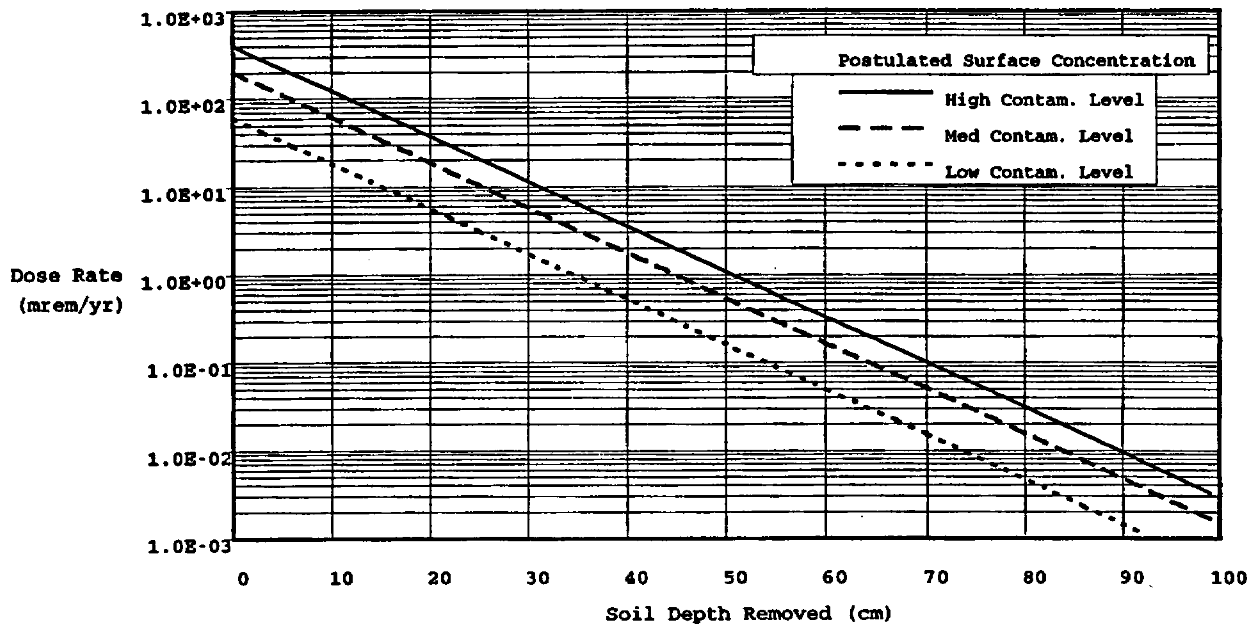

Figure C.5.3.1. Calculated Residual Thorium Radiation Dose Rate as a Function of Soil Depth Removed (Mixing/Landfilling Model, Unrestricted Land Use)

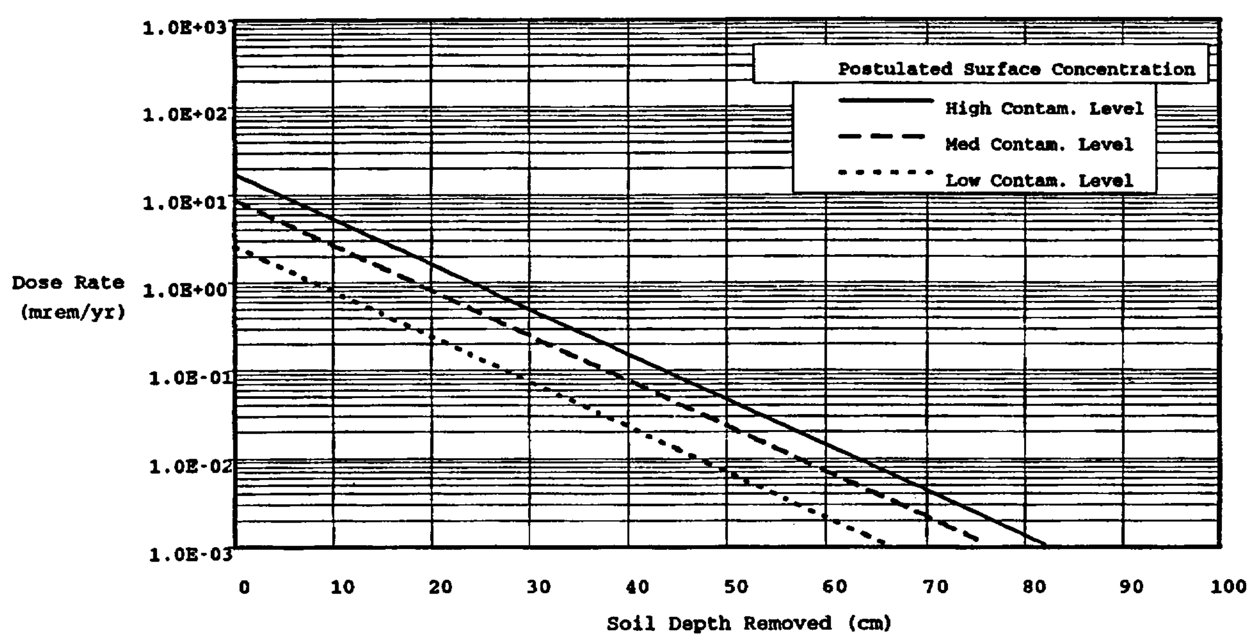

Fig. C.5.3.2. Calculated Residual Thorium Radiation Dose Rate as a Function of Soil Depth Removed (Mixing/Landfilling Model, Restricted Land Use)

C.6 Cost Methodology for Remediation of Concrete and Soils

The methods of calculating costs for removal and disposition of contaminated concrete and soils from decommissioned nuclear facilities are described in this chapter. The methodology for costing the removal and disposal of contaminated concrete surfaces is described first, followed by the methodology for costing removal and disposal of contaminated soils.

C.6.1 Concrete Surface Decontamination Cost Calculation Methodology

The approach used to calculate the costs of removal and disposition of contaminated concrete from facility surfaces is as follows:

- The area of contaminated surface is defined (facility-specific).
- The length of perimeter crack is defined (nominally the perimeter of the structure).
- The area of the "wet spots" is defined (nominally 2% of the ground floor area).
- The volume of concrete to be removed is determined, based on the dose calculations described in Section 6.2.3 of this report.
- The unit cost factors for removal of contaminated concrete from surfaces, cracks, and wet spots are defined. The removal cost for each of the contaminant situations (floors, walls, cracks, and wet spots) is calculated as the product of the area x the appropriate unit cost factor.
- The resulting volumes of removed material are expanded by a rubble expansion factor of 1.56 (Westinghouse Hanford Co., 1989), and the contaminated rubble is drummed. The cost of drums is calculated by the product of the number of drums x the unit cost of a drum.
- The cost of transport is calculated assuming a one-way shipment of 500 miles from the waste generator to the disposal site, for a legal-weight truck shipment, by dividing the number of drums of rubble generated by the number of drums per truck shipment x the cost per shipment.
- The cost of disposal is calculated assuming very low activity waste disposed at a licensed LLW disposal site: the number of cubic feet of waste x the appropriate disposal charge rate per cubic foot.
- The duration of the concrete removal period is based upon the number of person-hours required to remove the material, assuming two crews/shift and

two shifts/day, and specified removal rates (floors or walls) in square feet per crew-hour. On each shift, one crew works on floors and one crew works on walls. The total (floor or wall) area treated is divided by the appropriate removal rate in square feet per crew-hour to determine the number of crew-hours required to remove the material; i.e., the duration of the removal period. The overhead labor costs are determined by the size and makeup of the overhead staff and their salaries and the length of the removal period.

- The total cost for contaminated concrete removal is the sum of the costs for removal of surface layers on floors and walls, and the cost for removal of cracks and wet spots, plus the costs for packaging, transport, and disposal of the packaged material, plus the cost of project overhead staff during the removal period. As each successive layer of concrete is removed from floors and walls, these removal costs increase, together with packaging, transport and disposal costs. The cost elements for the cracks and wet spots are independent of the number of layers of floor and wall removed.

C.6.2 Concrete Surface Decontamination Technology and Cost

Decontamination of concrete surfaces of floors and walls is postulated to be accomplished using commercial equipment presently available. The equipment postulated to be used in these analyses is a pneumatically operated surface removal system (scabbler) manufactured by Pentex, Inc. (The Moose™ and associated smaller units). This device can chip away approximately 0.125 in. of surface depth per pass and has a skirted scabbling unit with a vacuum system which collects the dust and chips from the operation and deposits the waste material into a waste drum. Filters on the vacuum system discharge removed suspended dust particles from the air to prevent recontamination of the cleaned surfaces. Successive passes are required to remove deeper layers of contaminated concrete.

C.6.2.1 Rates of Floor and Wall Surface Removal

The removal rates for the scabbler devices are functions of the depth to be removed. Because the depth of cut for the scabbler is adjustable, different depths can be removed with a single pass. However, the deeper the cut, the slower the rate of removal in terms of surface area. For these analyses, a depth per cut of 0.125 in. is postulated, somewhere near optimum for maximizing the effectiveness of the equipment, which results in a removal rate of about 115 ft^2 per hour for a single pass of the equipment. The smaller units utilized for the edges of floors and for walls have a removal rate of about 30 ft^2 per hour for a single pass.

C.6.2.2 Unit Costs for Removing Contaminated Concrete Surfaces

The cost per square foot of surface removed is calculated based on the postulated crew makeup and size. For this type of operation, a crew consisting of 3 laborers, 0.25 of a health physics technician, and 0.25 of a crew-leader was postulated, which resulted in a cost per square foot, removed to a depth of 0.125 in., of \$2.20 for the floors and \$8.61 for the walls.

To compute the cost of removal and disposition of each layer of contaminated concrete in a facility, the estimated contaminated area of floors and walls is multiplied by the appropriate unit cost factors, and the results summed. Added to these removal costs are the costs of packaging (cost per drum), transport (legal-weight truck one-way for 500 miles), and disposal at a licensed LLW facility (disposal charge rates are based on the rates at the U.S. Ecology site at Richland, Washington [\$50/ft^3] and at the Chem-Nuclear site at Barnwell, South Carolina [\$350/ft^3]). The cost of the project overhead staff during the removal period is computed based on the duration of the removal period and added to the other costs of the effort.

C.6.2.3 Crack and Wet Spot Removal

Decontamination of cracks in the floor that contain contamination is accomplished by removal of the concrete surrounding the crack, using ordinary pneumatic hammers and vacuum systems for dust and particle collection. The cost of this operation is computed in a manner similar to the floor removal operations, using a unit cost factor for crack cleanout and the linear length of crack requiring removal. A crew is defined, labor rates are assigned, the rate of crack length removal is estimated, and the cost per linear foot of crack is calculated. This unit cost factor is multiplied by the number of linear feet of crack requiring removal to obtain the removal cost. The costs of packaging, transport, and disposal are calculated and added.

Decontamination of a crack is postulated to require removal of approximately 1 in. of concrete on either side of the crack, to an average depth of 6 in., resulting in a waste volume generated of about 0.13 ft^3 of contaminated rubble per linear foot of crack, including the 1.56 volume expansion for rubblizing. The removal rate is assumed to be 20 linear feet of crack per operating crew-hour, with a resulting cost per linear foot of crack of about \$7.40, including equipment costs. The length of crack for each facility was postulated to be equal to the perimeter of the structure, derived from the building footprint surface area, assuming a square structure:

$$\text{perimeter} = 4 \times (\text{number of floors}) \times (\text{footprint area})^{1/2}.$$

For the analyses presented in this report, a single story structure is assumed for all facilities.

For "wet spots"; i.e., areas that had been exposed to liquid contaminants for extended periods of time, the penetration of contaminants is considerably deeper than for dry contaminants, as discussed in Chapter 4 of the draft GEIS (NRC, 1994). Therefore, the entire thickness of a concrete floor is postulated to be removed for the area of the "wet spot" (2% of the area of the ground floor), using equipment similar to that described for crack removal. For these analyses, the floor thicknesses removed were assumed to be 6 in. thick. It is also postulated that the contamination will extend downward into the soil beneath the "wet spot" thereby requiring corresponding soil removal.

The removal rates, crew sizes, and costs for removal of the "wet spot" areas of concrete were obtained from Means (1993).

C.6.3 Removal of Activated Concrete From the Reactor Bioshield

Removal of the activated concrete from the reactor bioshield is accomplished using a drilling and blasting technology. Vertical holes are bored into the shield concrete at selected distances from the shield inner surface. Explosives are inserted into the holes and detonated, breaking up the inner segments of the shield. This operation is repeated as necessary to remove the required amount of the shield to reduce the surface radiation dose rate inside the shield cavity to acceptable levels.

Calculations of the activation of materials in the concrete biological shield that surrounds the reactor pressure vessel were reported in NUREG/CR-0130 (Smith et al., 1978) for the reference PWR (Trojan), for an assumed operating lifetime of 30 effective full-power years (i.e., 75% operating efficiency). These calculations did not include any ^{152}Eu because no information was available about the likely concentration of ^{152}Eu in the natural materials of the Trojan bioshield. However, measurements made at the Elk River Reactor decommissioning suggested that the Ci/m^3 attributable to ^{152}Eu was about the same as the Ci/m^3 associated with ^{60}Co. Thus, the total bioshield activity is postulated to be approximately twice the calculated activity of ^{60}Co, due to the anticipated ^{152}Eu activity.

Examination of the original calculations of activations in the bioshield suggests that at about 7 years following reactor shutdown, the residual activity levels in the bioshield will be such that removing 3.49 ft from the inner surface of the shield would result in a surface radiation dose rate of about 100 mrem/y; 3.92 ft removed for 25 mrem/y; 4.60 ft removed for 3 mrem/y; and 5.36 ft removed for 0.3 mrem/y. The costs associated with removal and disposal of that activated material were calculated using the unit cost factor algorithm for activated bioshield concrete removal presented in Section C.2.17 of Appendix C in NUREG/CR-5884, (Konzek et al., 1995) and the cost estimating computer program (CECP). The duration of the decontamination effort was calculated to be controlled by the shield removal initially, but after one pass of the floor-removal equipment, the floor removal duration controlled the duration of the effort, for the purpose of calculating project overhead costs to be added to the direct labor costs.

C.6.4 Soil Decontamination Cost Methodology

The costs for removal and disposition of contaminated soils are calculated in a somewhat similar manner. The area of contaminated soil is defined. The unit cost factors for soil removal, treatment (if any), packaging, transport, and disposition are defined. The depth of contaminant penetration into the soil is defined. Then, the total cost for contaminated soil removal is the sum of the individual cost elements, which are calculated using the appropriate unit cost factors. The cost calculation is based upon removing all of the soil to the depth necessary to achieve each of the alternate residual radiation dose rates. In addition, the soil volume removed from beneath 2% of the ground floor surface of each facility is added to the volume of exterior soil removed, for purposes of calculating the total removal, packaging, transport, and disposal cost for soils.

Subsequently, choices are made between treating the contaminated soil prior to disposition, or transporting the untreated contaminated soil to a regulated disposal facility for very low activity materials. In the treatment scenario, the cleaned soil is retained onsite for backfill, with the more contaminated residues removed by the treatment process being packaged and transported to an LLW disposal facility.

At the reference rare metal extraction facility, an alternate method of disposal of contaminated soils was also analyzed whereby the contaminated soil is not disposed of at an offsite disposal facility but is placed in a nearby or onsite tailings pile and then finally capped according to existing regulatory criteria. Appropriate costs of stabilization and capping the tailings pile are also included. The capped tailings pile site would necessarily be considered a form of restricted land use and would likely require continual monitoring. The costs associated with this required monitoring are not estimated since they are not fixed in a restricted land-use scenario.

In any actual situation, selection of one alternative over another would most likely be governed by the total cost for each choice.

Information on additional methods for restricting access to facilities is contained in Appendix F.

C.6.5 Soil Treatment Technologies

The various forms of soil washing represent the only commercially-demonstrated soil-cleaning techniques for radioactively-contaminated soils. Innovative techniques being developed (at present in the pilot plant or demonstration stage) include electrokinetics and magnetic separation. These latter two techniques offer some potential for cost-reduction but are likely to be applied as a polishing step after soil classification and washing rather than as stand-alone soil cleaning methods. In addition, biosorption/bioleaching technology, currently being used for metals extraction from ores in the mining industry (particularly uranium and copper) may be applied to contaminated soil cleanup, but it is currently a developing technology.

C.6.5.1 Soil Washing - General Description

Contaminated soil is removed from the site, classified to remove large particles and rocks, and washed by immersion with agitation in an aqueous solution. Chemical additives may be present in the wash solution to dissolve contaminants bound to soil particles. Several additives are available to facilitate the solution process depending on soil and contaminant type (Dennis et al., 1992; SEG, 1992; and Gerber et al., 1991). After washing, the soil is separated according to particle size. Since most of the contaminants bind to the fine soil particles (<250 micrometers) which account for between 10-40% of the total soil mass, the bulk of the soil can be returned to the original location. The remaining slurry of contaminated fines may have to be treated further to prepare for disposal (e.g., by drying and placing in drums). Removal rates of contaminants are enhanced by high liquid to soil ratios. Depending on the soil type and type of washing solution, this method may be effective in the removal of radionuclides. This is a relatively new technology for soil remediation, although it has been used in the mining industry for many years. The process has been commercially demonstrated in Europe and the U.S., mostly for organic-contaminated soils, although some data are available on its application to radiologically contaminated soil remediation.

C.6.5.2 Other Soil Cleanup Technologies

A DOE program is underway to evaluate innovative soil treatment technologies, including field testing at the Nevada Test Site (NTS), at the NTS Treatability Test Facility (operated by Reynold's Electrical & Engineering Co.). The soil treatment technologies under examination currently are restricted to plutonium removal but are likely to be equally effective for thorium and uranium (but not cesium or strontium), and include:

- Advanced Process Technologies, Salt Lake City, UT: Air-sparged hydrocyclone for removal of plutonium

- AWC/Lockheed, Las Vegas, NV: Mineral jig combination and shaker table

- Nuclear Remediation Technologies, San Diego, CA: Paramagnetic separation of plutonium from soil using Eriez Magnetics equipment

- Paramagnetics, Inc., Plant City, FL: Pretreatment washing, followed by Kolm Separator paramagnetic separation

- Scientific Ecology Group, Pittsburgh, PA: Multigravity separator; and high-gradient magnetic separator.

Site cleanup is expected to begin in 1996, using the selected successful technologies (Nuclear Waste News, 1993).

C.6.6 Cost and Labor Estimating Bases for Soil Remediation/Treatment

The information developed for cost and labor is based on unit cost and labor data presented in this section. Categories for which basic unit factors were developed include: soil excavation, both inside and outside the facility, soil washing, packaging, transportation, and disposal. Estimates were developed using a spreadsheet that calculates the cost and labor requirements as a function of volume removed for each site.

A soil washing option was considered for each site analyzed. The soil washing process would separate the contaminated soil from the clean soil in order to reduce the volume of soil that would be disposed of at a burial facility. In order to evaluate the cost effectiveness of soil washing, two scenarios were considered for each facility: one with soil washing and the other without soil washing.

C.6.6.1 Excavation

The unit cost and labor estimates for excavation of soil, or tailings pile, were obtained from Short (1989). This analysis assumed that the soil was excavated and removed from an area contaminated with radioactive residue resulting from facility operations. Radiological surveys are performed before, during, and after the excavation activities. Where appropriate, clean overburden was removed, contaminated soil excavated, and the clean overburden replaced. The unit cost of excavation was assumed to be $235/m^3 while labor requirements were assumed to be 1.62 person-hours/m^3.

C.6.6.2 Removal of Contaminated Soil Beneath Concrete Floor "Wet Spots"

A unit cost and labor factor was developed for removal of soil from beneath the 2% of the facility ground floor area that was considered a "wet spot." The same unit cost and labor factor for removal was used as for the exterior excavation activities.

C.6.6.3 Soil Washing

Soil washing is a water-based process for mechanically scrubbing and leaching waste constituents from a contaminated soil for recovery and treatment. It is an ex-situ toxicity reduction technology. The process removes contaminants from soils in one of two ways: by dissolving or suspending them in the wash solution, or by concentrating the contaminants into a smaller volume of soil through simple particle size separation techniques.

The cost of soil washing contaminated soil that was removed was obtained from the ENVEST Environmental Cost Engineering Model (ENVEST 1991) developed by the United States Air Force Environmental Restoration Program. The soil volume generated at each site was used as the cost estimating basis for the ENVEST model. It was assumed that a conservative efficiency of the soil washing process was 60%. Hence, 40% of the soil processed would be packaged and transported to a low-level radioactive waste burial facility. Soil washing unit costs were assumed to range from about $\$150/m^3$ for large volume projects to about $\$300/m^3$ for small volume projects. The unit labor factor for soil washing was assumed to be 0.17 person-hours/m^3 of soil processed.

C.6.6.4 Packaging

The cost for packaging containers was obtained from Konzek (1995). It was assumed that the material for disposal at an LLW disposal site would be packaged using B-25 metal containers and transported by truck. Packaging for soils being transported by gondola railcar would be limited to car covers. Packaging costs are assumed to be \$100/gondola car and $\$220/m^3$ for B-25 metal containers.

C.6.6.5 Transportation

Two alternatives were evaluated for transport of radioactive materials from the facility to an approved disposal site. One alternative was the use of gondola railcars for transport. Generalized cost information for the rail shipments was obtained from several operating railroads and assumed to be \$4,000/gondola car in these analyses. The other alternative was assumed to be accomplished by truck. A rate schedule from the Tri-State Motor Transit Company for truck shipment of radioactive material was used to estimate the transportation cost. The distance from the facility to the disposal site was assumed to be 500 miles. In addition, it was assumed that each truck could carry up to four containers. Truck transportation costs were assumed to be \$1,325/truck load.

C.6.6.6 Burial Costs

For this study, it was assumed that the contaminated waste generated at the sites would be shipped for disposal to a burial site; i.e., Envirocare, located in Utah, U.S. Ecology, Inc., located at Richland, Washington, or Chem-Nuclear, located at Barnwell, South Carolina. Disposal rates for Envirocare are estimated to be $\$10/ft^3$ and are $\$50/ft^3$ at U.S. Ecology, and $\$350/ft^3$ at Chem-Nuclear (see Section 6.2.2), which provide a fairly wide range of burial costs. The low activity, low concentration soils were assumed to be shipped to Envirocare in Utah, while the higher activity soils were assumed to be shipped to either U.S. Ecology at Richland or Chem-Nuclear at Barnwell.

C.6.6.7 Tailings Pile Stabilization and Capping Costs

As an alternative to disposing of slightly contaminated material at an offsite disposal facility, the option of disposing in a prepared tailings pile site either onsite or at a nearby location is postulated. The stabilization and capping costs were obtained from the ENVEST Environmental Cost Engineering Model (ENVEST, 1991) developed by the United States Air Force Environmental Restoration Program. Unit costs of $\$105/m^2$ were assumed for a tailing pile of 1.5 meters depth. Area of the tailings pile and the resulting multi-layered cap was calculated as a function of the respective contaminated soil volumes to be placed in the pile.

C.6.6.8 Occupational Radiation Dose Estimates

The occupational radiation dose estimates were derived from Short (1989) and Murphy (1981). Occupational radiation dose estimates are made by multiplying the person-hours required to decommission a site by an average radiation dose rate. The actual worker dose rate experienced during site decommissioning depends on several factors, including the type of radioactive contamination on the site, the location and concentration of contamination, the site parameters, and the work procedures and work schedules. Actual worker dose rates are expected to be site- and worker-specific.

Some information exists on dose rates at typical contaminated sites. For example, data from an operating low-level waste burial ground indicate an average dose rate at the site of about 1 mrem per 24-hour day (0.042 mrem/hr). Exposure records of 23 workers engaged in the removal of a contaminated industrial waste line showed that over a 3-month period, only four dosimeters recorded doses in excess of 10 millirem. The maximum total exposure for one worker for 1 month was 30 millirem. All of these dose rates refer to direct exposure and do not include contributions from inhalation of radioactive particles.

The inhalation of airborne radioactivity may make a significant contribution to occupational exposure for some site decommissioning operations, depending on the nature of the site and the decommissioning option. The inhalation dose would not normally be significant for site stabilization or for waste removal operations at sites where soil contamination is minimal. This dose could be significant during the removal of a tailings pile because of the dust problem. For site decommissioning operations, worker use of face masks or other respiratory equipment, the use of water sprays or foams to reduce dust concentrations, and possible use of portable enclosures to confine fugitive dust, would limit the occupational dose from inhalation of airborne radioactivity.

For this study, an average worker dose rate of 0.1 mrem/hr is assumed for site decommissioning operations. This value is believed to be reasonably conservative, based on available information about real sites. Decommissioning workers at potentially dusty sites are assumed to wear protective respiratory equipment to maintain occupational dose rates at or below this level.

C.7 Presentation of Analytical Results

The costs, labor requirements, and occupational dose associated with decontaminating previously contaminated facilities to alternate residual dose criteria are presented in this chapter. The models, methodologies, and assumptions discussed in Chapters 4 through 7 are the bases for these results. It needs to be emphasized that the purpose of these analyses was to provide a framework for differentiating the costs and impacts of decontaminating and decommissioning facilities to alternative residual cleanup levels, not to provide a comprehensive life-cycle estimate of these costs and impacts. These analyses therefore generally only assess those impacts that are a function of the alternative residual dose criteria and not those that are considered to be fixed across all residual dose levels being evaluated. An example of costs not evaluated includes the costs and labor requirements associated with the removal and disposal of contaminated equipment; e.g., steam generator (such analyses have been previously done in NRC, 1988). The costs associated with final status or termination surveys are presented in Appendix D of this report.

C.7.1 Analysis Bases

The analytical results provided in this chapter include analyses for the following alternative uses for the reference sites and structures after decommissioning and license termination:

(1) Industrial use of the site, including occupational use of the structures, which assumes occupation of the decontaminated buildings by workers during a normal work shift and potential renovation of the buildings for eventual occupation (i.e., walls/ceilings/floors are moved, replaced, etc.).

2) Residential use of the site, including use of groundwater for drinking, irrigation, and livestock. Occupation of the structures is also assumed.

The bases for these scenarios are taken from Kennedy and Strenge (1992). Important initial conditions and other analytical bases assumed in the scenario evaluations for decontamination of structures and remediation of soils and groundwater follow.

Facilities

Decontamination requirements of structures to allow for later reoccupation are estimated using the methodology presented in Chapter 4 of Appendix C of the draft GEIS (NRC, 1994) (see Appendix D). This methodology provides a tool for estimating the concentration of radionuclides at different depths in concrete walls/floors resulting from past facility operations, assuming a surface contamination level. Calculated radionuclide concentrations as a function of depth into the concrete are converted to dose rates using the Dose Conversion Factors provided in Attachment A. The depth of concrete requiring removal is then determined for the alternative residual dose rates being evaluated in the GEIS, which are 100, 60, 30, 25, 15, 10, 3, 0.3, and 0.03 mrem/y. The same level of decontamination of structures is required in both the unrestricted and restricted land-use scenarios since reoccupation of structures after decontamination is assumed in both.

In general, other major assumptions are as follows (variations from these major assumptions for individual scenarios are discussed in the next section):

- All in-process materials and products, major pieces of equipment, fixtures, floor coverings, and contaminated utilities such as drain lines and HVAC have been removed for disposal.

- Preliminary washdown of the site structures has been performed.

- The majority of contaminated concrete surface areas are scabbled to depths corresponding to the residual dose rate being evaluated, with the removed material being packaged, transported, and disposed (layers of concrete are assumed to be removed in 0.125-inch increments).

- The total thickness of contaminated concrete adjacent to contaminated cracks is removed, packaged, transported, and disposed.

- The total thickness of contaminated concrete in areas exposed to "wet spots" is removed, packaged, transported, and disposed.

Soils

Remediation requirements for soils for both the restricted and unrestricted land-use scenarios are estimated using the methodologies presented in Chapter 5 and in NRC, 1994. These methodologies provide tools for estimating the concentration of radionuclides at different depths in the soil column resulting from past facility operations, assuming a surface contamination level. Calculated radionuclide concentrations as a function of depth into the soil column are converted to dose rates using the Dose Conversion Factors provided in Attachment A. The depth of soil requiring remediation is then determined for the alternative residual dose rates being evaluated in the GEIS, which are 100, 60, 30, 25, 15, 10, 3, 0.3, and 0.03 mrem/y. The depth of soil contamination requiring remediation is different for the unrestricted and restricted land-use scenarios since assumptions on the type of receptors, nearness of the receptors to the source of contamination, and possible pathways of receptor exposure differ between each of these scenarios.

In general, other major assumptions are as follows (variations from these major assumptions for individual scenarios are discussed in the next section):

- Soils beneath buildings are contaminated in localized areas where the concrete has been exposed to "wet spots." These localized areas of contaminated soil are remediated by first removing the corresponding areas of contaminated concrete floor (the structure is not assumed to be demolished). The contaminated soil is then removed and either 1) packaged and disposed as low-level waste (LLW) or 2) treated via soil washing, with only the residual contaminated soil packaged and disposed as LLW and the clean soil returned to the site.

- Other "open-air" contaminated soils on the site are handled similarly in that it is removed and either 1) packaged and disposed as low-level waste (LLW) or 2) treated via soil washing, with only the residual contaminated soil packaged and disposed as LLW and the clean soil returned to the site.

- In either location, the contaminated soil is removed to the depth corresponding to the residual dose rate being evaluated. This depth is determined using the diffusion models described in NRC, 1994 for the "baseline" scenarios. The "real world" scenarios utilize the new models described in Section C.5 to determine the thickness of soil requiring remediation. In both the "baseline" and "real world" scenarios, the depth of contamination in soils beneath buildings is estimated using the diffusion models, which were believed to be a better representation of contaminant migration beneath buildings.

- For the "baseline" scenarios, contaminated soil in either location is the result of contaminant deposition on the surface of the soil followed by migration via diffusion down through the soil column. For the "real world" scenarios, the analyses assume that contaminant distribution in the soil column is the result of either significant mixing/landfilling utilizing contaminated soil/slag or spills/leaks of contaminated aqueous solutions.

A summary of the contaminated and total concrete and soil surface areas assumed for each of the reference facilities is provided in Table C.7.1.1. This table also shows the postulated maximum radioactivity on the concrete surface of structures for each reference facility prior to initiation of concrete removal activities. Table C.7.1.2 shows the range of postulated activities on the surface of contaminated soil sites for each of the radionuclides of interest. Lastly, the unit cost and dose factors, and values for other parameters, used in these analyses are summarized in Section C.6.

C.7.2 Analytical Results

The estimated costs of decontaminating contaminated concrete surfaces and remediating contaminated soils are presented in the following sections for each of the reference facilities. The indicated costs include that for direct labor, packaging, transport, and disposal of all of the material removed to reach the contaminant concentration level associated with the residual dose rate being evaluated. Also included in the costs are the project overhead staff costs incurred during the period of removal operations. The scenarios (both "baseline" and "real world" cases) evaluated for this study are identified in Table C.7.2.1; the results for each are discussed in Sections C.7.3 through C.7.7.

C.7.3 Reference Nuclear Power Plant

The cost, labor requirement, and occupational exposure resulting from decontamination of the reactor bioshield and other walls/floors of structures at the reference nuclear power plant for alternative residual dose levels are provided in Tables C.7.3.1 and C.7.3.2, respectively. These results are subdivided into two categories - the reactor bioshield and other concrete surfaces - because different technologies are required to decontaminate each. Removal of activated concrete from the reactor bioshield is via drilling and blasting technology because of the large depths of contaminated concrete requiring removal. The results in Table C.7.3.1 for decontamination of the reactor bioshield are shown for each of the different depths of concrete removal required to achieve the alternative residual dose rates being evaluated.

Radionuclide contamination in other concrete floors/walls is not nearly as deep as in the reactor bioshield and so is decontaminated using a pneumatically-operated concrete scabbler. Since the scabbler removes approximately 1/8-inch of concrete with each pass, the results shown in Table C.7.3.2 for other concrete surfaces are in 1/8-inch increments. However, the table also provides the calculated residual dose rate for each increment such that the depth of concrete requiring removal can be determined for each of the residual dose levels being evaluated. These are 0.5 inches for 100, 60, 30, 25, and 15 mrem/y, 0.625 inches for 10, 3, and 0.3 mrem/y, and 0.75 inches for 0.03 mrem/y.

The analysis results for remediation of contaminated soil at the reference nuclear power plant are provided in Tables C.7.3.3 and C.7.3.4 for the unrestricted and restricted land-use scenarios, respectively. Conclusions from these results include:

Unrestricted Land-Use Scenario

- As is to be expected, soil washing becomes increasingly more cost effective as soil disposal costs increase. In fact, soil washing is not worth the additional cost if the soil disposal costs are as low as $10 per cubic foot, but well worth the cost if soil disposal costs are as high as $350 per cubic foot (total costs are reduced by over 50% when compared with the direct disposal scenario).

- Soil remediation is required for the low surface contamination level case only for residual dose levels of less than 10 mrem/y.

- Since soil washing is a low labor-requirement operation, including soil washing in the soil remediation technology mix contributes little to the total occupational dose incurred during remediation operations.

Restricted Land-Use Scenario

- Total soil remediation costs are, as expected, significantly less than for the corresponding unrestricted land-use scenario.

- The general trends in costs and occupational dose are the same as described previously for the unrestricted land-use scenario.

- For all three surface contamination levels (high, medium, and low), soil remediation is not required at all for certain residual dose levels. In fact, no soil remediation is required for any of the cases unless the required residual dose level is 10 mrem/y or less.

Sensitivity Analyses

Two types of sensitivity analyses were performed on the reference nuclear power plant: 1) SAFSTOR for a period of 50 years prior to D&D and 2) soil contamination resulting from spills/leaks of contaminated aqueous solutions. The results of these analyses are discussed below.

50-Year SAFSTOR Period

The cost, labor requirement, and occupational exposure resulting from decontamination of the reactor bioshield and other walls/floors of structures at the reference nuclear power plant for different residual dose levels are provided in Tables C.7.3.5 and C.7.3.6, respectively. These analyses used the same diffusion model as was used in the previously described "baseline" scenarios, and which are described in NRC, 1994, to determine contaminant distribution in the concrete. However, in these scenarios, the model was run to simulate an additional 50 years of radionuclide migration and decay.

The required depth of concrete removal from the bioshield at any of the residual dose levels is significantly less than that for the scenario where the reference nuclear power plant is decommissioned soon after shutdown. This is due to the assumption that contamination in the bioshield is primarily from the activation product Co-60, which has a half-life of only 5.2 years. Cost savings are between 35 and 60% between the upper and lower residual dose levels, respectively (although the additional costs associated with monitoring and surveillance during the 50-year SAFSTOR period are not included in these estimates). The results are similar for decontamination of other concrete floors/walls.

The analysis results for remediation of contaminated soil at the reference nuclear power plant after a 50-year SAFSTOR period are provided in Tables C.7.3.7 and C.7.3.8 for the unrestricted and restricted land-use scenarios, respectively. Again, these analyses used the same diffusion model as was used in the "baseline" scenarios discussed previously, and which are described in NRC, 1994, to determine contaminant distribution in the soil column. However, in these scenarios, the model was run to simulate an additional 50 years of radionuclide migration and decay. Noteworthy conclusions from these results include:

- The general trends in costs and occupational dose are the same for these scenarios as described previously for those scenarios where decommissioning is initiated soon after shutdown. The costs associated with monitoring and surveillance during the 50-year SAFSTOR are not included in these analyses however.

- Because of the 50-year period allowing the radionuclide contaminants to decay, soil remediation is only required in those scenarios where the residual dose rate is reduced to less than 10 mrem/y for the unrestricted land-use scenarios or less than 0.3 mrem/y for the restricted land-use scenarios).

- However, the residual radionuclide contamination after 50 years has also had an additional 50 years to percolate deeper into the soil column. Because of this effect, soil remediation that is required at the low residual dose levels for these scenarios, in general, costs significantly more than remediation to similar levels did for those scenarios where decommissioning was initiated soon after shutdown (significantly greater soil volumes require remediation). This effect is more pronounced in the unrestricted land-use scenarios than in the restricted land-use scenarios due to the much higher Dose Conversion Factors associated with the unrestricted land-use scenario. Because of the relatively low Dose Conversion Factors used for the restricted land-use scenarios, very little soil volume requires remediation in any of the scenarios evaluated (whether D&D begins soon after shutdown or after a 50-year SAFSTOR).

Soil Contamination Resulting from Spills/Leaks of Contaminated Aqueous Solutions

These scenarios assume that soil contamination at the reference nuclear power plant site is due to leaks and/or spills of contaminated aqueous solutions resulting in much deeper zones of contamination than are assumed in the "baseline" scenarios. The analysis results for remediation of contaminated soil at the reference nuclear power plant are provided in Tables C.7.3.9 and C.7.3.10 for the unrestricted and restricted land-use scenarios, respectively. Tables C.7.3.11 and C.7.3.12 provide the same results for scenarios that assume a 50-year SAFSTOR period prior to remediation of the soil. For the 50-year SAFSTOR scenarios, the "real world" contaminant distribution profiles were input into the diffusion model, and 50 years of additional migration via diffusion was simulated. Conclusions from these results include:

- The soil remediation costs and occupational exposure are considerably greater than for the previously evaluated scenarios that assume only deposition of contamination on the surface of the soil followed by migration via diffusion (up to 50% and higher for residual dose rates less than 25 mrem/y). This is a direct result of the significantly greater depths and, correspondingly, volumes of soil requiring remediation in these scenarios.

- The general trends in costs and occupational dose are the same for these scenarios as described previously for the scenarios where contamination is assumed to be deposited on the surface of the soil.

- Soil remediation is not likely to be required in restricted land-use cases or if decommissioning is delayed for 50 years (i.e., the results for these scenarios indicate that, in the worst case, remediation would only be required for the residual dose rates of 15 mrem/y or lower).

C.7.4 Reference Uranium Fuel Fabrication Plant

The cost, labor requirement, and occupational exposure resulting from decontamination of the walls/floors of structures at the reference uranium fuel fabrication plant for different residual dose levels are provided in Table C.7.4.1. Radionuclide contamination in the concrete floors/walls is decontaminated using a pneumatically-operated concrete scabbler. Since the scabbler removes approximately 1/8-inch of concrete with each pass, the results shown in Table C.7.4.1 for concrete surfaces is in 1/8-inch increments. However, the table also provides the calculated residual dose rate for each increment such that the depth of concrete requiring removal can be determined for each of the residual dose levels being evaluated. Since the residual dose level after just one pass of the scabbler (1/8-inch) is 1.4×10^{-10}, only 1/8-inch of concrete requires removal to achieve any of the alternative residual dose levels being evaluated in the GEIS (i.e., 100, 60, 30, 25, 15, 10, 3, 0.3, and 0.03 mrem/y).

The analysis results for remediation of contaminated soil at the reference uranium fuel fabrication plant are provided in Tables C.7.4.2 and C.7.4.3 for the unrestricted and restricted land-use scenarios, respectively. These scenarios assume that uranium is deposited on the surface of the soil during operation of the facility, which then migrates down through the soil column over time via diffusion. Noteworthy conclusions from these results include:

Unrestricted Land-Use Scenario

- As is to be expected, soil washing becomes increasingly more cost effective as soil disposal costs increase. In fact, soil washing is not worth the additional cost if the soil disposal costs are as low as $10 per cubic foot, but well worth the cost if soil disposal costs are as high as $350 per cubic foot (total costs are reduced by over 50% when compared with the direct disposal scenario).

- No soil remediation is required for the low surface contamination level except for residual dose levels of 15 mrem/y or less.

- Since soil washing is a low labor-requirement operation, including soil washing in the soil remediation technology mix contributes little to the total occupational dose incurred during remediation operations.

- Total costs for remediation of the contaminated soil at this site is significantly greater than that for the reference nuclear power plant due to the much larger volumes of soil requiring remediation.

Restricted Land-Use Scenario

- Total soil remediation costs are, as expected, less than for the corresponding unrestricted land-use scenario.

- The general trends in costs and occupational dose are the same as described previously for the unrestricted land-use scenario.

- For all three surface contamination levels (high, medium, and low), soil remediation is not necessary at all for certain residual dose levels. In fact, no soil remediation is required for residual dose levels of 15 mrem/y or less.

Sensitivity Analyses

Due to uncertainties of contaminant behavior in the "real world," an additional set of scenarios was evaluated that assumed that significant soil contamination at the reference uranium fuel fabrication plant was due to mixing/landfilling of uranium-contaminated soil throughout the site. The analysis of these scenarios utilized the "real world" model discussed in Section C.5.2 for estimating the depth of contamination in the soil throughout the site. However, the depth of contamination in soil underneath buildings continued to be estimated using the "baseline" diffusion model since it is assumed that this soil is only contaminated as a result of leakages through floors of buildings and not from mixing/landfilling (i.e., the soil is assumed to have been clean when the building was constructed).

The analysis results for remediation of contaminated soil at the reference uranium fuel fabrication plant are provided in Tables C.7.4.4 and C.7.4.5 for the unrestricted and restricted land-use scenarios, respectively. Conclusions from these results include:

- The soil remediation costs and occupational exposure are significantly greater than for the previously evaluated scenarios that assume only deposition of contamination on the surface of the soil followed by migration via diffusion. This is a direct result of the significantly greater depths and, correspondingly, volumes of soil requiring remediation in these scenarios.

- The general trends in costs and occupational dose are the same for these scenarios as described previously for the scenarios where contamination is assumed to be deposited on the surface of the soil.

- Soil remediation is not likely to be required, or at most minimally required, if future uses of the site are restricted (i.e., the results for these scenarios indicate that, in the worst case, remediation would only be necessary for residual dose rates of 15 mrem/y or lower).

C.7.5 Reference Sealed Source Manufacturer

The cost, labor requirement, and occupational exposure resulting from decontamination of the walls/floors of structures at the reference sealed source manufacturer for different residual dose levels are provided in Table C.7.5.1. Radionuclide contamination in the concrete floors/walls is decontaminated using a pneumatically-operated concrete scabbler. Since the scabbler removes approximately 1/8-inch of concrete with each pass, the results shown in Table C.7.5.1 for concrete surfaces is in 1/8-inch increments. However, the table also provides the calculated residual dose rate for each increment such that the depth of concrete requiring removal can be determined for each of the alternative residual dose levels being evaluated. These are 0.25 inches for 100 and 60 mrem/y, 0.375 inches for 30, 25, and 15 mrem/y, 0.5 inches for 3 and 0.3 mrem/y, and 0.625 inches for 0.03 mrem/y.

The analysis results for remediation of contaminated soil at the reference sealed source manufacturer are provided in Tables C.7.5.2 and C.7.5.3 for the unrestricted and restricted land-use scenarios, respectively. These scenarios assume that radionuclide contamination is deposited on the surface of the soil during operation of the facility, which then migrates down through the soil column via diffusion over time. Noteworthy conclusions from these results are much the same as identified in previous sections and include:

Unrestricted Land-Use Scenario

- As is to be expected, soil washing becomes increasingly more cost effective as soil disposal costs increase. In fact, soil washing is not worth the additional cost if the soil disposal costs are as low as $10 per cubic foot, but well worth the cost if soil disposal costs are as high as $350 per cubic foot (total costs are reduced by over 50% when compared with the direct disposal scenario). At a disposal cost of $50 per cubic foot, the differences in remediation costs between the soil washing and direct disposal scenarios are essentially a wash.

- Soil remediation is not required for the low surface contamination level except for residual dose levels of 3 mrem/y or less.

- Since soil washing is a low labor-requirement operation, approximately 10% of the total labor required, including soil washing in the soil remediation technology mix contributes little to the total occupational dose incurred during remediation operations.

- Soil remediation costs are quite low when compared to the other reference sites. These types of manufacturing facilities, in general, are not expected to have significant soil remediation requirements during decommissioning because of the generally small quantities of radioisotopes handled and the well controlled nature with which they are handled.

Restricted Land-Use Scenario

- Total soil remediation costs are, as expected, considerably less than for the corresponding unrestricted land-use scenario.

- The general trends in costs and occupational dose are the same as described previously for the unrestricted land-use scenario.

- For all three surface contamination levels (high, medium, and low), soil remediation is not required at all for certain residual dose levels. In fact, soil remediation is not required for any of the cases except for residual dose levels of 10 mrem/y or less.

Sensitivity Analyses

Neither PNNL nor NRC staff were able to identify any actual real world situations where sealed source manufacturing sites had any soil contamination. However, a set of sensitivity cases was evaluated in which the "real world" spill/leak model for ^{60}Co and ^{137}Cs discussed in Section C.5.1 was used to represent the possibility of sites having deeper contamination than estimated by the "baseline" diffusion model. The spill/leak model developed from data available on soil contamination for the reference reactor (see Section C.5.1) was used in these analyses due to the lack of any specific data on sealed source manufacturing sites and because the postulated source of contamination was assumed to be similar (i.e., spills/leaks of aqueous solutions containing radioisotopes such as ^{60}Co and ^{137}Cs).

The analysis results for remediation of contaminated soil at the reference sealed source manufacturer are provided in Tables C.7.5.4 and C.7.5.5 for the unrestricted and restricted land-use scenarios, respectively. Conclusions from these results include:

- The soil remediation costs and occupational exposure are considerably greater than for the previously evaluated scenarios that assume only deposition of contamination on the surface of the soil followed by migration via diffusion (up to 150% and higher for residual dose rates less than 25 mrem/y). This is a direct result of the significantly greater depths and, correspondingly, volumes of soil requiring remediation in these scenarios.

- The general trends in costs and occupational dose are the same for these scenarios as described previously for the scenarios where contamination is assumed to be deposited on the surface of the soil.

- Soil remediation is not likely to be required in restricted land-use cases (i.e., the results for these scenarios indicate that, in the worst case, remediation would only be necessary for residual dose rates of 15 mrem/y or lower).

C.7.6 Reference Rare Metal Extraction Plant

The cost, labor requirement, and occupational exposure resulting from decontamination of the walls/floors of structures at the reference rare metal extraction plant for different residual dose levels are provided in Table C.7.6.1. Radionuclide contamination in the concrete floors/walls is decontaminated using a pneumatically-operated concrete scabbler. Since the scabbler removes approximately 1/8-inch of concrete with each pass, the results shown in Table C.7.6.1 for concrete surfaces is in 1/8-inch increments. However, the table also provides the calculated residual dose rate for each increment such that the depth of concrete requiring removal can be determined for each of the residual dose levels being evaluated. Since the residual dose level after just two passes of the scabbler (1/4-inch) is 0.023 mrem/y, only 1/4-inch of concrete requires removal to achieve any of the residual dose levels being evaluated in the GEIS (i.e., 100, 60, 30, 25, 15, 10, 3, 0.3, and 0.03 mrem/y).

The analysis results for remediation of contaminated soil at the reference rare metal extraction plant are provided in Tables C.7.6.2 and C.7.6.3 for the unrestricted and restricted land-use scenarios, respectively. These scenarios assume that thorium is deposited on the surface of the soil during operation of the facility, which then migrates down through the soil column via diffusion over time. Conclusions from these results include:

Unrestricted Land-Use Scenario

- Total soil volume (excluding the slag pile) requiring remediation is relatively small in these scenarios due to the very slow diffusion rate of thorium through the soil column (total depth of penetration of the thorium into the soil was less than 3 cm at a residual dose level of 0.03 mrem/y).

- While the results do show that soil washing becomes increasingly more cost effective as soil disposal costs increase, the net benefit of doing so is small due to the very small volume of soil that actually requires treatment. In fact, the soil washing and direct disposal scenarios are essentially a wash in terms of total costs when disposal costs are in the range of $10 to $50 per cubic foot. However, if disposal costs are as high as $350 per cubic foot, there is a cost advantage to including soil washing in the remediation solution.

- Furthermore, because the 7,000-m^3 slag pile is such a significant proportion of the total soil volume requiring remediation, and since this slag cannot be effectively washed to reduce the end volume requiring disposal, any benefit obtained from washing the little volume of soil available for treatment is masked by the cost of disposing of the very large volume associated with the slag pile.

- Soil remediation is not required for the low surface contamination level except for residual dose levels of 15 mrem/y or less, although remediation of the slag pile is still required.

- Since soil washing is a low labor-requirement operation, less than 10% of the total labor requirement, including soil washing in the soil remediation technology mix contributes little to the total occupational dose incurred during remediation operations.

Restricted Land-Use Scenario

- The restricted land-use scenario for the reference rare metal extraction plant was evaluated differently than for the other reference facilities. It is assumed in this scenario that contaminated soil is excavated and disposed of on the slag pile and that the slag pile as a whole is stabilized in place. Therefore, there are no costs associated with offsite disposal of the soil and slag pile. Only costs for excavation of the contaminated soil and stabilization of the slag pile are considered, consequently the total costs for this scenario are significantly less than for the unrestricted land-use scenarios.

- The total costs of the soil washing scenario are greater than for the direct disposal scenario because there is little cost associated with disposal of the contaminated soil on the slag pile. The only additional cost is associated with stabilization of the slag/contaminated soil pile after remediation is completed, which is a small incremental cost relative to the unit cost of disposal at an offsite disposal facility. However, the costs associated with long-term monitoring and surveillance of the site have not been accounted for in this analysis (although the incremental cost of these activities would be significantly less than the costs incurred from disposal at an offsite disposal facility).

- Soil remediation is not likely to be required in restricted land-use cases (i.e., the results for these scenarios indicate that, in the worst case, remediation would only be necessary for residual dose rates of 3 mrem/y or lower). However, stabilization of the slag pile is always required.

Sensitivity Analyses

Based on the uncertainties of slag/soil contamination behavior in the "real world," an additional set of scenarios was evaluated that assumed that significant soil contamination at the reference rare metal extraction plant was due to mixing/landfilling of thorium-contaminated slag/soil throughout the site. The analysis of these scenarios utilized the "real world" model developed in Section C.5.3 for estimating the depth of contamination in the soil throughout the site. However, the depth of contamination in soil underneath buildings continued to be estimated using the "baseline" diffusion model since it is assumed that this soil is only contaminated as a result of leakages through building floors and not from mixing/landfilling (i.e., the soil is assumed to have been clean when the building was constructed).

The analysis results for remediation of contaminated soil at the reference rare metal extraction plant are provided in Tables C.7.6.4 and C.7.6.5 for the unrestricted and restricted land-use scenarios, respectively. Principal conclusions from these results include:

- The soil remediation costs and occupational exposure are considerably greater than for the previously evaluated scenarios that assume only deposition of contamination on the surface of the soil followed by migration via diffusion. This is a direct result of the greater depths and, correspondingly, greater volumes of soil requiring remediation in these scenarios.

- The general trends in costs and occupational dose are the same for these scenarios as described previously for the scenarios where contamination is assumed to be deposited on the surface of the soil.

- Soil remediation is not likely to be required in restricted land-use cases (i.e., the results for these scenarios indicate that, in the worst case, remediation would only be necessary for residual dose rates of 15 mrem/y or lower). However, the slag pile requires remediation at all residual dose levels.

Table C.7.1.1. Total and Contaminated Surface Areas for Structures and Soils at Each of the Reference Facilities[a]

Reference Facility	Radionuclide Activity on Walls/Floors of Structures (dpm/100 cm^2)	Surface Areas of Structures				Surface Areas of Soil (ft^2)	
		ft^2		% Contaminated			
		Floor	Wall	Floor	Wall	Total Site	Contaminated
Nuclear Power Plant	7.5 x 10^6 ^{60}Co 2.4 x 10^6 ^{137}Cs	250,000	300,000	10	2	50 x 10^6	3,000
Uranium Fuel Fabrication Plant	18,000 U	240,000	240,000	50	5	4.7 x 10^6	100,000
Sealed Source Manufacturer	102,000 ^{60}Co 33,300 ^{137}Cs	6,000	4,600	10	5	40,000	5,000
Rare Metals Extraction Plant	18,000 Th	150,000	180,000	40	10	740,000	100,000

(a) The estimated surface areas are based on limited information and, in many cases, represent an engineering judgement estimate based on the total footprint of the structures and the types of operations. The estimates are believed to be conservatively large (i.e., probably overestimate actual surface areas).

Table C.7.1.2. Ranges of Soil Surface Activities for the Radionuclides of Interest

Radionuclide	Contamination Level	Surface Concentration (pCi/g)
Co-60	High	60
	Medium	30
	Low	2
Sr-90	High	9.00x10^{-3}
	Medium	2.25x10^{-3}
	Low	4.50x10^{-4}
Cs-137	High	20
	Medium	5
	Low	1
Thorium	High	200
	Medium	100
	Low	30
Uranium	High	1,000
	Medium	200
	Low	30

Table C.7.2.1. GEIS Scenario Matrix

Reference Facility	Unrestricted Land-Use												Restricted Land-Use											
	Baseline						50-Year SAFSTOR						Baseline						50-Year SAFSTOR					
	Soil Wash			Direct Disposal			Soil Wash			Direct Disposal			Soil Wash			Direct Disposal			Soil Wash			Direct Disposal		
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
PWR Power Reactor Site																								
- Deposition on Soil Surface	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
- Spill/Leak	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Uranium Fuel Fabrication Plant																								
- Deposition on Soil Surface	X	X	X	X	X	X							X	X	X	X	X	X						
- Mixing/Landfilling	X	X	X	X	X	X							X	X	X	X	X	X						
Sealed Source Manufacturer																								
- Deposition on Soil Surface	X	X	X	X	X	X							X	X	X	X	X	X						
- Spill/Leak	X	X	X	X	X	X							X	X	X	X	X	X						
Rare Metals Extraction Plant																								
- Deposition on Soil Surface	X	X	X	X	X	X							X	X	X	X	X	X						
- Mixing/Landfilling	X	X	X	X	X	X							X	X	X	X	X	X						

Table C.7.3.1. Calculated Costs and Other Parameters for Decontamination of Reactor Bioshield Concrete

Dose Rate (mrem/y)	Concrete Depth Removed (inches)	Volume of Concrete Requiring Disposal (ft^3)	Number of Concrete Transportation Shipments	Concrete Disposal Costs ($ millions)		Concrete Decontamination Labor (person-hours)	Total Occupational Dose (person-rem)
				($50/$ft^3$)	($350/$ft^3$)		
100	3.49	11,136	29	1.115	4.456	2,679	24.80
60	3.65	11,712	31	1.258	4.772	3,351	31.08
30	3.87	12,480	33	1.308	5.052	3,365	31.22
25	3.92	12,672	33	1.319	5.121	3,365	31.22
15	4.08	13,248	35	1.361	5.335	3,394	31.49
10	4.22	13,824	36	1.395	5.542	3,394	31.49
3	4.60	15,264	40	1.600	6.179	4,108	38.19
0.3	5.36	18,336	48	1.916	7.416	4,894	45.57
0.03	6.10	21,504	56	2.241	8.692	5,708	53.23

Table C.7.3.2. Calculated Costs and Other Parameters for Decontamination of Reactor Wall/Floor Concrete

Concrete Depth Removed (inches)	Dose Rate (mrem/y)	Volume of Concrete Requiring Disposal (ft^3)	Number of Concrete Transportation Shipments	Concrete Disposal Costs ($ millions)		Concrete Decontamination Labor (person-hours)	Total Occupational Dose (person-rem)
				($50/$ft^3$)	($350/$ft^3$)		
0.125	36,000	3,173	9	0.592	1.544	4,130	2.38
0.250	4,100	3,663	10	0.958	2.048	6,572	3.79
0.375	220	4,093	11	1.324	2.552	9,013	5.19
0.500	10.4	4,554	12	1.690	3.056	11,454	6.60
0.625	0.282	5,013	14	2.057	3.561	13,895	8.00
0.750	0.0035	5,473	15	2.423	4.065	16,337	9.41
0.875	<0.003	5,934	16	2.789	4.569	18,778	10.82
1.000	<0.003	6,394	17	3.155	5.074	21,219	12.22

Table C.7.3.3 Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant Unrestricted Land Use

Reference Nuclear Power Plant Unrestricted Land Use									
Residual Dose Rate (mrem/yr)	Soil Volume Remediated (m^3)	With Soil Washing				Direct Disposal			
		Dose (person-mrem)	Total Remediation Cost ($K): Disposal Cost ($/ft^3)			Dose (person-mrem)	Total Remediation Cost ($K): Disposal Cost ($/ft^3)		
			10	50	350		10	50	350
High									
100	24	4	54	67	170	4	18	58	315
60	34	6	61	82	227	6	24	81	444
30	44	8	67	94	280	7	30	104	569
25	46	8	69	97	294	8	31	110	601
15	52	9	73	105	327	8	35	123	676
10	58	10	76	114	359	9	38	136	748
3	86	15	95	152	515	14	59	201	1,109
0.3	152	27	138	241	886	25	102	356	1,967
0.03	185	33	164	286	1,070	30	121	435	2,396
Medium									
100	0	0	0	0	0	0	0	0	0
60	18	3	50	59	137	3	15	43	238
30	34	6	60	81	224	5	24	80	438
25	36	7	62	84	239	6	26	86	472
15	43	8	67	93	277	7	30	101	560
10	48	9	70	100	304	8	32	114	625
3	61	11	78	118	378	10	40	144	793
0.3	123	22	119	201	721	20	80	288	1,587
0.03	167	30	148	262	968	27	110	391	2,157
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	27	5	56	71	186	4	20	64	352
0.3	62	11	79	119	383	10	41	146	804
0.03	139	25	130	224	813	23	90	326	1,798

Table C.7.3.4 Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant Restricted Land Use

Reference Nuclear Power Plant Restricted Land Use									
Residual Dose Rate (mrem/yr)	Soil Volume Remediated (m^3)	With Soil Washing				Direct Disposal			
		Dose (person-mrem)	Total Remediation Cost ($K) Disposal Cost ($/ft^3)			Dose (person-mrem)	Total Remediation Cost ($K) Disposal Cost ($/ft^3)		
			10	50	350		10	50	350
High									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	12	2	46	51	102	2	11	29	156
3	39	7	64	87	251	6	27	91	501
0.3	62	11	79	119	381	10	40	145	800
0.03	79	14	90	142	479	13	55	187	1,029
Medium									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	28	5	56	73	190	4	20	65	358
0.3	56	10	75	111	348	9	37	132	725
0.03	74	13	87	135	447	12	52	173	953
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	17	3	49	58	130	3	14	41	222
0.03	52	9	72	105	324	8	35	121	670

Table C.7.3.5. Calculated Costs and Other Parameters for Decontamination of Reactor Bioshield Concrete (50-Year SAFSTOR)

Dose Rate (mrem/y)	Concrete Depth Removed (inches)	Volume of Concrete Requiring Disposal (ft^3)	Number of Concrete Transportation Shipments	Concrete Disposal Costs ($ millions)		Concrete Decontamination Labor (person-hours)	Total Occupational Dose (person-rem)
				($50/$ft^3$)	($350/$ft^3$)		
100	1.36	3,936	11	0.453	1.634	1,321	0.02
60	1.52	4,416	12	0.483	1.808	1,321	0.02
30	1.74	5,184	14	0.530	2.085	1,321	0.02
25	1.79	5,280	14	0.536	2.120	1,321	0.02
15	1.95	5,856	16	0.573	2.329	1,321	0.02
10	2.09	6,240	17	0.699	2.571	1,965	0.03
3	2.47	7,488	20	0.778	3.025	1,979	0.03
0.3	3.22	10,080	27	1.047	4.071	2,651	0.03
0.03	3.97	12,864	34	1.332	5.191	3,365	0.04

Table C.7.3.6. Calculated Costs and Other Parameters for Decontamination of Reactor Wall/Floor Concrete (50-Year SAFSTOR)

Concrete Depth Removed (inches)	Dose Rate (mrem/y)	Volume of Concrete Requiring Disposal (ft^3)	Number of Concrete Transportation Shipments	Concrete Disposal Costs ($ millions)		Concrete Decontamination Labor (person-hours)	Total Occupational Dose (person-rem)
				($50/$ft^3$)	($350/$ft^3$)		
0.125	535	3,173	9	0.592	1.544	4,130	0.003
0.250	376	3,663	10	0.958	2.048	6,572	0.005
0.375	210	4,093	11	1.324	2.552	9,013	0.007
0.500	93.8	4,554	12	1.690	3.056	11,454	0.009
0.625	33.4	5,013	14	2.057	3.561	13,895	0.011
0.750	9.51	5,473	15	2.423	4.065	16,337	0.013
0.875	2.15	5,934	16	2.789	4.569	18,778	0.015
1.000	0.389	6,394	17	3.155	5.074	21,219	0.017
1.125	0.056	6,854	18	3.522	5.578	23,660	0.056
1.250	0.006	7,314	19	3.888	6.082	26,102	0.006

Table 7.3.7. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant Unrestricted Land Use, 50-Year SAFSTOR

Reference Nuclear Power Plant Unrestricted Land Use - 50-Year SAFSTOR									
Residual Dose Rate	Soil Volume Remediated	With Soil Washing				Direct Disposal			
		Dose	Total Remediation Cost ($K) Disposal Cost ($/ft³)			Dose	Total Remediation Cost ($K) Disposal Cost ($/ft³)		
(mrem/yr)	(m³)	(person-mrem)	10	50	350	(person-mrem)	10	50	350
High									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	21	4	52	63	151	3	16	49	270
0.3	413	74	318	596	2,345	67	267	967	5,339
0.03	487	87	367	697	2,762	79	315	1,142	6,306
Medium									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	106	19	108	178	628	17	71	249	1,373
0.03	448	80	341	644	2,541	73	292	1,050	5,795
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0
0.03	373	67	292	541	2,122	60	244	875	4,826

Table 7.3.8. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant Restricted Land Use, 50-Year SAFSTOR

Reference Nuclear Power Plant Restricted Land Use - 50-Year SAFSTOR									
Residual Dose Rate (mrem/yr)	Soil Volume Remediated (m^3)	With Soil Washing				Direct Disposal			
		Dose (person-mrem)	Total Remediation Cost ($K) Disposal Cost ($/ft^3)			Dose (person-mrem)	Total Remediation Cost ($K) Disposal Cost ($/ft^3)		
			10	50	350		10	50	350
High									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0
0.03	44	8	67	94	279	7	30	103	565
Medium									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0
0.03	24	4	54	67	168	4	18	57	310
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0
0.03	0	0	0	0	0	0	0	0	0

Table 7.3.9. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant Unrestricted Land Use, Spill/Leak

Reference Nuclear Power Plant Unrestricted Land Use - Spill/Leak									
Residual Dose Rate	Soil Volume Remediated	With Soil Washing				Direct Disposal			
		Dose	Total Remediation Cost ($K)			Dose	Total Remediation Cost ($K)		
			Disposal Cost ($/ft^3)				Disposal Cost ($/ft^3)		
(mrem/yr)	(m^3)	(person-mrem)	10	50	350	(person-mrem)	10	50	350
High									
100	28	5	56	73	190	4	20	65	357
60	44	8	67	94	279	7	30	104	566
30	77	14	89	139	467	13	54	182	1,000
25	87	16	95	153	521	14	59	203	1,123
15	113	20	113	189	668	18	75	266	1,464
10	135	24	127	217	787	22	87	316	1,741
3	205	37	177	314	1,185	33	133	481	2,658
0.3	349	63	272	509	1,990	57	226	820	4,521
0.03	473	85	357	678	2,681	77	307	1,108	6,118
Medium									
100	5	1	42	42	64	1	7	13	66
60	21	4	52	63	153	3	17	50	274
30	42	8	66	92	272	7	29	100	549
25	50	9	71	102	313	8	33	117	645
15	75	14	88	137	457	12	53	177	976
10	97	17	102	166	575	16	65	226	1,249
3	158	28	142	250	920	26	105	371	2,049
0.3	299	54	239	442	1,711	49	197	702	3,875
0.03	430	77	329	619	2,441	70	282	1,008	5,563
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	3	0	40	39	50	0	6	7	35
3	31	6	59	78	210	5	23	73	405
0.3	143	26	132	229	835	23	96	336	1,851
0.03	293	52	235	432	1,674	47	193	686	3,789

Table 7.3.10. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant Restricted Land Use, Spill/Leak

Reference Nuclear Power Plant Restricted Land Use - Spill/Leak									
Residual Dose Rate	Soil Volume Remediated	With Soil Washing				Direct Disposal			
		Dose	Total Remediation Cost ($K) Disposal Cost ($/ft³)			Dose	Total Remediation Cost ($K) Disposal Cost ($/ft³)		
(mrem/yr)	(m³)	(person-mrem)	10	50	350	(person-mrem)	10	50	350
High									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	38	36	36	0	4	2	4
25	1	0	39	37	44	0	5	5	20
15	5	1	42	42	63	1	7	13	66
10	16	3	49	56	124	3	13	38	207
3	60	11	77	116	370	10	39	141	774
0.3	176	32	154	274	1,020	29	116	414	2,279
0.03	290	52	233	428	1,656	47	191	679	3,748
Medium									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	3	0	40	39	50	0	6	7	35
3	32	6	59	78	213	5	23	74	411
0.3	141	25	131	226	823	23	91	330	1,820
0.03	255	46	210	381	1,460	41	166	597	3,295
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	21	4	52	63	151	3	16	49	269
0.03	122	22	118	201	717	20	80	287	1,579

Table 7.3.11. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant Unrestricted Land Use, Spill/Leak, 50-Year SAFSTOR

Reference Nuclear Power Plant Unrestricted Land Use - Spill/Leak - 50-Year SAFSTOR									
Residual Dose Rate (mrem/yr)	Soil Volume Remediated (m^3)	With Soil Washing				Direct Disposal			
		Dose (person-mrem)	Total Remediation Cost ($K) Disposal Cost ($/ft^3) 10	50	350	Dose (person-mrem)	Total Remediation Cost ($K) Disposal Cost ($/ft^3) 10	50	350
High									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	19	3	51	60	140	3	15	45	245
3	55	10	74	110	344	9	36	130	714
0.3	228	41	192	345	1,312	37	151	535	2,952
0.03	453	81	344	650	2,568	73	295	1,061	5,856
Medium									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	14	2	47	53	111	2	12	33	178
0.3	112	20	112	187	660	18	74	263	1,446
0.03	329	59	259	483	1,878	53	214	772	4,260
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	33	6	60	80	221	5	24	79	430
0.03	157	28	142	248	915	25	105	369	2,035

Table 7.3.12. **Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Nuclear Power Plant Restricted Land Use, Spill/Leak, 50-Year SAFSTOR**

Reference Nuclear Power Plant Restricted Land Use - Spill/Leak - 50-Year SAFSTOR									
Residual Dose Rate (mrem/yr)	Soil Volume Remediated (m^3)	With Soil Washing				Direct Disposal			
		Dose (person-mrem)	Total Remediation Cost ($K) Disposal Cost ($/ft^3)			Dose (person-mrem)	Total Remediation Cost ($K) Disposal Cost ($/ft^3)		
			10	50	350		10	50	350
High									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	41	7	65	90	262	7	28	95	525
0.03	183	33	162	283	1,057	30	120	428	2,363
Medium									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0
0.03	87	16	95	154	523	14	59	205	1,129
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0
0.03	20	4	51	61	144	3	16	46	254

Table 7.4.1. Calculated Costs and Other Parameters for Decontamination of Uranium Fuel Fabrication Plant Wall/Floor Concrete

Concrete Depth Removed (inches)	Dose Rate (mrem/yr)	Volume of Concrete Requiring Disposal (ft^3)	Number of Concrete Transportation Shipments	Concrete Disposal Costs ($ millions)		Concrete Decontamination Labor (person-hours)	Total Occupational Dose (person-rem)
				($50/$ft^3$)	($350/$ft^3$)		
0.125	1.40×10^{-10}	10,185	27	1.889	4.944	12,090	6.96

Table 7.4.2. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant Unrestricted Land Use

Reference Uranium Fuel Fabrication Plant
Unrestricted Land Use

Residual Dose Rate (mrem/yr)	Soil Volume Remediated (m^3)	With Soil Washing: Dose (person-mrem)	With Soil Washing: Total Remediation Cost ($K), Disposal Cost ($/ft^3) 10	50	350	Direct Disposal: Dose (person-mrem)	Direct Disposal: Total Remediation Cost ($K), Disposal Cost ($/ft^3) 10	50	350
High									
100	1,789	320	1,256	2,466	10,047	290	1,159	4,191	23,144
60	1,922	344	1,343	2,647	10,790	311	1,245	4,502	24,860
30	2,078	372	1,450	2,860	11,666	337	1,345	4,869	26,884
25	2,115	379	1,474	2,910	11,875	343	1,367	4,956	27,368
15	2,215	397	1,544	3,046	12,433	359	1,434	5,190	28,658
10	2,291	410	1,594	3,149	12,856	371	1,483	5,366	29,635
3	2,492	446	1,734	3,422	13,982	404	1,613	5,839	32,239
0.3	2,817	504	1,952	3,864	15,804	456	1,821	6,601	36,450
0.03	3,106	556	2,150	4,257	17,420	503	2,007	7,277	40,185
Medium									
100	840	150	607	1,176	4,737	136	543	1,969	10,870
60	1,381	247	975	1,911	7,763	224	894	3,235	17,865
30	1,665	298	1,170	2,298	9,352	270	1,077	3,901	21,536
25	1,723	308	1,208	2,377	9,680	279	1,116	4,038	22,295
15	1,865	334	1,305	2,570	10,472	302	1,208	4,369	24,126
10	1,964	352	1,375	2,705	11,027	318	1,270	4,601	25,408
3	2,215	397	1,544	3,046	12,433	359	1,434	5,190	28,658
0.3	2,597	465	1,803	3,565	14,572	421	1,679	6,085	33,601
0.03	2,909	521	2,017	3,990	16,320	471	1,883	6,816	37,639
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	840	150	607	1,176	4,737	136	543	1,969	10,870
10	1,320	236	935	1,828	7,421	214	854	3,092	17,073
3	1,789	320	1,256	2,466	10,047	290	1,159	4,191	23,144
0.3	2,291	410	1,594	3,149	12,856	371	1,483	5,366	29,635
0.03	2,655	475	1,845	3,644	14,895	430	1,717	6,221	34,348

Table 7.4.3. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant Restricted Land Use

Reference Uranium Fuel Fabrication Plant Restricted Land Use									
Residual Dose Rate (mrem/yr)	Soil Volume Remediated (m^3)	With Soil Washing				Direct Disposal			
		Dose (person-mrem)	Total Remediation Cost ($K) Disposal Cost ($/ft^3)			Dose (person-mrem)	Total Remediation Cost ($K) Disposal Cost ($/ft^3)		
			10	50	350		10	50	350
High									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	1,056	189	753	1,470	5,945	171	683	2,475	13,663
10	1,379	247	974	1,909	7,754	223	893	3,231	17,842
3	1,817	325	1,274	2,504	10,204	294	1,175	4,258	23,508
0.3	2,308	413	1,609	3,172	12,952	374	1,493	5,408	29,860
0.03	2,671	478	1,856	3,666	14,987	433	1,727	6,258	34,560
Medium									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	1,056	189	753	1,470	5,945	171	683	2,475	13,663
0.3	1,989	356	1,391	2,739	11,168	322	1,289	4,660	25,733
0.03	2,423	434	1,685	3,329	13,596	393	1,569	5,676	31,345
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	1,379	247	974	1,909	7,754	223	893	3,231	17,842
0.03	2,077	372	1,449	2,859	11,661	337	1,345	4,867	26,875

Table 7.4.4. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant Unrestricted Land Use, Mixing/Landfilling

Reference Uranium Fuel Fabrication Plant Unrestricted Land Use - Mixing/Landfilling									
Residual Dose Rate (mrem/yr)	Soil Volume Remediated (m^3)	With Soil Washing				Direct Disposal			
		Dose (person-mrem)	Total Remediation Cost ($K) Disposal Cost ($/ft^3) 10	50	350	Dose (person-mrem)	Total Remediation Cost ($K) Disposal Cost ($/ft^3) 10	50	350
High									
100	4,188	750	2,886	5,728	23,477	678	2,709	9,812	54,182
60	5,185	928	3,566	7,082	29,053	840	3,353	12,145	67,072
30	8,676	1,553	5,378	11,262	48,030	1,406	5,607	20,325	112,244
25	9,441	1,690	5,801	12,206	52,214	1,529	6,102	22,117	122,136
15	11,426	2,045	6,904	14,657	63,077	1,851	7,384	26,767	147,817
10	13,290	2,379	7,943	16,958	73,277	2,153	8,587	31,134	171,933
3	18,518	3,315	10,847	23,413	101,886	3,000	11,965	43,380	239,563
0.3	28,009	5,014	16,126	35,131	153,828	4,538	18,097	65,615	362,357
0.03	37,672	6,743	21,496	47,061	206,706	6,103	24,342	88,251	487,366
Medium									
100	38	7	63	87	250	6	27	91	498
60	63	11	80	121	389	10	41	148	818
30	1,913	342	1,337	2,635	10,741	310	1,240	4,481	24,745
25	2,680	480	1,862	3,677	15,032	434	1,732	6,278	34,665
15	4,827	864	3,323	6,596	27,050	782	3,122	11,307	62,444
10	6,531	1,169	4,480	8,912	36,587	1,058	4,222	15,299	84,486
3	11,588	2,074	6,994	14,857	63,962	1,877	7,488	27,145	149,909
0.3	21,255	3,805	12,371	26,791	116,864	3,443	13,735	49,792	274,973
0.03	30,919	5,534	17,742	38,723	169,749	5,009	19,976	72,431	399,996
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	38	7	63	87	250	6	27	91	498
10	60	11	78	117	373	10	40	142	782
3	3,618	648	2,499	4,953	20,283	586	2,341	8,475	46,801
0.3	13,290	2,379	7,943	16,958	73,279	2,153	8,587	31,134	171,936
0.03	22,957	4,109	13,315	28,893	126,177	3,719	14,834	53,779	296,989

Table 7.4.5. **Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant Restricted Land Use, Mixing/Landfilling**

Reference Uranium Fuel Fabrication Plant Restricted Land Use - Mixing/Landfilling									
Residual Dose Rate	Soil Volume Remediated	With Soil Washing				Direct Disposal			
		Dose	Total Remediation Cost ($K)			Dose	Total Remediation Cost ($K)		
			Disposal Cost ($/ft^3)				Disposal Cost ($/ft^3)		
(mrem/yr)	(m^3)	(person-mrem)	10	50	350	(person-mrem)	10	50	350
High									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	48	9	70	100	305	8	33	114	626
10	63	11	80	121	389	10	41	148	817
3	4,047	724	2,789	5,535	22,683	656	2,618	9,481	52,351
0.3	13,719	2,456	8,179	17,487	75,624	2,222	8,864	32,138	177,479
0.03	23,385	4,186	13,555	29,422	128,522	3,788	15,111	54,782	302,532
Medium									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	48	9	70	100	305	8	33	114	626
0.3	6,959	1,246	4,774	9,495	38,987	1,127	4,499	16,304	90,033
0.03	16,629	2,977	9,795	21,080	91,549	2,694	10,744	38,955	215,127
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	63	11	80	121	389	10	41	148	817
0.03	8,567	1,534	5,315	11,128	47,434	1,403	5,599	20,293	112,067

Table 7.5.1. Calculated Costs and Other Parameters for Decontamination of Sealed Source Manufacturer Facility Wall/Floor Concrete

Concrete Depth Removed (inches)	Dose Rate (mrem/yr)	Volume of Concrete Requiring Disposal (ft^3)	Number of Concrete Transportation Shipments	Concrete Disposal Costs ($ millions)		Concrete Decontamination Labor (person-hours)	Total Occupational Dose (person-rem)
				($50/$ft^3$)	($350/$ft^3$)		
0.125	485	96	1	0.019	0.048	141	0.081
0.250	55.9	107	1	0.029	0.061	212	0.122
0.375	3.01	118	1	0.040	0.075	284	0.164
0.500	0.143	129	1	0.050	0.089	356	0.204
0.625	0.004	140	1	0.061	0.103	428	0.247

Table 7.5.2. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site Unrestricted Land Use

Reference Sealed Source Manufacturer Site Unrestricted Land Use									
Residual Dose Rate (mrem/yr)	Soil Volume Remediated (m^3)	With Soil Washing				Direct Disposal			
		Dose (person-mrem)	Total Remediation Cost ($K) Disposal Cost ($/ft^3) 10	50	350	Dose (person-mrem)	Total Remediation Cost ($K) Disposal Cost ($/ft^3) 10	50	350
High									
100	16	3	48	56	122	3	13	37	202
60	22	4	53	64	157	4	17	53	285
30	28	5	57	74	193	5	21	66	364
25	30	5	58	76	201	5	22	70	384
15	33	6	60	81	222	5	24	80	434
10	37	7	62	85	242	6	26	87	479
3	55	10	74	110	343	9	36	130	711
0.3	97	17	102	167	579	16	65	228	1,259
0.03	118	21	116	196	698	19	78	278	1,532
Medium									
100	0	0	0	0	0	0	0	0	0
60	12	2	46	51	101	2	11	29	153
30	22	4	52	64	155	4	17	51	280
25	23	4	54	66	165	4	18	56	303
15	28	5	56	73	190	4	20	65	359
10	31	6	58	77	208	5	22	73	400
3	39	7	64	88	254	6	27	92	507
0.3	78	14	90	141	473	13	54	185	1,016
0.03	107	19	108	179	631	17	71	250	1,380
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	17	3	50	58	132	3	14	41	225
0.3	40	7	64	89	257	6	27	94	515
0.03	89	16	97	156	533	14	60	209	1,151

Table 7.5.3. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site Restricted Land Use

Reference Sealed Source Manufacturer Site Restricted Land Use									
Residual Dose Rate	Soil Volume Remediated	With Soil Washing				Direct Disposal			
			Total Remediation Cost ($K)				Total Remediation Cost ($K)		
		Dose	Disposal Cost ($/ft^3)			Dose	Disposal Cost ($/ft^3)		
(mrem/yr)	(m^3)	(person-mrem)	10	50	350	(person-mrem)	10	50	350
High									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	8	1	43	45	78	1	9	18	99
3	25	4	54	68	173	4	19	59	321
0.3	40	7	64	89	256	6	27	93	512
0.03	51	9	72	103	319	8	34	120	658
Medium									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	18	3	50	59	134	3	15	42	229
0.3	36	6	62	84	235	6	25	85	464
0.03	47	8	69	99	298	8	32	111	611
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	11	2	45	50	96	2	11	27	143
0.03	33	6	60	80	220	5	24	79	430

Table 7.5.4. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site Unrestricted Land Use, Spill/Leak

Reference Sealed Source Manufacturer Site Unrestricted Land Use - Spill/Leak									
Residual Dose Rate	Soil Volume Remediated	With Soil Washing				Direct Disposal			
		Dose	Total Remediation Cost ($K)			Dose	Total Remediation Cost ($K)		
			Disposal Cost ($/ft³)				Disposal Cost ($/ft³)		
(mrem/yr)	(m³)	(person-mrem)	10	50	350	(person-mrem)	10	50	350
High									
100	21	4	52	63	152	3	16	49	271
60	38	7	63	86	245	6	26	89	487
30	84	15	93	149	504	14	57	196	1,083
25	97	17	102	167	578	16	65	228	1,256
15	135	24	127	217	789	22	88	317	1,746
10	165	30	147	259	958	27	109	387	2,134
3	254	46	210	381	1,459	41	166	597	3,292
0.3	426	76	327	614	2,420	69	279	1,000	5,515
0.03	598	107	444	848	3,383	97	389	1,402	7,738
Medium									
100	8	2	44	46	82	1	9	20	110
60	16	3	49	57	127	3	14	39	214
30	36	6	62	84	237	6	25	85	467
25	46	8	68	97	290	7	31	108	591
15	81	15	92	145	489	13	56	191	1,053
10	111	20	111	187	659	18	74	262	1,442
3	201	36	174	308	1,160	33	131	472	2,601
0.3	373	67	292	542	2,124	60	244	875	4,830
0.03	546	98	409	777	3,089	88	354	1,279	7,059
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	4	1	41	41	59	1	7	11	57
3	24	4	54	67	170	4	18	58	316
0.3	174	31	153	272	1,011	28	115	410	2,259
0.03	345	62	269	504	1,968	56	224	810	4,470

Table 7.5.5. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site Restricted Land Use, Spill/Leak

Reference Sealed Source Manufacturer Site Restricted Land Use - Spill/Leak									
Residual Dose Rate	Soil Volume Remediated	With Soil Washing				Direct Disposal			
		Dose	Total Remediation Cost ($K)			Dose	Total Remediation Cost ($K)		
			Disposal Cost ($/ft^3)				Disposal Cost ($/ft^3)		
(mrem/yr)	(m^3)	(person-mrem)	10	50	350	(person-mrem)	10	50	350
High									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	38	36	37	0	4	2	5
25	2	0	40	39	49	0	6	7	33
15	8	2	44	46	82	1	9	20	109
10	14	3	48	54	115	2	13	34	186
3	60	11	78	117	371	10	39	141	776
0.3	230	41	194	347	1,322	37	152	540	2,977
0.03	401	72	310	580	2,280	65	261	940	5,191
Medium									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	4	1	41	41	60	1	7	11	57
3	25	4	54	68	171	4	19	58	318
0.3	177	32	159	275	1,026	29	116	416	2,291
0.03	349	62	272	508	1,986	56	226	818	4,513
Low									
100	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
0.3	17	3	49	58	130	3	14	40	221
0.03	150	27	137	239	875	24	101	352	1,943

Table 7.6.1. Calculated Costs and Other Parameters for Decontamination of Rare Metal Extraction Plant Wall/Floor Concrete

Concrete Depth Removed (inches)	Dose Rate (mrem/yr)	Volume of Concrete Requiring Disposal (ft^3)	Number of Concrete Transportation Shipments	Concrete Disposal Costs ($ millions)		Concrete Decontamination Labor (person-hours)	Total Occupational Dose (person-rem)
				($50/$ft^3$)	($350/$ft^3$)		
0.125	3,600	5,054	14	1.281	2.797	8,304	4.78
0.250	0.023	6,232	17	2.277	4.146	14,971	8.62

Table 7.6.2. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant Unrestricted Land Use

Reference Rare Metal Extraction Plant Unrestricted Land Use									
Residual Dose Rate	Soil Volume Remediated	With Soil Washing				Direct Disposal			
			Total Remediation Cost ($K)				Total Remediation Cost ($K)		
		Dose	Disposal Cost ($/ft^3)			Dose	Disposal Cost ($/ft^3)		
(mrem/yr)	(m^3)	(person-mrem)	10	50	350	(person-mrem)	10	50	350
High									
100	7,015	1,137	4,567	16,453	90,677	1,136	4,536	16,434	90,752
60	7,050	1,143	4,594	16,501	90,873	1,142	4,556	16,516	91,205
30	7,076	1,148	4,611	16,536	91,020	1,146	4,572	16,577	91,545
25	7,081	1,148	4,614	16,542	91,044	1,147	4,579	16,588	91,603
15	7,089	1,150	4,620	16,555	91,094	1,148	4,584	16,607	91,715
10	7,094	1,151	4,623	16,561	91,119	1,149	4,586	16,619	91;772
3	7,157	1,162	4,664	16,646	91,471	1,159	4,627	16,766	92,588
0.3	7,191	1,168	4,687	16,692	91,662	1,165	4,648	16,846	93,030
0.03	7,278	1,184	4,748	16,812	92,152	1,179	4,703	17,051	94,160
Medium									
100	7,000	1,134	4,523	16,398	90,559	1,134	4,523	16,398	90,559
60	7,000	1,134	4,523	16,398	90,559	1,134	4,523	16,398	90,559
30	7,050	1,143	4,594	16,501	90,873	1,142	4,556	16,516	91,205
25	7,059	1,145	4,600	16,512	90,921	1,144	4,562	16,537	91,319
15	7,076	1,148	4,611	16,536	91,020	1,146	4,572	16,577	91,545
10	7,085	1,149	4,617	16,548	91,069	1,148	4,581	16,598	91,659
3	7,119	1,155	4,639	16,595	91,258	1,153	4,601	16,677	92,095
0.3	7,187	1,168	4,684	16,687	91,641	1,164	4,645	16,837	92,980
0.03	7,267	1,182	4,741	16,796	92,089	1,177	4,697	17,025	94,018
Low									
100	7,000	1,134	4,523	16,398	90,559	1,134	4,523	16,398	90,559
60	7,000	1,134	4,523	16,398	90,559	1,134	4,523	16,398	90,559
30	7,000	1,134	4,523	16,398	90,559	1,134	4,523	16,398	90,559
25	7,000	1,134	4,523	16,398	90,559	1,134	4,523	16,398	90,559
15	7,015	1,137	4,567	16,453	90,677	1,136	4,536	16,434	90,752
10	7,044	1,142	4,590	16,493	90,840	1,141	4,553	16,502	91,129
3	7,085	1,149	4,617	16,548	91,069	1,148	4,581	16,598	91,659
0.3	7,169	1,164	4,673	16,664	91,542	1,161	4,635	16,796	92,751
0.03	7,216	1,173	4,707	16,726	91,802	1,169	4,662	16,905	93,354

Table 7.6.3. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant Restricted Land Use

Residual Dose Rate (mrem/yr)	Soil Volume Remediated (m^3)	With Soil Washing: Dose (person-mrem)	With Soil Washing: Total Remediation Cost ($K) No Offsite Disposal	Direct Disposal: Dose (person-mrem)	Direct Disposal: Total Remediation Cost ($K) No Offsite Disposal
Reference Rare Metal Extraction Plant Restricted Land Use					
High					
100	7,000	23	490	23	490
60	7,000	23	490	23	490
30	7,000	23	490	23	490
25	7,000	23	490	23	490
15	7,000	23	490	23	490
10	7,000	23	490	23	490
3	7,017	31	547	30	503
0.3	7,043	43	582	41	523
0.03	7,074	57	626	54	547
Medium					
100	7,000	23	490	23	490
60	7,000	23	490	23	490
30	7,000	23	490	23	490
25	7,000	23	490	23	490
15	7,000	23	490	23	490
10	7,000	23	490	23	490
3	7,000	23	490	23	490
0.3	7,036	39	573	38	518
0.03	7,071	55	621	53	545
Low					
100	7,000	23	490	23	490
60	7,000	23	490	23	490
30	7,000	23	490	23	490
25	7,000	23	490	23	490
15	7,000	23	490	23	490
10	7,000	23	490	23	490
3	7,000	23	490	23	490
0.3	7,025	34	558	33	509
0.03	7,055	48	598	46	532

Table 7.6.4. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant Unrestricted Land Use, Mixing/Landfilling

Reference Rare Metal Extraction Plant Unrestricted Land Use - Mixing/Landfilling									
Residual Dose Rate (mrem/yr)	Soil Volume Remediated (m^3)	With Soil Washing				Direct Disposal			
		Dose (person-mrem)	Total Remediation Cost ($K): Disposal Cost ($/ft³) 10	50	350	Dose (person-mrem)	Total Remediation Cost ($K): Disposal Cost ($/ft³) 10	50	350
High									
100	8,093	1,330	5,304	17,918	96,710	1,311	5,231	18,959	104,700
60	8,495	1,402	5,577	18,465	98,963	1,376	5,493	19,902	109,906
30	9,041	1,499	5,948	19,207	102,016	1,465	5,842	21,180	116,963
25	9,184	1,525	6,047	19,403	102,820	1,488	5,935	21,516	118,818
15	9,586	1,597	6,319	19,948	105,067	1,553	6,196	22,457	124,015
10	9,905	1,654	6,537	20,381	106,852	1,605	6,399	23,203	128,138
3	10,853	1,824	7,181	21,670	112,158	1,758	7,014	25,425	140,404
0.3	12,663	2,148	8,412	24,132	122,292	2,051	8,182	29,665	163,826
0.03	14,475	2,472	9,232	26,177	132,017	2,345	9,354	33,911	187,269
Medium									
100	7,548	1,232	4,930	17,177	93,659	1,223	4,878	17,683	97,647
60	7,949	1,304	5,206	17,723	95,906	1,288	5,139	18,623	102,841
30	8,495	1,402	5,577	18,465	98,963	1,376	5,493	19,902	109,906
25	8,639	1,427	5,676	18,661	99,768	1,400	5,585	20,238	111,763
15	9,041	1,499	5,948	19,207	102,016	1,465	5,842	21,180	116,963
10	9,360	1,556	6,166	19,641	103,802	1,516	6,050	21,927	121,088
3	10,307	1,726	6,809	20,928	109,103	1,670	6,661	24,145	133,341
0.3	12,119	2,050	8,042	23,391	119,243	1,963	7,833	28,389	156,777
0.03	13,930	2,375	9,278	25,853	129,383	2,257	9,001	32,634	180,218
Low									
100	7,000	1,134	4,523	16,398	90,559	1,134	4,523	16,398	90,559
60	7,003	1,135	4,559	16,437	90,610	1,135	4,525	16,407	90,600
30	7,548	1,232	4,930	17,177	93,659	1,223	4,878	17,683	97,647
25	7,691	1,258	5,028	17,373	94,462	1,246	4,970	18,018	99,501
15	8,093	1,330	5,304	17,918	96,710	1,311	5,231	18,959	104,700
10	8,413	1,387	5,519	18,353	98,499	1,363	5,436	19,707	108,833
3	9,360	1,556	6,166	19,641	103,802	1,516	6,050	21,927	121,088
0.3	11,172	1,881	7,399	22,104	113,944	1,810	7,218	26,172	144,530
0.03	12,983	2,205	8,630	24,565	124,079	2,103	8,390	30,413	167,957

Table 7.6.5. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant Restricted Land Use, Mixing/Landfilling

Reference Rare Metal Extraction Plant Restricted Land Use - Mixing/Landfilling					
		With Soil Washing		Direct Disposal	
Residual Dose Rate (mrem/yr)	Soil Volume Remediated (m^3)	Dose (person-mrem)	Total Remediation Cost ($K) No Offsite Disposal	Dose (person-mrem)	Total Remediation Cost ($K) No Offsite Disposal
High					
100	7,000	23	490	23	490
60	7,000	23	490	23	490
30	7,000	23	490	23	490
25	7,000	23	490	23	490
15	7,047	44	588	43	526
10	7,174	103	762	96	624
3	7,553	277	1,279	256	916
0.3	8,278	609	2,267	561	1,475
0.03	9,002	942	3,256	867	2,034
Medium					
100	7,000	23	490	23	490
60	7,000	23	490	23	490
30	7,000	23	490	23	490
25	7,000	23	490	23	490
15	7,000	23	490	23	490
10	7,000	23	490	23	490
3	7,335	177	981	164	748
0.3	8,060	509	1,969	469	1,307
0.03	8,784	842	2,958	775	1,866
Low					
100	7,000	23	490	23	490
60	7,000	23	490	23	490
30	7,000	23	490	23	490
25	7,000	23	490	23	490
15	7,000	23	490	23	490
10	7,000	23	490	23	490
3	7,000	23	490	23	490
0.3	7,681	335	1,453	310	1,015
0.03	8,405	668	2,441	615	1,573

Table 7.7.1. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Mill Unrestricted Land Use

Reference Uranium Mill Unrestricted Land Use					
		With Soil Washing		Direct Disposal	
Residual Dose Rate (mrem/yr)	Soil Volume Remediated (m^3)	Dose (person-mrem)	Total Remediation Cost ($K) No Offsite Disposal	Dose (person-mrem)	Total Remediation Cost ($K) No Offsite Disposal
High					
100	156,337	27,984	61,977	25,327	37,262
60	167,931	30,060	66,533	27,205	40,026
30	181,602	32,507	71,904	29,420	43,284
25	184,874	33,093	73,190	29,950	44,064
15	193,587	34,652	76,613	31,361	46,141
10	200,186	35,833	79,206	32,430	47,713
3	217,774	38,982	86,117	35,279	51,906
0.3	246,224	44,074	97,296	39,888	58,686
0.03	271,454	48,590	107,209	43,976	64,700
Medium					
100	73,423	13,143	29,399	11,895	17,500
60	120,681	21,602	47,967	19,550	28,764
30	145,476	26,040	57,710	23,567	34,674
25	150,603	26,958	59,725	24,398	35,896
15	162,976	29,173	64,586	26,402	38,845
10	171,631	30,722	67,987	27,804	40,908
3	193,587	34,652	76,613	31,361	46,141
0.3	226,985	40,630	89,736	36,772	54,101
0.03	254,260	45,512	100,453	41,190	60,602
Low					
100	0	0	0	0	0
60	0	0	0	0	0
30	0	0	0	0	0
25	0	0	0	0	0
15	73,423	13,143	29,399	11,895	17,500
10	115,324	20,643	45,863	18,683	27,487
3	156,337	27,984	61,977	25,327	37,262
0.3	200,186	35,833	79,206	32,430	47,713
0.03	232,023	41,532	91,716	37,588	55,302

Table 7.7.2. Summary of Costs and Occupational Dose for Remediation of Contaminated Soil at the Reference Uranium Mill Restricted Land Use

Reference Uranium Mill Restricted Land Use					
Residual Dose Rate (mrem/yr)	Soil Volume Remediated (m^3)	With Soil Washing		Direct Disposal	
		Dose (person-mrem)	Total Remediation Cost ($K) No Offsite Disposal	Dose (person-mrem)	Total Remediation Cost ($K) No Offsite Disposal
High					
100	0	0	0	0	0
60	0	0	0	0	0
30	0	0	0	0	0
25	0	0	0	0	0
15	92,287	16,519	36,811	14,951	21,996
10	120,525	21,574	47,906	19,525	28,727
3	158,794	28,424	62,943	25,725	37,848
0.3	201,704	36,105	79,803	32,676	48,075
0.03	233,458	41,789	92,279	37,820	55,644
Medium					
100	0	0	0	0	0
60	0	0	0	0	0
30	0	0	0	0	0
25	0	0	0	0	0
15	0	0	0	0	0
10	0	0	0	0	0
3	92,287	16,519	36,811	14,951	21,996
0.3	173,832	31,116	68,851	28,161	41,432
0.03	211,741	37,902	83,746	34,302	50,467
Low					
100	0	0	0	0	0
60	0	0	0	0	0
30	0	0	0	0	0
25	0	0	0	0	0
15	0	0	0	0	0
10	0	0	0	0	0
3	0	0	0	0	0
0.3	120,525	21,574	47,906	19,525	28,727
0.03	181,537	32,495	71,879	29,409	43,269

C.8 Analysis of Groundwater Remediation

In Section 6.2 of Volume 1, it was concluded that, for unrestricted use, the cost-benefit ratio for soil removal which would result in a dose of 25 mrem/y or less is generally unreasonably high when compared to the range used in NRC's decisionmaking guidance of NUREG/BR-0058 and NUREG-1530 (see Section 6.1 of Volume 1). It was also concluded that site-specific situations can be a factor that permits doses to be reduced below 25 mrem/y using ALARA considerations. Such site-specific considerations are especially necessary when dealing with groundwater contamination. This section considers potential groundwater contamination situations for NRC licensees (i.e., unlikely, possible, and likely (see Attachment E to Appendix C for a list of groundwater contamination indicators)), and corresponding Reference Cases 1, 2, and 3 are developed specifically for these potential groundwater contamination scenarios. For each of the reference cases, examples of site-specific situations are considered and analysis performed to estimate cost-benefit ratio increments in reducing doses from 25 mrem/y to levels approaching background (only analysis of remediation of groundwater to levels at or below 25 mrem/y is considered in this section based on the results of Section 6.2 of Volume 1). The analysis includes cost-benefit consideration of impacts for the dose levels associated with maximum contaminate levels in the National Primary Drinking Water regulations in 40 CFR 141. The analysis presented below illustrates potential ALARA considerations at levels below 25 mrem/y.

C.8.1 Groundwater Remediation Reference Cases

NRC facilities have been divided into the following possible reference cases based on their likelihood for significant soil/groundwater contamination (see Attachment E to Appendix C for more complete description and discussion):

1. Licensees with little contamination and therefore very low potential for soil/groundwater contamination - certain sealed source manufacturers, short-lived radionuclide users, and other small licensees with little contamination (e.g., small research reactors)

2. Licensees with low to medium indicators for soil/groundwater contamination - research reactors, certain sealed source manufacturers and broad R&D facilities, some power reactors, etc.

3. Licensees with medium to high indicators for soil/groundwater contamination - SDMP sites, large uranium/thorium facilities, some power reactors

Based on a broad review of licensees, there are about 6000 NRC licensees in Reference Case 1 and about 500-700 NRC licensees in Reference Cases 2 and 3.

The following is an analysis of Reference Cases 1 - 3.

C.8.1.1 Reference Case 1

Because it is unlikely that these facilities will have any soil contamination or groundwater contamination, a screening analysis is likely to be sufficient to demonstrate that these facilities meet a 25 mrem/y all-pathways TEDE standard and do not have a significant dose contribution from the drinking water pathway.

Therefore, implementation of ALARA levels below the dose standards is likely to involve minimal effort.

C.8.1.2 Reference Cases 2 and 3

While, generally, Reference Case 3 has a higher potential for groundwater contamination than Reference Case 2, they are discussed together in this section because some of the same steps in considering further remediation would be similar.

Because there is generally some soil contamination at Reference Case 2 sites, but not anticipated current groundwater contamination, specific efforts at characterization of groundwater are not necessarily done routinely as part of normal operations or decommissioning. Reference Case 3 sites have medium/high indicators for subsurface soil and groundwater contamination, and therefore would generally have to do groundwater characterization, either as part of their operations or as part of a decommissioning effort.

In situations where lower contamination levels are present, a screening analysis would generally be done to demonstrate compliance with an all-pathways TEDE dose. In the absence of any evidence of existing groundwater contamination (see Attachment E to Appendix C), this would be an analysis of prospective future contamination. If screening shows doses from the site are less than a 25 mrem/y all-pathways TEDE and doses are low or nonexistent from the drinking water pathway based on groundwater sources, further ALARA considerations would likely not result in the need for additional remediation to reduce doses from the drinking water pathway. If screening shows the site dose is less than a 25-mrem/y all-pathways TEDE but the dose from the drinking water pathway based on groundwater sources makes up a large fraction of the all-pathways dose, a licensee may perform more detailed site-specific evaluation or additional site characterization. Most sites would be able to show that doses from the groundwater pathway are quite low without the need for such site characterizations. If these additional analyses show the doses through the drinking water pathway are low or nonexistent, no remediation would likely be needed.

In those cases where contamination is more extensive, groundwater characterization may be done. If such characterization shows that groundwater contamination does not exist, licensees would still have to do prospective modeling of future groundwater contamination based on the soil contamination present at their site. If this evaluation shows that the site dose is less than a 25-mrem/y all-pathways TEDE but that the dose through the drinking water pathway makes up a large fraction of that dose, the licensee could consider remediation of the site to further reduce the dose to ALARA levels. Possible remediations in such cases where there is prospective contamination of the groundwater include soil removal, restricting future water use while supplying replacement water, or source stabilization.

This evaluation of prospective contamination would consider radionuclides in the soil such as Co-60, Cs-137, Sr-90, H-3, thorium, and uranium. Because uranium is the most likely radionuclide to move through soil to groundwater at a fast enough pace or have a long enough half-life to cause significant groundwater contamination, the scenario described below considers uranium contamination. Similar analyses could be considered for Co-60, Cs-137, Sr-90, H-3, or thorium.

As noted above, a licensee would consider all the site-specific factors involved as part of an ALARA analysis before undertaking remediations. For example, Tables 4.5.3 and 4.5.4 of the "Draft EIS Decommissioning of the Shieldalloy Metallurgical Corporation, Cambridge, Ohio, Facility," NUREG-1543, July 1996, describe site-specific considerations related to estimating doses from drinking water pathways. For the purposes of this generic analysis, it is conservatively assumed that uranium contamination in soil moves such that groundwater contamination will occur over time and the resulting drinking water dose is 50% of the TEDE based on the models of NUREG/CR-5512 (NRC 1992), and that this dose occurs both onsite and offsite. While an ALARA analysis will be highly dependent on site-specific factors that affect both the transport of contaminants to the aquifer and the available remediation options, there are two principal remediation methods that could be used if necessary: removal of soil and restricting site use. Soil could be removed from onsite to prevent further migration of uranium to groundwater resulting in costs of soil removal. The cost benefit analysis for soil removal could be approximated by that in Table C.8.1 and would likely not be cost effective unless the population served by the groundwater resource was large enough. Alternatively, there could be restrictions placed onsite and/or offsite. This alternative is discussed further below.

Another potential situation is that the characterization of groundwater may show that there is existing groundwater contamination and that the dose through drinking water pathway is less than a 25 mrem/y all-pathways TEDE but that the dose through the groundwater pathway makes up a large fraction of that dose. For these cases, licensees might need to remediate their site depending on results of an ALARA analysis. Possible remediations include pump and treat or restricting water use while providing replacement water. A review of current licensees in Attachment E of Appendix C ("Groundwater Contamination Detected at NRC Licensed Facilities") indicates that some sites have existing groundwater contaminated with Sr-90, H-3, Tc-99, alpha emitting nuclides, or uranium. Such contamination generally takes place because of a specific release event rather than a slow release from contaminated soil. Three potential scenarios are considered based on a review of the licensees in Attachment E to Appendix C for certain materials facilities (Sr-90, Tc-99, alpha emitting nuclides), reactors (H-3), and uranium facilities and include:

1. A composite case of a materials facility with Sr-90 groundwater contamination such that the dose through the drinking water pathway is 20 mrem/y.

2. A composite case of a reactor with H-3 groundwater contamination at or slightly in excess of 20,000 pCi/L.

3. A composite case of a uranium facility with uranium groundwater contamination.

An ALARA analysis of these cases would be highly dependent on site-specific factors that affect both the transport of contaminants to the aquifer and the available remediation options, and a variety of outcomes is possible. The following are potential outcomes based on a generic analysis of the composite cases:

a. The drinking water dose from groundwater is assumed conservatively to occur both onsite and offsite.

b. In general, remediation of a site to reduce doses to below 25 mrem/y to meet ALARA levels could be accomplished in the following manner:

   1) The groundwater below the site could be remediated by pump and treat operations to reduce the nuclide concentration levels. The incremental costs for pump and treat are in Column 2 of Tables C.8.2 and C.8.3 for Sr-90 and uranium contamination, respectively. Costs and impacts are not analyzed for H-3 contamination because groundwater below the site cannot be treated by pump and treat operations to remove H-3. The benefits of reduced exposure to the contaminated plume are estimated based on assuming 25 persons would take their drinking water from the contaminated plume. The cost-benefit analysis of such a situation is shown in Column 4 of Tables C.8.2 and C.8.3 and would not be cost-effective. This analysis is illustrative and demonstrates that for site-specific situations where larger populations may exist, a cost-benefit analysis should be done to indicate whether remediation is cost-effective.

   2) There could be restrictions placed on the onsite and/or offsite use of the water which would be applicable to the Sr-90, H-3, or uranium contamination cases. For onsite restrictions, it is assumed there would not be costs for replacement water because the site could be zoned for industrial use. For offsite restrictions, it is assumed that replacement water supplies would have to be provided; the cost benefit analysis for replacement water assumes that 25 persons would take their drinking water from the contaminated plume. It is not assumed that the land would be purchased as the costs of this are too indeterminate and uncertain for a generic analysis. The costs of replacement water for 25 persons are shown in Table C.8.4, Column 2, and the cost benefit analysis is shown in Column 4.

Table C.8.1

Soil Removal to Control Prospective Uranium Contamination
Incremental Costs and Impacts from 25 mrem/y
Based on Usage by 25 Persons
(Incremental Cost-benefit Results in \$M/estimated mortality averted)

Dose Reduction (mrem/y)	Soil removal cost at \$10/ft^3 burial charge (\$M)	Soil removal cost at \$50/ft^3 burial charge (\$M)	Incremental Estimated Mortality	Cost/benefit for \$10/ft^3 burial charge	Cost/benefit for \$50/ft^3
25-15	7.8	27	0.12	12	38
15-3	13	44	0.15	45	130
3-background	>20	>70	0.15	110	440

Table C.8.2

Strontium-90 Remediation by Pump and Treat
Incremental Costs and Impacts from 25 mrem/y
Based on Usage by 25 Persons
(Incremental Cost-benefit Results in $M/estimated mortality averted)

Dose Reduction (mrem/y)	Incremental cost ($M)	Incremental estimated mortality	Incremental cost /benefit
25-15	1.7	0.0055	309
15-3	5.4	0.0116	466
3-background	32	0.0139	2300

Table C.8.3

Uranium Remediation by Pump and Treat
Incremental Costs and Impacts from 25 mrem/y
Based on Usage by 25 Persons
(Incremental Cost-benefit Results in $M/estimated mortality averted)

Dose Reduction (mrem/y)	Incremental cost ($M)	Incremental estimated mortality	Incremental cost /benefit
25-15	17	0.13	131
15-3	124	0.26	477
3-background	306	0.31	987

Table C.8.4

Remediation by Restricting Use & Providing Replacement
Water for a Strontium-90 and Uranium Site
Incremental Costs and Impacts from 25 mrem/y
Based on Usage by 25 Persons
(Incremental Cost-benefit Results in $M/estimated mortality averted)

Dose Reduction (mrem/y)	Incremental cost ($M)	Incremental estimated mortality	Incremental cost/benefit
Sr-90 site: 25 mrem/y - background	3.3	0.0139	250
Uranium site: 25 mrem/y - background	11	0.31	36

C.9 References

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ATTACHMENT A

CALCULATED DOSE FACTORS FOR THREE LAND-USE SCENARIOS

CALCULATED DOSE CONVERSION FACTORS

Table A-1 Building Occupancy Scenario

Radionuclide	Dose Conversion Factor (mrem/y) per (dpm/100 cm^2)	Year Analyzed	Controlling Pathway
^{60}Co	2.89E-3	1	external (~91%)
^{90}Sr	1.51E-3	1	ingestion (~84%)
^{137}Cs	1.11E-3	1	external (~59%)
^{232}Th	2.63E-2	1	inhalation (^{232}Th ~67%, ^{228}Th ~14%)
U nat	1.61E-2	1	inhalation (^{238}U ~69%), ingestion (^{234}U ~14%, ^{238}U ~12%)

Table A-2 Unrestricted Land Use Scenario

Radionuclide	Dose Conversion Factor (mrem/y) per (pCi/gm)
^{60}Co	5.0562
^{90}Sr	1.3183
^{137}Cs	1.4027
^{232}Th	1.754
U nat	0.76453

Table A-3 Restricted Land Use Scenario

Radionuclide	Dose Conversion Factor (mrem/y) per (pCi/gm)
^{60}Co	0.368
^{90}Sr	0.0015
^{137}Cs	0.0869
^{232}Th	0.076
U nat	0.0254

ATTACHMENT B

DOSE RATE SPREADSHEETS FOR CONTAMINATED SOILS

ATTACHMENT B

DOSE RATE SPREADSHEETS FOR CONTAMINATED SOILS

This attachment provides the underlying data from which the dose rates versus depth of contamination in soil figures in Section 5 were generated. Section 5 provides a description of the "real world" models used to generate the tables in this attachment. Tables B.1 and B.2 provide spreadsheets, for the unrestricted and restricted land-use scenarios, respectively, showing dose rate (and contaminant concentration) versus depth into the soil column for the "real world" ^{60}Co and ^{137}Cs models discussed in Section 5.1. The profiles in these tables represent the scenario in which the reference facility is assumed to be decommissioned soon after permanent shutdown. Tables B.3 and B.4 represent the same set of scenarios with the exception that the reference facility is assumed to be decommissioned after a 50-year SAFSTOR period.

The "real world" model for predicting the distribution of uranium in soil is provided in Table B.5 for both the unrestricted and restricted land-use scenarios. This distribution is based on the "real world" model for uranium discussed in Section 5.2. Correspondingly, Table B.6 provides the spreadsheet for the distribution of thorium contamination in the soil column for both the unrestricted and restricted land-use scenarios. The "real world" model for thorium from which this model was generated is discussed in Section 5.3.

Table B.1. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Unrestricted Land Use, Real World Model for Cobalt-60 and Cesium-137)

Soil Depth (cm)	Concentration, pCi/g		1 cm Layers Removed	Co-60 Dose Rate, mrem/y			Cs-137 Dose Rate, mrem/y		
				Surface Contamination Level, pCi/g			Surface Contamination Level, pCi/g		
				2	30	60	1	5	20
	Co-60	Cs-137		Low	Med	High	Low	Med	High
1	5.22E+02	1.48E+02	0	1.31E+01	1.97E+02	3.94E+02	1.61E+00	8.07E+00	3.23E+01
2	3.06E+02	8.89E+01	1	8.59E+00	1.29E+02	2.58E+02	1.07E+00	5.36E+00	2.14E+01
3	1.81E+02	5.41E+01	2	5.91E+00	8.87E+01	1.77E+02	7.45E-01	3.72E+00	1.49E+01
4	1.09E+02	3.35E+01	3	4.32E+00	6.48E+01	1.30E+02	5.44E-01	2.72E+00	1.09E+01
5	6.77E+01	2.13E+01	4	3.34E+00	5.02E+01	1.00E+02	4.18E-01	2.09E+00	8.36E+00
6	4.34E+01	1.40E+01	5	2.73E+00	4.10E+01	8.19E+01	3.37E-01	1.68E+00	6.74E+00
7	2.92E+01	9.61E+00	6	2.33E+00	3.50E+01	6.99E+01	2.82E-01	1.41E+00	5.65E+00
8	2.07E+01	6.92E+00	7	2.05E+00	3.08E+01	6.16E+01	2.44E-01	1.22E+00	4.89E+00
9	1.56E+01	5.25E+00	8	1.85E+00	2.78E+01	5.56E+01	2.16E-01	1.08E+00	4.32E+00
10	1.25E+01	4.18E+00	9	1.70E+00	2.54E+01	5.09E+01	1.94E-01	9.71E-01	3.88E+00
11	1.05E+01	3.47E+00	10	1.57E+00	2.35E+01	4.71E+01	1.76E-01	8.82E-01	3.53E+00
12	9.10E+00	2.98E+00	11	1.46E+00	2.19E+01	4.38E+01	1.61E-01	8.07E-01	3.23E+00
13	8.13E+00	2.62E+00	12	1.36E+00	2.04E+01	4.09E+01	1.48E-01	7.42E-01	2.97E+00
14	7.40E+00	2.35E+00	13	1.28E+00	1.91E+01	3.83E+01	1.37E-01	6.84E-01	2.73E+00
15	6.81E+00	2.13E+00	14	1.20E+00	1.79E+01	3.59E+01	1.26E-01	6.31E-01	2.53E+00
16	6.32E+00	1.95E+00	15	1.12E+00	1.68E+01	3.37E+01	1.17E-01	5.84E-01	2.34E+00
17	5.89E+00	1.79E+00	16	1.05E+00	1.58E+01	3.16E+01	1.08E-01	5.40E-01	2.16E+00
18	5.51E+00	1.65E+00	17	9.89E-01	1.48E+01	2.97E+01	1.00E-01	5.00E-01	2.00E+01
19	5.17E+00	1.52E+00	18	9.30E-01	1.39E+01	2.79E+01	9.27E-02	4.63E-01	1.85E+00
20	4.85E+00	1.40E+00	19	8.73E-01	1.31E+01	2.62E+01	8.58E-02	4.29E-01	1.72E+00
21	4.55E+00	1.30E+00	20	8.21E-01	1.23E+01	2.46E+01	7.95E-02	3.98E-01	1.59E+00
22	4.27E+00	1.20E+00	21	7.71E-01	1.16E+01	2.31E+01	7.37E-02	3.68E-01	1.47E+00
23	4.01E+00	1.11E+00	22	7.25E-01	1.09E+01	2.17E+01	6.83E-02	3.41E-01	1.37E+00
24	3.77E+00	1.03E+00	23	6.81E-01	1.02E+01	2.04E+01	6.32E-02	3.16E-01	1.26E+00
25	3.54E+00	9.55E-01	24	6.40E-01	9.60E+00	1.92E+01	5.86E-02	2.93E-01	1.17E+00
26	3.33E+00	8.85E-01	25	6.01E-01	9.02E+00	1.80E+01	5.43E-02	2.72E-01	1.09E+00
27	3.13E+00	8.20E-01	26	5.65E-01	8.48E+00	1.70E+01	5.03E-02	2.52E-01	1.01E+00
28	2.94E+00	7.60E-01	27	5.31E-01	7.97E+00	1.59E+01	4.66E-02	2.33E-01	9.32E-01
29	2.76E+00	7.04E-01	28	4.99E-01	7.49E+00	1.50E+01	4.32E-02	2.16E-01	8.64E-01
30	2.59E+00	6.52E-01	29	4.69E-01	7.04E+00	1.41E+01	4.00E-02	2.00E-01	8.00E-01
31	2.44E+00	6.05E-01	30	4.41E-01	6.61E+00	1.32E+01	3.71E-02	1.85E-01	7.42E-01
32	2.29E+00	5.60E-01	31	4.14E-01	6.21E+00	1.24E+01	3.44E-02	1.72E-01	6.87E-01
33	2.15E+00	5.19E-01	32	3.89E-01	5.84E+00	1.17E+01	3.18E-02	1.59E-01	6.37E-01
34	2.02E+00	4.81E-01	33	3.66E-01	5.49E+00	1.10E+01	2.95E-02	1.47E-01	5.90E-01
35	1.90E+00	4.46E-01	34	3.44E-01	5.16E+00	1.03E+01	2.73E-02	1.37E-01	5.47E-01
36	1.79E+00	4.13E-01	35	3.23E-01	4.84E+00	9.69E+00	2.53E-02	1.27E-01	5.07E-01
37	1.68E+00	3.83E-01	36	3.03E-01	4.55E+00	9.10E+00	2.35E-02	1.17E-01	4.69E-01
38	1.58E+00	3.55E-01	37	2.85E-01	4.28E+00	8.55E+00	2.17E-02	1.09E-01	4.35E-01
39	1.48E+00	3.29E-01	38	2.68E-01	4.02E+00	8.04E+00	2.02E-02	1.01E-01	4.03E-01
40	1.39E+00	3.04E-01	39	2.52E-01	3.78E+00	7.55E+00	1.87E-02	9.34E-02	3.73E-01

Table B.1. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Unrestricted Land Use, Real World Model for Cobalt-60 and Cesium-137) (continued)

Soil Depth (cm)	Concentration, pCi/g		1 cm Layers Removed	Co-60 Dose Rate, mrem/y — Surface Contamination Level, pCi/g			Cs-137 Dose Rate, mrem/y — Surface Contamination Level, pCi/g		
	Co-60	Cs-137		2 Low	30 Med	60 High	1 Low	5 Med	20 High
41	1.31E+00	2.82E-01	40	2.37E-01	3.55E+00	7.10E+00	1.73E-02	8.65E-02	3.46E-01
42	1.23E+00	2.61E-01	41	2.22E-01	3.34E+00	6.67E+00	1.60E-02	8.02E-02	3.21E-01
43	1.16E+00	2.42E-01	42	2.09E-01	3.13E+00	6.27E+00	1.49E-02	7.43E-02	2.97E-01
44	1.09E+00	2.24E-01	43	1.96E-01	2.95E+00	5.89E+00	1.38E-02	6.88E-02	2.75E-01
45	1.02E+00	2.08E-01	44	1.85E-01	2.77E+00	5.54E+00	1.28E-02	6.38E-02	2.55E-01
46	9.59E-01	1.93E-01	45	1.73E-01	2.60E+00	5.20E+00	1.18E-02	5.91E-02	2.36E-01
47	9.02E-01	1.79E-01	46	1.63E-01	2.44E+00	4.89E+00	1.10E-02	5.48E-02	2.19E-01
48	8.47E-01	1.65E-01	47	1.53E-01	2.30E+00	4.59E+00	1.01E-02	5.07E-02	2.03E-01
49	7.96E-01	1.53E-01	48	1.44E-01	2.16E+00	4.32E+00	9.40E-03	4.70E-02	1.88E-01
50	7.48E-01	1.42E-01	49	1.35E-01	2.03E+00	4.06E+00	8.71E-03	4.36E-02	1.74E-01
51	7.03E-01	1.32E-01	50	1.27E-01	1.91E+00	3.81E+00	8.07E-03	4.04E-02	1.61E-01
52	6.61E-01	1.22E-01	51	1.19E-01	1.79E+00	3.58E+00	7.48E-03	3.74E-02	1.50E-01
53	6.21E-01	1.13E-01	52	1.12E-01	1.68E+00	3.37E+00	6.93E-03	3.47E-02	1.39E-01
54	5.83E-01	1.05E-01	53	1.05E-01	1.58E+00	3.16E+00	6.42E-03	3.21E-02	1.28E-01
55	5.48E-01	9.70E-02	54	9.91E-02	1.49E+00	2.97E+00	5.95E-03	2.98E-02	1.19E-01
56	5.15E-01	8.99E-02	55	9.31E-02	1.40E+00	2.79E+00	5.52E-03	2.76E-02	1.10E-01
57	4.84E-01	8.33E-02	56	8.75E-02	1.31E+00	2.63E+00	5.11E-03	2.56E-02	1.02E-01
58	4.55E-01	7.72E-02	57	8.22E-02	1.23E+00	2.47E+00	4.73E-03	2.37E-02	9.47E-02
59	4.28E-01	7.15E-02	58	7.73E-02	1.16E+00	2.32E+00	4.39E-03	2.19E-02	8.77E-02
60	4.02E-01	6.63E-02	59	7.26E-02	1.09E+00	2.18E+00	4.06E-03	2.03E-02	8.13E-02
61	3.78E-01	6.14E-02	60	6.82E-02	1.02E+00	2.05E+00	3.77E-03	1.88E-02	7.53E-02
62	3.55E-01	5.69E-02	61	6.41E-02	9.62E-01	1.92E+00	3.49E-03	1.74E-02	6.98E-02
63	3.33E-01	5.27E-02	62	6.03E-02	9.04E-01	1.81E+00	3.23E-03	1.62E-02	6.47E-02
64	3.13E-01	4.89E-02	63	5.66E-02	8.50E-01	1.70E+00	3.00E-03	1.50E-02	5.99E-02
65	2.94E-01	4.53E-02	64	5.32E-02	7.98E-01	1.60E+00	2.78E-03	1.39E-02	5.55E-02
66	2.77E-01	4.19E-02	65	5.00E-02	7.50E-01	1.50E+00	2.57E-03	1.29E-02	5.15E-02
67	2.60E-01	3.89E-02	66	4.70E-02	7.05E-01	1.41E+00	2.38E-03	1.19E-02	4.77E-02
68	2.44E-01	3.60E-02	67	4.42E-02	6.63E-01	1.33E+00	2.21E-03	1.10E-02	4.42E-02
69	2.30E-01	3.34E-02	68	4.15E-02	6.23E-01	1.25E+00	2.05E-03	1.02E-02	4.09E-02
70	2.16E-01	3.09E-02	69	3.90E-02	5.85E-01	1.17E+00	1.90E-03	9.48E-03	3.79E-02
71	2.03E-01	2.87E-02	70	3.66E-02	5.50E-01	1.10E+00	1.76E-03	8.79E-03	3.51E-02
72	1.91E-01	2.66E-02	71	3.44E-02	5.17E-01	1.03E+00	1.63E-03	8.14E-03	3.26E-02
73	1.79E-01	2.46E-02	72	3.24E-02	4.85E-01	9.71E-01	1.51E-03	7.55E-03	3.02E-02
74	1.68E-01	2.28E-02	73	3.04E-02	4.56E-01	9.12E-01	1.40E-03	6.99E-03	2.80E-02
75	1.58E-01	2.11E-02	74	2.86E-02	4.29E-01	8.57E-01	1.30E-03	6.48E-03	2.59E-02
76	1.49E-01	1.96E-02	75	2.69E-02	4.03E-01	8.06E-01	1.20E-03	6.00E-03	2.40E-02
77	1.40E-01	1.81E-02	76	2.52E-02	3.79E-01	7.57E-01	1.11E-03	5.56E-03	2.22E-02
78	1.31E-01	1.68E-02	77	2.37E-02	3.56E-01	7.11E-01	1.03E-03	5.15E-03	2.06E-02
79	1.23E-01	1.56E-02	78	2.23E-02	3.34E-01	6.69E-01	9.55E-04	4.78E-03	1.91E-02
80	1.16E-01	1.44E-02	79	2.09E-02	3.14E-01	6.28E-01	8.85E-04	4.43E-03	1.77E-[illegible]

Table B.1. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Unrestricted Land Use, Real World Model for Cobalt-60 and Cesium-137) (continued)

Soil Depth (cm)	Concentration, pCi/g		1 cm Layers Removed	Co-60 Dose Rate, mrem/y — Surface Contamination Level, pCi/g			Cs-137 Dose Rate, mrem/y — Surface Contamination Level, pCi/g		
	Co-60	Cs-137		2 Low	30 Med	60 High	1 Low	5 Med	20 High
81	1.09E-01	1.34E-02	80	1.97E-02	2.95E-01	5.90E-01	8.20E-04	4.10E-03	1.64E-02
82	1.02E-01	1.24E-02	81	1.85E-02	2.77E-01	5.55E-01	7.60E-04	3.80E-03	1.52E-02
83	9.62E-02	1.15E-02	82	1.74E-02	2.61E-01	5.21E-01	7.04E-04	3.52E-03	1.41E-02
84	9.04E-02	1.06E-02	83	1.63E-02	2.45E-01	4.90E-01	6.53E-04	3.26E-03	1.31E-02
85	8.49E-02	9.85E-03	84	1.53E-02	2.30E-01	4.60E-01	6.05E-04	3.02E-03	1.21E-02
86	7.98E-02	9.13E-03	85	1.44E-02	2.16E-01	4.33E-01	5.60E-04	2.80E-03	1.12E-02
87	7.50E-02	8.46E-03	86	1.36E-02	2.03E-01	4.07E-01	5.19E-04	2.60E-03	1.04E-02
88	7.05E-02	7.84E-03	87	1.27E-02	1.91E-01	3.82E-01	4.81E-04	2.40E-03	9.62E-03
89	6.62E-02	7.26E-03	88	1.20E-02	1.80E-01	3.59E-01	4.46E-04	2.23E-03	8.91E-[illegible]
90	6.22E-02	6.73E-03	89	1.12E-02	1.69E-01	3.37E-01	4.13E-04	2.06E-03	8.26E-[illegible]
91	5.85E-02	6.24E-03	90	1.06E-02	1.59E-01	3.17E-01	3.83E-04	1.91E-03	7.65E-[illegible]
92	5.50E-02	5.78E-03	91	9.93E-03	1.49E-01	2.98E-01	3.55E-04	1.77E-03	7.09E-03
93	5.16E-02	5.36E-03	92	9.33E-03	1.40E-01	2.80E-01	3.28E-04	1.64E-03	6.57E-03
94	4.85E-02	4.96E-03	93	8.77E-03	1.32E-01	2.63E-01	3.04E-04	1.52E-03	6.09E-03
95	4.56E-02	4.60E-03	94	8.24E-03	1.24E-01	2.47E-01	2.82E-04	1.41E-03	5.64E-03
96	4.29E-02	4.26E-03	95	7.74E-03	1.16E-01	2.32E-01	2.61E-04	1.31E-03	5.23E-03
97	4.03E-02	3.95E-03	96	7.28E-03	1.09E-01	2.18E-01	2.42E-04	1.21E-03	4.84E-03
98	3.78E-02	3.66E-03	97	6.84E-03	1.03E-01	2.05E-01	2.24E-04	1.12E-03	4.49E-03
99	3.56E-02	3.39E-03	98	6.43E-03	9.64E-02	1.93E-01	2.08E-04	1.04E-03	4.1[illegible]E-03
100	3.34E-02	3.14E-03	99	6.04E-03	9.06E-02	1.81E-01	1.93E-04	9.63E-04	3.85E-03
101	3.14E-02	2.91E-03	100	5.67E-03	8.51E-02	1.70E-01	1.79E-04	8.93E-04	3.57E-03
102	2.95E-02	2.70E-03	101	5.33E-03	8.00E-02	1.60E-01	1.65E-04	8.27E-04	3.31E-03
103	2.77E-02	2.50E-03	102	5.01E-03	7.52E-02	1.50E-01	1.53E-04	7.66E-04	3.07E-03
104	2.61E-02	2.32E-03	103	4.71E-03	7.06E-02	1.41E-01	1.42E-04	7.10E-04	2.84E-03
105	2.45E-02	2.15E-03	104	4.43E-03	6.64E-02	1.33E-01	1.32E-04	6.58E-04	2.63E-03
106	2.30E-02	1.99E-03	105	4.16E-03	6.24E-02	1.25E-01	1.22E-04	6.10E-04	2.44E-03
107	2.16E-02	1.84E-03	106	3.91E-03	5.86E-02	1.17E-01	1.13E-04	5.65E-04	2.26E-03
108	2.03E-02	1.71E-03	107	3.67E-03	5.51E-02	1.10E-01	1.05E-04	5.23E-04	2.09E-03
109	1.91E-02	1.58E-03	108	3.45E-03	5.18E-02	1.04E-01	9.70E-05	4.85E-04	1.94E-03
110	1.79E-02	1.47E-03	109	3.24E-03	4.86E-02	9.73E-02	8.99E-05	4.49E-04	1.80E-03
111	1.69E-02	1.36E-03	110	3.05E-03	4.57E-02	9.14E-02	8.33E-05	4.16E-04	1.67E-03
112	1.58E-02	1.26E-03	111	2.86E-03	4.30E-02	8.59E-02	7.72E-05	3.86E-04	1.54E-03
113	1.49E-02	1.17E-03	112	2.69E-03	4.04E-02	8.07E-02	7.15E-05	3.58E-04	1.43E-03
114	1.40E-02	1.08E-03	113	2.53E-03	3.79E-02	7.59E-02	6.63E-05	3.31E-04	1.33E-03
115	1.31E-02	1.00E-03	114	2.38E-03	3.56E-02	7.13E-02	6.14E-05	3.07E-04	1.23E-03
116	1.24E-02	9.28E-04	115	2.23E-03	3.35E-02	6.70E-02	5.69E-05	2.84E-04	1.14E-03
117	1.16E-02	8.59E-04	116	2.10E-03	3.15E-02	6.30E-02	5.27E-05	2.64E-04	1.05E-03
118	1.09E-02	7.96E-04	117	1.97E-03	2.96E-02	5.92E-02	4.88E-05	2.44E-04	9.77E-04
119	1.03E-02	7.38E-04	118	1.85E-03	2.78E-02	5.56E-02	4.53E-05	2.26E-04	9.05E-04
120	9.64E-03	6.84E-04	119	1.74E-03	2.61E-02	5.22E-02	4.19E-05	2.10E-04	8.39E-04

Table B.2. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Restricted Land Use, Real World Model for Cobalt-60 and Cesium-137)

Soil Depth (cm)	Concentration, pCi/g		1 cm Layers Removed	Co-60 Dose Rate, mrem/y — Surface Contamination Level, pCi/g			Cs-137 Dose Rate, mrem/y — Surface Contamination Level, pCi/g		
	Co-60	Cs-137		2 Low	30 Med	60 High	1 Low	5 Med	20 High
1	5.22E+02	1.48E+02	0	9.56E-01	1.43E+01	2.87E+01	9.99E-02	5.00E-01	2.00E+00
2	3.06E+02	8.89E+01	1	6.25E-01	9.37E+00	1.87E+01	6.64E-02	3.32E-01	1.33E+00
3	1.81E+02	5.41E+01	2	4.30E-01	6.46E+00	1.29E+01	4.61E-02	2.31E-01	9.22E-01
4	1.09E+02	3.35E+01	3	3.14E-01	4.71E+00	9.43E+00	3.37E-02	1.68E-01	6.73E-01
5	6.77E+01	2.13E+01	4	2.43E-01	3.65E+00	7.30E+00	2.59E-02	1.29E-01	5.18E-01
6	4.34E+01	1.40E+01	5	1.99E-01	2.98E+00	5.96E+00	2.09E-02	1.04E-01	4.17E-01
7	2.92E+01	9.61E+00	6	1.70E-01	2.54E+00	5.09E+00	1.75E-02	8.75E-02	3.50E-01
8	2.07E+01	6.92E+00	7	1.50E-01	2.24E+00	4.49E+00	1.51E-02	7.57E-02	3.03E-01
9	1.56E+01	5.25E+00	8	1.35E-01	2.02E+00	4.05E+00	1.14E-02	6.69E-02	2.68E-01
10	1.25E+01	4.18E+00	9	1.23E-01	1.85E+00	3.70E+00	1.20E-02	6.02E-02	2.41E-01
11	1.05E+01	3.47E+00	10	1.14E-01	1.71E+00	3.42E+00	1.09E-02	5.46E-02	2.19E-01
12	9.10E+00	2.98E+00	11	1.06E-01	1.59E+00	3.19E+00	1.00E-02	5.00E-02	2.00E-01
13	8.13E+00	2.62E+00	12	9.92E-02	1.49E+00	2.98E+00	9.19E-03	4.60E-02	1.84E-01
14	7.40E+00	2.35E+00	13	9.28E-02	1.39E+00	2.79E+00	8.47E-03	4.23E-02	1.69E-01
15	6.81E+00	2.13E+00	14	8.70E-02	1.31E+00	2.61E+00	7.82E-03	3.91E-02	1.56E-01
16	6.32E+00	1.95E+00	15	8.17E-02	1.22E+00	2.45E+00	7.23E-03	3.62E-02	1.45E-01
17	5.89E+00	1.79E+00	16	7.67E-02	1.15E+00	2.30E+00	6.69E-03	3.35E-02	1.34E-01
18	5.51E+00	1.65E+00	17	7.20E-02	1.08E+00	2.16E+00	6.20E-03	3.10E-02	1.24E-01
19	5.17E+00	1.52E+00	18	6.77E-02	1.01E+00	2.03E+00	5.74E-03	2.87E-02	1.15E-01
20	4.85E+00	1.40E+00	19	6.36E-02	9.53E-01	1.91E+00	5.32E-03	2.66E-02	1.06E-01
21	4.55E+00	1.30E+00	20	5.97E-02	8.96E-01	1.79E+00	4.93E-03	2.46E-02	9.85E-02
22	4.27E+00	1.20E+00	21	5.61E-02	8.42E-01	1.68E+00	4.56E-03	2.28E-02	9.13E-02
23	4.01E+00	1.11E+00	22	5.27E-02	7.91E-01	1.58E+00	4.23E-03	2.11E-02	8.46E-02
24	3.77E+00	1.03E+00	23	4.96E-02	7.43E-01	1.49E+00	3.92E-03	1.96E-02	7.83E-02
25	3.54E+00	9.55E-01	24	4.66E-02	6.98E-01	1.40E+00	3.63E-03	1.82E-02	7.26E-02
26	3.33E+00	8.85E-01	25	4.38E-02	6.56E-01	1.31E+00	3.36E-03	1.68E-02	6.73E-02
27	3.13E+00	8.20E-01	26	4.11E-02	6.17E-01	1.23E+00	3.12E-03	1.56E-02	6.23E-02
28	2.94E+00	7.60E-01	27	3.86E-02	5.80E-01	1.16E+00	2.89E-03	1.44E-02	5.77E-02
29	2.76E+00	7.04E-01	28	3.63E-02	5.45E-01	1.09E+00	2.68E-03	1.34E-02	5.35E-02
30	2.59E+00	6.52E-01	29	3.41E-02	5.12E-01	1.02E+00	2.48E-03	1.24E-02	4.96E-02
31	2.44E+00	6.05E-01	30	3.21E-02	4.81E-01	9.62E-01	2.30E-03	1.15E-02	4.59E-02
32	2.29E+00	5.60E-01	31	3.01E-02	4.52E-01	9.04E-01	2.13E-03	1.06E-02	4.26E-02
33	2.15E+00	5.19E-01	32	2.83E-02	4.25E-01	8.49E-01	1.97E-03	9.86E-03	3.94E-02
34	2.02E+00	4.81E-01	33	2.66E-02	3.99E-01	7.98E-01	1.83E-03	9.14E-03	3.65E-02
35	1.90E+00	4.46E-01	34	2.50E-02	3.75E-01	7.50E-01	1.69E-03	8.47E-03	3.39E-02
36	1.79E+00	4.13E-01	35	2.35E-02	3.52E-01	7.05E-01	1.57E-03	7.84E-03	3.14E-02
37	1.68E+00	3.83E-01	36	2.21E-02	3.31E-01	6.62E-01	1.45E-03	7.27E-03	2.91E-02
38	1.58E+00	3.55E-01	37	2.08E-02	3.11E-01	6.23E-01	1.35E-03	6.74E-03	2.69E-02
39	1.48E+00	3.29E-01	38	1.95E-02	2.93E-01	5.85E-01	1.25E-03	6.24E-03	2.50E-02
40	1.39E+00	3.04E-01	39	1.83E-02	2.75E-01	5.50E-01	1.16E-03	5.78E-03	2.31E-02

Table B.2. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Restricted Land Use, Real World Model for Cobalt-60 and Cesium-137) (continued)

Soil Depth (cm)	Concentration, pCi/g		1 cm Layers Removed	Co-60 Dose Rate, mrem/y			Cs-137 Dose Rate, mrem/y		
				Surface Contamination Level, pCi/g			Surface Contamination Level, pCi/g		
				2	30	60	1	5	20
	Co-60	Cs-137		Low	Med	High	Low	Med	High
41	1.31E+00	2.82E-01	40	1.72E-02	2.58E-01	5.17E-01	1.07E-03	5.36E-03	2.14E-02
42	1.23E+00	2.61E-01	41	1.62E-02	2.43E-01	4.85E-01	9.93E-04	4.97E-03	1.99E-02
43	1.16E+00	2.42E-01	42	1.52E-02	2.28E-01	4.56E-01	9.20E-04	4.60E-03	1.84E-02
44	1.09E+00	2.24E-01	43	1.43E-02	2.14E-01	4.29E-01	8.52E-04	4.26E-03	1.70E-02
45	1.02E+00	2.08E-01	44	1.34E-02	2.01E-01	4.03E-01	7.90E-04	3.95E-03	1.58E-02
46	9.59E-01	1.93E-01	45	1.26E-02	1.89E-01	3.79E-01	7.32E-04	3.66E-03	1.46E-02
47	9.02E-01	1.79E-01	46	1.19E-02	1.78E-01	3.56E-01	6.78E-04	3.39E-03	1.36E-02
48	8.47E-01	1.65E-01	47	1.11E-02	1.67E-01	3.34E-01	6.29E-04	3.14E-03	1.26E-02
49	7.96E-01	1.53E-01	48	1.05E-02	1.57E-01	3.14E-01	5.82E-04	2.91E-03	1.16E-02
50	7.48E-01	1.42E-01	49	9.84E-03	1.48E-01	2.95E-01	5.40E-04	2.70E-03	1.08E-02
51	7.03E-01	1.32E-01	50	9.25E-03	1.39E-01	2.77E-01	5.00E-04	2.50E-03	1.00E-02
52	6.61E-01	1.22E-01	51	8.69E-03	1.30E-01	2.61E-01	4.63E-04	2.32E-03	9.27E-03
53	6.21E-01	1.13E-01	52	8.17E-03	1.22E-01	2.45E-01	4.29E-04	2.15E-03	8.59E-03
54	5.83E-01	1.05E-01	53	7.67E-03	1.15E-01	2.30E-01	3.98E-04	1.99E-03	7.95E-03
55	5.48E-01	9.70E-02	54	7.21E-03	1.08E-01	2.16E-01	3.69E-04	1.84E-03	7.37E-03
56	5.15E-01	8.99E-02	55	6.78E-03	1.02E-01	2.03E-01	3.42E-04	1.71E-03	6.83E-03
57	4.84E-01	8.33E-02	56	6.37E-03	9.55E-02	1.91E-01	3.17E-04	1.58E-03	6.33E-03
58	4.55E-01	7.72E-02	57	5.99E-03	8.98E-02	1.80E-01	2.93E-04	1.47E-03	5.87E-03
59	4.28E-01	7.15E-02	58	5.62E-03	8.44E-02	1.69E-01	2.72E-04	1.36E-03	5.44E-03
60	4.02E-01	6.63E-02	59	5.28E-03	7.93E-02	1.59E-01	2.52E-04	1.26E-03	5.04E-03
61	3.78E-01	6.14E-02	60	4.97E-03	7.45E-02	1.49E-01	2.33E-04	1.17E-03	4.67E-03
62	3.55E-01	5.69E-02	61	4.67E-03	7.00E-02	1.40E-01	2.16E-04	1.08E-03	4.32E-03
63	3.33E-01	5.27E-02	62	4.39E-03	6.58E-02	1.32E-01	2.00E-04	1.00E-03	4.01E-03
64	3.13E-01	4.89E-02	63	4.12E-03	6.18E-02	1.24E-01	1.86E-04	9.28E-04	3.71E-03
65	2.94E-01	4.53E-02	64	3.87E-03	5.81E-02	1.16E-0	1.72E-04	8.60E-04	3.44E-03
66	2.77E-01	4.19E-02	65	3.64E-03	5.46E-02	1.09E-01	1.59E-04	7.97E-04	3.19E-03
67	2.60E-01	3.89E-02	66	3.42E-03	5.13E-02	1.03E-01	1.48E-04	7.38E-04	2.95E-03
68	2.44E-01	3.60E-02	67	3.21E-03	4.82E-02	9.64E-02	1.37E-04	6.84E-04	2.74E-03
69	2.30E-01	3.34E-02	68	3.02E-03	4.53E-02	9.06E-02	1.27E-04	6.34E-04	2.54E-03
70	2.16E-01	3.09E-02	69	2.84E-03	4.26E-02	8.52E-02	1.17E-04	5.87E-04	2.35E-03
71	2.03E-01	2.87E-02	70	2.67E-03	4.00E-02	8.00E-02	1.09E-04	5.44E-04	2.18E-03
72	1.91E-01	2.66E-02	71	2.51E-03	3.76E-02	7.52E-02	1.01E-04	5.04E-04	2.02E-03
73	1.79E-01	2.46E-02	72	2.35E-03	3.53E-02	7.06E-02	9.35E-05	4.67E-04	1.87E-03
74	1.68E-01	2.28E-02	73	2.21E-03	3.32E-02	6.64E-02	8.66E-05	4.33E-04	1.73E-03
75	1.58E-01	2.11E-02	74	2.08E-03	3.12E-02	6.24E-02	8.03E-05	4.01E-04	1.61E-03
76	1.49E-01	1.96E-02	75	1.95E-03	2.93E-02	5.86E-02	7.44E-05	3.72E-04	1.49E-03
77	1.40E-01	1.81E-02	76	1.84E-03	2.75E-02	5.51E-02	6.89E-05	3.44E-04	1.38E-03
78	1.31E-01	1.68E-02	77	1.73E-03	2.59E-02	5.18E-02	6.38E-05	3.19E-04	1.28E-03
79	1.23E-01	1.56E-02	78	1.62E-03	2.43E-02	4.87E-02	5.92E-05	2.96E-04	1.18E-03
80	1.16E-01	1.44E-02	79	1.52E-03	2.29E-02	4.57E-02	5.48E-05	2.74E-04	1.10E-03

Table B.2. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Restricted Land Use, Real World Model for Cobalt-60 and Cesium-137) (continued)

	Concentration, pCi/g			Co-60 Dose Rate, mrem/y			Cs-137 Dose Rate, mrem/y		
			1 cm	Surface Contamination Level, pCi/g			Surface Contamination Level, pCi/g		
Soil Depth			Layers	2	30	60	1	5	20
(cm)	Co-60	Cs-137	Removed	Low	Med	High	Low	Med	High
81	1.09E-01	1.34E-02	80	1.43E-03	2.15E-02	4.30E-02	5.08E-05	2.54E-04	1.02E-03
82	1.02E-01	1.24E-02	81	1.35E-03	2.02E-02	4.04E-02	4.71E-05	2.35E-04	9.41E-04
83	9.62E-02	1.15E-02	82	1.26E-03	1.90E-02	3.79E-02	4.36E-05	2.18E-04	8.72E-04
84	9.04E-02	1.06E-02	83	1.19E-03	1.78E-02	3.57E-02	4.04E-05	2.02E-04	8.08E-04
85	8.49E-02	9.85E-03	84	1.12E-03	1.68E-02	3.35E-02	3.74E-05	1.87E-04	7.49E-04
86	7.98E-02	9.13E-03	85	1.05E-03	1.57E-02	3.15E-02	3.47E-05	1.73E-04	6.94E-04
87	7.50E-02	8.46E-03	86	9.86E-04	1.48E-02	2.96E-02	3.22E-05	1.61E-04	6.43E-04
88	7.05E-02	7.84E-03	87	9.27E-04	1.39E-02	2.78E-02	2.98E-05	1.49E-04	5.96E-04
89	6.62E-02	7.26E-03	88	8.71E-04	1.31E-02	2.61E-02	2.76E-05	1.38E-04	5.52E-04
90	6.22E-02	6.73E-03	89	8.19E-04	1.23E-02	2.46E-02	2.56E-05	1.28E-04	5.12E-04
91	5.85E-02	6.24E-03	90	7.69E-04	1.15E-02	2.31E-02	2.37E-05	1.18E-04	4.74E-04
92	5.50E-02	5.78E-03	91	7.23E-04	1.08E-02	2.17E-02	2.20E-05	1.10E-04	4.39E-04
93	5.16E-02	5.36E-03	92	6.79E-04	1.02E-02	2.04E-02	2.03E-05	1.02E-04	4.07E-04
94	4.85E-02	4.96E-03	93	6.38E-04	9.57E-03	1.91E-02	1.89E-05	9.43E-05	3.77E-04
95	4.56E-02	4.60E-03	94	6.00E-04	9.00E-03	1.80E-02	1.75E-05	8.74E-05	3.49E-04
96	4.29E-02	4.26E-03	95	5.64E-04	8.45E-03	1.69E-02	1.62E-05	8.09E-05	3.24E-04
97	4.03E-02	3.95E-03	96	5.30E-04	7.94E-03	1.59E-02	1.50E-05	7.50E-05	3.00E-04
98	3.78E-02	3.66E-03	97	4.98E-04	7.47E-03	1.49E-02	1.39E-05	6.95E-05	2.78E-04
99	3.56E-02	3.39E-03	98	4.68E-04	7.02E-03	1.40E-02	1.29E-05	6.44E-05	2.58E-04
100	3.34E-02	3.14E-03	99	4.40E-04	6.59E-03	1.32E-02	1.19E-05	5.97E-05	2.39E-04
101	3.14E-02	2.91E-03	100	4.13E-04	6.19E-03	1.24E-02	1.11E-05	5.53E-05	2.21E-04
102	2.95E-02	2.70E-03	101	3.88E-04	5.82E-03	1.16E-02	1.02E-05	5.12E-05	2.05E-04
103	2.77E-02	2.50E-03	102	3.65E-04	5.47E-03	1.09E-02	9.49E-06	4.75E-05	1.90E-04
104	2.61E-02	2.32E-03	103	3.43E-04	5.14E-03	1.03E-02	8.80E-06	4.40E-05	1.76E-04
105	2.45E-02	2.15E-03	104	3.22E-04	4.83E-03	9.66E-03	8.15E-06	4.08E-05	1.63E-04
106	2.30E-02	1.99E-03	105	3.03E-04	4.54E-03	9.08E-03	7.55E-06	3.78E-05	1.51E-04
107	2.16E-02	1.84E-03	106	2.84E-04	4.27E-03	8.53E-03	7.00E-06	3.50E-05	1.40E-04
108	2.03E-02	1.71E-03	107	2.67E-04	4.01E-03	8.02E-03	6.49E-06	3.24E-05	1.30E-04
109	1.91E-02	1.58E-03	108	2.51E-04	3.77E-03	7.54E-03	6.01E-06	3.00E-05	1.20E-04
110	1.79E-02	1.47E-03	109	2.36E-04	3.54E-03	7.08E-03	5.57E-06	2.78E-05	1.11E-04
111	1.69E-02	1.36E-03	110	2.22E-04	3.33E-03	6.65E-03	5.16E-06	2.58E-05	1.03E-04
112	1.58E-02	1.26E-03	111	2.08E-04	3.13E-03	6.25E-03	4.78E-06	2.39E-05	9.56E-05
113	1.49E-02	1.17E-03	112	1.96E-04	2.94E-03	5.88E-03	4.43E-06	2.22E-05	8.86E-05
114	1.40E-02	1.08E-03	113	1.84E-04	2.76E-03	5.52E-03	4.11E-06	2.05E-05	8.21E-05
115	1.31E-02	1.00E-03	114	1.73E-04	2.59E-03	5.19E-03	3.80E-06	1.90E-05	7.61E-05
116	1.24E-02	9.28E-04	115	1.63E-04	2.44E-03	4.88E-03	3.52E-06	1.76E-05	7.05E-05
117	1.16E-02	8.59E-04	116	1.53E-04	2.29E-03	4.58E-03	3.27E-06	1.63E-05	6.53E-05
118	1.09E-02	7.96E-04	117	1.44E-04	2.15E-03	4.31E-03	3.03E-06	1.51E-05	6.05E-05
119	1.03E-02	7.38E-04	118	1.35E-04	2.02E-03	4.05E-03	2.80E-06	1.40E-05	5.61E-05
120	9.64E-03	6.84E-04	119	1.27E-04	1.90E-03	3.80E-03	2.60E-06	1.30E-05	5.20E-05

Table B.3. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Unrestricted Land Use, Real World Model for Cobalt-60 and Cesium-137, 50-Year SAFSTOR)

Soil Depth	Concentration, pCi/g		1 cm Layers	Co-60 Dose Rate, mrem/y			Cs-137 Dose Rate, mrem/y		
				Surface Contamination Level, pCi/g			Surface Contamination Level, pCi/g		
				2	30	60	1	5	20
(cm)	Co-60	Cs-137	Removed	Low	Med	High	Low	Med	High
1	6.57E-05	6.02E+00	0	2.07E-02	3.11E-01	6.22E-01	6.29E-01	3.15E+00	1.26E+01
2	6.45E-04	1.60E+01	1	2.07E-02	3.11E-01	6.22E-01	6.01E-01	3.01E+00	1.20E+01
3	3.17E-03	2.23E+01	2	2.07E-02	3.11E-01	6.21E-01	5.26E-01	2.63E+00	1.05E+01
4	1.05E-02	2.21E+01	3	2.07E-02	3.10E-01	6.20E-01	4.22E-01	2.11E+00	8.44E+00
5	2.60E-02	1.79E+01	4	2.06E-02	3.08E-01	6.17E-01	3.18E-01	1.59E+00	6.37E+00
6	5.18E-02	1.29E+01	5	2.03E-02	3.04E-01	6.08E-01	2.35E-01	1.17E+00	4.69E+00
7	8.67E-02	8.68E+00	6	1.97E-02	2.95E-01	5.91E-01	1.74E-01	8.72E-01	3.49E+00
8	1.25E-01	5.75E+00	7	1.87E-02	2.81E-01	5.61E-01	1.34E-01	6.69E-01	2.68E+00
9	1.59E-01	3.87E+00	8	1.73E-02	2.60E-01	5.19E-01	1.07E-01	5.35E-01	2.14E+00
10	1.82E-01	2.69E+00	9	1.55E-02	2.33E-01	4.66E-01	8.89E-02	4.44E-01	1.78E+00
11	1.88E-01	1.96E+00	10	1.35E-02	2.02E-01	4.04E-01	7.63E-02	3.82E-01	1.53E+00
12	1.80E-01	1.50E+00	11	1.14E-02	1.70E-01	3.41E-01	6.71E-02	3.36E-01	1.34E+00
13	1.60E-01	1.21E+00	12	9.34E-03	1.40E-01	2.80E-01	6.01E-02	3.01E-01	1.20E+00
14	1.34E-01	1.01E+00	13	7.54E-03	1.13E-01	2.26E-01	5.45E-02	2.72E-01	1.09E+00
15	1.06E-01	8.72E-01	14	6.04E-03	9.06E-02	1.81E-01	4.97E-02	2.49E-01	9.94E-01
16	8.09E-02	7.71E-01	15	4.85E-03	7.27E-02	1.45E-01	4.56E-02	2.28E-01	9.13E-01
17	6.00E-02	6.92E-01	16	3.94E-03	5.91E-02	1.18E-01	4.20E-02	2.10E-01	8.41E-01
18	4.38E-02	6.28E-01	17	3.27E-03	4.90E-02	9.80E-02	3.88E-02	1.94E-01	7.76E-01
19	3.21E-02	5.75E-01	18	2.77E-03	4.16E-02	8.32E-02	3.59E-02	1.79E-01	7.17E-01
20	2.39E-02	5.28E-01	19	2.41E-03	3.62E-02	7.24E-02	3.32E-02	1.66E-01	6.63E-01
21	1.83E-02	4.87E-01	20	2.15E-03	3.22E-02	6.44E-02	3.07E-02	1.53E-01	6.14E-01
22	1.45E-02	4.49E-01	21	1.94E-03	2.91E-02	5.82E-02	2.84E-02	1.42E-01	5.68E-01
23	1.20E-02	4.16E-01	22	1.78E-03	2.67E-02	5.33E-02	2.63E-02	1.32E-01	5.26E-01
24	1.03E-02	3.85E-01	23	1.64E-03	2.46E-02	4.93E-02	2.44E-02	1.22E-01	4.88E-01
25	9.09E-03	3.56E-01	24	1.53E-03	2.29E-02	4.58E-02	2.26E-02	1.13E-01	4.52E-01
26	8.19E-03	3.30E-01	25	1.42E-03	2.14E-02	4.27E-02	2.09E-02	1.05E-01	4.18E-01
27	7.50E-03	3.05E-01	26	1.33E-03	2.00E-02	4.00E-02	1.94E-02	9.69E-02	3.88E-01
28	6.93E-03	2.83E-01	27	1.25E-03	1.87E-02	3.74E-02	1.79E-02	8.97E-02	3.59E-01
29	6.44E-03	2.62E-01	28	1.17E-03	1.75E-02	3.51E-02	1.66E-02	8.31E-02	3.33E-01
30	6.01E-03	2.43E-01	29	1.10E-03	1.65E-02	3.29E-02	1.54E-02	7.70E-02	3.08E-01
31	5.63E-03	2.25E-01	30	1.03E-03	1.54E-02	3.09E-02	1.43E-02	7.13E-02	2.85E-01
32	5.27E-03	2.08E-01	31	9.67E-04	1.45E-02	2.90E-02	1.32E-02	6.61E-02	2.64E-01
33	4.95E-03	1.93E-01	32	9.07E-04	1.36E-02	2.72E-02	1.22E-02	6.12E-02	2.45E-01
34	4.65E-03	1.79E-01	33	8.52E-04	1.28E-02	2.56E-02	1.13E-02	5.67E-02	2.27E-01
35	4.36E-03	1.66E-01	34	7.99E-04	1.20E-02	2.40E-02	1.05E-02	5.25E-02	2.10E-01
36	4.10E-03	1.54E-01	35	7.50E-04	1.13E-02	2.25E-02	9.72E-03	4.86E-02	1.94E-01
37	3.85E-03	1.42E-01	36	7.04E-04	1.06E-02	2.11E-02	9.00E-03	4.50E-02	1.80E-01
38	3.62E-03	1.32E-01	37	6.61E-04	9.92E-03	1.98E-02	8.34E-03	4.17E-02	1.67E-01
39	3.40E-03	1.22E-01	38	6.20E-04	9.31E-03	1.86E-02	7.72E-03	3.86E-02	1.54E-01
40	3.20E-03	1.13E-01	39	5.82E-04	8.74E-03	1.75E-02	7.15E-03	3.58E-02	1.43E-01

Table B.3. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Unrestricted Land Use, Real World Model for Cobalt-60 and Cesium-137, 50-Year SAFSTOR) (continued)

	Concentration, pCi/g			Co-60 Dose Rate, mrem/y			Cs-137 Dose Rate, mrem/y		
				Surface Contamination Level, pCi/g			Surface Contamination Level, pCi/g		
			1 cm Layers	2	30	60	1	5	20
Soil Depth (cm)	Co-60	Cs-137	Removed	Low	Med	High	Low	Med	High
41	3.00E-03	1.05E-01	40	5.46E-04	8.20E-03	1.64E-02	6.62E-03	3.31E-02	1.32E-01
42	2.82E-03	9.73E-02	41	5.13E-04	7.69E-03	1.54E-02	6.13E-03	3.06E-02	1.23E-01
43	2.65E-03	9.01E-02	42	4.81E-04	7.21E-03	1.44E-02	5.67E-03	2.84E-02	1.13E-01
44	2.49E-03	8.35E-02	43	4.51E-04	6.77E-03	1.35E-02	5.25E-03	2.63E-02	1.05E-01
45	2.34E-03	7.74E-02	44	4.23E-04	6.35E-03	1.27E-02	4.86E-03	2.43E-02	9.72E-02
46	2.20E-03	7.17E-02	45	3.97E-04	5.95E-03	1.19E-02	4.50E-03	2.25E-02	9.00E-02
47	2.07E-03	6.64E-02	46	3.72E-04	5.58E-03	1.12E-02	4.16E-03	2.08E-02	8.33E-02
48	1.94E-03	6.16E-02	47	3.49E-04	5.23E-03	1.05E-02	3.85E-03	1.93E-02	7.71E-02
49	1.83E-03	5.70E-02	48	3.27E-04	4.90E-03	9.81E-03	3.57E-03	1.78E-02	7.13E-02
50	1.72E-03	5.29E-02	49	3.06E-04	4.60E-03	9.19E-03	3.30E-03	1.65E-02	6.60E-02
51	1.61E-03	4.90E-02	50	2.87E-04	4.31E-03	8.61E-03	3.05E-03	1.53E-02	6.10E-02
52	1.52E-03	4.54E-02	51	2.69E-04	4.04E-03	8.07E-03	2.82E-03	1.41E-02	5.64E-02
53	1.42E-03	4.21E-02	52	2.52E-04	3.78E-03	7.56E-03	2.61E-03	1.31E-02	5.22E-02
54	1.34E-03	3.90E-02	53	2.36E-04	3.54E-03	7.08E-03	2.41E-03	1.21E-02	4.83E-02
55	1.26E-03	3.61E-02	54	2.21E-04	3.31E-03	6.63E-03	2.23E-03	1.12E-02	4.46E-02
56	1.18E-03	3.35E-02	55	2.07E-04	3.10E-03	6.21E-03	2.06E-03	1.03E-02	4.12E-02
57	1.11E-03	3.10E-02	56	1.94E-04	2.90E-03	5.81E-03	1.91E-03	9.53E-03	3.81E-02
58	1.04E-03	2.87E-02	57	1.81E-04	2.72E-03	5.43E-03	1.76E-03	8.81E-03	3.52E-02
59	9.81E-04	2.66E-02	58	1.69E-04	2.54E-03	5.08E-03	1.63E-03	8.13E-03	3.25E-02
60	9.21E-04	2.47E-02	59	1.58E-04	2.38E-03	4.75E-03	1.50E-03	7.51E-03	3.00E-02
61	8.66E-04	2.29E-02	60	1.48E-04	2.22E-03	4.44E-03	1.39E-03	6.94E-03	2.77E-02
62	8.14E-04	2.12E-02	61	1.38E-04	2.07E-03	4.15E-03	1.28E-03	6.40E-03	2.56E-02
63	7.65E-04	1.96E-02	62	1.29E-04	1.94E-03	3.87E-03	1.18E-03	5.91E-03	2.36E-02
64	7.19E-04	1.82E-02	63	1.21E-04	1.81E-03	3.62E-03	1.09E-03	5.45E-03	2.18E-02
65	6.75E-04	1.68E-02	64	1.12E-04	1.69E-03	3.37E-03	1.00E-03	5.02E-03	2.01E-02
66	6.35E-04	1.56E-02	65	1.05E-04	1.57E-03	3.15E-03	9.26E-04	4.63E-03	1.85E-02
67	5.96E-04	1.45E-02	66	9.77E-05	1.47E-03	2.93E-03	8.53E-04	4.26E-03	1.71E-02
68	5.60E-04	1.34E-02	67	9.10E-05	1.37E-03	2.73E-03	7.85E-04	3.93E-03	1.57E-02
69	5.27E-04	1.24E-02	68	8.47E-05	1.27E-03	2.54E-03	7.22E-04	3.61E-03	1.44E-02
70	4.95E-04	1.15E-02	69	7.88E-05	1.18E-03	2.36E-03	6.64E-04	3.32E-03	1.33E-02
71	4.65E-04	1.07E-02	70	7.33E-05	1.10E-03	2.20E-03	6.11E-04	3.05E-03	1.22E-02
72	4.37E-04	9.88E-03	71	6.80E-05	1.02E-03	2.04E-03	5.61E-04	2.80E-03	1.12E-02
73	4.11E-04	9.16E-03	72	6.31E-05	9.47E-04	1.89E-03	5.14E-04	2.57E-03	1.03E-02
74	3.86E-04	8.48E-03	73	5.85E-05	8.78E-04	1.76E-03	4.71E-04	2.36E-03	9.43E-03
75	3.63E-04	7.86E-03	74	5.42E-05	8.13E-04	1.63E-03	4.32E-04	2.16E-03	8.64E-03
76	3.41E-04	7.28E-03	75	5.01E-05	7.52E-04	1.50E-03	3.95E-04	1.98E-03	7.90E-03
77	3.20E-04	6.75E-03	76	4.63E-05	6.94E-04	1.39E-03	3.61E-04	1.80E-03	7.22E-03
78	3.01E-04	6.25E-03	77	4.27E-05	6.40E-04	1.28E-03	3.29E-04	1.65E-03	6.59E-03
79	2.83E-04	5.79E-03	78	3.93E-05	5.90E-04	1.18E-03	3.00E-04	1.50E-03	6.00E-03
80	2.66E-04	5.37E-03	79	3.61E-05	5.42E-04	1.08E-03	2.73E-04	1.37E-03	5.46E-03

Table B.3. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Unrestricted Land Use, Real World Model for Cobalt-60 and Cesium-137, 50-Year SAFSTOR) (continued)

Soil Depth (cm)	Concentration, pCi/g		1 cm Layers Removed	Co-60 Dose Rate, mrem/y — Surface Contamination Level, pCi/g			Cs-137 Dose Rate, mrem/y — Surface Contamination Level, pCi/g		
	Co-60	Cs-137		2 Low	30 Med	60 High	1 Low	5 Med	20 High
81	2.50E-04	4.98E-03	80	3.31E-05	4.97E-04	9.94E-04	2.48E-04	1.24E-03	4.96E-03
82	2.35E-04	4.61E-03	81	3.03E-05	4.55E-04	9.10E-04	2.25E-04	1.12E-03	4.49E-03
83	2.21E-04	4.27E-03	82	2.77E-05	4.15E-04	8.31E-04	2.03E-04	1.02E-03	4.06E-03
84	2.07E-04	3.96E-03	83	2.52E-05	3.78E-04	7.56E-04	1.83E-04	9.16E-04	3.66E-03
85	1.95E-04	3.67E-03	84	2.29E-05	3.43E-04	6.86E-04	1.65E-04	8.23E-04	3.29E-03
86	1.83E-04	3.40E-03	85	2.07E-05	3.10E-04	6.21E-04	1.48E-04	7.38E-04	2.95E-03
87	1.72E-04	3.15E-03	86	1.86E-05	2.79E-04	5.59E-04	1.32E-04	6.58E-04	2.63E-03
88	1.62E-04	2.92E-03	87	1.67E-05	2.51E-04	5.01E-04	1.17E-04	5.85E-04	2.34E-03
89	1.52E-04	2.70E-03	88	1.49E-05	2.23E-04	4.47E-04	1.03E-04	5.16E-04	2.07E-03
90	1.43E-04	2.51E-03	89	1.32E-05	1.98E-04	3.95E-04	9.06E-05	4.53E-04	1.81E-03
91	1.34E-04	2.32E-03	90	1.16E-05	1.74E-04	3.47E-04	7.89E-05	3.95E-04	1.58E-03
92	1.26E-04	2.15E-03	91	1.01E-05	1.51E-04	3.02E-04	6.81E-05	3.40E-04	1.36E-03
93	1.18E-04	1.99E-03	92	8.65E-06	1.30E-04	2.60E-04	5.80E-05	2.90E-04	1.16E-03
94	1.11E-04	1.85E-03	93	7.32E-06	1.10E-04	2.20E-04	4.87E-05	2.43E-04	9.73E-04
95	1.05E-04	1.71E-03	94	6.07E-06	9.11E-05	1.82E-04	4.00E-05	2.00E-04	8.00E-04
96	9.83E-05	1.59E-03	95	4.89E-06	7.34E-05	1.47E-04	3.20E-05	1.60E-04	6.40E-04
97	9.24E-05	1.47E-03	96	3.79E-06	5.69E-05	1.14E-04	2.46E-05	1.23E-04	4.92E-04
98	8.68E-05	1.36E-03	97	2.75E-06	4.13E-05	8.26E-05	1.77E-05	8.87E-05	3.55E-04
99	8.16E-05	1.26E-03	98	1.78E-06	2.67E-05	5.33E-05	1.14E-05	5.68E-05	2.27E-04
100	7.66E-05	1.17E-03	99	8.61E-07	1.29E-05	2.58E-05	5.47E-06	2.73E-05	1.09E-04

Table B.4. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Restricted Land Use, Real World Model for Cobalt-60 and Cesium-137, 50-Year SAFSTOR)

				Co-60 Dose Rate, mrem/y			Cs-137 Dose Rate, mrem/y		
	Concentration, pCi/g			Surface Contamination Level, pCi/g			Surface Contamination Level, pCi/g		
Soil Depth			1 cm Layers	2	30	60	1	5	20
(cm)	Co-60	Cs-137	Removed	Low	Med	High	Low	Med	High
1	6.57E-05	6.02E+00	0	1.51E-03	2.26E-02	4.52E-02	3.90E-02	1.95E-01	7.79E-01
2	6.45E-04	1.60E+01	1	1.51E-03	2.26E-02	4.52E-02	3.72E-02	1.86E-01	7.44E-01
3	3.17E-03	2.23E+01	2	1.51E-03	2.26E-02	4.52E-02	3.26E-02	1.63E-01	6.52E-01
4	1.05E-02	2.21E+01	3	1.51E-03	2.26E-02	4.52E-02	2.61E-02	1.31E-01	5.23E-01
5	2.60E-02	[illegible].79E+01	4	1.50E-03	2.24E-02	4.49E-02	1.97E-02	9.86E-02	3.95E-01
6	5.18E-02	[illegible].29E+01	5	1.48E-03	2.21E-02	4.43E-02	1.45E-02	7.27E-02	2.91E-01
7	8.67E-02	[illegible].68E+00	6	1.43E-03	2.15E-02	4.30E-02	1.08E-02	5.40E-02	2.16E-01
8	1.25E-01	[illegible].75E+00	7	1.36E-03	2.04E-02	4.09E-02	8.29E-03	4.15E-02	1.66E-01
9	1.59E-01	[illegible].87E+00	8	1.26E-03	1.89E-02	3.78E-02	6.63E-03	3.31E-02	1.33E-01
10	1.82E-01	[illegible].69E+00	9	1.13E-03	1.69E-02	3.39E-02	5.50E-03	2.75E-02	1.10E-01
11	1.88E-01	[illegible].96E+00	10	9.81E-04	1.47E-02	2.94E-02	4.73E-03	2.36E-02	9.45E-02
12	1.80E-01	1.50E+00	11	8.27E-04	1.24E-02	2.48E-02	4.16E-03	2.08E-02	8.32E-02
13	1.60E-01	1.21E+00	12	6.80E-04	1.02E-02	2.04E-02	3.72E-03	1.86E-02	7.44E-02
14	1.34E-01	1.01E+00	13	5.49E-04	8.23E-03	1.65E-02	3.37E-03	1.69E-02	6.74E-02
15	1.06E-01	8.72E-01	14	4.40E-04	6.59E-03	1.32E-02	3.08E-03	1.54E-02	6.16E-02
16	8.09E-02	7.71E-01	15	3.53E-04	5.29E-03	1.06E-02	2.83E-03	1.41E-02	5.65E-02
17	6.00E-02	6.92E-01	16	2.87E-04	4.30E-03	8.60E-03	2.60E-03	1.30E-02	5.21E-02
18	4.38E-02	6.28E-01	17	2.38E-04	3.57E-03	7.13E-03	2.40E-03	1.20E-02	4.81E-02
19	3.21E-02	5.75E-01	18	2.02E-04	3.03E-03	6.05E-03	2.22E-03	1.11E-02	4.44E-02
20	2.39E-02	5.28E-01	19	1.76E-04	2.63E-03	5.27E-03	2.05E-03	1.03E-02	4.11E-02
21	1.83E-02	4.87E-01	20	1.56E-04	2.34E-03	4.68E-03	1.90E-03	9.51E-03	3.80E-02
22	1.45E-02	4.49E-01	21	1.41E-04	2.12E-03	4.24E-03	1.76E-03	8.80E-03	3.52E-02
23	1.20E-02	4.16E-01	22	1.29E-04	1.94E-03	3.88E-03	1.63E-03	8.15E-03	3.26E-02
24	1.03E-02	3.85E-01	23	1.19E-04	1.79E-03	3.58E-03	1.51E-03	7.55E-03	3.02E-02
25	9.09E-03	3.56E-01	24	1.11E-04	1.67E-03	3.33E-03	1.40E-03	6.99E-03	2.80E-02
26	8.19E-03	3.30E-01	25	1.04E-04	1.55E-03	3.11E-03	1.30E-03	6.48E-03	2.59E-02
27	7.50E-03	3.05E-01	26	9.69E-05	1.45E-03	2.91E-03	1.20E-03	6.00E-03	2.40E-02
28	6.93E-03	2.83E-01	27	9.08E-05	1.36E-03	2.72E-03	1.11E-03	5.56E-03	2.22E-02
29	6.44E-03	2.62E-01	28	8.51E-05	1.28E-03	2.55E-03	1.03E-03	5.15E-03	2.06E-02
30	6.01E-03	2.43E-01	29	7.99E-05	1.20E-03	2.40E-03	9.54E-04	4.77E-03	1.91E-02
31	5.63E-03	2.25E-01	30	7.50E-05	1.12E-03	2.25E-03	8.84E-04	4.42E-03	1.77E-02
32	5.27E-03	2.08E-01	31	7.03E-05	1.06E-03	2.11E-03	8.19E-04	4.09E-03	1.64E-02
33	4.95E-03	1.93E-01	32	6.60E-05	9.91E-04	1.98E-03	7.58E-04	3.79E-03	1.52E-02
34	4.65E-03	1.79E-01	33	6.20E-05	9.30E-04	1.86E-03	7.02E-04	3.51E-03	1.40E-02
35	4.36E-03	1.66E-01	34	5.82E-05	8.73E-04	1.75E-03	6.50E-04	3.25E-03	1.30E-02
36	4.10E-03	1.54E-01	35	5.46E-05	8.19E-04	1.64E-03	6.02E-04	3.01E-03	1.20E-02
37	3.85E-03	1.42E-01	36	5.13E-05	7.69E-04	1.54E-03	5.58E-04	2.79E-03	1.12E-02
38	3.62E-03	1.32E-01	37	4.81E-05	7.22E-04	1.44E-03	5.16E-04	2.58E-03	1.03[illegible]02
39	3.40E-03	1.22E-01	38	4.52E-05	6.77E-04	1.35E-03	4.78E-04	2.39E-03	9.56[illegible]
40	3.20E-03	1.13E-01	39	4.24E-05	6.36E-04	1.27E-03	4.43E-04	2.21E-03	8.86[illegible]

Table B.4. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Restricted Land Use, Real World Model for Cobalt-60 and Cesium-137, 50-Year SAFSTOR) (continued)

Soil Depth (cm)	Concentration, pCi/g		1 cm Layers Removed	Co-60 Dose Rate, mrem/y — Surface Contamination Level, pCi/g			Cs-137 Dose Rate, mrem/y — Surface Contamination Level, pCi/g		
	Co-60	Cs-137		2 Low	30 Med	60 High	1 Low	5 Med	20 High
41	3.00E-03	1.05E-01	40	3.98E-05	5.96E-04	1.19E-03	4.10E-04	2.05E-03	8.20E-03
42	2.82E-03	9.73E-02	41	3.73E-05	5.60E-04	1.12E-03	3.79E-04	1.90E-03	7.59E-03
43	2.65E-03	9.01E-02	42	3.50E-05	5.25E-04	1.05E-03	3.51E-04	1.76E-03	7.03E-03
44	2.49E-03	8.35E-02	43	3.28E-05	4.93E-04	9.85E-04	3.25E-04	1.63E-03	6.51E-03
45	2.34E-03	7.74E-02	44	3.08E-05	4.62E-04	9.23E-04	3.01E-04	1.51E-03	6.02E-03
46	2.20E-03	7.17E-02	45	2.89E-05	4.33E-04	8.66E-04	2.79E-04	1.39E-03	5.57E-03
47	2.07E-03	6.64E-02	46	2.71E-05	4.06E-04	8.12E-04	2.58E-04	1.29E-03	5.16E-03
48	1.94E-03	6.16E-02	47	2.54E-05	3.81E-04	7.62E-04	2.39E-04	1.19E-03	4.77E-03
49	1.83E-03	5.70E-02	48	2.38E-05	3.57E-04	7.14E-04	2.21E-04	1.10E-03	4.42E-03
50	1.72E-03	5.29E-02	49	2.23E-05	3.35E-04	6.69E-04	2.04E-04	1.02E-03	4.09E-03
51	1.61E-03	4.90E-02	50	2.09E-05	3.13E-04	6.27E-04	1.89E-04	9.45E-04	3.78E-[illegible]
52	1.52E-03	4.54E-02	51	1.96E-05	2.94E-04	5.87E-04	1.75E-04	8.74E-04	3.50E-03
53	1.42E-03	4.21E-02	52	1.83E-05	2.75E-04	5.50E-04	1.62E-04	8.08E-04	3.23E-03
54	1.34E-03	3.90E-02	53	1.72E-05	2.58E-04	5.15E-04	1.50E-04	7.48E-04	2.99E-03
55	1.26E-03	3.61E-02	54	1.61E-05	2.41E-04	4.82E-04	1.38E-04	6.91E-04	2.76E-03
56	1.18E-03	3.35E-02	55	1.51E-05	2.26E-04	4.52E-04	1.28E-04	6.39E-04	2.56E-03
57	1.11E-03	3.10E-02	56	1.41E-05	2.11E-04	4.23E-04	1.18E-04	5.90E-04	2.36E-03
58	1.04E-03	2.87E-02	57	1.32E-05	1.98E-04	3.95E-04	1.09E-04	5.45E-04	2.18E-03
59	9.81E-04	2.66E-02	58	1.23E-05	1.85E-04	3.70E-04	1.01E-04	5.04E-04	2.02E-03
60	9.21E-04	2.47E-02	59	1.15E-05	1.73E-04	3.46E-04	9.31E-05	4.65E-04	1.86E-03
61	8.66E-04	2.29E-02	60	1.08E-05	1.62E-04	3.23E-04	8.59E-05	4.30E-04	1.72E-03
62	8.14E-04	2.12E-02	61	1.01E-05	1.51E-04	3.02E-04	7.93E-05	3.97E-04	1.59E-03
63	7.63E-04	1.96E-02	62	9.40E-06	1.41E-04	2.82E-04	7.32E-05	3.66E-04	1.46E-03
64	7.19E-04	1.82E-02	63	8.77E-06	1.32E-04	2.63E-04	6.75E-05	3.37E-04	1.35E-03
65	6.75E-04	1.68E-02	64	8.18E-06	1.23E-04	2.46E-04	6.22E-05	3.11E-04	1.24E-03
66	6.35E-04	1.56E-02	65	7.63E-06	1.14E-04	2.29E-04	5.73E-05	2.87E-04	1.15E-03
67	5.96E-04	1.45E-02	66	7.11E-06	1.07E-04	2.13E-04	5.28E-05	2.64E-04	1.06E-03
68	5.60E-04	1.34E-02	67	6.63E-06	9.94E-05	1.99E-04	4.86E-05	2.43E-04	9.72E-04
69	5.27E-04	1.24E-02	68	6.17E-06	9.25E-05	1.85E-04	4.47E-05	2.24E-04	8.95E-04
70	4.95E-04	1.15E-02	69	5.74E-06	8.60E-05	1.72E-04	4.12E-05	2.06E-04	8.23E-04
71	4.65E-04	1.07E-02	70	5.33E-06	8.00E-05	1.60E-04	3.78E-05	1.89E-04	7.56E-04
72	4.37E-04	9.88E-03	71	4.95E-06	7.43E-05	1.49E-04	3.47E-05	1.74E-04	6.94E-04
73	4.11E-04	9.16E-03	72	4.59E-06	6.89E-05	1.38E-04	3.19E-05	1.59E-04	6.37E-04
74	3.86E-04	8.48E-03	73	4.26E-06	6.39E-05	1.28E-04	2.92E-05	1.46E-04	5.84E-04
75	3.63E-04	7.86E-03	74	3.94E-06	5.91E-05	1.18E-04	2.68E-05	1.34E-04	5.35E-04
76	3.41E-04	7.28E-03	75	3.65E-06	5.47E-05	1.09E-04	2.45E-05	1.22E-04	4.89E-04
77	3.20E-04	6.75E-03	76	3.37E-06	5.05E-05	1.01E-04	2.24E-05	1.12E-04	4.47E-04
78	3.01E-04	6.25E-03	77	3.10E-06	4.66E-05	9.31E-05	2.04E-05	1.02E-04	4.08E-04
79	2.83E-04	5.79E-03	78	2.86E-06	4.29E-05	8.58E-05	1.86E-05	9.30E-05	3.72E-04
80	2.66E-04	5.37E-03	79	2.63E-06	3.94E-05	7.88E-05	1.69E-05	8.46E-05	3.38E-04

Table B.4. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Restricted Land Use, Real World Model for Cobalt-60 and Cesium-137, 50-Year SAFSTOR) (continued)

Soil Depth (cm)	Concentration, pCi/g		1 cm Layers Removed	Co-60 Dose Rate, mrem/y Surface Contamination Level, pCi/g			Cs-137 Dose Rate, mrem/y Surface Contamination Level, pCi/g		
	Co-60	Cs-137		2 Low	30 Med	60 High	1 Low	5 Med	20 High
81	2.50E-04	4.98E-03	80	2.41E-06	3.62E-05	7.23E-05	1.54E-05	7.68E-05	3.07E-04
82	2.35E-04	4.61E-03	81	2.21E-06	3.31E-05	6.62E-05	1.39E-05	6.96E-05	2.78E-04
83	2.21E-04	4.27E-03	82	2.01E-06	3.02E-05	6.04E-05	1.26E-05	6.29E-05	2.52E-04
84	2.07E-04	3.96E-03	83	1.83E-06	2.75E-05	5.50E-05	1.13E-05	5.67E-05	2.27E-04
85	1.95E-04	3.67E-03	84	1.66E-06	2.50E-05	4.99E-05	1.02E-05	5.10E-05	2.04E-04
86	1.83E-04	3.40E-03	85	1.51E-06	2.26E-05	4.52E-05	9.14E-06	4.57E-05	1.83E-04
87	1.72E-04	3.15E-03	86	1.36E-06	2.03E-05	4.07E-05	8.15E-06	4.08E-05	1.63E-04
88	1.62E-04	2.92E-03	87	1.22E-06	1.82E-05	3.65E-05	7.24E-06	3.62E-05	1.15E-04
89	1.52E-04	2.70E-03	88	1.08E-06	1.62E-05	3.25E-05	6.40E-06	3.20E-05	1.28E-04
90	1.43E-04	2.51E-03	89	9.59E-07	1.44E-05	2.88E-05	5.61E-06	2.81E-05	1.12E-04
91	1.34E-04	2.32E-03	90	8.42E-07	1.26E-05	2.53E-05	4.89E-06	2.44E-05	9.77E-05
92	1.26E-04	2.15E-03	91	7.33E-07	1.10E-05	2.20E-05	4.22E-06	2.11E-05	8.43E-05
93	1.18E-04	1.99E-03	92	6.30E-07	9.44E-06	1.89E-05	3.59E-06	1.80E-05	7.18E-05
94	1.11E-04	1.85E-03	93	5.33E-07	7.99E-06	1.60E-05	3.01E-06	1.51E-05	6.03E-05
95	1.05E-04	1.71E-03	94	4.42E-07	6.63E-06	1.33E-05	2.48E-06	1.24E-05	4.96E-05
96	9.83E-05	1.59E-03	95	3.56E-07	5.34E-06	1.07E-05	1.98E-06	9.92E-06	3.97E-05
97	9.24E-05	1.47E-03	96	2.76E-07	4.14E-06	8.28E-06	1.52E-06	7.62E-06	3.05E-05
98	8.68E-05	1.36E-03	97	2.00E-07	3.00E-06	6.01E-06	1.10E-06	5.49E-06	2.20E-05
99	8.16E-05	1.26E-03	98	1.29E-07	1.94E-06	3.88E-06	7.04E-07	3.52E-06	1.41E-05
100	7.66E-05	1.17E-03	99	6.27E-08	9.40E-07	1.88E-06	3.39E-07	1.69E-06	6.77E-06

Table B.5. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Unrestricted and Restricted Land Use, Real World Model for Uranium)

Soil Depth (cm)	Concentration, pCi/g Nat. U
1	3.04E-01
2	2.97E-01
3	2.91E-01
4	2.85E-01
5	2.78E-01
6	2.72E-01
7	2.66E-01
8	2.60E-01
9	2.55E-01
10	2.49E-01
11	2.44E-01
12	2.38E-01
13	2.33E-01
14	2.28E-01
15	2.23E-01
16	2.18E-01
17	2.13E-01
18	2.09E-01
19	2.04E-01
20	2.00E-01
21	1.95E-01
22	1.91E-01
23	1.87E-01
24	1.83E-01
25	1.79E-01
26	1.75E-01
27	1.71E-01
28	1.67E-01
29	1.63E-01
30	1.60E-01
31	1.56E-01
32	1.53E-01
33	1.50E-01
34	1.46E-01
35	1.43E-01
36	1.40E-01
37	1.37E-01
38	1.34E-01
39	1.31E-01
40	1.28E-01

	Natural Uranium Dose Rate, mrem/y					
	Unrestricted			Restricted		
1 cm Layers Removed	Surface Contamination Level, pCi/g 30 Low	200 Med	1,000 High	Surface Contamination Level, pCi/g 30 Low	200 Med	1,000 High
0	6.97E+00	4.65E+01	2.32E+02	2.32E-01	1.54E+00	7.72E+00
1	6.82E+00	4.55E+01	2.27E+02	2.27E-01	1.51E+00	7.55E+00
2	6.67E+00	4.45E+01	2.22E+02	2.22E-01	1.48E+00	7.39E+00
3	6.53E+00	4.35E+01	2.18E+02	2.17E-01	1.45E+00	7.23E+00
4	6.38E+00	4.26E+01	2.13E+02	2.12E-01	1.41E+00	7.07E+00
5	6.24E+00	4.16E+01	2.08E+02	2.07E-01	1.38E+00	6.91E+00
6	6.11E+00	4.07E+01	2.04E+02	2.03E-01	1.35E+00	6.76E+00
7	5.97E+00	3.98E+01	1.99E+02	1.98E-01	1.32E+00	6.61E+00
8	5.84E+00	3.89E+01	1.95E+02	1.94E-01	1.29E+00	6.47E+00
9	5.71E+00	3.81E+01	1.90E+02	1.90E-01	1.27E+00	6.33E+00
10	5.59E+00	3.73E+01	1.86E+02	1.86E-01	1.24E+00	6.19E+00
11	5.47E+00	3.64E+01	1.82E+02	1.82E-01	1.21E+00	6.05E+00
12	5.35E+00	3.56E+01	1.78E+02	1.78E-01	1.18E+00	5.92E+00
13	5.23E+00	3.49E+01	1.74E+02	1.74E-01	1.16E+00	5.79E+00
14	5.11E+00	3.41E+01	1.70E+02	1.70E-01	1.13E+00	5.66E+00
15	5.00E+00	3.33E+01	1.67E+02	1.66E-01	1.11E+00	5.54E+00
16	4.89E+00	3.26E+01	1.63E+02	1.63E-01	1.08E+00	5.42E+00
17	4.78E+00	3.19E+01	1.59E+02	1.59E-01	1.06E+00	5.30E+00
18	4.68E+00	3.12E+01	1.56E+02	1.55E-01	1.04E+00	5.18E+00
19	4.58E+00	3.05E+01	1.53E+02	1.52E-01	1.01E+00	5.07E+00
20	4.48E+00	2.98E+01	1.49E+02	1.49E-01	9.92E-01	4.96E+00
21	4.38E+00	2.92E+01	1.46E+02	1.45E-01	9.70E-01	4.85E+00
22	4.28E+00	2.86E+01	1.43E+02	1.42E-01	9.49E-01	4.74E+00
23	4.19E+00	2.79E+01	1.40E+02	1.39E-01	9.28E-01	4.64E+00
24	4.10E+00	2.73E+01	1.37E+02	1.36E-01	9.07E-01	4.54E+00
25	4.01E+00	2.67E+01	1.34E+02	1.33E-01	8.88E-01	4.44E+00
26	3.92E+00	2.61E+01	1.31E+02	1.30E-01	8.68E-01	4.34E+00
27	3.83E+00	2.56E+01	1.28E+02	1.27E-01	8.49E-01	4.25E+00
28	3.75E+00	2.50E+01	1.25E+02	1.25E-01	8.30E-01	4.15E+00
29	3.67E+00	2.44E+01	1.22E+02	1.22E-01	8.12E-01	4.06E+00
30	3.59E+00	2.39E+01	1.20E+02	1.19E-01	7.94E-01	3.97E+00
31	3.51E+00	2.34E+01	1.17E+02	1.17E-01	7.77E-01	3.89E+00
32	3.43E+00	2.29E+01	1.14E+02	1.14E-01	7.60E-01	3.80E+00
33	3.36E+00	2.24E+01	1.12E+02	1.11E-01	7.43E-01	3.72E+00
34	3.28E+00	2.19E+01	1.09E+02	1.09E-01	7.27E-01	3.64E+00
35	3.21E+00	2.14E+01	1.07E+02	1.07E-01	7.11E-01	3.56E+00
36	3.14E+00	2.09E+01	1.05E+02	1.04E-01	6.95E-01	3.48E+00
37	3.07E+00	2.05E+01	1.02E+02	1.02E-01	6.80E-01	3.40E+00
38	3.00E+00	2.00E+01	1.00E+02	9.98E-02	6.65E-01	3.33E+00
39	2.94E+00	1.96E+01	9.79E+01	9.76E-02	6.51E-01	3.25E+00

Table B.5. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Unrestricted and Restricted Land Use, Real World Model for Uranium) (continued)

	Concentration, pCi/g		Natural Uranium Dose Rate, mrem/y					
			Unrestricted			Restricted		
		1 cm Layers	Surface Contamination Level, pCi/g			Surface Contamination Level, pCi/g		
Soil Depth			30	200	1,000	30	200	1,000
(cm)	Nat. U	Removed	Low	Med	High	Low	Med	High
41	1.25E-01	40	2.87E+00	1.92E+01	9.58E+01	9.55E-02	6.36E-01	3.18E+00
42	1.23E-01	41	2.81E+00	1.87E+01	9.37E+01	9.34E-02	6.23E-01	3.11E+00
43	1.20E-01	42	2.75E+00	1.83E+01	9.16E+01	9.13E-02	6.09E-01	3.04E+00
44	1.17E-01	43	2.69E+00	1.79E+01	8.96E+01	8.93E-02	5.96E-01	2.98E+00
45	1.15E-01	44	2.63E+00	1.75E+01	8.77E+01	8.74E-02	5.82E-01	2.91E+00
46	1.12E-01	45	2.57E+00	1.71E+01	8.57E+01	8.55E-02	5.70E-01	2.85E+00
47	1.10E-01	46	2.52E+00	1.68E+01	8.39E+01	8.36E-02	5.57E-01	2.79E+00
48	1.07E-01	47	2.46E+00	1.64E+01	8.20E+01	8.17E-02	5.45E-01	2.72E+00
49	1.05E-01	48	2.41E+00	1.60E+01	8.02E+01	8.00E-02	5.33E-01	2.67E+00
50	1.03E-01	49	2.35E+00	1.57E+01	7.85E+01	7.82E-02	5.21E-01	2.61E+00
51	1.00E-01	50	2.30E+00	1.53E+01	7.67E+01	7.65E-02	5.10E-01	2.55E+00
52	9.82E-02	51	2.25E+00	1.50E+01	7.51E+01	7.48E-02	4.99E-01	2.49E+00
53	9.60E-02	52	2.20E+00	1.47E+01	7.34E+01	7.32E-02	4.88E-01	2.44E+00
54	9.39E-02	53	2.15E+00	1.44E+01	7.18E+01	7.16E-02	4.77E-01	2.39E+00
55	9.19E-02	54	2.11E+00	1.40E+01	7.02E+01	7.00E-02	4.67E-01	2.33E+00
56	8.98E-02	55	2.06E+00	1.37E+01	6.87E+01	6.85E-02	4.56E-01	2.28E+00
57	8.79E-02	56	2.02E+00	1.34E+01	6.72E+01	6.70E-02	4.46E-01	2.23E+00
58	8.59E-02	57	1.97E+00	1.31E+01	6.57E+01	6.55E-02	4.37E-01	2.18E+00
59	8.41E-02	58	1.93E+00	1.29E+01	6.43E+01	6.41E-02	4.27E-01	2.14E+00
60	8.22E-02	59	1.89E+00	1.26E+01	[illegible]29E+01	6.27E-02	4.18E-01	2.09E+00
61	8.04E-02	60	1.84E+00	1.23E+01	6.15E+01	6.13E-02	4.09E-01	2.04E+00
62	7.87E-02	61	1.80E+00	1.20E+01	6.[illegible]E+01	5.99E-02	4.00E-01	2.00E+00
63	7.69E-02	62	1.76E+00	1.18E+01	5.88E+01	5.86E-02	3.91E-01	1.95E+00
64	7.52E-02	63	1.73E+00	1.15E+01	5.75E+01	5.73E-02	3.82E-01	1.91E+00
65	7.36E-02	64	1.69E+00	1.13E+01	5.63E+01	5.61E-02	3.74E-01	1.87E+00
66	7.20E-02	65	1.65E+00	1.10E+01	5.50E+01	5.49E-02	3.66E-01	1.83E+00
67	7.04E-02	66	1.61E+00	1.08E+01	5.38E+01	5.36E-02	3.58E-01	1.79E+00
68	6.89E-02	67	1.58E+00	1.05E+01	5.26E+01	5.25E-02	3.50E-01	1.75E+00
69	6.73E-02	68	1.54E+00	1.03E+01	5.15E+01	5.13E-02	3.42E-01	1.71E+00
70	6.59E-02	69	1.51E+00	1.01E+01	5.04E+01	5.02E-02	3.35E-01	1.67E+00
71	6.44E-02	70	1.48E+00	9.85E+00	4.93E+01	4.91E-02	3.27E-01	1.64E+00
72	6.30E-02	71	1.45E+00	9.64E+00	4.82E+01	4.80E-02	3.20E-01	1.60E+00
73	6.16E-02	72	1.41E+00	9.42E+00	4.71E+01	4.70E-02	3.13E-01	1.57E+00
74	6.03E-02	73	1.38E+00	9.22E+00	4.61E+01	4.59E-02	3.06E-01	1.53E+00
75	5.90E-02	74	1.35E+00	9.02E+00	4.51E+01	4.49E-02	3.00E-01	1.50E+00
76	5.77E-02	75	1.32E+00	8.82E+00	4.41E+01	4.39E-02	2.93E-01	1.46E+00
77	5.64E-02	76	1.29E+00	8.63E+00	4.31E+01	4.30E-02	2.87E-01	1.43E+00
78	5.52E-02	77	1.27E+00	8.44E+00	4.22E+01	4.20E-02	2.80E-01	1.40E+00
79	5.40E-02	78	1.24E+00	8.25E+00	4.13E+01	4.11E-02	2.74E-01	1.37E+00
80	5.28E-02	79	1.21E+00	8.07E+00	4.03[illegible]+01	4.02E-02	2.68E-01	1.34E+00

Table B.5. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Unrestricted and Restricted Land Use, Real World Model for Uranium) (continued)

Soil Depth (cm)	Concentration, pCi/g Nat. U
81	5.16E-02
82	5.05E-02
83	4.94E-02
84	4.83E-02
85	4.72E-02
86	4.62E-02
87	4.52E-02
88	4.42E-02
89	4.32E-02
90	4.23E-02
91	4.14E-02
92	4.04E-02
93	3.96E-02
94	3.87E-02
95	3.78E-02
96	3.70E-02
97	3.62E-02
98	3.54E-02
99	3.46E-02
100	3.39E-02
101	3.31E-02
102	3.24E-02
103	3.17E-02
104	3.10E-02
105	3.03E-02
106	2.97E-02
107	2.90E-02
108	2.84E-02
109	2.77E-02
110	2.71E-02
111	2.65E-02
112	2.60E-02
113	2.54E-02
114	2.48E-02
115	2.43E-02
116	2.38E-02
117	2.32E-02
118	2.27E-02
119	2.22E-02
120	2.17E-02

1 cm Layers Removed	Natural Uranium Dose Rate, mrem/y					
	Unrestricted			Restricted		
	Surface Contamination Level, pCi/g			Surface Contamination Level, pCi/g		
	30 Low	200 Med	1,000 High	30 Low	200 Med	1,000 High
80	1.18E+00	7.89E+00	3.95E+01	3.93E-02	2.62E-01	1.31E+00
81	1.16E+00	7.72E+00	3.86E+01	3.85E-02	2.56E-01	1.28E+00
82	1.13E+00	7.55E+00	3.78E+01	3.76E-02	2.51E-01	1.25E+00
83	1.11E+00	7.39E+00	3.69E+01	3.68E-02	2.45E-01	1.23E+00
84	1.08E+00	7.22E+00	3.61E+01	3.60E-02	2.40E-01	1.20E+00
85	1.06E+00	7.07E+00	3.53E+01	3.52E-02	2.35E-01	1.17E+00
86	1.04E+00	6.91E+00	3.45E+01	3.44E-02	2.30E-01	1.15E+00
87	1.01E+00	6.76E+00	3.38E+01	3.37E-02	2.25E-01	1.12E+00
88	9.92E-01	6.61E+00	3.31E+01	3.29E-02	2.20E-01	1.10E+00
89	9.70E-01	6.47E+00	3.23E+01	3.22E-02	2.15E-01	1.07E+00
90	9.49E-01	6.32E+00	3.16E+01	3.15E-02	2.10E-01	1.05E+00
91	9.28E-01	6.19E+00	3.09E+01	3.08E-02	2.05E-01	1.03E+00
92	9.07E-01	6.05E+00	3.02E+01	3.01E-02	2.01E-01	1.00E+00
93	8.88E-01	5.92E+00	2.96E+01	2.95E-02	1.97E-01	9.83E-01
94	8.68E-01	5.79E+00	2.89E+01	2.88E-02	1.92E-01	9.61E-01
95	8.49E-01	5.66E+00	2.83E+01	2.82E-02	1.88E-01	9.40E-01
96	8.30E-01	5.54E+00	2.77E+01	2.76E-02	1.84E-01	9.20E-01
97	8,12E-01	5.41E+00	2.71E+01	2.70E-02	1.80E-01	8.99E-01
98	7.94E-01	5.30E+00	2.65E+01	2.64E-02	1.76E-01	8.80E-01
99	7.77E-01	5.18E+00	2.59E+01	2.58E-02	1.72E-01	8.60E-01
100	7.60E-01	5.07E+00	2 53E+01	2.52E-02	1.68E-01	8.42E-01
101	7.43E-01	4.96E+00	2.48E+01	2.47E-02	1.65E-01	8.23E-01
102	7.27E-01	4.85E+00	2.42E+01	2.42E-02	1.61E-01	8.05E-01
103	7.11E-01	4.74E+00	2.37E+01	2.36E-02	1.57E-01	7.87E-01
104	6.95E-01	4.64E+00	2.32E+01	2.31E-02	1.54E-01	7.70E-01
105	6.80E-01	4.54E+00	2.27E+01	2.26E-02	1.51E-01	7.53E-01
106	6.65E-01	4.44E+00	2.22E+01	2.21E-02	1.47E-01	7.37E-01
107	6.51E-01	4.34E+00	2.17E+01	2.16E-02	1.44E-01	7.21E-01
108	6.36E-01	4.24E+00	2.12E+01	2.11E-02	1.41E-01	7.05E-01
109	6.23E-01	4.15E+00	2.07E+01	2.07E-02	1.38E-01	6.89E-01
110	6.09E-01	4.06E+00	2.03E+01	2.02E-02	1.35E-01	6.74E-01
111	5.96E-01	3.97E+00	1.98E+01	1.98E-02	1.32E-01	6.60E-01
112	5.82E-01	3.88E+00	1.94E+01	1.94E-02	1.29E-01	6.45E-01
113	5.70E-01	3.80E+00	1.90E+01	1.89E-02	1.26E-01	6.31E-01
114	5.57E-01	3.71E+00	1.86E+01	1.85E-02	1.23E-01	6.17E-01
115	5.45E-01	3.63E+00	1.82E+01	1.81E-02	1.21E-01	6.04E-01
116	5.33E-01	3.55E+00	1.78E+01	1.77E-02	1.18E-01	5.90E-01
117	5.21E-01	3.48E+00	1.74E+01	1.73E-02	1.15E-01	5.77E-01
118	5.10E-01	3.40E+00	1.70E+01	1.69E-02	1.13E-01	5.65E-01
119	4.99E-01	3.33E+00	1.66E+01	1.66E-02	1.10E-01	5.52E-01

Table B.6. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Unrestricted and Restricted Land Use, Real World Model for Thorium)

Soil Depth (cm)	Concentration, pCi/g Nat. U	1 cm Layers Removed	Thorium Dose Rate, mrem/y: Unrestricted, Surface Contamination Level, pCi/g 30 Low	Unrestricted 100 Med	Unrestricted 200 High	Restricted, Surface Contamination Level, pCi/g 30 Low	Restricted 100 Med	Restricted 200 High
1	1.14E+02	0	6.02E+01	2.01E+02	4.02E+02	2.61E+00	8.70E+00	1.74E+01
2	1.02E+02	1	5.35E+01	1.78E+02	3.57E+02	2.32E+00	7.73E+00	1.55E+01
3	9.04E+01	2	4.76E+01	1.59E+02	3.17E+02	2.06E+00	6.87E+00	1.37E+01
4	8.03E+01	3	4.23E+01	1.41E+02	2.82E+02	1.83E+00	6.10E+00	1.22E+01
5	7.13E+01	4	3.75E+01	1.25E+02	2.50E+02	1.63E+00	5.42E+00	1.08E+01
6	6.34E+01	5	3.34E+01	1.11E+02	2.22E+02	1.45E+00	4.82E+00	9.64E+00
7	5.63E+01	6	2.96E+01	9.88E+01	1.98E+02	1.28E+00	4.28E+00	8.56E+00
8	5.00E+01	7	2.63E+01	8.78E+01	1.76E+02	1.14E+00	3.80E+00	7.61E+00
9	4.45E+01	8	2.34E+01	7.80E+01	1.56E+02	1.01E+00	3.38E+00	6.76E+00
10	3.95E+01	9	2.08E+01	6.93E+01	1.39E+02	9.01E-01	3.00E+00	6.01E+00
11	3.51E+01	10	1.85E+01	6.16E+01	1.23E+02	8.00E-01	2.67E+00	5.34E+00
12	3.12E+01	11	1.64E+01	5.47E+01	1.09E+02	7.11E-01	2.37E+00	4.74E+00
13	2.77E+01	12	1.46E+01	4.86E+01	9.72E+01	6.32E-01	2.11E+00	4.21E+00
14	2.46E+01	13	1.30E+01	4.32E+01	8.64E+01	5.61E-01	1.87E+00	3.74E+00
15	2.19E+01	14	1.15E+01	3.84E+01	7.67E+01	4.99E-01	1.66E+00	3.33E+00
16	1.94E+01	15	1.02E+01	3.41E+01	6.82E+01	4.43E-01	1.48E+00	2.95E+00
17	1.73E+01	16	9.09E+00	3.03E+01	6.06E+01	3.94E-01	1.31E+00	2.63E+00
18	1.53E+01	17	8.07E+00	2.69E+01	5.38E+01	3.50E-01	1.17E+00	2.33E+00
19	1.36E+01	18	7.17E+00	2.39E+01	4.78E+01	3.11E-01	1.04E+00	2.07E+00
20	1.21E+01	19	6.37E+00	2.12E+01	4.25E+01	2.76E-01	9.21E-01	1.84E+00
21	1.08E+01	20	5.66E+00	1.89E+01	3.78E+01	2.45E-01	8.18E-01	1.64E+00
22	9.56E+00	21	5.03E+00	1.68E+01	3.35E+01	2.18E-01	7.27E-01	1.45E+00
23	8.50E+00	22	4.47E+00	1.49E+01	2.98E+01	1.94E-01	6.46E-01	1.29E+00
24	7.55E+00	23	3.97E+00	1.32E+01	2.65E+01	1.72E-01	5.74E-01	1.15E+00
25	6.71E+00	24	3.53E+00	1.18E+01	2.35E+01	1.53E-01	5.10E-01	1.02E+00
26	5.96E+00	25	3.14E+00	1.05E+01	2.09E+01	1.36E-01	4.53E-01	9.06E-01
27	5.30E+00	26	2.79E+00	9.29E+00	1.86E+01	1.21E-01	4.02E-01	8.05E-01
28	4.71E+00	27	2.48E+00	8.25E+00	1.65E+01	1.07E-01	3.58E-01	7.15E-01
29	4.18E+00	28	2.20E+00	7.33E+00	1.47E+01	9.53E-02	3.18E-01	6.35E-01
30	3.71E+00	29	1.95E+00	6.52E+00	1.30E+01	8.47E-02	2.82E-01	5.65E-01
31	3.30E+00	30	1.74E+00	5.79E+00	1.16E+01	7.52E-02	2.51E-01	5.02E-01
32	2.93E+00	31	1.54E+00	5.14E+00	1.03E+01	6.69E-02	2.23E-01	4.46E-01
33	2.61E+00	32	1.37E+00	4.57E+00	9.14E+00	5.94E-02	1.98E-01	3.96E-01
34	2.31E+00	33	1.22E+00	4.06E+00	8.12E+00	5.28E-02	1.76E-01	3.52E-01
35	2.06E+00	34	1.08E+00	3.61E+00	7.22E+00	4.69E-02	1.56E-01	3.13E-01
36	1.83E+00	35	9.62E-01	3.21E+00	6.41E+00	4.17E-02	1.39E-01	2.78E-01
37	1.62E+00	36	8.54E-01	2.85E+00	5.70E+00	3.70E-02	1.23E-01	2.47E-01
38	1.44E+00	37	7.59E-01	2.53E+00	5.06E+00	3.29E-02	1.10E-01	2.19E-01
39	1.28E+00	38	6.75E-01	2.25E+00	4.50E+00	2.92E-02	9.74E-02	1.95E-01
40	1.14E+00	39	5.99E-01	2.00E+00	4.00E+00	2.60E-02	8.66E-02	1.73E-01

Table B.6. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Unrestricted and Restricted Land Use, Real World Model for Thorium) (continued)

Soil Depth (cm)	Concentration, pCi/g Nat. U
41	1.01E+00
42	8.99E-01
43	7.99E-01
44	7.10E-01
45	6.31E-01
46	5.60E-01
47	4.98E-01
48	4.42E-01
49	3.93E-01
50	3.49E-01
51	3.10E-01
52	2.76E-01
53	2.45E-01
54	2.18E-01
55	1.93E-01
56	1.72E-01
57	1.53E-01
58	1.36E-01
59	1.21E-01
60	1.07E-01
61	9.51E-02
62	8.45E-02
63	7.51E-02
64	6.67E-02
65	5.93E-02
66	5.27E-02
67	4.68E-02
68	4.16E-02
69	3.70E-02
70	3.28E-02
71	2.92E-02
72	2.59E-02
73	2.30E-02
74	2.05E-02
75	1.82E-02
76	1.62E-02
77	1.44E-02
78	1.28E-02
79	1.13E-02
80	1.01E-02

	Thorium Dose Rate, mrem/y					
	Unrestricted			Restricted		
	Surface Contamination Level, pCi/g			Surface Contamination Level, pCi/g		
1 cm Layers Removed	30 Low	100 Med	200 High	30 Low	100 Med	200 High
40	5.32E-01	1.77E+00	[illegible].55E+00	2.31E-02	7.69E-02	1.54E-01
41	4.73E-01	1.58E+00	3.15E+00	2.05E-02	6.83E-02	1.37E-01
42	4.20E-01	1.40E+00	2.80E+00	1.82E-02	6.07E-02	1.21E-01
43	3.74E-01	1.25E+00	2.49E+00	1.62E-02	5.39E-02	1.08E-01
44	3.32E-01	1.11E+00	2.21E+00	1.44E-02	4.79E-02	9.59E-02
45	2.95E-01	9.83E-01	1.97E+00	1.28E-02	4.26E-02	8.52E-02
46	2.62E-01	8.73E-01	1.75E+00	1.14E-02	3.78E-02	7.57E-02
47	2.33E-01	7.76E-01	1.55E+00	1.01E-02	3.36E-02	6.72E-02
48	2.07E-01	6.89E-01	1.38E+00	8.96E-03	2.99E-02	5.97E-02
49	1.84E-01	6.13E-01	1.23E+00	7.96E-03	2.65E-02	5.31E-02
50	1.63E-01	5.44E-01	1.09E+00	7.07E-03	2.36E-02	4.72E-02
51	1.45E-01	4.84E-01	9.67E-01	6.29E-03	2.10E-02	4.19E-02
52	1.29E-01	4.30E-01	8.59E-01	5.59E-03	1.86E-02	3.72E-02
53	1.15E-01	3.82E-01	7.64E-01	4.96E-03	1.65E-02	3.31E-02
54	1.02E-01	3.39E-01	6.78E-01	4.41E-03	1.47E-02	2.94E-02
55	9.04E-02	3.01E-01	6.03E-01	3.92E-03	1.31E-02	2.61E-02
56	8.03E-02	2.68E-01	5.36E-01	3.48E-03	1.16E-02	2.32E-02
57	7.14E-02	2.38E-01	4.76E-01	3.09E-03	1.03E-02	2.06E-02
58	6.34E-02	2.11E-01	4.23E-01	2.75E-03	9.16E-03	1.83E-02
59	5.63E-02	1.88E-01	3.76E-01	2.44E-03	8.14E-03	1.63E-02
60	5.01E-02	1.67E-01	3.34E-01	2.17E-03	7.23E-03	1.45E-02
61	4.45E-02	1.48E-01	2.97E-01	1.93E-03	6.42E-03	1.28E-02
62	3.95E-02	1.32E-01	2.63E-01	1.71E-03	5.71E-03	1.14E-02
63	3.51E-02	1.17E-01	2.34E-01	1.52E-03	5.07E-03	1.01E-02
64	3.12E-02	1.04E-01	2.08E-01	1.35E-03	4.51E-03	9.01E-03
65	2.77E-02	9.24E-02	1.85E-01	1.20E-03	4.00E-03	8.01E-03
66	2.46E-02	8.21E-02	1.64E-01	1.07E-03	3.56E-03	7.12E-03
67	2.19E-02	7.30E-02	1.46E-01	9.48E-04	3.16E-03	6.32E-03
68	1.94E-02	6.48E-02	1.30E-01	8.43E-04	2.81E-03	5.62E-03
69	1.73E-02	5.76E-02	1.15E-01	7.49E-04	2.50E-03	4.99E-03
70	1.54E-02	5.12E-02	1.02E-01	6.65E-04	2.22E-03	4.43E-03
71	1.36E-02	4.55E-02	9.09E-02	5.91E-04	1.97E-03	3.94E-03
72	1.21E-02	4.04E-02	8.08E-02	5.25E-04	1.75E-03	3.50E-03
73	1.08E-02	3.59E-02	7.18E-02	4.67E-04	1.56E-03	3.11E-0[illegible]
74	9.57E-03	3.19E-02	6.38E-02	4.15E-04	1.38E-03	2.76E-03
75	8.50E-03	2.83E-02	5.67E-02	3.68E-04	1.23E-03	2.46E-03
76	7.55E-03	2.52E-02	5.04E-02	3.27E-04	1.09E-03	2.18E-03
77	6.71E-03	2.24E-02	4.47E-02	2.91E-04	9.69E-04	1.94E-03
78	5.96E-03	1.99E-02	3.97E-02	2.58E-04	8.61E-04	1.72E-03
79	5.30E-03	1.77E-02	3.53E-02	2.30E-04	7.65E-04	1.53E-03

Table B.6. Calculated Residual Radiation Dose Rates as a Function of Soil Depth Removed, (Unrestricted and Restricted Land Use, Real World Model for Thorium) (continued)

Soil Depth (cm)	Concentration, pCi/g Nat. U
81	8.95E-03
82	7.95E-03
83	7.06E-03
84	6.27E-03
85	5.57E-03
86	4.95E-03
87	4.40E-03
88	3.91E-03
89	3.47E-03
90	3.09E-03
91	2.74E-03
92	2.44E-03
93	2.17E-03
94	1.92E-03
95	1.71E-03
96	1.52E-03
97	1.35E-03
98	1.20E-03
99	1.07E-03
100	9.47E-04
101	8.41E-04
102	7.47E-04
103	6.64E-04
104	5.90E-04
105	5.24E-04
106	4.66E-04
107	4.14E-04
108	3.68E-04
109	3.27E-04
110	2.90E-04
111	2.58E-04
112	2.29E-04
113	2.04E-04
114	1.81E-04
115	1.61E-04
116	1.43E-04
117	1.27E-04
118	1.13E-04
119	1.00E-04
120	8.90E-05

1 cm Layers Removed	Thorium Dose Rate, mrem/y					
	Unrestricted			Restricted		
	Surface Contamination Level, pCi/g			Surface Contamination Level, pCi/g		
	30 Low	100 Med	200 High	30 Low	100 Med	200 High
80	4.71E-03	1.57E-02	3.14E-02	2.04E-04	6.80E-04	1.36E-03
81	4.18E-03	1.39E-02	2.79E-02	1.81E-04	6.04E-04	1.21E-03
82	3.72E-03	1.24E-02	2.48E-02	1.61E-04	5.37E-04	1.07E-03
83	3.30E-03	1.10E-02	2.20E-02	1.43E-04	4.77E-04	9.54E-04
84	2.93E-03	9.78E-03	1.96E-02	1.27E-04	4.24E-04	8.47E-04
85	2.61E-03	8.69E-03	1.74E-02	1.13E-04	3.76E-04	7.53E-04
86	2.32E-03	7.72E-03	1.54E-02	1.00E-04	3.34E-04	6.69E-04
87	2.06E-03	6.86E-03	1.37E-02	8.92E-05	2.97E-04	5.94E-04
88	1.83E-03	6.09E-03	1.22E-02	7.92E-05	2.64E-04	5.28E-04
89	1.62E-03	5.41E-03	1.08E-02	7.04E-05	2.35E-04	4.69E-04
90	1.44E-03	4.81E-03	9.62E-03	6.25E-05	2.08E-04	4.17E-04
91	1.28E-03	4.27E-03	8.55E-03	5.56E-05	1.85E-04	3.70E-04
92	1.14E-03	3.80E-03	7.60E-03	4.94E-05	1.65E-04	3.29E-04
93	1.01E-03	3.37E-03	6.75E-03	4.39E-05	1.46E-04	2.92E-04
94	8.99E-04	3.00E-03	6.00E-03	3.90E-05	1.30E-04	2.60E-04
95	7.99E-04	2.66E-03	5.33E-03	3.46E-05	1.15E-04	2.31E-04
96	7.10E-04	2.37E-03	4.73E-03	3.08E-05	1.03E-04	2.05E-04
97	6.31E-04	2.10E-03	4.21E-03	2.73E-05	9.11E-05	1.82E-04
98	5.61E-04	1.87E-03	3.74E-03	2.43E-05	8.10E-05	1.62E-04
99	4.98E-04	1.66E-03	3.32E-03	2.16E-05	7.19E-05	1.44E-04
100	4.43E-04	1.48E-03	2.95E-03	1.92E-05	6.39E-05	1.28E-04
101	3.93E-04	1.31E-03	2.62E-03	1.70E-05	5.68E-05	1.14E-04
102	3.49E-04	1.16E-03	2.33E-03	1.51E-05	5.05E-05	1.01E-04
103	3.10E-04	1.03E-03	2.07E-03	1.35E-05	4.48E-05	8.97E-05
104	2.76E-04	9.19E-04	1.84E-03	1.20E-05	3.98E-05	7.97E-05
105	2.45E-04	8.17E-04	1.63E-03	1.06E-05	3.54E-05	7.08E-05
106	2.18E-04	7.26E-04	1.45E-03	9.43E-06	3.14E-05	6.29E-05
107	1.93E-04	6.45E-04	1.29E-03	8.38E-06	2.79E-05	5.59E-05
108	1.72E-04	5.73E-04	1.15E-03	7.45E-06	2.48E-05	4.97E-05
109	1.53E-04	5.09E-04	1.02E-03	6.62E-06	2.21E-05	4.41E-05
110	1.36E-04	4.52E-04	9.05E-04	5.88E-06	1.96E-05	3.92E-05
111	1.21E-04	4.02E-04	8.04E-04	5.22E-06	1.74E-05	3.48E-05
112	1.07E-04	3.57E-04	7.14E-04	4.64E-06	1.55E-05	3.09E-05
113	9.52E-05	3.17E-04	6.35E-04	4.12E-06	1.37E-05	2.75E-05
114	8.46E-05	2.82E-04	5.64E-04	3.66E-06	1.22E-05	2.44E-05
115	7.51E-05	2.50E-04	5.01E-04	3.26E-06	1.09E-05	2.17E-05
116	6.68E-05	2.23E-04	4.45E-04	2.89E-06	9.64E-06	1.93E-05
117	5.93E-05	1.98E-04	3.95E-04	2.57E-06	8.57E-06	1.71E-05
118	5.27E-05	1.76E-04	3.51E-04	2.28E-06	7.61E-06	1.52E-05
119	4.68E-05	1.56E-04	3.12E-04	2.03E-06	6.76E-06	1.35E-05

ATTACHMENT C

DETAILED SPREADSHEETS

CALCULATED COSTS AND OTHER PARAMETERS FOR REMEDIATION OF CONTAMINATED SOIL AT NUCLEAR FACILITIES

ATTACHMENT C

DETAILED SPREADSHEETS

CALCULATED COSTS AND OTHER PARAMETERS FOR REMEDIATION OF CONTAMINATED SOIL AT NUCLEAR FACILITIES

This attachment provides the detailed results for the analyses summarized in Sections 2 and 7. A separate table, or spreadsheet, is provided for each scenario analyzed. For completeness of basic information, detailed results are provided for the alternative residual dose levels evaluated (i.e., 100, 60, 30, 25, 15, 10, 3, 0.3, and 0.03 mrem/y), including estimates for 1) the volume of soil requiring remediation, 2) the costs associated with excavating, treating, packaging, transporting, and disposing of the excavated soil, 3) the number of labor hours required to excavate and treat the soil, and 4) the total occupational dose incurred during excavation and treatment of the soil. Each table reports these results for the assumed high, medium, and low surface contamination levels.

Table C.1 provides an index to the results for each scenario presented in this attachment. Identified in the table is the table, or spreadsheet, number, the reference facility evaluated, the contaminant distribution profile (i.e., "baseline" or "real world"), the time of decommissioning (i.e., soon after shutdown or after a 50-year SAFSTOR period), the land-use assumed (i.e., restricted or unrestricted), and the soil treatment train (i.e., direct disposal of the soil or washing of the soil to remove contaminants prior to its disposal).

Table C.1. Index to Spreadsheets

Reference Facility	Table Number	Contaminant Distribution Model	Time of Decommissioning	Land-Use	Contaminated Soil Disposition
Nuclear Power Plant	C.1.1	"Baseline" or Diffusion	Soon After Shutdown	Unrestricted	Washed Prior to Disposal
Nuclear Power Plant	C.1.2	"Baseline" or Diffusion	Soon After Shutdown	Unrestricted	Direct Disposal
Nuclear Power Plant	C.1.3	"Baseline" or Diffusion	Soon After Shutdown	Restricted	Washed Prior to Disposal
Nuclear Power Plant	C.1.4	"Baseline" or Diffusion	Soon After Shutdown	Restricted	Direct Disposal
Nuclear Power Plant	C.1.5	"Baseline" or Diffusion	SAFSTOR	Unrestricted	Washed Prior to Disposal
Nuclear Power Plant	C.1.6	"Baseline" or Diffusion	SAFSTOR	Unrestricted	Direct Disposal
Nuclear Power Plant	C.1.7	"Baseline" or Diffusion	SAFSTOR	Restricted	Washed Prior to Disposal
Nuclear Power Plant	C.1.8	"Baseline" or Diffusion	SAFSTOR	Restricted	Direct Disposal
Nuclear Power Plant	C.1.9	"Real World" or Spill/Leak	Soon After Shutdown	Unrestricted	Washed Prior to Disposal
Nuclear Power Plant	C.1.10	"Real World" or Spill/Leak	Soon After Shutdown	Unrestricted	Direct Disposal
Nuclear Power Plant	C.1.11	"Real World" or Spill/Leak	Soon After Shutdown	Restricted	Washed Prior to Disposal
Nuclear Power Plant	C.1.12	"Real World" or Spill/Leak	Soon After Shutdown	Restricted	Direct Disposal
Nuclear Power Plant	C.1.13	"Real World" or Spill/Leak	SAFSTOR	Unrestricted	Washed Prior to Disposal
Nuclear Power Plant	C.1.14	"Real World" or Spill/Leak	SAFSTOR	Unrestricted	Direct Disposal
Nuclear Power Plant	C.1.15	"Real World" or Spill/Leak	SAFSTOR	Restricted	Washed Prior to Disposal
Nuclear Power Plant	C.1.16	"Real World" or Spill/Leak	SAFSTOR	Restricted	Direct Disposal
Uranium Fuel Fabrication Plant	C.2.1	"Baseline" or Diffusion	Soon After Shutdown	Unrestricted	Washed Prior to Disposal
Uranium Fuel Fabrication Plant	C.2.2	"Baseline" or Diffusion	Soon After Shutdown	Unrestricted	Direct Disposal
Uranium Fuel Fabrication Plant	C.2.3	"Baseline" or Diffusion	Soon After Shutdown	Restricted	Washed Prior to Disposal
Uranium Fuel Fabrication Plant	C.2.4	"Baseline" or Diffusion	Soon After Shutdown	Restricted	Direct Disposal

Table C.1. Index to Spreadsheets

Reference Facility	Table Number	Contaminant Distribution Model	Time of Decommissioning	Land-Use	Contaminated Soil Disposition
Uranium Fuel Fabrication Plant	C.2.5	"Real World" or Mixing/Landfilling	Soon After Shutdown	Unrestricted	Washed Prior to Disposal
Uranium Fuel Fabrication Plant	C.2.6	"Real World" or Mixing/Landfilling	Soon After Shutdown	Unrestricted	Direct Disposal
Uranium Fuel Fabrication Plant	C.2.7	"Real World" or Mixing/Landfilling	Soon After Shutdown	Restricted	Washed Prior to Disposal
Uranium Fuel Fabrication Plant	C.2.8	"Real World" or Mixing/Landfilling	Soon After Shutdown	Restricted	Direct Disposal
Sealed Source Manufacturer	C.3.1	"Baseline" or Diffusion	Soon After Shutdown	Unrestricted	Washed Prior to Disposal
Sealed Source Manufacturer	C.3.2	"Baseline" or Diffusion	Soon After Shutdown	Unrestricted	Direct Disposal
Sealed Source Manufacturer	C.3.3	"Baseline" or Diffusion	Soon After Shutdown	Restricted	Washed Prior to Disposal
Sealed Source Manufacturer	C.3.4	"Baseline" or Diffusion	Soon After Shutdown	Restricted	Direct Disposal
Sealed Source Manufacturer	C.3.5	"Real World" or Spill/Leak	Soon After Shutdown	Unrestricted	Washed Prior to Disposal
Sealed Source Manufacturer	C.3.6	"Real World" or Spill/Leak	Soon After Shutdown	Unrestricted	Direct Disposal
Sealed Source Manufacturer	C.3.7	"Real World" or Spill/Leak	Soon After Shutdown	Restricted	Washed Prior to Disposal
Sealed Source Manufacturer	C.3.8	"Real World" or Spill/Leak	Soon After Shutdown	Restricted	Direct Disposal
Rare Metal Extraction Plant	C.4.1	"Baseline" or Diffusion	Soon After Shutdown	Unrestricted	Washed Prior to Disposal
Rare Metal Extraction Plant	C.4.2	"Baseline" or Diffusion	Soon After Shutdown	Unrestricted	Direct Disposal
Rare Metal Extraction Plant	C.4.3	"Baseline" or Diffusion	Soon After Shutdown	Restricted	Washed Prior to Disposal
Rare Metal Extraction Plant	C.4.4	"Baseline" or Diffusion	Soon After Shutdown	Restricted	Direct Disposal
Rare Metal Extraction Plant	C.4.5	"Real World" or Spill/Leak	Soon After Shutdown	Unrestricted	Washed Prior to Disposal
Rare Metal Extraction Plant	C.4.6	"Real World" or Spill/Leak	Soon After Shutdown	Unrestricted	Direct Disposal
Rare Metal Extraction Plant	C.4.7	"Real World" or Spill/Leak	Soon After Shutdown	Restricted	Washed Prior to Disposal

Table C.1. Index to Spreadsheets

Reference Facility	Table Number	Contaminant Distribution Model	Time of Decommissioning	Land-Use	Contaminated Soil Disposition
Rare Metal Extraction Plant	C.4.8	"Real World" or Spill/Leak	Soon After Shutdown	Restricted	Direct Disposal
Uranium Mill	C.5.1	"Baseline" or Diffusion	Soon After Shutdown	Unrestricted	Washed Prior to Disposal
Uranium Mill	C.5.2	"Baseline" or Diffusion	Soon After Shutdown	Unrestricted	Direct Disposal
Uranium Mill	C.5.3	"Baseline" or Diffusion	Soon After Shutdown	Restricted	Washed Prior to Disposal
Uranium Mill	C.5.4	"Baseline" or Diffusion	Soon After Shutdown	Restricted	Direct Disposal

Table C.1.1. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, With Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	3.3	9	3.3	15	24	5,707
60	3,000	4.6	13	4.6	21	34	8,049
30	3,000	5.9	16	5.9	27	44	10,315
25	3,000	6.2	17	6.2	29	46	10,893
15	3,000	7.0	20	7.0	33	52	12,283
10	3,000	7.8	22	7.8	36	58	13,573
3	3,000	11.5	32	11.5	54	86	20,151
0.3	3,000	20.5	57	20.5	95	152	35,729
0.03	3,000	24.9	69	24.9	116	185	43,492
MEDIUM							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	2.5	7	2.5	11	18	4,310
30	3,000	4.5	13	4.5	21	34	7,940
25	3,000	4.9	14	4.9	23	36	8,557
15	3,000	5.8	16	5.8	27	43	10,169
10	3,000	6.5	18	6.5	30	48	11,339
3	3,000	8.2	23	8.2	38	61	14,389
0.3	3,000	16.5	46	16.5	77	123	28,803
0.03	3,000	22.4	62	22.4	104	167	39,158
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	3.6	10	3.6	17	27	6,374
0.3	3,000	8.4	23	8.4	39	62	14,599
0.03	3,000	18.7	52	18.7	87	139	32,646
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (250,000 ft^2)		$235/m^3

Table C.1.1. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, With Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	24	30	40,914	100	2,137	1	1	4,000	1,325	3,431	17,153	120,072
60	34	42	43,717	100	3,014	1	2	4,000	2,650	4,838	24,190	169,333
30	44	53	46,430	100	3,863	1	2	4,000	2,650	6,200	31,001	217,007
25	46	56	47,122	100	4,079	1	2	4,000	2,650	6,548	32,739	229,173
15	52	64	48,786	100	4,600	1	2	4,000	2,650	7,383	36,917	258,419
10	58	70	50,330	100	5,083	1	3	4,000	3,975	8,159	40,793	285,550
3	86	104	58,204	100	7,546	1	4	4,000	5,300	12,113	60,563	423,938
0.3	152	185	76,852	100	13,379	1	6	4,000	7,950	21,477	107,384	751,686
0.03	185	226	86,145	200	16,287	2	7	8,000	9,275	26,143	130,716	915,012
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	18	22	39,241	100	1,614	1	1	4,000	1,325	2,591	12,953	90,670
30	34	41	43,587	100	2,973	1	2	4,000	2,650	4,773	23,864	167,045
25	36	44	44,325	100	3,204	1	2	4,000	2,650	5,143	25,717	180,021
15	43	53	46,255	100	3,808	1	2	4,000	2,650	6,113	30,563	213,944
10	48	59	47,655	100	4,246	1	2	4,000	2,650	6,816	34,078	238,547
3	61	75	51,307	100	5,388	1	3	4,000	3,975	8,649	43,246	302,724
0.3	123	149	68,560	100	10,786	1	5	4,000	6,625	17,313	86,566	605,965
0.03	167	203	80,956	100	14,663	1	7	4,000	9,275	23,538	117,689	823,822
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	27	33	41,712	100	2,387	1	1	4,000	1,325	3,831	19,156	134,093
0.3	62	76	51,558	100	5,467	1	3	4,000	3,975	8,775	43,877	307,142
0.03	139	169	73,162	100	12,225	1	6	4,000	7,950	19,624	98,119	686,830
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.1.1.

Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, With Soil Washing)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs			Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
		@ $10/ft^3 Disposal Costs	@ $50/ft^3 Disposal Costs	@ $350/ft^3 Disposal Costs				
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	10	54,152	67,237	170,155	4	39	43	4
60	14	60,704	81,620	226,763	6	55	61	6
30	18	67,045	94,258	280,264	7	71	79	8
25	19	68,663	97,483	293,918	8	76	83	8
15	21	72,553	105,236	326,738	9	85	94	9
10	23	76,161	113,763	358,510	10	94	103	10
3	34	94,567	151,763	515,138	15	139	153	15
0.3	61	138,158	241,294	885,596	26	246	272	27
0.03	74	163,980	285,914	1,070,211	31	300	331	33
MEDIUM								
100	0	0	0	0	0	0	0	0
60	7	50,242	59,443	137,160	3	30	33	3
30	14	60,400	81,014	224,195	6	55	60	6
25	15	62,125	84,453	238,757	6	59	65	7
15	17	66,637	93,446	276,827	7	70	77	8
10	19	68,909	99,968	304,437	8	78	86	9
3	24	78,445	118,305	377,783	10	99	110	11
0.3	49	118,777	201,341	720,739	21	199	219	22
0.03	67	147,752	261,741	967,874	28	270	298	30
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	11	56,017	70,954	185,891	5	44	49	5
0.3	25	79,033	119,476	382,741	11	101	111	11
0.03	56	129,532	224,102	812,813	24	225	249	25
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.1.2.

Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Without Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	3.3	9	3.3	15	24	5,707
60	3,000	4.6	13	4.6	21	34	8,049
30	3,000	5.9	16	5.9	27	44	10,315
25	3,000	6.2	17	6.2	29	46	10,893
15	3,000	7.0	20	7.0	33	52	12,283
10	3,000	7.8	22	7.8	36	58	13,673
3	3,000	11.5	32	11.5	54	86	20,151
0.3	3,000	20.5	57	20.5	95	152	35,729
0.03	3,000	24.9	69	24.9	116	185	43,492
MEDIUM							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	2.5	7	2.5	11	18	4,310
30	3,000	4.5	13	4.5	21	34	7,940
25	3,000	4.9	14	4.9	23	36	8,557
15	3,000	5.8	16	5.8	27	43	10,169
10	3,000	6.5	18	6.5	30	48	11,339
3	3,000	8.2	23	8.2	38	61	14,389
0.3	3,000	16.5	46	16.5	77	123	28,803
0.03	3,000	22.4	62	22.4	104	167	39,158
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	3.6	10	3.6	17	27	6,374
0.3	3,000	8.4	23	8.4	39	62	14,599
0.03	3,000	18.7	52	18.7	87	139	32,646
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (250,000 ft^2)		$235/m^3

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Table C.1.2.

Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Without Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	24	30	0	100	5,343	1	3	4,000	3,975	8,577	42,883	300,179
60	34	42	0	100	7,535	1	4	4,000	5,300	12,095	60,476	423,332
30	44	53	0	100	9,658	1	5	4,000	6,625	15,500	77,502	542,517
25	4[illegible]	56	0	100	10,198	1	5	4,000	6,625	16,370	81,848	572,934
15	5[illegible]	64	0	100	11,499	1	5	4,000	6,625	18,459	92,293	646,048
10	5[illegible]	70	0	100	12,706	1	6	4,000	7,950	20,396	101,982	713,874
3	8[illegible]	104	0	200	18,864	2	8	8,000	10,600	30,281	151,407	1,059,846
0.3	15[illegible]	186	0	300	33,449	3	14	12,000	18,550	53,692	268,459	1,879,215
0.03	18[illegible]	226	0	300	40,716	3	18	12,000	23,850	65,358	326,790	2,287,530
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	18	22	0	100	4,035	1	2	4,000	2,650	6,476	32,382	226,676
30	34	41	0	100	7,433	1	4	4,000	5,300	11,932	59,659	417,612
25	36	44	0	100	8,011	1	4	4,000	5,300	12,859	64,293	450,052
15	43	53	0	100	9,520	1	4	4,000	5,300	15,282	76,409	534,860
10	48	59	0	100	10,615	1	5	4,000	6,625	17,039	85,195	596,367
3	61	75	0	100	13,471	1	6	4,000	7,950	21,623	108,116	756,809
0.3	123	149	0	200	26,964	2	12	8,000	15,900	43,283	216,416	1,514,914
0.03	167	203	0	300	36,659	3	16	12,000	21,200	58,844	294,222	2,059,555
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	27	33	0	100	5,967	1	3	4,000	3,975	9,578	47,890	335,233
0.3	62	76	0	100	13,667	1	6	4,000	7,950	21,939	109,693	767,854
0.03	139	169	0	200	30,563	2	13	8,000	17,225	49,059	245,296	1,717,075
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	96 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.1.2. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Without Soil Washing)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $50/ft^3 Disposal Costs	Costs @ $360/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	24	18,384	57,908	315,204	0	39	39	4
60	34	24,244	81,360	444,216	0	55	55	6
30	44	29,915	104,099	569,113	0	71	71	7
25	46	31,363	109,564	600,649	0	75	75	8
15	52	34,842	122,700	676,456	0	85	85	8
10	58	38,069	136,211	748,103	0	94	94	9
3	86	58,632	201,022	1,109,461	0	139	139	14
0.3	152	101,721	356,187	1,966,943	0	246	246	25
0.03	185	121,150	434,349	2,395,589	0	300	300	30
MEDIUM								
100	0	0	[illegible]	0	0	0	0	0
60	18	14,886	43,377	237,670	0	30	30	3
30	34	23,972	80,132	438,286	0	55	55	5
25	36	25,515	86,160	471,919	0	59	59	6
15	43	29,551	101,398	559,849	0	70	70	7
10	48	32,478	113,774	624,946	0	78	78	8
3	61	40,112	143,925	792,619	0	99	99	10
0.3	123	80,286	288,083	1,586,581	0	199	199	20
0.03	167	110,302	391,239	2,156,572	0	270	270	27
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	27	20,052	64,208	351,549	0	44	44	4
0.3	62	40,638	145,910	804,070	0	101	101	10
0.03	139	89,906	325,731	1,797,509	0	225	225	23
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.1.3.

Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, With Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	1.6	4	1.6	7	12	2,808
3	3,000	5.2	15	5.2	24	39	9,089
0.3	3,000	8.3	23	8.3	39	62	14,523
0.03	3,000	10.7	30	10.7	50	79	18,673
MEDIUM							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	3.7	10	3.7	17	28	6,494
0.3	3,000	7.5	21	7.5	35	56	13,149
0.03	3,000	9.9	28	9.9	46	74	17,309
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	2.3	6	2.3	11	17	4,024
0.03	3,000	7.0	19	7.0	32	52	12,166
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (260,000 ft^2)		$235/m^3

Table C.1.3. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, With Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	12	15	37,444	100	1,052	1	1	4,000	1,325	1,688	8,440	59,083
3	39	47	44,962	100	3,403	1	2	4,000	2,650	5,463	27,316	191,209
0.3	62	75	51,467	100	5,438	1	3	4,000	3,975	8,730	43,649	305,545
0.03	79	97	56,435	100	6,993	1	3	4,000	3,975	11,225	56,123	392,860
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	28	34	41,856	100	2,432	1	2	4,000	2,650	3,903	19,517	136,621
0.3	56	68	49,822	100	4,924	1	3	4,000	3,975	7,804	39,518	276,629
0.03	74	90	54,802	100	6,482	1	3	4,000	3,975	10,404	52,021	364,150
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	17	21	38,899	100	1,507	1	1	4,000	1,325	2,419	12,093	84,654
0.03	52	63	48,633	100	4,552	1	2	4,000	2,650	7,307	36,534	255,738
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	85 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.1.3.

Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, With Soil Washing)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs @ $10/ft^3 Disposal Costs	Total Soil Remediation Costs @ $60/ft^3 Disposal Costs	Total Soil Remediation Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	5	46,041	51,070	101,713	2	19	21	2
3	15	63,614	87,419	251,313	7	63	69	7
0.3	25	78,820	119,053	380,949	11	100	111	11
0.03	32	90,433	142,199	478,936	14	129	142	14
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	11	56,353	72,949	190,053	5	45	49	5
0.3	22	74,974	111,388	348,499	10	91	100	10
0.03	29	86,615	134,589	446,717	13	119	132	13
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	7	49,442	57,848	130,408	3	28	31	3
0.03	21	72,196	104,526	323,729	9	84	93	9
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.1.4. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Without Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	1.6	4	1.6	7	12	2,808
3	3,000	5.2	15	5.2	24	39	9,089
0.3	3,000	8.3	23	8.3	39	62	14,523
0.03	3,000	10.7	30	10.7	50	79	18,673
MEDIUM							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	3.7	10	3.7	17	28	6,494
0.3	3,000	7.5	21	7.5	35	56	13,149
0.03	3,000	9.9	28	9.9	46	74	17,309
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	2.3	6	2.3	11	17	4,024
0.03	3,000	7.0	19	7.0	32	52	12,156
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (260,000 ft^2)		$235/m^3

Table C.1.4. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Without Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	12	15	0	100	2,629	1	2	4,000	2,650	4,220	21,101	147,709
3	39	47	0	100	8,508	1	4	4,000	5,300	13,658	68,289	478,023
0.3	62	75	0	100	13,596	1	6	4,000	7,950	21,825	109,123	763,863
0.03	79	97	0	200	17,482	2	8	8,000	10,600	28,061	140,307	982,149
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	28	34	0	100	6,079	1	3	4,000	3,975	9,759	48,793	341,553
0.3	56	68	0	100	12,309	1	6	4,000	7,950	19,759	98,796	691,573
0.03	74	90	0	200	16,204	2	7	8,000	9,275	26,011	130,054	910,375
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	17	21	0	100	3,767	1	2	4,000	2,650	6,047	30,233	211,634
0.03	52	63	0	100	11,380	1	5	4,000	6,625	18,267	91,335	639,345
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.1.4. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Without Soil Washing)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $50/ft^3 Disposal Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	12	11,129	29,189	155,796	0	19	19	2
3	39	26,846	91,186	500,921	0	63	63	6
0.3	62	40,448	145,193	799,932	0	100	100	10
0.03	79	54,935	187,062	1,028,904	0	129	129	13
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	28	20,353	65,341	358,101	0	45	45	4
0.3	56	37,008	132,204	724,981	0	91	91	9
0.03	74	51,520	172,841	953,163	0	119	119	12
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	17	14,170	40,674	222,075	0	28	28	3
0.03	52	34,523	121,496	669,506	0	84	84	8
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.1.5.

Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, With Soil Washing, 50-Year SAFSTOR)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	2.8	8	2.8	13	21	4,895
0.3	3,000	55.5	155	55.5	258	413	96,990
0.03	3,000	65.6	183	65.6	305	487	114,548
MEDIUM							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	14.3	40	14.3	66	106	24,937
0.03	3,000	60.3	168	60.3	280	448	105,238
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	0.0	0	0.0	0	0	0
0.03	3,000	50.2	140	50.2	233	373	87,647
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (250,000 ft^2)		$235/m^3

Table C.1.5. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, With Soil Washing, 50-Year SAFSTOR)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	21	25	39,942	100	1,833	1	1	4,000	1,325	2,842	14,712	102,982
0.3	413	503	150,183	300	36 320	3	16	12,000	21,200	58,301	291,503	2,040,519
0.03	487	594	171,201	300	42 895	3	18	12,000	23,850	68,855	344,273	2,409,912
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	106	129	63,933	100	9,338	1	4	4,000	5,300	14,990	74,948	524,634
0.03	448	546	160,056	300	39,408	3	17	12,000	22,525	63,258	316,292	2,214,041
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0
0.03	373	454	138,999	300	32,821	3	14	12,000	18,550	52,684	263,422	1,843,952
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	85 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.1.5. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, With Soil Washing, 50-Year SAFSTOR)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs @ $10/ft^3 Disposal Costs	@ $50/ft^3 Disposal Costs	@ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	8	51,879	62,706	150,976	4	34	37	4
0.3	165	317,774	596,196	2,345,211	70	669	739	74
0.03	195	368,904	696,767	2,762,406	83	790	873	87
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	42	107,959	178,456	628,142	18	172	190	19
0.03	179	340,852	643,519	2,541,268	76	725	802	80
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0
0.03	149	291,630	541,439	2,121,969	63	604	668	67
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.1.6. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Without Soil Washing, 50-Year SAFSTOR)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	2.8	8	2.8	13	21	4,895
0.3	3,000	55.5	155	55.5	258	413	96,990
0.03	3,000	65.6	183	65.6	305	487	114,548
MEDIUM							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	14.3	40	14.3	66	106	24,937
0.03	3,000	60.3	168	60.3	280	448	105,238
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	0.0	0	0.0	0	0	0
0.03	3,000	50.2	140	50.2	233	373	87,647
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (250,000 ft^2)		$235/m^3

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Table C.1.6. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Without Soil Washing, 50-Year SAFSTOR)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $60/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	21	25	0	100	4,582	1	2	4,000	2,650	7,356	36,779	257,454
0.3	413	503	0	600	90,799	6	38	24,000	50,350	145,751	728,757	5,101,296
0.03	487	594	0	700	107,237	7	45	28,000	59,625	172,137	860,683	6,024,780
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	106	129	0	200	23,345	2	10	8,000	13,250	37,474	187,369	1,311,585
0.03	448	546	0	700	98,521	7	42	28,000	55,650	158,146	790,729	5,535,101
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0
0.03	373	454	0	600	82,052	6	35	24,000	48,375	131,711	658,554	4,609,880
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	86 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $60/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.1.6. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Without Soil Washing, 50-Year SAFSTOR)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs @ $10/ft^3 Disposal Costs	Total Soil Remediation Costs @ $50/ft^3 Disposal Costs	Total Soil Remediation Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	21	16,351	48,907	269,581	0	34	34	3
0.3	413	267,341	966,896	5,339,436	0	669	669	67
0.03	487	315,385	1,142,093	6,306,190	0	790	790	79
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	(	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	106	70,611	248,902	1,373,118	0	172	172	17
0.03	448	292,084	1,050,137	5,794,510	0	725	725	73
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0
0.03	373	243,958	874,629	4,825,954	0	604	604	60
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.1.7. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, With Soil Washing, 50-Year SAFSTOR)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	0.0	0	0.0	0	0	0
0.03	3,000	5.9	16	5.9	27	44	10,243
MEDIUM							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	0.0	0	0.0	0	0	0
0.03	3,000	3.2	9	3.2	15	24	5,612
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	0.0	0	0.0	0	0	0
0.03	3,000	0.0	0	0.0	0	0	0
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (250,000 ft^2)		$236/m^3

Table C.1.7. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, With Soil Washing, 50-Year SAFSTOR)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0
0.03	44	53	46,343	100	3,836	1	2	4,000	2,650	6,157	30,784	215,489
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0
0.03	24	29	40,800	100	2,101	1	1	4,000	1,325	3,373	16,866	118,061
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0
0.03	0	0	0	0	0	0	0	0	0	0	0	0
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	96 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.1.7. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, With Soil Washing, 50-Year SAFSTOR)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs @ $10/ft^3 Disposal Costs	@ $50/ft^3 Disposal Costs	@ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0
0.03	17	66,843	93,856	278,561	7	71	78	8
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0
0.03	10	53,885	66,704	167,899	4	39	43	4
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0
0.03	0	0	0	0	0	0	0	0
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr lrbor

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Table C.1.8. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Without Soil Washing, 50-Year SAFSTOR)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	0.0	0	0.0	0	0	0
0.03	3,000	5.9	16	5.9	27	44	10,243
MEDIUM							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	C	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	0.0	0	0.0	0	0	0
0.03	3,000	3.2	9	3.2	15	24	5,612
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	0.0	0	0.0	0	0	0
0.03	3,000	0.0	0	0.0	0	0	0
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (250,000 ft^2)		$236/m^3

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Table C.1.8. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Without Soil Washing, 50-Year SAFSTOR)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0
0.03	44	53	0	100	9,589	1	5	4,000	6,625	15,392	76,960	538,723
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0
0.03	24	29	0	100	5,253	1	3	4,000	3,975	8,433	42,165	295,152
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0
0.03	0	0	0	0	0	0	0	0	0	0	0	0
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.1.8. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Without Soil Washing, 50-Year SAFSTOR)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $50/ft^3 Disposal Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0
0.03	44	29,735	103,417	565,179	0	71	71	7
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0
0.03	24	18,145	57,005	309,992	0	39	39	4
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0
0.03	0	0	0	0	0	0	0	0
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.1.9. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, With Soil Washing, Real World Soil Profile)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	4.4	12	3.3	15	28	6,471
60	3,000	8.0	22	4.6	21	44	10,281
30	3,000	17.9	50	5.9	27	77	18,149
25	3,000	20.8	58	6.2	29	87	20,400
15	3,000	28.9	80	7.0	33	113	26,582
10	3,000	35.3	98	7.8	36	135	31,609
3	3,000	54.5	152	11.5	54	205	48,279
0.3	3,000	91.3	254	20.5	95	349	82,107
0.03	3,000	128.2	357	24.9	116	473	111,116
MEDIUM							
100	3,000	1.8	5	0.0	0	5	1,191
60	3,000	3.5	10	2.5	11	21	4,980
30	3,000	7.6	21	4.5	21	42	9,969
25	3,000	9.7	27	4.9	23	50	11,704
15	3,000	17.4	48	5.8	27	75	17,729
10	3,000	23.8	66	6.5	30	97	22,691
3	3,000	43.1	120	8.2	38	158	37,205
0.3	3,000	80.0	223	16.5	77	299	70,372
0.03	3,000	116.9	326	22.4	104	430	101,043
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.9	3	0.0	0	3	611
3	3,000	5.1	14	3.6	17	31	7,356
0.3	3,000	37.4	104	8.4	39	143	33,596
0.03	3,000	73.9	206	18.7	87	293	68,826
Unit Rates and Notes		Humboldt Bay soil profile		Diffusion model soil profile used below buildings	2% of building floor area (250,000 ft^2)		$235/m^3

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Table C.1.9. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, With Soil Washing, Real World Soil Profile)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	28	34	41,828	100	2,423	1	2	4,000	2,650	3,889	19,447	136,130
60	44	53	46,366	100	3,843	1	2	4,000	2,650	6,168	30,840	215,882
30	77	94	55,807	100	6,796	1	3	4,000	3,975	10,909	54,546	381,823
25	87	106	58,502	100	7,639	1	4	4,000	5,300	12,263	61,313	429,189
15	113	138	65,902	100	9,954	1	5	4,000	6,625	15,978	79,892	559,247
10	135	164	71,920	100	11,837	1	5	4,000	6,625	19,000	95,001	665,004
3	205	250	91,874	200	18,079	2	8	8,000	10,600	29,020	145,101	1,015,708
0.3	349	426	132,368	200	30,747	2	13	8,000	17,225	49,354	246,772	1,727,406
0.03	473	576	167,092	300	41,609	3	18	12,000	23,850	66,791	333,957	2,337,696
MEDIUM												
100	5	6	35,508	100	446	1	1	4,000	1,325	716	3,579	25,056
60	21	26	40,043	100	1,865	1	1	4,000	1,325	2,993	14,966	104,763
30	42	52	46,016	100	3,[illegible]33	1	2	4,000	2,650	5,993	29,963	209,741
25	50	61	48,093	100	4,[illegible]83	1	2	4,000	2,650	7,035	35,177	246,236
15	75	92	55,305	100	6,639	1	3	4,000	3,975	10,657	53,284	372,986
10	97	118	61,245	100	8,497	1	4	4,000	5,300	13,640	68,198	477,388
3	158	193	78,619	100	13,932	1	6	4,000	7,950	22,364	111,820	782,741
0.3	299	365	118,320	200	26,352	2	12	8,000	15,900	42,300	211,502	1,480,513
0.03	430	524	155,034	300	37,837	3	16	2,000	21,200	60,737	303,683	2,125,782
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	3	3	34,814	100	229	1	1	4,000	1,325	367	1,836	12,853
3	31	38	42,888	100	2,756	1	2	4,000	2,650	4,422	22,109	154,765
0.3	143	174	74,299	100	12,581	1	6	4,000	7,950	20,195	100,973	706,814
0.03	293	357	116,469	200	25,773	2	11	8,000	14,575	41,371	206,856	1,447,982
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.1.9. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, With Soil Washing, Real World Soil Profile)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs @ $10/ft^3 Disposal Costs	Total Soil Remediation Costs @ $50/ft^3 Disposal Costs	Total Soil Remediation Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	11	56,288	72,819	189,502	5	45	49	5
60	17	66,895	93,960	279,001	7	71	78	8
30	31	88,965	139,274	466,561	13	125	138	14
25	35	95,265	153,164	521,030	15	141	155	16
15	45	112,563	188,956	668,311	19	183	202	20
10	54	126,629	216,991	786,994	23	218	241	24
3	82	177,373	313,933	1,184,540	35	333	368	37
0.3	140	272,030	509,219	1,989,853	59	566	625	63
0.03	189	357,299	677,623	2,681,363	80	766	846	85
MEDIUM								
100	2	41,515	42,050	63,526	1	8	9	1
60	8	52,116	63,179	152,975	4	34	38	4
30	17	66,078	92,332	272,110	7	69	76	8
25	20	70,932	102,006	313,066	8	81	89	9
15	30	87,790	136,931	456,633	13	122	135	14
10	39	101,676	166,931	575,121	16	156	173	17
3	63	142,288	249,526	920,448	27	256	283	28
0.3	120	239,192	442,446	1,711,457	51	485	536	54
0.03	172	329,114	618,798	2,440,896	73	697	770	77
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	1	39,892	38,815	49,831	0	4	5	0
3	13	58,766	77,758	210,414	5	51	56	6
0.3	57	132,190	229,399	835,240	24	232	256	26
0.03	117	234,866	432,497	1,673,626	50	474	524	52
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.1.10. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Without Soil Washing, Real World Soil Profile)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	4.4	12	3.3	15	28	6,471
60	3,000	8.0	22	4.6	21	44	10,261
30	3,000	17.9	50	5.9	27	77	18,149
25	3,000	20.8	58	6.2	29	87	20,400
15	3,000	28.9	80	7.0	33	113	26,582
10	3,000	35.3	98	7.8	36	135	31,609
3	3,000	54.5	152	11.5	54	205	48,279
0.3	3,000	91.3	254	20.5	95	349	82,107
0.03	3,000	128.2	357	24.9	116	473	111,116
MEDIUM							
100	3,000	1.8	5	0.0	0	5	1,191
60	3,000	3.5	10	2.5	11	21	4,980
30	3,000	7.6	21	4.5	21	42	9,969
25	3,000	9.7	27	4.9	23	50	11,704
15	3,000	17.4	48	5.8	27	75	17,729
10	3,000	23.8	66	6.5	30	97	22,691
3	3,000	43.1	120	8.2	38	158	37,205
0.3	3,000	80.0	223	16.5	77	299	70,372
0.03	3,000	116.9	326	22.4	104	430	101,043
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.9	3	0.0	0	3	611
3	3,000	5.1	14	3.6	17	31	7,356
0.3	3,000	37.4	104	8.4	39	143	33,596
0.03	3,000	73.9	206	18.7	87	293	68,826
Unit Rates and Notes		Humboldt Bay soil profile		Diffusion model soil profile used below buildings	2% of building floor area (250,000 ft^2)		$235/m^3

Table C.1.10. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Without Soil Washing, Real World Soil Profile)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	28	34	0	100	6,058	1	3	4,000	3,975	9,724	48,618	340,326
60	44	53	0	100	9,606	1	5	4,000	6,625	15,420	77,101	539,704
30	77	94	0	200	16,990	2	8	8,000	10,600	27,273	136,365	954,558
25	87	106	0	200	19,098	2	8	8,000	10,600	30,656	153,282	1,072,972
15	113	138	0	200	24,885	2	11	8,000	14,575	39,946	199,731	1,398,117
10	135	164	0	200	29,591	2	13	8,000	17,225	47,500	237,501	1,662,510
3	205	250	0	300	45,197	3	19	12,000	25,175	72,551	362,753	2,539,271
0.3	349	426	0	500	76,866	5	33	20,000	43,725	123,386	616,931	4,318,515
0.03	473	576	0	700	104,023	7	44	28,000	58,300	166,978	834,891	5,844,240
MEDIUM												
100	5	6	0	100	1,115	1	1	4,000	1,325	1,790	8,949	62,641
60	21	26	0	100	4,662	1	2	4,000	2,650	7,483	37,415	261,907
30	42	52	0	100	9,333	1	4	4,000	5,300	14,981	74,907	524,352
25	50	61	0	100	10,957	1	5	4,000	6,625	17,588	87,941	615,590
15	75	92	0	200	16,597	2	7	8,000	9,275	26,642	133,209	932,466
10	97	118	0	200	21,243	2	9	8,000	11,925	34,099	170,496	1,193,470
3	158	193	0	300	34,831	3	15	12,000	19,875	55,910	279,551	1,956,854
0.3	299	365	0	500	65,880	5	28	20,000	37,100	105,751	528,755	3,701,283
0.03	430	524	0	700	94,593	7	40	28,000	53,000	151,842	759,208	5,314,455
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	3	3	0	100	572	1	1	4,000	1,325	918	4,590	32,132
3	31	38	0	100	6,887	1	3	4,000	3,975	11,055	55,273	386,912
0.3	143	174	0	300	31,452	3	14	12,000	18,550	50,487	252,434	1,767,035
0.03	293	357	0	500	64,432	5	27	20,000	35,775	103,427	517,138	3,619,955
Unit Rates and Notes		7[illegible] lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.1.10. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Without Soil Washing, Real World Soil Profile)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $50/ft^3 Disposal Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	28	20,294	65,121	356,829	0	45	45	4
60	44	29,781	103,593	566,197	0	71	71	7
30	77	53,622	182,105	1,000,297	0	125	125	13
25	87	59,257	203,380	1,123,070	0	141	141	14
15	113	74,728	265,774	1,464,160	0	183	183	18
10	135	87,309	315,927	1,740,935	0	218	218	22
3	205	133,129	481,404	2,657,922	0	333	333	33
0.3	349	225,993	819,629	4,521,214	0	566	566	57
0.03	473	306,794	1,108,330	6,117,679	0	766	766	77
MEDIUM								
100	5	7,081	12,580	66,272	0	8	8	1
60	21	16,563	49,707	274,198	0	34	34	3
30	42	29,051	99,510	548,954	0	69	69	7
25	50	33,392	117,228	644,876	0	81	81	8
15	75	52,671	176,810	976,067	0	122	122	12
10	97	64,990	226,355	1,249,329	0	156	156	16
3	158	105,415	371,461	2,048,764	0	256	256	26
0.3	299	196,623	702,107	3,874,635	0	485	485	49
0.03	430	281,584	1,007,844	5,563,091	0	697	697	70
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	3	5,629	7,098	34,640	0	4	4	0
3	31	22,511	73,491	405,130	0	51	51	5
0.3	143	96,383	338,032	1,850,633	0	232	232	23
0.03	293	192,753	686,169	3,788,988	0	474	474	47
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.1.11. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, With Soil Washing, Real World Soil Profile)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.1	0	0.0	0	0	41
25	3,000	0.5	1	0.0	0	1	350
15	3,000	1.8	5	0.0	0	5	1,188
10	3,000	3.0	8	1.6	7	16	3,748
3	3,000	12.8	36	5.2	24	60	14,050
0.3	3,000	49.3	137	8.3	39	176	41,381
0.03	3,000	86.1	240	10.7	50	290	68,078
MEDIUM							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.9	3	0.0	0	3	617
3	3,000	5.2	14	3.7	17	32	7,458
0.3	3,000	37.9	106	7.5	35	141	33,063
0.03	3,000	74.8	209	9.9	46	255	59,832
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	3.6	10	2.3	11	21	4,878
0.03	3,000	32.2	90	7.0	32	122	28,657
Unit Rates and Notes		Humboldt Bay soil profile		Diffusion model soil profile used below buildings	2% of building floor area (250,000 ft^2)		$235/m^3

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Table C.1.11. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, With Soil Washing, Real World Soil Profile)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	34,132	100	15	1	1	4,000	1,325	25	124	868
25	1	2	34,502	100	131	1	1	4,000	1,325	211	1,053	7,373
15	5	6	35,504	100	445	1	1	4,000	1,325	714	3,569	24,984
10	16	19	38,569	100	1,404	1	1	4,000	1,325	2,253	11,266	78,860
3	60	73	50,900	100	5,261	1	3	4,000	3,975	8,445	42,226	295,582
0.3	176	215	83,617	100	15,496	1	7	4,000	9,275	24,874	124,370	870,590
0.03	290	353	115,574	200	25,493	2	11	8,000	14,575	40,922	204,608	1,432,256
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	3	3	34,822	100	231	1	1	4,000	1,325	371	1,856	12,990
3	32	39	43,010	100	2,793	1	2	4,000	2,650	4,483	22,414	156,897
0.3	141	171	73,661	100	12,381	1	6	4,000	7,950	19,874	99,372	695,602
0.03	255	310	105,703	200	22,405	2	10	8,000	13,250	35,965	179,824	1,258,769
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	21	25	39,922	100	1,827	1	1	4,000	1,325	2,932	14,662	102,631
0.03	122	149	68,385	100	10,731	1	5	4,000	6,625	17,225	86,127	602,889
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,298 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.1.11. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, With Soil Washing, Real World Soil Profile)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs			Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
		@ $10/ft^3 Disposal Costs	@ $[illegible]/ft^3 Disposal Costs	@ $350/ft^3 Disposal Costs				
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	38,298	35,638	36,382	0	0	0	0
25	1	39,163	37,362	43,682	0	2	3	0
15	2	41,505	42,030	63,445	1	8	9	1
10	6	48,671	56,312	123,907	3	26	29	3
3	24	77,495	116,412	369,768	10	97	107	11
0.3	70	153,972	274,139	1,020,359	30	285	315	32
0.03	116	232,774	428,329	1,655,976	49	469	519	52
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	1	39,910	38,851	49,985	0	4	5	0
3	13	59,050	78,324	212,807	5	51	57	6
0.3	56	130,698	226,427	822,657	24	228	252	25
0.03	102	209,700	381,015	1,459,959	43	412	456	46
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	8	51,832	62,613	150,582	4	34	37	4
0.03	49	118,367	200,525	717,287	21	198	218	22
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.1.12. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Without Soil Washing, Real World Soil Profile)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.1	0	0.0	0	0	41
25	3,000	0.5	1	0.0	0	1	350
15	3,000	1.8	5	0.0	0	5	1,188
10	3,000	3.0	8	1.6	7	16	3,748
3	3,000	12.8	36	5.2	24	60	14,050
0.3	3,000	49.3	137	8.3	39	176	41,381
0.03	3,000	86.1	240	10.7	50	290	68,078
MEDIUM							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.9	3	0.0	0	3	617
3	3,000	5.2	14	3.7	17	32	7,458
0.3	3,000	37.9	106	7.5	35	141	33,063
0.03	3,000	74.8	209	9.9	46	255	59,832
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	3.6	10	2.3	11	21	4,878
0.03	3,000	32.2	90	7.0	32	122	28,657
Unit Rates and Notes		Humboldt Bay soil profile		Diffusion model soil profile used below buildings	2% of building floor area (250,000 ft^2)		$235/m^3

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Table C.1.12. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Without Soil Washing, Real World Soil Profile)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	100	39	1	1	4,000	1,325	62	310	2,171
25	1	2	0	100	328	1	1	4,000	1,325	527	2,633	18,433
15	5	6	0	100	1,112	1	1	4,000	1,325	1,785	8,923	62,460
10	16	19	0	100	3,509	1	2	4,000	2,650	5,633	28,164	197,151
3	60	73	0	100	13,153	1	6	4,000	7,950	21,113	105,565	738,955
0.3	176	215	0	300	38,740	3	17	12,000	22,525	62,185	310,925	2,176,476
0.03	290	353	0	500	63,733	5	27	20,000	35,775	102,304	511,520	3,580,639
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	3	3	0	100	578	1	1	4,000	1,325	928	4,639	32,474
3	32	39	0	100	6,982	1	3	4,000	3,975	11,207	56,035	392,244
0.3	141	171	0	200	30,953	2	13	8,000	17,225	49,686	248,429	1,739,005
0.03	255	310	0	400	56,013	4	24	16,000	31,800	89,912	449,560	3,146,922
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	21	25	0	100	4,567	1	2	4,000	2,650	7,331	36,654	256,576
0.03	122	149	0	200	26,827	2	12	8,000	15,900	43,063	215,317	1,507,222
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.1.12. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Without Soil Washing, Real World Soil Profile)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $50/ft^3 Disposal Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	4,203	1,715	3,576	0	0	0	0
25	1	4,977	4,637	20,437	0	2	2	0
15	5	7,072	12,547	66,085	0	8	8	1
10	16	13,481	38,072	207,058	0	26	26	3
3	60	39,263	140,717	774,107	0	97	97	10
0.3	176	115,866	413,571	2,279,121	0	285	285	29
0.03	290	190,882	679,106	3,748,225	0	469	469	47
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	3	5,645	7,160	34,994	0	4	4	0
3	32	22,765	74,449	410,658	0	51	51	5
0.3	141	90,948	329,671	1,820,246	0	228	228	23
0.03	255	166,144	597,205	3,294,566	0	412	412	41
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	21	16,309	48,749	268,671	0	34	34	3
0.03	122	79,920	286,701	1,578,606	0	198	198	20
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.1.13. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, With Soil Washing, Real World Data, 50-Year SAFSTOR)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	2.5	7	2.5	12	19	4,451
3	3,000	7.4	21	7.4	34	55	12,943
0.3	3,000	30.7	86	30.7	143	228	53,626
0.03	3,000	60.9	170	60.9	283	453	106,357
MEDIUM							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	1.8	5	1.8	9	14	3,217
0.3	3,000	15.0	42	15.0	70	112	26,246
0.03	3,000	44.3	123	44.3	206	329	77,360
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	4.5	12	4.5	21	33	7,796
0.03	3,000	21.2	59	21.2	98	157	36,955
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (250,000 ft^2)		$235/m^3

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Table C.1.13. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, With Soil Washing, Real World Data, 50-Year SAFSTOR)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	19	23	39,410	100	1,667	1	1	4,000	1,326	2,675	13,377	93,641
3	55	67	49,576	100	4,847	1	3	4,000	3,976	7,780	38,901	272,306
0.3	228	278	98,274	200	20,081	2	9	8,000	11,926	32,234	161,171	1,128,197
0.03	453	551	161,395	300	39,827	3	17	12,000	22,525	63,931	319,654	2,237,579
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	14	17	37,933	100	1,205	1	1	4,000	1,326	1,934	9,668	67,679
0.3	112	136	65,500	100	9,828	1	5	4,000	6,625	15,776	78,882	552,177
0.03	329	401	126,685	200	28,969	2	13	8,000	17,225	46,501	232,504	1,627,527
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	33	40	43,414	100	2,919	1	2	4,000	2,650	4,686	23,430	164,012
0.03	157	192	78,319	100	13,838	1	6	4,000	7,950	22,213	111,067	777,469
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.1.13. **Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, With Soil Washing, Real World Data , 50-Year SAFSTOR)**

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs @ $10/ft^3 Disposal Costs	@ $50/ft^3 Disposal Costs	@ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	8	50,637	60,230	140,494	3	31	34	3
3	22	74,400	110,242	343,647	9	89	99	10
0.3	91	192,334	346,077	1,312,103	39	370	408	41
0.03	181	343,983	649,758	2,567,683	77	733	810	81
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	5	47,184	53,348	111,359	2	22	25	2
0.3	45	111,623	187,082	660,377	19	181	200	20
0.03	132	258,745	482,742	1,877,766	56	533	589	59
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	13	59,996	80,210	220,791	6	54	59	6
0.03	63	141,587	248,129	914,531	27	255	281	28
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.1.14. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Without Soil Washing, Real World Data, 50-Year SAFSTOR)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	2.5	7	2.5	12	19	4,451
3	3,000	7.4	21	7.4	34	55	12,943
0.3	3,000	30.7	86	30.7	143	228	53,626
0.03	3,000	60.9	170	60.9	283	453	106,357
MEDIUM							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	1.8	5	1.8	9	14	3,217
0.3	3,000	15.0	42	15.0	70	112	26,246
0.03	3,000	44.3	123	44.3	206	329	77,360
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	4.5	12	4.5	21	33	7,796
0.03	3,000	21.2	59	21.2	98	157	36,955
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (250,000 ft^2)		$235/m^3

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Table C.1.14. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Without Soil Washing, Real World Data, 50-Year SAFSTOR)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	19	23	0	100	4,167	1	2	4,000	2,650	6,689	33,443	234,102
3	56	67	0	100	12,117	1	6	4,000	7,950	19,450	97,252	680,765
0.3	228	278	0	400	50,203	4	21	16,000	27,825	80,585	402,927	2,820,492
0.03	463	561	0	700	99,568	7	42	28,000	55,650	159,827	799,135	5,593,946
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	14	17	0	100	3,012	1	2	4,000	2,650	4,834	24,171	169,198
0.3	112	136	0	200	24,571	2	11	8,000	14,576	39,441	197,206	1,380,443
0.03	329	401	0	500	72,422	5	31	20,000	41,076	116,252	581,260	4,068,818
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	33	40	0	100	7,298	1	4	4,000	5,300	11,716	58,576	410,030
0.03	157	192	0	300	34,596	3	15	12,000	19,875	55,534	277,668	1,943,673
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.1.14. **Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Unrestricted Land Use, Without Soil Washing, Real World Data, 50-Year SAFSTOR)**

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $50/ft^3 Dispos-l Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing - Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	19	15,240	44,711	245,369	0	31	31	3
3	55	36,494	130,263	713,776	0	89	89	9
0.3	228	150,611	534,581	2,952,145	0	370	370	37
0.03	453	294,884	1,060,710	5,855,521	0	733	733	73
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	14	12,151	33,050	178,076	0	22	22	2
0.3	112	73,887	262,598	1,445,835	0	181	181	18
0.03	329	214,112	772,116	4,259,675	0	533	533	53
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	33	23,611	78,970	430,424	0	54	54	5
0.03	157	104,788	365,093	2,035,098	0	255	255	26
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.1.15. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, With Soil Washing, Real World Data, 50-Year SAFSTOR)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	5.5	15	5.5	25	41	9,538
0.03	3,000	24.6	68	24.6	114	183	42,915
MEDIUM							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	0.0	0	0.0	0	0	0
0.03	3,000	11.7	33	11.7	54	87	20,482
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	0.0	0	0.0	0	0	0
0.03	3,000	2.6	7	2.6	12	20	4,601
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (250,000 ft^2)		$235/m^3

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Table C.1.15. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, With Soil Washing, Real World Data, 50-Year SAFSTOR)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	41	49	45,499	100	3,572	1	2	4,000	2,650	5,733	28,665	200,658
0.03	183	223	85,454	200	16,070	2	7	8,000	9,275	25,796	128,982	902,872
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0
0.03	87	106	58,601	100	7,670	1	4	4,000	5,300	12,312	61,559	430,915
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0
0.03	20	24	39,590	100	1,723	1	1	4,000	1,325	2,766	13,828	96,799
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.1.15. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, With Soil Washing, Real World Data, 50-Year SAFSTOR)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs @ $10/ft^3 Disposal Costs	@ $50/ft^3 Disposal Costs	@ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	16	64,870	89,924	261,917	7	66	73	7
0.03	73	162,368	282,696	1,056,587	31	296	327	33
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0
0.03	35	95,496	153,612	522,967	15	141	156	16
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0
0.03	8	51,057	61,068	144,038	3	32	35	4
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.1.16. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Without Soil Washing, Real World Data, 50-Year SAFSTOR)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	5.5	15	5.5	25	41	9,538
0.03	3,000	24.6	68	24.6	114	183	42,916
MEDIUM							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	0.0	0	0.0	0	0	0
0.03	3,000	11.7	33	11.7	54	87	20,482
LOW							
100	3,000	0.0	0	0.0	0	0	0
60	3,000	0.0	0	0.0	0	0	0
30	3,000	0.0	0	0.0	0	0	0
25	3,000	0.0	0	0.0	0	0	0
15	3,000	0.0	0	0.0	0	0	0
10	3,000	0.0	0	0.0	0	0	0
3	3,000	0.0	0	0.0	0	0	0
0.3	3,000	0.0	0	0.0	0	0	0
0.03	3,000	2.6	7	2.6	12	20	4,601
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (250,000 ft^2)		$235/m^3

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Table C.1.16. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Without Soil Washing, Real World Data, 50-Year SAFSTOR)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	41	49	0	100	8,929	1	4	4,000	5,300	14,333	71,664	501,646
0.03	183	223	0	300	40,176	3	17	12,000	22,525	64,491	322,454	2,257,181
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0
0.03	87	106	0	200	19,175	2	9	8,000	11,925	30,780	153,898	1,077,286
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0	0	0	0	0
0.03	20	24	0	100	4,307	1	2	4,000	2,650	6,914	34,571	241,998
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.1.16. **Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Nuclear Power Plant (Restricted Land Use, Without Soil Washing, Real World Data, 50-Year SAFSTOR)**

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs @ $10/ft^3 Disposal Costs	Total Soil Remediation Costs @ $50/ft^3 Disposal Costs	Total Soil Remediation Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	41	27,970	95,430	525,412	0	66	66	7
0.03	183	119,706	428,[illegible]71	2,362,797	0	296	296	30
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0
0.03	87	59,462	205,480	1,128,869	0	141	141	14
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	0	0	0	0	0	0	0	0
0.03	20	15,615	46,130	253,557	0	32	32	3
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.2.1. **Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, With Soil Washing)**

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	100,000	18.4	1,707	18.4	82	1,789	420,394
60	100,000	19.7	1,834	19.7	88	1,922	451,570
30	100,000	21.3	1,983	21.3	95	2,078	488,333
25	100,000	21.7	2,019	21.7	97	2,115	497,132
15	100,000	22.8	2,114	22.8	101	2,215	520,560
10	100,000	23.5	2,186	23.5	105	2,291	538,305
3	100,000	25.6	2,378	25.6	114	2,492	585,601
0.3	100,000	28.9	2,688	28.9	129	2,817	662,103
0.03	100,000	31.9	2,964	31.9	142	3,106	729,948
MEDIUM							
100	100,000	8.6	802	8.6	38	840	197,438
60	100,000	14.2	1,318	14.2	63	1,381	324,514
30	100,000	17.1	1,588	17.1	76	1,665	391,190
25	100,000	17.7	1,644	17.7	79	1,723	404,977
15	100,000	19.2	1,779	19.2	85	1,865	438,246
10	100,000	20.2	1,874	20.2	90	1,964	461,522
3	100,000	22.8	2,114	22.8	101	2,215	520,560
0.3	100,000	26.7	2,478	26.7	119	2,597	610,368
0.03	100,000	29.9	2,776	29.9	133	2,909	683,711
LOW							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	8.6	802	8.6	38	840	197,438
10	100,000	13.6	1,259	13.6	60	1,320	310,110
3	100,000	18.4	1,707	18.4	82	1,789	420,394
0.3	100,000	23.5	2,186	23.5	105	2,291	538,305
0.03	100,000	27.3	2,533	27.3	122	2,655	623,915
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (240,000 ft2)		$236/m^3

Table C.2.1. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, With Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	1,789	2,180	537,310	1,100	157,424	11	66	44,000	87,450	252,698	1,263,490	8,844,427
60	1,922	2,341	574,628	1,100	169,099	11	71	44,000	94,075	271,438	1,357,189	9,500,320
30	2,078	2,532	618,635	1,200	182,865	12	77	48,000	102,025	293,536	1,467,680	10,273,758
25	2,115	2,578	629,168	1,200	186,160	12	78	48,000	103,350	298,825	1,494,126	10,458,884
15	2,215	2,699	657,212	1,300	194,933	13	82	52,000	108,650	312,907	1,564,536	10,951,755
10	2,291	2,791	678,453	1,300	201,578	13	85	52,000	112,625	323,574	1,617,868	11,325,079
3	2,492	3,036	735,069	1,500	219,289	15	92	60,000	121,900	352,004	1,760,018	12,320,124
0.3	2,817	3,433	826,644	1,600	247,936	16	104	64,000	137,800	397,988	1,989,942	13,929,597
0.03	3,106	3,785	907,857	1,800	273,342	18	115	72,000	152,375	438,770	2,193,851	15,356,959
MEDIUM												
100	840	1,024	270,423	500	73,934	5	31	20,000	41,075	118,679	593,397	4,153,776
60	1,381	1,683	422,538	800	121,520	8	51	32,000	67,575	195,065	975,324	6,827,268
30	1,665	2,028	502,351	1,000	146,488	10	62	40,000	82,150	235,143	1,175,716	8,230,015
25	1,723	2,100	518,855	1,000	151,651	10	64	40,000	84,800	243,431	1,217,154	8,520,078
15	1,865	2,272	558,679	1,100	164,109	11	69	44,000	91,425	263,429	1,317,144	9,220,010
10	1,964	2,393	586,541	1,200	172,825	12	73	48,000	96,725	277,420	1,387,099	9,709,692
3	2,215	2,699	657,212	1,300	194,933	13	82	52,000	108,650	312,907	1,564,536	10,951,755
0.3	2,597	3,165	764,716	1,500	228,563	15	96	60,000	127,200	366,891	1,834,455	12,841,182
0.03	2,909	3,545	852,510	1,700	256,028	17	108	63,000	143,100	410,978	2,054,888	14,384,213
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	840	1,024	270,423	500	73,934	5	31	20,000	41,075	118,679	593,397	4,153,776
10	1,320	1,608	405,296	800	116,126	8	49	32,000	64,925	186,407	932,033	6,524,230
3	1,789	2,180	537,310	1,100	157,424	11	66	44,000	87,450	252,698	1,263,490	8,844,427
0.3	2,291	2,791	678,453	1,300	201,578	13	85	52,000	112,625	323,574	1,617,868	11,325,079
0.03	2,655	3,235	780,932	1,600	233,636	16	98	64,000	129,850	375,034	1,875,171	13,126,194
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,326 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.2.1. **Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, With Soil Washing)**

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs @ $10/ft^3 Disposal Costs	Total Soil Remediation Costs @ $60/ft^3 Disposal Costs	Total Soil Remediation Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	716	1,255,501	2,466,067	10,047,004	304	2,898	3,202	320
60	769	1,342,736	2,646,560	10,789,692	327	3,113	3,440	344
30	831	1,449,704	2,859,538	11,665,617	353	3,368	3,720	372
25	846	1,474,326	2,909,937	11,874,695	360	3,427	3,787	379
15	886	1,543,979	3,045,891	12,433,110	377	3,589	3,965	397
10	916	1,593,631	3,148,829	12,856,040	389	3,711	4,100	410
3	997	1,734,173	3,421,876	13,981,982	424	4,037	4,461	446
0.3	1,127	1,952,335	3,864,425	15,804,080	479	4,564	5,043	504
0.03	1,242	2,150,376	4,257,374	17,420,482	528	5,032	5,560	556
MEDIUM								
100	336	607,040	1,176,266	4,736,645	143	1,361	1,504	150
60	552	974,917	1,911,472	7,763,416	235	2,237	2,472	247
30	666	1,169,684	2,297,895	9,352,194	283	2,697	2,980	298
25	689	1,208,263	2,3[illegible]7,437	9,680,361	293	2,792	3,085	308
15	746	1,305,454	2,569,604	10,472,470	317	3,021	3,338	334
10	786	1,374,683	2,704,712	11,027,305	334	3,182	3,515	352
3	886	1,543,979	3,045,891	12,433,110	377	3,589	3,965	397
0.3	1,039	1,803,475	3,565,301	14,572,028	442	4,208	4,649	465
0.03	1,164	2,016,899	3,990,238	16,319,563	495	4,713	5,208	521
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	336	607,040	1,176,266	4,736,645	143	1,361	1,504	150
10	528	934,613	1,828,490	7,420,688	224	2,138	2,362	236
3	716	1,255,501	2,466,067	10,047,004	304	2,898	3,202	320
0.3	916	1,593,631	3,148,829	12,856,040	389	3,711	4,100	410
0.03	1,082	1,845,481	3,643,504	14,894,528	461	4,301	4,752	475
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.2.2. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, Without Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	100,000	18.4	1,707	18.4	82	1,789	420,394
60	100,000	19.7	1,834	19.7	88	1,922	451,570
30	100,000	21.3	1,983	21.3	95	2,078	488,333
25	100,000	21.7	2,019	21.7	97	2,115	497,132
15	100,000	22.8	2,114	22.8	101	2,215	520,560
10	100,000	23.5	2,186	23.5	105	2,291	538,305
3	100,000	25.6	2,378	25.6	114	2,492	585,601
0.3	100,000	28.9	2,688	28.9	129	2,817	662,103
0.03	100,000	31.9	2,964	31.9	142	3,106	729,948
MEDIUM							
100	100,000	8.6	802	8.6	38	840	197,438
60	100,000	14.2	1,318	14.2	63	1,381	324,514
30	100,000	17.1	1,588	17.1	76	1,665	391,190
25	100,000	17.7	1,644	17.7	79	1,723	404,977
15	100,000	19.2	1,779	19.2	85	1,865	438,246
10	100,000	20.2	1,874	20.2	90	1,964	461,522
3	100,000	22.8	2,114	22.8	101	2,215	520,560
0.3	100,000	26.7	2,478	26.7	119	2,597	610,368
0.03	100,000	29.9	2,776	29.9	133	2,909	683,711
LOW							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	8.6	802	8.6	38	840	197,438
10	100,000	13.6	1,259	13.6	60	1,320	310,110
3	100,000	18.4	1,707	18.4	82	1,789	420,394
0.3	100,000	23.5	2,186	23.5	105	2,291	538,305
0.03	100,000	27.3	2,533	27.3	122	2,655	623,915
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (240,000 ft2)		$235/m^3

Table C.2.2. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, Without Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $60/ft^3	Soil Disposal Costs @ $360/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	1,789	2,180	0	2,600	393,560	26	165	104,000	218,625	631,745	3,158,724	22,111,067
60	1,922	2,341	0	2,800	422,746	28	177	112,000	234,525	678,594	3,392,971	23,750,800
30	2,078	2,532	0	3,000	457,163	30	192	120,000	254,400	733,840	3,669,199	25,684,396
25	2,115	2,578	0	3,000	465,401	30	195	120,000	258,375	747,063	3,735,316	26,147,209
15	2,215	2,699	0	3,200	487,332	32	204	128,000	270,300	782,268	3,911,341	27,379,389
10	2,291	2,791	0	3,300	503,945	33	211	132,000	279,575	808,934	4,044,671	28,312,699
3	2,492	3,036	0	3,600	548,222	36	230	144,000	304,750	880,009	4,400,044	30,800,309
0.3	2,817	3,433	0	4,000	619,841	40	260	160,000	344,500	994,971	4,974,856	34,823,993
0.03	3,106	3,785	0	4,400	683,356	44	286	176,000	378,950	1,096,926	5,484,628	38,392,398
MEDIUM												
100	840	1,024	0	1,200	184,835	12	78	48,000	103,350	296,698	1,483,491	10,384,440
60	1,381	1,683	0	2,000	303,801	20	127	80,000	168,275	487,662	2,438,310	17,068,171
30	1,665	2,028	0	2,400	366,220	24	154	96,000	204,050	587,858	2,939,291	20,575,039
25	1,723	2,100	0	2,500	379,127	25	159	100,000	210,675	608,577	3,042,885	21,300,195
15	1,865	2,272	0	2,700	410,273	27	172	108,000	227,900	658,572	3,292,861	23,050,025
10	1,964	2,393	0	2,800	432,063	28	181	112,000	239,825	693,549	3,467,747	24,274,230
3	2,215	2,699	0	3,200	487,332	32	204	128,000	270,300	782,268	3,911,341	27,379,389
0.3	2,597	3,165	0	3,700	571,408	37	239	148,000	316,675	917,227	4,586,136	32,102,954
0.03	2,909	3,545	0	4,200	640,070	42	268	168,000	355,100	1,027,444	5,137,219	35,960,532
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	840	1,024	0	1,200	184,835	12	78	48,000	103,350	296,698	1,483,491	10,384,440
10	1,320	1,608	0	1,900	290,316	19	122	76,000	161,650	466,016	2,330,082	16,310,575
3	1,789	2,180	0	2,600	393,560	26	165	104,000	218,625	631,745	3,158,724	22,111,067
0.3	2,291	2,791	0	3,300	503,945	33	211	132,000	279,575	808,934	4,044,671	28,312,699
0.03	2,655	3,235	0	3,800	584,091	38	245	152,000	324,625	937,585	4,687,926	32,815,484
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,298 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $60/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $360/ft^3; truck transport only.

Table C.2.2. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, Without Soil Washing)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $50/ft^3 Disposal Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	1,789	1,158,739	4,191,303	23,143,646	0	2,898	2,898	290
60	1,922	1,244,964	4,501,813	24,859,641	0	3,113	3,113	311
30	2,078	1,345,173	4,869,095	26,884,292	0	3,366	3,366	337
25	2,115	1,367,196	4,956,224	27,368,117	0	3,427	3,427	343
15	2,215	1,434,028	5,189,533	28,657,581	0	3,589	3,589	359
10	2,291	1,482,539	5,366,495	29,634,523	0	3,711	3,711	371
3	2,492	1,613,210	5,838,617	32,238,882	0	4,037	4,037	404
0.3	2,817	1,821,074	6,601,300	36,450,436	0	4,564	4,564	456
0.03	3,106	2,007,274	7,276,882	40,184,652	0	5,032	5,032	503
MEDIUM								
100	840	543,336	1,969,114	10,870,063	0	1,361	1,361	136
60	1,381	894,176	3,234,900	17,864,760	0	2,237	2,237	224
30	1,665	1,077,448	3,900,751	21,536,499	0	2,697	2,697	270
25	1,723	1,116,054	4,037,664	22,294,975	0	2,792	2,792	279
15	1,865	1,207,518	4,369,280	24,126,444	0	3,021	3,021	302
10	1,964	1,269,871	4,601,157	25,407,639	0	3,182	3,182	318
3	2,215	1,434,028	5,189,533	28,657,581	0	3,589	3,589	359
0.3	2,597	1,679,295	6,084,588	33,601,405	0	4,208	4,208	421
0.03	2,909	1,883,355	6,816,101	37,639,413	0	4,713	4,713	471
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	840	543,336	1,969,114	10,870,063	0	1,361	1,361	136
10	1,320	854,027	3,092,158	17,072,651	0	2,138	2,138	214
3	1,789	1,158,739	4,191,303	23,143,646	0	2,898	2,898	290
0.3	2,291	1,482,539	5,366,495	29,634,523	0	3,711	3,711	371
0.03	2,655	1,717,300	6,220,557	34,348,116	0	4,301	4,301	430
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.2.3. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, With Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	10.8	1,008	10.8	48	1,056	248,163
10	100,000	14.2	1,316	14.2	63	1,379	324,096
3	100,000	18.7	1,734	18.7	83	1,817	427,001
0.3	100,000	23.7	2,202	23.7	106	2,308	542,387
0.03	100,000	27.4	2,549	27.4	122	2,671	627,774
MEDIUM							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	0.0	0	0.0	0	0	0
10	100,000	0.0	0	0.0	0	0	0
3	100,000	10.8	1,008	10.8	48	1,056	248,163
0.3	100,000	20.4	1,898	20.4	91	1,989	467,439
0.03	100,000	24.9	2,312	24.9	111	2,423	569,376
LOW							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	0.0	0	0.0	0	0	0
10	100,000	0.0	0	0.0	0	0	0
3	100,000	0.0	0	0.0	0	0	0
0.3	100,000	14.2	1,316	14.2	63	1,379	324,096
0.03	100,000	21.3	1,982	21.3	95	2,077	488,158
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (240,000 ft2)		$236/m^3

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Table C.2.3. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, With Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	1,056	1,287	331,143	600	92,929	6	39	24,000	51,675	149,171	745,853	5,220,968
10	1,379	1,680	422,038	800	121,364	8	51	32,000	67,575	194,814	974,068	6,818,476
3	1,817	2,214	545,219	1,100	159,898	11	67	44,000	88,775	256,670	1,283,346	8,983,436
0.3	2,308	2,812	683,339	1,400	203,106	14	85	56,000	112,625	326,027	1,630,137	11,410,961
0.03	2,671	3,255	785,551	1,600	235,081	16	99	64,000	131,175	377,353	1,886,767	13,207,372
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	1,056	1,287	331,143	600	92,929	6	39	24,000	51,675	149,171	745,853	5,220,968
0.3	1,989	2,424	593,624	1,200	175,041	12	74	48,000	98,050	280,977	1,404,883	9,834,181
0.03	2,423	2,952	715,647	1,400	213,213	14	90	56,000	119,250	342,251	1,711,255	11,978,784
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	1,379	1,680	422,038	800	121,364	8	51	32,000	67,575	194,814	974,068	6,818,476
0.03	2,077	2,531	618,425	1,200	182,799	12	77	48,000	102,025	293,431	1,467,153	10,270,070
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.2.3. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, With Soil Washing)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs @ $10/ft^3 Disposal Costs	@ $60/ft^3 Disposal Costs	@ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	422	753,077	1,469,764	5,944,879	180	1,711	1,890	189
10	552	973,748	1,909,141	7,753,549	234	2,234	2,469	247
3	727	1,273,990	2,504,242	10,204,329	309	2,944	3,252	325
0.3	923	1,609,154	3,171,595	12,952,419	392	3,739	4,131	413
0.03	1,069	1,856,278	3,666,349	14,986,953	454	4,328	4,782	478
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	422	753,077	1,469,764	5,944,879	180	1,711	1,890	189
0.3	796	1,391,240	2,739,037	11,168,335	338	3,222	3,560	356
0.03	969	1,684,675	3,328,742	13,596,271	412	3,925	4,337	434
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	552	973,748	1,909,141	7,753,549	234	2,234	2,469	247
0.03	831	1,449,214	2,858,561	11,661,478	353	3,365	3,718	372
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.2.4. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, Without Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	10.8	1,008	10.8	48	1,056	248,163
10	100,000	14.2	1,316	14.2	63	1,379	324,096
3	100,000	18.7	1,734	18.7	83	1,817	427,001
0.3	100,000	23.7	2,202	23.7	106	2,308	542,387
0.03	100,000	27.4	2,549	27.4	122	2,671	627,774
MEDIUM							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	0.0	0	0.0	0	0	0
10	100,000	0.0	0	0.0	0	0	0
3	100,000	10.8	1,008	10.8	48	1,056	248,163
0.3	100,000	20.4	1,898	20.4	91	1,989	467,439
0.03	100,000	24.9	2,312	24.9	111	2,423	569,376
LOW							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	0.0	0	0.0	0	0	0
10	100,000	0.0	0	0.0	0	0	0
3	100,000	0.0	0	0.0	0	0	0
0.3	100,000	14.2	1,316	14.2	63	1,379	324,096
0.03	100,000	21.3	1,982	21.3	95	2,077	488,158
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (240,000 ft2)		$235/m^3

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Table C.2.4. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, Without Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	1,056	1,287	0	1,500	232,323	15	98	60,000	129,850	372,926	1,864,631	13,052,420
10	1,379	1,680	0	2,000	303,409	20	127	80,000	168,275	487,034	2,435,170	17,046,191
3	1,817	2,214	0	2,600	399,746	26	168	104,000	222,600	641,674	3,208,370	22,458,589
0.3	2,308	2,812	0	3,300	507,766	33	213	132,000	282,225	815,069	4,075,343	28,527,404
0.03	2,671	3,255	0	3,800	587,703	38	246	152,000	325,950	943,384	4,716,919	33,018,430
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	1,056	1,287	0	1,500	232,323	15	98	60,000	129,850	372,926	1,864,631	13,052,420
0.3	1,989	2,424	0	2,900	437,602	29	183	116,000	242,475	702,441	3,512,207	24,585,452
0.03	2,423	2,952	0	3,500	533,033	35	223	140,000	295,475	855,627	4,278,137	29,946,961
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	1,379	1,680	0	2,000	303,409	20	127	80,000	168,275	487,034	2,435,170	17,046,191
0.03	2,077	2,531	0	3,000	456,999	30	192	120,000	254,400	733,576	3,667,882	25,675,176
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,326 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.2.4. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, Without Soil Washing)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $60/ft^3 Disposal Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	1,056	682,590	2,474,968	13,662,757	0	1,711	1,711	171
10	1,379	893,130	3,230,951	17,841,971	0	2,234	2,234	223
3	1,817	1,175,275	4,257,717	23,507,936	0	2,944	2,944	294
0.3	2,308	1,492,755	5,407,721	29,859,782	0	3,739	3,739	374
0.03	2,671	1,726,958	6,258,346	34,559,857	0	4,328	4,328	433
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	1,056	682,590	2,474,968	13,662,757	0	1,711	1,711	171
0.3	1,989	1,288,780	4,659,724	25,732,968	0	3,222	3,222	322
0.03	2,423	1,568,504	5,676,022	31,344,846	0	3,925	3,925	393
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	1,379	893,130	3,230,951	17,841,971	0	2,234	2,234	223
0.03	2,077	1,344,734	4,867,439	26,874,732	0	3,365	3,365	337
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.2.5. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, With Soil Washing, Mixing/Landfilling)

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Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	100,000	44.2	4,106	18.4	82	4,188	984,207
60	100,000	54.9	5,096	19.7	88	5,185	1,218,359
30	100,000	92.4	8,581	21.3	95	8,676	2,038,911
25	100,000	100.6	9,344	21.7	97	9,441	2,218,582
15	100,000	121.9	11,325	22.8	101	11,426	2,685,102
10	100,000	141.9	13,185	23.5	105	13,290	3,123,158
3	100,000	198.1	18,403	25.6	114	18,518	4,351,642
0.3	100,000	300.1	27,880	28.9	129	28,009	6,582,230
0.03	100,000	404.0	37,530	31.9	142	37,672	8,853,017
MEDIUM							
100	100,000	0.0	0	8.6	38	38	9,043
60	100,000	0.0	0	14.2	63	63	14,863
30	100,000	19.8	1,837	17.1	76	1,913	449,495
25	100,000	28.0	2,601	17.7	79	2,680	629,684
15	100,000	51.0	4,741	19.2	85	4,827	1,134,290
10	100,000	69.3	6,441	20.2	90	6,531	1,534,674
3	100,000	123.6	11,486	22.8	101	11,588	2,723,100
0.3	100,000	227.5	21,136	26.7	119	21,255	4,994,893
0.03	100,000	331.4	30,786	29.9	133	30,919	7,265,932
LOW							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	0.0	0	8.6	38	38	9,043
10	100,000	0.0	0	13.6	60	60	14,204
3	100,000	38.1	3,536	18.4	82	3,618	850,129
0.3	100,000	141.9	13,185	23.5	105	13,290	3,123,209
0.03	100,000	245.8	22,835	27.3	122	22,957	5,394,810
Unit Rates and Notes		Ventren adjusted soil profile		Diffusion model soil profile used below buildings	2% of building floor area (240,000 ft2)		$235/m^3

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Table C.2.5. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, With Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	4,188	5,103	1,212,215	2,400	368,554	24	155	96,000	205,375	591,605	2,958,024	20,706,165
60	5,185	6,317	1,492,503	3,000	456,236	30	191	120,000	253,075	732,353	3,661,764	25,632,348
30	8,676	10,572	1,908,044	5,000	763,507	50	320	200,000	424,000	1,225,585	6,127,926	42,895,481
25	9,441	11,504	2,027,759	5,400	830,788	54	348	216,000	461,100	1,333,585	6,667,924	46,675,466
15	11,426	13,922	2,338,602	6,500	1,005,485	65	421	260,000	557,825	1,614,009	8,070,046	56,490,324
10	13,290	16,194	2,630,480	7,600	1,169,523	76	489	304,000	647,925	1,877,324	9,386,619	65,706,330
3	18,518	22,564	3,449,020	10,500	1,629,551	105	682	420,000	903,650	2,615,762	13,078,812	91,551,687
0.3	28,009	34,129	4,935,264	15,900	2,464,835	159	1,031	636,000	1,366,075	3,956,564	19,782,821	138,479,746
0.03	37,672	45,904	6,448,292	21,300	3,315,172	213	1,386	852,000	1,836,450	5,321,530	26,607,648	186,253,533
MEDIUM												
100	38	47	44,907	100	3,386	1	2	4,000	2,650	5,436	27,178	190,249
60	63	77	51,874	100	5,566	1	3	4,000	3,975	8,934	44,671	312,699
30	1,913	2,331	572,145	1,100	168,322	11	71	44,000	94,075	270,190	1,350,952	9,456,666
25	2,680	3,265	787,838	1,600	235,797	16	99	64,000	131,175	378,502	1,892,509	13,247,563
15	4,827	5,881	1,391,870	2,800	424,755	28	178	112,000	235,850	681,819	3,409,096	23,863,672
10	6,531	7,957	1,871,145	3,700	574,687	37	241	148,000	319,325	922,490	4,612,448	32,287,134
3	11,588	14,119	2,363,920	6,600	1,019,714	66	427	264,000	565,775	1,636,850	8,184,248	57,289,737
0.3	21,255	25,899	3,877,619	12,100	1,870,428	121	782	484,000	1,036,150	3,002,420	15,012,098	105,084,687
0.03	30,919	37,674	5,390,816	17,500	2,720,860	175	1,138	700,000	1,507,850	4,367,536	21,837,682	152,863,771
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	38	47	44,907	100	3,386	1	2	4,000	2,650	5,436	27,178	190,249
10	60	74	51,085	100	5,319	1	3	4,000	3,975	8,538	42,689	298,820
3	3,618	4,408	1,051,718	2,100	318,346	21	134	84,000	177,550	511,011	2,555,053	17,885,373
0.3	13,290	16,194	2,630,514	7,600	1,169,542	76	489	304,000	647,925	1,877,354	9,386,772	65,707,401
0.03	22,957	27,972	4,144,084	13,000	2,020,184	130	845	520,000	1,119,625	3,242,809	16,214,044	113,498,307
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.2.5. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, With Soil Washing, Mixing/Landfilling)

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Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $50/ft^3 Disposal Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	1,675	2,886,427	5,728,375	23,476,516	712	6,785	7,497	750
60	2,074	3,566,215	7,081,937	29,052,522	881	8,399	9,280	928
30	3,470	5,377,541	11,262,388	48,029,943	1,475	14,055	15,530	1,553
25	3,776	5,801,326	12,206,152	52,213,695	1,605	15,294	16,899	1,690
15	4,570	6,904,214	14,657,061	63,077,339	1,942	18,510	20,452	2,045
10	5,316	7,942,561	16,957,704	73,277,416	2,259	21,530	23,789	2,379
3	7,407	10,846,924	23,412,675	101,885,549	3,148	29,999	33,147	3,31[illegible]
0.3	11,204	16,125,957	35,131,224	153,828,149	4,762	45,375	50,137	5,01[illegible]
0.03	15,069	21,496,138	47,060,579	206,706,464	6,404	61,029	67,434	6,74[illegible]
MEDIUM								
100	15	63,486	87,165	250,236	7	62	69	7
60	25	79,772	120,950	388,978	11	102	113	11
30	765	1,336,930	2,634,988	10,740,702	325	3,099	3,424	342
25	1,072	1,861,624	3,677,002	15,032,058	456	4,341	4,796	480
15	1,931	3,322,779	6,595,861	27,050,437	821	7,819	8,640	864
10	2,612	4,480,009	8,912,279	36,586,965	1,110	10,579	11,690	1,169
3	4,635	6,994,470	14,856,758	63,962,246	1,970	18,772	20,742	2,074
0.3	8,502	12,371,032	26,791,188	116,863,777	3,613	34,433	38,046	3,805
0.03	12,368	17,741,784	38,723,139	169,749,229	5,256	50,089	55,345	5,534
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	15	63,486	87,165	250,236	7	62	69	7
10	24	77,926	117,270	373,402	10	98	108	11
3	1,447	2,498,958	4,952,796	20,283,116	615	5,860	6,475	648
0.3	5,316	7,942,677	16,957,961	73,278,591	2,259	21,530	23,790	2,379
0.03	9,183	13,314,703	28,892,747	126,177,010	3,903	37,190	41,092	4,109
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.2.6. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, Without Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	100,000	44.2	4,106	18.4	82	4,188	984,207
60	100,000	54.9	5,096	19.7	88	5,185	1,218,359
30	100,000	92.4	8,581	21.3	95	8,676	2,038,911
25	100,000	100.6	9,344	21.7	97	9,441	2,218,582
15	100,000	121.9	11,325	22.8	101	11,426	2,685,102
10	100,000	141.9	13,185	23.5	105	13,290	3,123,158
3	100,000	198.1	18,403	25.6	114	18,518	4,351,642
0.3	100,000	300.1	27,880	28.9	129	28,009	6,582,230
0.03	100,000	404.0	37,530	31.9	142	37,672	8,853,017
MEDIUM							
100	100,000	0.0	0	8.6	38	38	9,043
60	100,000	0.0	0	14.2	63	63	14,863
30	100,000	19.8	1,837	17.1	76	1,913	449,495
25	100,000	28.0	2,601	17.7	79	2,680	629,684
15	100,000	51.0	4,741	19.2	85	4,827	1,134,290
10	100,000	69.3	6,441	20.2	90	6,531	1,534,674
3	100,000	123.6	11,486	22.8	101	11,588	2,723,100
0.3	100,000	227.5	21,136	26.7	119	21,255	4,994,893
0.03	100,000	331.4	30,786	29.9	133	30,919	7,265,932
LOW							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	0.0	0	8.6	38	38	9,043
10	100,000	0.0	0	13.6	60	60	14,204
3	100,000	38.1	3,536	18.4	82	3,618	850,129
0.3	100,000	141.9	13,185	23.5	105	13,290	3,123,209
0.03	100,000	245.8	22,835	27.3	122	22,957	5,394,810
Unit Rates and Notes		Ventron adjusted soil profile		Diffusion model soil profile used below buildings	2% of building floor area (240,000 ft2)		$236/m^3

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Table C.2.6. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, Without Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	4,188	5,103	0	6,000	921,385	60	386	240,000	511,450	1,479,012	7,395,059	51,765,413
60	5,185	6,317	0	7,400	1,140,591	74	477	296,000	632,025	1,830,882	9,154,410	64,080,871
30	8,676	10,572	0	12,300	1,908,768	123	798	492,000	1,057,350	3,063,963	15,319,816	107,238,702
25	9,441	11,504	0	13,400	2,076,970	134	869	536,000	1,151,425	3,333,962	16,669,809	116,688,664
15	11,426	13,922	0	16,200	2,513,713	162	1,051	648,000	1,392,575	4,035,023	20,175,116	141,225,811
10	13,290	16,194	0	18,800	2,923,808	188	1,223	752,000	1,620,475	4,693,309	23,466,546	164,265,824
3	18,518	22,564	0	26,200	4,073,877	262	1,704	1,048,000	2,257,800	6,539,406	32,697,031	228,879,218
0.3	28,009	34,129	0	39,600	6,162,087	396	2,576	1,584,000	3,413,200	9,891,410	49,457,052	346,199,365
0.03	37,672	45,904	0	53,300	8,287,931	533	3,465	2,132,000	4,591,125	13,303,824	66,519,119	465,633,832
MEDIUM												
100	38	47	0	100	8,466	1	4	4,000	5,300	13,589	67,946	475,623
60	63	77	0	100	13,915	1	6	4,000	7,950	22,336	111,678	781,748
30	1,913	2,331	0	2,800	420,804	28	176	112,000	233,200	675,476	3,377,381	23,641,665
25	2,680	3,265	0	3,800	589,492	38	247	152,000	327,275	946,254	4,731,272	33,118,907
15	4,827	5,881	0	6,900	1,061,888	69	444	276,000	588,300	1,704,548	8,522,740	59,659,180
10	6,531	7,957	0	9,300	1,436,717	93	601	372,000	796,325	2,306,224	11,531,119	80,717,836
3	11,588	14,119	0	16,400	2,549,285	164	1,066	656,000	1,412,450	4,092,124	20,460,620	143,224,343
0.3	21,255	25,899	0	30,100	4,676,070	301	1,955	1,204,000	2,590,375	7,506,049	37,530,245	262,711,717
0.03	30,919	37,674	0	43,700	6,802,149	437	2,844	1,748,000	3,768,300	10,918,841	54,594,204	382,159,429
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	38	47	0	100	8,466	1	4	4,000	5,300	13,589	67,946	475,623
10	60	74	0	100	13,297	1	6	4,000	7,950	21,344	106,721	747,049
3	3,618	4,408	0	5,200	795,865	52	333	208,000	441,225	1,277,527	6,387,633	44,713,431
0.3	13,290	16,194	0	18,800	2,923,855	188	1,223	752,000	1,620,475	4,693,386	23,466,929	164,268,504
0.03	22,957	27,972	0	32,500	5,050,460	325	2,112	1,300,000	2,798,400	8,107,022	40,535,109	283,745,766
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.2.6. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Unrestricted Land Use, Without Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ \$10/ft^3 Disposal Costs	Remediation @ \$50/ft^3 Disposal Costs	Costs @ \$350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	\$	\$	\$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	4,188	2,709,219	9,812,101	54,182,456	0	6,785	6,785	678
60	5,185	3,352,641	12,145,385	67,071,846	0	8,399	8,399	840
30	8,676	5,607,174	20,324,844	112,243,731	0	14,055	14,055	1,406
25	3,441	6,101,944	22,116,786	122,135,641	0	15,294	15,294	1,529
15	1,426	7,384,325	26,766,506	147,817,201	0	18,510	18,510	1,851
10	3,290	8,587,267	31,133,987	171,933,265	0	21,530	21,530	2,153
3	8,518	11,965,248	43,380,350	239,562,537	0	29,999	29,999	3,000
0.3	28,009	18,097,240	65,614,569	362,356,882	0	45,375	45,375	4,538
0.03	37,672	24,342,140	88,251,191	487,365,904	0	61,029	61,029	6,103
MEDIUM								
100	38	26,732	90,755	498,432	0	62	62	6
60	63	41,299	148.406	818,476	0	102	102	10
30	1,913	1,239,771	4,48 ,879	24,745,164	0	3,099	3,099	310
25	2,680	1,731,739	6,277,723	34,665,358	0	4,341	4,341	434
15	4,827	3,121,738	11,307,218	62,443,658	0	7,819	7,819	782
10	6,531	4,222,198	15,298,835	84,485,552	0	10,579	10,579	1,058
3	11,588	7,487,624	27,145,456	149,909,178	0	18,772	18,772	1,877
0.3	21,255	13,735,042	49,791,584	274,973,056	0	34,433	34,433	3,443
0.03	30,919	19,976,473	72,430,585	399,995,810	0	50,089	50,089	5,009
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	38	26,732	90,755	498,432	0	62	62	6
10	60	39,648	142,172	782,500	0	98	98	10
3	3,618	2,340,855	8,474,852	46,800,650	0	5,860	5,860	586
0.3	13,290	8,587,395	31,134,468	171,936,043	0	21,530	21,530	2,153
0.03	22,957	14,834,332	53,778,780	296,989,437	0	37,190	37,190	3,719
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.2.7. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, With Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	0.0	0	10.8	48	48	11,366
10	100,000	0.0	0	14.2	63	63	14,844
3	100,000	42.7	3,963	18.7	83	4,047	950,944
0.3	100,000	146.5	13,613	23.7	106	13,719	3,223,908
0.03	100,000	250.4	23,263	27.4	122	23,385	5,495,499
MEDIUM							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	0.0	0	0.0	0	0	0
10	100,000	0.0	0	0.0	0	0	0
3	100,000	0.0	0	10.8	48	48	11,366
0.3	100,000	73.9	6,868	20.4	91	6,959	1,635,421
0.03	100,000	177.8	16,518	24.9	111	16,629	3,907,770
LOW							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	0.0	0	0.0	0	0	0
10	100,000	0.0	0	0.0	0	0	0
3	100,000	0.0	0	0.0	0	0	0
0.3	100,000	0.0	0	14.2	63	63	14,844
0.03	100,000	92.2	8,567	21.3		8,567	2,013,330
Unit Rates and Notes		Ventron adjusted soil profile		Diffusion model soil profile used below buildings	2% of building floor area (240,000 ft2)		$236/m^3

Table C.2.7. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, With Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	48	59	47,688	100	4,256	1	2	4,000	2,650	6,832	34,161	239,128
10	63	77	51,851	100	5,559	1	3	4,000	3,975	8,923	44,614	312,297
3	4,047	4,931	1,172,397	2,300	356,098	23	149	92,000	197,425	571,610	2,858,051	20,006,358
0.3	13,719	16,716	2,697,610	7,800	1,207,251	78	505	312,000	669,125	1,937,884	9,689,422	67,825,954
0.03	23,385	28,495	4,211,173	13,300	2,057,889	133	861	532,000	1,140,825	3,303,333	16,516,663	15,616,644
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	48	59	47,688	100	4,256	1	2	4,000	2,650	6,832	34,161	239,128
0.3	6,959	8,480	1,991,743	4,000	612,413	40	257	160,000	340,525	983,048	4,915,241	34,406,690
0.03	16,629	20,262	3,153,268	9,400	1,463,335	94	612	376,000	810,900	2,348,952	11,744,761	82,213,327
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	63	77	51,851	100	5,559	1	3	4,000	3,975	8,923	44,614	312,297
0.03	8,567	10,439	1,891,000	4,900	753,928	49	316	196,000	418,700	1,210,208	6,051,042	42,357,294
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.2.7. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, With Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $50/ft^3 Disposal Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	19	69,987	100,122	305,089	8	78	87	9
10	25	79,718	120,843	388,526	11	102	113	11
3	1,619	2,789,251	5,534,915	22,683,222	688	6,555	7,243	724
0.3	5,488	8,179,202	17,487,316	75,623,848	2,332	22,224	24,557	2,456
0.03	9,354	13,555,305	29,4[illegible]2,050	128,522,030	3,975	37,884	41,859	4,186
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	19	69,987	100,122	305,089	8	78	87	9
0.3	2,784	4,774,212	9,495,343	38,986,792	1,183	11,274	12,457	1,246
0.03	6,652	9,795,390	21,080,034	91,548,600	2,827	26,939	29,766	2,977
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	25	79,718	120,843	388,526	11	102	113	11
0.03	3,427	5,315,438	11,128,000	47,434,252	1,456	13,879	15,336	1,534
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.82 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.2.8. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, Without Soil Washing, Mixing/Landfilling)

Residual Dose Rate mrem/yr	Contaminated Site Soil Area ft^2	Site Soil Depth cm	Site Soil Volume m^3	Below-Building Soil Depth cm	Below-Building Soil Volume m^3	Total Soil Volume Removed m^3	Site Soil Excavation Costs $
HIGH							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	0.0	0	10.8	48	48	11,366
10	100,000	0.0	0	14.2	63	63	14,844
3	100,000	42.7	3,963	18.7	83	4,047	950,944
0.3	100,000	146.5	13,613	23.7	106	13,719	3,223,908
0.03	100,000	250.4	23,263	27.4	122	23,385	5,495,499
MEDIUM							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	0.0	0	0.0	0	0	0
10	100,000	0.0	0	0.0	0	0	0
3	100,000	0.0	0	10.8	48	48	11,366
0.3	100,000	73.9	6,868	20.4	91	6,959	1,635,421
0.03	100,000	177.8	16,518	24.9	111	16,629	3,907,770
LOW							
100	100,000	0.0	0	0.0	0	0	0
60	100,000	0.0	0	0.0	0	0	0
30	100,000	0.0	0	0.0	0	0	0
25	100,000	0.0	0	0.0	0	0	0
15	100,000	0.0	0	0.0	0	0	0
10	100,000	0.0	0	0.0	0	0	0
3	100,000	0.0	0	0.0	0	0	0
0.3	100,000	0.0	0	14.2	63	63	14,844
0.03	100,000	92.2	8,567	21.3	95	8,663	2,035,688
Unit Rates and Notes		Vent ron adjusted soil profile		Diffusion model soil profile used below buildings	2% of building floor area (240,000 ft2)		$235/m^3

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Table C.2.8. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, Without Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	48	59	0	100	10,641	1	5	4,000	6,625	17,081	85,403	597,821
10	63	77	0	100	13,897	1	6	4,000	7,950	22,307	111,535	780,742
3	4,047	4,931	0	5,800	890,245	58	373	232,000	494,225	1,429,026	7,145,128	50,015,896
0.3	13,719	16,716	0	19,400	3,018,127	194	1,282	776,000	1,672,150	4,844,711	24,223,555	169,564,885
0.03	23,385	28,495	0	33,100	5,144,722	331	2,151	1,324,000	2,850,075	8,258,332	41,291,658	289,041,609
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	48	59	0	100	10,641	1	5	4,000	6,625	17,081	85,403	597,821
0.3	6,959	8,480	0	9,900	1,531,033	99	641	396,000	849,325	2,457,621	12,288,103	86,016,724
0.03	16,629	20,262	0	23,500	3,658,338	235	1,530	940,000	2,027,250	5,872,381	29,361,903	205,533,318
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	63	77	0	100	13,897	1	6	4,000	7,950	22,307	111,535	780,742
0.03	8,663	10,555	0	12,300	1,905,751	123	797	492,000	1,056,025	3,059,120	15,295,600	107,069,197
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	96 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,326 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.2.8. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Uranium Fuel Fabrication Plant (Restricted Land Use, Without Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $50/ft^3 Disposal Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	48	32,547	114,035	626,453	0	78	78	8
10	63	41,251	148,225	817,432	0	102	102	10
3	4,047	2,617,769	9,480,542	52,351,310	0	6,555	6,555	656
0.3	13,719	8,864,019	32,137,740	177,479,070	0	22,224	22,224	2,222
0.03	23,385	15,110,931	54,781,955	302,531,905	0	37,884	37,884	3,788
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	48	32,547	114,035	626,453	0	78	78	8
0.3	6,959	4,498,942	16,303,883	90,032,503	0	11,274	11,274	1,127
0.03	16,629	10,743,650	38,955,260	215,126,676	0	26,939	26,939	2,694
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	63	41,251	148,225	817,432	0	102	102	10
0.03	8,663	5,599,108	20,293,064	112,066,662	0	14,033	14,033	1,403
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.3.1. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, With Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	5,000	3.3	15	3.3	0	16	3,653
60	5,000	4.6	21	4.6	1	22	5,151
30	5,000	5.9	27	5.9	1	28	6,601
25	5,000	6.2	29	6.2	1	30	6,972
15	5,000	7.0	33	7.0	1	33	7,861
10	5,000	7.8	36	7.8	1	37	8,687
3	5,000	11.5	54	11.5	1	55	12,896
0.3	5,000	20.5	95	20.5	2	97	22,867
0.03	5,000	24.9	116	24.9	3	118	27,836
MEDIUM							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	2.5	11	2.5	0	12	2,758
30	5,000	4.5	21	4.5	1	22	5,082
25	5,000	4.9	23	4.9	1	23	5,476
15	5,000	5.8	27	5.8	1	28	6,508
10	5,000	6.5	30	6.5	1	31	7,257
3	5,000	8.2	38	8.2	1	39	9,209
0.3	5,000	16.5	77	16.5	2	78	18,434
0.03	5,000	22.4	104	22.4	2	107	25,061
LOW							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.0	0	0.0	0	0	0
25	5,000	0.0	0	0.0	0	0	0
15	5,000	0.0	0	0.0	0	0	0
10	5,000	0.0	0	0.0	0	0	0
3	5,000	3.6	17	3.6	0	17	4,079
0.3	5,000	8.4	39	8.4	1	40	9,343
0.03	5,000	18.7	87	18.7	2	89	20,894
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (8,000 ft^2)		$236/m^3

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Table C.3.1. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, With Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	16	19	38,455	100	1,368	1	1	4,000	1,325	2,196	10,978	76,846
60	22	27	40,249	100	1,929	1	1	4,000	1,325	3,096	15,482	108,373
30	28	34	41,985	100	2,472	1	2	4,000	2,650	3,968	19,841	138,884
25	30	36	42,428	100	2,611	1	2	4,000	2,650	4,191	20,953	146,671
15	33	41	43,493	100	2,944	1	2	4,000	2,650	4,725	23,627	165,388
10	37	45	44,481	100	3,253	1	2	4,000	2,650	5,221	26,107	182,752
3	55	67	49,520	100	4,829	1	3	4,000	3,975	7,752	38,760	271,320
0.3	97	119	61,455	100	8,563	1	4	4,000	5,300	13,745	68,726	481,079
0.03	118	144	67,402	100	10,423	1	5	4,000	6,625	16,732	83,658	585,608
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	12	14	37,384	100	1,033	1	1	4,000	1,325	1,658	8,290	58,029
30	22	26	40,165	100	1,903	1	1	4,000	1,325	3,055	15,273	106,909
25	23	28	40,638	100	2,051	1	1	4,000	1,325	3,292	16,459	115,213
15	28	34	41,873	100	2,437	1	2	4,000	2,650	3,912	19,561	136,924
10	31	38	42,769	100	2,717	1	2	4,000	2,650	4,362	21,810	152,670
3	39	48	45,106	100	3,448	1	2	4,000	2,650	5,536	27,678	193,743
0.3	78	96	56,148	100	6,903	1	3	4,000	3,975	11,081	55,403	387,818
0.03	107	130	64,082	100	9,385	1	4	4,000	5,300	15,064	75,321	527,246
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	17	21	38,965	100	1,528	1	1	4,000	1,325	2,452	12,260	85,820
0.3	40	48	45,267	100	3,499	1	2	4,000	2,650	5,616	28,082	196,571
0.03	89	108	59,093	100	7,824	1	4	4,000	5,300	12,559	62,796	439,571
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	96 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.3.1. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, With Soil Washing)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs @ $10/ft^3 Disposal Costs	Total Soil Remediation Costs @ $50/ft^3 Disposal Costs	Total Soil Remediation Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	6	48,403	55,778	121,646	3	25	28	3
60	9	52,596	64,136	157,027	4	36	39	4
30	11	56,654	73,549	192,592	5	46	50	5
25	12	57,690	75,613	201,331	5	48	53	5
15	13	60,179	80,575	222,336	6	54	60	6
10	15	62,489	85,177	241,822	6	60	66	7
3	22	74,268	109,981	342,541	9	89	98	10
0.3	39	102,167	166,910	579,263	17	158	174	17
0.03	47	116,069	195,944	697,893	20	192	212	21
MEDIUM								
100	0	0	0	0	0	0	0	0
60	5	45,900	50,790	100,529	2	19	21	2
30	9	52,401	63,748	155,384	4	35	39	4
25	9	53,506	65,949	164,703	4	38	42	4
15	11	56,394	73,029	190,393	5	45	50	5
10	12	58,488	77,203	208,063	5	50	55	6
3	16	63,951	88,091	254,157	7	63	70	7
0.3	31	89,763	140,863	473,278	13	127	140	14
0.03	43	108,307	179,148	631,073	18	173	191	19
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	7	49,597	58,157	131,717	3	28	31	3
0.3	16	64,327	88,841	257,330	7	64	71	7
0.03	36	96,646	155,907	532,682	15	144	159	16
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.3.2. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, Without Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	5,000	3.3	15	3.3	0	16	3,653
60	5,000	4.6	21	4.6	1	22	5,151
30	5,000	5.9	27	5.9	1	28	6,601
25	5,000	6.2	29	6.2	1	30	6,972
15	5,000	7.0	33	7.0	1	33	7,861
10	5,000	7.8	36	7.8	1	37	8,687
3	5,000	11.5	54	11.5	1	55	12,896
0.3	5,000	20.5	95	20.5	2	97	22,867
0.03	5,000	24.9	116	24.9	3	118	27,835
MEDIUM							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	2.5	11	2.5	0	12	2,758
30	5,000	4.5	21	4.5	1	22	5,082
25	5,000	4.9	23	4.9	1	23	5,476
15	5,000	5.8	27	5.8	1	28	6,508
10	5,000	6.5	30	6.5	1	31	7,257
3	5,000	8.2	38	8.2	1	39	9,209
0.3	5,000	16.5	77	16.5	2	78	18,434
0.03	5,000	22.4	104	22.4	2	107	25,061
LOW							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.0	0	0.0	0	0	0
25	5,000	0.0	0	0.0	0	0	0
15	5,000	0.0	0	0.0	0	0	0
10	5,000	0.0	0	0.0	0	0	0
3	5,000	3.6	17	3.6	0	17	4,079
0.3	5,000	8.4	39	8.4	1	40	9,343
0.03	5,000	18.7	87	18.7	2	89	20,894
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (6,000 ft^2)		$235/m^3

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Table C.3.2. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, Without Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	16	19	0	100	3,419	1	2	4,000	2,650	5,489	27,445	192,115
60	22	27	0	100	4,822	1	3	4,000	3,975	7,741	38,705	270,933
30	28	34	0	100	6,180	1	3	4,000	3,975	9,920	49,602	347,211
25	30	36	0	100	6,527	1	3	4,000	3,975	10,476	52,382	366,677
15	33	41	0	100	7,359	1	4	4,000	5,300	11,813	59,067	413,471
10	37	45	0	100	8,132	1	4	4,000	5,300	13,054	65,268	456,879
3	55	67	0	100	12,073	1	6	4,000	7,950	19,380	96,900	678,301
0.3	97	119	0	200	21,407	2	9	8,000	11,925	34,363	171,814	1,202,697
0.03	118	144	0	200	26,458	2	11	8,000	14,575	41,829	209,146	1,464,019
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	12	14	0	100	2,582	1	2	4,000	2,650	4,145	20,725	145,072
30	22	26	0	100	4,757	1	2	4,000	2,650	7,636	38,182	267,272
25	23	28	0	100	5,127	1	3	4,000	3,975	8,230	41,148	288,033
15	28	34	0	100	6,093	1	3	4,000	3,975	9,780	48,902	342,311
10	31	38	0	100	6,794	1	3	4,000	3,975	10,905	54,525	381,675
3	39	48	0	100	8,621	1	4	4,000	5,300	13,839	69,194	484,358
0.3	78	96	0	200	17,257	2	8	8,000	10,600	27,701	138,506	969,545
0.03	107	130	0	200	23,461	2	10	8,000	13,250	37,660	188,302	1,318,115
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	17	21	0	100	3,819	1	2	4,000	2,650	6,130	30,650	214,549
0.3	40	48	0	100	8,747	1	4	4,000	5,300	14,041	70,204	491,427
0.03	89	108	0	200	19,560	2	9	8,000	11,925	31,398	156,990	1,098,928
Unit Rates and Notes.		78 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	96 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,326 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.3.2. **Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, Without Soil Washing)**

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $[illegible]0/ft^3 Disposal Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	16	13,242	37,167	201,837	0	25	25	3
60	22	18,992	52,653	284,881	0	36	36	4
30	28	20,622	66,358	363,967	0	46	46	5
25	30	21,548	69,856	384,151	0	48	48	5
15	33	23,775	79,588	433,992	0	54	54	5
10	37	25,840	87,387	478,998	0	60	60	6
3	55	36,376	129,820	711,221	0	89	89	9
0.3	97	65,429	228,013	1,258,896	0	158	158	16
0.03	118	77,864	277,614	1,532,488	0	192	192	19
MEDIUM								
100	0	0	0	0	0	0	0	0
60	12	11,003	28,715	153,063	0	19	19	2
30	22	16,818	50,671	279,761	0	35	35	4
25	23	17,806	55,726	302,611	0	38	38	4
15	28	20,389	65,478	358,887	0	45	45	4
10	31	22,262	72,550	399,700	0	50	50	5
3	39	27,148	92,324	507,488	0	63	63	6
0.3	78	54,335	184,797	1,015,836	0	127	127	13
0.03	107	70,922	250,075	1,379,888	0	173	173	17
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	17	14,309	41,198	225,097	0	28	28	3
0.3	40	27,484	93,594	514,817	0	64	64	6
0.03	89	60,492	209,369	1,151,307	0	144	144	14
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.3.3. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, With Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.0	0	0.0	0	0	0
25	5,000	0.0	0	0.0	0	0	0
15	5,000	0.0	0	0.0	0	0	0
10	5,000	1.6	7	1.6	0	8	1,797
3	5,000	5.2	24	5.2	1	25	5,817
0.3	5,000	8.3	39	8.3	1	40	9,295
0.03	5,000	10.7	50	10.7	1	51	11,951
MEDIUM							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.0	0	0.0	0	0	0
25	5,000	0.0	0	0.0	0	0	0
15	5,000	0.0	0	0.0	0	0	0
10	5,000	0.0	0	0.0	0	0	0
3	5,000	3.7	17	3.7	0	18	4,156
0.3	5,000	7.5	35	7.5	1	36	8,415
0.03	5,000	9.9	46	9.9	1	47	11,078
LOW							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.0	0	0.0	0	0	0
25	5,000	0.0	0	0.0	0	0	0
15	5,000	0.0	0	0.0	0	0	0
10	5,000	0.0	0	0.0	0	0	0
3	5,000	0.0	0	0.0	0	0	0
0.3	5,000	2.3	11	2.3	0	11	2,575
0.03	5,000	7.0	32	7.0	1	33	7,780
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (6,000 ft^2)		$235/m^3

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Table C.3.3. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, With Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	8	9	36,234	100	673	1	1	4,000	1,325	1,080	5,402	37,813
3	25	30	41,045	100	2,178	1	1	4,000	1,325	3,496	17,482	122,374
0.3	40	48	45,209	100	3,481	1	2	4,000	2,650	5,587	27,936	195,549
0.03	51	62	48,388	100	4,475	1	2	4,000	2,650	7,184	35,919	251,430
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	18	22	39,057	100	1,556	1	1	4,000	1,325	2,498	12,491	87,437
0.3	36	44	44,156	100	3,151	1	2	4,000	2,650	5,058	25,292	177,043
0.03	47	57	47,343	100	4,148	1	2	4,000	2,650	6,659	33,294	233,056
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	11	13	37,165	100	964	1	1	4,000	1,325	1,548	7,740	54,178
0.03	33	40	43,395	100	2,913	1	2	4,000	2,650	4,676	23,382	163,672
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.3.3. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, With Soil Washing)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs @ $10/ft^3 Disposal Costs	Total Soil Remediation Costs @ $50/ft^3 Disposal Costs	Total Soil Remediation Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	3	43,212	45,431	77,843	1	12	14	1
3	10	54,458	67,847	172,739	4	40	44	4
0.3	16	64,191	88,570	256,183	7	64	71	7
0.03	20	71,623	103,383	318,895	9	82	91	9
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	7	49,812	58,586	133,532	3	29	32	3
0.3	14	61,729	83,664	235,416	6	58	64	6
0.03	19	69,179	98,512	298,275	8	76	84	8
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	4	45,388	49,769	96,208	2	18	20	2
0.03	13	59,951	80,120	220,410	6	54	59	6
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.3.4. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, Without Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.0	0	0.0	0	0	0
25	5,000	0.0	0	0.0	0	0	0
15	5,000	0.0	0	0.0	0	0	0
10	5,000	1.6	7	1.6	0	8	1,797
3	5,000	5.2	24	5.2	1	25	5,817
0.3	5,000	8.3	39	8.3	1	40	9,295
0.03	5,000	10.7	50	10.7	1	51	11,951
MEDIUM							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.0	0	0.0	0	0	0
25	5,000	0.0	0	0.0	0	0	0
15	5,000	0.0	0	0.0	0	0	0
10	5,000	0.0	0	0.0	0	0	0
3	5,000	3.7	17	3.7	0	18	4,156
0.3	5,000	7.5	35	7.5	1	36	8,415
0.03	5,000	9.9	46	9.9	1	47	11,078
LOW							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.0	0	0.0	0	0	0
25	5,000	0.0	0	0.0	0	0	0
15	5,000	0.0	0	0.0	0	0	0
10	5,000	0.0	0	0.0	0	0	0
3	5,000	0.0	0	0.0	0	0	0
0.3	5,000	2.3	11	2.3	0	11	2,575
0.03	5,000	7.0	32	7.0	1	33	7,780
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (6,000 ft^2)		$235/m^3

Table C.3.4. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, Without Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	8	9	0	100	1,683	1	1	4,000	1,325	2,701	13,505	94,534
3	25	30	0	100	5,445	1	3	4,000	3,975	8,741	43,705	305,935
0.3	40	48	0	100	8,702	1	4	4,000	5,300	13,968	69,839	488,872
0.03	51	62	0	100	11,188	1	5	4,000	6,625	17,959	89,797	628,576
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	C	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	18	22	0	100	3,891	1	2	4,000	2,650	6,246	31,228	218,594
0.3	36	44	0	100	7,878	1	4	4,000	5,300	12,646	63,230	442,607
0.03	47	57	0	100	10,371	1	5	4,000	6,625	16,847	83,234	582,640
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	11	13	0	100	2,411	1	2	4,000	2,650	3,870	19,349	135,446
0.03	33	40	0	100	7,283	1	4	4,000	5,300	11,691	58,454	409,181
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	96 tons of soil per railcar	7,288 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $360/ft^3; truck transport only.

Table C.3.4. **Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, Without Soil Washing)**

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs @ $10/ft^3 Disposal Costs	Total Soil Remediation Costs @ $50/ft^3 Disposal Costs	Total Soil Remediation Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	8	8,598	18,310	99,339	0	12	12	1
3	25	18,658	58,942	321,172	0	40	40	4
0.3	40	27,363	93,135	512,169	0	64	64	6
0.03	51	34,010	119,561	658,340	0	82	82	8
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	18	14,502	41,925	229,291	0	29	29	3
0.3	36	25,161	84,823	464,200	0	58	58	6
0.03	47	31,824	111,307	610,713	0	76	76	8
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	11	10,545	26,985	143,082	0	18	18	0
0.03	33	23,571	78,817	429,544	0	54	54	2
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.3.5. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, With Soil Washing, Real World Data)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	5,000	4.4	21	3.3	0	21	4,925
60	5,000	8.0	37	4.6	1	38	8,839
30	5,000	17.9	83	5.9	1	84	19,668
25	5,000	20.8	96	6.2	1	97	22,817
15	5,000	28.9	134	7.0	1	135	31,693
10	5,000	35.3	164	7.8	1	165	38,747
3	5,000	54.5	253	11.5	1	254	59,777
0.3	5,000	91.3	424	20.5	2	426	100,163
0.03	5,000	128.2	595	24.9	3	598	140,540
MEDIUM							
100	5,000	1.8	8	0.0	0	8	1,985
60	5,000	3.5	16	2.5	0	16	3,875
30	5,000	7.6	36	4.5	1	36	8,464
25	5,000	9.7	45	4.9	1	46	10,722
15	5,000	17.4	81	5.8	1	81	19,108
10	5,000	23.8	111	6.5	1	111	26,178
3	5,000	43.1	200	8.2	1	201	47,236
0.3	5,000	80.0	371	16.5	2	373	87,716
0.03	5,000	116.9	543	22.4	2	546	128,203
LOW							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.0	0	0.0	0	0	0
25	5,000	0.0	0	0.0	0	0	0
15	5,000	0.0	0	0.0	0	0	0
10	5,000	0.9	4	0.0	0	4	1,018
3	5,000	5.1	24	3.6	0	24	5,717
0.3	5,000	37.4	174	8.4	1	174	41,006
0.03	5,000	73.9	343	18.7	2	345	81,192
Unit Rates and Notes		Humboldt Bay soil profile		Diffusion model soil profile used below buildings	2% of building floor area (6,000 ft^2)		$235/m^3

Table C.3.5. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, With Soil Washing, Real World Data)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	21	26	39,978	100	1,844	1	1	4,000	1,325	2,960	14,802	103,611
60	38	46	44,663	100	3,310	1	2	4,000	2,650	5,313	26,565	185,955
30	84	102	57,614	100	7,361	1	4	4,000	5,300	11,817	59,083	413,578
25	97	118	61,395	100	8,544	1	4	4,000	5,300	13,715	68,576	480,030
15	135	164	72,020	100	11,868	1	5	4,000	6,625	19,051	95,253	666,768
10	165	201	80,464	100	14,510	1	7	4,000	9,275	23,291	116,454	815,175
3	254	310	105,637	200	22,384	2	10	8,000	13,250	35,932	179,658	1,257,604
0.3	426	519	153,982	300	37,508	3	16	12,000	21,200	60,208	301,040	2,107,279
0.03	598	729	202,315	400	52,628	4	23	16,000	30,475	84,479	422,393	2,956,748
MEDIUM												
100	8	10	36,459	100	743	1	1	4,000	1,325	1,193	5,966	41,760
60	16	20	38,721	100	1,451	1	1	4,000	1,325	2,329	11,645	81,517
30	36	44	44,214	100	3,169	1	2	4,000	2,650	5,088	25,438	178,068
25	46	56	46,917	100	4,015	1	2	4,000	2,650	6,445	32,225	225,572
15	81	99	56,955	100	7,155	1	3	4,000	3,975	11,486	57,428	401,995
10	111	136	65,418	100	9,803	1	5	4,000	6,625	15,735	78,677	550,739
3	201	245	90,626	200	17,688	2	8	8,000	10,600	28,394	141,968	993,773
0.3	373	455	139,081	300	32,847	3	14	12,000	18,550	52,726	263,628	1,845,397
0.03	546	665	187,546	400	48,008	4	21	16,000	27,825	77,062	385,311	2,697,179
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	4	5	35,301	100	381	1	1	4,000	1,325	612	3,060	21,421
3	24	30	40,926	100	2,141	1	1	4,000	1,325	3,436	17,182	120,272
0.3	174	213	83,168	100	15,355	1	7	4,000	9,275	24,648	123,242	862,691
0.03	345	421	131,273	200	30,404	2	13	8,000	17,225	48,805	244,023	1,708,158
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.3.5. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, With Soil Washing, Real World Data)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $50/ft^3 Disposal Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	8	51,963	62,873	151,682	4	34	38	4
60	15	62,915	86,026	245,416	6	61	67	7
30	33	93,189	149,016	503,512	14	136	150	15
25	39	102,027	166,632	578,086	17	157	174	17
15	54	126,863	217,458	788,974	23	218	241	24
10	66	146,602	259,449	958,171	28	267	295	30
3	102	209,545	380,706	1,458,652	43	412	455	46
0.3	170	326,653	613,893	2,420,132	72	690	763	76
0.03	239	443,733	848,350	3,382,706	102	969	1,070	107
MEDIUM								
100	3	43,737	46,478	82,272	1	14	15	2
60	7	49,024	57,016	126,888	3	27	30	3
30	14	61,866	8[illegible] 936	236,566	6	58	64	6
25	18	68,184	96,528	289,876	8	74	82	8
15	33	91,648	144,621	489,187	14	132	146	15
10	45	111,431	186,701	658,762	19	180	199	20
3	80	174,455	308,118	1,169,923	34	326	360	36
0.3	149	291,822	541,822	2,123,591	63	605	668	67
0.03	218	409,210	776,892	3,088,760	93	884	977	98
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	2	41,032	41,086	59,447	1	7	8	1
3	10	54,179	67,290	170,381	4	39	44	4
0.3	70	152,921	272,045	1,011,495	30	283	312	31
0.03	138	269,469	504,116	1,968,252	59	560	618	62
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.3.6. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, Without Soil Washing, Real World Data)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	5,000	4.4	21	3.3	0	21	4,925
60	5,000	8.0	37	4.6	1	38	8,839
30	5,000	17.9	83	5.9	1	84	19,658
25	5,000	20.8	96	6.2	1	97	22,817
15	5,000	28.9	134	7.0	1	135	31,693
10	5,000	35.3	164	7.8	1	165	38,747
3	5,000	54.5	253	11.5	1	254	59,777
0.3	5,000	91.3	424	20.5	2	426	100,163
0.03	5,000	128.2	595	24.9	3	598	140,540
MEDIUM							
100	5,000	1.8	8	0.0	0	8	1,985
60	5,000	3.6	16	2.5	0	16	3,875
30	5,000	7.6	36	4.5	1	36	8,464
25	5,000	9.7	45	4.9	1	46	10,722
15	5,000	17.4	81	5.8	1	81	19,108
10	5,000	23.8	111	6.5	1	111	26,178
3	5,000	43.1	200	8.2	1	201	47,236
0.3	5,000	80.0	371	16.5	2	373	87,716
0.03	5,000	116.9	543	22.4	2	546	128,203
LOW							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.0	0	0.0	0	0	0
25	5,000	0.0	0	0.0	0	0	0
15	5,000	0.0	0	0.0	0	0	0
10	5,000	0.9	4	0.0	0	4	1,018
3	5,000	5.1	24	3.6	0	24	5,717
0.3	5,000	37.4	174	8.4	1	174	41,006
0.03	5,000	73.9	343	18.7	2	345	81,192
Unit Rates and Notes		Humboldt Bay soil profile		Diffusion model soil profile used below buildings	2% of building floor area (6,000 ft^2)		$235/m^3

Table C.3.6. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, Without Soil Washing, Real World Data)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	21	26	0	100	4,610	1	2	4,000	2,650	7,401	37,004	259,026
60	38	46	0	100	8,275	1	4	4,000	5,300	13,282	66,412	464,886
30	84	102	0	200	18,403	2	8	8,000	10,600	29,541	147,707	1,033,946
25	97	118	0	200	21,360	2	9	8,000	11,925	34,288	171,439	1,200,074
15	135	164	0	200	29,670	2	13	8,000	17,225	47,626	238,131	1,666,919
10	165	201	0	300	36,274	3	16	12,000	21,200	58,227	291,134	2,037,939
3	254	310	0	400	55,981	4	24	16,000	31,800	89,829	449,144	3,144,010
0.3	426	519	0	700	93,770	7	40	28,000	53,000	150,520	752,600	5,268,198
0.03	598	729	0	900	131,570	9	56	36,000	74,200	211,196	1,055,981	7,391,870
MEDIUM												
100	8	10	0	100	1,858	1	1	4,000	1,325	2,983	14,914	104,401
60	16	20	0	100	3,627	1	2	4,000	2,650	5,823	29,113	203,791
30	36	44	0	100	7,924	1	4	4,000	5,300	12,719	63,596	445,171
25	46	56	0	100	10,038	1	5	4,000	6,625	16,112	80,561	563,930
15	81	99	0	200	17,888	2	8	8,000	10,600	28,714	143,569	1,004,986
10	111	136	0	200	24,507	2	11	8,000	14,575	39,338	196,692	1,376,846
3	201	245	0	300	44,221	3	19	12,000	25,175	70,984	354,919	2,484,432
0.3	373	455	0	600	82,117	6	35	24,000	46,375	131,814	659,071	4,613,494
0.03	546	665	0	800	120,019	8	51	32,000	67,575	192,656	963,278	6,742,948
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	4	5	0	100	953	1	1	4,000	1,325	1,530	7,650	53,553
3	24	30	0	100	5,352	1	3	4,000	3,975	8,591	42,954	300,681
0.3	174	213	0	300	38,388	3	17	12,000	22,525	61,621	308,104	2,156,728
0.03	345	421	0	500	76,010	5	32	20,000	42,400	122,011	610,056	4,270,395
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.3.6. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Unrestricted Land Use, Without Soil Washing, Real World Data)

Residual Dose Rate mrem/yr	Total Soil Volume Disposed m^3	Total Soil @ $10/ft^3 Disposal Costs $	Remediation @ $50/ft^3 Disposal Costs $	Costs @ $350/ft^3 Disposal Costs $	Soil Washing Labor man-hr	Soil Excavation Labor man-hr	Total Soil Remediation Labor man-hr	Total Occupational Dose person-mrem
HIGH								
100	21	16,426	49,189	271,212	0	34	34	3
60	38	26,221	88,826	487,300	0	61	61	6
30	84	57,400	196,368	1,082,608	0	136	136	14
25	97	65,305	227,541	1,256,176	0	157	157	16
15	135	87,519	316,719	1,745,507	0	218	218	22
10	165	109,274	387,355	2,134,159	0	267	267	27
3	254	166,005	596,682	3,291,647	0	412	412	41
0.3	426	279,383	999,533	5,515,132	0	690	690	69
0.03	598	388,637	1,402,291	7,738,180	0	969	969	97
MEDIUM								
100	8	9,068	20,083	109,569	0	14	14	1
60	16	13,797	39,265	213,943	0	27	27	3
30	36	25,283	85,284	466,859	0	58	58	6
25	46	30,934	107,946	591,314	0	74	74	7
15	81	56,022	191,165	1,052,582	0	132	132	13
10	111	73,716	261,952	1,442,106	0	180	180	18
3	201	130,520	471,551	2,601,064	0	326	326	33
0.3	373	244,130	875,278	4,829,701	0	605	605	60
0.03	546	353,658	1,279,075	7,058,744	0	884	884	88
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	4	6,648	10,947	56,849	0	7	7	1
3	24	18,408	57,998	315,725	0	39	39	4
0.3	174	114,926	410,023	2,258,647	0	283	283	28
0.03	345	223,704	809,658	4,469,997	0	560	560	56
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.3.7. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, With Soil Washing, Real World Data)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.1	0	0.0	0	0	69
25	5,000	0.5	2	0.0	0	2	584
15	5,000	1.8	8	0.0	0	8	1,979
10	5,000	3.0	14	1.6	0	14	3,384
3	5,000	12.8	59	5.2	1	60	14,085
0.3	5,000	49.3	229	8.3	1	230	54,058
0.03	5,000	86.1	400	10.7	1	401	94,292
MEDIUM							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.0	0	0.0	0	0	0
25	5,000	0.0	0	0.0	0	0	0
15	5,000	0.0	0	0.0	0	0	0
10	5,000	0.9	4	0.0	0	4	1,029
3	5,000	5.2	24	3.7	0	25	5,762
0.3	5,000	37.9	176	7.5	1	177	41,606
0.03	5,000	74.8	348	9.9	1	349	81,949
LOW							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.0	0	0.0	0	0	0
25	5,000	0.0	0	0.0	0	0	0
15	5,000	0.0	0	0.0	0	0	0
10	5,000	0.0	0	0.0	0	0	0
3	5,000	0.0	0	0.0	0	0	0
0.3	5,000	3.6	17	2.3	0	17	3,999
0.03	5,000	32.2	149	7.0	1	150	35,281
Unit Rates and Notes		Humboldt Bay soil profile		Diffusion model soil profile used below buildings	2% of building floor area (6,000 ft^2)		$235/m^3

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Table C.3.7. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, With Soil Washing, Real World Data)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	34,165	100	26	1	1	4,000	1,325	41	207	1,447
25	2	3	34,782	100	219	1	1	4,000	1,325	351	1,756	12,289
15	8	10	36,452	100	741	1	1	4,000	1,325	1,190	5,949	41,640
10	14	17	38,109	100	1,260	1	1	4,000	1,325	2,022	10,111	70,775
3	60	73	50,943	100	5,274	1	3	4,000	3,975	8,467	42,333	296,328
0.3	230	280	98,792	200	20,243	2	9	8,000	11,925	32,494	162,470	1,137,291
0.03	401	489	146,954	300	35,309	3	15	12,000	19,875	56,679	283,394	1,983,757
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	4	5	35,314	100	385	1	1	4,000	1,325	619	3,093	21,649
3	25	30	40,980	100	2,158	1	1	4,000	1,325	3,464	17,319	121,231
0.3	177	216	83,887	200	15,580	2	7	8,000	9,275	25,009	125,047	875,330
0.03	349	425	132,179	200	30,687	2	13	8,000	17,225	49,260	246,298	1,724,087
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	17	21	38,870	100	1,498	1	1	4,000	1,325	2,404	12,020	84,140
0.03	150	183	76,315	100	13,212	1	6	4,000	7,950	21,207	106,037	742,257
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.3.7. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, With Soil Washing, Real World Data)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil Remediation Costs @ $10/ft^3 Disposal Costs	Total Soil Remediation Costs @ $50/ft^3 Disposal Costs	Total Soil Remediation Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	38,375	35,791	37,031	0	0	1	0
25	1	39,817	38,665	49,198	0	4	4	0
15	3	43,721	46,446	82,137	1	14	15	2
10	6	47,596	54,169	114,833	2	23	26	3
3	24	77,594	116,610	370,606	10	97	107	1[illegible]
0.3	92	193,543	347 488	1,322,308	39	373	412	41
0.03	160	310,224	579 824	2,280,187	68	650	718	72
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	2	41,062	41,146	59,703	1	7	8	1
3	10	54,306	67,544	171,457	4	40	44	4
0.3	71	158,702	275,396	1,025,679	30	287	317	32
0.03	139	271,588	508,339	1,986,128	59	565	624	62
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	7	49,373	67,712	129,832	3	28	30	3
0.03	60	136,904	238,795	875,015	26	243	269	27
Unit Rates and Notes	Disposal volume is 40% of total soil vol.; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.3.8. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, Without Soil Washing, Real World Data)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.1	0	0.0	0	0	69
25	5,000	0.5	2	0.0	0	2	584
15	5,000	1.8	8	0.0	0	8	1,979
10	5,000	3.0	14	1.6	0	14	3,364
3	5,000	12.8	59	5.2	1	60	14,085
0.3	5,000	49.3	229	8.3	1	230	54,058
0.03	5,000	86.1	400	10.7	1	401	94,292
MEDIUM							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.0	0	0.0	0	0	0
25	5,000	0.0	0	0.0	0	0	0
15	5,000	0.0	0	0.0	0	0	0
10	5,000	0.9	4	0.0	0	4	1,029
3	5,000	5.2	24	3.7	0	25	5,762
0.3	5,000	37.9	176	7.5	1	177	41,606
0.03	5,000	74.8	348	9.9	1	349	81,949
LOW							
100	5,000	0.0	0	0.0	0	0	0
60	5,000	0.0	0	0.0	0	0	0
30	5,000	0.0	0	0.0	0	0	0
25	5,000	0.0	0	0.0	0	0	0
15	5,000	0.0	0	0.0	0	0	0
10	5,000	0.0	0	0.0	0	0	0
3	5,000	0.0	0	0.0	0	0	0
0.3	5,000	3.6	17	2.3	0	17	3,999
0.03	5,000	32.2	149	7.0	1	150	35,281
Unit Rates and Notes		Humboldt Bay soil profile		Diffusion model soil profile used below buildings	2% of building floor area (5,000 ft^2)		$235/m^3

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Table C.3.8. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, Without Soil Washing, Real World Data)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	100	64	1	1	4,000	1,325	103	517	3,618
25	2	3	0	100	547	1	1	4,000	1,325	878	4,389	30,722
15	8	10	0	100	1,853	1	1	4,000	1,325	2,974	14,872	104,101
10	14	17	0	100	3,149	1	2	4,000	2,650	5,055	25,277	176,937
3	60	73	0	100	13,186	1	6	4,000	7,950	21,166	105,832	740,821
0.3	230	280	0	400	50,607	4	22	16,000	29,150	81,235	406,175	2,843,227
0.03	401	489	0	600	88,273	6	37	24,000	49,025	141,697	708,485	4,959,392
MEDIUM												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	4	5	0	100	983	1	1	4,000	1,325	1,546	7,732	54,123
3	25	30	0	100	5,395	1	3	4,000	3,975	8,659	43,297	303,079
0.3	177	216	0	300	38,951	3	17	12,000	22,525	62,524	312,618	2,188,326
0.03	349	425	0	500	76,719	5	33	20,000	43,725	123,149	615,746	4,310,218
LOW												
100	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
0.3	17	21	0	100	3,744	1	2	4,000	2,650	6,010	30,050	210,350
0.03	150	183	0	300	33,029	3	14	12,000	18,550	53,018	265,092	1,855,642
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

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Table C.3.8. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Sealed Source Manufacturer Site (Restricted Land Use, Without Soil Washing, Real World Data)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $50/ft^3 Disposal Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	4,272	1,975	5,076	0	0	0	0
25	2	5,562	6,845	33,178	0	4	4	0
15	8	9,054	20,029	109,258	0	14	14	1
10	14	12,519	34,440	186,100	0	23	23	2
3	60	39,351	141,053	776,042	0	97	97	10
0.3	230	151,693	539,990	2,977,042	0	373	373	37
0.03	401	260,589	940,075	5,190,982	C	650	650	65
MEDIUM								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	4	6,675	11,049	57,441	0	7	7	1
3	25	18,522	58,429	318,211	0	40	40	4
0.3	177	116,430	415,700	2,291,408	0	287	287	29
0.03	349	225,599	818,138	4,512,611	0	565	565	56
LOW								
100	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
0.3	17	14,109	40,443	220,743	0	28	28	3
0.03	150	100,599	351,952	1,942,502	0	243	243	24
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.4.1. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Unrestricted Land Use, With Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Slag Pile Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	m^3	$
HIGH								
100	100,000	0.16	14	0.16	0	7,000	7,015	1,648,490
60	100,000	0.52	48	0.52	1	7,000	7,050	1,656,733
30	100,000	0.80	74	0.80	2	7,000	7,076	1,662,916
25	100,000	0.84	78	0.84	2	7,000	7,081	1,663,946
15	100,000	0.93	87	0.93	3	7,000	7,089	1,666,007
10	100,000	0.98	91	0.98	3	7,000	7,094	1,667,037
3	100,000	1.64	152	1.64	5	7,000	7,157	1,681,839
0.3	100,000	2.00	185	2.00	6	7,000	7,191	1,689,976
0.03	100,000	2.91	270	2.91	8	7,000	7,278	1,710,406
MEDIUM								
100	100,000	0	0	0	0	7,000	7,000	1,645,000
60	100,000	0	0	0	0	7,000	7,000	1,645,000
30	100,000	0.52	48	0.52	1	7,000	7,050	1,656,733
25	100,000	0.61	57	0.61	2	7,000	7,059	1,658,794
15	100,000	0.80	74	0.80	2	7,000	7,076	1,662,916
10	100,000	0.89	83	0.89	2	7,000	7,085	1,664,977
3	100,000	1.24	115	1.24	3	7,000	7,119	1,672,908
0.3	100,000	1.96	182	1.96	5	7,000	7,187	1,688,983
0.03	100,000	2.79	260	2.79	8	7,000	7,267	1,707,825
LOW								
100	100,000	0	0	0	0	7,000	7,000	1,645,000
60	100,000	0	0	0	0	7,000	7,000	1,645,000
30	100,000	0	0	0	0	7,000	7,000	1,645,000
25	100,000	0	0	0	0	7,000	7,000	1,645,000
15	100,000	0.16	14	0.16	0	7,000	7,015	1,648,490
10	100,000	0.46	43	0.46	1	7,000	7,044	1,655,359
3	100,000	0.89	83	0.89	2	7,000	7,085	1,664,977
0.3	100,000	1.77	164	1.77	5	7,000	7,169	1,684,815
0.03	100,000	2.26	210	2.26	6	7000	7,216	1,695,779
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (150,000 ft^2)			$235/m^3

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Table C.4.1. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Unrestricted Land Use, With Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Volume of Soil Washed	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	m^3	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH													
100	7,015	8,548	15	38,260	9,900	1,541,307	99	645	396,000	854,625	2,474,113	12,370,563	86,593,943
60	7,050	8,590	50	48,127	10,000	1,544,394	100	646	400,000	855,950	2,479,068	12,395,339	86,767,372
30	7,076	8,622	76	55,528	10,000	1,546,709	100	647	400,000	857,275	2,482,784	12,413,920	86,897,443
25	7,081	8,628	81	56,762	10,000	1,547,095	100	647	400,000	857,275	2,483,403	12,417,017	86,919,122
15	7,089	8,638	89	59,229	10,000	1,547,866	100	648	400,000	858,600	2,484,642	12,423,211	86,962,479
10	7,094	8,644	94	60,462	10,000	1,548,252	100	648	400,000	858,600	2,485,262	12,426,308	86,984,158
3	7,157	8,720	157	78,180	10,000	1,553,795	100	650	400,000	861,250	2,494,159	12,470,793	87,295,550
0.3	7,191	8,762	191	87,801	10,000	1,556,805	100	651	400,000	862,575	2,498,990	12,494,950	87,464,648
0.03	7,278	8,869	278	112,376	10,100	1,564,492	101	655	404,000	867,875	2,511,330	12,556,651	87,896,560
MEDIUM													
100	7,000	8,529	0	0	9,900	1,540,000	99	644	396,000	853,300	2,472,015	12,360,075	86,520,525
60	7,000	8,529	0	0	9,900	1,540,000	99	644	396,000	853,300	2,472,015	12,360,075	86,520,525
30	7,050	8,590	50	48,127	10,000	1,544,394	100	646	400,000	855,950	2,479,068	12,395,339	86,767,372
25	7,059	8,601	59	50,594	10,000	1,545,165	100	646	400,000	855,950	2,480,307	12,401,533	86,810,729
15	7,076	8,622	76	55,528	10,000	1,546,709	100	647	400,000	857,275	2,482,784	12,413,920	86,897,443
10	7,085	8,633	85	57,995	10,000	1,547,481	100	647	400,000	857,275	2,484,023	12,420,114	86,940,801
3	7,119	8,674	119	67,489	10,000	1,550,451	100	649	400,000	859,925	2,488,790	12,443,952	87,107,663
0.3	7,187	8,757	187	86,732	10,000	1,556,470	100	651	400,000	862,575	2,498,453	12,492,266	87,445,859
0.03	7,267	8,855	267	109,286	10,100	1,563,526	101	654	404,000	866,550	2,509,779	12,548,894	87,842,257
LOW													
100	7,000	8,529	0	0	9,900	1,540,000	99	644	396,000	853,300	2,472,015	12,360,075	86,520,525
60	7,000	8,529	0	0	9,900	1,540,000	99	644	396,000	853,300	2,472,015	12,360,075	86,520,525
30	7,000	8,529	0	0	9,900	1,540,000	99	644	396,000	853,300	2,472,015	12,360,075	86,520,525
25	7,000	8,529	0	0	9,900	1,540,000	99	644	396,000	853,300	2,472,015	12,360,075	86,520,525
15	7,015	8,548	15	38,260	9,900	1,541,307	99	645	396,000	854,625	2,474,113	12,370,563	86,593,943
10	7,044	8,583	44	46,483	10,000	1,543,879	100	646	400,000	855,950	2,478,242	12,391,210	86,738,467
3	7,085	8,633	85	57,995	10,000	1,547,481	100	647	400,000	857,275	2,484,023	12,420,114	86,940,801
0.3	7,169	8,736	169	81,743	10,000	1,554,910	100	651	400,000	862,575	2,495,948	12,479,740	87,358,179
0.03	7,216	8,793	216	94,867	10,100	1,559,015	101	652	404,000	863,900	2,502,538	12,512,692	87,588,845
Unit Rates and Notes		76 lbs/ft^3	Only soil from contam. site is washed, and not the 7,000 m^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.4.1. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Unrestricted Land Use, With Soil Washing)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $60/ft^3 Disposal Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	7,006	4,566,762	16,453,245	90,676,624	3	11,364	11,367	1,137
60	7,020	4,593,928	16,500,543	90,872,576	8	11,421	11,429	1,143
30	7,030	4,611,228	16,536,348	91,019,871	13	11,464	11,476	1,148
25	7,032	4,614,111	16,542,095	91,044,199	14	11,471	11,484	1,148
15	7,036	4,619,878	16,554,913	91,094,181	15	11,485	11,500	1,150
10	7,038	4,622,761	16,560,660	91,118,510	16	11,492	11,508	1,151
3	7,063	4,664,177	16,645,856	91,470,613	27	11,594	11,621	1,162
0.3	7,076	4,686,667	16,692,006	91,661,704	32	11,649	11,682	1,168
0.03	7,111	4,748,212	16,811,800	92,151,708	47	11,791	11,838	1,184
MEDIUM								
100	7,000	4,522,915	16,398,375	90,558,825	0	11,340	11,340	1,134
60	7,000	4,522,915	16,398,375	90,558,825	0	11,340	11,340	1,134
30	7,020	4,593,928	16,500,543	90,872,576	8	11,421	11,429	1,143
25	7,023	4,599,695	16,512,037	90,921,233	10	11,435	11,445	1,145
15	7,030	4,611,228	16,536,348	91,019,871	13	11,464	11,476	1,148
10	7,034	4,616,995	16,547,842	91,068,528	14	11,478	11,492	1,149
3	7,048	4,639,168	16,594,725	91,258,436	20	11,532	11,553	1,155
0.3	7,075	4,684,168	16,687,026	91,640,619	32	11,643	11,675	1,168
0.03	7,107	4,740,989	16,796,080	92,089,444	45	11,773	11,819	1,182
LOW								
100	7,000	4,522,915	16,398,375	90,558,825	0	11,340	11,340	1,134
60	7,000	4,522,915	16,398,375	90,558,825	0	11,340	11,340	1,134
30	7,000	4,522,915	16,398,375	90,558,825	0	11,340	11,340	1,134
25	7,000	4,522,915	16,398,375	90,558,825	0	11,340	11,340	1,134
15	7,006	4,566,762	16,453,245	90,676,624	3	11,364	11,367	1,137
10	7,018	4,590,084	16,492,881	90,840,138	7	11,411	11,419	1,142
3	7,034	4,616,995	16,547,842	91,068,528	14	11,478	11,492	1,149
0.3	7,068	4,672,506	16,663,763	91,542,222	29	11,614	11,643	1,164
0.03	7,086	4,707,285	16,726,254	91,802,408	37	11,690	11,727	1,173
Unit Rates and Notes	Disposal vol. is total soil vol. minus 60% of washed soil; remaining vol. is released			Page 3 of 3	0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.4.2. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Unrestricted Land Use, Without Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Slag Pile Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	m^3	$
HIGH								
100	100,000	0.16	14	0.16	0	7,000	7,015	1,648,490
60	100,000	0.52	48	0.52	1	7,000	7,050	1,656,733
30	100,000	0.80	74	0.80	2	7,000	7,076	1,662,916
25	100,000	0.84	78	0.84	2	7,000	7,081	1,663,946
15	100,000	0.93	87	0.93	3	7,000	7,089	1,666,007
10	100,000	0.98	91	0.98	3	7,000	7,094	1,667,037
3	100,000	1.64	152	1.64	5	7,000	7,157	1,681,839
0.3	100,000	2.00	185	2.00	6	7,000	7,191	1,689,876
0.03	100,000	2.91	270	2.91	8	7,000	7,278	1,710,406
MEDIUM								
100	100,000	0	0	0	0	7,000	7,000	1,645,000
60	100,000	0	0	0	0	7,000	7,000	1,645.000
30	100,000	0.52	48	0.52	1	7,000	7,050	1,656,733
25	100,000	0.61	57	0.61	2	7,000	7,059	1,658,794
15	100,000	0.80	74	0.80	2	7,000	7,076	1,662,916
10	100,000	0.89	83	0.89	2	7,000	7,085	1,664,977
3	100,000	1.24	115	1.24	3	7,000	7,119	1,672,908
0.3	100,000	1.96	182	1.96	5	7,000	7,187	1,688,983
0.03	100,000	2.79	260	2.79	8	7,000	7,267	1,707,825
LOW								
100	100,000	0	0	0	0	7,000	7,000	1,645,000
60	100,000	0	0	0	0	7,000	7,000	1,645,000
30	100,000	0	0	0	0	7,000	7,000	1,645,000
25	100,000	0	0	0	0	7,000	7,000	1,645,000
15	100,000	0.16	14	0.16	0	7,000	7,015	1,648,490
10	100,000	0.46	43	0.46	1	7,000	7,044	1,655,359
3	100,000	0.89	83	0.89	2	7,000	7,085	1,664,977
0.3	100,000	1.77	164	1.77	5	7,000	7,169	1,684,815
0.03	100,000	2.26	210	2.26	6	7000	7,216	1,695,779
Unit Rates and Notes		Diffusion model soil profile used below buildings		Diffusion model soil profile used below buildings	2% of building floor area (150,000 ft^2)			$235/m^3

Table C.4.2. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Unrestricted Land Use, Without Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $60/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	7,015	8,548	0	10,000	1,543,267	100	646	400,000	855,950	2,477,259	12,386,296	86,704,070
60	7,050	8,590	0	10,000	1,550,984	100	649	400,000	859,925	2,489,647	12,448,235	87,137,642
30	7,076	8,622	0	10,000	1,556,772	100	651	400,000	862,576	2,498,938	12,494,689	87,462,821
25	7,081	8,629	0	10,100	1,557,737	101	652	404,000	863,900	2,500,486	12,502,431	87,517,017
15	7,089	8,638	0	10,100	1,559,666	101	652	404,000	863,900	2,503,583	12,517,916	87,625,410
10	7,094	8,644	0	10,100	1,560,631	101	653	404,000	865,225	2,505,132	12,525,658	87,679,607
3	7,157	8,720	0	10,200	1,574,487	102	659	408,000	873,175	2,527,374	12,636,870	88,458,087
0.3	7,191	8,762	0	10,200	1,582,012	102	662	408,000	877,150	2,539,452	12,697,262	88,880,832
0.03	7,278	8,869	0	10,300	1,601,2[illegible]	103	670	412,000	887,750	2,570,303	12,851,516	89,960,612
MEDIUM												
100	7,000	8,529	0	9,900	1,540,0[illegible]0	99	644	396,000	853,300	2,472,015	12,360,075	86,520,525
60	7,000	8,529	0	9,900	1,540,000	99	644	396,000	853,300	2,472,015	12,360,075	86,520,525
30	7,050	8,590	0	10,000	1,550,984	100	649	400,000	859,925	2,489,647	12,448,235	87,137,642
25	7,059	8,601	0	10,000	1,552,9[illegible]4	100	650	400,000	861,250	2,492,744	12,463,719	87,246,035
15	7,076	8,622	0	10,000	1,556,772	100	651	400,000	862,575	2,498,938	12,494,689	87,462,821
10	7,085	8,633	0	10,100	1,558,701	101	652	404,000	863,900	2,502,035	12,510,173	87,571,214
3	7,119	8,674	0	10,100	1,566,127	101	656	404,000	867,875	2,513,953	12,569,767	87,988,370
0.3	7,187	8,757	0	10,200	1,581,176	102	661	408,000	875,825	2,538,110	12,690,551	88,833,860
0.03	7,267	8,855	0	10,300	1,598,815	103	669	412,000	886,425	2,566,424	12,832,122	89,824,855
LOW												
100	7,000	8,529	0	9,900	1,540,000	99	644	396,000	853,300	2,472,015	12,360,075	86,520,525
60	7,000	8,529	0	9,900	1,540,000	99	644	396,000	853,300	2,472,015	12,360,075	86,520,525
30	7,000	8,529	0	9,900	1,540,000	99	644	396,000	853,300	2,472,015	12,360,075	86,520,525
25	7,000	8,529	0	9,900	1,540,0[illegible]0	99	644	396,000	853,300	2,472,015	12,360,075	86,520,525
15	7,015	8,548	0	10,000	1,543,267	100	646	400,000	855,950	2,477,259	12,386,296	86,704,070
10	7,044	8,583	0	10,000	1,549,698	100	648	400,000	858,600	2,487,582	12,437,911	87,065,380
3	7,085	8,633	0	10,100	1,558,701	101	652	404,000	863,900	2,502,035	12,510,173	87,571,214
0.3	7,169	8,736	0	10,200	1,577,274	102	660	408,000	874,500	2,531,847	12,659,237	88,614,659
0.03	7,216	8,793	0	10,200	1,587,538	102	664	408,000	879,800	2,548,324	12,741,618	89,191,326
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	85 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $60/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.4.2. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Unrestricted Land Use, Without Soil Washing)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $[illegible]/ft^3 Dispose. Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	7,015	4,535,749	16,434,002	90,751,777	0	11,364	11,364	1,136
60	7,050	4,556,380	16,515,877	91,205,284	0	11,421	11,421	1,142
30	7,076	4,571,853	16,576,952	91,545,084	0	11,464	11,464	1,146
25	7,081	4,578,532	16,588,014	91,602,600	0	11,471	11,471	1,147
15	7,089	4,583,690	16,607,489	91,714,983	0	11,485	11,485	1,148
10	7,094	4,586,269	16,618,551	91,772,500	0	11,492	11,492	1,149
3	7,157	4,627,412	16,766,370	92,587,588	0	11,594	11,594	1,159
0.3	7,191	4,647,528	16,846,299	93,029,870	0	11,649	11,649	1,165
0.03	7,278	4,703,009	17,050,903	94,159,998	0	11,791	11,791	1,179
MEDIUM								
100	7,000	4,522,915	16,398,375	90,558,825	0	11,340	11,340	1,134
60	7,000	4,522,915	16,398,375	90,558,825	0	11,340	11,340	1,134
30	7,050	4,556,380	16,515,877	91,205,284	0	11,421	11,421	1,142
25	7,059	4,561,538	16,536,677	91,318,993	0	11,435	11,435	1,144
15	7,076	4,571,853	16,576,952	91,545,084	0	11,464	11,464	1,146
10	7,085	4,581,111	16,597,751	91,658,792	0	11,478	11,478	1,148
3	7,119	4,600,961	16,676,677	92,095,280	0	11,532	11,532	1,153
0.3	7,187	4,645,293	16,836,535	92,979,844	0	11,643	11,643	1,164
0.03	7,267	4,696,549	17,025,186	94,017,920	0	11,773	11,773	1,177
LOW								
100	7,000	4,522,915	16,398,375	90,558,825	0	11,340	11,340	1,134
60	7,000	4,522,915	16,398,375	90,558,825	0	11,340	11,340	1,134
30	7,000	4,522,915	16,398,375	90,558,825	0	11,340	11,340	1,134
25	7,000	4,522,915	16,398,375	90,558,825	0	11,340	11,340	1,134
15	7,015	4,535,749	16,434,002	90,751,777	0	11,364	11,364	1,136
10	7,044	4,552,942	16,501,569	91,129,037	0	11,411	11,411	1,141
3	7,085	4,581,111	16,597,751	91,658,792	0	11,478	11,478	1,148
0.3	7,169	4,634,863	16,795,826	92,751,248	0	11,614	11,614	1,161
0.03	7,216	4,662,303	16,904,736	93,354,444	0	11,690	11,690	1,169
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.4.3. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, With Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	100,000	0.00	0	0.00	0	0	0
60	100,000	0.00	0	0.00	0	0	0
30	100,000	0.00	0	0.00	0	0	0
25	100,000	0.00	0	0.00	0	0	0
15	100,000	0.00	0	0.00	0	0	0
10	100,000	0.00	0	0.00	0	0	0
3	100,000	0.44	41	0.44	1	42	9,830
0.3	100,000	1.12	104	1.12	3	107	25,158
0.03	100,000	1.94	181	1.94	5	186	43,708
MEDIUM							
100	100,000	0.00	0	0.00	0	0	0
60	100,000	0.00	0	0.00	0	0	0
30	100,000	0.00	0	0.00	0	0	0
25	100,000	0.00	0	0.00	0	0	0
15	100,000	0.00	0	0.00	0	0	0
10	100,000	0.00	0	0.00	0	0	0
3	100,000	0.00	0	0.00	0	0	0
0.3	100,000	0.94	88	0.94	3	90	21,245
0.03	100,000	1.85	172	1.85	5	177	41,647
LOW							
100	100,000	0.00	0	0.00	0	0	0
60	100,000	0.00	0	0.00	0	0	0
30	100,000	0.00	0	0.00	0	0	0
25	100,000	0.00	0	0.00	0	0	0
15	100,000	0.00	0	0.00	0	0	0
10	100,000	0.00	0	0.00	0	0	0
3	100,000	0.00	0	0.00	0	0	0
0.3	100,000	0.65	60	0.65	2	62	14,586
0.03	100,000	1.42	132	1.42	4	136	32,029
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (160,000 ft^2)	Excludes the 7000 m^3 slag pile, which becomes the capped tailings pile	$235/m^3

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Table C.4.3. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, With Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Volume of Soil Washed	Soil Washing Costs	Soil Transport Loads, Rail Gondolas Off-Site	Soil Transport Loads, Truck Off Site	Soil Transport Costs, Rail Off-Site	Soil Transport Costs, Truck On-site	On-Site Soil Stabilization & Capping Costs
mrem/yr	m^3	MT	m^3	$	# cars	# Trucks	$	$	$
HIGH									
100	0	0	0	0	0	0	0	0	490,000
60	0	0	0	0	0	0	0	0	490,000
30	0	0	0	0	0	0	0	0	490,000
25	0	0	0	0	0	0	0	0	490,000
15	0	0	0	0	0	0	0	0	490,000
10	0	0	0	0	0	0	0	0	490,000
3	42	51	42	45,849	0	0	0	56	491,171
0.3	107	130	107	64,198	0	0	0	143	492,898
0.03	186	227	186	86,403	0	0	0	249	495,208
MEDIUM									
100	0	0	0	0	0	0	0	0	490,000
60	0	0	0	0	0	0	0	0	490,000
30	0	0	0	0	0	0	0	0	490,000
25	0	0	0	0	0	0	0	0	490,000
15	0	0	0	0	0	0	0	0	490,000
10	0	0	0	0	0	0	0	0	490,000
3	0	0	0	0	0	0	0	0	490,000
0.3	90	110	90	59,513	0	0	0	121	492,531
0.03	177	216	177	83,935	0	0	0	237	494,962
LOW									
100	0	0	0	0	0	0	0	0	490,000
60	0	0	0	0	0	0	0	0	490,000
30	0	0	0	0	0	0	0	0	490,000
25	0	0	0	0	0	0	0	0	490,000
15	0	0	0	0	0	0	0	0	490,000
10	0	0	0	0	0	0	0	0	490,000
3	0	0	0	0	0	0	0	0	490,000
0.3	62	76	62	51,542	0	0	0	83	491,738
0.03	136	166	136	72,422	0	0	0	182	493,816
Unit Rates and Notes		76 lbs/ft^3 soil.	Only soil from contam. site is washed, and not the 7,000 m^3 slag pile	From RACER Model	Not used for Rare Metals Facility	Not used for Rare Metals Facility	$4,000 per gondola railcar. Not used for Rare Metals Facility	Rent for 25-ton (20 yd^3) dump trucks @ $580.80/d. Driver costs $239/d. Truck hauls 320 yd^3 per day.	Stabilization & capping costs for onsite tailings pile 1.5 m deep @ $105/m^2 (RACER Model)

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Table C.4.3. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, With Soil Washing)

Residual Dose Rate	Total On-Site Disposal Volume	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $60/ft^3	Soil Disposal Costs @ $350/ft^3	Total Soil Remediation Costs	Soil Washing Labor	Soil Excavation & Stabilization Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	$	person-hr	person-hr	person-hr	person-mrem
HIGH									
100	7,000	0	0	0	490,000	0	229	229	23
60	7,000	0	0	0	490,000	0	229	229	23
30	7,000	0	0	0	490,000	0	229	229	23
25	7,000	0	0	0	490,000	0	229	229	23
15	7,000	0	0	0	490,000	0	229	229	23
10	7,000	0	0	0	490,000	0	229	229	23
3	7,017	0	0	0	546,906	7	299	306	31
0.3	7,043	0	0	0	582,497	18	407	425	43
0.03	7,074	0	0	0	625,567	32	539	570	57
MEDIUM									
100	7,000	0	0	0	490,000	0	229	229	23
60	7,000	0	0	0	490,000	0	229	229	23
30	7,000	0	0	0	490,000	0	229	229	23
25	7,000	0	0	0	490,000	0	229	229	23
15	7,000	0	0	0	490,000	0	229	229	23
10	7,000	0	0	0	490,000	0	229	229	23
3	7,000	0	0	0	490,000	0	229	229	23
0.3	7,036	0	0	0	573,410	15	379	395	39
0.03	7,071	0	0	0	620,782	30	524	554	55
LOW									
100	7,000	0	0	0	490,000	0	229	229	23
60	7,000	0	0	0	490,000	0	229	229	23
30	7,000	0	0	0	490,000	0	229	229	23
25	7,000	0	0	0	490,000	0	229	229	23
15	7,000	0	0	0	490,000	0	229	229	23
10	7,000	0	0	0	490,000	0	229	229	23
3	7,000	0	0	0	490,000	0	229	229	23
0.3	7,025	0	0	0	557,949	11	332	343	34
0.03	7,055	0	0	0	598,449	23	456	479	48
Unit Rates and Notes	Remainder of contam. soil (40% after washing) is consolidated with the slag pile into an onsite capped tailings pile.	Costs for bulk disposal at LARW disposal facility, $10/ft^3. Not used for Rare Metals Facility	Costs for in-compact disposal at existing LLW disposal facility, $60/ft^3. Not used for Rare Metals Facility	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3. Not used for Rare Metals Facility		0.17 person-hr per m^3	1.82 person-hr/m^3 for excavation, 0.6 person-hr / truck load (20 yd^3) for transport to on-site burial, 0.5 person-hr / truck load for stabil.		0.1 mrem per person-hr labor

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Table C.4.4. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, Without Soil Washing)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	100,000	0.00	0	0.00	0	0	0
60	100,000	0.00	0	0.00	0	0	0
30	100,000	0.00	0	0.00	0	0	0
25	100,000	0.00	0	0.00	0	0	0
15	100,000	0.00	0	0.00	0	0	0
10	100,000	0.00	0	0.00	0	0	0
3	100,000	0.44	41	0.44	1	42	9,830
0.3	100,000	1.12	104	1.12	3	107	25,158
0.03	100,000	1.94	181	1.94	5	186	43,708
MEDIUM							
100	100,000	0.00	0	0.00	0	0	0
60	100,000	0.00	0	0.00	0	0	0
30	100,000	0.00	0	0.00	0	0	0
25	100,000	0.00	0	0.00	0	0	0
15	100,000	0.00	0	0.00	0	0	0
10	100,000	0.00	0	0.00	0	0	0
3	100,000	0.00	0	0.00	0	0	0
0.3	100,000	0.94	88	0.94	3	90	21,245
0.03	100,000	1.85	172	1.85	5	177	41,647
LOW							
100	100,000	0.00	0	0.00	0	0	0
60	100,000	0.00	0	0.00	0	0	0
30	100,000	0.00	0	0.00	0	0	0
25	100,000	0.00	0	0.00	0	0	0
15	100,000	0.00	0	0.00	0	0	0
10	100,000	0.00	0	0.00	0	0	0
3	100,000	0.00	0	0.00	0	0	0
0.3	100,000	0.65	60	0.65	2	62	14,586
0.03	100,000	1.42	132	1.42	4	136	32,029
Unit Rates and Notes		Diffusion model soil profile		Diffusion model soil profile used below buildings	2% of building floor area (150,000 ft^2)	Excludes the 7000 m^3 slag pile, which becomes the capped tailings pile	$235/m^3

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Table C.4.4. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, Without Soil Washing)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Transport Loads, Rail Gondolas Off-Site	Soil Transport Loads, Truck Off Site	Soil Transport Costs, Rail Off-Site	Soil Transport Costs, Truck On-Site	On-Site Soil Stabilization & Capping Costs
mrem/yr	m^3	MT	$	# cars	# Trucks	$	$	$
HIGH								
100	0	0	0	0	0	0	0	490,000
60	0	0	0	0	0	0	0	490,000
30	0	0	0	0	0	0	0	490,000
25	0	0	0	0	0	0	0	490,000
15	0	0	0	0	0	0	0	490,000
10	0	0	0	0	0	0	0	490,000
3	42	51	0	0	0	0	140	492,928
0.3	107	130	0	0	0	0	358	497,494
0.03	186	227	0	0	0	0	622	503,019
MEDIUM								
100	0	0	0	0	0	0	0	490,000
60	0	0	0	0	0	0	0	490,000
30	0	0	0	0	0	0	0	490,000
25	0	0	0	0	0	0	0	490,000
15	0	0	0	0	0	0	0	490,000
10	0	0	0	0	0	0	0	490,000
3	0	0	0	0	0	0	0	490,000
0.3	90	110	0	0	0	0	302	496,328
0.03	177	216	0	0	0	0	593	502,405
LOW								
100	0	0	0	0	0	0	0	490,000
60	0	0	0	0	0	0	0	490,000
30	0	0	0	0	0	0	0	490,000
25	0	0	0	0	0	0	0	490,000
15	0	0	0	0	0	0	0	490,000
10	0	0	0	0	0	0	0	490,000
3	0	0	0	0	0	0	0	490,000
0.3	62	76	0	0	0	0	208	494,345
0.03	136	166	0	0	0	0	456	499,540
Unit Rates and Notes		76 lbs/ft^3 soil.	From RACER Model	Not used for Rare Metals Facility	Not used for Rare Metals Facility	$4,000 per gondola railcar. Not used for Rare Metals Facility	Rent for 25-ton (20 yd^3) dump trucks @ $680.80/d. Driver costs $238/d. Truck hauls 320 yd^3 per day.	Stabilization & capping costs for onsite tailings pile 1.5 m deep @ $105/m^2 (RACER Model)

Table C.4.4. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, Without Soil Washing)

Residual Dose Rate	Total On-Site Disposal Volume	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3	Total Soil Remediation Costs	Soil Washing Labor	Soil Excavation & Stabilization Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	$	person-hr	person-hr	person-hr	person-mrem
HIGH									
100	7,000	0	0	0	490,000	0	229	229	23
60	7,000	0	0	0	490,000	0	229	229	23
30	7,000	0	0	0	490,000	0	229	229	23
25	7,000	0	0	0	490,000	0	229	229	23
15	7,000	0	0	0	490,000	0	229	229	23
10	7,000	0	0	0	490,000	0	229	229	23
3	7,042	0	0	0	502,897	0	299	299	30
0.3	7,107	0	0	0	523,010	0	409	409	1
0.03	7,186	0	0	0	547,350	0	542	542	54
MEDIUM									
100	7,000	0	0	0	490,000	0	229	229	23
60	7,000	0	0	0	490,000	0	229	229	23
30	7,000	0	0	0	490,000	0	229	229	23
25	7,000	0	0	0	490,000	0	229	229	23
15	7,000	0	0	0	490,000	0	229	229	23
10	7,000	0	0	0	490,000	0	229	229	23
3	7,000	0	0	0	490,000	0	229	229	23
0.3	7,090	0	0	0	517,875	0	381	381	38
0.03	7,177	0	0	0	544,645	0	528	528	53
LOW									
100	7,000	0	0	0	490,000	0	229	229	23
60	7,000	0	0	0	490,000	0	229	229	23
30	7,000	0	0	0	490,000	0	229	229	23
25	7,000	0	0	0	490,000	0	229	229	23
15	7,000	0	0	0	490,000	0	229	229	23
10	7,000	0	0	0	490,000	0	229	229	23
3	7,000	0	0	0	490,000	0	229	229	23
0.3	7,062	0	0	0	509,138	0	333	333	33
0.03	7,136	0	0	0	532,025	0	459	459	46
Unit Rates and Notes	Contam. soil is consolidated with the slag pile into an onsite capped tailings pile.	Costs for bulk disposal at LARW disposal facility, $10/ft^3. Not used for Rare Metals Facility	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3. Not used for Rare Metals Facility	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3. Not used for Rare Metals Facility		0.17 person-hr per m^3	1.62 person-hr/m^3 for excavation, 0.5 person-hr / truck load (20 yd^3) for transport to on-site burial, 0.5 person-hr / truck load for stabil.		0.1 mrem per person-hr labor

Table C.4.5. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metals Extraction Plant (Unrestricted Land Use, With Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Slag Pile Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	m^3	$
HIGH								
100	100,000	11.76	1,093	0.16	0	7,000	8,093	1,901,859
60	100,000	16.08	1,494	0.52	1	7,000	8,495	1,996,438
30	100,000	21.95	2,039	0.80	2	7,000	9,041	2,124,628
25	100,000	23.49	2,182	0.84	2	7,000	9,184	2,158,329
15	100,000	27.81	2,583	0.93	3	7,000	9,586	2,252,728
10	100,000	31.24	2,902	0.98	3	7,000	9,905	2,327,639
3	100,000	41.47	3,848	1.64	5	7,000	10,853	2,550,419
0.3	100,000	60.9[illegible]	5,658	2.00	6	7,000	12,663	2,975,893
0.03	100,000	80.[illegible]	7,467	2.91	8	7,000	14,475	3,401,731
MEDIUM								
100	100,000	5.90	548	0	0	7,000	7,548	1,773,747
60	100,000	10.2[illegible]	949	0	0	7,000	7,949	1,868,086
30	100,000	16.09	1,494	0.52	1	7,000	8,495	1,996,438
25	100,000	17.62	1,637	0.61	2	7,000	8,639	2,030,169
15	100,000	21.95	2,039	0.80	2	7,000	9,041	2,124,628
10	100,000	25.38	2,357	0.89	2	7,000	9,360	2,199,569
3	100,000	35.56	3,304	1.24	3	7,000	10,307	2,422,149
0.3	100,000	55.04	5,113	1.96	5	7,000	12,119	2,847,857
0.03	100,000	74.52	6,923	2.79	8	7,000	13,930	3,273,646
LOW								
100	100,000	0	0	0	0	7,000	7,000	1,645,000
60	100,000	0.03	3	0	0	7,000	7,003	1,645,737
30	100,000	5.90	548	0	0	7,000	7,548	1,773,747
25	100,000	7.44	691	0	0	7,000	7,691	1,807,418
15	100,000	11.76	1,093	0.16	0	7,000	8,093	1,901,859
10	100,000	15.19	1,411	0.46	1	7,000	8,413	1,976,940
3	100,000	25.38	2,357	0.89	2	7,000	9,360	2,199,569
0.3	100,000	44.85	4,167	1.77	5	7,000	11,172	2,625,387
0.03	100,000	64.33	5,976	2.26	6	7000	12,983	3,050,946
Unit Rates and Notes		Molycorp soil profile		Diffusion model soil profile used below buildings	2% of building floor area (150,000 ft^2)			$235/m^3

Table C.4.5. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metals Extraction Plant (Unrestricted Land Use, With Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Volume of Soil Washed	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3
mrem/yr	m^3	MT	m^3	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH													
100	8,093	9,861	1,093	341,552	10,600	1,636,185	106	684	424,000	906,300	2,626,412	13,132,061	91,924,430
60	8,495	10,352	1,495	454,767	10,800	1,671,602	108	699	432,000	926,175	2,683,264	13,416,318	93,914,224
30	9,041	11,016	2,041	608,215	11,100	1,719,605	111	719	444,000	952,675	2,760,318	13,801,592	96,611,141
25	9,184	11,191	2,184	648,556	11,200	1,732,225	112	725	448,000	960,625	2,780,576	13,902,880	97,320,158
15	9,586	11,681	2,586	761,555	11,400	1,767,575	114	739	456,000	979,175	2,837,319	14,186,595	99,306,164
10	9,905	12,069	2,905	851,227	11,600	1,795,627	116	751	464,000	995,075	2,882,348	14,411,739	100,882,174
3	10,853	13,224	3,853	1,117,903	12,100	1,879,051	121	786	484,000	1,041,450	3,016,260	15,081,302	105,569,115
0.3	12,663	15,430	5,663	1,627,211	13,100	2,038,377	131	853	524,000	1,130,225	3,272,012	16,360,060	114,520,418
0.03	14,475	17,638	7,475	1,720,027	14,200	2,197,840	142	919	568,000	1,217,675	3,527,982	17,639,911	123,479,377
MEDIUM													
100	7,548	9,197	548	188,198	10,200	1,588,212	102	664	408,000	879,800	2,549,405	12,747,023	89,229,164
60	7,949	9,686	949	301,125	10,500	1,623,539	105	679	420,000	899,675	2,606,112	13,030,558	91,213,907
30	8,495	10,352	1,495	454,767	10,800	1,671,602	108	699	432,000	926,175	2,683,264	13,416,318	93,914,224
25	8,639	10,527	1,639	495,144	10,900	1,684,233	109	705	436,000	934,125	2,703,539	13,517,696	94,623,873
15	9,041	11,016	2,041	608,215	11,100	1,719,605	111	719	444,000	952,675	2,760,318	13,801,592	96,611,141
10	9,360	11,405	2,360	697,922	11,300	1,747,668	113	731	452,000	968,575	2,805,365	14,026,826	98,187,783
3	10,307	12,559	3,307	964,359	11,800	1,831,017	118	766	472,000	1,014,950	2,939,158	14,695,788	102,870,514
0.3	12,119	14,766	5,119	1,473,947	12,800	1,990,432	128	833	512,000	1,103,725	3,195,050	15,975,249	111,826,743
0.03	13,930	16,974	6,930	1,983,632	13,900	2,149,876	139	899	556,000	1,191,175	3,450,990	17,254,952	120,784,667
LOW													
100	7,000	8,529	0	0	9,900	1,540,000	99	644	396,000	853,300	2,472,015	12,360,075	86,520,525
60	7,003	8,533	3	34,965	9,900	1,540,276	99	644	396,000	853,300	2,472,458	12,362,291	86,536,035
30	7,548	9,197	548	188,198	10,200	1,588,212	102	664	408,000	879,800	2,549,405	12,747,023	89,229,164
25	7,691	9,372	691	228,503	10,300	1,600,820	103	670	412,000	887,750	2,569,644	12,848,221	89,937,549
15	8,093	9,861	1,093	341,552	10,600	1,636,185	106	684	424,000	906,300	2,626,412	13,132,061	91,924,430
10	8,413	10,251	1,413	431,427	10,700	1,664,301	107	696	428,000	922,200	2,671,543	13,357,717	93,504,019
3	9,360	11,405	2,360	697,922	11,300	1,747,668	113	731	452,000	968,575	2,805,365	14,026,826	98,187,783
0.3	11,172	13,613	4,172	1,207,642	12,300	1,907,124	123	798	492,000	1,057,350	3,061,323	15,306,617	107,146,318
0.03	12,983	15,819	5,983	1,717,052	13,300	2,066,482	133	864	532,000	1,144,800	3,317,126	16,585,631	116,099,415
Unit Rates and Notes		76 lbs/ft^3	Only soil from contam. site is washed, and not the 7,000 m^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	95 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3; truck transport only.

Table C.4.5. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metals Extraction Plant (Unrestricted Land Use, With Soil Washing, Mixing/Landfilling)

Residual Dose Rate mrem/yr	Total Soil Volume Disposed m^3	Total Soil @ $10/ft^3 Disposal Costs $	Remediation @ $50/ft^3 Disposal Costs $	Costs @ $350/ft^3 Disposal Costs $	Soil Washing Labor man-hr	Soil Excavation Labor man-hr	Total Soil Remediation Labor man-hr	Total Occupational Dose person-mrem
HIGH								
100	7,437	5,304,423	17,917,958	96,710,327	186	13,111	13,298	1,330
60	7,598	5,577,268	18,465,300	98,963,208	254	13,763	14,017	1,402
30	7,816	5,948,261	19,206,715	102,016,264	347	14,646	14,993	1,499
25	7,874	6,046,661	19,402,615	102,819,894	371	14,879	15,250	1,525
15	8,034	6,319,002	19,947,628	105,067,197	440	15,529	15,969	1,597
10	8,162	6,536,813	20,381,306	106,851,741	494	16,046	16,540	1,654
3	8,541	7,180,682	21,670,124	112,157,937	655	17,582	18,237	1,824
0.3	9,265	8,412,216	24,131,766	122,292,124	963	20,515	21,477	2,148
0.03	9,990	9,231,940	26,177,184	132,016,650	1,271	23,450	24,721	2,472
MEDIUM								
100	7,219	4,929,550	17,176,980	93,659,120	93	12,228	12,321	1,[illegible]32
60	7,380	5,206,823	17,[illegible]2,983	95,906,331	161	12,878	13,039	1,304
30	7,598	5,577,268	18,465,300	98,963,208	254	13,763	14,017	1,402
25	7,656	5,675,752	18,661,367	99,767,544	279	13,995	14,274	1,427
15	7,816	5,948,261	19,206,715	102,016,264	347	14,646	14,993	1,499
10	7,944	6,166,156	19,640,561	103,801,518	401	15,163	15,564	1,556
3	8,323	6,809,465	20,928,263	109,102,989	562	16,697	17,260	1,726
0.3	9,047	8,041,654	23,391,210	119,242,704	870	19,632	20,502	2,050
0.03	9,772	9,278,168	25,853,281	129,382,995	1,178	22,567	23,745	2,375
LOW								
100	7,000	4,522,915	16,398,375	90,558,825	0	11,340	11,340	1,134
60	7,001	4,559,060	16,436,569	90,610,314	1	11,345	11,346	1,135
30	7,219	4,929,550	17,176,980	93,659,120	93	12,228	12,321	1,232
25	7,276	5,027,866	17,372,713	94,462,041	117	12,460	12,577	1,258
15	7,437	5,304,423	17,917,958	96,710,327	186	13,111	13,296	1,330
10	7,565	5,518,610	18,352,585	98,498,887	240	13,628	13,868	1,387
3	7,944	6,166,156	19,640,561	103,801,518	401	15,163	15,564	1,556
0.3	8,669	7,398,652	22,104,119	113,943,820	709	18,098	18,808	1,881
0.03	9,393	8,630,424	24,564,911	124,078,695	1,017	21,032	22,049	2,205
Unit Rates and Notes	Disposal vol. is total soil vol. minus 60% of washed soil; remaining vol. is released				0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

Table C.4.6. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metals Extraction Plant (Unrestricted Land Use, Without Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Slag Pile Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	m^3	$
HIGH								
100	100,000	11.76	1,093	0.16	0	7,000	8,093	1,901,859
60	100,000	16.08	1,494	0.52	1	7,000	8,495	1,996,438
30	100,000	21.95	2,039	0.80	2	7,000	9,041	2,124,628
25	100,000	23.49	2,182	0.84	2	7,000	9,184	2,158,329
15	100,000	27.81	2,583	0.93	3	7,000	9,586	2,252,728
10	100,000	31.24	2,902	0.98	3	7,000	9,905	2,327,639
3	100,000	41.42	3,848	1.64	5	7,000	10,853	2,550,419
0.3	100,000	60.90	5,658	2.00	6	7,000	12,663	2,975,893
0.03	100,000	80.38	7,467	2.91	8	7,000	14,475	3,401,731
MEDIUM								
100	100,000	5.90	548	0	0	7,000	7,548	1,773,747
60	100,000	10.22	949	0	0	7,000	7,949	1,868,086
30	100,000	16.08	1,494	0.52	1	7,000	8,495	1,996,438
25	100,000	17.62	1,637	0.61	2	7,000	8,639	2,030,169
15	100,000	21.95	2,039	0.80	2	7,000	9,041	2,124,628
10	100,000	25.38	2,357	0.89	2	7,000	9,360	2,199,569
3	100,000	35.56	3,304	1.24	3	7,000	10,307	2,422,149
0.3	100,000	55.04	5,113	1.96	5	7,000	12,119	2,847,857
0.03	100,000	74.52	6,923	2.79	8	7,000	13,930	3,273,646
LOW								
100	100,000	0	0	0	0	7,000	7,000	1,645,000
60	100,000	0.03	3	0	0	7,000	7,003	1,645,737
30	100,000	5.90	548	0	0	7,000	7,548	1,773,747
25	100,000	7.44	691	0	0	7,000	7,691	1,807,418
15	100,000	11.76	1,093	0.16	0	7,000	8,093	1,901,859
10	100,000	15.19	1,411	0.46	1	7,000	8,413	1,976,940
3	100,000	25.38	2,357	0.89	2	7,000	9,360	2,199,569
0.3	100,000	44.85	4,167	1.77	5	7,000	11,172	2,625,387
0.03	100,000	64.33	5,976	2.26	6	7000	12,983	3,050,946
Unit Rates and Notes		Molycorp soil profile		Diffusion model soil profile used below buildings	2% of building floor area (150,000 ft^2)			$235/m^3

Table C.4.6. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metals Extraction Plant (Unrestricted Land Use, Without Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Packaging Costs, Gondola Car	Soil Packaging Costs, B-25 Boxes	Soil Transport Loads, Gondola Cars	Soil Transport Loads, Truck Loads	Soil Transport Costs, Rail	Soil Transport Costs, Truck	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $360/ft^3
mrem/yr	m^3	MT	$	$	$	# cars	# Trucks	$	$	$	$	$
HIGH												
100	8,093	9,861	0	11,500	1,780,464	115	745	460,000	987,125	2,858,008	14,290,041	100,030,288
60	8,495	10,352	0	12,100	1,869,006	121	782	484,000	1,036,150	3,000,136	15,000,682	105,004,774
30	9,041	11,016	0	12,800	1,989,013	128	832	512,000	1,102,400	3,192,773	15,963,867	111,747,066
25	9,184	11,191	0	13,000	2,020,563	130	845	520,000	1,119,625	3,243,417	16,217,087	113,519,608
15	9,586	11,681	0	13,600	2,108,937	136	882	544,000	1,168,650	3,385,275	16,926,375	118,484,622
10	9,905	12,069	0	14,000	2,179,066	140	911	560,000	1,207,075	3,497,847	17,489,235	122,424,648
3	10,853	13,224	0	15,400	2,387,626	154	999	616,000	1,323,675	3,832,629	19,163,143	134,142,000
0.3	12,663	15,430	0	17,900	2,785,942	179	1,165	716,000	1,543,625	4,472,007	22,360,037	156,520,259
0.03	14,475	17,638	0	20,500	3,184,599	205	1,332	820,000	1,764,900	5,111,933	25,559,665	178,917,654
MEDIUM												
100	7,548	9,197	0	10,700	1,660,529	107	695	428,000	920,875	2,665,489	13,327,446	93,292,122
60	7,949	9,686	0	11,300	1,748,847	113	732	452,000	969,900	2,807,257	14,036,283	98,253,979
30	8,495	10,352	0	12,100	1,869,006	121	782	484,000	1,036,150	3,000,136	15,000,682	105,004,774
25	8,639	10,527	0	12,300	1,900,584	123	795	492,000	1,053,375	3,050,826	15,254,128	106,778,894
15	9,041	11,016	0	12,800	1,989,013	128	832	512,000	1,102,400	3,192,773	15,963,867	111,747,066
10	9,360	11,405	0	13,300	2,059,171	133	861	532,000	1,140,825	3,305,391	16,526,953	115,688,670
3	10,307	12,559	0	14,600	2,267,544	146	948	584,000	1,256,100	3,639,871	18,199,357	127,395,498
0.3	12,119	14,766	0	17,200	2,666,079	172	1,115	688,000	1,477,375	4,279,602	21,398,010	149,786,070
0.03	13,930	16,974	0	19,700	3,064,690	197	1,282	788,000	1,698,650	4,919,454	24,597,269	172,180,880
LOW												
100	7,000	8,529	0	9,900	1,540,000	99	644	396,000	853,300	2,472,015	12,360,075	86,520,525
60	7,003	8,533	0	9,900	1,540,690	99	645	396,000	854,625	2,473,123	12,365,614	86,559,301
30	7,548	9,197	0	10,700	1,660,529	107	695	428,000	920,875	2,665,489	13,327,446	93,292,122
25	7,691	9,372	0	10,900	1,692,051	109	708	436,000	938,100	2,716,088	13,580,441	95,063,085
15	8,093	9,861	0	11,500	1,780,464	115	745	460,000	987,125	2,858,008	14,290,041	100,030,288
10	8,413	10,251	0	11,900	1,850,752	119	774	476,000	1,025,550	2,970,836	14,854,180	103,979,259
3	9,360	11,405	0	13,300	2,059,171	133	861	532,000	1,140,825	3,305,391	16,526,953	115,688,670
0.3	11,172	13,613	0	15,800	2,457,809	158	1,028	632,000	1,362,100	3,945,286	19,726,430	138,085,008
0.03	12,983	15,819	0	18,400	2,856,205	184	1,194	736,000	1,582,050	4,584,793	22,923,964	160,467,750
Unit Rates and Notes		76 lbs/ft^3	From RACER Model	$100 per gondola car for plastic liner and cover	$220/m^3	86 tons of soil per railcar	7,296 lbs/box and 4 boxes/truck load, or 29,184 lbs soil/load	$4,000 per gondola railcar	$1,325 per truck load	Costs for bulk disposal at LARW disposal facility, $10/ft^3; rail transport only	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3; truck transport only.	Possible costs for future in-compact disposal facilities for LLW, $360/ft^3; truck transport only.

Table C.4.6. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metals Extraction Plant (Unrestricted Land Use, Without Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Total Soil Volume Disposed	Total Soil @ $10/ft^3 Disposal Costs	Remediation @ $50/ft^3 Disposal Costs	Costs @ $350/ft^3 Disposal Costs	Soil Washing Labor	Soil Excavation Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH								
100	8,093	5,231,367	18,959,489	104,699,736	0	13,111	13,111	1,311
60	8,495	5,492,674	19,902,275	109,906,367	0	13,763	13,763	1,376
30	9,041	5,842,201	21,179,908	116,963,107	0	14,646	14,646	1,465
25	9,184	5,934,746	21,515,604	118,818,125	0	14,879	14,879	1,488
15	9,586	6,195,603	22,456,689	124,014,936	0	15,529	15,529	1,553
10	9,905	6,399,486	23,203,016	128,138,428	0	16,046	16,046	1,605
3	10,853	7,014,448	25,424,863	140,403,720	0	17,582	17,582	1,758
0.3	12,663	8,181,800	29,665,497	163,825,719	0	20,515	20,515	2,051
0.03	14,475	9,354,164	33,910,895	187,268,884	0	23,450	23,450	2,345
MEDIUM								
100	7,548	4,877,936	17,682,597	97,647,273	0	12,228	12,228	1,223
60	7,949	5,138,643	18,623,115	102,840,812	0	12,878	12,878	1,288
30	8,495	5,492,674	19,902,275	109,906,367	0	13,763	13,763	1,376
25	8,639	5,585,294	20,238,255	111,763,022	0	13,995	13,995	1,400
15	9,041	5,842,201	21,179,908	116,963,107	0	14,646	14,646	1,465
10	9,360	6,050,260	21,926,518	121,088,235	0	15,163	15,163	1,516
3	10,307	6,660,620	24,145,149	133,341,291	0	16,697	16,697	1,670
0.3	12,119	7,832,659	28,389,321	156,777,381	0	19,632	19,632	1,963
0.03	13,930	9,000,799	32,634,254	180,217,865	0	22,567	22,567	2,257
LOW								
100	7,000	4,522,915	16,398,375	90,558,825	0	11,340	11,340	1,134
60	7,003	4,524,760	16,406,667	90,600,354	0	11,345	11,345	1,135
30	7,548	4,877,936	17,682,597	97,647,273	0	12,228	12,228	1,223
25	7,691	4,970,406	18,018,010	99,500,655	0	12,460	12,460	1,246
15	8,093	5,231,367	18,959,489	104,699,736	0	13,111	13,111	1,311
10	8,413	5,435,676	19,707,422	108,832,502	0	13,628	13,628	1,363
3	9,360	6,050,260	21,926,518	121,088,235	0	15,163	15,163	1,516
0.3	11,172	7,218,473	26,171,725	144,530,303	0	18,098	18,098	1,810
0.03	12,983	8,390,139	30,413,165	167,956,950	0	21,032	21,032	2,103
Unit Rates and Notes					0.17 man-hr per m^3	1.62 man-hr per m^3		0.1 mrem per man-hr labor

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Table C.4.7. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, With Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	100,000	0.00	0	0.00	0	0	0
60	100,000	0.00	0	0.00	0	0	0
30	100,000	0.00	0	0.00	0	0	0
25	100,000	0.00	0	0.00	0	0	0
15	100,000	1.26	117	0.00	0	117	27,422
10	100,000	4.69	435	0.00	0	435	102,303
3	100,000	14.87	1,381	0.44	1	1,383	324,938
0.3	100,000	34.35	3,191	1.12	3	3,194	750,625
0.03	100,000	53.83	5,001	1.94	5	5,006	1,176,405
MEDIUM							
100	100,000	0.00	0	0.00	0	0	0
60	100,000	0.00	0	0.00	0	0	0
30	100,000	0.00	0	0.00	0	0	0
25	100,000	0.00	0	0.00	0	0	0
15	100,000	0.00	0	0.00	0	0	0
10	100,000	0.00	0	0.00	0	0	0
3	100,000	9.01	837	0.00	0	837	196,842
0.3	100,000	28.49	2,646	0.94	3	2,649	622,501
0.03	100,000	47.96	4,456	1.85	5	4,461	1,048,335
LOW							
100	100,000	0.00	0	0.00	0	0	0
60	100,000	0.00	0	0.00	0	0	0
30	100,000	0.00	0	0.00	0	0	0
25	100,000	0.00	0	0.00	0	0	0
15	100,000	0.00	0	0.00	0	0	0
10	100,000	0.00	0	0.00	0	0	0
3	100,000	0.00	0	0.00	0	0	0
0.3	100,000	18.30	1,700	0.65	2	1,702	399,958
0.03	100,000	37.78	3,510	1.42	4	3,514	825,706
Unit Rates and Notes		Molycorp soil profile		Diffusion model soil profile used below buildings	2% of building floor area (150,000 ft^2)	Excludes the 7000 m^3 slag pile, which becomes the capped tailings pile	$\$235/m^3$

Table C.4.7. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, With Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Total Soil Volume Removed	Total Soil Weight	Volume of Soil Washed	Soil Washing Costs	Soil Transport Loads, Rail Gondoles Off-Site	Soil Transport Loads, Truck Off Site	Soil Transport Costs, Rail Off-Site	Soil Transport Costs, Truck On-site	On-Site Soil Stabilization & Capping Costs
mrem/yr	m^3	MT	m^3	$	# cars	# Trucks	$	$	$
HIGH									
100	0	0	0	0	0	0	0	0	490,000
60	0	0	0	0	0	0	0	0	490,000
30	0	0	0	0	0	0	0	0	490,000
25	0	0	0	0	0	0	0	0	490,000
15	117	142	117	66,908	0	0	0	156	493,267
10	435	530	435	156,543	0	0	0	583	502,189
3	1,383	1,685	1,383	423,046	0	0	0	1,851	528,716
0.3	3,194	3,892	3,194	932,608	0	0	0	4,275	579,436
0.03	5,006	6,100	5,006	1,442,283	0	0	0	6,700	630,167
MEDIUM									
100	0	0	0	0	0	0	0	0	490,000
60	0	0	0	0	0	0	0	0	490,000
30	0	0	0	0	0	0	0	0	490,000
25	0	0	0	0	0	0	0	0	490,000
15	0	0	0	0	0	0	0	0	490,000
10	0	0	0	0	0	0	0	0	490,000
3	837	1,020	837	269,470	0	0	0	1,120	513,430
0.3	2,649	3,228	2,649	779,239	0	0	0	3,545	564,170
0.03	4,461	5,436	4,461	1,288,978	0	0	0	5,970	614,908
LOW									
100	0	0	0	0	0	0	0	0	490,000
60	0	0	0	0	0	0	0	0	490,000
30	0	0	0	0	0	0	0	0	490,000
25	0	0	0	0	0	0	0	0	490,000
15	0	0	0	0	0	0	0	0	490,000
10	0	0	0	0	0	0	0	0	490,000
3	0	0	0	0	0	0	0	0	490,000
0.3	1,702	2,074	1,702	512,847	0	0	0	2,278	537,655
0.03	3,514	4,281	3,514	1,022,483	0	0	0	4,702	588,382
Unit Rates and Notes		78 lbs/ft^3 soil.	Only soil from contam. site is washed, and not the 7,000 m^3 slag pile	From RACER Model	Not used for Rare Metals Facility	Not used for Rare Metals Facility	$4,000 per gondola railcar. Not used for Rare Metals Facility	Rent for 25-ton (20 yd^3) dump trucks @ $580.60/d. Driver costs $238/d. Truck hauls 320 yd^3 per day.	Stabilization & capping costs for onsite tailings pile 1.5 m deep @ $105/m^2 (RACER Model)

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Table C.4.7. **Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, With Soil Washing, Mixing/Landfilling)**

Residual Dose Rate	Total On-Site Disposal Volume	Soil Disposal Costs @ $10/ft^3	Soil Disposal Costs @ $50/ft^3	Soil Disposal Costs @ $350/ft^3	Total Soil Remediation Costs	Soil Washing Labor	Soil Excavation & Stabilization Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	$	$	$	$	person-hr	person-hr	person-hr	person-mrem
HIGH									
100	7,000	0	0	0	490,000	0	229	229	23
60	7,000	0	0	0	490,000	0	229	229	23
30	7,000	0	0	0	490,000	0	229	229	23
25	7,000	0	0	0	490,000	0	229	229	23
15	7,047	0	0	0	587,754	20	423	443	44
10	7,174	0	0	0	761,618	74	954	1,028	103
3	7,553	0	0	0	1,278,551	235	2,532	2,767	277
0.3	8,278	0	0	0	2,266,944	543	5,550	6,093	609
0.03	9,002	0	0	0	3,255,555	851	8,568	9,419	942
MEDIUM									
100	7,000	0	0	0	490,000	0	229	229	23
60	7,000	0	0	0	490,000	0	229	229	23
30	7,000	0	0	0	490,000	0	229	229	23
25	7,000	0	0	0	490,000	0	229	229	23
15	7,000	0	0	0	490,000	0	229	229	23
10	7,000	0	0	0	490,000	0	229	229	23
3	7,335	0	0	0	980,662	142	1,623	1,765	177
0.3	8,060	0	0	0	1,969,455	450	4,641	5,092	509
0.03	8,784	0	0	0	2,958,192	758	7,660	8,418	842
LOW									
100	7,000	0	0	0	490,000	0	229	229	23
60	7,000	0	0	0	490,000	0	229	229	23
30	7,000	0	0	0	490,000	0	229	229	23
25	7,000	0	0	0	490,000	0	229	229	23
15	7,000	0	0	0	490,000	0	229	229	23
10	7,000	0	0	0	490,000	0	229	229	23
3	7,000	0	0	0	490,000	0	229	229	23
0.3	7,681	0	0	0	1,452,737	289	3,064	3,353	335
0.03	8,405	0	0	0	2,441,274	597	6,082	6,679	668
Unit Rates and Notes	Remainder of contam. soil (40% after washing) is consolidated with the slag pile into an onsite capped tailings pile.	Costs for bulk disposal at LARW disposal facility, $10/ft^3. Not used for Rare Metals Facility	Costs for in-compact disposal at existing LLW disposal facility, $50/ft^3. Not used for Rare Metals Facility	Possible costs for future in-compact disposal facilities for LLW, $350/ft^3. Not used for Rare Metals Facility		0.17 person-hr per m^3	1.82 person-hr/m^3 for excavation, 0.5 person-hr / truck load (20 yd^3) for transport to on-site burial, 0.5 person-hr / truck load for stabil.		0.1 mrem per person-hr labor

Table C.4.8. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, Without Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Contaminated Site Soil Area	Site Soil Depth	Site Soil Volume	Below-Building Soil Depth	Below-Building Soil Volume	Total Soil Volume Removed	Site Soil Excavation Costs
mrem/yr	ft^2	cm	m^3	cm	m^3	m^3	$
HIGH							
100	100,000	0.00	0	0.00	0	0	0
60	100,000	0.00	0	0.00	0	0	0
30	100,000	0.00	0	0.00	0	0	0
25	100,000	0.00	0	0.00	0	0	0
15	100,000	1.26	117	0.00	0	117	27,422
10	100,000	4.69	435	0.00	0	435	102,303
3	100,000	14.87	1,381	0.44	1	1,383	324,938
0.3	100,000	34.35	3,191	1.12	3	3,194	750,625
0.03	100,000	53.83	5,001	1.94	5	5,006	1,176,405
MEDIUM							
100	100,000	0.00	0	0.00	0	0	0
60	100,000	0.00	0	0.00	0	0	0
30	100,000	0.00	0	0.00	0	0	0
25	100,000	0.00	0	0.00	0	0	0
15	100,000	0.00	0	0.00	0	0	0
10	100,000	0.00	0	0.00	0	0	0
3	100,000	9.01	837	0.00	0	837	196,642
0.3	100,000	28.49	2,646	0.94	3	2,649	622,501
0.03	100,000	47.96	4,456	1.85	5	4,461	1,048,335
LOW							
100	100,000	0.00	0	0.00	0	0	0
60	100,000	0.00	0	0.00	0	0	0
30	100,000	0.00	0	0.00	0	0	0
25	100,000	0.00	0	0.00	0	0	0
15	100,000	0.00	0	0.00	0	0	0
10	100,000	0.00	0	0.00	0	0	0
3	100,000	0.00	0	0.00	0	0	0
0.3	100,000	18.30	1,700	0.65	2	1,702	399,958
0.03	100,000	37.78	3,510	1.42	4	3,514	825,706
Unit Rates and Notes		Molycorp soil profile		Diffusion model soil profile used below buildings	2% of building floor area (160,000 ft^2)	Excludes the 7000 m^3 slag pile, which becomes the capped tailings pile	$235/m^3

Table C.4.8. **Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, Without Soil Washing, Mixing/Landfilling)**

Residue Dose Rate	Total Soil Volume Removed	Total Soil Weight	Soil Washing Costs	Soil Transport Loads, Rail Gondolas Off-Site	Soil Transport Loads, Truck Off Site	Soil Transport Costs, Rail Off-Site	Soil Transport Costs, Truck On-Site	On-Site Soil Stabilization & Capping Costs
mrem/yr	m^3	MT	$	# cars	# Trucks	$	$	$
HIGH								
100	0	0	0	0	0	0	0	490,000
60	0	0	0	0	0	0	0	490,000
30	0	0	0	0	0	0	0	490,000
25	0	0	0	0	0	0	0	490,000
15	117	142	0	0	0	0	390	498,168
10	435	530	0	0	0	0	1,457	520,473
3	1,383	1,685	0	0	0	0	4,626	586,790
0.3	3,194	3,892	0	0	0	0	10,687	713,590
0.03	5,006	6,100	0	0	0	0	16,749	840,419
MEDIUM								
100	0	0	0	0	0	0	0	490,000
60	0	0	0	0	0	0	0	490,000
30	0	0	0	0	0	0	0	490,000
25	0	0	0	0	0	0	0	490,000
15	0	0	0	0	0	0	0	490,000
10	0	0	0	0	0	0	0	490,000
3	837	1,020	0	0	0	0	2,800	548,574
0.3	2,649	3,228	0	0	0	0	8,863	675,426
0.03	4,461	5,436	0	0	0	0	14,925	802,270
LOW								
100	0	0	0	0	0	0	0	490,000
60	0	0	0	0	0	0	0	490,000
30	0	0	0	0	0	0	0	490,000
25	0	0	0	0	0	0	0	490,000
15	0	0	0	0	0	0	0	490,000
10	0	0	0	0	0	0	0	490,000
3	0	0	0	0	0	0	0	490,000
0.3	1,702	2,074	0	0	0	0	5,694	609,136
0.03	3,514	4,281	0	0	0	0	11,758	735,955
Unit Rates and Notes		76 lbs/ft^3 soil.	From RACER Model	Not used for Rare Metals Facility	Not used for Rare Metals Facility	$4,000 per gondola railcar. Not used for Rare Metals Facility	Rent for 25-ton (20 yd^3) dump trucks @ $580.80/d. Driver costs $230/d. Truck hauls 320 yd^3 per day.	Stabilization & capping costs for onsite tailings pile 1.5 m deep @ $105/m^2 (RACER Model)

Table C.4.8. Calculated Costs and Other Parameters for Remediation of Contaminated Soil at the Reference Rare Metal Extraction Plant (Restricted Land Use, Without Soil Washing, Mixing/Landfilling)

Residual Dose Rate	Total On-Site Disposal Volume	Soil Disposal Costs @ \$10/ft^3	Soil Disposal Costs @ \$50/ft^3	Soil Disposal Costs @ \$350/ft^3	Total Soil Remediation Costs	Soil Washing Labor	Soil Excavation & Stabilization Labor	Total Soil Remediation Labor	Total Occupational Dose
mrem/yr	m^3	\$	\$	\$	\$	person-hr	person-hr	person-hr	person-mrem
HIGH									
100	7,000	0	0	0	490,000	0	229	229	23
60	7,000	0	0	0	490,000	0	229	229	23
30	7,000	0	0	0	490,000	0	229	229	23
25	7,000	0	0	0	490,000	0	229	229	23
15	7,117	0	0	0	525,981	0	426	426	43
10	7,435	0	0	0	624,233	0	963	963	96
3	8,383	0	0	0	916,355	0	2,559	2,559	256
0.3	10,194	0	0	0	1,474,902	0	5,612	5,612	561
0.03	12,006	0	0	0	2,033,572	0	8,666	8,666	867
MEDIUM									
100	7,000	0	0	0	490,000	0	229	229	23
60	7,000	0	0	0	490,000	0	229	229	23
30	7,000	0	0	0	490,000	0	229	229	23
25	7,000	0	0	0	490,000	0	229	229	23
15	7,000	0	0	0	490,000	0	229	229	23
10	7,000	0	0	0	490,000	0	229	229	23
3	7,837	0	0	0	748,016	0	1,639	1,639	164
0.3	9,649	0	0	0	1,306,789	0	4,693	4,693	469
0.03	11,461	0	0	0	1,865,531	0	7,747	7,747	775
LOW									
100	7,000	0	0	0	490,000	0	229	229	23
60	7,000	0	0	0	490,000	0	229	229	23
30	7,000	0	0	0	490,000	0	229	229	23
25	7,000	0	0	0	490,000	0	229	229	23
15	7,000	0	0	0	490,000	0	229	229	23
10	7,000	0	0	0	490,000	0	229	229	23
3	7,000	0	0	0	490,000	0	229	229	23
0.3	8,702	0	0	0	1,014,789	0	3,097	3,097	310
0.03	10,514	0	0	0	1,573,417	0	6,151	6,151	615
Unit Rates and Notes	Contam. soil is consolidated with the slag pile into an onsite capped tailings pile.	Costs for bulk disposal at LARW disposal facility, \$10/ft^3. Not used for Rare Metals Facility	Costs for in-compact disposal at existing LLW disposal facility, \$50/ft^3. Not used for Rare Metals Facility	Possible costs for future in-compact disposal facilities for LLW, \$350/ft^3. Not used for Rare Metals Facility		0.17 person-hr per m^3	1.62 person-hr/m^3 for excavation, 0.5 person-hr / truck load (20 yd^3) for transport to on-site burial, 0.5 person-hr / truck load for stabil.		0.1 mrem per person-hr labor

ATTACHMENT D

REPRODUCED APPENDIX C OF DRAFT GEIS

ATTACHMENT D

REPRODUCED APPENDIX C OF DRAFT GEIS

In several places in this final GEIS, reference is made to analysis and results from Appendix C of the draft GEIS. To assist the user of this report and to provide completeness, Appendix C of the draft GEIS is reproduced here as Attachment D. The section numbering system indicating that this was Appendix C has been retained.

REPRODUCED APPENDIX C OF DRAFT GEIS

C.1 INTRODUCTION

Decommissioning is currently defined in the Commission's regulations as removing a facility safely from service and reducing residual radioactivity to a level that permits release of the property for unrestricted use and termination of license. Criteria and practices are described in several NRC guidance documents which have been used for a number of years. The NRC is conducting a rulemaking to establish radiological criteria for the decommissioning of NRC-licensed facilities. The facilities that would be covered by such a rulemaking include nuclear power plants, non-power reactors, fuel fabrication plants, uranium hexafluoride production plants, uranium mills, independent spent fuel installations, and non-fuel-cycle facilities.

According to the requirements of NEPA and of the Commission's regulations in 10 CFR 51, the planned rulemaking needs to be accompanied by an environmental impact statement (EIS) which analyzes costs and impacts associated with rulemaking alternatives.

In preparing the EIS, one of the principal decommissioning activities expected to be sensitive to residual radioactivity criteria is the cost of cleaning, removal, and disposal of contaminated concrete and soil. Assessment of the differential in decommissioning costs related to alternate residual radioactivity criteria is difficult because of problems in making a generic evaluation of contamination levels on and within concrete and soil surfaces, including concrete cracks and hot spots, and because of questions regarding the amount of radioactive dose reduction achieved by concrete and soil removal techniques.

The proposed amendment to 10 CFR Part 20 to include radiological criteria for termination of licenses would be applicable to almost all of the facilities and sites that the NRC licenses. The nuclear facilities that will require decommissioning and would be affected by this action includes the following facilities involved in the nuclear fuel cycle:

- nuclear power plants
- non-power (research and test) reactors
- fuel fabrication plants
- uranium hexafluoride production plants
- uranium mill facilities
- independent spent fuel storage installations,
- non-fuel-cycle nuclear material facilities.

The materials licensees include universities, medical institutions, radioactive source manufacturers, and companies that use radioisotopes for industrial purposes. Over 75% of the NRC's materials licensees use either sealed radioactive sources or small amounts of short-lived radioactive materials. Decommissioning of these facilities should be relatively easy because there is usually little or no residual radioactive contamination to be cleaned up and disposed of.

Of the remaining 25%, a small number (e.g., radioactive source manufacturers, radiopharmaceutical producers, and radioactive ore processors) conduct operations which could produce substantial radioactive contamination in portions of their facilities.

The amended Part 20 would not apply to the disposition of uranium mill tailings, low-level waste disposal facilities, or high-level waste repositories because these have already been addressed in separate regulatory actions.

This Appendix provides supportable technical models for estimating facility concrete contaminant penetration and soil contaminant penetration, realistic technical methods for facility and soil decontamination during decommissioning, and a generic analysis of the differentials in decommissioning costs associated with decontaminating the facility and its site to alternate residual contamination levels.

C.2 STUDY APPROACH

The approach taken to develop the needed information on facility and soils characterization, how and where the facility and soils decontamination technique information was obtained, how the scenarios were defined for subsequent analysis of estimated costs and surface dose rates associated with various levels of cleanup, and the cumulative annual radiation doses associated with those surface dose rates are discussed in this chapter.

Technical expertise in the area of concrete, other building materials, and soil contamination levels as well as decontamination and removal and cost analysis were used in developing a technical basis for preparation of the GEIS. A supportable technical model, based on experience and information gained in other projects, was developed for use in generic analysis of concrete, other building materials, and soil contamination and decontamination, for use in assessing the costs involved in reaching alternate residual radioactivity criteria. The information developed can then be used in generic input and analyses for alternative residual dose criteria.

Specifically, technical bases and models describing contamination levels on and within concrete and other building materials are provided, with supporting references from the technical literature.

C.2.1 Nuclear Reactors

The model developed for nuclear reactors incorporates the following information:

- A description of radionuclide surface and volumetric contamination levels in various areas of the facility;
- The extent, profile, and variability of the physical distribution of radionuclide contamination into the concrete and other building materials;
- The extent, profile, and variability of the activated concrete in the reactor building;
- Contamination levels in cracks and corners, and in other potential contamination hot spots in concrete and other building materials, including a description of frequency and dimensions of these hot spots and variability of hot spot contamination;
- Contamination levels in soils at the site associated with contaminant spills, described similarly as above.

The model for contamination at reactors is based on previous and current technical work done by PNL in its series of reports prepared for the NRC on technology, safety, and costs of decommissioning (Smith et al. 1978)(Konzek et al. 1982a, 1982b, 1993), and on previous and current reports prepared by PNL describing residual radionuclide contamination within and around nuclear power plants (Abel et al. 1986; Robertson et al. 1989). Where appropriate, existing literature was reviewed to determine if the conclusions of the previous PNL reports remain valid.

C.2.2 Fuel Cycle and Non-Fuel Cycle Facilities

Facilities in these categories include fuel fabrication plants, uranium hexafluoride plants, uranium mills, sealed source manufacturers, broad R&D facilities, ISFSIs, and rare metal extraction processors.

Information presented on these facilities includes:

- A description of radionuclide surface and volumetric contamination levels in various areas of the facility;

- The extent, profile, and variability of the physical distribution of radionuclide contamination into the concrete and other building materials;

- Contamination levels in cracks and corners, and in other potential contamination hot spots in concrete and other building materials, including a description of frequency and dimensions of these hot spots and variability of hot spot contamination;

- Contamination levels in soils at the site were described similarly as above, with specific attention to special contamination features and their variability.

The model for contamination at fuel cycle and non-fuel cycle facilities was developed using technical bases similar to those noted in Section 2.1 above (Elder and Blahnik 1980a, 1980b; Elder 1981; and Murphy 1981). The amount of recent and relevant technical data for these facilities was more limited than that which exists for reactors. However, a generic model was developed based on extrapolating information developed for reactors, or based on other PNL data on uranium facilities and non-fuel cycle facilities, or by obtaining available information on these other facilities from other sources such as DOE or NRC.

C.2.3 Decontamination Methods and Costs

Realistic descriptive summaries are provided, including cost and decontamination effectiveness, of cleanup and removal techniques anticipated to be used in decommissioning the nuclear facilities listed in Sections 2.1 and 2.2.

Likely practical methods of concrete decontamination/removal for use in a large-scale industrial process like decommissioning of a facility are described. For example, this Appendix addresses whether it is practical or likely that a licensee would remove layers of concrete during a decommissioning to achieve alternate contamination criteria and how this would be accomplished.

For decontamination of soil, practical soil cleanup and removal methods likely to be used in the decommissioning of nuclear facilities are described.

This analysis was based on the information sources indicated above, on information which has been obtained from recent decommissioning experience at Shippingport, etc., and on recent technical information obtained regarding decontamination methods.

Based on the results of the analyses described in Sections 2.1 and 2.2, generic analyses of concrete, other building material, and soil cleanup procedures and associated costs to reach alternate residual contamination levels for decommissioning for the facilities are provided. The analyses in the report assume that the contaminated equipment has been removed and the nondestructive decontamination has been completed. For building areas requiring destructive decontamination of concrete and other building materials, the following information is presented:

- The estimated contamination levels in those areas;

- The extent of contamination removal by realistic removal techniques (including stepwise removal and the need for removal of hot spots and contamination in cracks) to reach alternate contamination levels;

- The costs associated with these removal techniques, including waste disposal costs.

Analyses have resulted in estimates of the amounts of concrete and other building materials which are necessary to be cleaned or removed in order to meet alternate residual radioactivity contamination levels. The analyses are quantitative in nature to the extent feasible, quantifying the amount of contamination removed and the amount of contamination remaining, and the associated costs required to achieve that contamination level.

For land areas, the following information is presented:

- The method of cleanup or removal that would be used in various site areas having contamination;

- The estimated contamination levels in those areas;

- The extent of contamination reduction by soil cleanup or removal, if necessary, to reach alternate contamination levels;

- The costs associated with such removal.

C.3 RESULTS OF THE ANALYSES

Based on the models of radionuclide surface contamination and penetration profiles and the costs of remedial actions, an assessment was made of decommissioning costs for reference nuclear facilities. Models were developed for use in calculating contaminant penetration profiles and associated residual radiation dose rates as successive amounts of the contaminated material are removed. Based on the depths of materials removed, decommissioning costs were calculated as a function of residual radioactivity and associated annual radiation dose criteria. The results of these analyses are summarized in Chapter 7, with additional details given in Attachments A and B.

C.4 CHARACTERIZATION OF REFERENCE FACILITY BUILDING CONTAMINATION

This chapter includes information on the types and concentrations of radionuclides and the quantities of surface areas contaminated for each of several reference facility types. Actual concentration profiles for penetration of radionuclides into concrete surfaces are provided, where possible. Theoretical concentration profiles are developed for ^{137}Cs, ^{60}Co, uranium, and thorium, using diffusivity coefficients where actual data are not available. Sections 4.1 - 4.7 present information on the areal extent and level of contamination on building surfaces for reference facilities. Section 4.8 presents summary information on surface contamination levels and information on contamination profiles with depth below the surface. Similar information for soils is presented in Chapter 5.

C.4.1 Reference Nuclear Power Reactor Station

A representative 1095-MWe pressurized water reactor plant that is preparing for D&D is the reference plant for this analysis. Conceptual decommissioning of this plant has been reported previously (Smith et al. 1978, Konzek et al. 1993).

Extent of Surface Contamination in Nuclear Plants

The extent of surface radionuclide contamination on floors of the various buildings of the reference PWR nuclear power station was estimated by reviewing detailed contamination survey maps supplied by the utility for contaminated areas of the station. The contamination surveys were conducted by taking smears of removable radioactive material from 100 cm^2 areas of floor surfaces. In a number of locations in the reactor containment building, contaminated walls were also surveyed for removable radioactive contamination. A summary of the contaminated surface areas is given in Table 4.1.1. As shown in the table, all of the floor surfaces in the reactor containment building (estimated area of about 1900 m^2) are assumed to be contaminated at levels which would require scabbling to reduce the contamination levels to acceptable residual concentrations.

Contamination penetrated into concrete below-grade floors in the Sodium Reactor Experiment Facility approximately 1/8 to 3/8 inches on the average and up to the full thickness of walls and floors where cracks and joints existed (Brengle 1979). Angus et al. (1990) found that ^{137}Cs penetrated deeply into areas of surface porosity and cracks. Information on surface contamination of concrete in the Japan Power Demonstration Reactor (Yasunaka et al. 1987) indicated that most of the contamination penetrated less than 2 cm and only 15% penetrated up to 3 cm. In the liquid waste treatment building, the deepest penetration was up to 11 cm in the vicinity of cracks, but elsewhere it was less than 2 cm. Therefore, complete removal of concrete will likely be required in the vicinity of contaminated cracks. The perimeter of the concrete floors is assumed to contain 1500 m of cracks. Because contamination tends to penetrate rapidly into cracks, contaminated crack regions are expected to require complete removal.

The interior walls of certain locations within the reactor containment building also contain significant radionuclide contamination, particularly the upper and lower cavity areas surrounding the pressure vessel. Although summaries of wall contamination are not included in Table 4.1.1, it is estimated that approximately 400 to 600 m^2 of wall area from these locations have been contaminated at levels ranging from about 1000 to 60,000 pCi/100 cm^2. Other portions of the interior wall surfaces in the containment building may also be contaminated and require some type of decontamination.

TABLE 4.1.1. Extent of Surface Radionuclide Contamination in the ReferencePWR Nuclear Power Station[a]

Building	Approximate Floor Surface Area, ft^2	Estimated % of Floor Area Contaminated	Estimated Needing Cleanup, ft^2
Reactor Containment	20,400	100	20,400
Auxiliary (6 levels)	43,000	1-5	430 - 2,200
Fuel Building (5 levels)	53,800	1-5	540 - 2,690
Turbine Building	61,300 per level	0	0
Control Building	7,500 per level	0	0

(a) From Smith et al. 1978.

In addition to the widespread surface contamination of concrete and patchy areas of contamination associated with spills or high radiation areas where maintenance work was conducted, radioactive contamination is produced in-situ by neutron activation of concrete shields. Concrete areas subjected to neutron exposure within the plant are limited primarily to the bioshield and the sump area directly beneath the reactor vessel. Concrete core samples collected directly beneath the pressure vessel show the effects of both surface contamination and subsurface neutron activation of stable elements present in the concrete (Abel et al. 1986). The concentration of radionuclides, such as ^{60}Co, decreases rapidly (by approximately four orders of magnitude) with depth from the surface to about 2 cm beneath the surface. This concentration profile is attributed to diffusion of surface contamination. The radioisotopes produced by neutron activation extend much deeper (even feet) in nuclear reactors (Abel et al. 1986; Irving 1980). The concentration may peak at depths where the neutron energy spectrum coincides with peaks in the capture cross section for the parent isotope. The subsurface contamination produced by neutron activation is too deep to be removed by surface scabbling, and must be removed by procedures for concrete demolition.

The auxiliary and fuel buildings also have some areas of floor contamination, but not nearly to the extent of that observed in the reactor containment building. It has been estimated, based on survey reports (Smith et al. 1978), that about 1 to 5% of the floor area (representing about 430 to 2,200 ft^2) in the auxiliary building has radioactive contamination levels in the range of 500 to 3600 pCi/100 cm^2. The fuel handling building also has a small amount of floor contamination, estimated at approximately 540 to 2,690 ft^2, with contamination levels ranging from about 500 to 2300 pCi/100 cm^2.

The other buildings, including the turbine building, the control building, radwaste handling warehouse, and the condenser building, generally do not have any measurable radioactive contamination on any surfaces.

Within the common variabilities of contamination levels in nuclear power plants, the analysis for a PWR reasonably estimates the contaminants and contamination levels for a BWR. Within these variabilities and considering the information shown in Table 4.1.2, the radioactive contamination in the various types of reactors appears to be similar. The primary difference is in the areas and volumes of the structures. Dry active waste (DAW) is a mixture of radioactively contaminated items typically generated at nuclear power stations, (e.g., trash, protective clothing, gloves, equipment, tape, plastic sheeting and bags, etc.) and the radioactive material associated with DAW would be expected to be reasonably representative of that found on surface contaminated concrete. These measurements were made on over 100 DAW samples during a recent study conducted by Battelle, Pacific Northwest Laboratories for the Electric Power Research Institute to determine the industry-wide variability in the radionuclide composition of very low-level wastes generated at nuclear power stations (Robertson et al. 1989).

Section 4.8 provides a summary assessment of the level of surface and shallow subsurface building contamination. Based on the information in that section and data obtained on contamination at power reactors, the level of surface contamination assumed for the reference power reactor is the high contamination level in Table 4.8.1. The shallow subsurface contamination depth profile is described in Section 4.8.3. The information on the building surface contamination levels and areal extents are summarized in Table 7.1.1.

C.4.2 Radionuclide Source Term for Nonpower Reactors - Test and Research Reactors

Nonpower reactors generally are divided into two classes: research reactors and test reactors. A test reactor is defined in 10 CFR 50.2 as a nuclear reactor licensed for operation at a thermal power level in excess of 10 MW or a thermal power level in excess of 1 MW if the reactor contains a circulating loop through the core to conduct fuel experiments, or a liquid fuel loading, or an experimental facility in the core in excess of 16 in^2 in cross section. A research reactor is defined in 10 CFR 170.3(h) as a nuclear reactor licensed for operation at a thermal power level of 10 MW or less and which is not a testing facility.

TABLE 4.1.2. Gamma-Emitting Radionuclide Distributions in Dry Active Waste (Robertson et al. 1989, 1991)

Radionuclide	All PWR Stations[a]	All BWR Stations[b]	All Stations Combined[c]
	Average % Composition of γ-Emitting Radionuclides		
^{60}Co	49 ± 34[d]	78 ± 2.6	61 ± 30
^{137}Cs	27 ± 22	11 ± 2.2	20 ± 18
^{134}Cs	8.6 ± 7.3	2.5 ± 1.2	6.1 ± 6.3
^{58}Co	9.8 ± 9.8	0.59 ± 0.43	6.7 ± 9.0
^{54}Mn	0.7 ± 0.5	6.4 ± 3.6	3.0 ± 3.6
^{106}Ru	2.4 ± 2.1	1.8 ± 0.4	2.1 ± 1.4
^{125}Sb	0.6 ± 0.3	0.69 ± 0.47	0.6 ± 0.4
^{95}Nb	2.4 ± 3.2	0.2 ± 0.09	1.8 ± 2.8
^{95}Zr	0.7 ± 0.5	-	0.7 ± 0.5
^{110m}Ag	0.3 ± 0.5	0.12	0.3 ± 0.4

(a) Includes 6 stations and 60 samples.
(b) Includes 4 stations and 42 samples.
(c) Includes 10 stations and 102 samples.
(d) ± values are the standard deviation (1σ).

C.4.2.1 Description of Reference Facility Structures and Lands

The reference test reactor is the Plum Brook Reactor at Sandusky, Ohio (Konzek et al. 1982a, b). It is a 60 MWt test reactor formerly operated by the National Aeronautics and Space Administration and is located on a site approximately 50 x 10^6 ft^2. It is a light water-moderated and cooled plant, used in testing materials for specific applications. The testing system of the Plum Brook reactor is made up principally of the test reactor vessel (containing the nuclear core and experimental beam tubes) and the reactor water recirculation system. Major structures comprising the reference test reactor include:

- reactor building (housing the test reactor)
- hot laboratory building with seven hot cells
- a primary pump house
- an office and laboratory building (housing radiochemistry laboratories)

- a fan house (ventilation systems and waste ion exchanger and filters)
- a hot retention area (holding waste tanks)
- a cold retention area and an emergency retention basin
- a waste handling building.

The reference research reactor for this analysis is the Oregon State University 1 MWt TRIGA reactor. This reference facility is described by Konzek et al. (1982a, b) and Chapter 7 of NRC (1988). It is located on a site of approximately 150,000 ft^2. It is an open-pool nuclear training and research facility. It is made up of a reactor tank and a core structure and a TRIGA type control system. Major structures comprising the reference research reactor that are likely to be contaminated include a reactor building (housing the TRIGA reactor and support area), a cooling tower, an annex (housing a hot laboratory area and hot cell), a heat exchanger building (housing a water purification system, water pumping systems, and air compressor systems), and a pump house.

C.4.2.2 Contamination Data

Information on the extent and nature of contamination in the structures, and in surrounding on-site lands for the reference research and test reactors, is taken from Konzek et al. (1982a, b) and Abel et al. (1986). The locations and sizes of the contaminated areas are summarized in Tables 4.2.1 and 4.2.2. The crack lengths, assumed to approximate the perimeter of the reference test reactor and the reference research reactor, are estimated to be 2,900 and 1,300 ft, respectively. Section 4.8 provides a summary assessment of the level of surface and shallow subsurface building contamination. Based on that information and on data obtained on contamination at research and test reactors, the levels of surface contamination assumed for the reference test and research reactors are the high contamination level and the medium contamination levels, respectively, from Table 4.8.1. The shallow subsurface contamination depth profile is described in Section 4.8.3. The information on the building surface contamination levels and areal extents is summarized in Table 7.1.1.

C.4.3 Reference Uranium Fuel Fabrication Plant

The reference uranium fuel fabrication plant processes an average of
1000 MT/y. Buildings or site areas associated with the reference uranium fuel fabrication plant include:

- Processing buildings, which are typically two-story windowless structures of concrete and steel. Interior walls, typically of concrete block, divide the buildings into discrete operations areas that house each of the production steps.

- On-site waste ponds containing calcium fluoride; calcium fluoride is a waste product that is produced by treating the fluoride wastes with $Ca(OH)_2$. The calcium fluoride is stored in waste ponds on the site.

- A site area of 4.7×10^6 ft^2.

TABLE 4.2.1. Distribution of Contaminated Concrete Surface Areas within the Reference Test Reactor[a,b]

Location	Estimated Surface Area, ft^2
Reactor Building and Containment Vessel	61,000
Hot Laboratory Building	24,000
Fan House	750
Waste Handling Building	4,230
Primary Pump House	2,500
Hot Retention Area	450
Cold Retention Area	13,470
Office and Laboratory Building and Sumps	1,100
Total	107,500

(a) (Konzek et al. 1982a, b)
(b) Estimates of percent of surface area contaminated given in Konzek 1982 are considered to be too high for an operating plant. An average value of 10% is used in Table 7.1.1 based on operating data from power reactors.

C.4.3.1 Description of Reference Facility

The General Electric Company's Wilmington facility has previously been evaluated as a reference plant for conceptual decommissioning activities (Elder and Blahnik 1980a). It is licensed, a major fabricator of commercial nuclear fuel, and considered to have characteristics similar to other existing commercial uranium fabrication plants. Contamination of equipment and floors results during normal operations and, on at least one occasion, from a spill that caused uranium to penetrate through cracks in the concrete floor into soil beneath the fuel processing building.

The feed to the plant is slightly enriched uranium in the chemical form of UF_6. The plant uses two chemical processes for converting the UF_6 to UO_2. The primary method is a chemical process that reacts UF_6 with ammonia to form ammonium diuranate (ADU) precipitate and reduces and calcines the ADU to dry UO_2 powder. The second method involves direct conversion of the UF_6 to U_3O_8 to UO_2 powder in a reduction calciner. The UO_2 powder from each process is subsequently milled and pressed into pellets that are sintered and ground to size. The pellets are loaded into rods and sealed. The rods are assembled into fuel bundles ready for use in light water reactors.

TABLE 4.2.2. Distribution of Contaminated Concrete Surface Areas within the Reference Research Reactor[a]

Location	Estimated Surface Area, ft^2	Estimated Area Contaminated, %
Reactor Building		
Surfaces	1050	100
Reactor Top	100	20
Fuel Storage Pits	5	100
Annex		
Hot Cell	145	100
Hot Lab	430	10
Hot Lab Sump	160	100
HX Building		
Floor	580	10
Sump	160	100
Pump House		
Concrete Floor	645	10
Sump	160	100
Waste Storage Room		
Concrete Floor	410	10
Sump	160	100
Radiation Center Building	30,000	4
Total	35,005	10

(a) (Konzek et al. 1982a, b)

Liquid waste streams containing uranium are kept separate to facilitate uranium recovery operations. They are classified as nitrate wastes, fluoride wastes, and radwastes. Uranium-bearing nitrate sludge is sent to an offsite contractor for uranium recovery. Calcium fluoride solids entrap uranium residuals in the waste from the UF_6 to UO_2 conversion process. CaF_2 solids are stored onsite for eventual reprocessing to recover the uranium residuals.

C.4.3.2 Contamination Data

The reference fuel fabrication plant consists of five potentially contaminated buildings (Elder and Blahnik 1980b, p. A-18). There are an average of two floors per building with a total floor space of approximately 235,000 ft^2 (about 22,000 m^2). Contamination incidents, as well as releases during normal operations, are assumed to have affected 50% of the surface of the process areas. The principal contaminant is uranium, and its concentration at the exposed surface after removal of the covering and after surface washing is 1 g U/m^2 (33 pCi/g of concrete). Therefore, approximately 11,000 m^2 are assumed to be contaminated to a level of 1 g U/m^2 (33 pCi/g of concrete) and require decontamination by surface removal.

Floor tiles cover 100% of the process area floors. Replacement of the floor tiles and linoleum coverings removes significant contamination. However, recontamination during operation requires floor tiles to be replaced annually for ALARA considerations. The tiles are also removed during normal decommissioning operations. Because of contaminant penetration through seams between tiles, it is assumed in Table 4.3.1 that 50% of the concrete floor has become contaminated[1]. The chemical area has a sealed concrete floor. It is assumed that 50% of the concrete floor surface under the seal is contaminated. Offices and change rooms have tiled or painted floors (Elder and Blahnik 1980a, p. 7-17); it is assumed that the concrete surfaces below these surface coverings are not contaminated

TABLE 4.3.1. Distribution of Contaminated Concrete Floor Area in the Reference Uranium Fuel Fabrication Facility[(a)]

Location	Estimated Surface Area, ft^2	Estimated Area Contaminated, %	Contamination Level, pCi/cm^3
Fuel Manufacturing Building	208,000	50	73
Chemical Metallurgical Laboratory	8,300	40	73
Uranium Scrap Recovery Room	3,700	90	73
UO_2 Powder Warehouse	8,700	30	73
Contaminated Waste Incinerator	2,400	100	73
Fluoride and Nitrate Waste Treatment Plant	2,500	100	73
Boiler Steam House	1,100	0	0
Total	234,700	50	-

(a) (Elder and Blahnik 1980b, p. A-18)

1 Note: this assumption deviates from that made by Elder and Blahnik (1980) in that they assumed the concrete was not contaminated. Penetration and spread of contamination through seams between tiles is assumed in Table 4.3.1 to result in approximately 50% of the concrete floor becoming contaminated.

For an assumed average wall height of 10 ft, the total interior wall surface area is approximately 236,700 ft^2 (22,000 m^2). Most of this wall area is cleaned by washing during normal decommissioning operations. The estimated remaining distribution of contamination for walls is indicated in Table 7.1.1.

The crack length in the concrete floors is taken to be equal to the sum of the building perimeter, i.e., approximately 3,000 ft. Uranium from contamination incidents has penetrated through the concrete in regions of cracks, crevices, porosity, and unsealed joints. The contamination in cracks is assumed to have penetrated through the complete 6-in. thickness of the floor.

Elder and Blahnik (1980a) estimated the surface concentration of uranium on horizontal surfaces to be approximately 1 g U/m^2 (33 pCi U/g of concrete)[2]. Approximately 700 samples were taken from the main building block and brick walls at the Babcock and Wilcox Apollo plant in Pennsylvania. The majority of the wall contamination was <30 pCi U/g with some selective areas containing up to 2,000 pCi U/g (Haase, et al. 1992). The characterization of surface contamination was complicated by the heterogeneous nature of the contamination and, in some areas, the number of overlying pours of concrete that were made to cover contaminated floor areas.

Measurements at the DOE Fernald facility have shown some floor regions with extreme uranium contamination approaching 10,000,000 dpm/100 cm^2 with an average maximum of 2,220,000 dpm/100 cm^2 (DOE 1992). These high levels are believed to be an upper bound and are used only in calculation of the penetration profiles in Section 4.8.

The three uranium fuel fabrication facilities provide information on three levels of contamination: an estimated 33 pCi U/g from Wilmington, up to 2,000 pCi U/g measured for Apollo, and a maximum beta-gamma of nearly 16,000 pCi U/g for Fernald. These data were converted to dpm/100 cm^2 and resulted in values of 18,000 dpm/100 cm^2 (low); 1,100,000 dpm/100 cm^2 (medium); and 10,000,000 dpm/100 cm^2 (high). Based on the above discussion, the level of surface contamination after surface washing assumed for the reference uranium fuel fabrication facility is 18,000 dpm/100 cm^2. The information on the building surface contamination levels and areal extents are summarized in Table 7.1.1

C.4.3.3 Reference Depth Contamination Data

Documentation was reviewed (Elder and Blahnik 1980a, b; Babcock and Wilcox 1992a, b; Haase et al. 1992; DOE 1992) for the penetration of uranium into concrete; however, no experimental data were found. Two methods of theoretical calculations provide independent methods for calculating penetration profiles. These two methods involve: 1) the use of the diffusivity for uranium in concrete; and 2) data for the distribution coefficients from leaching

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[2] 1 g U/m^2 = 0.7 x 10^6 pCi/m^2 x 0.472 pCi/g per pCi/cm^2 x 10^{-4} m^2/cm^2 = 33 pCi/g

studies with uranium and concrete and cement. The relative values for the distribution coefficients for uranium were compared to cesium for which there are also data for diffusivity in concrete as well as penetration profiles. These relationships permit the development of a cohesive presentation of penetration profiles for uranium. Section 4.8.5 contains information regarding an assessment of the depth profile for uranium.

C.4.4 Uranium Hexafluoride Plant

The reference uranium hexafluoride facility processes 10,000 MT/y of natural uranium. The Kerr McGee plant was used as the reference facility
(Elder 1981).

C.4.4.1 Description of Reference Uranium Hexafluoride Facility

Buildings or site areas associated with the reference uranium hexafluoride plant include:

- the total buildings, including the warehouse and storage areas, contain approximately 120,000 ft^2 of floor area. The floor area of the main processing areas in two buildings is approximately 84,000 ft^2. Some of the main processing rooms are described in Table 4.4.1 to provide an estimate of the average radionuclide surface concentration. The buildings are of normal industrial construction with heavy concrete floors to support equipment. The wall surface area is estimated to be 130,000 ft^2.

- a series of on-site retention ponds for storage of process raffinates and sanitary wastes

- lagoon areas for neutralized liquid effluents
- a burial area for disposal of defunct equipment

- a site area of 200 x 10^6 ft^2.

C.4.4.2 Surface Contamination Data

The extent of contamination in these structures, and in surrounding on-site lands, is taken from Elder (1981). The reference uranium hexafluoride plant includes at least twelve separate rooms, several in the main building and several in small adjacent buildings, in which various steps related to the process were carried out. The primary contamination in the plant is assumed to be in these process rooms, which are listed in Table 4.4.1. The contamination estimated to be on the process equipment after decontamination is then used as the basis for estimating the amount of contamination remaining in the room after removal of the equipment. For these estimates, the following assumptions are made:

- The amount of contamination on the floor and walls is 15% of the amount listed for the equipment itself, as a worst case.

- This contamination is distributed as follows: one-half on the floor and the other half distributed over the walls, i.e., one-eighth of the total on each wall, which are assumed to be about 33 ft high.

- The length of the perimeter represents a crack length of 1,300 ft contaminated with uranium and must be removed.

Based on the quantities of uranium on the floor and wall surfaces, the level of surface contamination after surface washing assumed for the reference uranium hexafluoride plant is the medium contamination level indicated, i.e., 1 x 10^6 dpm/100 cm^2. The information on the building contamination surface contamination levels and areal extents are summarized in Table 7.1.1.

C.4.4.3 Depth Contamination Data

The primary contaminant for the uranium hexafluoride conversion plant is uranium. There were no experimental data for the depth of uranium penetration into concrete. See Section 4.8.5. for further development of the distribution of uranium contamination in concrete.

TABLE 4.4.1. Distribution of Uranium in the Reference Uranium Hexafluoride Plant[a]

Room/Building	Contamination on Equipment, Kg U	Contamination in Room, g U	Floor Area, ft2	Area of Opposite Walls, ft²	Contamination on Floor, pCi/cm³	Contamination on Opposite Walls, g U/m²
Sampling Station	110	17,000	1,830	1,080/1,830	1,650	700/430
Solvent Extraction	550	83,000	4,090	2,040/2,150	3,600	1,800/1,700
Concentration Area	855	128,000	1,400	1,080/1,400	16,200	5,280/4,060
Denitration Area	555	83,000	1,400	1,080/1,400	10,500	3,430/2,640
Reduction Area	200	30,000	2,900	1,610/1,940	1850	825/690
Hydrofluorination Area	1050	158,000	2,800	1,400/2,150	10,000	5,000/3,270
Fluorination Area	1300	195,000	2,900	1,610,1,940	11,900	5,380/4,460
UF_4 Slurry Processing	~900	135,000	540	775/750	44,600	7,720/7,950
Incinerator	~900	135,000	1,610	1,080/1,610	14,900	5,580/3,730
Dissolution of Ore Concentration	~500	75,000	2,150	1.080/2,150	6,200	3,100/1,550
Fluorine Generation Area	~500	75,000	16,140	2,690/6,460	825	1,250/530
Laboratory	~50	8,000	1,610	1,610/1,940	890	320/200
Total	7470	1,122,000	39,400	-	-	-

(a) Elder 1981.

C.4.5 Reference Non-Fuel-Cycle Plants

Non-fuel-cycle facilities are those facilities which handle byproduct, source, and/or special nuclear materials but are not involved in the production of nuclear power.

Non-fuel-cycle facilities make up a wide variety of different facilities with widely varying levels of contamination. For the purposes of developing reference facilities for analysis, the wide variety of facilities are broken down into the following general types:

- material manufacturers, including (1) radioactive sealed source manufacturers, and (2) radiochemical and radiopharmaceutical manufacturers
- broad research and development program facilities including academic and medical institutions, and companies using, distributing, or handling radioisotopes for industrial purposes, etc.
- ore processors
- licensees who use either sealed radioactive sources or small amounts of short-lived radioactive materials, including sealed gauges, well loggers, sealed radiographer sources, sealed irradiator sources, sealed special nuclear material sources, and leak-test sources.

These latter types of facilities are not examined in the analyses presented in this report because, unless there has been an unusual occurrence, the sealed sources can be removed with no remaining contamination. In the event of an unusual occurrence that leads to contamination, the common practice is to immediately remove the contamination and restore the facility to normal conditions for unrestricted use. Reference facilities are analyzed for each of the above categories, as described in the following subsections.

C.4.5.1 Reference Sealed Source Manufacturer

The sealed source manufacturing process is a hand operation that is carried out in buildings which contain a number of small laboratories, each of which is devoted to a specific process and/or isotope. The reference sealed source manufacturer is a laboratory which processes ^{137}Cs and ^{60}Co. Contaminated facilities associated with the reference sealed source manufacturer include:

- hot cells, fume hoods, workbenches, sinks
- laboratory floor and wall areas
- building areas used for storage of waste drums.

The situation for radiochemical and radiopharmaceutical manufacturers would be very similar to that of the sealed source manufacturer, and is not examined further in this report.

Advanced Medical Systems, Inc. (AMS) is used as the reference sealed source manufacturer. It is a licensed non-fuel-cycle plant in Cleveland, Ohio, that manufactures cobalt-60 and cesium-137 capsule sources for use in medical teletherapy devices and radiography machines (NRC 1993).

The AMS operations occupy about one quarter of an 8,000-ft^2 (ground floor) warehouse building. The remainder of the building is unused. The facility occupies portions of three floors in the warehouse. The first floor consists of an office area, an isotope shop area, a hot cell, a shielded work room, and a storage area. The second floor area houses a mechanical equipment room and an exhaust ventilation equipment room. A liquid waste handling room and the former liquid waste holdup tank room and dry waste storage area are located in the basement. Waste is stored in a locked room with roped areas on the south side of the warehouse area.

The floor surface areas are estimated to be 6,000 ft^2 (assuming three floors). The indoor surface area of the walls (estimated at 10-ft high) is estimated to be 4,600 ft^2. The perimeter crack length is estimated to be approximately 300 ft.

A 1985 survey by Oak Ridge Associated Universities (ORAU) found surface contamination in a hot cell, the ventilation system, the dry waste storage area, the liquid waste area, and the holding tank and its piping. No offsite contamination was found. However, some detectable activity (attributed to stack effluent releases) was found in sediments, soil, and vegetation in the southern portion of the AMS property. The ORAU survey showed contamination up to 1.51×10^6 dpm/100 cm^2 in the hot cell access port in the isotope shop area, an area normally expected to be highly contaminated. A water sample from the liquid waste room floor contained 1.75×10^5 pCi ^{60}Co/L. Sediment from the loading dock drain showed low, but detectable levels of activity.

About one-tenth of the concrete surface area is assumed to be contaminated with ^{60}Co, which was the principal contaminant measured by ORAU. Section 4.8 provides a summary assessment of the level of surface and shallow subsurface building contamination. Based on the information in that section and the data obtained on contamination at the non-fuel-cycle facilities, the level of surface contamination after surface washing assumed for the reference sealed source manufacturer is the medium contamination level in Table 4.8.1. The shallow subsurface contamination depth profile is described in Section 4.8.3. The information on the building surface contamination levels and areal extents are summarized in Table 7.1.1.

C.4.5.2 Reference Rare Metal Extraction Facility

The reference rare metal ore processor is a plant that refines raw ore materials for the recovery of rare metals such as tantalum and niobium. The raw ores can contain appreciable quantities of uranium and thorium, which are waste tailings of the refining process.

Contaminated facilities and areas associated with the reference rare metal ore processor include:

- Buildings in which slag is processed and the rare metals are extracted. Significant building contamination is not expected.
- Settling ponds on-site containing the tailings from the metal extraction process, and containing essentially all of the thorium and uranium. The pond is assumed to be unlined at the reference rare metal ore processor, although it may be lined at newer facilities.
- A site area of 7.4×10^5 ft^2
- Slag Pile containing solid wastes from the extraction process.

The reference rare metal extraction facility is the Molybdenum Corporation of America facility (NRC 1993), which occupies a 17 acre (740,000 ft^2) site, and produced a ferro-columbium alloy from a Brazilian ore from 1964 to 1970 (Martin 1985). The ore contained licensable concentrations of thorium (1-1.5%), and so the operation produced thorium-bearing slag and contaminated soil. The material was collected and segregated in 1972, and some of it was removed off-site. The remainder was placed in a clay-capped pile on the property.

The site contains a number of buildings, eight holding ponds and a large slag pile. Building 34 has up to 90 dpm/100 cm^2 fixed alpha contamination, up to 8680 dpm/100 cm^2 fixed beta contamination, and direct radiation levels up to 169 μR/h. The source of the direct radiation level is suspected to be below the floor. The total area of floors is estimated from Figure 7 in Martin (1985) to be 150,000 ft^2; 40% of this surface is estimated to be contaminated with thorium. The surface area of the walls is estimated to be 180,000 ft^2 and 10% is estimated to be contaminated with thorium. Thorium contamination levels and extent for the reference facility are given in Table 7.1.1.

C.4.5.3 Reference Broad Research and Development Facility

Research and development facilities using radioactive materials cover a broad range of activities including the use of laboratories or health treatment facilities that use radioisotopes. Both short-lived (^{3}H) and long-lived isotopes (^{14}C) may be used. The reference facility includes rooms for synthesis of labeled compounds and for preparing radioactive samples, a laboratory, a counting room, and a storage room. Only long-lived nuclides are included in this analysis. Contaminated facilities associated with the reference broad research and development facility include:

- glove boxes, fume hoods, sinks, workbenches;
- laboratory floor and wall areas;
- a storage area.

A generic single building facility is used in the analyses for a reference broad R&D facility, because such facilities vary widely in size. However, for an R&D facility comprised of several buildings, the waste volumes, costs, etc. can be reasonably approximated by multiplying the results for a single building by the number of buildings in the facility.

The floor area of the facility is estimated to be approximately 6,000 ft^2. Approximately 10% of this area is estimated to be contaminated with ^{137}Cs and ^{60}Co. The crack length is estimated to be approximately 320 ft. The wall area is estimated to be approximately 4,600 ft^2. Approximately 5% of this area is estimated to be contaminated. Section 4.8 provides a summary assessment of the level of surface and shallow subsurface building contamination. Based on the information in that section and the data obtained on contamination at the non-fuel cycle facilities, the level of surface contamination after surface washing assumed for the reference broad R&D facility is the medium contamination level in Table 4.8.1. The shallow subsurface contamination depth profile is described in Section 4.8.3. The information on the building surface contamination levels and areal extents are summarized in Table 7.1.1.

C.4.6 Reference Uranium Mills

Milling of uranium ores involves the following basic steps: 1) ore handling and preparation, which may include blending, crushing, grinding, and pretreatment; 2) chemical processing and concentration, and 3) product recovery, in which the product is recovered by chemical precipitation and dried and packaged for shipment.

Conventional uranium mills licensed by the NRC, and currently or previously operating, ranged from a capacity of about 500 MT/day to 6000 MT/day with most in the range of 1000 to 2500 MT/day. Uranium tailings represent the bulk of the wastes generated during the milling process. When discharged from the mill, the tailings material is pumped to an impoundment (tailings pond). Tailings pond areas ranged from 50 acres to 300 acres with most in the range of 100 to 250 acres (NRC 1980, Vol. III, Table T.1).

The Monticello mill site is used as the reference uranium mill site as it provides an example of a contaminated site undergoing cleanup. Originally owned by the Vanadium Corporation of America, the site was used as a vanadium mill from 1942-1943, and a vanadium/uranium mill from 1943-1944 (EPA 1990). In 1948 the site was purchased by the Atomic Energy Commission and used for uranium milling from 1949-1960, when it was closed permanently. Numerous milling operations were used during the site's history, including raw ore carbonate leach, low-temperature roast/hot carbonate leach, salt roast/hot carbonate leach, acid leach resin-in-pulp with raw ore carbonate leach, and carbonate pressure leach resin-in-pulp processes. Tailings piles were regraded, stabilized, and vegetated by the AEC from 1961-1964. In 1972, additional radiation surveys conducted for the AEC indicated uncovered residual surface contamination in soil, which was removed and dumped on top of the previously covered tailings piles. The Monticello millsite (78 acres) was included as a part of DOE's Surplus Facilities Management Program in 1980, and contaminated vicinity properties (240 acres) designated as a separate remedial action project in 1983.

Based on photographs of a model mill shown in NRC (1980 Vol. I), the area of the floors (assumed to be concrete) and walls are estimated to be 100,000 and 130,000 ft^2, respectively. The perimeter crack length is estimated to be 2,000 ft. Based on the apparent nature of the operations they are assumed to be contaminated over 100% of the surfaces. The contamination level is assumed to be the medium level from Section 4.8.1.

With regard to the tailings impoundment, a general license is issued under 10 CFR 40.28 for the custody and long-term care of the tailings to comply with standards for uranium mill tailings sites reclaimed under the Uranium Mill Tailings Radiation Control Act of 1978. The licensee for the tailings impoundment will be the DOE, other Federal agencies, or States. Hence, long-term management of the tailings impoundment is outside the scope of this report and is not discussed further.

C.4.7 Reference Dry Independent Spent Fuel Storage Installation

The large majority of ISFSIs in the U.S. use some form of dry storage. The reference ISFSI is a dry ISFSI with capacity of 811 MT of fuel.

Potentially contaminated facilities and areas associated with the reference dry ISFSI vary with the type of design, but the only dry ISFSIs now licensed are collocated at reactor sites. The reference dry ISFSI is collocated at the Virginia Power Company's Surry Reactor Plant (McKay et al. 1989). The fully implemented ISFSI facility will consist of three reinforced open air concrete pads on which the vertical sealed metal casks are placed. The concrete pads are 70 m by 10 m by approximately 1 m thick. The total surface area of the three pads is about 23,000 ft^2. Each pad is designed to accommodate 28 casks. There are no hot cells; the fuel is loaded into sealed casks and/or canisters at the reactor fuel handling facility. The casks arrive free of contamination at the storage site.

Although the dry storage ISFSI cask is designed and sealed to prevent release of radionuclides and contamination is not expected, it is assumed that 10% of the concrete surface becomes contaminated. The basis for this estimate is release of undetected contamination carried on the external surfaces of the storage cask to the storage pad. The dry storage casks will be removed prior to site decommissioning.

Section 4.8 provides a summary assessment of the level of surface and shallow subsurface building contamination. Based on the information in that section and the data obtained on contamination at ISFSIs, the level of surface contamination after surface washing assumed for the reference broad R&D facility is the low contamination level in Table 4.8.1. The shallow subsurface contamination depth profile is described in Section 4.8.3. The information on the building surface contamination levels and areal extents are summarized in Table 7.1.1.

C.4.8 Contaminant Surface Levels and Penetration Profiles

An important part of the analyses is the definition of the radionuclide surface contamination and the concentration profiles of contaminants that have penetrated the surfaces. Surface contaminant and concentration profiles were based on actual data, when available, and on theoretical estimates based on calculated diffusivity coefficients for the various radionuclide species of interest in these analyses when actual data were not available.

C.4.8.1 Empirically Measured Radionuclide Source Term and Depth Distribution in Concrete

Radionuclide contamination of concrete surfaces at nuclear power stations is of two types: 1) surface and shallow subsurface contamination resulting from both spills/leakage of radioactive materials and/or deposition of radioactive aerosols, and 2) contamination produced *in situ* by neutron activation of concrete located near the pressure vessel by the small flux of neutrons escaping from the vessel. Contamination produced by neutron activation is discussed in Sections 4.1 and 6.3. The following sections address surface and shallow subsurface contamination, and include an estimation of the isotopic composition, quantities, extent of contaminated surfaces, and depth of penetration of the radionuclides in the concrete. Since this assessment will ultimately lead to an estimation of the amount of concrete that must be removed to comply with alternative dose criteria associated with residual levels of contamination, only those gamma-emitting radionuclides of significant abundance have been considered. Although typical residual radionuclide compositions from nuclear power plants do contain significant amounts of several pure beta or low-energy photon emitters (e.g., ^{55}Fe, ^{63}Ni), their contribution to the total gamma dose rate would be trivial.

C.4.8.2 Radionuclide Source Term for Surface Concrete Contamination

Approximately 100 concrete cores from seven nuclear power stations were collected and analyzed for radionuclide constituents during an earlier investigation (Abel et al. 1986). This data base has been reassessed to provide a range and geometric mean of the radioactivity levels observed in contaminated concrete from many different areas within a nuclear power plant, as shown in Table 4.8.1. These core samples were collected approximately 20 years after the plant operations were begun. Therefore, the value of 20 years was used for time dependent calculations. These radioactivity levels would be lower after a longer time period because of radionuclide decay. The ^{60}Co and ^{137}Cs concentrations found in the surface concrete (pCi/cm^3) for all the concrete cores obtained during the earlier study are shown in Figures 4.8.1 and 4.8.2 respectively. The three numbers labeled on the graph are the geometric means of each group from Table 4.8.1. Concrete cores were from areas affected by both wet and dry contaminants. These figures show the surface concentration on the vertical axis versus percentile ranking. The relatively straight line semi-log percentile plots indicate the data are log-normally distributed and can therefore be best represented by a geometric mean.

Three radioactivity concentration ranges were selected for conveniently describing the quantities of the most abundant gamma-emitting radionuclides (^{60}Co and ^{137}Cs) observed in the concrete:

- Low contamination = <100 pCi/cm^3
- Moderate contamination = 100 to 10,000 pCi/cm^3
- High contamination = >10,000 pCi/cm^3.

The log-normal distributions demonstrated in Figures 4.8.1 and 4.8.2 provide the justification for selecting the geometric mean to represent the contamination level for each of the three groupings. For definition of the three levels of contaminated core samples, contamination was defined as low when both ^{60}Co and ^{137}Cs were below 100 pCi/cm^3, as moderate when either ^{60}Co or ^{137}Cs were above 100 pCi/cm^3 and both were below 10,000 pCi/cm^3, and as high when either ^{60}Co or ^{137}Cs exceeded 10,000 pCi/cm^3. Therefore, the geometric mean for cesium identified by the arrow in the high range in Figure 4.8.2 is located near the medium to high boundary and was influenced by samples that were highly contaminated with ^{60}Co while the same samples contained less than 10,000 pCi/cm3 ^{137}Cs at the surface.

TABLE 4.8.1. Radionuclide Contamination Calculated for Surface-Contaminated Concrete from Seven Nuclear Power Stations

	Geometric Mean Concentration,[a] pCi/cm^3		
Radionuclide	Low Contamination	Moderate Contamination	High Contamination
^{60}Co	4.4	460	34,000
^{137}Cs	1.4	150	11,000
^{134}Cs	0.45	46	3400
^{58}Co	0.49	50	3700
^{54}Mn	0.22	23	1700
$^{106}Ru/Rh$	0.15	16	1200
$^{95}Zr/Nb$	0.18	19	1400
^{125}Sb	0.04	4.5	330
^{110m}Ag	0.22	2.3	170

(a) 1 pCi/cm^3 is equivalent to 222 dpm/100 cm^2.

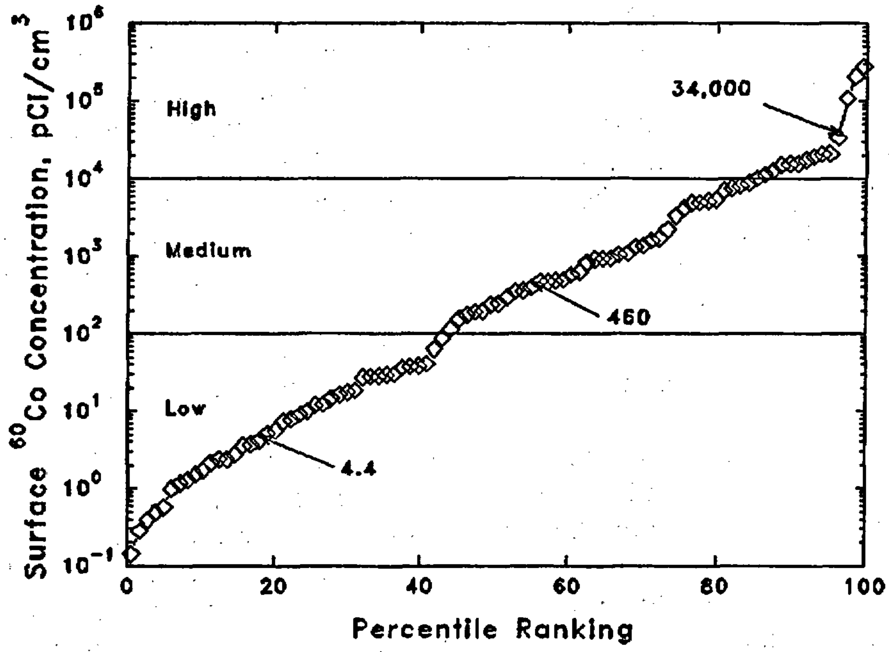

FIGURE 4.8.1. Concentrations of ^{60}Co in pCi/cm^3 Measured on Surface Concrete from Seven Nuclear Power Stations

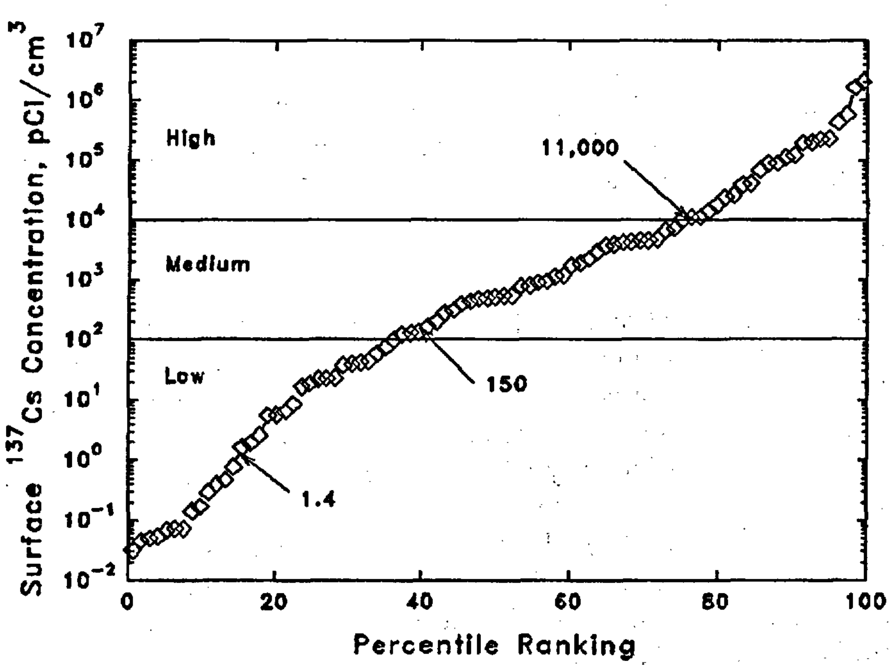

FIGURE 4.8.2. Concentrations of ^{137}Cs in pCi/cm^3 Measured on Surface Concrete from Seven Nuclear Power Stations

In general, the gamma-emitting radionuclide composition at commercial nuclear power stations is reasonably uniform throughout the nuclear power industry. Table 4.1.2, shown previously, lists the average percent composition of gamma-emitting radionuclides in dry active waste (a good analog for contaminated concrete surfaces) for six PWR stations and four BWR stations, and the average percent composition for all ten stations combined. Dry active waste (DAW) is a mixture of radioactively contaminated items typically generated at nuclear power stations, (e.g., trash, protective clothing, gloves, equipment, tape, plastic sheeting and bags, etc.) and the radioactive material associated with DAW would be expected to be reasonably representative of that found on surface contaminated concrete. These measurements were made on over 100 DAW samples during a recent study conducted by Battelle, Pacific Northwest Laboratories for the Electric Power Research Institute to determine the industry-wide variability in the radionuclide composition of very low-level wastes generated at nuclear power stations (Robertson et al. 1989).

^{60}Co plus ^{137}Ce comprise 81% of the total gamma-emitting radionuclides for the average composition of DAW for all stations. The geometric mean concentrations for these two nuclides were then divided by 0.81 to obtain the geometric mean concentrations for the total of all of the significant gamma-emitting radionuclides measured. The total geometric mean values were then broken down into the individual isotopic geometric means for each gamma-emitting radionuclide in surface-contaminated concrete using the average percentage composition for all stations given in Table 4.8.1. The individual isotopic geometric mean values, given in Table 4.8.1, represent the source term for gamma-emitting radionuclide concentrations for the three levels of contamination (low, moderate, and high) observed on the concrete surfaces. A similar analysis for uranium-contaminated facilities was given in Section 4.3.2

Sections 4.1, 4.2, 4.5, and 4.7 use the information in Table 4.8.1 for the level of building surface contamination for the different reference facilities. The level of contamination assumed depends on the type of facility.

C.4.8.3 Depth Distribution of Radionuclides in Concrete

Estimation of the concentration of radionuclide contamination with concrete depth is necessary to estimate the amount of contaminated concrete which must be removed to attain an acceptable surface gamma dose rate following decommissioning. This assessment is difficult because of the many factors which affect the penetration rates of radionuclides in concrete (e.g., the use and integrity of protective coatings on the concrete, the degree and frequency of wetting of the concrete surfaces, the existence of cracks in the concrete, the mineralogy of the concrete, etc.). However, a conservative estimate of the depth of penetration of the radionuclides has been made which will allow for reasonable estimates of the costs for concrete remediation during decommissioning. This estimate was made in the manner described below. Analyses considering both empirical and theoretical assessments are discussed in the sections below.

C.4.8.4 Use of Empirical Data

First, the depth distributions of ^{60}Co and ^{137}Cs (the two most abundant gamma-emitting radionuclides in contaminated concrete) in a number of concrete cores from retired nuclear power stations measured in an earlier study (Abel et al. 1986) were examined to select the most conservative (fastest) penetration rates. Several cores collected from the sump floor of the reactor containment building of the Indian Point Unit 1 nuclear power station were selected because the surface of this concrete was bare (not painted) and wet, and represented the most favorable conditions for penetration into the concrete. This reactor, a 285 MWe PWR, had operated from 1962 until 1974, and the concrete cores were collected in 1982, some 8 years after reactor operations ceased.

Concrete core IP-15 from the condensate and condensate return area was selected as the core representing the most rapid penetration of ^{60}Co and ^{137}Cs into the concrete, and the depth distribution of these radionuclides to 3 cm into the concrete is presented in Figure 4.8.3. As shown in the figure, the ^{137}Cs concentration decreased by over four orders of magnitude in the first 1 cm of concrete and much less thereafter. The ^{137}Cs observed below a depth of 1 cm may possibly be due to cross-contamination of the lower sections resulting from the coring and sectioning operations. The ^{60}Co concentrations decreased only two orders of magnitude over the first 1 cm of concrete and appeared to penetrate much deeper into the concrete. This indicates that the ^{60}Co penetrates into the concrete at a faster rate compared to the ^{137}Cs, under wetted surface conditions.

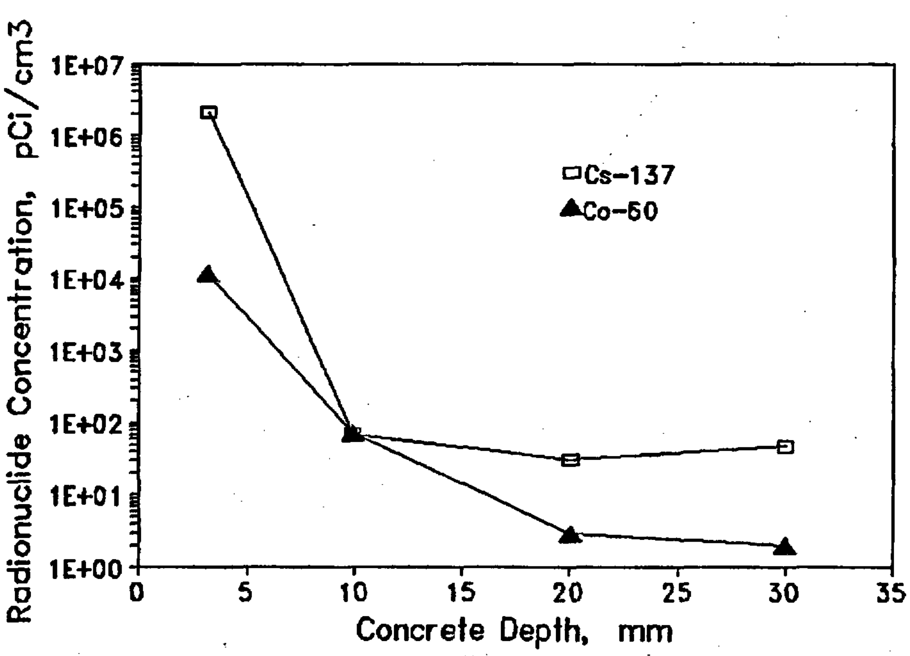

FIGURE 4.8.3. Depth Distribution of ^{60}Co and ^{137}Cs in Indian Point Unit 1 Concrete Core IP-15

The depth distribution of ^{60}Co in concrete core IP-15 was then fit with a logarithmic equation using a curve-fitting software program. This plot and fitted curve describing the depth distribution of ^{60}Co in mm is shown in Figure 4.8.4. This equation can then be applied to the geometric mean surface radionuclide concentrations for the three levels of concrete contamination given in Table 4.8.1, and the depth distributions of the radionuclides can be calculated. However, this source term model predicts higher levels of activity than the diffusion models because of the influence of high activity tails in some of these samples at depths beyond 2 cm. These high activity tails were associated with samples taken from areas frequently exposed to aqueous contaminants and are not representative of samples from most of the facility areas (approximately 90 to 95%) where the surfaces are normally dry and contaminants are dry (wet spills are wiped up or evaporate quickly) and the radionuclide penetration is shallow. The diffusion of radionuclides into concrete surfaces that have been extensively exposed to water is faster because diffusion takes place by a different mechanism through pores that are saturated with water than through pores that are dry. Radionuclides in samples of dry concrete were distributed much closer to the surface than for samples taken from wet areas. The evaluation of the samples taken from dry regions which are typical for most of the reactor facilities are treated in Section 4.8.5.

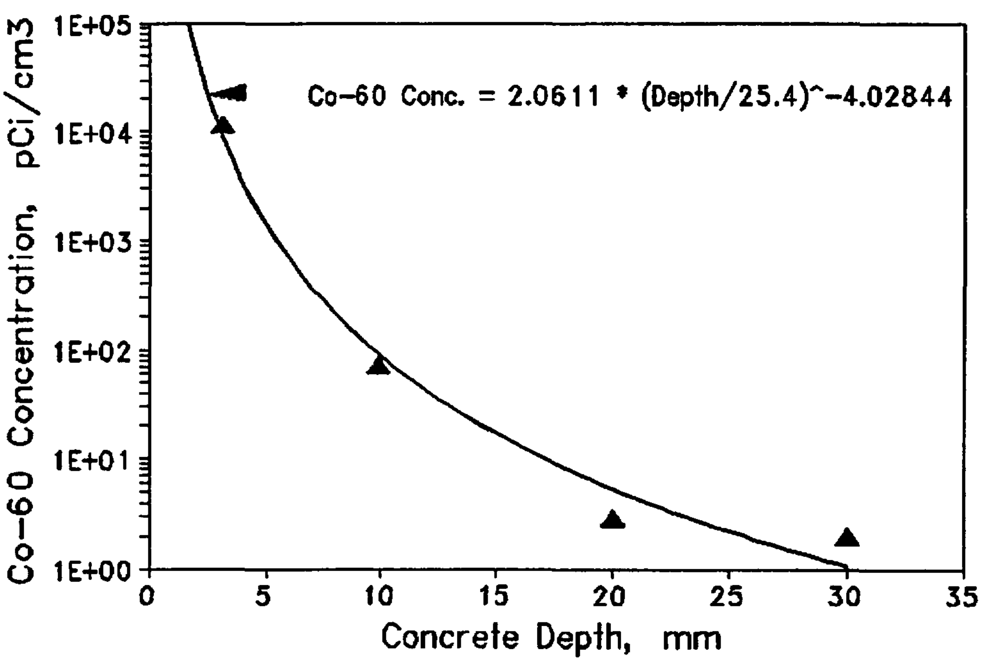

FIGURE 4.8.4.Comparison of Depth Distribution of ^{60}Co in Indian Point Unit 1 Concrete Core IP-15 with Exponential Curve Fit

The concrete core samples taken at nuclear power stations during an earlier study were generally taken in areas of known or suspected contamination. Many of the cores were taken in areas where spills occurred occasionally to frequently. It would appear that penetration has occurred in many of the cores which exceeds the depth predicted from diffusion theory. There are several possible explanations for the observed versus predicted concentration profiles.

First, there exists the possibility that the lower segments of cores could have been cross-contaminated during the sample preparation process. The core sectioning was accomplished using a lapidary saw with recycling water for blade coolant. This coolant could possibly have introduced contamination onto the surface of the lower section of the core during the cutting process. This does not appear to be the most likely explanation, since not all cores appear to have been affected. Additionally, core segments were well rinsed with distilled water after segmentation.

To verify that the radionuclide concentration tails were not originally contained in the concrete prior to contamination, it is noted that core samples of concrete taken from Pathfinder that had been coated with epoxy, clear sealer, and gray paint prior to becoming contaminated were below the limits of detectibility for both ^{137}Cs and ^{60}Co below a depth of 1 cm (Abel et al. 1986). For these samples, most of the contamination was removed with the coating and little contamination remained to contaminate the concrete core samples.

The most plausible explanation appears to be that those cores where deeper penetration of radioisotopes has occurred were frequently in locations that were wet to damp such as around drains, sumps, and pits. In such cases, deeper penetration than expected from diffusion of dry contaminants has been reported by Angus et al. (1990). Additional credibility is added to this hypothesis by the fact that more cores at Indian Point Unit 1 appear to have deeper penetration. This facility had a history of spills and leaks. Finally, one core taken at Dresden Unit 1 over a chemical spill which occurred during the Dow Chemical decontamination of the coolant system showed very enhanced penetration for both ^{60}Co and ^{137}Cs. This core definitely illustrates that chemical parameters can influence and enhance radionuclide migration into the concrete.

Angus et al. (1990) reported that ^{137}Cs in an aqueous solution continuously in contact with concrete penetrates deeper than from a dry surface contaminant. Soluble ^{137}Cs in contact with an unprotected concrete surface migrates through the water-filled pore network and contaminates the concrete to a depth dependent on the rate of liquid diffusion and the extent to which that isotope is sorbed in the concrete. The pore network of dry concrete is dried out close to the surface; the aqueous transport mechanisms required for transport of the activity into the concrete are therefore limited. This effect is illustrated in Figure 4.8.5 as the 1 x 10^5 pCi/g (0.1 μCi/g) cesium-137 tail that extends to a depth of at least 15 cm. The lower-level concentration tails shown in Figure 4.8.5 are attributed to effects of exposure of the concrete to wet contamination and cross contamination of samples. A minor contribution to these tails may be attributable to neutron-induced fission of uranium that occurs naturally in concrete at levels of approximately 2 ppm[3] in concrete core samples removed from areas located near reactor cores.

C.4.8.5 Calculation of Concrete Radionuclide Penetration by Diffusion

The penetration of diffusing radioisotopes into a semi-infinite medium of concrete was calculated using the solution given in Crank (1956 Equation 2.7), for linear flow from a planar source deposited initially at the surface of a semi-infinite cylinder (single contamination event). The solution is shown as Equation 1. Other solutions are available in cases where the planar source varies with time (multiple contamination events). If the value of the diffusivity for the isotope is assumed to be constant and the concrete is free of significant porosity or cracks, then the concentration penetrated at the end of a specific exposure period is

$$C(x,t) = [C(x,0)/(\pi Dt)^{0.5}]\exp(-x^2/4Dt) \qquad [1]$$

where

$C(x,t)$ = concentration of the isotope at distance "x" beneath the surface at time t

$C(x,0)$ = concentration of the isotope deposited initially

x = distance beneath the surface

D = diffusivity

t = exposure period.

The surface concentration at time t is

$$\begin{aligned} C(0,t) &= C(x,0)/(\pi Dt)^{0.5} \exp(-x^2/4Dt) \qquad [2] \\ &= C(x,0)/(\pi Dt)^{0.5} \end{aligned}$$

If $C(x,0)$ is unknown, then $C(x,0)/(\pi Dt)^{0.5}$ can be replaced with $C(0,t)$ which is the more commonly available surface concentration after exposure period t.

Then

$$C(x,t) = C(0,t)\exp(-x^2/4Dt) \qquad [3]$$

Diffusivity for ^{137}Cs

The value selected for this diffusivity for ^{137}Cs is:

$D = 1$ to 10×10^{-11} cm^2/s (Muurinen, Penttilae, and Rantanen 1986)

[3] Abel, K. H. 1993. Personal Communication, Pacific Northwest Laboratory, Richland, Washington.

The concentration of ^{137}Cs from diffusion predicted for this range of values for the diffusivity according to Equation 3 is shown in Figure 4.8.5. Also included in Figure 4.8.5 are some data from analyses of slabs taken from concrete cores from floors contaminated with ^{137}Cs. Because the plants had operated for approximately 20 years, 20 years was used for the time parameter in Equation 3 and is also noted on Figures 4.8.5 through 4.8.14. The tails are attributed to effects of aqueous contamination that penetrated deeper than found for dry contamination. Some samples are shown in Figure 4.8.6 to be free of detectable contamination.

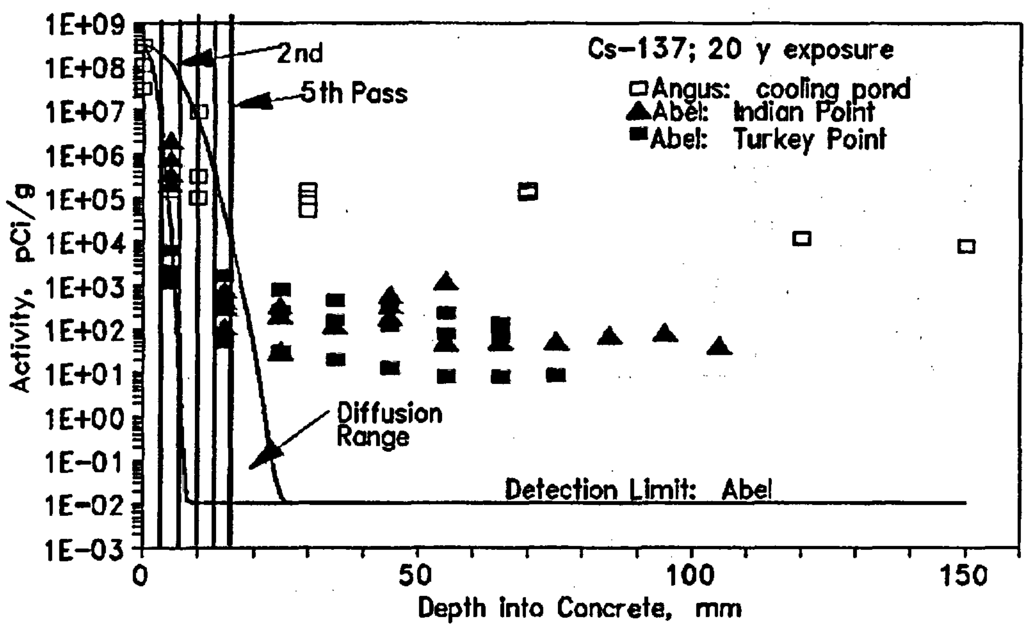

FIGURE 4.8.5. Comparison of Predicted Range of ^{137}Cs Penetration into Concrete with Experimental Core Analyses

These samples were generally not exposed to aqueous contaminants. The high concentrations in the tail for the data by Angus et al. (1990) are attributed to the effect of constant exposure of the concrete to the radioisotope in the aqueous form and the longer 30 y exposure. The calculations are not applicable to constant exposure of the concrete to an aqueous solution of the radionuclides.

A comparison of the penetration predicted by diffusion calculations with the activity for samples taken from dry areas lies below the diffusion curve and near the detection limit, as shown in Figure 4.8.6. The vertical lines correspond to 0.125-in. increments of concrete surface removed during decontamination by the MOOSE™ remotely operated floor scabbler as described by Konzek et al. (1993) and illustrated in Kaiser Engineers Hanford Company (1993).

The profile corresponding to the maximum value of the diffusivity provided the most conservative agreement with the data and is considered to be applicable to migration of dry contaminants. Therefore the maximum diffusivity will be used for further evaluations of ^{137}Cs concentrations in concrete.

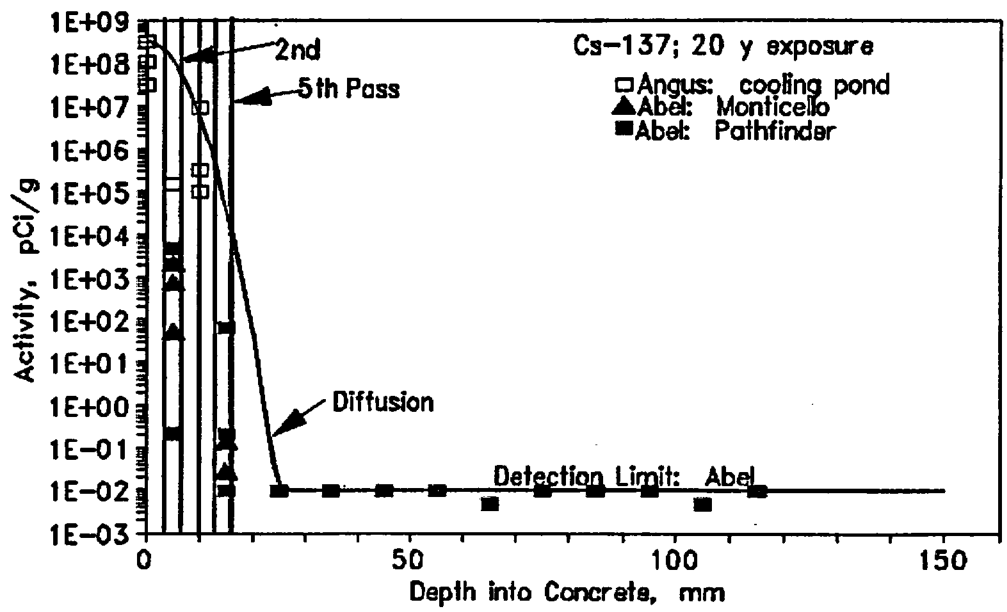

FIGURE 4.8.6. Comparison of Predicted Maximum ^{137}Cs Penetration into Concrete with Experimental Core Analyses

Serne[4] indicated that the values for diffusivity of ^{137}Cs (approximately 5 to 10 x 10^{-9} cm^2/s) for grout and cement from Matsuzuru and Ito (1977) and by Dayal, Arora, and Morcos (1983) may be higher than that found for concrete because 1) the high salt content of the grout samples may reduce the potential for chemical reaction of ^{137}Cs with the base grout consistency and thereby increase the mobility of the ^{137}Cs and 2) the aggregate and other constituents in concrete that are not present in the cement grout compounds may chemically react with ^{137}Cs and retard its mobility. Because the range of values reported by Muurinen, Penttilae, and Rantanen (1986), are preferred for concrete and provide the best consistency with the penetration profiles for surface contaminated concrete, as presented in Figure 4.8.6, they are used in this analysis.

4 Personal Communication by R. J. Serne to E. R. Gilbert, June 1993, Pacific Northwest Laboratory, Richland, Washington.

Diffusivity for ^{60}Co

The maximum value of diffusivity for ^{60}Co in concrete given by Serne et al. (1987) is:

$D = <5 \times 10^{-11}\ cm^2/s$ (Serne et al. 1987)

Based on the order of magnitude range of values for the distribution coefficient given by Allard et al. (1984) and the inverse relationship between distribution coefficient and diffusivity, the minimum value for the diffusivity for ^{60}Co in concrete is given as:

$D = >5 \times 10^{-12}\ cm^2/s$

The concentration of ^{60}Co from diffusion predicted for this range of values for the diffusivity according to Equation 3 is shown in Figure 4.8.7. Also included in Figure 4.8.7 are some data from analyses of slabs taken from concrete cores from floors contaminated with ^{60}Co. The tails are attributed to concrete slab samples taken from wet areas in the plants. Samples with penetration tails considerably above the detection limit were taken from wet areas or were slightly neutron activated. The vertical lines correspond to 0.125-in. increments of concrete surface that would be removed during decontamination using the MOOSE™ remotely operated floor scabbler as described by Konzek et al. (1993) and illustrated in Kaiser Engineers Hanford Company (1993).

The profile corresponding to the maximum value of the diffusivity provides the most conservative agreement with the data for dry contamination and is shown in Figure 4.8.8. Samples near the diffusion curve and the detection limit were taken from dry areas. Some ^{60}Co data were slightly above the diffusion curve; however, for these cases the concentration was expressed as less than the specified value. Therefore, the maximum diffusivity will be used for further evaluations of ^{60}Co concentrations in concrete from dry contaminants.

Diffusivity for Uranium

The maximum value of diffusivity for uranium in concrete given by Serne et al. (1989) is:

$D = <1 \times 10^{-12}\ cm^2/s$ (Serne et al. 1989)

Based on the order of magnitude range of values for the distribution coefficient given by Allard et al. (1984) and the inverse relationship between distribution coefficient and diffusivity, the minimum value for the diffusivity for uranium in concrete is given as:

$D = >1 \times 10^{-13}\ cm^2/s$

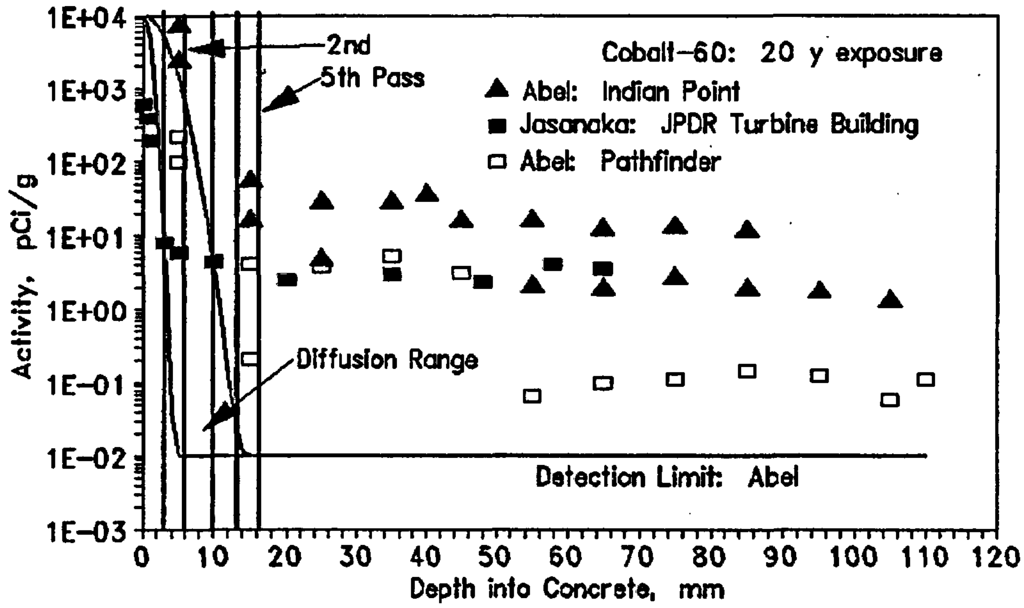

FIGURE 4.8.7. Comparison of Predicted Range of ^{60}Co Penetration into Concrete with Experimental Core Analyses

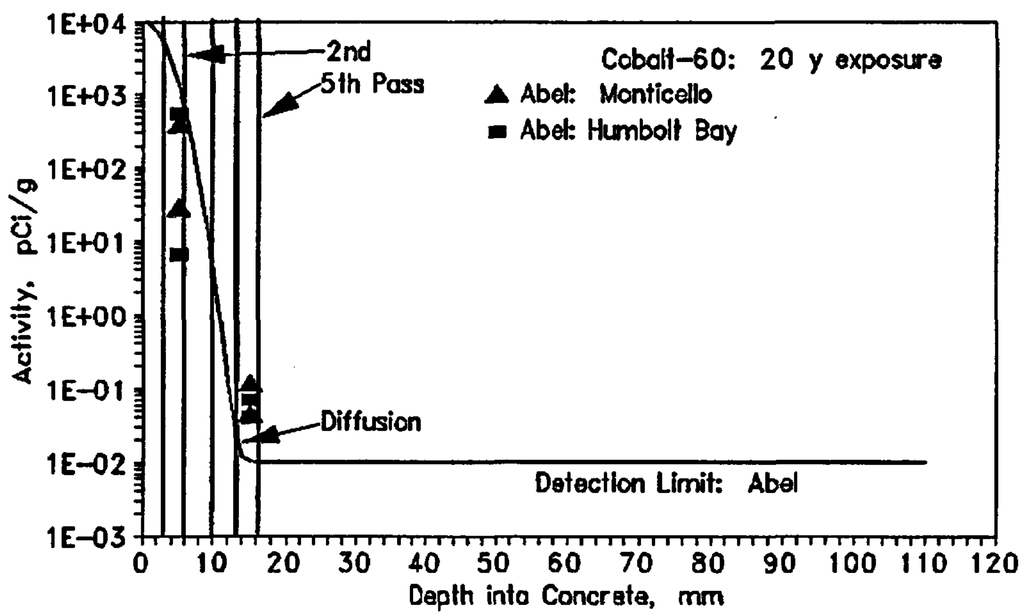

FIGURE 4.8.8. Comparison of Predicted Maximum ^{60}Co Penetration into Concrete with Experimental Core Analyses

The concentration profile for uranium from diffusion predicted for this range of values for the diffusivity according to Equation 3 is shown in Figure 4.8.9.

The vertical lines correspond to 0.125-in. increments of concrete surface that would be removed during decontamination using the MOOSE™ remotely operated floor scabbler as described by Konzek et al. (1993) and illustrated in Kaiser Engineers Hanford Company (1993). Tails in the concentration profiles are shown in Figure 4.8.9. This tail in the concentration profile for uranium in concrete is predicted because of the natural occurrence of uranium in concrete. Typical levels are approximately 2 to 3 ppm[5]. The profile corresponding to the maximum value of the diffusivity provides the most conservative predictions for dry contaminant. Therefore, the maximum diffusivity will be used for further evaluations of uranium concentrations in concrete from diffusion of dry surface contaminant. Uranium from wet contaminants would be expected to penetrate much deeper, similar to the cases for ^{137}Cs and ^{60}Co, shown in Figures 4.8.5 and 4.8.7.

<u>Diffusivity for Thorium</u>

The maximum value of diffusivity for thorium in concrete is based on estimates by Serne and Wood (1990) that are based on thorium solubility in cement (Ewart et al. 1992):

$$D = <1 \times 10^{-11}\ \text{cm}^2/\text{s}.$$

A value of 1×10^{-12} cm²/s is considered more reasonable. Both values are plotted in Figure 4.8.10, but for conservatism the value of 1×10^{-11} cm²/s is used in this analysis.

<u>Summary of Values Used in Analyses for Radionuclide Diffusivities</u>

<u>Diffusivity for ^{137}Cs</u>	$D = 1$ to 10×10^{-11} cm²/s (Muurinen, Penttilae, and Rantanen 1986)
<u>Diffusivity for ^{60}Co</u>	$D = 5 \times 10^{-11}$ cm²/s (Serne et al. 1987)
<u>Diffusivity for Uranium</u>	$D = <1 \times 10^{-12}$ cm²/s (Serne et al. 1989)
<u>Diffusivity for Thorium</u>	$D = <1 \times 10^{-11}$ cm²/s (Serne and Wood 1990)

5 Uranium occurs naturally in concrete at a concentration of approximately 2.7 μg U/g (2.7 μg U/g x 0.7 pCi/μg U ≈ 1.9 pCi U/g; 1.9 pCi U/g + 7.06 x 10^5 pCi/g U ≈ 2.69 ppm).

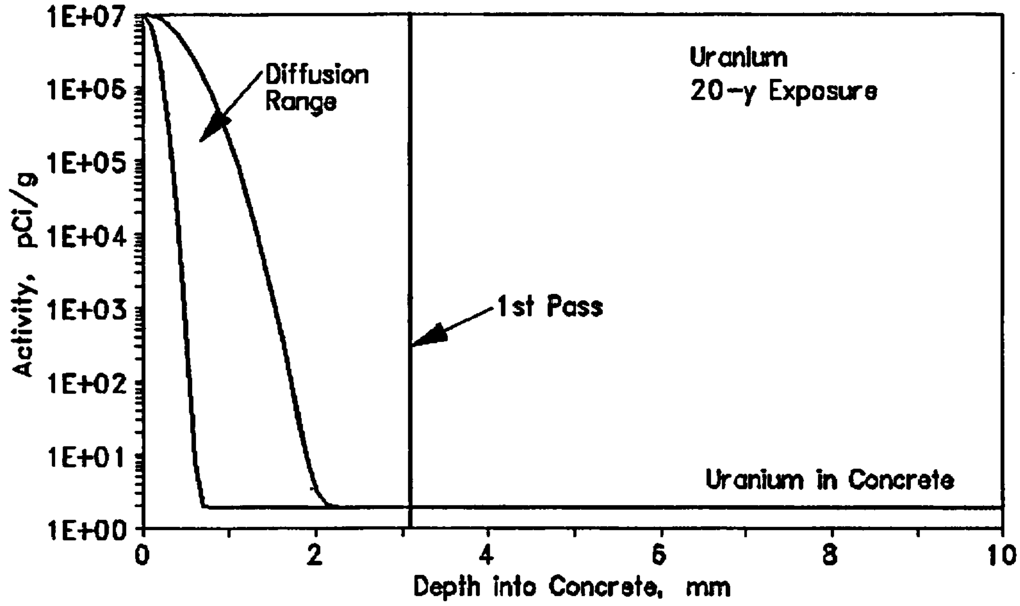

FIGURE 4.8.9. Predicted Range of Uranium Penetration into Concrete

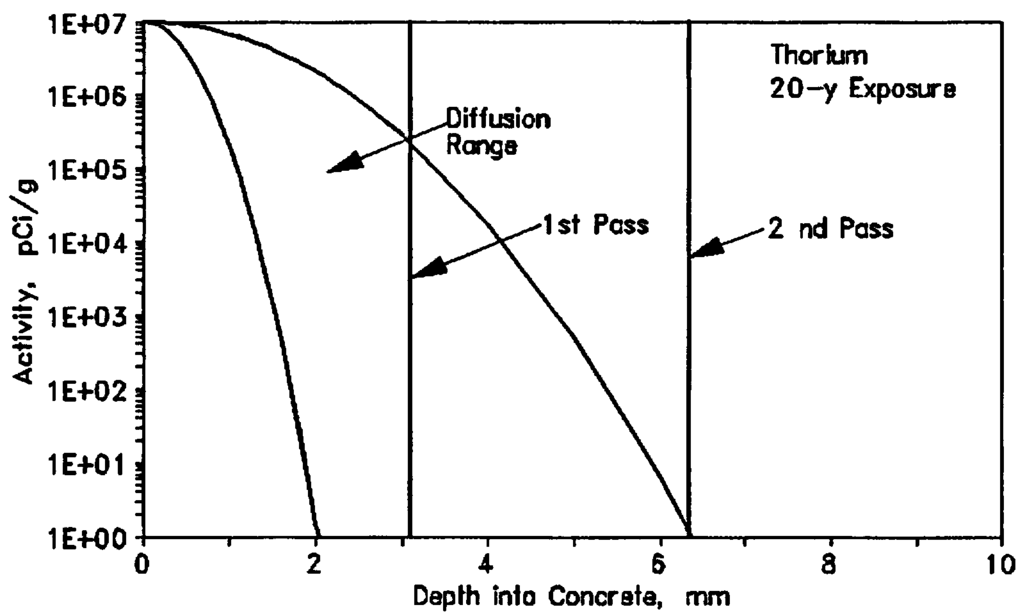

FIGURE 4.8.10. Predicted Range of Thorium Penetration into Concrete

Materials Other than Concrete

Concrete is the major construction material in volume and surface area. Materials other than concrete, including concrete block, may be absorbent, unless coated with a sealer. The effectiveness of the seal depends on the paint quality. Because there are lower volumes of these materials and most of the contamination can be removed by washing, they are generally washed, surveyed, and disposed according to the residual level of radioactivity.

C.4.8.6 Dose Calculation Methodology

The methodology employed in this study to calculate the radiation dose rates at the surface of contaminated concrete as successive layers of that concrete are removed is described in this section.

The contaminant profile data of Abel et al. (1986) was obtained by counting each 1 cm layer of a core of contaminated concrete and plotting the measured value (pCi/cm^3) at the depth of the midplane of the layer. This approach gives an inherently incorrect depth distribution, because the contaminant concentration is dropping rapidly with increasing depth, such that the depth-averaged average contaminant concentration is actually located closer to the surface of the layer than to the midplane, with the actual location being dependent upon the slope of the contaminant concentration curve.

The value of the contaminant concentration (C_0) at the surface of the concrete is calculated, using the measured data of Abel (C_{ij}) and the equation for diffusion of contaminants into solid materials, Equation 3 of Section 4.8.5 with some redefinition of terms:

$$C_{ij} = C_0 \exp(-X_{ij}^2/4D_jt) \qquad (4)$$

where X_{ij} is the depth beneath the original surface at which the concentration of the jth radionuclide is to be calculated, D_j is the diffusivity of concrete for the jth radionuclide, and t is the time that the diffusion process has proceeded (assumed to be 20 years in these analyses).

By integrating this equation over successive 1 cm layers, the depth-averaged contaminant concentrations are calculated for each successive layer, L_i, of concrete beneath the original surface. The location of that average value is determined on the curve originally defined when the measured data were plotted at the mid-plane of each layer, thus defining the actual positions where those average values should exist. Using the locations of the average values of the contaminants for the first 1-cm layer, given in Table 4.8.2, the values of C_0 for the diffusion equation are determined by evaluating the equation at the appropriate depth and solving for C_0.

TABLE 4.8.2. Depth Beneath the Upper Surface at Which the Average Value Exists

1-cm Layer Number	Calculated Depth, cm			
	^{60}Co	^{137}Cs	Uranium	Thorium
1	0.3846	0.4538	0.1154	0.22
2	0.1692	0.2462	-	-
3	0.1000	0.1538	-	-
4	0.0769	0.1385	-	-
5	0.0769	0.1154	-	-
6	0.0769	0.1154	-	-
7	-	0.0846	-	-

These values of C_0 are then used in the diffusion equation to calculate the values of the contaminant concentrations at the surface of the exposed concrete as each successive 0.125 in. (0.3175 cm) layer of concrete is removed by the scabbling process. These average concentrations are converted into annual radiation dose rates at the surfaces of the successive layers using the conversion for pCi/cm^3 to dpm/100 cm^2:

$$1 \text{ pCi/cm}^3 = 222 \text{ dpm/100 cm}^2$$

and the concentration-to-dose conversion factors (see Appendix A) developed using the methodology presented in NUREG/CR-5512 (Kennedy and Strenge 1992) for the building occupancy scenario,

$$F_j \text{ [mrem/yr]/[dpm/100 cm}^2]$$

the appropriate factor for the jth radionuclide. Thus, the resulting dose rate is:

$$DR\{X_{ij}\} = C\{X_{ij}\}[\text{pCi/cm}^3] \times 222 \text{ [dpm/100 cm}^2)/(\text{pCi/cm}^3)] \times F_j \text{ [(mrem/yr)/(dpm/100 cm}^2)] \qquad (5)$$

where the argument of the variables DR and C is the depth of the average concentration location for the jth radionuclide beneath the surface of layer L_{i+1}. The resulting values of residual annual radiation dose rate as a function of depth of concrete removed are given in Table 4.8.3, and illustrated in Figures 4.8.11, 4.8.12, 4.8.13 and 4.8.14.

For locations that are contaminated by more than one radioisotope, the total surface radiation dose rate is the sum of the individual dose rates calculated by the methodology given above.

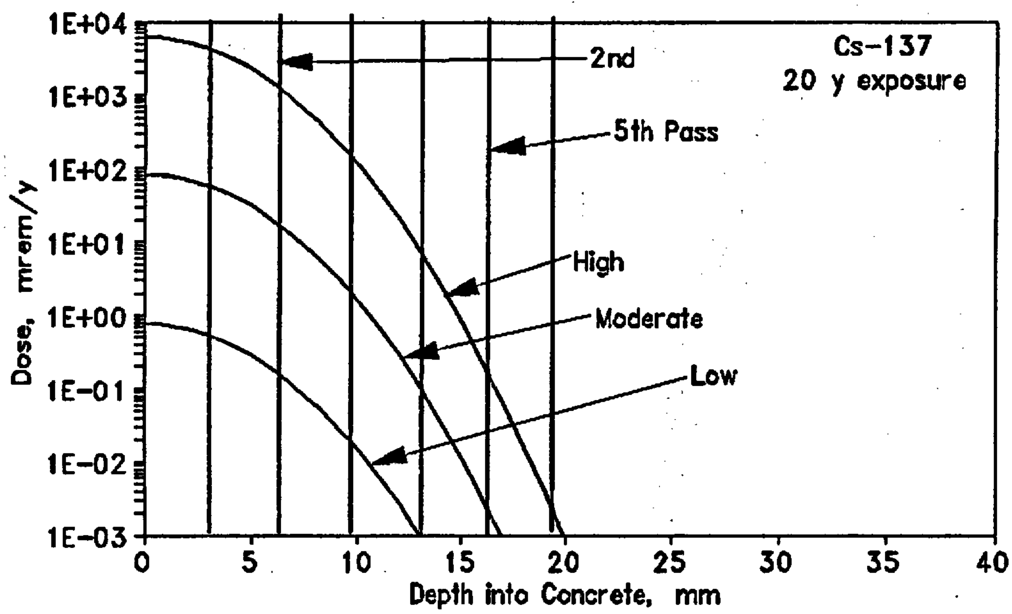

FIGURE 4.8.11. Dose as a Function of Surface Layers Removed from Concrete Contaminated with High, Moderate, and Low ^{137}Cs Contamination Levels

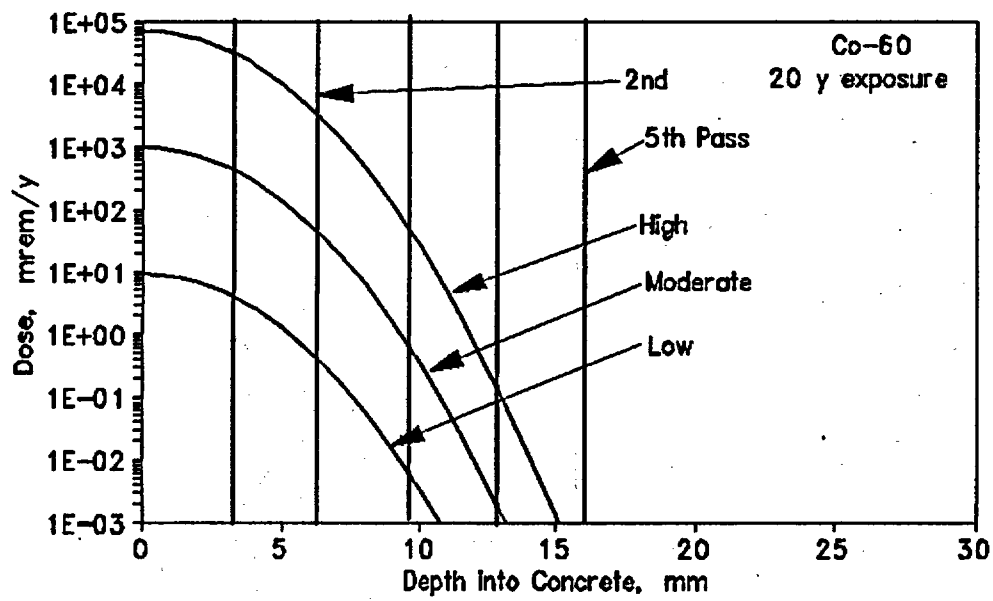

FIGURE 4.8.12. Dose as a Function of Surface Layers Removed from Concrete Contaminated with High, Moderate, and Low ^{60}Co Contamination Levels

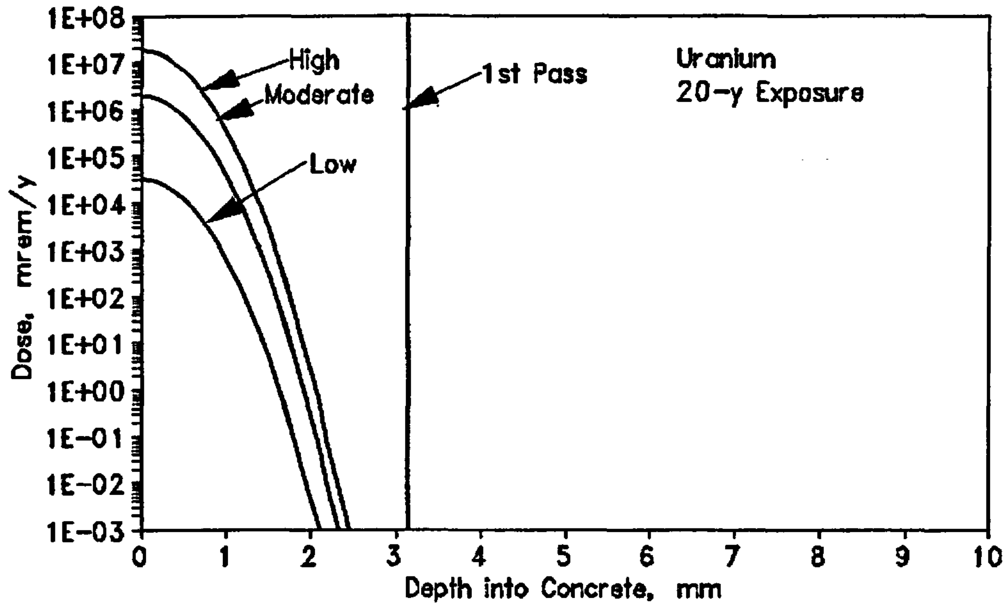

FIGURE 4.8.13. Dose as a Function of Surface Layers Removed from Concrete Contaminated with High, Moderate, and Low Uranium Contamination Levels

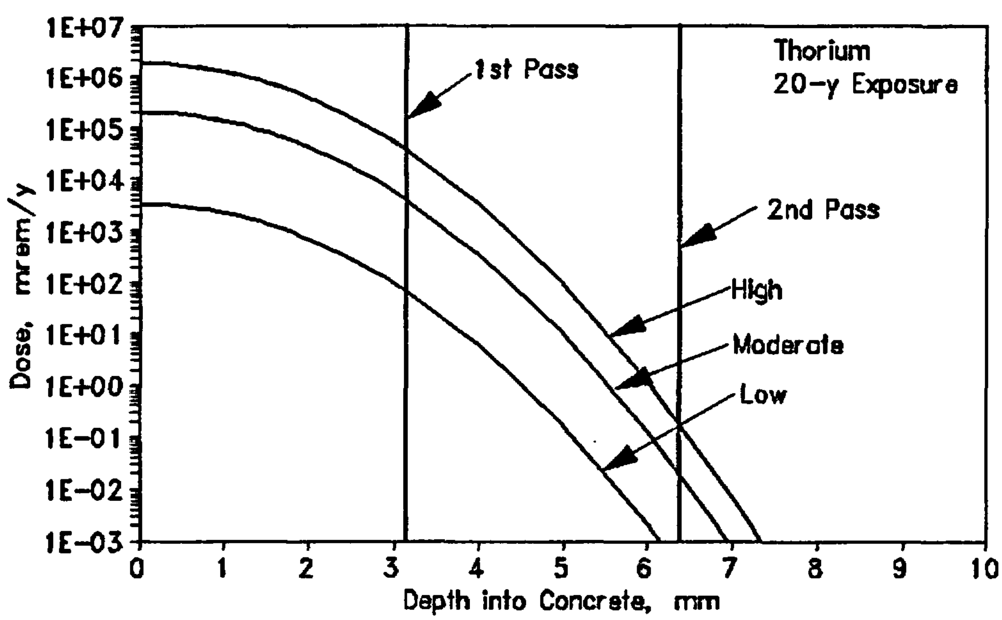

FIGURE 4.8.14. Dose as a Function of Surface Layers Removed from Concrete Contaminated with High, Moderate, and Low Thorium Contamination Levels

TABLE 4.8.3. Calculated Surface Radiation Dose Rates as Functions of the Number of Surface Layers Removed

Depth to New Surface, in./cm	Surface Dose Rate, mrem/y					
	^{60}Co			^{137}Cs		
	Low	Moderate	High	Low	Moderate	High
0.125/ 0.3175	4.09	428	31,700	0.519	56.2	4,060
0.250/ 0.635	0.0372	39.0	2,890	0.156	16.9	1,220
0.375/ 0.9525	0.00685	0.717	53.1	0.0212	2.3	166
0.500/ 1.27	2.55×10^{-5}	0.00267	0.198	0.00129	0.140	10.1
0.625/ 1.5875	1.92×10^{-8}	2.01×10^{-6}	1.49×10^{-4}	3.55×10^{-5}	3.85×10^{-3}	0.278
0.750/ 1.905	2.92×10^{-12}	3.05×10^{-12}	2.26×10^{-8}	4.38×10^{-7}	4.74×10^{-5}	3.43×10^{-3}
0.875/ 2.223	8.97×10^{-17}	9.40×10^{-15}	6.96×10^{-13}	2.43×10^{-9}	2.63×10^{-7}	1.90×10^{-5}
1.000/ 2.54	5.59×10^{-22}	5.85×10^{-20}	4.33×10^{-18}	6.06×10^{-12}	6.56×10^{-10}	4.75×10^{-8}
	Uranium			Thorium		
0.125/ 0.3175	7.55×10^{-14}	4.6×10^{-12}	4.2×10^{-11}	59.3	3,620	32,900
0.250/ 0.635	-	-	-	0.000369	0.0225	0.205

C.5 CHARACTERIZATION OF REFERENCE FACILITY SOIL CONTAMINATION

Soil contamination information from several facilities that have significant levels of soil contamination is contained in this chapter. Facilities other than those selected as the reference for building contamination are described as the reference facility for soil contamination if the data were more relevant. For example, the General Electric uranium fuel fabrication plant was described as the reference facility for characterization of building contamination, but the reference facility selected for characterization of soil contamination is the Babcock and Wilcox nuclear fuel manufacturing plant in Apollo, Pennsylvania.

The following information related to contaminant penetration into soils was derived from Ames and Rai (1978), unless otherwise referenced.

C.5.1 Parameters Affecting Radionuclide Penetration Into Soil

Unlike concrete, soil is a widely variable medium and the penetration of individual radionuclides through this medium is highly individual and complex. Prediction of contamination profiles in soils from a knowledge of the surface source term and penetration time is not possible without considerable additional information on soil composition (clay, sand, humus), particle size distribution, pH, ion-exchange capacity, etc., and cumulative rainfall on the surface. In addition, most sites are not placed on top of a homogeneous soil, but on top of several layers, which may contain varying amounts of sand, gravel, clay, rocks (all of varying thicknesses). Other factors must be considered for each site, such as the gradient of the contaminated area, the amount of runoff, whether cracks or channels may arise in the soil, depth of groundwater, and so on. Models exist for calculation of profiles given all of this data, as described below, but model developers consistently caution of problems regarding results from non-expert use of the models. The science of profile calculation using surface source data and computer models is in its infancy and currently the only reliable way of determining radionuclide profiles in soil is to measure them. Given this caveat, once site soil and other parameters have been completely characterized, contamination profiles can be calculated. The following subsections provide information on soil variability and its effect on radionuclide mobility useful to understanding the problems in making these calculations.

C.5.1.1 Soil Cation Exchange Capacity

There is considerable variability in the cation exchange capacity of various soil components, as shown in Table 5.1.1. Cation exchange capacity varies with particle size and pH, among other factors.

TABLE 5.1.1. Cation Exchange Capacities of Soil Components[a]

Mineral	Cation Exchange Capacity, meq/100 g
Kaolinite	3-15
Smectites	36-100
Vermiculite	100-150
Zeolites	100-300
Organic matter in soils (humus)	130-350
Feldspar	<1
Quartz	<1

(a) Ames and Rai 1978

C.5.1.2 Diffusion

The transport of matter in the absence of bulk flow is known as diffusion. A surface spill will move downwards through the soil, but there may also be some movement laterally and radially outward away from the spill point by the diffusion process. Under most conditions, to a first approximation, this is a relatively small correction to the model and may be neglected. Most models assume a cylindrical downwards flow of contaminant and will tend to slightly overestimate concentrations and underestimate contaminated soil volumes. The aqueous diffusion coefficient in a binary electrolyte (contaminant salt in solution) is given by the equation:

$$D_o = (2u_1u_2RT)/(u_1 + u_2)F$$

where u_1 and u_2 are the mobilities of the cation and anion, respectively, RT is the gas constant times temperature in Kelvin, and F is a Faraday. The dimensions of D_o are in cm^2/sec. Factors tending to reduce the diffusion rate are combined into a "retardation factor" (R_d), given by:

$$R_d = 1 + (p/e)K_d$$

where p is the soil bulk density, e is the pore fraction (volume occupied by the solution phase), and K_d is the equilibrium distribution coefficient (mL/g). K_d is itself a complex parameter which is affected by a number of soil variables and must be determined experimentally for each site.

C.5.1.3 Hydraulic conductivity

In migration of radionuclides, hydraulic conductivity is of primary importance. Hydraulic conduction is the ratio of the flux density (volume of water flowing through a cross-sectional area per unit time) to the hydraulic gradient (head drop per unit distance in the flow direction). If the soil water does not move, then radionuclide contaminants only move by diffusion, which is a relatively slow process. In spill sites which are exposed to the weather, rainfall (and hydraulic conduction) are likely to be the primary causes of radionuclide movement in soil; in areas where spills have leaked through and under concrete, diffusion may be the primary cause of movement in the absence of significant water flow.

C.5.1.4 Saturated and Unsaturated Soils

Unsaturated soils contain varying amounts of air-filled pores which reduce the conductive cross-sectional area relative to saturated soils where all of the pores are filled with water. As a result of this change in area available for the passage of water, the transition from saturated to unsaturated flow may result in a steep drop in hydraulic conductivity of several orders of magnitude. Contaminated sites in desert climates with sandy soil will tend to have unsaturated flow conditions, while sites in wet climates with clay soil will tend to have saturated conditions. Where conditions periodically change from one to the other condition, calculation of ionic movement becomes complicated.

C.5.2 Individual Radionuclide Adsorption on soils

Different radionuclides move through soils at different rates, which are controlled by a number of parameters. The behavior of the radionuclides of interest in this analysis is discussed below.

C.5.2.1 Cesium

Trace cesium concentrations in soil (at 1% of soil capacity or lower) tend to be completely absorbed and difficult to displace, possibly due to the presence in the soil of small amounts of minerals with high selectivity for cesium. K_d values for various U.S. soil types and locations are reproduced in Table 5.2.1, below, and illustrate the considerable range of values as a function of location and soil particle size.

TABLE 5.2.1. Cesium Distribution Coefficients in Various Soil Types[(a)]

Soil Medium	Cesium K_d, mL/g	Particle Size
Alluvium, Central NV	121-3165	500 - 4000 μm
Desert Alluvium,	70-2640	500 - 4000 μm
Hot Creek Valley, NV	-	-
Tuff, Rainier Mesa NV	1020	>400 μm
Tuff, Rainier Mesa, NV	12,100-17,800	100 - 200 mesh
Carbonate, Yucca Flats, NV	13.5	>4000 μm
Granodiorite, Climax	8-9	100 - 200 mesh
Stock, NV	1030-1810	0.5 - 1.0 mm
Alluvium, INEL, ID	285-360	(Lab. soil)
	450-950	(Field soil)
Granite, Central NV	34.3	>4000 μm
Basalt, NTS, NV	792-9520	32 - 80 mesh
Shaley Siltstone, NM	309	>4000 μm
Sandstone, NM	102	>4000 μm

(a) Table 3.19, p. 3-40, Ames and Rai (1978).

C.5.2.2 Cobalt

The major soil contaminant observed at nuclear power plant sites is ^{60}Co. Cobalt chemistry in soil is a highly complex function of soil pH and the oxidation-reduction environment. Cobalt can be present in soil as Co-II and Co-III oxidation states and as solution complexes with hydroxide, chloride, sulfate, and nitrate, as well as insoluble phosphate and carbonate. Cobalt is relatively easily complexed with natural organics and is adsorbed by ferric oxide and illite. In one reported case (Ames and Rai 1978, p. 3-74), leakage of ^{60}Co from the Nuclear Fuel Services plant in western New York State comprised <0.1% of the beta activity in surface drainage, but was all migrating as a complexed, soluble species. In a study of Hanford trench wastes (Ames and Rai, 1978, p. 3-74), complexed cobalt passed freely through the soil column to the groundwater at a depth of 68 m in a period of 12 years.

C.5.2.3 Strontium

Strontium in solution exists as Sr-II, is exchangeable on soils, and is mobilized mostly by calcium ions. Low pH and a high calcium content in soils results in high mobility of ^{90}Sr. Secondary minerals such as clays and zeolites absorb strontium more strongly and selectively than primary minerals such as quartz, feldspars, and pyroxenes. Table 5.2.2 shows selected K_d data for strontium on various soil types:

TABLE 5.2.2. Strontium Distribution Coefficients in Various Soil Types[a]

Material	Strontium K_d, mL/g	Particle Size
Alluvium, Central NV	48 - 2454	500 - 4000 μm
Sandstone, fine	1.26 - 1.88	4000 - <62 μm
Shaley siltstone (carbonaceous)	8.32 - 9.56	4000 - <62 μm
Shaley limestone, NM	8.32	>4000 μm
Sandstone, NM	1.37	>4000 μm
Alluvium, INEL, ID	7.2 - 10.5	(Lab. soil)
	40	(Field soil)
Tuff, Rainier Mesa, NV	260	>400 μm
Tuff, NTS, NV	4000	---
Limestone, Yucca Flats, NV	0.19	>4000 μm
Granodiorite, Climax	4 - 9	100 - 200 mesh
stock	11 - 23	0.5 - 1.0 mm
Granite, Central NV	1.7	>4000 μm
Basalt, Buckboard Mesa, NV	16 - 135	32 - 80 mesh

(a) Ames and Rai 1978, p. 3-174/5.

C.5.2.4 Thorium

Thorium contamination in soils may occur from metal ore tailings piles. Thorium is strongly adsorbed by clay particles and tends to precipitate as thorium hydroxide and hydrated thorium oxide in soils. Low pH and high humic acid content in soils tends to cause more rapid migration of thorium. Typical measured K_d values ranged from 40 - 130 mL/g (medium sand), 310 - 470 (fine sand), and 2700 - 10,000 (silt-clay), respectively (Ames and Rai 1978, p. 3-215).

C.5.2.5 Uranium

Uranium is of primary importance in decommissioning and disposal of contaminated soils, and is present in soils mostly as U-IV and U-VI, depending on soil pH and the oxidation-reduction environment. Uranium retention by oxidizing (low humus) alkaline soils is poor because the uranium is present mostly in anionic form. Uranium is solubilized and highly mobile in carbonate-containing waters. Uranyl ion can be adsorbed by clay and humic substances, especially at low pH. Typical K_d values obtained for uranium in various soil types are shown in Table 5.2.3.

TABLE 5.2.3. Uranium Distribution Coefficients in Various Soil Types[a]

Material	K_d, mL/g
River sediment (clay, $CaCO_3$)	39
River peat (humic)	33
Sediment (clay, $CaCO_3$)	16
Altered schist (clay)	270
Quartz	0
Calcite	7
Illite	139

(a) Ames and Rai 1978, p. 3-235

C.5.3 Issues Relating to Soil Radionuclide Profile Determination

Transport of radionuclides in soil is based on the concept of solution flow driven by downward movement of water, opposed by various physical and chemical processes which retard the radionuclide movement, summarized in a "retardation factor". Adsorption processes are known to increase travel times for some radionuclides by 10^3 - 10^6 times relative to groundwater. The net effect is captured in the distribution coefficient for the particular radionuclide and soil conditions. Furthermore, some adsorption processes are essentially irreversible and permanently remove radionuclides from the groundwater (Serne, 1992). Use of the distribution coefficient approach to calculation of specific radionuclide movement is universal in soil transport models.

C.5.3.1 Distribution Ratios

Each of the conceptual adsorption models relies on the experimental determination of distribution ratios (ratio of radionuclide on solid:radionuclide in solution). Because these ratios are themselves dependent on a large number of variables, the more complete the experimental determination of these variables, the better the accuracy of the profile calculation. However, more complete experimental determination of variables costs more in time, effort, and expense.

C.5.3.2 Constancy of Retardation Factor (R_d)

Transport model calculations depend on the constant value for retardation of each radionuclide. The retardation factor is itself dependent on other variables and requires a complete knowledge of the soil profile. For example, if several types of soil underlie a contaminant spill location, the retardation factors will be different in each layer (topsoil, silt, sand, gravel, for example).

C.5.3.3 Unexplained Variability of R_d

Unexplained variability of retardation factors may be due to solubility-controlled retardation reactions (precipitation), which are highly dependent on radionuclide concentration at a specific depth and hence on the initial concentration of the radionuclide at the surface, since these are equilibrium-controlled reactions. That is, the amount of radionuclide absorbed is dependent on the initial mass present.

C.5.4 Calculation of Radionuclide Contaminant Profiles in Soils

Models and computer codes for calculation of radionuclide contaminant profiles in soils from initial surface loadings, elapsed time, and soil, climate, and geographic parameters are at an early stage of development and are evolving rapidly. The approach taken in this analysis is based upon that described in NUREG-5512 (Kennedy and Strenge 1992), although for the purposes of estimating residual radionuclide concentrations in soils, the simple model has been modified and expanded to give a more realistic result. The following description explains the basic NUREG-5512 model assumptions and the modifications made to it. The major difference is the thickness of the initial contaminated soil layer (1 cm instead of 1 m) and the number of consecutive layers (100 instead of 1) into which the 1 m near-surface soil column is divided.

In the reference scenario, the contaminant of interest was deposited at the top of the soil column (the vadose zone) at time zero and has penetrated the soil for a known period of time. A contaminant plume has spread within the vadose zone but has not yet reached the groundwater table. Lateral diffusion is assumed to be zero (a simplification discussed previously) and the profile is assumed to be within a vertical cylinder of contaminated soil. The required outputs of the model are the amounts of the contaminant that have reached specific depths.

Assumptions for the Simplified Diffusion Analysis

- One-dimensional transport (down)
- Darcy water flux density (through the entire vadose zone) is constant in time
- the chemistry is described by linear sorption coefficients, K_ds
- only aqueous solute transport is considered
- single radionuclide at a time, not the entire decay chain
- assume a homogeneous vadose zone (only one layer)
- numerical solution to the differential equations preferred.

Input Parameters Required

For using the code for calculating radionuclide concentration profiles, the following numerical input data are required (values used in parenthesis):

- number of years (20)
- number of steps per year (120)
- number of layers desired (100)
- number of layers for which initial concentration is given (1)
- initial concentration of radionuclide (1.0 pCi/cm^3 in first box)
- contamination rate (pCi/yr)(1.0 or 0.0)
- integration time step, days (365/120)
- total soil thickness, m (1)
- infiltration rate, m/yr (0.18)
- saturation ratio, dimensionless (1.0)
- total porosity, dimensionless (0.3)
- bulk density, g/cm^3 (1.625)
- sorption, mL/g (various)
- radionuclide half-life, years (various).

For simplicity, a given inventory of a given radionuclide is postulated to be present in the initial surface layer of soil, arbitrarily set at 1 cm thick. The dispersion of that inventory downward into the soil over time is calculated using a modification of the computer code initially developed by C.G. Cole of PNL in support of the methodology presented in NUREG/CR-5512. This code calculates the dispersion of the initial inventory as a function of time and annual rainfall, taking into account the specific K_d value of the radionuclide for this soil, and the soil porosity. In the calculations performed for these porosities the number of successive layers of soil was arbitrarily set to be 100, the period of infiltration of the contaminant was set at 20 years, and the annual rainfall was assumed to be 0.18 m/yr. The K_d values for each radionuclide were taken from the set presented in NUREG/CR-5512, the soil density was set at 1.625 g/cm^3, and the soil porosity was set to be 0.3 for all layers of soil (i.e., the soil was assumed to be homogeneous over the total depth). An initial deposition of 1 pCi/cm^3 of the radionuclide in question was assumed to be deposited into the initial 1 cm soil layer at time zero.

By selecting the soil layer thickness to be 1 cm, the inventory in each layer can be expressed as a concentration in pCi/cm^3, as can the calculated inventory in each layer at the end of the 20-year infiltration period. Dividing the soil concentration in pCi/cm^3 by the soil density in g/cm^3 gave the concentration in each layer in terms of pCi/g of soil, the same units which are needed for use with the dose factors developed for the residential scenario in NUREG/CR-5512.

Because the dose factors are designed to be applied to the average concentration of contaminant remaining in the soil, it was necessary to calculate the average concentration of contaminant as each successive layer was removed, starting at the surface. The procedure used is described in the next section.

C.5.5 Methodology for Calculating Soil Residual Dose Rates

The differential equation for the diffusion of material through a solid medium is solved and evaluated for an assumed initial deposition of 1 pCi/cm^3 in the first 1-cm thickness of soil, using the parameters described above, for each radionuclide of interest. The basic procedure for determining the radiation dose rate from radionuclides remaining in the soil at the end of the 20-year period is described below.

The concentration profile for each radionuclide (j) is calculated, using the method described above. The average concentration in each 1 cm thick layer of soil is calculated, and includes the effects of radioactive decay over the 20-year period.

The average concentration over the uppermost 5 cm of soil is calculated, using the layer by layer concentrations calculated above.

$$C_{A5} = \sum_{i=1}^{5} (C_i)/5$$

The concentration profile is normalized by dividing each layer value by C_{A5}, to obtain a profile wherein the average value over the top 5 cm is
1 pCi/cm^3, i.e.,

$$CN_i = C_i/C_{A5}, \text{ and } \sum_{i=1}^{5} CN_i = 1$$

The total normalized inventory over the 100-cm depth of soil is simply the sum over all layers, of the normalized concentration in each layer, i.e.,

$$I_{total} = \sum_{i=1}^{100} CN_i$$

This normalized inventory represents the inventory that, when distributed according to the concentration profile, would result in an average value of unity for the concentration over the top 5 cm.

The inventory remaining after some of the surface layers have been removed is given by:

$$I_{remaining} = I_{total} - \sum_{i=1}^{n} CN_i$$

where n is the number of layers removed. This residual inventory is postulated to reside in the 15-cm layer lying directly beneath the new surface, following soil removal, to be compatible with the model with which the dose factors for post-remediation use of the soil were calculated, i. e., NUREG/CR-5512. The average concentration in that 15-cm layer is given by:

$$CNA_i = I_{remaining}/15 = (1/15)\left(\sum_{i=1}^{100} CN_i - \sum_{i=1}^{n} CN_i \right)$$

Each time some additional soil is removed, the remaining inventory is presumed to again reside in the next 15-cm layer beneath the surface.

The remaining inventory values are calculated for removal of each cm of soil. Each value is multiplied by the dose factor for the residential scenario, as calculated using the NUREG/CR-5512 model. The resulting table of values as a function of depth reflect the underlying concentration profile that was normalized to have an average concentration of unity over the top 5 cm. Each value in the table can now be multiplied by a measured average concentration over the top 5 cm of soil, to obtain a table of residual dose rate values in mrem/yr as a function of depth of soil removed.

Residual Dose Rate(j) =	Dose Factor(j)	x	$(CNA_i)_j$ x Average measured
[mrem/yr]	[mrem/yr]/[pCi/g]		concentration, top 5 cm [pCi/g]

where the subscript (j) refers to the j^{th} radionuclide.

For uranium contamination, there is little or no data available relating to the top 5 cm of soil. Available data generally indicate that up to 200 pCi/g is present, without specifying where in the soil column this value was measured. Thus, it seems appropriate to assume that the quoted values are the maximum values found in the soil column, which would be in the vicinity of the peak of the concentration distribution curve. To facilitate using these kinds of data in the analyses, it is necessary to normalize the concentration distribution to have the value of unity over the 5-cm region centered on the peak of the distribution, nominally about 15 cm beneath the soil surface.

$$C_{P5} = \sum_{i=13}^{17} (C_i)/5$$

The new normalized concentration profile for uranium is given by:

$$CN_i = C_i/C_{P5}, \quad \text{and} \quad \sum_{i=13}^{17} CN_i = 1$$

The rest of the analysis is identical with the original analysis for the other radionuclides, using the modified CN_i.

Results

Some typical output results of the calculations for several radionuclides commonly encountered in soils at nuclear facilities are presented in Figures 5.5.1 through 5.5.6 as a function of several different surface contamination levels. Section 5.7 provides a discussion of the bases for the surface contamination levels used for the reference facilities. The calculated data underlying the figures are given in Table 5.5.1.

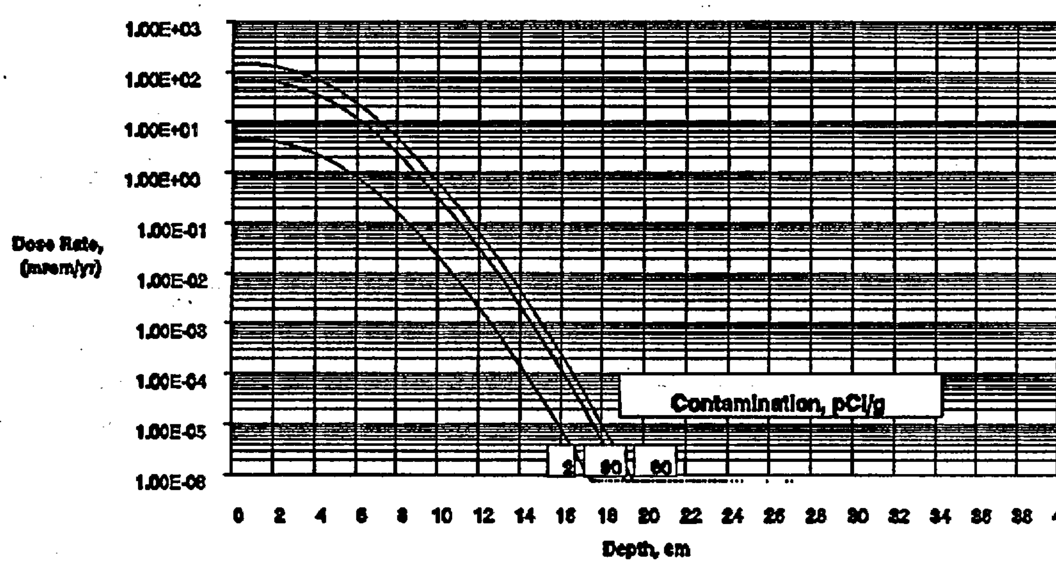

FIGURE 5.5.1. Calculated Residual ^{60}Co Radiation Dose Rates as a Function of Soil Depth Removed, with the Surface Contamination Level as a Parameter

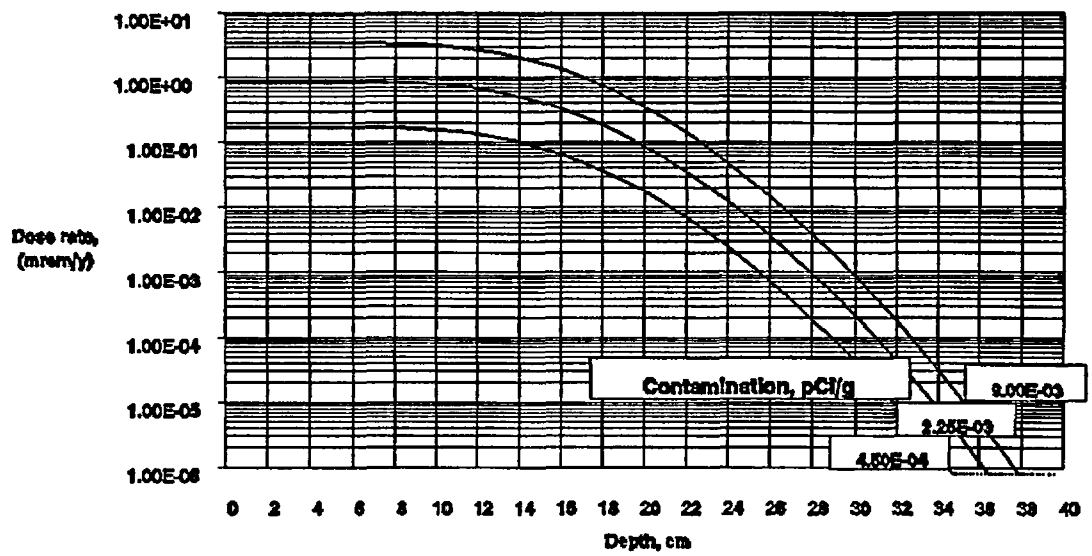

FIGURE 5.5.2. Calculated Residual ^{90}Sr Radiation Dose Rates as a Function of Soil Depth Removed, with the Surface Contamination Level as a Parameter

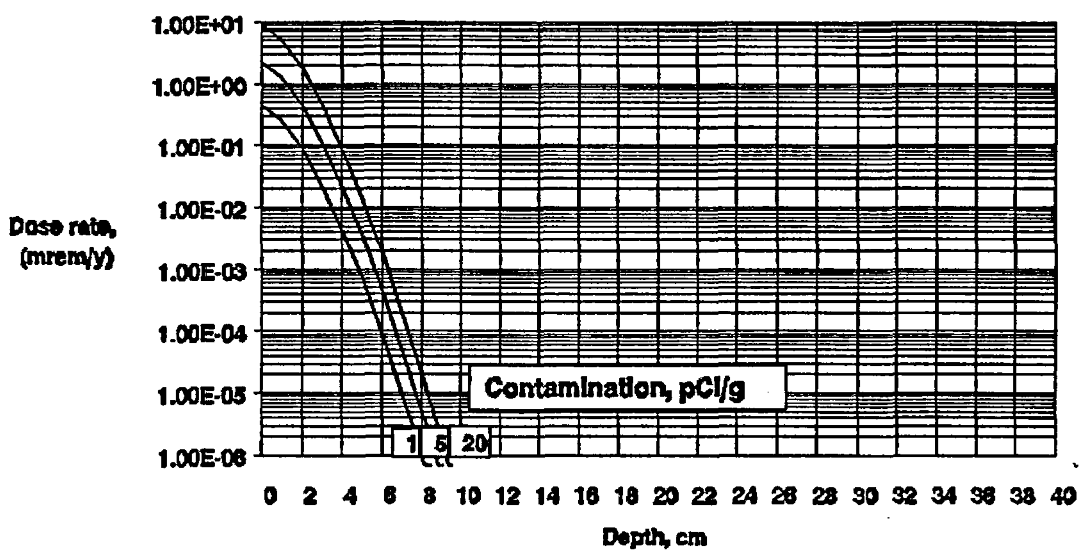

FIGURE 5.5.3. Calculated Residual ^{137}Cs Radiation Dose Rates as a Function of Soil Depth Removed, with the Surface Contamination Level as a Parameter

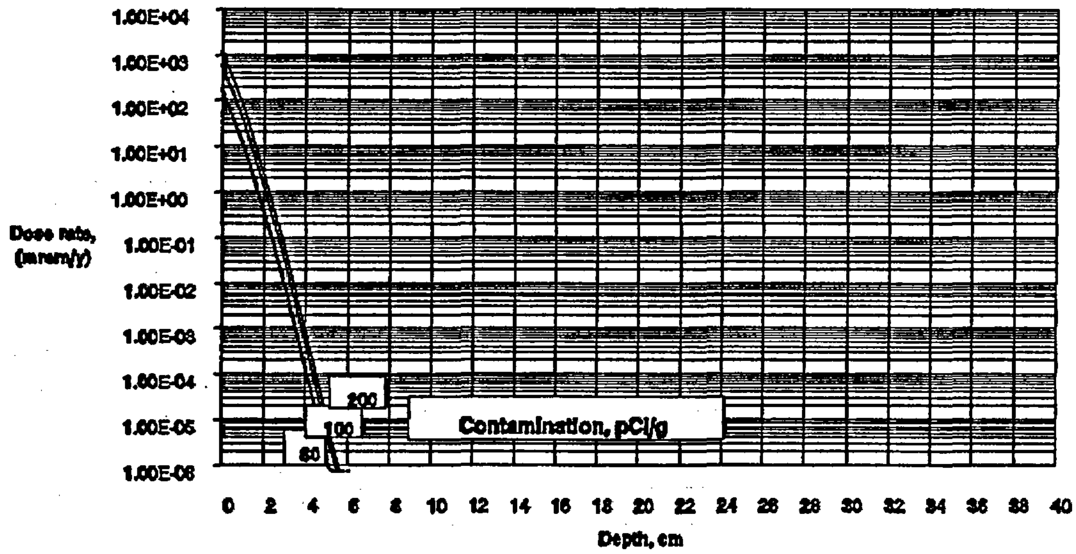

FIGURE 5.5.4. Calculated Residual ^{228}Th Radiation Dose Rates as a Function of Soil Depth Removed, with the Surface Contamination Level as a Parameter

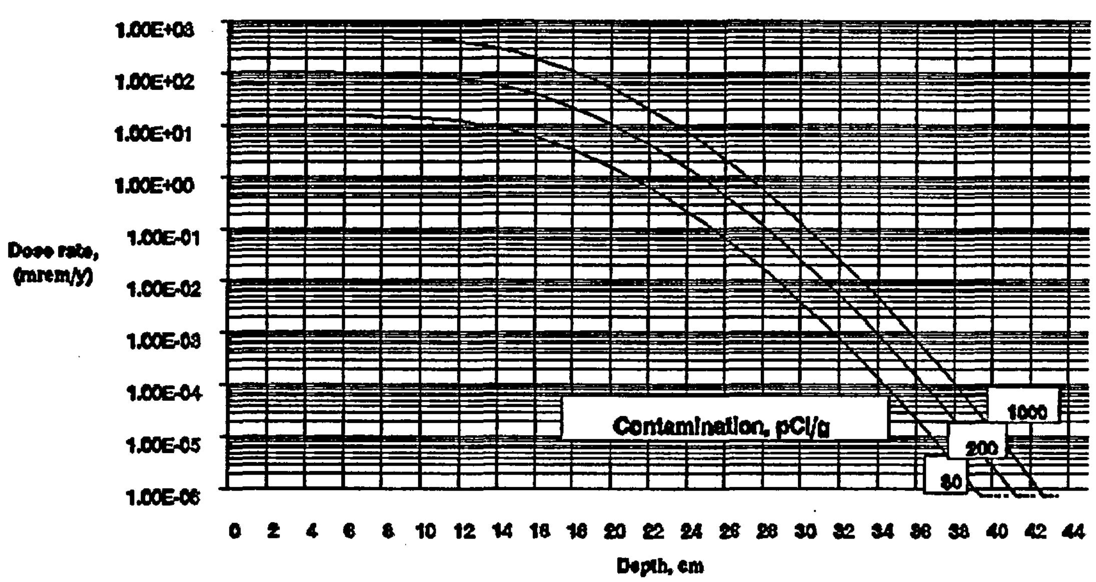

FIGURE 5.5.5. Calculated Residual ^{235}U Radiation Dose Rates as a Function of Soil Depth Removed, with the Surface Contamination Level as a Parameter

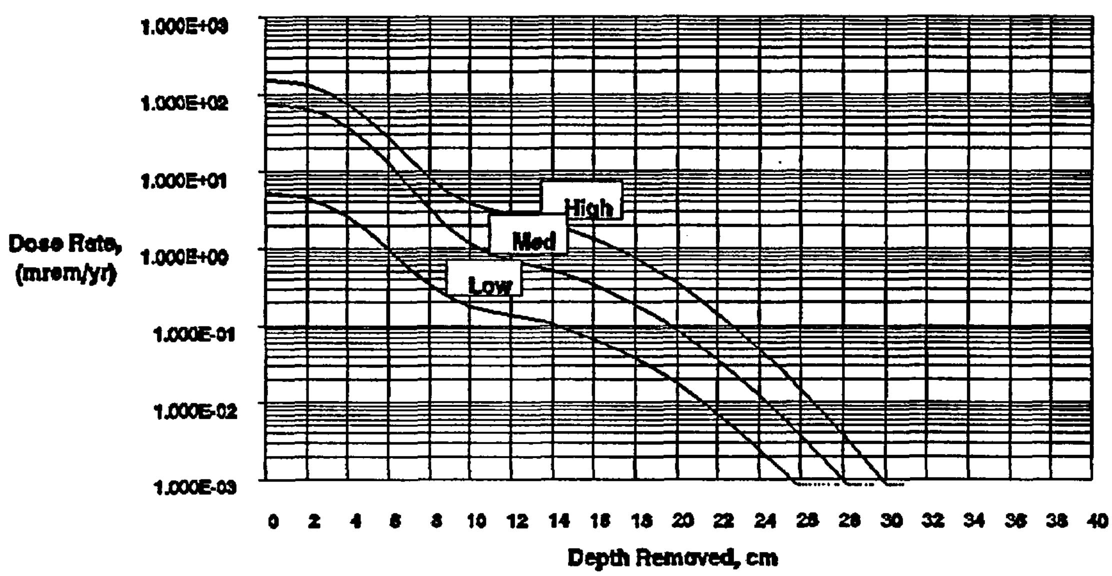

FIGURE 5.5.6. Calculated Composite ^{60}Co, ^{90}Sr, and ^{137}Cs Residual Radiation Dose Rates as a Function of Soil Depth Removed, with the Surface Contamination Level as a Parameter

TABLE 5.5.1. Calculated Residual Radiation Dose Rates as Functions of Soil Depth Removed, with Surface Contamination Level as a Parameter

Layers Removed	Dose in mrem/y per pCi/g Co-60	Sr-90	Cs-137	Th-228	U-235
0	2.44E+00	3.87E+02	4.68E-01	5.85E+00	2.26E+02
1	2.38E+00	3.87E+02	2.62E-01	3.92E-01	2.26E+02
2	2.16E+00	3.87E+02	9.29E-02	1.34E-02	2.26E+02
3	1.74E+00	3.87E+02	2.36E-02	3.07E-04	2.26E+02
4	1.23E+00	3.87E+02	4.62E-03	5.29E-06	2.25E+02
5	7.57E-01	3.87E+02	7.34E-04	7.29E-08	2.25E+02
6	4.09E-01	3.86E+02	9.81E-05	8.38E-10	2.25E+02
7	1.96E-01	3.83E+02	1.13E-05	8.26E-12	2.23E+02
8	8.41E-02	3.78E+02	1.14E-06	7.12E-14	2.20E+02
9	3.25E-02	3.69E+02	1.03E-07	5.45E-16	2.15E+02
10	1.14E-02	3.55E+02	8.32E-09	3.76E-18	2.07E+02
11	3.68E-03	3.33E+02	6.14E-10	2.35E-20	1.94E+02
12	1.09E-03	3.05E+02	4.15E-11	1.35E-22	1.78E+02
13	3.01E-04	2.70E+02	2.60E-12	7.16E-25	1.57E+02
14	7.73E-05	2.31E+02	1.51E-13	3.52E-27	1.35E+02
15	1.85E-05	1.91E+02	8.16E-15	1.61E-29	1.11E+02
16	4.18E-06	1.51E+02	4.15E-16	6.94E-32	8.79E+01
17	8.89E-07	1.15E+02	1.98E-17	2.81E-34	6.69E+01
18	1.79E-07	8.40E+01	8.95E-19	1.07E-36	4.89E+01
19	3.40E-08	5.90E+01	3.82E-20	3.87E-39	3.43E+01
20	6.17E-09	3.97E+01	1.55E-21	1.22E-41	2.31E+01
21	1.06E-09	2.57E+01	6.01E-23	0.00E+00	1.50E+01
22	1.76E-10	1.60E+01	2.22E-24	0.00E+00	9.32E+00
23	2.77E-11	9.61E+00	7.82E-26	0.00E+00	5.59E+00
24	4.19E-12	5.55E+00	2.64E-27	0.00E+00	3.23E+00
25	6.08E-13	3.09E+00	8.58E-29	0.00E+00	1.80E+00
26	8.50E-14	1.66E+00	2.68E-30	0.00E+00	9.66E-01
27	1.14E-14	8.64E-01	8.03E-32	0.00E+00	5.02E-01
28	1.48E-15	4.34E-01	2.33E-33	0.00E+00	2.52E-01
29	1.85E-16	2.11E-01	6.49E-35	0.00E+00	1.22E-01
30	2.24E-17	9.92E-02	1.75E-36	0.00E+00	5.76E-02
31	2.63E-18	4.53E-02	4.58E-38	0.00E+00	2.63E-02
32	2.98E-19	2.00E-02	1.16E-39	0.00E+00	1.16E-02
33	3.28E-20	8.61E-03	2.82E-41	0.00E+00	5.00E-03
34	3.49E-21	3.60E-03	5.83E-43	0.00E+00	2.09E-03
35	3.62E-22	1.46E-03	0.00E+00	0.00E+00	8.47E-04
36	3.65E-23	5.77E-04	0.00E+00	0.00E+00	3.34E-04
37	3.57E-24	2.22E-04	0.00E+00	0.00E+00	1.29E-04
38	3.41E-25	8.31E-05	0.00E+00	0.00E+00	4.82E-05
39	3.17E-26	3.04E-05	0.00E+00	0.00E+00	1.76E-05
40	2.87E-27	1.08E-05	0.00E+00	0.00E+00	6.27E-06
41	2.53E-28	3.76E-06	0.00E+00	0.00E+00	2.18E-06
42	2.18E-29	1.28E-06	0.00E+00	0.00E+00	7.40E-07
43	1.84E-30	4.24E-07	0.00E+00	0.00E+00	2.46E-07
44	1.51E-31	1.37E-07	0.00E+00	0.00E+00	7.96E-08
45	1.21E-32	4.36E-08	0.00E+00	0.00E+00	2.52E-08

Layers Removed	(mrem/y per pCi/g)	Co-60 Dose in mrem/y, pCi/g--> 2: Low	30: Med	60: High
0	2.44E+00	4.88E+00	7.33E+01	1.47E+02
1	2.38E+00	4.76E+00	7.14E+01	1.43E+02
2	2.16E+00	4.31E+00	6.47E+01	1.29E+02
3	1.74E+00	3.48E+00	5.22E+01	1.04E+02
4	1.23E+00	2.46E+00	3.68E+01	7.37E+01
5	7.57E-01	1.51E+00	2.27E+01	4.54E+01
6	4.09E-01	8.19E-01	1.23E+01	2.46E+01
7	1.96E-01	3.92E-01	5.89E+00	1.18E+01
8	8.41E-02	1.68E-01	2.52E+00	5.05E+00
9	3.25E-02	6.50E-02	9.75E-01	1.95E+00
10	1.14E-02	2.29E-02	3.43E-01	6.86E-01
11	3.68E-03	7.37E-03	1.11E-01	2.21E-01
12	1.09E-03	2.19E-03	3.28E-02	6.56E-02
13	3.01E-04	6.02E-04	9.04E-03	1.81E-02
14	7.73E-05	1.55E-04	2.32E-03	4.64E-03
15	1.85E-05	3.71E-05	5.56E-04	1.11E-03
16	4.18E-06	8.36E-06	1.25E-04	2.51E-04
17	8.89E-07	1.78E-06	2.67E-05	5.33E-05
18	1.79E-07	3.57E-07	5.36E-06	1.07E-05
19	3.40E-08	6.81E-08	1.02E-06	2.04E-06
20	6.17E-09	1.23E-08	1.85E-07	3.70E-07
21	1.06E-09	2.13E-09	3.19E-08	6.39E-08
22	1.76E-10	3.51E-10	5.27E-09	1.05E-08
23	2.77E-11	5.54E-11	8.31E-10	1.66E-09
24	4.19E-12	8.38E-12	1.26E-10	2.51E-10
25	6.08E-13	1.22E-12	1.83E-11	3.65E-11
26	8.50E-14	1.70E-13	2.55E-12	5.10E-12
27	1.14E-14	2.28E-14	3.43E-13	6.85E-13
28	1.48E-15	2.96E-15	4.44E-14	8.89E-14
29	1.85E-16	3.71E-16	5.56E-15	1.11E-14
30	2.24E-17	4.49E-17	6.73E-16	1.35E-15
31	2.63E-18	5.25E-18	7.88E-17	1.58E-16
32	2.98E-19	5.96E-19	8.94E-18	1.79E-17
33	3.28E-20	6.55E-20	9.83E-19	1.97E-18
34	3.49E-21	6.99E-21	1.05E-19	2.10E-19
35	3.62E-22	7.24E-22	1.09E-20	2.17E-20
36	3.65E-23	7.29E-23	1.09E-21	2.19E-21
37	3.57E-24	7.15E-24	1.07E-22	2.14E-22
38	3.41E-25	6.81E-25	1.02E-23	2.04E-23
39	3.17E-26	6.33E-26	9.50E-25	1.90E-24
40	2.87E-27	5.73E-27	8.60E-26	1.72E-25
41	2.53E-28	5.06E-28	7.59E-27	1.52E-26
42	2.18E-29	4.36E-29	6.54E-28	1.31E-27
43	1.84E-30	3.67E-30	5.51E-29	1.10E-28
44	1.51E-31	3.02E-31	4.53E-30	9.05E-30
45	1.21E-32	2.43E-32	3.64E-31	7.28E-31

Layers Removed	(mrem/y per pCi/g)	Sr-90 Dose in mrem/y, pCi/g--> 4.50E-04: Low	2.25E-03: Med	9.00E-03: High
0	3.87E+02	1.74E-01	8.71E-01	3.48E+00
1	3.87E+02	1.74E-01	8.71E-01	3.48E+00
2	3.87E+02	1.74E-01	8.71E-01	3.48E+00
3	3.87E+02	1.74E-01	8.71E-01	3.48E+00
4	3.87E+02	1.74E-01	8.71E-01	3.48E+00
5	3.87E+02	1.74E-01	8.70E-01	3.48E+00
6	3.86E+02	1.74E-01	8.68E-01	3.47E+00
7	3.83E+02	1.73E-01	8.63E-01	3.45E+00
8	3.78E+02	1.70E-01	8.52E-01	3.41E+00
9	3.69E+02	1.66E-01	8.31E-01	3.33E+00
10	3.55E+02	1.60E-01	7.98E-01	3.19E+00
11	3.33E+02	1.50E-01	7.50E-01	3.00E+00
12	3.05E+02	1.37E-01	6.86E-01	2.74E+00
13	2.70E+02	1.22E-01	6.08E-01	2.43E+00
14	2.31E+02	1.04E-01	5.20E-01	2.08E+00
15	1.91E+02	8.58E-02	4.29E-01	1.72E+00
16	1.51E+02	6.80E-02	3.40E-01	1.36E+00
17	1.15E+02	5.17E-02	2.59E-01	1.03E+00
18	8.40E+01	3.78E-02	1.89E-01	7.56E-01
19	5.90E+01	2.65E-02	1.33E-01	5.31E-01
20	3.97E+01	1.79E-02	8.94E-02	3.58E-01
21	2.57E+01	1.16E-02	5.79E-02	2.32E-01
22	1.60E+01	7.22E-03	3.61E-02	1.44E-01
23	9.61E+00	4.33E-03	2.16E-02	8.65E-02
24	5.55E+00	2.50E-03	1.25E-02	5.00E-02
25	3.09E+00	1.39E-03	6.96E-03	2.78E-02
26	1.66E+00	7.48E-04	3.74E-03	1.50E-02
27	8.64E-01	3.89E-04	1.94E-03	7.77E-03
28	4.34E-01	1.95E-04	9.76E-04	3.90E-03
29	2.11E-01	9.48E-05	4.74E-04	1.90E-03
30	9.92E-02	4.46E-05	2.23E-04	8.93E-04
31	4.53E-02	2.04E-05	1.02E-04	4.07E-04
32	2.00E-02	9.01E-06	4.51E-05	1.80E-04
33	8.61E-03	3.87E-06	1.94E-05	7.75E-05
34	3.60E-03	1.62E-06	8.09E-06	3.24E-05
35	1.46E-03	6.57E-07	3.28E-06	1.31E-05
36	5.77E-04	2.60E-07	1.30E-06	5.19E-06
37	2.22E-04	9.98E-08	4.99E-07	2.00E-06
38	8.31E-05	3.74E-08	1.87E-07	7.48E-07
39	3.04E-05	1.37E-08	6.83E-08	2.73E-07
40	1.08E-05	4.87E-09	2.44E-08	9.74E-08
41	3.76E-06	1.69E-09	8.47E-09	3.39E-08
42	1.28E-06	5.75E-10	2.88E-09	1.15E-08
43	4.24E-07	1.91E-10	9.54E-10	3.82E-09
44	1.37E-07	6.19E-11	3.09E-10	1.24E-09
45	4.36E-08	1.96E-11	9.81E-11	3.92E-10

TABLE 5.5.1. Calculated Residual Radiation Dose Rates as Functions of Soil Depth Removed, with Surface Contamination Level as a Parameter (continued)

Layers Removed	(mrem/y per pCi/g)	Cs-137 Dose in mrem/y Low	Med	High
	pCi/g-->	1	5	20
0	4.68E-01	4.68E-01	2.34E+00	9.37E+00
1	2.62E-01	2.62E-01	1.31E+00	5.24E+00
2	9.29E-02	9.29E-02	4.65E-01	1.86E+00
3	2.36E-02	2.36E-02	1.18E-01	4.71E-01
4	4.62E-03	4.62E-03	2.31E-02	9.23E-02
5	7.34E-04	7.34E-04	3.67E-03	1.47E-02
6	9.81E-05	9.81E-05	4.90E-04	1.96E-03
7	1.13E-05	1.13E-05	5.64E-05	2.26E-04
8	1.14E-06	1.14E-06	5.70E-06	2.28E-05
9	1.03E-07	1.03E-07	5.13E-07	2.05E-06
10	8.32E-09	8.32E-09	4.16E-08	1.66E-07
11	6.14E-10	6.14E-10	3.07E-09	1.23E-08
12	4.15E-11	4.15E-11	2.08E-10	8.31E-10
13	2.60E-12	2.60E-12	1.30E-11	5.19E-11
14	1.51E-13	1.51E-13	7.53E-13	3.01E-12
15	8.16E-15	8.16E-15	4.08E-14	1.63E-13
16	4.15E-16	4.15E-16	2.07E-15	8.29E-15
17	1.98E-17	1.98E-17	9.91E-17	3.96E-16
18	8.95E-19	8.95E-19	4.47E-18	1.79E-17
19	3.82E-20	3.82E-20	1.91E-19	7.65E-19
20	1.55E-21	1.55E-21	7.77E-21	3.11E-20
21	6.01E-23	6.01E-23	3.00E-22	1.20E-21
22	2.22E-24	2.22E-24	1.11E-23	4.43E-23
23	7.82E-26	7.82E-26	3.91E-25	1.56E-24
24	2.64E-27	2.64E-27	1.32E-26	5.29E-26
25	8.58E-29	8.58E-29	4.29E-28	1.72E-27
26	2.68E-30	2.68E-30	1.34E-29	5.35E-29
27	8.03E-32	8.03E-32	4.02E-31	1.61E-30
28	2.33E-33	2.33E-33	1.16E-32	4.65E-32
29	6.49E-35	6.49E-35	3.25E-34	1.30E-33
30	1.75E-36	1.75E-36	8.76E-36	3.51E-35
31	4.58E-38	4.58E-38	2.29E-37	9.15E-37
32	1.16E-39	1.16E-39	5.79E-39	2.31E-38
33	2.82E-41	2.82E-41	1.41E-40	5.64E-40
34	5.83E-43	5.83E-43	2.92E-42	1.17E-41
35	0.00E+00	0.00E+00	0.00E+00	0.00E+00
36	0.00E+00	0.00E+00	0.00E+00	0.00E+00
37	0.00E+00	0.00E+00	0.00E+00	0.00E+00
38	0.00E+00	0.00E+00	0.00E+00	0.00E+00
39	0.00E+00	0.00E+00	0.00E+00	0.00E+00
40	0.00E+00	0.00E+00	0.00E+00	0.00E+00
41	0.00E+00	0.00E+00	0.00E+00	0.00E+00
42	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	0.00E+00	0.00E+00	0.00E+00	0.00E+00
44	0.00E+00	0.00E+00	0.00E+00	0.00E+00
45	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Layers Removed	(mrem/y per pCi/g)	Th-228 Dose in mrem/y Low	Med	High
	pCi/g-->	30	100	200
0	5.85E+00	1.76E+02	5.85E+02	1.17E+03
1	3.92E-01	1.17E+01	3.92E+01	7.83E+01
2	1.34E-02	4.02E-01	1.34E+00	2.68E+00
3	3.07E-04	9.21E-03	3.07E-02	6.14E-02
4	5.29E-06	1.59E-04	5.29E-04	1.06E-03
5	7.29E-08	2.19E-06	7.29E-06	1.46E-05
6	8.38E-10	2.51E-08	8.38E-08	1.68E-07
7	8.26E-12	2.48E-10	8.26E-10	1.65E-09
8	7.12E-14	2.14E-12	7.12E-12	1.42E-11
9	5.45E-16	1.64E-14	5.45E-14	1.09E-13
10	3.76E-18	1.13E-16	3.76E-16	7.52E-16
11	2.35E-20	7.06E-19	2.35E-18	4.71E-18
12	1.35E-22	4.05E-21	1.35E-20	2.70E-20
13	7.16E-25	2.15E-23	7.16E-23	1.43E-22
14	3.52E-27	1.06E-25	3.52E-25	7.04E-25
15	1.61E-29	4.84E-28	1.61E-27	3.23E-27
16	6.94E-32	2.08E-30	6.94E-30	1.39E-29
17	2.81E-34	8.42E-33	2.81E-32	5.61E-32
18	1.07E-36	3.21E-35	1.07E-34	2.14E-34
19	3.87E-39	1.16E-37	3.87E-37	7.75E-37
20	1.22E-41	3.65E-40	1.22E-39	2.43E-39
21	0.00E+00	0.00E+00	0.00E+00	0.00E+00
22	0.00E+00	0.00E+00	0.00E+00	0.00E+00
23	0.00E+00	0.00E+00	0.00E+00	0.00E+00
24	0.00E+00	0.00E+00	0.00E+00	0.00E+00
25	0.00E+00	0.00E+00	0.00E+00	0.00E+00
26	0.00E+00	0.00E+00	0.00E+00	0.00E+00
27	0.00E+00	0.00E+00	0.00E+00	0.00E+00
28	0.00E+00	0.00E+00	0.00E+00	0.00E+00
29	0.00E+00	0.00E+00	0.00E+00	0.00E+00
30	0.00E+00	0.00E+00	0.00E+00	0.00E+00
31	0.00E+00	0.00E+00	0.00E+00	0.00E+00
32	0.00E+00	0.00E+00	0.00E+00	0.00E+00
33	0.00E+00	0.00E+00	0.00E+00	0.00E+00
34	0.00E+00	0.00E+00	0.00E+00	0.00E+00
35	0.00E+00	0.00E+00	0.00E+00	0.00E+00
36	0.00E+00	0.00E+00	0.00E+00	0.00E+00
37	0.00E+00	0.00E+00	0.00E+00	0.00E+00
38	0.00E+00	0.00E+00	0.00E+00	0.00E+00
39	0.00E+00	0.00E+00	0.00E+00	0.00E+00
40	0.00E+00	0.00E+00	0.00E+00	0.00E+00
41	0.00E+00	0.00E+00	0.00E+00	0.00E+00
42	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	0.00E+00	0.00E+00	0.00E+00	0.00E+00
44	0.00E+00	0.00E+00	0.00E+00	0.00E+00
45	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Layers Removed	(mrem/y per pCi/g)	U-235 Dose in mrem/y Low	Med	High
	pCi/g-->	30	200	1000
0	5.23E-01	1.57E+01	1.05E+02	5.23E+02
1	5.23E-01	1.57E+01	1.05E+02	5.23E+02
2	5.23E-01	1.57E+01	1.05E+02	5.23E+02
3	5.23E-01	1.57E+01	1.05E+02	5.23E+02
4	5.23E-01	1.57E+01	1.05E+02	5.23E+02
5	5.22E-01	1.57E+01	1.04E+02	5.22E+02
6	5.21E-01	1.56E+01	1.04E+02	5.21E+02
7	5.18E-01	1.55E+01	1.04E+02	5.18E+02
8	5.11E-01	1.53E+01	1.02E+02	5.11E+02
9	4.99E-01	1.50E+01	9.98E+01	4.99E+02
10	4.79E-01	1.44E+01	9.58E+01	4.79E+02
11	4.50E-01	1.35E+01	9.00E+01	4.50E+02
12	4.12E-01	1.23E+01	8.23E+01	4.12E+02
13	3.65E-01	1.09E+01	7.30E+01	3.65E+02
14	3.12E-01	9.36E+00	6.24E+01	3.12E+02
15	2.57E-01	7.72E+00	5.14E+01	2.57E+02
16	2.04E-01	6.11E+00	4.08E+01	2.04E+02
17	1.55E-01	4.65E+00	3.10E+01	1.55E+02
18	1.13E-01	3.40E+00	2.27E+01	1.13E+02
19	7.95E-02	2.39E+00	1.59E+01	7.95E+01
20	5.36E-02	1.61E+00	1.07E+01	5.36E+01
21	3.47E-02	1.04E+00	6.94E+00	3.47E+01
22	2.16E-02	6.48E-01	4.32E+00	2.16E+01
23	1.30E-02	3.89E-01	2.59E+00	1.30E+01
24	7.48E-03	2.25E-01	1.50E+00	7.48E+00
25	4.17E-03	1.25E-01	8.34E-01	4.17E+00
26	2.24E-03	6.72E-02	4.48E-01	2.24E+00
27	1.16E-03	3.49E-02	2.33E-01	1.16E+00
28	5.84E-04	1.75E-02	1.17E-01	5.84E-01
29	2.84E-04	8.51E-03	5.67E-02	2.84E-01
30	1.33E-04	4.01E-03	2.67E-02	1.33E-01
31	6.09E-05	1.83E-03	1.22E-02	6.09E-02
32	2.70E-05	8.09E-04	5.39E-03	2.70E-02
33	1.16E-05	3.47E-04	2.32E-03	1.16E-02
34	4.84E-06	1.45E-04	9.67E-04	4.84E-03
35	1.96E-06	5.89E-05	3.93E-04	1.96E-03
36	7.75E-07	2.33E-05	1.55E-04	7.75E-04
37	2.98E-07	8.95E-06	5.96E-05	2.98E-04
38	1.12E-07	3.35E-06	2.23E-05	1.12E-04
39	4.08E-08	1.22E-06	8.16E-06	4.08E-05
40	1.45E-08	4.36E-07	2.91E-06	1.45E-05
41	5.05E-09	1.52E-07	1.01E-06	5.05E-06
42	1.72E-09	5.15E-08	3.43E-07	1.72E-06
43	5.69E-10	1.71E-08	1.14E-07	5.69E-07
44	1.85E-10	5.54E-09	3.69E-08	1.85E-07
45	5.85E-11	1.76E-09	1.17E-08	5.85E-08

C.5.6 Reference Facility Soil Contamination

Soil contamination information from 10 reference facilities is contained in this section. Also contained in this section are the surface areas of contaminated soil at the reference facilities, which are summarized in Table 7.1.1. Volumes of contaminated soil are calculated as a function of thickness removed and are summarized in Tables 7.2.2 and 7.2.3. Facilities other than those selected as the reference for building contamination may be described as the reference facility for soil contamination if the data were more relevant. For example, the General Electric uranium fuel fabrication plant was described as the reference facility for characterization of building contamination, but the reference facility selected for characterization of soil contamination is the Babcock and Wilcox nuclear fuel manufacturing plant in Apollo, Pennsylvania.

The data on the level of soil contamination presented in the following sections is limited and also shows considerable variability. Such contamination would be expected to vary for specific sites. Therefore, three sets of reference soil contamination levels have been developed for each of the reference facilities, called "high," "medium," and "low," to provide some bounding of the situation and to provide a range of the possible contamination levels that may be present. The soil surfaces are assumed to be contaminated at these nominal contamination levels, for purposes of these analyses.

C.5.6.1 Reference Power Reactor

A reference facility based on the Trojan Reactor Plant has been described in Section 4.1. The concentration ranges of radionuclides in contaminated surface soils (to a depth of 4 cm) has also been reported by Abel et. al. (1986, Table 4.7, p. 27) for six other reactor plants and are reproduced in Table 5.6.1. Cobalt-60 was the largest contributor to radiation dose from radionuclides in soils at those plants.

<u>Geographic Profile</u>

Radionuclide concentrations in soils at nuclear power plant sites were located in small patches of very low concentrations located within the security fences and were mostly at known spill sites. These locations were generally close to condensate or borated water storage tanks, effluent sampling points, or equipment maintenance and/or cleaning areas. Small areas of contaminated soils at most plants would require remedial action, such as excavation and disposal as low-level waste. Volumes are relatively low - tens of cubic meters (Abel et al. 1986) Additional volumes of contaminated soil might occur during decontamination and/or dismantling, as additional spills occur or covered areas (e.g., underneath spent fuel storage pools) are found to be contaminated. The highest levels of radionuclides found in "hot spots" (soil samples and holding pond sediments) consisted of ^{60}Co (up to 377 pCi/g) and ^{137}Cs (up to 91 pCi/g) (Abel et al. 1986).

TABLE 5.6.1. **Concentration Ranges of Radionuclides in Contaminated Surface Soils (0-4 cm) from Radiation Controlled Areas (pCi/g) (Abel et al. 1986, Table 4.7, p. 27)**

Radionuclide	Pathfinder[a]	Humboldt Bay(b)	Dresden[c]	Monticello[d]	Turkey Point[e]	Rancho Seco[f]
^{54}Mn	<0.005-0.06	0.45-5.5	0.02-0.23	<0.004-<0.02	0.03-0.34	<0.003-0.27
^{60}Co	<0.01-1.7	26-377	1.3-161	0.006-0.45	4.0-45	0.012-11
^{106}Ru	<0.1-0.36	<0.02-<0.05	<0.07-0.2	<0.07	<0.1-0.2	<0.03-<0.09
^{125}Sb	<0.02	<0.4-4.9	<0.03-<1	<0.03	<0.6-22	<0.006-0.75
^{134}Cs	<0.04-<0.01	1.5-6.1	<0.01-6.3	<0.004-0.16	0.28-5.5	0.01-0.95
^{137}Cs	0.15-2.9	25-91	0.49-260	0.068-2.1	1.7-11	0.05-4.9
^{144}Ce	<0.03-0.18	<0.3-1.3	<0.04-1.5	0.083-0.17	<0.05-0.27	<0.02
^{238}Pu	3-41 x 10^{-5}	8.2-170 x 10^{-3}	N.M.[g]	N.M.	N.M.	N.M.
$^{239-240}$Pu	6-42 x 10^{-4}	9.5-230 x 10^{-3}	N.M.	N.M.	N.M.	N.M.

(a) Fourteen soil samples

(b) Five soil samples

(c) Four soil samples; highest observed contamination was at a depth of 15-30 cm.

(d) Four soil samples

(e) Six soil samples

(f) Seven soil samples

(g) N.M. represents Not Measured

Reference Scenario - Nuclear Power Plant

For the reference nuclear power plant decommissioning scenario, it is estimated that approximately 2000 ft^3 of soil contaminated with ^{60}Co and ^{137}Cs may be identified from (a) known and recorded spills, (b) spills of solutions and sludges during surface cleaning and decommissioning operations, and (c) spills into soil which are discovered during the post-decommissioning, pre-release radiological survey. The high, medium, and low values are given in Table 5.5.1 and Figures 5.5.1 - 5.5.3 for ^{60}Co, ^{137}Cs, and ^{90}Sr and are used in estimating surface soil contamination at the reference power reactor. Since this soil will be of relatively low activity and contain no alpha-emitting radionuclides above release limits, it can be treated as low-level waste, placed in drums, and transported to a LLW repository.

C.5.6.2 Reference Test Reactor and Research Reactor

The site area of the reference Plum Brook test reactor is estimated at 50 x 10^6 ft^2. There are approximately 3,400 linear feet of asphalt-lined drainage ditches at the reference test reactor facility (Konzek et al. 1982b). Before concrete pipes were laid on the asphalt lining, it is assumed that there was potential leakage of contaminated water into the soil beneath the asphalt. If the ditches were approximately 1.5 ft wide, the area of the contaminated soil is estimated to be approximately 5,000 ft^2. Radioactivity released to the soil from the retention basins is assumed to be negligible.

The site area of the reference Oregon State University (OSU) TRIGA research reactor is estimated to be 150,000 ft^2. No specific data on contaminated soil areas were found for the OSU reactor site. Therefore, the area of contaminated soil is estimated to be 500 ft^2, scaled from the contaminated area estimated for the test reactor, reflecting the reduced scale of operations at a research reactor.

The high, medium, and low values for surface contamination are given in Table 5.5.1 and Figures 5.5.1, 5.5.2, and 5.5.3, for ^{60}Co, ^{37}Cs, and ^{90}Sr, and are used to estimate the surface soil contamination at the reference test and research reactors.

C.5.6.3 Reference Nuclear Fuel Fabrication Facility

Although the General Electric Wilmington Plant is the reference nuclear fuel fabrication facility, more information on the condition of the soils at the site were found for the Apollò plant. Therefore, soils at the Apollo plant are described in this section.

The plant is a former nuclear fuel manufacturing site in Apollo, PA, which is currently undergoing decontamination (Babcock and Wilcox 1992a, 1992b). The fuel manufacturing operations were performed in one part of the facility, owned by Babcock and Wilcox, and located on the east side of the site in approximately one acre of roofed two-story buildings. Other parts of the complex included a parking lot (2.5 acre) and an "off-site area" (3 acres) which included a metals-processing complex, laundry, railroad spur, and equipment storage building.

Principal NRC-licensed manufacturing operations at the Apollo site included the manufacture of low- and high-enriched uranium oxide fuels for commercial nuclear power plants and for nuclear-powered naval ships. Nuclear fuel manufacturing commenced in the main building in 1957 and was terminated in 1983. The manufacturing process was the chemical conversion of uranium hexafluoride to uranium oxide powder. All operations were terminated in 1984.

Contamination Information

Site soil has been estimated to be potentially contaminated above 30 pCi U/g, at depths ranging from near-surface to >25 feet. Uranium contamination concentrations of 24 - 300 pCi U/g were found beneath part of Building 3 and the east end of Building 4, at depths from 6 -96 inches. The riverbank soils are also being characterized; three samples taken from near the plant exceeded 30 pCi U/g. A surface area of approximately 50,000 ft^2 is estimated to be contaminated to varying degrees with uranium. Based on the available information, high, medium, and low levels of surface contamination are estimated. The values for uranium contamination at the surface for the reference uranium fuel fabrication facility are given in Table 5.5.1 and Figure 5.5.5.

C.5.6.4 Reference Uranium Hexafluoride Plant

The uranium hexafluoride gaseous diffusion plant Portsmouth, Ohio, was selected as a reference plant for the contaminated soils portion of this report because it provides some information on the extent of contamination. The Portsmouth Gaseous Diffusion Plant is located on a government-owned reservation 126 km from Columbus, Ohio and 32 km north of Portsmouth, OH, next to the Scioto River and at an elevation of 650 - 700 feet above sea level. The plant is operated for the U.S. Department of Energy (DOE) by Martin Marietta Energy Systems, Ltd., and provides enriched uranium fuel to the nuclear power industry from isotope separation via gaseous diffusion.

Radioactive contamination in the soil at this site is currently being investigated as part of a comprehensive RCRA (Resource Conservation and Recovery Act) Facility Investigation (RFI). The site has been divided into four quadrants. [Complete data are currently available for only one of these - Quadrant I (Geraghty and Miller, Inc., 1990a, 1990b), but a general site overview has been included in these references].

Based on the available information, the high, medium, and low levels of surface contamination given in Table 5.5.1 and Figure 5.5.5 are used in estimating surface soil contamination at the reference uranium hexafluoride plant. The estimated site area is 200×10^6 ft^2. The contaminated area is estimated to be 100,000 ft^2.

C.5.6.5 Reference Non-Fuel-Cycle Plants

The reference non-fuel-cycle plants evaluated for soils contamination are a sealed source manufacturing facility, a generic broad research and development facility, and a rare metal extraction facility.

C.5.6.5.1 Reference Sealed Source Manufacturing Facility

The reference sealed source manufacturer is the Advanced Medical Systems facility. The site area is estimated to be 40,000 ft^2. The contaminated area is estimated to be 5,000 ft^2, based on assumed stack effluent releases. Advanced Medical Systems, Inc. manufactures ^{60}Co and ^{137}Cs sources for medical use. A small amount of detectable activity has been found in site soil, and was assumed to be due to stack effluent releases. Apart from this, the major route to soil contamination would be via liquid waste spills on building floors running off through floor-wall seams in the concrete (NRC 1993).

For purposes of estimating soil contamination, the high, medium, and low values given in Table 5.5.1 and figures 5.5.1 and 5.5.3 for ^{60}Co and ^{137}Cs are used in estimating surface soil contamination at the reference sealed source manufacturer. It is likely that the low value is appropriate in most situations for these facilities.

C.5.6.5.2 Rare Metal Extraction Facility

The reference rare metal extraction facility is the Molybdenum Corporation of America facility in Washington, PA, which occupies a 17 acre (740,000 ft^2) site, and produced a ferrocolumbium alloy from a Brazilian ore from 1964 to 1970. The ore contained licensable concentrations of thorium (1-1.5% by weight), and so the operation produced thorium-bearing slag and contaminated soil. Some of the slag was used as fill over portions of the site, which includes a number of buildings, eight holding ponds, and a large (7,000 m^3) slag pile with an average activity of 1,250 pCi/g on the southern part of the property (NRC 1993, p. A-65). Average concentrations over most of the site ranged between 100-200 pCi/g. Therefore, 200 pCi/g was used for the high value in Figure 5.5.4. The area of contaminated soil is estimated to be 100,000 ft^2 based on extensive handling and storing of ore and slag at the site. It is estimated that there is 1.1×10^5 kg of thorium on-site in the form of contaminated soils and slags.

C.5.6.5.3 Broad Research and Development Facility

The reference broad R&D facility is a generic, single-building facility on a 40,000 ft^2 site. Licensed nuclear fuels R&D was performed on the site. A site-wide radiological survey indicated contamination in several areas of soil, with subsurface cesium contamination from 20-48 pCi/g at two locations, and with contaminated septic tank sludge and contaminated soil under a downspout. Sediment samples from the site contained ^{137}Cs (up to 9.9 pCi/g) (NRC 1993). Although radioactivity levels in soil were generally quite low, contamination in "hot spots" appeared to be quite widespread; therefore, the area of contaminated soil is assumed to be 5000 ft^2.

The high, medium, and low values given in Table 5.5.1 and Figure 5.5.3 for ^{137}Cs are used in estimating surface soil contamination at the reference broad R&D facility.

C.5.6.6 Reference Conventional Uranium Mill

The scope of this document is limited to the uranium mill buildings and the immediate lands surrounding the mill buildings, and specifically the residual radioactivity criteria for contamination which may be present in those buildings or lands. With regard to the tailings impoundment, a general license is issued under 10 CFR 40.28 for the custody and long-term care of the tailings to comply with standards for uranium mill tailings sites closed under the Uranium Mill Tailings Radiation Control Act of 1978. The licensee for the tailings impoundment will be the DOE, other Federal agency, or State. Therefore, long-term management of the tailings impoundment is outside the scope of this document and is not discussed further.

Apart from the tailings piles, contaminated soil is assumed to be present in the former mill area and on the vicinity properties, which is believed to have originated from storage of ore in open piles, roaster stack emissions, tailings pond overflow, and erosion of tailings piles by wind and water. The average contamination (given as ^{226}Ra activity, which is a characteristic measurement for these sites) is 20 pCi/g of soil for the former millsite, with possible contamination of the subsurface to a depth of up to 6.5 ft.

The NRC (Sections 8.5 and 9.5 and Appendix K of NUREG-0706) has analyzed the decommissioning of the model mill. Concrete floors, foundations, and sumps from the mill buildings would be broken up, removed, and buried in the tailings impoundment. Contaminated soil beneath foundations of the mill building would be excavated and also taken to the tailings impoundment. Contaminated areas outside the mill buildings, such as ore pads and collection ponds, would be excavated and the soil removed to the tailings impoundment. All excavated areas would be backfilled, graded, and revegetated. It was estimated, based on the areas of the leaching and countercurrent decontamination tanks, that 35,000 ft^2 of concrete and underlying soil would be removed to a depth of six feet and placed into the tailings pile. It was also estimated that the ore pad and other more highly contaminated areas have an area of 20 acres and would be sent to the tailings piles and that for other mill site areas, 300 acres of soil with a removal depth of 6 inches would be sent to the tailings pile. Estimates were based on residual contamination criteria existing or proposed at the time of publication of NUREG-0706 (Table 9-14 of NUREG-0706). Costs and impacts associated with decommissioning of the model mill are included in Sections 8.5 and 9.5 and Appendix K of NUREG-0706.

Based on Appendix K, and on recent NRC experience regarding the conduct of decommissioning operations by the currently licensed uranium mills, decommissioning of the reference conventional mill is assumed as follows. For the reference conventional uranium mill, the mill structure (including concrete floors and foundations) would be demolished, removed, and buried in the tailings impoundment, contaminated earth beneath removed foundations and contaminated areas outside the buildings, such as ore pads and collection ponds and other areas in the vicinity of the mill structure, would be excavated and the soil removed to the tailings impoundment. Foundations and portions of the mill buildings may be disposed in place and covered with soil and erosion protection layers as part of the tailings reclamation plan. As indicated above, the tailings impoundment would remain under general license by the DOE. For the reference conventional uranium mill, because of the proximity of the mill building area to the tailings impoundment, the area at the mill building and its vicinity would become part of the DOE-licensed area under the general license for long-term care of the tailings pile and would not be released for unrestricted use. Therefore, decommissioning of the reference conventional uranium mill facility would not be impacted by the alternatives under consideration in this report.

Uncertainty Analysis of Decommissioning Analysis of Reference Conventional Uranium Mill

Decommissioning of a conventional mill in which the owner made a decision to release all or part of the mill area for unrestricted use would be evaluated on a case-by-case basis. As noted above, it has been estimated (Appendix K of NUREG-0706) that 35,000 square feet of concrete and underlying soil would be removed to a depth of six feet and placed into the tailings pile. It was also estimated that the ore pad has an area of 20 acres and an excavation depth of 3 feet (100,000 yd^3), and that for other mill site areas, 300 acres of soil with a removal depth of 6 in. are sent to the tailings pile. If a reference case is postulated for a complete or partial release of a site based on the volumes estimated, the quantities of contaminated material estimated for removal and disposal is less than that for a uranium fuel fabrication plant or uranium hexafluoride plant analyzed in Sections 4.3 and 4.4 of this report. Hence the evaluation of alternatives and release criteria estimated for those facilities could be applicable to the reference uranium mill case where there is release of some or all of the site for unrestricted use.

C.5.6.7 Reference Independent Spent Fuel Storage Installation

The reference dry ISFSI collocated at the Surry Reactor Plant has a site area of of 500,000 ft^2. The area of contaminated soil is postulated to be 500 ft^2. The high, medium, and low values given in Table 5.5.1 and Figures 5.5.1-5.5.3 for ^{60}Co, ^{137}Cs, and ^{90}Sr are used in estimating surface soil contamination at the reference ISFSI. It is likely that the low value is appropriate in most situations for these facilities.

C.6. COST METHODOLOGY FOR DECONTAMINATION OF CONCRETE AND SOILS

The methods of calculating costs for removal and disposition of contaminated concrete and soils from decommissioned nuclear facilities are described in this chapter. The methodology for costing the removal and disposal of contaminated concrete surfaces is described first, followed by the methodology for costing removal and disposal of contaminated soils.

C.6.1 Concrete Surface Decontamination Cost Calculation Methodology

The approach used to calculate the costs of removal and disposition of contaminated concrete from facility surfaces is as follows:

- The area of contaminated surface is defined.
- The length of perimeter crack is defined.
- The area of the "wet spots" is defined.
- The volume of concrete to be removed is determined, based on the dose calculations described in Sections 4.8.6 and 6.2.3 of this report.
- The unit cost factors for removal of contaminated concrete from surfaces, cracks, and wet spots are defined. The removal cost for each of the contaminant situations (floors, walls, cracks, and wet spots) is calculated as the product of the area x the appropriate unit cost factor.
- The resulting volumes of removed material are expanded by a rubble expansion factor of 1.56 (Westinghouse Hanford Co. 1989) and the contaminated rubble is drummed. The cost of drums is calculated by the product of the number of drums x the unit cost of a drum.
- The cost of transport is calculated assuming a one-way shipment of 500 miles from the waste generator to the disposal site, for a legal-weight truck shipment, by dividing the number of drums of rubble generated by the number of drums per truck shipment x the cost per shipment.
- The cost of disposal is calculated assuming very low activity waste disposed at a licensed LLW disposal site: the number of cubic feet of waste x the appropriate disposal charge rate per cubic foot.

- The duration of the concrete removal period is based upon the number of person-hours required to remove the material, assuming two crews/shift and two shifts/day, and specified removal rates (floors or walls) in square feet per crew-hour. On each shift, one crew works on floors and one crew works on walls. The total (floor or wall) area treated is divided by the appropriate removal rate in square feet per crew-hour to determine the number of crew-hours required to remove the material, i.e., the duration of the removal period. The overhead labor costs are determined by the size and makeup of the overhead staff and their salaries, and the length of the removal period.

- The total cost for contaminated concrete removal is the sum of the costs for removal of surface layers on floors and walls, and the cost for removal of cracks and wet spots, plus the costs for packaging, transport, and disposal of the packaged material, plus the cost of project overhead staff during the removal period. As each successive layer of concrete is removed from floors and walls, these removal costs increase, together with packaging, transport and disposal costs. The cost elements for the cracks and wet spots are independent of the number of layers of floor and wall removed.

C.6.2. Concrete Surface Decontamination Technology and Cost

Decontamination of concrete surfaces of floors and walls is postulated to be accomplished using commercial equipment presently available. The equipment postulated to be used in these analyses is a pneumatically operated surface removal system (scabbler) manufactured by Pentex, Inc. (The Moose™ and associated smaller units). This device can chip away approximately 0.125 in. of surface depth per pass, and has a skirted scabbling unit with a vacuum system which collects the dust and chips from the operation and deposits the waste material into a waste drum. Filters on the vacuum system discharge remove suspended dust particles from the air to prevent recontamination of the cleaned surfaces. Successive passes are required to remove deeper layers of contaminated concrete.

C.6.2.1 Rates of Floor and Wall Surface Removal

The removal rates for the scabbler devices are functions of the depth to be removed. Because the depth of cut for the scabbler is adjustable, different depths can be removed with a single pass. However, the deeper the cut, the slower the rate of removal in terms of surface area. For these analyses, a depth per cut of 0.125 in. is postulated, somewhere near optimum for maximizing the effectiveness of the equipment, which results in a removal rate of about 115 ft^2 per hour for a single pass of the equipment. The smaller units utilized for the edges of floors and for walls have a removal rate of about 30 ft^2 per hour for a single pass.

C.6.2.2 Unit Costs for Removing Contaminated Concrete Surfaces

The cost per square foot of surface removed is calculated based on the postulated crew makeup and size. For this type of operation, a crew consisting of 3 laborers, 0.25 of a health physics technician, and 0.25 of a crew-leader was postulated, which resulted in a cost per square foot removed to a depth of 0.125 in. of \$2.20 for the floors and \$8.61 for the walls.

To compute the cost of removal and disposition of each layer of contaminated concrete in a facility, the estimated contaminated area of floors and walls is multiplied by the appropriate unit cost factors, and the results summed. Added to these removal costs are the costs of packaging (cost per drum), transport (legal-weight truck one-way for 500 miles), and disposal at a licensed LLW facility (disposal charge rates are based on an average of the rates at the U.S. Ecology site at Hanford and the within Compact and outside of Compact rates at the Chem-Nuclear site at Barnwell, about \$148/ft^3). The cost of the project overhead staff during the removal period is computed based on the duration of the removal period and added to the other costs of the effort.

C.6.2.3 Crack and Wet Spot Removal

Decontamination of cracks in the floor that contain contamination is accomplished by removal of the concrete surrounding the crack, using ordinary pneumatic hammers and vacuum systems for dust and particle collection. The cost of this operation is computed in a manner similar to the floor removal operations, using a unit cost factor for crack cleanout and the linear length of crack requiring removal. A crew is defined, labor rates are assigned, the rate of crack length removal is estimated, and the cost per linear foot of crack is calculated. This unit cost factor is multiplied by the number of linear feet of crack requiring removal to obtain the removal cost. The costs of packaging, transport, and disposal are calculated and added.

Decontamination of a crack is postulated to require removal of approximately 1 in. of concrete on either side of the crack, to an average depth of 6 in., resulting in a waste volume generated of about 0.13 ft^3 of contaminated rubble per linear foot of crack, including the 1.56 volume expansion for rubblizing. The removal rate is assumed to be 20 linear feet of crack per operating crew-hour, with a resulting cost per linear foot of crack of about \$7.40, including equipment costs. The length of crack for each facility was postulated to be equal to the perimeter of the structure, derived from the building footprint surface area, assuming a square structure:

perimeter = 4 x (number of floors) x (footprint area)$^{1/2}$.

For the analyses presented in this report, a single story structure is assumed for all facilities.

For "wet spots", i.e., areas that had been exposed to liquid contaminants for extended periods of time, the penetration of contaminants is considerably deeper than for dry contaminants, as discussed in Chapter 4. Therefore, the entire thickness of a concrete floor is postulated to be removed for the area of the "wet spot", using equipment similar to that described for crack removal. For these analyses, the floor thicknesses removed were assumed to be 6 in. thick. It is also postulated that the contamination will extend downward into the soil beneath the "wet spot" such that, on the average, about 5 ft. of soil must be removed. The costs of removing and disposing of the "wet spot" concrete and the associated soil are summarized and included with the soils removal and disposal costs in Tables 7.2.3 and 7.2.4 of Chapter 7.

The removal rates, crew sizes, and costs for removal of the "wet spot" areas of concrete were obtained from Means (1993).

The results of the calculations for the cost of removal, packaging, transport, and disposal are summarized in Chapter 7 in Table 7.2.1 for the volumes of contaminated concrete removed from cracks, and in Tables 7.2.2 and 7.2.3 for the "wet spots".

C.6.3
Removal of Activated Concrete From the Reactor Bioshield

Removal of the activated concrete from the reactor bioshield is accomplished using a drilling and blasting technology. Vertical holes are bored into the shield concrete at selected distances from the shield inner surface. Explosives are inserted into the holes and detonated, breaking up the inner segments of the shield. This operation is repeated as necessary to remove the required amount of the shield, to reduce the surface radiation dose rate inside the shield cavity to acceptable levels.

Calculations of the activation of materials in the concrete biological shield that surrounds the reactor pressure vessel were reported in NUREG/CR-0130 (Smith et al. 1978) for the reference PWR (Trojan), for an assumed operating lifetime of 30 effective full-power years (i.e., 75% operating efficiency). These calculations did not include any ^{152}Eu because no information was available about the likely concentration of ^{152}Eu in the natural materials of the Trojan bioshield. However, measurements made at the Elk River Reactor decommissioning suggested that the Ci/m^3 attributable to ^{152}Eu was about the same as the Ci/m^3 associated with ^{60}Co. Thus, the total bioshield activity is postulated to be approximately twice the calculated activity of ^{60}Co, due to the anticipated ^{152}Eu activity.

Examination of the original calculations of activations in the bioshield suggests that at about 7 years following reactor shutdown, the residual activity levels in the bioshield will be such that removing 3.97 ft from the inner surface of the shield would result in a surface radiation dose rate of about 10 mrem/yr; 4.78 ft removed for 1 mrem/yr; and 5.57 ft removed for 0.1 mrem/yr. The costs associated with removal and disposal of that activated material were calculated using the unit cost factor algorithm for activated bioshield concrete removal presented in Section C.2.15 of Appendix C in NUREG/CR-5884, (Konzek et al. 1993) and the cost estimating computer program (CECP). The length of the decontamination effort was calculated to be controlled by the shield removal initially, but after one pass of the floor-removal equipment, the floor removal duration controlled the duration of the effort, for the purpose of calculating project overhead costs to be added to the direct labor costs.

C.6.4. Soil Decontamination Cost Methodology

The costs for removal and disposition of contaminated soils are calculated in a somewhat similar manner. The area of contaminated soil is defined. The unit cost factors for soil removal, treatment (if any), packaging, transport, and disposition are defined. The depth of contaminant penetration into the soil is defined. Then, the total cost for contaminated soil removal is the sum of the individual cost elements, which are calculated using the appropriate unit cost factors. The cost calculation is based upon removing all of the soil to the depth necessary to achieve each of the alternate residual radiation dose rates. Subsequently, choices are made between treating the contaminated soil prior to disposition, or transporting the untreated contaminated soil to a regulated disposal facility for very low activity materials. In the treatment scenario, the cleaned soil is retained on-site for backfill, with the more contaminated residues removed by the treatment process being packaged and transported to a LLW disposal facility. In any actual situation, selection of one path over another would most likely be governed by the total cost for each choice.

C.6.5 Soil Treatment Technologies

The various forms of soil washing represent the only commercially-demonstrated soil-cleaning techniques for radioactively-contaminated soils. Innovative techniques being developed (at present in the pilot plant or demonstration stage) include electrokinetics, and magnetic separation. These latter two techniques offer some potential for cost-reduction, but are likely to be applied as a polishing step after soil classification and washing rather than as stand-alone soil cleaning methods. In addition, biosorption/bioleaching technology, currently being used for metals extraction from ores in the mining industry (particularly uranium and copper) may be applied to contaminated soil cleanup, but it is currently a developing technology.

C.6.5.1 Soil Washing - General Description

Contaminated soil is removed from the site, classified to remove large particles and rocks, and washed by immersion with agitation in an aqueous solution. Chemical additives may be present in the wash solution to dissolve contaminants bound to soil particles. Several additives are available to facilitate the solution process depending on soil and contaminant type (Dennis et al. 1992, SEG 1992, and Gerber et al. 1991). After washing, the soil is separated according to particle size. Since most of the contaminants bind to the fine soil particles (<250 micrometers) which account for between 10-40% of the total soil mass, the bulk of the soil can be returned to the original location. The remaining slurry of contaminated fines may have to be treated further to prepare for disposal (e.g., by drying and placing in drums). Removal rates of contaminants are enhanced by high liquid to soil ratios. Depending on the soil type and type of washing solution, this method may be effective in the removal of radionuclides. This is a relatively new technology for soil remediation, although it has been used in the mining industry for many years. The process has been commercially demonstrated in Europe and the U.S., mostly for organic-contaminated soils, although some data are available on its application to radiologically contaminated soil remediation.

C.6.5.2 Other Soil Cleanup Technologies

A DOE program is under way to evaluate innovative soil treatment technologies, including field testing at the Nevada Test Site (NTS), at the NTS Treatability Test Facility (operated by Reynold's Electrical & Engineering Co.). The soil treatment technologies under examination currently are restricted to plutonium removal, but are likely to be equally effective for thorium and uranium (but not cesium or strontium), and include:

Advanced Process Technologies, Salt Lake City, UT: Air-sparged hydrocyclone for removal of plutonium

- AWC/Lockheed, Las Vegas, NV: Mineral jig combination and shaker table

- Nuclear Remediation Technologies, San Diego, CA: Paramagnetic separation of plutonium from soil using Eriez Magnetics equipment

- Paramagnetics, Inc., Plant City, FL: Pretreatment washing, followed by Kolm Separator paramagnetic separation

- Scientific Ecology Group, Pittsburgh, PA: Multigravity separator; and high-gradient magnetic separator.

Site cleanup is expected to begin in 1996, using the selected successful technologies (Nuclear Waste News, 1993).

C.6.6Cost and Labor Estimating Bases for Soil Remediation/Treatment

The information developed for cost and labor is based on unit cost and labor data presented in this section. Categories for which basic unit factors were developed include: excavation, demolition of foundations, soil washing, packaging, transportation, and disposal. Estimates were developed using a spreadsheet that calculates the cost and labor requirements as a function of volume removed for each site.

A soil washing option was considered for each site analyzed. The soil washing process would separate the contaminated soil from the clean soil in order to reduce the volume of soil that would be disposed of at a burial facility. In order to evaluate the cost effectiveness of soil washing, two scenarios were considered for each facility, one with soil washing and the other without soil washing.

C.6.6.1 Excavation

The unit cost and labor estimates for excavation of soil were obtained from Short (1988). The unit factors were then escalated to 1992 dollars. This analysis assumed that the soil was excavated and removed from an area contaminated with radioactive residue resulting from facility operations. Radiological surveys are performed by a work crew consisting of a foreman and three health physics technicians from the site owner's organization. The contractor's work crew for removal and handling of contaminated soil includes a foreman, two equipment operators, and two laborers. This crew is assisted by a health physics technician. Backfilling and grading of the site is accomplished by a work crew that includes a foreman, two equipment operators, and a laborer.

C.6.6.2 Removal of Concrete Floor and Underlying Soil

A unit cost and labor factor was developed for removal of portions of the facility floor area and about 5 ft. of soil beneath the removed portion of the floor. The unit cost and labor factor was based on the previous excavation cost, the cost for demolition of concrete footings and foundations, and placement of the demolished material into packages for transport to a disposal facility. The cost and labor factors for demolition of concrete foundations were obtained from Means (1993). It was assumed that the foundations contained reinforced steel and were demolished using pneumatic equipment, a backhoe, and crawler. The rubble was then loaded onto trucks. It was assumed that the concrete had been decontaminated, but a 15% work difficultly factor was applied to ensure that proper personnel protective equipment (similar to asbestos removal) was used during demolition.

C.6.6.3 Soil Washing

Soil washing is a water-based process for mechanically scrubbing and leaching waste constituents from a contaminated soil for recovery and treatment. It is an ex-situ toxicity reduction technology. The process removes contaminants from soils in one of two ways: by dissolving or suspending them in the wash solution, or by concentrating the contaminants into a smaller volume of soil through simple particle size separation techniques.

The cost of soil washing contaminated soil that was removed was obtained from the ENVEST Environmental Cost Engineering Model (ENVEST 1991) developed by the United States Air Force Environmental Restoration Program. The soil volume generated at each site was used as the cost estimating basis for the ENVEST model. It was assumed that a conservative efficiency of the soil washing process was 60%. Hence, 40% of the soil processed would be packaged and transported to a low-level radioactive waste burial facility.

C.6.6.4 Packaging

The cost for packaging containers was obtained from Konzek (1993). It was assumed that the material would be packaged for shallow-land burial using B-25 metal containers.

C.6.6.5 Transportation

Transport of radioactive materials from the facility to an approved disposal site was assumed to be accomplished by truck. A rate schedule from the Tri-State Motor Transit Company for truck shipment of radioactive material was used to estimate the transportation cost. The distance from the facility to the disposal site was assumed to be 500 miles. In addition, it was assumed that each truck could carry up to four containers.

C.6.6.6 Burial Costs

For this study, it was assumed that the waste generated at the sites would be shipped for disposal to a burial site, i.e., U.S. Ecology, Inc. located in Richland, Washington, or Chem Nuclear located in Barnwell, South Carolina. These sites were chosen due to the availability of cost information. Due to the uncertainty of the final disposition of the waste, an average of the U.S. Ecology (US Ecology) disposal rates and the Chem Nuclear (Chem Nuclear) disposal for both in-the-Southeast Compact and out-of-the-South Compact was used, about $\$148/ft^3$.

The Vitro Chemical Plant located in Utah has accepted large quantities (2.16 million cubic meters) of radium-contaminated soil for shallow land burial. However, no current data could be obtained for the cost of disposal at this facility.

C.6.6.7 Occupational Radiation Dose Estimates

The occupational radiation dose estimates were obtained from Short (1988). Occupational radiation dose estimates are made by multiplying the person-hours required to decommission a site by an average radiation dose rate. The actual worker dose rate experienced during site decommissioning depends on several factors, including the type of radioactive contamination on the site, the location and concentration of contamination, the site parameters, and the work procedures and work schedules. Actual worker dose rates are expected to be site- and worker-specific.

Some information exists on dose rates at typical contaminated sites. For example, data from an operating low-level waste burial ground indicate an average dose rate at the site of about 1 mrem per 24-hour day (0.042 mrem/hr). Exposure records of 23 workers engaged in the removal of a contaminated industrial waste line showed that over a 3-month period, only four dosimeters recorded doses in excess of 10 millirem. The maximum total exposure for one worker for 1 month was 30 millirem. Background values of gamma radiation at the inactive uranium mill tailings site at Tuba City, Arizona, have been measured at 0.01 mR/hr. All of these dose rates refer to direct exposure and do not include contributions from inhalation of radioactive particles.

The inhalation of airborne radioactivity may make a significant contribution to occupational exposure for some site decommissioning operations, depending on the nature of the site and the decommissioning option. The inhalation dose would not normally be significant for site stabilization or for waste removal operations at sites where soil contamination is minimal. This dose could be significant during the removal of a tailings pile because of the dust problem. For site decommissioning operations, worker use of face masks or other respiratory equipment or the use of water sprays to reduce dust concentrations would limit the occupational dose from inhalation of airborne radioactivity.

For this study, an average worker dose rate of 0.1 mrem/hr is assumed for site decommissioning operations. This value is believed to be reasonably conservative, based on available information about real sites. Decommissioning workers at potentially dusty sites are assumed to wear protective respiratory equipment to maintain occupational dose rates at or below this level.

The results of calculations of the costs of treating contaminated soils are summarized in Tables 7.2.2 and 7.2.3 of Chapter 7. The detailed spreadsheets for these calculations are presented in Appendix B of this report.

C.7 ANALYSES RESULTS

The costs of decontaminating previously contaminated facilities and their surrounding sites to meet alternate residual radiation criteria at those facilities are presented in this chapter. For concrete decontamination, the cost for satisfying a pre-determined residual allowable level was not calculated, because the concrete surface removal process tends to be a series of removals of discrete thicknesses. Instead, the postulated decontamination process removed a defined thickness of the contaminated material surface, and the resulting cost (which included removal, packaging, transport, and disposal) and the resulting residual radiation dose rate at the new surface were calculated. For soils decontamination, it was possible to define the depth of removal required to achieve the desired residual radiation dose rate level, and the removal process was generally accomplished with a single removal operation, down to the desired depth. The cost for soils decontamination included removal, treatment (if appropriate), packaging, transport, and disposal. The volumes of waste requiring disposal, total labor hours, the occupational radiation doses to workers, and the number of shipments between the site and the LLW disposal facility were also calculated for each residual radiation dose rate level considered.

The methodologies for calculating the residual radiation dose rates at the various depths of surface removal are presented in Chapters 4 and 5. The methodologies for calculating the costs of concrete surface removal and of soil surface removal are presented in Chapter 6. The results of these calculations are summarized in this chapter.

The following potential situations regarding the post-decommissioning and post-license termination use of the site are evaluated:

(1) Occupational use of the facility in which the facility buildings are occupied by a worker during a normal 8-hour shift.

(2) Renovation of the facility in which workers occupy the facility buildings during a normal work day, for the purpose of moving/removing walls, ceilings, etc.

(3) Residential use of the site in which persons live on the site and obtain drinking water from the site.

The bases for these scenarios are taken from Kennedy and Strenge (1992). The first two situations are evaluated in the same manner, i.e., using the methodology presented in Section 4.8.6 for radiation dose rate calculation, where the residual concentrations of contaminants are transformed into surface contamination levels, and the dose rates are calculated from those surface contamination levels using the surface contamination conversion factors contained in Appendix A.

The third situation listed above (residential and drinking water) is evaluated using the methodology developed in Sections 5.4 and 5.5 for estimating the residual radiation dose rates as a function of the depth of soil removal, for the contaminants of interest, i.e., ^{60}Co, ^{90}Sr, ^{137}Cs, uranium, and thorium. Based on the postulated initial contamination levels and the calculated contaminant penetration profiles, the residual radiation dose rates following removal of successive layers of soil were calculated, and the depths of removal necessary to achieve the selected residual dose rates were determined from the data. The cost of removing, possibly treating, packaging, transport, and disposal of the removed soil was calculated for each removal depth selected. Two estimates were developed for soils removal, one with treatment of the soil by washing, and one without treatment of the soil.

The initial conditions and the analysis bases for decontamination of floors and walls for facilities and of soils on the surrounding sites are as follows:

Facilities

- All in-process materials and products, major pieces of equipment, fixtures, floor coverings, and contaminated utilities such as drain lines and HVAC have been removed for disposal.
- Preliminary washdown of the facilities has been completed
- The neutron-activated concrete in the reactor bioshields is removed to depths corresponding to the alternate residual dose rates, i.e., 100, 10, 3, 1, 0.1, and 0.01 mrem/yr.
- The total thickness of concrete adjacent to contaminated cracks is removed.
- The total thickness of concrete in areas exposed to wet contaminants is removed.
- The surface of concrete areas exposed to dry contaminants are scabbled to depths corresponding to the alternate residual dose rates.

Soils

- Localized contaminated soil beneath structures is removed by removing local sections of the floor, without demolition of the structures. The removed concrete is disposed as LLW, the removed soils are either packaged and disposed as LLW, or treated, with the residual contaminated soils packaged and disposed as LLW, and the cleaned soil restored to the site.
- Other contaminated soils on the site are handled in the same manner as those contaminated soils removed from beneath the floor, i.e., contaminated soil external to structures is either removed and disposed as LLW, or treated, with the cleaned soils restored to the site, and residual contaminated soil disposed as LLW.

C.7.1 Analysis Bases

A summary of the total and contaminated surface areas of the reference structures and soils for the reference sites is presented in Table 7.1.1, together with the postulated maximum surface activity levels at those facilities and sites prior to surface removal efforts.

TABLE 7.1.1. Total and Contaminated Surface Areas for Structures and Soils at Reference Sites(1)

Reference Facility	Structures Radionuclide Activity(2), dpm/100 cm²	Structures Surface Areas, ft²		Structures Surface Areas, % Contaminated		Soil Surface Area, ft²	
		Floor	Wall	Floor	Wall	Total Site	Contaminated(2)
Power Reactor	7.5 x 10^6 ^{60}Co 2.4 x 10^6 ^{137}Cs	250,000	300,000	10	2	50 x 10^6	2,000
Test Reactor	7.5 x 10^6 ^{60}Co 2.4 x 10^6 ^{137}Cs	100,000	120,000	10	2	50 x 10^6	5,000
Research Reactor	102,000 ^{60}Co 33,300 ^{137}Cs	35,000	40,000	10	2	150,000	500
Uranium Fuel Fab	18,000 U	240,000	240,000	50	5	4.7 x 10^6	50,000
Hexafluoride	1.1 x 10^6 U	120,000	130,000	50	45	200 x 10^6	100,000
Sealed Source Manufacturer	102,000 ^{60}Co 33,300 ^{137}Cs	6,000	4,600	10	5	40,000	5,000
Rare Metal Extraction	18,000 Th	150,000	180,000	40	10	740,000	100,000
Broad R&D Facility (Generic)	102,000 ^{60}Co 33,300 ^{137}Cs	6,000	4,600	10	5	40,000	5,000
Uranium Mill	1.1 x 10^6 U	100,000	130,000	100	100	1.4 x 10^7	8.8 x 10^5
Dry ISFSI	980 ^{60}Co 310 ^{137}Cs	23,000	0	10	-	500,000	500

(1) The estimated surface areas listed above are based on very limited information, and in many cases represent an engineering judgment estimate based on the size of the building structural facilities and types of operations. The estimates are believed to be conservatively large, i.e., probably overestimate the actual areas involved.

(2) Radionuclide activity shown is for building surfaces. Radionuclide activity for soil surfaces is based on Figures 5.5.1 - 5.5.5.

C.7.2 Analyses Results

The estimated costs of removing the layers of contaminated concrete surface and cracks (and activated concrete, for the power reactor) from the reference facilities are presented in this chapter. The indicated costs include the direct labor, packaging, transport, and disposal costs for all of the material removed to reach the indicated depth, and the project overhead staff costs during the period of removal operations.

Facility Decontamination

The residual surface radiation dose rates from the contaminated (not activated) floors and walls as functions of the depth of surface removed are given in Table 7.2.1 for the reference facilities considered in this analysis. The required depth of removal and the costs to decontaminate those surfaces to alternate dose criteria can be inferred from the results given in Table 7.2.1.

The removal of the activated concrete from the bioshield in the reactor analysis creates a separate set of values, independent of the normal contaminated surface removal analyses. As noted in Section 6.3, removal of activated concrete from the bioshield is accomplished using a drilling and blasting technology. Vertical holes are bored into the shield concrete and explosives are inserted into the holes and detonated, breaking up the inner segments of the shield. In actual situations, there would likely be a tendency to attempt to accomplish the removal in one step because of the difficulty and tedious nature of the drilling and blasting efforts. Also, because of the nature of the blasting operation it is difficult to be precise regarding the amount of depth removed. Therefore, a relatively simple analysis is performed with regard to the depths of shield removed and residual criteria, resulting in residual radiation dose rates at the inner surfaces of the bioshield of 100, 10, 3, 1, 0.1, and 0.01 mrem/yr, for the removal of 3.49 ft, 4.22 ft, 4.60 ft, 4.95 ft, 5.68 ft, and 6.5 ft, respectively. These results are also presented in Table 7.2.1. The lower values are intended to demonstrate general behavior as criteria approximating a removal of all radioactivity attributable to licensed operations and return to background are investigated.

Additional information in Table 7.2.1 includes the volume of LLW generated for each removal depth, the occupational radiation dose accumulated by the workers in performing the removal operations, the labor hours required to accomplish the removal effort, and the number of shipments of LLW from the site to the LLW disposal facility.

Soils Decontamination

The costs of decontaminating the soil surfaces at each site are summarized in Tables 7.2.2 and 7.2.3, for the alternatives of 1) soil treatment (washing), and 2) no soil treatment. The costs of removing the thickness of contaminated concrete floor that was in a wet environment, and the soil beneath the "wet spot", are also included. Using the methodology presented in Section 5.5, the depths of soil removal required to achieve residual radiation dose rates of 100, 60, 30, 15, 10, 3, 0.3 and 0.03 mrem/yr were determined for each of the reference facilities, for the low, medium, and high contamination levels discussed in Chapter 5. The costs for removal, treatment (if applicable), packaging, transport, and disposal are calculated for the volumes of LLW resulting from these operations to achieve the alternate residual radiation dose rates. Also presented in Tables 7.2.2 and 7.2.3 are LLW disposal volumes, the number of truck shipments from the reference site to the LLW disposal facility, the labor hours required to accomplish the effort, and the occupational radiation dose to workers performing the tasks.

The resultant total cost for decontaminating a facility and site to a residual radiation dose rate level of less than some prescribed value is estimated by summing the appropriate value from Table 7.2.1 for a given facility, and Table 7.2.2 or Table 7.2.3 for the associated soil for that facility.

Table 7.2.1 Calculated Costs for Decontamination of Nuclear Facilities by Removing Different Depths of Concrete Surfaces

Facility Type	Parameter	Value of Parameter to Remove Concrete to the Depth Indicated							
Reactor Bioshield	(depth, ft)	3.49	4.22	4.60	4.95	5.68	6.50		
	Cost (1993 $M) [a]	1.922	2.391	2.661	2.895	3.415	4.027		
	Volume (ft^3)	1.1E+04	1.4E+04	1.5E+04	1.7E+04	1.9E+04	2.3E+04		
	Shipments	29	36	40	44	52	61		
	Person-rem	20.979	21.315	21.541	21.773	22.298	22.811		
	Labor Hours	2.7E+03	3.4E+03	4.1E+03	4.2E+03	5.0E+03	5.8E+03		
	mrem/yr	100	10	3	1	0.1	0.01		
Surface Removal	(depth, in.)	0.125	0.250	0.375	0.500	0.625	0.750	0.875	1.000
Reactor Surface Removal									
	Cost (1993 $M) [a]	0.421	0.766	1.110	1.455	1.799	2.144	2.488	2.833
	Volume (ft^3) [b]	764	1,268	1,772	2,276	2,780	3,284	3,788	4,292
	Shipments	2	4	5	6	8	9	10	11
	Person-rem	1.670	3.140	4.610	6.080	7.550	9.020	10.490	11.960
	Labor Hours	2,553	4,758	6,963	9,168	11,373	13,578	15,783	17,988
	mrem/yr	3.6E+04	4.1E+03	2.2E+02	10.29	0.278	0.0034	<0.003	<0.003
Test Reactor									
	Cost (1993 $M) [a]	0.388	0.726	1.065	1.404	1.743	2.082	2.421	2.760
	Volume (ft^3) [b]	522	880	1,238	1,595	1,953	2,311	2,668	3,026
	Shipments	2	3	4	5	5	6	7	8
	Person-rem	1.866	3.606	5.346	7.086	8.826	10.566	12.306	14.046
	Labor Hours	2,830	5,440	8,050	10,660	13,270	15,880	18,490	21,100
	mrem/yr	3.6E+04	4.1E+03	2.2E+02	10.29	0.278	0.0034	<0.003	<0.003

Table 7.2.1 Calculated Costs for Decontamination of Nuclear Facilities by Removing Different Depths of Concrete Surfaces (continued)

Facility Type	Parameter	Value of Parameter to Remove Concrete to the Depth Indicated							
Surface Removal (depth, in.)		0.125	0.250	0.375	0.500	0.625	0.750	0.875	1.000
Sealed Source Manufacturer									
	Cost (1993 $M) [a]	0.022	0.032	0.042	0.052	0.062	0.072	0.082	0.092
	Volume (ft^3) [b]	54	67	81	94	108	121	135	148
	Shipments	1	1	1	1	1	1	1	1
	Person-rem	0.077	0.122	0.168	0.213	0.259	0.305	0.350	0.396
	Labor Hours	122	191	259	328	396	464	533	601
	mrem/yr	4.8E+02	55.9	3.017	0.143	0.0037	<0.0037	<0.0037	<0.0037
Rare Metal Processor									
	Cost (1993 $M) [a]	0.962	1.864	2.766	3.668	4.570	5.472	6.374	7.276
	Volume (ft^3) [b]	1,470	2,738	4,006	5,275	6,543	7,811	9,079	10,348
	Shipments	4	7	11	14	17	20	24	27
	Person-rem	4.115	8.075	12.035	15.995	19.955	23.915	27.875	31.835
	Labor Hours	6,210	12,150	18,090	24,030	29,970	35,910	41,850	47,790
	mrem/yr	4.6E-12	<4.6E-12	<4.6E-12	<4.6E-12	<4.6E-12	<4.6E-12	<4.6E-12	<4.6E-12
Research and Development Facility (Generic)									
	Cost (1993 $M) [a]	0.022	0.032	0.042	0.052	0.062	0.072	0.082	0.092
	Volume (ft^3) [b]	54	67	81	94	108	121	135	148
	Shipments	1	1	1	1	1	1	1	1
	Person-rem	0.077	0.122	0.168	0.213	0.259	0.305	0.350	0.396
	Labor Hours	122	191	259	328	396	464	533	601
	mrem/yr	4.8E+02	55.9	3.017	0.143	0.0037	<0.0037	<0.0037	<0.0037

Table 7.2.1. Calculated Costs for Decontamination of Nuclear Facilities by Removing Different Depths of Concrete Surfaces (continued)

Facility Type	Parameter	Value of Parameter to Remove Concrete to the Depth Indicated							
Surface Removal (depth, in.)		0.125	0.250	0.375	0.500	0.625	0.750	0.875	1.000
Research Reactor									
	Cost (1993 $M) [a]	0.076	0.124	0.171	0.218	0.266	0.313	0.360	0.408
	Volume (ft^3) [b]	167	237	307	377	447	517	587	657
	Shipments	1	1	1	1	2	2	2	2
	Person-rem	0.276	0.477	0.678	0.879	1.080	1.281	1.482	1.683
	Labor Hours	432	733	1,035	1,336	1,638	1,939	2,241	2,542
	mrem/yr	4.8E+02	55.9	3.017	0.143	0.0037	<0.0037	<0.0037	<0.0037
Uranium Fuel Fabrication Plant									
	Cost (1993 $M) [a]	1.377	---[d]	---	---	---	---	---	---
	Volume (ft^3) [b]	2,401	---	---	---	---	---	---	---
	Shipments	7	---	---	---	---	---	---	---
	Person-rem	5.236	---	---	---	---	---	---	---
	Labor Hours	7,901	---	---	---	---	---	---	---
	mrem/yr	4.2E-11	---	---	---	---	---	---	---
UF_6 Conversion Plant									
	Cost (1993 $M) [a]	1.804	---[d]	---	---	---	---	---	---
	Volume (ft^3) [b]	2,107	---	---	---	---	---	---	---
	Shipments	6	---	---	---	---	---	---	---
	Person-rem	8.959	---	---	---	---	---	---	---
	Labor Hours	13,471	---	---	---	---	---	---	---
	mrem/yr	4.2E-11	---	---	---	---	---	---	---

Table 7.2.1. Calculated Costs for Decontamination of Nuclear Facilities by Removing Different Depths of Concrete Surfaces (continued)

Facility Type	Parameter	Value of Parameter to Remove Concrete to the Depth Indicated							
Surface Removal (depth, in.)		0.125	0.250	0.375	0.500	0.625	0.750	0.875	1.000
Uranium Mill [c]									
	Cost (1993 $M) [a]	6.404	—[d]	—	—	—	—	—	—
	Volume (ft^3)	—[e]	—	—	—	—	—	—	—
	Shipments	0	—	—	—	—	—	—	—
	Person-rem	29.072	—	—	—	—	—	—	—
	Labor Hours	5.0E+04	—	—	—	—	—	—	—
	mrem/yr	—[f]	—	—	—	—	—	—	—
Dry ISFSI Facility									
	Cost (1993 $M) [a]	0.020	0.040	0.060	0.081	0.101	0.121	0.141	0.161
	Volume (ft^3) [b][g]	37	75	112	150	187	224	262	299
	Shipments	1	1	1	1	1	1	1	1
	Person-rem	0.069	0.138	0.207	0.276	0.345	0.414	0.483	0.552
	Labor Hours	104	207	311	414	518	621	725	828
	mrem/yr	4.609	0.193	0.022	0.001	<0.001	<0.001	<0.001	<0.001

(a) All disposal costs are based on disposal charge rates, which are an average for the U.S. Ecology site at Richland, Washington and the Chem-Nuclear site at Barnwell, South Carolina.
(b) Wet Spot concrete volumes and costs included with soils decontamination in Tables 7.2.2 and 7.2.3.
(c) All Uranium Mill concrete removed and placed into tailings pile on-site.
(d) — indicates that for the uranium facilities, a single removal action was sufficient.
(e) No volumes for shipment off-site.
(f) No residual dose rate calculated, since all of the material was removed.
(g) No cracks are assumed to be present in the ISFSI pads.

TABLE 7.2.2 Summary of Costs and Other Parameters for Remediation Activities With Soil Washing for Sites Contaminated with Co and Cs

FACILITY	Manufacturer of Sealed Sources				
Contaminated Soil Area, ft²	5000				
Facility Area, ft²	6000				
Residual Conc. in Soil, mrem/yr	Soil Depth Removed	Disposal Volume	Total Soil Decon Cost	Labor Requirements	Occupational Dose
	cm	m³	$	man-hrs	person-mrem
HIGH					
100	3.00	14	$92,838	73	7
60	4.30	16	$108,636	84	8
30	5.50	19	$123,110	94	9
15	7.00	21	$139,954	106	11
10	7.30	22	$144,922	109	11
3	8.60	24	$160,720	120	12
0.3	11.00	29	$191,095	140	14
0.03	12.70	32	$211,684	154	15
MEDIUM					
60	2.50	13	$85,498	69	7
30	4.50	17	$110,981	86	9
15	6.00	20	$127,825	98	10
10	6.40	20	$134,016	101	10
3	7.70	23	$149,814	112	11
0.3	10.20	27	$181,411	133	13
0.03	12.00	31	$203,224	148	15
LOW					
3	3.60	15	$100,075	78	8
0.3	7.30	22	$144,922	109	11
0.03	9.70	26	$174,072	129	13

TABLE 7.2.2 Summary of Cost and Other Parameters for Remediation Activities With Soil Washing for Sites Contaminated with Co, Sr, and Cs

FACILITY		Power Reactor				Test Reactor			
Contaminated Soil Area, ft^2		2000				5000			
Facility Area, ft^2		250000				100000			
Residual Conc. in Soil, mrem/yr	Soil Depth	Cost	Disposal Vol	Labor	Dose	Cost	Disposal Vol	Labor	Dose
	cm	$	m^3	man-hr	person-mrem	$	m^3	man-hr	person-mrem
HIGH									
100	3.00	2,279,032	352	2019	202	943,318	145	829	83
60	4.5	2,286,769	353	2024	202	961,461	148	841	84
30	6.2	2,295,730	354	2030	203	983,375	151	855	86
15	7	2,299,323	355	2032	203	992,559	153	862	86
10	7.8	2,303,916	355	2035	203	1,002,742	154	868	87
3	11.5	2,321,535	358	2047	205	1,047,489	161	899	90
0.3	20.4	2,364,510	365	2077	208	1,157,977	178	973	97
0.03	24.9	2,388,048	368	2092	209	1,212,507	186	1011	101
MEDIUM									
100	0	2,264,557	349	2009	201	907,031	140	804	80
60	2.5	2,276,786	351	2017	202	937,203	144	824	82
30	4.5	2,286,769	353	2024	202	960,660	148	841	84
15	6	2,294,832	354	2029	203	978,930	151	853	85
10	6.4	2,296,628	354	2030	203	985,621	152	857	86
3	8.2	2,305,713	356	2036	204	1,007,233	155	872	87
0.3	16.4	2,344,544	362	2064	206	1,108,136	170	940	94
0.03	22.3	2,374,044	366	2083	208	1,181,012	181	989	99
LOW									
100,60,30,10	0	2,264,557	349	2009	201	907,031	140	804	80
3	3.6	2,281,727	352	2021	202	950,555	146	834	83
0.3	8.3	2,306,162	356	2037	204	1,008,756	155	873	87
0.03	18.6	2,354,426	363	2071	207	1,134,840	174	958	96

TABLE 7.2.2 Summary of Cost and Other Parameters for Remediation Activities With Soil Washing for Sites Contaminated with Co, Sr, and Cs

FACILITY		Research Reactor				Generic R & D Facility			
Contaminated Soil Area, ft^2		500				5000			
Facility Area, ft^2		35000				6000			
Residual Conc. in Soil, mrem/yr	Soil Depth	Cost	Disposal Vol	Labor	Dose	Cost	Disposal Vol	Labor	Dose
	cm	$	m^3	man-hrs	person-mrem	$	m^3	man-hrs	person-mrem
HIGH									
100	3.00	321,509	49	2844	288	110,768	14	73	7
60	4.5	323,393	50	2855	288	128,941	17	86	9
30	6.2	325,402	50	2866	299	149,551	20	1000	10
15	7	326,301	50	2877	299	158,654	21	1066	11
10	7.8	327,299	50	2888	299	169,037	23	1133	11
3	11.5	331,854	51	2911	299	215,139	30	1444	14
0.3	20.4	342,647	53	2988	300	324,202	46	2188	22
0.03	24.9	348,000	54	3022	300	380,047	55	2555	26
MEDIUM									
100	0	317,940	49	2811	288	73,026	8	48	5
60	2.5	320,948	49	2833	288	103,448	13	69	7
30	4.5	323,393	50	2855	288	128,941	17	86	9
15	6	325,078	50	2866	299	145,925	20	98	10
10	6.4	325,627	50	2877	299	151,796	20	1011	10
3	8.2	327,748	50	2888	299	173,909	24	1166	12
0.3	16.4	337,356	52	2955	299	274,541	39	1855	18
0.03	22.3	344,881	53	3000	300	347,247	50	2344	23
LOW									
100,60,30,10	0	317,940	49	2811	288	73,096	8	48	5
3	3.6	322,183	50	2844	288	118,075	15	78	8
0.3	8.3	327,860	50	2888	299	175,031	24	1177	12
0.03	18.6	339,926	52	2977	300	302,470	43	2033	20

TABLE 7.2.2 Summary of Cost and Other Parameters for Remediation Activities With Soil Washing for Sites Contaminated with Co, Sr, and Cs

FACILITY		DRY ISFSI			
Contaminated Soil Area, ft^2		500			
Facility Area, ft^2		23000			
Residual Conc. in Soil, mrem/yr	Soil Depth	Cost	Disposal Vol	Labor	Dose
	cm	$	m^3	man-hrs	person-mrem
HIGH					
100	3.00	213,192	33	187777	19999
60	4.5	214,976	33	189999	19999
30	6.2	216,985	33	190000	19999
15	7	217,983	33	191111	19999
10	7.8	218,982	34	191111	19999
3	11.5	223,336	34	194444	19999
0.3	20.4	234,130	36	202222	20000
0.03	24.9	239,683	37	206666	21111
MEDIUM					
100	0	209,623	32	185555	18888
60	2.5	212,530	33	187777	19999
30	4.5	214,976	33	189999	19999
15	6	216,761	33	190000	19999
10	6.4	217,310	33	190000	19999
3	8.2	219,431	34	192222	19999
0.3	16.4	229,439	35	198888	20000
0.03	22.3	236,564	36	203333	20000
LOW					
100,60,30,10	0	209,623	32	185555	18888
3	3.6	213,866	33	188888	19999
0.3	8.3	219,543	34	192222	19999
0.03	18.6	232,009	36	200000	20000

TABLE 7.2.2 Summary of Costs and Other Parameters for Remediation Activities With Soil Washing of Soil Sites Contaminated with Thorium

FACILITY		Rare Metals Extraction				Rare Metals Extraction Tailings Pile(a)			
Contaminated Soil Area, ft^2		100000				60035			
Facility Area, ft^2		150000				0			
Residual Conc. in soil, mrem/yr	Soil Depth	Cost	Disposal Vol	Labor	Dose	Cost	Disposal Vol	Labor	Dose
	cm	$	m^3	man-hrs	person-mrem	$	m^3	man-hrs	person-mrem
HIGH									
100	0.80	1,558,020	239	1338	134	13,911	0	72	7
60	1.1	1,630,018	251	1388	139	17,843	0	99	10
30	1.2	1,654,676	254	1405	140	19,154	0	108	11
15	1.4	1,700,917	262	1438	144	21,775	0	126	13
10	1.5	1,728,375	265	1455	145	23,086	0	136	14
3	2	1,850,990	284	1538	154	29,639	0	181	18
0.3	2.6	1,998,387	306	1638	164	37,503	0	235	23
0.03	3.1	2,121,002	325	1721	172	44,056	0	280	28
LOW									
100	0.2	1,411,622	217	1239	124	6,047	0	18	2
60	0.4	1,461,363	225	1272	127	8,669	0	36	4
30	0.6	1,516,404	232	1305	131	11,290	0	54	5
15	1.1	1,633,218	251	1388	139	17,843	0	99	10
10	1.1	1,633,218	251	1388	139	17,843	0	99	10
3	1.3	1,691,134	258	1422	142	20,464	0	117	12
0.3	2	1,860,990	284	1538	154	29,639	0	181	18
0.03	2.6	1,873,387	306	1638	164	37,503	0	235	23

(a) Costs are for consolidation of contamination into the tailings pile and capping the pile only

TABLE 7.2.2 Summary of Costs and Other Parameters for Remediation Activities With Soil Washing for Sites Contaminated With Uranium

FACILITY		Uranium Fuel Fabrication Facility				Uranium Mill			
Contaminated Soil Area, ft²		50000				880000			
Facility Area, ft²		240000				100000			
Residual Conc. in Soil, mrem/yr	Soil Depth	Cost	Disposal Vol	Labor	Dose	Cost	Disposal Vol	Labor	Dose
	cm	$	m³	man-hr	person-mrem	$	m³	man-hr	person-mrem
HIGH									
100	18.40	4,435,576	677	3458	346	39,876,409	6128	27729	2773
60	18.7	4,473,588	683	3483	348	40,514,573	6227	28168	2817
30	21.2	4,780,287	729	3691	369	45,819,817	7044	31827	3183
15	23	4,986,383	763	3841	384	49,534,452	7633	34461	3446
10	23.3	5,038,070	768	3866	387	50,289,616	7731	34900	3490
3	25.5	5,309,082	809	4049	405	54,950,695	8450	38119	3812
0.3	29	5,739,721	874	4340	434	62,372,036	9595	43241	4324
0.03	32	6,107,890	930	4589	459	68,725,328	10576	47631	4763
MEDIUM									
100	10	3,403,768	521	2760	276	22,117,861	3382	15437	1544
60	14.3	3,932,564	601	3118	312	31,207,740	4788	21730	2173
30	17.2	4,289,504	655	3359	336	37,335,427	5736	25973	2597
15	19	4,494,275	689	3508	351	41,099,062	6325	28607	2861
10	20.2	4,657,672	711	3608	361	43,708,719	6717	30363	3036
3	22.8	4,976,600	759	3824	382	49,225,567	7567	34168	3417
0.3	26.6	5,445,251	830	4140	414	57,268,072	8810	39729	3973
0.03	29.8	5,837,878	889	4406	441	64,048,249	9856	44412	4441
LOW									
100,60,30	0	2,174,322	336	1929	193	749,887	111	804	80
15	7	3,095,599	466	2511	251	15,774,569	2401	11047	1105
10	13.8	3,871,094	592	3076	308	30,140,691	4624	20998	2100
3	18.4	4,435,576	677	3458	346	39,876,409	6128	27729	2773
0.3	23.4	5,050,299	770	3874	387	50,481,896	7763	35046	3505
0.03	27.2	5,517,625	841	4190	419	58,544,726	9006	40607	4061

TABLE 7.2.2 Summary of Costs and Other Parameters for Remediation Activities With Soil Washing for Sites Contaminated With Uranium

FACILITY		Uranium Hexafluoride Facility			
Contaminated Soil Area, ft²		100000			
Facility Area, ft²		120000			
Residual Conc. in Soil, mrem/yr	Soil Depth	Cost	Disposal Vol	Labor	Dose
	cm	$	m³	man-hr	person-mrem
HIGH					
100	18.40	5,611,009	827	4024	402
60	18.7	5,684,708	838	4074	407
30	21.2	6,299,431	931	4490	449
15	23	6,723,299	997	4789	479
10	23.3	7,087,672	1009	4839	484
3	25.5	7,357,022	1090	5205	520
0.3	29	8,216,974	1220	5787	579
0.03	32	8,958,312	1332	6286	629
MEDIUM					
100	10	3,546,068	514	2627	263
60	14.3	4,603,659	674	3342	334
30	17.2	5,316,539	782	3825	382
15	19	5,735,407	849	4124	412
10	20.2	6,053,877	893	4323	432
3	22.8	6,693,058	990	4756	476
0.3	26.6	7,628,034	1131	5388	539
0.03	29.8	8,413,288	1250	5920	592
LOW					
100,60,30	0	1,088,001	143	964	96
15	7	2,771,731	403	2128	213
10	13.8	4,481,045	656	3259	326
3	18.4	5,611,009	827	4024	402
0.3	23.4	6,831,455	1012	4856	486
0.03	27.2	7,774,107	1154	5487	549

TABLE 7.2.3. Summary of Cost and Other Parameters for Remediation Activities Without Soil Washing for Sites Contaminated with Co and Cs

FACILITY	Manufacturer of Sealed Sources				
Contaminated Soil Area, ft²	5000				
Facility Area, ft²	6000				
	Soil Depth	Disposal Volume	Total Soil Remediation Cost	Labor Requirements	Occupational Dose
Residual Conc. in Soil, mrem/yr	cm	m³	$	man-hrs	person-mrem
HIGH					
(mrem/yr)					
100	3.00	32	$188,723	68	7
60	4.30	38	$223,089	78	8
30	5.50	44	$256,136	87	9
15	7.00	51	$295,788	98	10
10	7.30	52	$303,719	100	10
3	8.60	58	$339,409	110	11
0.3	11.00	70	$404,178	128	13
0.03	12.70	77	$449,118	141	14
MEDIUM					
100	0.00	18	$108,093	45	5
60	2.50	30	$175,506	64	6
30	4.50	39	$228,376	79	8
15	6.00	46	$269,353	91	9
10	6.40	48	$279,927	94	9
3	7.70	54	$314,293	103	10
0.3	10.20	66	$381,705	122	12
0.03	12.00	74	$430,613	136	14
LOW					
100,60,30,10	0	18	$108,093	45	5
3	3.6	35	$204,584	72	7
0.3	7.3	52	$303,719	100	10
0.03	9.7	63	$368,488	118	12

TABLE 7.2.3. Summary of Costs and Other Parameters for Remediation Activities Without Soil Washing for Sites Contaminated with Co, Sr, and Cs

FACILITY		Power Reactor				Test Reactor			
Contaminated Soil Area, ft^2		2000				5000			
Facility Area, ft^2		250000				100000			
Residual Conc. in soil, mrem/yr	Soil Depth	Cost	Disposal Vol	Labor	Dose	Cost	Disposal Vol	Labor	Dose
	cm	$	m^3	man-hrs	person-mrem	$	m^3	man-hrs	person-mrem
HIGH									
100	3.00	4,486,266	773	1900	190	1,862,926	321	779	78
60	4.5	4,503,452	776	1904	190	1,903,903	328	790	79
30	6.2	4,521,428	779	1909	191	1,948,843	336	803	80
15	7	4,529,887	781	1912	191	1,969,991	340	809	81
10	7.8	4,538,347	782	1914	191	1,992,464	343	815	81
3	11.5	4,578,795	789	1925	193	2,091,599	360	843	84
0.3	20.4	4,674,229	805	1952	195	2,330,846	402	910	91
0.03	24.9	4,721,812	814	1965	197	2,452,453	423	944	94
MEDIUM									
100	0	4,454,544	768	1891	189	854,031	140	756	76
60	2.5	4,480,979	772	1898	190	1,849,708	319	775	78
30	4.5	4,503,452	776	1904	190	1,903,903	328	790	79
15	6	4,519,313	779	1909	191	1,943,556	335	801	80
10	6.4	4,523,543	779	1910	191	1,954,130	337	804	80
3	8.2	4,542,576	783	1915	192	2,003,038	345	818	82
0.3	16.4	4,630,608	798	1940	194	2,223,780	383	880	88
0.03	22.3	4,694,320	809	1958	196	2,382,397	411	924	92
LOW									
100,60,30,10	0	4,454,544	768	1891	189	854,031	140	756	76
3	3.6	4,492,611	774	1901	190	1,878,787	324	783	78
0.3	8.3	4,543,634	783	1915	192	2,005,682	346	819	82
0.03	18.6	4,653,871	802	1947	195	2,281,938	393	896	90

TABLE 7.2.3. Summary of Costs and Other Parameters for Remediation Activities Without Soil Washing for Sites Contaminated with Co, Sr, and Cs

FACILITY		Research Reactor			
Contaminated Soil Area, ft^2		500			
Facility Area, ft^2		35000			
Residual Conc. in soil, mrem/yr	Soil Depth	Cost	Disposal Vol	Labor	Dose
	cm	$	m^3	man-hrs	person-mrem
HIGH					
100	3.00	633,224	109	267	27
60	4.5	637,189	110	268	27
30	6.2	641,683	110	269	27
15	7	643,798	111	270	27
10	7.8	645,912	111	271	27
3	11.5	655,693	113	273	27
0.3	20.4	679,220	117	280	28
0.03	24.9	691,116	119	283	28
MEDIUM					
100	0	623,968	107	265	26
60	2.5	630,577	109	267	27
30	4.5	637,189	110	268	27
15	6	641,154	110	269	27
10	6.4	642,211	110	269	27
3	8.2	646,970	111	271	27
0.3	16.4	668,646	115	277	28
0.03	22.3	684,243	118	281	28
LOW					
100,60,30,100	0	623,968	107	265	26
3	3.6	634,810	109	267	27
0.3	8.3	647,234	111	271	27
0.03	18.6	674,462	116	279	28

TABLE 7.2.3. Summary of Costs and Other Parameters for Remediation Activities Without Soil Washing for Sites Contaminated with Co, Sr, and Cs

FACILITY		Generic R & D Facility				DRY ISFSI			
Contaminated Soil Area, ft²		5000				500			
Facility Area, ft²		40000				23000			
Residual Conc. in soil, mrem/yr	Soil Depth	Cost	Disposal Vol	Labor	Dose	Cost	Disposal Vol	Labor	Dose
	cm	$	m³	man-hrs	person-mrem	$	m³	man-hrs	person-mrem
HIGH									
100	3.00	188.723	32	68	7	419.0	72	176	18
60	4.5	228.376	39	79	8	423.0	73	177	18
30	6.2	274.640	47	92	9	427.5	73	179	18
15	7	295.788	51	98	10	429.6	74	179	18
10	7.8	318.261	55	104	10	431.7	74	180	18
3	11.5	417.396	72	132	13	441.5	76	183	18
0.3	20.4	656.643	113	199	20	465.0	80	189	19
0.03	24.9	776.926	134	233	23	478.2	82	193	19
MEDIU									
100	0	108.093	18	45	5	411.1	71	174	17
60	2.5	175.506	30	64	6	417.7	72	176	18
30	4.5	228.376	39	79	8	423.0	73	177	18
15	6	269.353	46	91	9	427.0	73	178	18
10	6.4	279.927	48	94	9	428.0	74	179	18
3	8.2	328.835	57	107	11	432.8	74	180	18
0.3	16.4	548.253	95	169	17	454.4	78	186	19
0.03	22.3	706.869	122	213	21	470.0	81	191	19
LOW									
100.60.3	0	108.093	18	45	5	411.1	71	174	17
3	3.6	204.584	35	72	7	420.6	72	177	18
0.3	8.3	331.479	57	108	11	433.0	74	180	18
0.03	18.6	607.735	105	185	19	460.3	79	188	19

TABLE 7.2.3. Summary of Costs and Other Parameters for Remediation Activities Without Soil Washing for Sites Contaminated with Thorium

FACILITY		Rare Metals Extraction				Rare Metals Extraction Tailings Pile(a)			
Contaminated Soil Area, ft^2		100000				60035			
Facility Area, ft^2		150000				0			
Residual Conc in Soil, mrem/yr	Soil Depth	Cost	Disposal Vol	Labor	Dose	Cost	Disposal Vol	Labor	Dose
	cm	$	m^3	man-hrs	person-mrem	$	m^3	man-hrs	person-mrem
HIGH									
100	0.80	3,103,51	535	1255	125	13,911	0	72	7
60	1.1	3,264,77	563	1300	130	17,843	0	99	10
30	1.2	3,318,97	572	1315	131	19,154	0	108	11
15	1.4	3,426,03	591	1345	135	21,775	0	126	13
10	1.5	3,480,23	600	1360	136	23,086	0	136	14
3	2	3,748,55	646	1435	144	29,639	0	181	18
0.3	2.6	4,071,07	702	1526	153	37,503	0	235	23
0.03	3.1	4,340,72	749	1601	160	44,056	0	280	28
LOW									
100	0.2	2,780,99	479	1164	116	6,047	0	18	2
60	0.4	2,888,05	498	1195	119	8,669	0	36	4
30	0.6	2,995,12	516	1225	122	11,290	0	54	5
15	1.1	3,264,77	563	1300	130	17,843	0	99	10
10	1.1	3,264,77	563	1300	130	17,843	0	99	10
3	1.3	3,371,84	581	1330	133	20,464	0	117	12
0.3	2	3,748,55	646	1435	144	29,639	0	181	18
0.03	2.6	4,071,07	702	1526	153	37,503	0	235	23

(a) Costs are for consolidation of contamination into the tailings pile and capping the pile only

TABLE 7.2.3. Summary of Costs and Other Parameters for Remediation Activities Without Soil Washing for Sites Contaminated Uranium

FACILITY		Uranium Fuel Fabrication Facility				Uranium Mill			
Contaminated Soil Area, ft²		50000				880000			
Facility Area, ft²		240000				100000			
Residual Conc. in soil, mrem/yr	Soil Depth	Cost	Disposal Vol	Labor	Dose	Cost	Disposal Vol	Labor	Dose
	cm	$	m³	man-hrs	person-mrem	$	m³	man-hrs	person-mrem
HIGH									
100	18.40	9,224.27	1592	3199	320	3,614.74	0	25125	2512
60	18.7	9,304.90	1605	3222	322	3,672.38	0	25522	2552
30	21.2	9,976.37	1722	3410	341	4,152.67	0	28833	2883
15	23	10,460.1	1805	3546	355	4,498.48	0	31217	3122
10	23.3	10,540.7	1819	3568	357	4,556.12	0	31614	3161
3	25.5	11,132.9	1921	3734	373	4,978.77	0	34528	3453
0.3	29	12,074.0	2084	3997	400	5,651.18	0	39163	3916
0.03	32	12,880.3	2223	4223	422	6,227.54	0	43136	4314
MEDIU									
100	10	6,965.30	1201	2567	257	2,000.96	0	14000	1400
60	14.3	8,121.88	1401	2891	289	2,827.06	0	19695	1969
30	17.2	8,900.42	1536	3109	311	3,384.20	0	23536	2354
15	19	9,385.53	1619	3245	324	3,730.01	0	25919	2592
10	20.2	9,708.05	1675	3335	333	3,960.55	0	27509	2751
3	22.8	10,407.2	1796	3531	353	4,460.06	0	30952	3095
0.3	26.6	11,429.0	1972	3817	382	5,190.10	0	35985	3598
0.03	29.8	12,288.2	2121	4057	406	5,804.88	0	40223	4022
LOW									
100,60,30	0	4,276.74	737	1815	181	79,790	0	756	76
15	7	6,159.00	1062	2342	234	1,424.61	0	10027	1003
10	13.8	7,987.05	1378	2853	285	2,731.00	0	19033	1903
3	18.4	9,224.27	1592	3199	320	3,614.74	0	25125	2512
0.3	23.4	10,568.5	1824	3576	358	4,575.33	0	31747	3175
0.03	27.2	11,590.3	2000	3862	386	5,305.37	0	36779	3678

TABLE 7.2.3. Summary of Costs and Other Parameters for Remediation Activities Without Soil Washing for Sites Contaminated with Uranium

FACILITY		Uranium Hexafluoride Facility			
Contaminated Soil Area, ft^2		100000			
Facility Area, ft^2		120000			
Residual Conc. in soil, mrem/yr	Soil Depth	Cost	Disposal Vol.	Labor	Dose
	cm	$	m^3	man-hrs	person-mrem
HIGH					
100	18.40	12,032,935	2078	3677	368
60	18.7	12,194,195	2106	3722	372
30	21.2	14,507,359	2505	4369	437
15	23	13,538,472	2338	4098	410
10	23.3	14,668,619	2533	4414	441
3	25.5	15,851,636	2737	4745	475
0.3	29	17,733,889	3063	5272	527
0.03	32	19,346,492	3341	5723	572
MEDIUM					
100	10	7,516,323	1297	2412	241
60	14.3	9,828,161	1697	3060	306
30	17.2	11,387,894	1966	3496	350
15	19	12,355,455	2134	3767	377
10	20.2	13,001,821	2245	3948	395
3	22.8	14,398,969	2487	4339	434
0.3	26.6	16,442,482	2840	4911	491
0.03	29.8	18,163,475	3137	5392	539
LOW					
100,60,30	0	2,139,214	368	907	91
15	7	2,139,214	368	907	91
10	13.8	9,559,836	1650	2984	298
3	18.4	12,032,935	2078	3677	368
0.3	23.4	14,721,489	2542	4429	443
0.03	27.2	16,765,003	2895	5001	500

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SUBATTACHMENT A TO ATTACHMENT D

CALCULATED DOSE FACTORS

FOR

THREE SCENARIOS

Building Occupancy Scenario

Radionuclide	mrem/y per dpm/100 cm^2	Year Analyzed	Controlling Pathway
^{60}Co	2.89E-3	1	external (~91%)
^{90}Sr	1.51E-3	1	ingestion (~84%)
^{137}Cs	1.11E-3	1	external (~59%)
^{232}Th	2.63E-2	1	inhalation (^{232}Th ~67%, ^{228}Th ~14%)
U nat	9.07E-3	1	inhalation (^{238}U ~69%), ingestion (^{234}U ~14%, ^{238}U ~12%)

Nuclide	Initial Inventory (dpm/100 cm**2)	Peak Year	Total Dose (mrem/yr per dpm/100 cm**2)
Co-60	1.00E+00	1	2.89E-03
Sr-90	1.00E+00	1	1.41E-03
Y-90	0.00E+00		1.02E-04
			1.51E-03
Cs-137	1.00E+00	1	4.49E-04
Ba-137m	0.00E+00		6.57E-04
			1.11E-03
Th-232	1.00E+00	1	2.02E-01
Ra-228	1.00E+00		1.35E-02
Ac-228	1.00E+00		1.17E-03
Th-228	1.00E+00		4.05E-02
Ra-224	1.00E+00		3.65E-03
Rn-220	1.00E+00		4.57E-07
Po-216	1.00E+00		1.99E-08
Pb-212	1.00E+00		5.99E-04
Bi-212	1:00E+00		2.26E-04
Po-212	6.41E-01		0.00E+00
Tl-208	3.59E-01		1.29E-03
			2.63E-01
U-238	4.89E-01	1	7.38E-03
Th-234	0.00E+00		6.05E-05
Pa-234m	0.00E+00		8.10E-08

Pa-234	0.00E+00	1.91E-06
U-234	4.89E-01	1.26E-03
Th-230	0.00E+00	8.84E-08
Ra-226	0.00E+00	4.10E-12
Rn-222	0.00E+00	1.44E-16
Po-218	0.00E+00	3.24E-18
Pb-214	0.00E+00	9.07E-14
Bi-214	0.00E+00	5.17E-13
Po-214	0.00E+00	2.97E-17
Pb-210	0.00E+00	1.15E-13
Bi-210	0.00E+00	1.17E-16
Po-210	0.00E+00	1.06E-14
U-235	2.25E-02	3.57E-04
Th-231	0.00E+00	7.73E-07
Pa-231	0.00E+00	5.51E-08
Ac-227	0.00E+00	2.10E-09
Fr-223	0.00E+00	4.98E-15
Th-227	0.00E+00	4.36E-12
Ra-223	0.00E+00	1.19E-11
Rn-219	0.00E+00	1.13E-13
Po-215	0.00E+00	3.59E-16
Pb-211	0.00E+00	1.14E-13
Bi-211	0.00E+00	9.40E-14
Po-211	0.00E+00	4.37E-17
Tl-207	0.00E+00	7.70E-15
		9.07E-03

Building Renovation Scenario

Radionuclide	mrem/y per pCi/g	Year Analyzed	Controlling Pathway
^{60}Co	7.72E-1	1	external (~100%)
^{90}Sr	2.16E-3	1	external (~61%)
^{137}Cs	1.75E-1	1	external (~100%)
^{232}Th	9.19E-1	1	external (^{208}Tl ~41%, ^{228}Ac ~32%), inhalation (^{232}Th ~11%)

U nat	8.21E-3	1	inhalation (^{238}U ~42%), external (^{234m}Pa ~17%, ^{235}U ~11%)

Nuclide	Initial Inventory (pCi/g)	Peak Year	Total Dose (mrem/yr per pCi/g)
Co-60	1.00E+00	1	7.72E-01
Sr-90	1.00E+00	1	8.23E-04
Y-90	0.00E+00		1.33E-03
			2.16E-03
Cs-137	1.00E+00	1	2.93E-04
Ba-137m	0.00E+00		1.75E-01
			1.75E-01
Th-232	1.00E+00	1	1.12E-01
Ra-228	1.00E+00		7.46E-03
Ac-228	1.00E+00		2.98E-01
Th-228	1.00E+00		2.29E-02
Ra-224	1.00E+00		4.85E-03
Rn-220	1.00E+00		1.19E-04
Po-216	1.00E+00		5.27E-06
Pb-212	1.00E+00		3.94E-02
Bi-212	1.00E+00		5.80E-02
Po-212	6.41E-01		0.00E+00
Tl-208	3.59E-01		3.76E-01
			9.19E-01
U-238	4.89E-01	1	4.10E-03
Th-234	0.00E+00		4.63E-04
Pa-234m	0.00E+00		1.42E-03
Pa-234	0.00E+00		3.64E-04
U-234	4.89E-01		7.08E-04
Th-230	0.00E+00		1.21E-08
Ra-226	0.00E+00		1.72E-13
Rn-222	0.00E+00		2.00E-15
Po-218	0.00E+00		4.60E-17
Pb-214	0.00E+00		1.17E-12
Bi-214	0.00E+00		7.64E-12
Po-214	0.00E+00		4.20E-18
Pb-210	0.00E+00		8.16E-16
Bi-210	0.00E+00		5.29E-18
Po-210	0.00E+00		1.59E-17

U-235	2.25E-02	1.11E-03
Th-231	0.00E+00	4.67E-05
Pa-231	0.00E+00	7.93E-09
Ac-227	0.00E+00	6.85E-11
Fr-223	0.00E+00	[illegible]
Th-227	0.00E+00	2.05E-12
Ra-223	0.00E+00	1.46E-12
Rn-219	0.00E+00	6.53E-13
Po-215	0.00E+00	2.11E-15
Pb-211	0.00E+00	6.17E-13
Bi-211	0.00E+00	5.40E-13
Po-211	0.00E+00	2.67E-16
Tl-207	0.00E+00	4.01E-14
		8.21E-03

Drinking Water Scenario

Radionuclide	Max. TEDE mrem/y per pCi	Peak Year	Max. HOCDE mrem/y per pCi	Max. Organ
^{60}Co	1.134E-11	9	2.103E-11	LLI wall
^{137}Cs	6.554E-12	42	7.282E-12	adrenals
^{90}Sr	3.095E-09	22	3.133E-08	b surface
^{232}Th	2.570E-09	9639	4.540E-08	b surface
U nat	5.504E-09	47	7.918E-08	b surface

Nuclide	Initial Inventory (pCi)	Peak Year	Maximum TEDE (mrem/yr)
Co-60	1.00E+00	9	1.13E-11
Sr-90	1.00E+00	22	3.10E-09
Cs-137	1.00E+00	42	6.55E-12
Th-232	1.00E+00	9639	2.57E-09
U-238	4.89E-01	47	2.67E-09
U-235	2.25E-02	48	5.67E-12
U-234	4.89E-01	47	2.83E-09
			5.50E-09

Residential Scenario

^{60}Co Pathway	Primary Nuclide	mrem/y per pCi/g parent	Secondary Nuclide	mrem/y per pCi/g parent	Total Dose mrem/y per pCi/g parent
External	^{60}Co	4.98058E+00	N/A	N/A	4.98058E+00
Inhalation	^{60}Co	1.37355E-04	N/A	N/A	1.37355E-04
Agricultural	^{60}Co	7.50995E-02	N/A	N/A	7.50995E-02
Soil	^{60}Co	4.61020E-04	N/A	N/A	4.61020E-04
Water	^{60}Co	1.34145E-05	N/A	N/A	1.34145E-05
Aquatic	^{60}Co	4.84789E-05	N/A	N/A	4.84789E-05
					5.05634E+00

^{90}Sr Pathway	Primary Nuclide	mrem/y per pCi/g parent	Secondary Nuclide	mrem/y per pCi/g parent	Total Dose mrem/y per pCi/g parent
External	^{90}Y	8.53182E-03	^{90}Sr	2.68957E-04	8.80078E-03
Inhalation	^{90}Sr	8.56971E-04	^{90}Y	5.49233E-06	8.62463E-04
Agricultural	^{90}Sr	1.21685E+00	^{90}Y	8.73595E-02	1.30421E+00
Soil	^{90}Sr	2.57067E-03	^{90}Y	1.92277E-04	2.76295E-03
Water	^{90}Sr	1.04310E-03	^{90}Y	7.54898E-05	1.11859E-03
Aquatic	^{90}Sr	6.53608E-04	^{90}Y	2.38990E-05	6.77507E-04
					1.31843E+00

^{137}Cs Pathway	Primary Nuclide	mrem/y per pCi/g parent	Secondary Nuclide	mrem/y per pCi/g parent	Total Dose mrem/y per pCi/g parent
External	^{137m}Ba	1.17358E+00	^{137}Cs	2.84997E-04	1.17386E+00
Inhalation	^{137}Cs	2.10787E-05	^{137m}Ba	0.00000E-00	2.10787E-05
Agricultural	^{137}Cs	2.28090E-01	^{137m}Ba	0.00000E-00	2.28090E-01
Soil	^{137}Cs	9.01794E-04	^{137m}Ba	0.00000E-00	9.01794E-04
Water	^{137}Cs	1.46349E-06	^{137m}Ba	0.00000E-00	1.46349E-06
Aquatic	^{137}Cs	2.93688E-05	^{137m}Ba	0.00000E-00	2.93688E-05
					1.40290E+00

^{232}Th Pathway	Primary Nuclide	mrem/y per pCi/g initial conc.	Secondary Nuclide	mrem/y per pCi/g initial conc.	Total Dose mrem/y per initial conc.
External	^{208}Tl	2.54625E+00	^{228}Ac	2.01751E+00	5.24482E+00
Inhalation	^{232}Th	1.09367E+00	^{228}Th	2.27869E-01	1.32716E+00
Agricultural	^{232}Th	5.88653E+00	^{228}Ra	3.24762E+00	1.08998E+01
Soil	^{232}Th	4.98676E-02	^{228}Ra	2.62176E-02	9.08882E-02
Water	^{228}Ra	9.23157E-06	^{228}Th	1.09247E-06	1.19082E-05
Aquatic	^{228}Ra	8.32257E-06	^{228}Th	1.39534E-06	1.13579E-05
					1.75627E+01

U nat Pathway	Primary Nuclide	mrem/y per pCi/g initial conc.	Secondary Nuclide	mrem/y per pCi/g initial conc.	Total Dose mrem/y per initial conc.
External	^{234m}Pa	2.29389E-03	^{235}U	9.46140E-04	4.61744E-03
Inhalation	^{238}U	5.91468E-03	^{235}U	2.82353E-04	6.26693E-03
Agricultural	^{234}U	4.96760E-02	^{238}U	4.46176E-02	9.93776E-02
Soil	^{234}U	3.87516E-04	^{238}U	3.48056E-04	7.76070E-04
Water	^{234}U	2.01181E-01	^{238}U	1.80695E-01	3.99691E-01
Aquatic	^{234}U	1.27402E-01	^{238}U	1.14429E-01	2.59017E-01
					7.69746E-01

SUBATTACHMENT B TO ATTACHMENT D

SPREADSHEET RESULTS

FOR

SOIL CLEANUP

TABLE B.1. **Detail of Costs and Other Parameters for Remediation of a Sealed Source Manufacturer Soil Site, Without Soil Washing**

	Contaminated Area	Soil Depth	Soil Vol.	Soil Excavation Costs	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Total Concrete	Waste Packaging Cost	Transport Reqds
Units				$235/m^3		$411/m²			$220/m³	
Rates	ft²	cm	m³	$	m²	$	m³	m³	m³	# trucks
HIGH										
100	5000	3.00	14	3,275	11	4,582	31	2	7,118	3
60	5000	4.3	20	4,694	11	4,582	37	2	8,447	3
30	5000	5.5	26	6,004	11	4,582	42	2	9,673	4
15	5000	7	33	7,641	11	4,582	49	2	11,206	4
10	5000	7.3	34	7,968	11	4,582	51	2	11,512	4
3	5000	8.6	40	9,388	11	4,582	57	2	12,841	5
0.3	5000	11	51	12,007	11	4,582	68	2	15,294	6
0.03	5000	12.7	59	13,863	11	4,582	76	2	17,031	6
MEDIUM										
100	5000	0	0	0	11	4,582	17	2	4,053	2
60	5000	2.5	12	2,729	11	4,582	28	2	6,607	3
30	5000	4.5	21	4,912	11	4,582	38	2	8,651	3
15	5000	6	28	6,549	11	4,582	45	2	10,184	4
10	5000	6.4	30	6,986	11	4,582	46	2	10,593	4
3	5000	7.7	36	8,405	11	4,582	52	2	11,921	4
0.3	5000	10.2	47	11,134	11	4,582	64	2	14,476	5
0.03	5000	12	56	13,099	11	4,582	72	2	16,315	6
LOW										
100,60,30,10	5000	0	0	0	11	4,582	17	2	4,053	2
3	5000	3.6	17	3,930	11	4,582	33	2	7,731	3
0.3	5000	7.3	34	7,968	11	4,582	51	2	11,512	4
0.03	5000	9.7	45	10,588	11	4,582	62	2	13,965	5

TABLE B.1. **Detail of Costs and Other Parameters for Remediation of a Sealed Source Manufacturer Soil Site, Without Soil Washing (continued)**

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Soil Excavation Labor	Floor Demo Labor	TOTAL LABOR	Occup. Dose
Rates	$1325/ truck		Northwest Compact	Southeast Compact	Out-of-SE Compact			1.62 manhr/m^3	4.07 manhr/m^2		0.1 mrem/hr
	$	m^3	$	$	$	$	$	man-hr	man-hr	man-hr	Per-mrem
HIGH											
100	3,975	32	46,736	153,593	308,991	169,773	188,723	23	45	68	7
60	3,975	38	55,259	182,258	366,657	201,391	223,089	32	45	78	8
30	5,300	44	63,127	208,717	419,888	230,577	256,136	41	45	87	9
15	5,300	51	72,961	241,792	486,425	267,059	295,788	53	45	98	10
10	5,300	52	74,928	248,407	499,733	274,356	303,719	55	45	100	10
3	6,625	58	83,452	277,071	557,399	305,974	339,409	65	45	110	11
0.3	7,950	70	99,187	329,991	663,860	364,346	404,178	83	45	128	13
0.03	7,950	77	110,333	367,475	739,269	405,692	449,118	96	45	141	14
MEDIUM											
100	2,650	18	27,066	87,444	175,915	96,809	108,093	0	45	45	5
60	3,975	30	43,457	142,568	286,812	157,612	175,506	19	45	64	6
30	3,975	39	56,570	186,667	375,529	206,256	228,376	34	45	79	8
15	5,300	46	66,405	219,742	442,067	242,738	269,353	45	45	91	9
10	5,300	48	69,027	228,562	459,810	252,467	279,927	48	45	94	9
3	5,300	54	77,551	257,227	517,476	284,085	314,293	58	45	103	10
0.3	6,625	66	93,942	312,351	628,373	344,889	381,705	77	45	122	12
0.03	7,950	74	105,743	352,040	708,218	388,667	430,613	90	45	136	14
LOW											
100,60,30,10	2,650	18	27,066	87,444	175,915	96,809	108,093	0	45	45	5
3	3,975	35	50,669	166,823	335,606	184,366	204,584	27	45	72	7
0.3	5,300	52	74,928	248,407	499,733	274,356	303,719	55	45	100	10
0.03	6,625	63	90,664	301,326	606,194	332,728	368,488	73	45	118	12

TABLE B.2. Detail of Costs and Other Parameters for Remediation of a Generic R&D Facility Soil Site, Without Soil Washing

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Waste Packaging Cost	Transport Reqds
Rates				$235/m³		$411/m²			$220/m³	
Units:	ft²	cm	m³	$	m²	$	m³	m³	$	# trucks
HIGH										
100	5000	3.00	14	3,275	11	4,582	31	2	7,118	3
60	5000	4.5	21	4,912	11	4,582	38	2	8,651	3
30	5000	6.2	29	6,768	11	4,582	46	2	10,388	4
15	5000	7	33	7,641	11	4,582	49	2	11,206	4
10	5000	7.8	36	8,514	11	4,582	53	2	12,023	5
3	5000	11.5	53	12,553	11	4,582	70	2	15,804	6
0.3	5000	20.4	95	22,268	11	4,582	111	2	24,899	9
0.03	5000	24.9	116	27,180	11	4,582	132	2	29,498	10
MEDIUM										
100	5000	0	0	0	11	4,582	17	2	4,053	2
60	5000	2.5	12	2,729	11	4,582	28	2	6,607	3
30	5000	4.5	21	4,912	11	4,582	38	2	8,651	3
15	5000	6	28	6,549	11	4,582	45	2	10,184	4
10	5000	6.4	30	6,986	11	4,582	46	2	10,593	4
3	5000	8.2	38	8,951	11	4,582	55	2	12,432	5
0.3	5000	16.4	76	17,902	11	4,582	93	2	20,812	7
0.03	5000	22.3	104	24,342	11	4,582	120	2	26,841	9
LOW										
100,60,30,1	5000	0	0	0	11	4,582	17	2	4,053	2
3	5000	3.6	17	3,930	11	4,582	33	2	7,731	3
0.3	5000	8.3	39	9,060	11	4,582	55	2	12,534	5
0.03	5000	18.6	86	20,303	11	4,582	103	2	23,060	8

TABLE B.2. Detail of Costs and Other Parameters for Remediation of a Generic R&D Facility Soil Site, Without Soil Washing (continued)

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor Demo Labor	TOTAL LABOR	Occup. Dose
Rates	$1325/ truck		Northwest Compact	Southeast Compact	Out-of-SE Compact			1.62 manhr/m³	4.07 manhr/m²		0.1 mrem/hr
Units:	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH											
100	3,975	32	46,736	153,593	308,991	169,773	188,723	23	45	68	7
60	3,975	39	56,570	186,667	375,529	206,256	228,376	34	45	79	8
30	5,300	47	67,716	224,152	450,939	247,602	274,640	47	45	92	9
15	5,300	51	72,961	241,792	486,425	267,059	295,788	53	45	98	10
10	6,625	55	78,206	259,431	521,912	286,517	318,261	59	45	104	10
3	7,950	72	102,465	341,015	686,039	376,507	417,396	87	45	132	13
0.3	11,925	113	160,817	537,258	1,080,830	592,969	656,643	154	45	199	20
0.03	13,250	134	190,321	636,481	1,280,444	702,416	776,926	187	45	233	23
MEDIUM											
100	2,650	18	27,066	87,444	175,915	96,809	108,093	0	45	45	5
60	3,975	30	43,457	142,568	286,812	157,612	175,506	19	45	64	6
30	3,975	39	56,570	186,667	375,529	206,256	228,376	34	45	79	8
15	5,300	46	66,405	219,742	442,067	242,738	269,353	45	45	91	9
10	5,300	48	69,027	228,562	459,810	252,467	279,927	48	45	94	9
3	6,625	57	80,829	268,251	539,656	296,245	328,835	62	45	107	11
0.3	9,275	95	134,592	449,059	903,396	495,682	548,253	123	45	169	17
0.03	11,925	122	173,275	579,152	1,165,112	639,179	706,869	168	45	213	21
LOW											
100,60,30,1	2,650	18	27,066	87,444	175,915	96,809	108,093	0	45	45	5
3	3,975	35	50,669	166,823	335,606	184,366	204,584	27	45	72	7
0.3	6,625	57	81,485	270,456	544,092	298,678	331,479	62	45	108	11
0.03	10,600	105	149,016	497,568	1,000,985	549,190	607,735	140	45	185	19

TABLE B.3. **Detail of Costs and Other Parameters for Remediation of a Dry ISFSI Soil Site, Without Soil Washing**

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Waste Packaging Cost	Transport Reqds
Rates				\$235/m³		\$411/m²			\$220/m³	
Units	ft²	cm	m³	\$	m²	\$	m³	m³	\$	# of Trucks
HIGH										
100	500	3.00	1	327	43	17,564	65	7	15,842	6
60	500	4.5	2	491	43	17,564	66	7	15,995	6
30	500	6.2	3	677	43	17,564	67	7	16,169	6
15	500	7	3	764	43	17,564	67	7	16,250	6
10	500	7.8	4	851	43	17,564	68	7	16,332	6
3	500	11.5	5	1,255	43	17,564	69	7	16,710	6
0.3	500	20.4	9	2,227	43	17,564	74	7	17,620	6
0.03	500	24.9	12	2,718	43	17,564	76	7	18,080	7
MEDIUM										
100	500	0	0	0	43	17,564	64	7	15,535	6
60	500	2.5	1	273	43	17,564	65	7	15,790	6
30	500	4.5	2	491	43	17,564	66	7	15,995	6
15	500	6	3	655	43	17,564	67	7	16,148	6
10	500	6.4	3	699	43	17,564	67	7	16,189	6
3	500	8.2	4	895	43	17,564	68	7	1[illegible],373	6
0.3	500	16.4	8	1,790	43	17,564	72	7	1[illegible],211	6
0.03	500	22.3	10	2,434	43	17,564	74	7	1[illegible],814	6
LOW										
100,60,30,10	500	0	0	0	43	17,564	64	7	15,535	6
3	500	3.6	2	393	43	17,564	66	7	15,903	6
0.3	500	8.3	4	906	43	17,564	68	7	16,383	6
0.03	500	18.6	9	2,030	43	17,564	73	7	17,436	6

TABLE B.3. Detail of Costs and Other Parameters for Remediation of a Dry ISFSI Soil Site, Without Soil Washing (continued)

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COST	Excavation Labor	Floor Demo Labor	TOTAL LABOR	Occup. Dose
Rates	$1325/m³		Northwest Compact	Southeast Compact	Out-of-SE Compact			1.62 manhr/m³	4.07 manhr/m²		0.1 mrem/hr
Units	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	mrem
HIGH											
100	7,950	72	102,703	341,816	687,650	377,390	419,073	2	174	176	18
60	7,950	73	103,687	345,124	694,304	381,038	423,038	3	174	177	18
30	7,950	73	104,801	348,872	701,845	385,173	427,532	5	174	179	18
15	7,950	74	105,326	350,636	705,394	387,119	429,647	5	174	179	18
10	7,950	74	105,850	352,400	708,942	389,064	431,761	6	174	180	18
3	7,950	76	108,276	360,558	725,355	398,063	441,542	9	174	183	18
0.3	7,950	80	114,112	380,183	764,834	419,709	465,070	15	174	189	19
0.03	9,275	82	117,062	390,105	784,795	430,654	478,290	19	174	193	19
MEDIUM											
100	7,950	71	100,736	335,201	674,343	370,093	411,142	0	174	174	17
60	7,950	72	102,375	340,714	685,432	376,174	417,751	2	174	176	18
30	7,950	73	103,687	345,124	694,304	381,038	423,038	3	174	177	18
15	7,950	73	104,670	348,431	700,958	384,686	427,003	5	174	178	18
10	7,950	74	104,933	349,313	702,732	385,659	428,061	5	174	179	18
3	7,950	74	106,113	353,282	710,717	390,037	432,819	6	174	180	18
0.3	7,950	78	111,489	371,363	747,091	409,981	454,496	12	174	186	19
0.03	7,950	81	115,357	384,372	773,262	424,331	470,092	17	174	191	19
LOW											
100,60,30,10	7,950	71	100,736	335,201	674,343	370,093	411,142	0	174	174	17
3	7,950	72	103,097	343,139	690,312	378,849	420,659	3	174	177	18
0.3	7,950	74	106,178	353,503	711,160	390,280	433,083	6	174	180	18
0.03	7,950	79	112,931	376,214	756,850	415,332	460,311	14	174	188	19

TABLE B.4. **Details of Costs and Other Parameters for Remediation of Test Reactor Soil Site, Without Soil Washing**

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Waste Packaging Cost	Transport Reqds
Rates:				$235/m³		$411/m³			$220/m³	
Units	ft²	cm	m³	$	m²	$	m³	m³	$	# trucks
HIGH										
100	5000	3.00	14	3,275	186	76,364	293	28	70,609	24
60	5000	4.5	21	4,912	186	76,364	300	28	72,142	25
30	5000	6.2	29	6,768	186	76,364	307	28	73,879	25
15	5000	7	33	7,641	186	76,364	311	28	74,[illegible]97	25
10	5000	7.8	36	8,514	186	76,364	315	28	75,[illegible]14	26
3	5000	11.5	53	12,553	186	76,364	332	28	79,[illegible]95	[illegible]
0.3	5000	20.4	95	22,268	186	76,364	373	28	88,[illegible]90	30
0.03	5000	24.9	116	27,180	186	76,364	394	28	92,989	32
MEDIUM										
100	5000	0	0	0	186	76,364	279	28	30,755	11
60	5000	2.5	12	2,729	186	76,364	290	28	70,098	24
30	5000	4.5	21	4,912	186	76,364	300	28	72,142	25
15	5000	6	28	6,549	186	76,364	307	28	73,675	25
10	5000	6.4	30	6,986	186	76,364	308	28	74,084	25
3	5000	8.2	38	8,951	186	76,364	317	28	75,923	26
0.3	5000	16.4	76	17,902	186	76,364	355	28	84,303	29
0.03	5000	22.3	104	24,342	186	76,364	382	28	90,332	31
LOW										
100,60,30,	5000	0	0	0	186	76,364	279	28	30,755	11
3	5000	3.6	17	3,930	186	76,364	295	28	71,222	24
0.3	5000	8.3	39	9,060	186	76,364	317	28	76,025	26
0.03	5000	18.6	86	20,303	186	76,364	365	28	86,551	29

TABLE B.4. Details of Costs and Other Parameters for Remediation of a Research Reactor Soil Site, Without Soil Washing (continued)

	Transport Costs	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor Demo Labor	TOTAL LABOR	Occup. Dose
Rates:	$1325/m^3		Northwest Compact	Southeast Compact	Out-of-SE Compact			1.62 manhr/m^3	4.07 manhr/m^2		0.1 mrem/hr
Units	$	m^3	$	$	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH											
100	31,800	321	454,088	1,523,546	3,065,000	1,680,878	1,862,92	23	756	779	78
60	33,125	328	463,923	1,556,621	3,131,538	1,717,360	1,903,90	34	756	790	79
30	33,125	336	475,069	1,594,105	3,206,948	1,758,707	1,948,84	47	756	803	80
15	33,125	340	480,314	1,611,745	3,242,434	1,778,164	1,969,99	53	756	809	81
10	34,450	343	485,559	1,629,385	3,277,921	1,797,622	1,992,46	59	756	815	81
3	35,775	360	509,818	1,710,968	3,442,048	1,887,611	2,091,59	87	756	843	84
0.3	39,750	402	568,170	1,907,211	3,836,839	2,104,073	2,330,84	154	756	910	91
0.03	42,400	423	597,674	2,006,434	4,036,453	2,213,520	2,452,45	187	756	944	94
MEDIUM											
100	14,575	140	198,387	663,608	1,335,016	732,337	854,031	0	756	756	76
60	31,800	319	450,810	1,512,521	3,042,821	1,668,717	1,849,70	19	756	775	78
30	33,125	328	463,923	1,556,621	3,131,538	1,717,360	1,903,90	34	756	790	79
15	33,125	335	473,757	1,589,695	3,198,076	1,753,843	1,943,55	45	756	801	80
10	33,125	337	476,380	1,598,515	3,215,819	1,763,571	1,954,13	48	756	804	80
3	34,450	345	488,182	1,638,204	3,295,665	1,807,350	2,003,03	62	756	818	82
0.3	38,425	383	541,944	1,819,012	3,659,405	2,006,787	2,223,78	123	756	880	88
0.03	41,075	411	580,627	1,949,105	3,921,121	2,150,284	2,382,39	168	756	924	92
LOW											
100,60,30,10,10	14,575	140	198,387	663,608	1,335,016	732,337	854,031	0	756	756	76
3	31,800	324	458,022	1,536,776	3,091,615	1,695,471	1,878,78	27	756	783	78
0.3	34,450	346	488,837	1,640,409	3,300,101	1,809,782	2,005,68	62	756	819	82
0.03	38,425	393	556,368	1,867,521	3,756,994	2,060,295	2,281,93	140	756	896	90

TABLE B.5. Detail of Costs and Other Parameters for Remediation of a Research Reactor Soil Site, Without Soil Washing

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Wast, Pack ging Cost	Transport Reqds
Rates:				$235/m³		$411/m²			$220/m³	
Units:	m³	cm	m³	$	m²	$	m³	m³	$	# trucks
HIGH										
100	500	3.00	1	327	65	26,727	99	10	23,947	9
60	500	4.5	2	491	65	26,727	100	10	24,100	9
30	500	6.2	3	677	65	26,727	100	10	24,274	9
15	500	7	3	764	65	26,727	101	10	24,356	9
10	500	7.8	4	851	65	26,727	101	10	24,437	9
3	500	11.5	5	1,255	65	26,727	103	10	24,815	9
0.3	500	20.4	9	2,227	65	26,727	107	10	25,725	9
0.03	500	24.9	12	2,718	65	26,727	109	10	26,185	9
MEDIUM										
100	500	0	0	0	65	26,727	98	10	23,640	8
60	500	2.5	1	273	65	26,727	99	10	23,896	8
30	500	4.5	2	491	65	26,727	100	10	24,100	9
15	500	6	3	655	65	26,727	100	10	24,253	9
10	500	6.4	3	699	65	26,727	101	10	24,294	9
3	500	8.2	4	895	65	26,727	101	10	24,478	9
0.3	500	16.4	8	1,790	65	26,727	105	10	25,316	9
0.03	500	22.3	10	2,434	65	26,727	108	10	25,919	9
LOW										
100,60,30,10	500	0	0	0	65	26,727	98	10	23,640	8
3	500	3.6	2	393	65	26,727	99	10	24,008	9
0.3	500	8.3	4	906	65	26,727	101	10	24,488	9
0.03	500	18.6	9	2,030	65	26,727	106	10	25,541	9

TABLE B.5. Detail of Costs and Other Parameters for Remediation of a Research Reactor Soil Site, Without Soil Washing (continued)

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor Demo Labor	TOTAL LABOR	Occup. Dose
Rates:	$1325/m^3		Northwest Compact	Southeast Compact	Out-of-SE Compact			1.62 manhr/m^3	4.07 manhr/m^2		0.1 mrem/hr
Units:	$	m^3	$	$	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH											
100	11,925	109	154,706	516,704	1,039,481	570,297	633,224	2	265	267	27
60	11,925	110	155,689	520,011	1,046,135	573,945	637,189	3	265	268	27
30	11,925	110	156,804	523,760	1,053,676	578,080	641,683	5	265	269	27
15	11,925	111	157,328	525,524	1,057,225	580,026	643,798	5	265	270	27
10	11,925	111	157,853	527,288	1,060,773	581,971	645,912	6	265	271	27
3	11,925	113	160,279	535,446	1,077,186	590,970	655,693	9	265	273	27
0.3	11,925	117	166,114	555,070	1,116,665	612,616	679,220	15	265	280	28
0.03	11,925	119	169,064	564,993	1,136,626	623,561	691,116	19	265	283	28
MEDIUM											
100	10,600	107	152,739	510,089	1,026,174	563,000	623,968	0	265	265	26
60	10,600	109	154,378	515,601	1,037,263	569,081	630,577	2	265	267	27
30	11,925	110	155,689	520,011	1,046,135	573,945	637,189	3	265	268	27
15	11,925	110	156,673	523,319	1,052,789	577,593	641,154	5	265	269	27
10	11,925	110	156,935	524,201	1,054,563	578,566	642,211	5	265	269	27
3	11,925	111	158,115	528,170	1,062,548	582,944	646,970	6	265	271	27
0.3	11,925	115	163,491	546,250	1,098,922	602,888	668,646	12	265	277	28
0.03	11,925	118	167,360	559,260	1,125,093	617,238	684,243	17	265	281	28
LOW											
100,60,30,10	10,600	107	152,739	510,089	1,026,174	563,000	623,968	0	265	265	26
3	11,925	109	155,099	518,027	1,042,143	571,756	634,810	3	265	267	27
0.3	11,925	111	158,181	528,390	1,062,991	583,187	647,234	6	265	271	27
0.03	11,925	116	164,934	551,101	1,108,680	608,239	674,462	14	265	279	28

TABLE B.6. Detail of Costs and Other Parameters for Remediation of a Power Reactor Soil Site, Without Soil Washing

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Waste Packaging Cost	Transport Reqds.
Rates:				$235/m³		$411/m²			$220/m³	
Units:	ft²	cm	m³	$	m²	$	m³	m³	$	# trucks
HIGH										
100	2000	3.00	6	1,310	465	190,910	702	71	170,085	57
60	2000	4.5	8	1,965	465	190,910	705	71	170,698	58
30	2000	6.2	12	2,707	465	190,910	708	71	171,393	58
15	2000	7	13	3,056	465	190,910	710	71	171,720	58
10	2000	7.8	14	3,406	465	190,910	711	71	172,047	58
3	2000	11.5	21	5,021	465	190,910	718	71	173,559	59
0.3	2000	20.4	38	8,907	465	190,910	735	71	177,197	60
0.03	2000	24.9	46	10,872	465	190,910	743	71	179,037	60
MEDIUM										
100	2000	0	0	0	465	190,910	697	71	168,859	57
60	2000	2.5	5	1,092	465	190,910	701	71	169,881	57
30	2000	4.5	8	1,965	465	190,910	705	71	170,698	58
15	2000	6	11	2,620	465	190,910	708	71	171,311	58
10	2000	6.4	12	2,794	465	190,910	709	71	171,475	58
3	2000	8.2	15	3,580	465	190,910	712	71	172,211	58
0.3	2000	16.4	30	7,161	465	190,910	727	71	175,562	59
0.03	2000	22.3	41	9,737	465	190,910	738	71	177,974	60
LOW										
100,60,30,10	2000	0	0	0	465	190,910	697	71	168,859	57
3	2000	3.6	7	1,572	465	190,910	703	71	170,330	57
0.3	2000	8.3	15	3,624	465	190,910	712	71	172,251	58
0.03	2000	18.6	35	8,121	465	190,910	731	71	176,462	59

TABLE B.6. **Detail of Costs and Other Parameters for Remediation of a Power Reactor Soil Site, Without Soil Washing (continued)**

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor Demo Labor	TOTAL LABOR	Occup. Dose
Rates:	$1325/ truck		Northwest Compact	Southeast Compact	Out-or-SE Compact			1.62 manhr/m³	4.07 manhr/m²		0.1 mrem/hr
Units:	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH											
100	75,525	773	1,092,317	3,669,952	7,383,041	4,048,437	4,486,266	9	1891	1900	190
60	76,850	776	1,096,251	3,683,182	7,409,656	4,063,030	4,503,452	14	1891	1904	190
30	76,850	779	1,100,710	3,698,176	7,439,820	4,079,568	4,521,428	19	1891	1909	191
15	76,850	781	1,102,808	3,705,231	7,454,015	4,087,351	4,529,887	21	1891	1912	191
10	76,850	782	1,104,906	3,712,287	7,468,210	4,095,134	4,538,347	23	1891	1914	191
3	78,175	789	1,114,609	3,744,921	7,533,860	4,131,130	4,578,795	35	1891	1925	193
0.3	79,500	805	1,137,950	3,823,418	7,691,777	4,217,715	4,674,229	61	1891	1952	195
0.03	79,500	814	1,149,752	3,863,107	7,771,622	4,261,494	4,721,812	75	1891	1965	197
MEDIUM											
100	75,525	768	1,084,450	3,643,492	7,329,811	4,019,251	4,454,544	0	1891	1891	189
60	75,525	772	1,091,006	3,665,542	7,374,170	4,043,573	4,480,979	8	1891	1898	190
30	76,850	776	1,096,251	3,683,182	7,409,656	4,063,030	4,503,452	14	1891	1904	190
15	76,850	779	1,100,185	3,696,412	7,436,272	4,077,623	4,519,313	18	1891	1909	191
10	76,850	779	1,101,234	3,699,940	7,443,369	4,081,514	4,523,543	19	1891	1910	191
3	76,850	783	1,105,955	3,715,815	7,475,307	4,099,026	4,542,576	25	1891	1915	192
0.3	78,175	798	1,127,460	3,788,138	7,620,803	4,178,800	4,630,608	49	1891	1940	194
0.03	79,500	809	1,142,933	3,840,176	7,725,489	4,236,199	4,694,320	67	1891	1958	196
LOW											
100,60,30,10	75,525	768	1,084,450	3,643,492	7,329,811	4,019,251	4,454,544	0	1891	1891	189
3	75,525	774	1,093,891	3,675,244	7,393,687	4,054,274	4,492,611	11	1891	1901	190
0.3	76,850	783	1,106,217	3,716,697	7,477,081	4,099,999	4,543,634	25	1891	1915	192
0.03	78,175	802	1,133,230	3,807,542	7,659,839	4,200,203	4,653,871	56	1891	1947	195

TABLE B.7. **Detail of Costs and Other Parameters for Remediation of a Rare Metals Extraction Soil Site, Without Soil Washing**

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume*	Total Concrete Volume	Waste Packaging Cost	Transport Reqds
Rates:				$235/m³		$411/m²			$220/m³	
Units:	ft²	cm	m³	$	m²	$	m³	m³	$	# trucks
HIGH										
100	100000	0.80	74	17,465	279	114,546	492	42	117,666	40
60	100000	1.1	102	24,015	279	114,546	520	42	123,797	42
30	100000	1.2	111	26,198	279	114,546	530	42	125,841	43
15	100000	1.4	130	30,564	279	114,546	548	42	129,928	44
10	100000	1.5	139	32,747	279	114,546	557	42	131,972	45
3	100000	2	186	43,663	279	114,546	604	42	142,191	48
0.3	100000	2.6	242	56,762	279	114,546	660	42	154,454	52
0.03	100000	3.1	288	67,678	279	114,546	706	42	164,673	56
LOW										
100	100000	0.2	19	4,366	279	114,546	437	42	105,403	36
60	100000	0.4	37	8,733	279	114,546	455	42	109,490	37
30	100000	0.6	56	13,099	279	114,546	474	42	113,578	38
15	100000	1.1	102	24,015	279	114,546	520	42	123,797	42
10	100000	1.1	102	24,015	279	114,546	520	42	123,797	42
3	100000	1.3	121	28,381	279	114,546	539	42	127,885	43
0.3	100000	2	186	43,663	279	114,546	604	42	142,191	48
0.03	100000	2.6	242	56,762	279	114,546	660	42	154,454	52

TABLE B.7. **Detail of Costs and Other Parameters for Remediation of a Rare Metals Extraction Soil Site, Without Soil Washing (continued)**

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor Demo Labor	TOTAL LABOR	Occup. Dose
Rates:	$1325/ truck		Northwest Compact	Southeast Compact	Out-of-SE Compact			1.62 manhr/m³	4.07 manhr/m²		0.1 mrem/hr
Units:	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH											
100	53,000	535	755,999	2,538,891	5,107,624	2,800,8	3,103,514	120	1134	1255	125
60	55,650	563	795,337	2,671,189	5,373,775	2,946,7	3,264,774	166	1134	1300	130
30	56,975	572	808,450	2,715,288	5,462,492	2,995,4	3,318,970	181	1134	1315	131
15	58,300	591	834,676	2,803,487	5,639,927	3,092,6	3,426,035	211	1134	1345	135
10	59,625	600	847,789	2,847,586	5,728,644	3,141,3	3,480,230	226	1134	1360	136
3	63,600	646	913,353	3,068,083	6,172,230	3,384,5	3,748,555	301	1134	1435	144
0.3	68,900	702	992,030	3,332,680	6,704,532	3,676,4	4,071,076	391	1134	1526	153
0.03	74,200	749	1,057,595	3,553,177	7,148,118	3,919,6	4,340,726	467	1134	1601	160
LOW											
100	47,700	479	677,322	2,274,294	4,575,321	2,508,9	2,780,994	30	1134	1164	116
60	49,025	498	703,547	2,362,493	4,752,755	2,606,2	2,888,059	60	1134	1195	119
30	50,350	516	729,773	2,450,692	4,930,189	2,703,5	2,995,124	90	1134	1225	122
15	55,650	563	795,337	2,671,189	5,373,775	2,946,7	3,264,774	166	1134	1300	130
10	55,650	563	795,337	2,671,189	5,373,775	2,946,7	3,264,774	166	1134	1300	130
3	56,975	581	821,563	2,759,388	5,551,210	3,044,0	3,371,840	196	1134	1330	133
0.3	63,600	646	913,353	3,068,083	6,172,230	3,384,5	3,748,555	301	1134	1435	144
0.03	68,900	702	992,030	3,332,680	6,704,532	3,676,4	4,071,076	391	1134	1526	153

TABLE B.8. **Details of Cost and Other Parameters for Remediation of a Rare Metals Extraction Tailings Pile, Without Soil Washing (continued)**

	Transport Costs	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COST	Excavation Labor	Floor Demo Labor	Soil Washing Labor	TOTAL LABOR	Occup. Dose
Rates:	2 wk rental		Northwest Compact	Southeast Compact	Out-of-SE Compact			1.62 manhr/m³	4.07 manhr/m²	0.17 manhr/m³		0.1 mrem/hr
Units:	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	man-hr	person-mrem
HIGH												
100	3,426	0	0	0	0	0	13,911	72	0	0	72	7
60	3,426	0	0	0	0	0	17,843	99	0	0	99	10
30	3,426	0	0	0	0	0	19,154	108	0	0	108	11
15	3,426	0	0	0	0	0	21,775	126	0	0	126	13
10	3,426	0	0	0	0	0	23,086	136	0	0	136	14
3	3,426	0	0	0	0	0	29,639	181	0	0	181	18
0.3	3,426	0	0	0	0	0	37,503	235	0	0	235	23
0.03	3,426	0	0	0	0	0	44,056	280	0	0	280	28
LOW												
100	3,426	0	0	0	0	0	6,047	18	0	0	18	2
60	3,426	0	0	0	0	0	8,669	36	0	0	36	4
30	3,426	0	0	0	0	0	11,290	54	0	0	54	5
15	3,426	0	0	0	0	0	17,843	99	0	0	99	10
10	3,426	0	0	0	0	0	17,843	99	0	0	99	10
3	3,426	0	0	0	0	0	20,464	117	0	0	117	12
0.3	3,426	0	0	0	0	0	29,639	181	0	0	181	18
0.03	3,426	0	0	0	0	0	37,503	235	0	0	235	23

TABLE B.9. **Detail of Costs and Other Parameters for Remediation of a Uranium Fuel Fabrication Facility Soil Site, Without Soil Washing**

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Waste Packaging Cost	Transport Reqds
Rates:				$235/m³		$411/m²			$220/m³	
Units:	ft²	cm	m³	$	m²	$	m³	m³	$	# trucks
HIGH										
100	50000	18.40	855	200,850	446	183,273	1524	68	350,134	118
60	50000	18.7	869	204,125	446	183,273	1537	68	353,200	119
30	50000	21.2	985	231,414	446	183,273	1654	68	378,747	127
15	50000	23	1068	251,062	446	183,273	1737	68	397,141	133
10	50000	23.3	1082	254,337	446	183,273	1751	68	400,207	134
3	50000	25.5	1184	278,352	446	183,273	1853	68	422,689	142
0.3	50000	29	1347	316,557	446	183,273	2016	68	458,455	154
0.03	50000	32	1486	349,304	446	183,273	2155	68	489,112	164
MEDIUM										
100	50000	10	465	109,158	446	183,273	1133	68	264,294	89
60	50000	14.3	664	156,095	446	183,273	1333	68	308,236	104
30	50000	17.2	799	187,751	446	183,273	1468	68	337,871	113
15	50000	19	883	207,399	446	183,273	1551	68	356,265	120
10	50000	20.2	938	220,498	446	183,273	1607	68	368,528	124
3	50000	22.8	1059	248,879	446	183,273	1728	68	395,098	133
0.3	50000	26.6	1236	290,359	446	183,273	1904	68	433,930	146
0.03	50000	29.8	1384	325,289	446	183,273	2053	68	466,631	156
LOW										
100,60,30	50000	0	0	0	446	183,273	669	68	1[illegible]2,104	55
15	50000	7	325	76,410	446	183,273	994	68	2[illegible]3,637	79
10	50000	13.8	641	150,637	446	183,273	1310	68	3[illegible]3,127	102
3	50000	18.4	855	200,850	446	183,273	1524	68	350,134	118
0.3	50000	23.4	1087	255,429	446	183,273	1756	68	401,229	135
0.03	50000	27.2	1263	296,908	446	183,273	1932	68	440,061	148

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TABLE B.9. Detail of Costs and Other Parameters for Remediation of a Uranium Fuel Fabrication Facility Soil Site, Without Soil Washing (continued)

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor Demo Labor	TOTAL LABOR	Occup. Dose
Rates:	$1325/ truck		Northwest Compact	Southeast Compact	Out-of-SE Compact			1.62 manhr/m³	4.07 manhr/m²		0.1 mrem/hr
Units:	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	person-mrem
HIGH											
100	156,350	1592	2,247,498	7,554,89	15,198,59	8,333,664	9,224,271	1385	1815	3199	320
60	157,675	1605	2,267,167	7,621,04	15,331,67	8,406,628	9,304,901	1407	1815	3222	322
30	168,275	1722	2,431,078	8,172,28	16,440,63	9,014,668	9,976,377	1595	1815	3410	341
15	176,225	1805	2,549,093	8,569,18	17,239,09	9,452,456	10,460,15	1731	1815	3546	355
10	177,550	1819	2,568,763	8,635,33	17,372,16	9,525,421	10,540,78	1753	1815	3568	357
3	188,150	1921	2,713,004	9,120,42	18,348,05	10,060,495	11,132,95	1919	1815	3734	373
0.3	204,050	2084	2,942,479	9,892,16	19,900,60	10,911,750	12,074,08	2182	1815	3997	400
0.03	217,300	2223	3,139,172	10,553,6	21,231,36	11,641,397	12,880,38	2408	1815	4223	422
MEDIUM											
100	117,925	1201	1,696,757	5,702,72	11,472,47	6,290,652	6,965,302	752	1815	2567	257
60	137,800	1401	1,978,684	6,650,86	13,379,89	7,336,479	8,121,884	1076	1815	2891	289
30	149,725	1536	2,168,820	7,290,30	14,666,29	8,041,805	8,900,425	1294	1815	3109	311
15	159,000	1619	2,286,836	7,687,19	15,464,74	8,479,593	9,385,531	1430	1815	3245	324
10	164,300	1675	2,365,513	7,951,79	15,997,05	8,771,452	9,708,051	1520	1815	3335	333
3	176,225	1796	2,535,981	8,525,08	17,150,37	9,403,813	10,407,28	1716	1815	3531	353
0.3	193,450	1972	2,785,125	9,362,97	18,836,00	10,328,032	11,429,04	2002	1815	3817	382
0.03	206,700	2121	2,994,931	10,068,5	20,255,47	11,106,323	12,288,21	2242	1815	4057	406
LOW											
100,60,30	72,875	737	1,041,114	3,497,75	7,036,619	3,858,495	4,276,748	0	1815	1815	181
15	104,675	1062	1,500,064	5,041,23	10,141,71	5,561,005	6,159,001	527	1815	2342	234
10	135,150	1378	1,945,902	6,540,61	13,158,10	7,214,872	7,987,059	1038	1815	2853	285
3	156,350	1592	2,247,498	7,554,89	15,198,59	8,333,664	9,224,271	1385	1815	3199	320
0.3	178,875	1824	2,575,319	8,657,38	17,416,52	9,549,742	10,568,54	1761	1815	3576	358
0.03	196,100	2000	2,824,464	9,495,27	19,102,15	10,473,962	11,590,30	2047	1815	3862	386

TABLE B.10. Details of Costs and Other Parameters for Remediation of a Uranium Mill Soil Site, Without Soil Washing

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Waste Packaging Cost	Transport Reqds
Rates:				$235/m³		$411/m²			$220/m³	
Units:	ft²	cm	m³	$	m²	$	m³	m³	$	# trucks
HIGH										
100	880000	18.40	15042	3,534,956	186	76,364	15321	28	0	0
60	880000	18.70	15288	3,592,592	186	76,364	15566	28	0	0
30	880000	21.20	17331	4,072,885	186	76,364	17610	28	0	0
15	880000	23.00	18803	4,418,696	186	76,364	19082	28	0	0
10	880000	23.30	19048	4,476,331	186	76,364	19327	28	0	0
3	880000	25.50	20847	4,898,989	186	76,364	21125	28	0	0
0.3	880000	29.00	23708	5,571,399	186	76,364	23987	28	0	0
0.03	880000	32.00	26161	6,147,750	186	76,364	26439	28	0	0
MEDIUM										
100	880000	10.00	8175	1,921,172	186	76,364	8454	28	0	0
60	880000	14.30	11691	2,747,276	186	76,364	11969	28	0	0
30	880000	17.20	14061	3,304,416	186	76,364	14340	28	0	0
15	880000	19.00	15533	3,650,227	186	76,364	15812	28	0	0
10	880000	20.20	16514	3,880,767	186	76,364	16793	28	0	0
3	880000	22.80	18639	4,380,272	186	76,364	18918	28	0	0
0.3	880000	26.60	21746	5,110,318	186	76,364	22025	28	0	0
0.03	880000	29.80	24362	5,725,093	186	76,364	24641	28	0	0
LOW										
100,60,30	880000	0.00	0	0	186	76,364	279	28	0	0
15	880000	7.00	5723	1,344,820	186	76,364	6001	28	0	0
10	880000	13.80	11282	2,651,217	186	76,364	11560	28	0	0
3	880000	18.40	15042	3,534,956	186	76,364	15321	28	0	0
0.3	880000	23.40	19130	4,495,542	186	76,364	19409	28	0	0
0.03	880000	27.20	22237	5,225,588	186	76,364	22515	28	0	0

TABLE B.10. **Details of Costs and Other Parameters for Remediation of a Uranium Mill Soil Site, Without Soil Washing (continued)**

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Costs	TOTAL COSTS	Excavation Labor	Floor Demo Labor	TOTAL LABOR	Occup. Dose
			Northwest Compact	Southeast Compact	Out-of-SE Compact						
Rates:	$1325/ truck							1.62 manhr/m³	4.07 manhr/m²		0.1 mrem/hr
Units:	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	person
HIGH											
100	3,426	0	0	0	0	0	3,614,746	24369	756	25125	2512
60	3,426	0	0	0	0	0	3,672,381	24766	756	25522	2552
30	3,426	0	0	0	0	0	4,152,674	28077	756	28833	2883
15	3,426	0	0	0	0	0	4,498,485	30461	756	31217	3122
10	3,426	0	0	0	0	0	4,556,121	30858	756	31614	3161
3	3,426	0	0	0	0	0	4,978,778	33772	756	34528	3453
0.3	3,426	0	0	0	0	0	5,651,189	38407	756	39163	3916
0.03	3,426	0	0	0	0	0	6,227,540	42380	756	43136	4314
MEDIU											
100	3,426	0	0	0	0	0	2,000,962	13244	756	14000	1400
60	3,426	0	0	0	0	0	2,827,066	18939	756	19695	1969
30	3,426	0	0	0	0	0	3,384,206	22779	756	23536	2354
15	3,426	0	0	0	0	0	3,730,017	25163	756	25919	2592
10	3,426	0	0	0	0	0	3,960,557	26753	756	27509	2751
3	3,426	0	0	0	0	0	4,460,062	30196	756	30952	3095
0.3	3,426	0	0	0	0	0	5,190,107	35229	756	35985	3598
0.03	3,426	0	0	0	0	0	5,804,882	39467	756	40223	4022
LOW											
100,60,	3,426	0	0	0	0	0	79,790	0	756	756	76
15	3,426	0	0	0	0	0	1,424,610	9271	756	10027	1003
10	3,426	0	0	0	0	0	2,731,007	18276	756	19033	1903
3	3,426	0	0	0	0	0	3,614,746	24369	756	25125	2512
0.3	3,426	0	0	0	0	0	4,575,332	30991	756	31747	3175
0.03	3,426	0	0	0	0	0	5,305,378	36023	756	36779	3678

TABLE B.11. **Detail of Costs and Other Parameters for Remediation of a Uranium Hexafluoride Soil Site, Without Soil Washing**

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Waste Packaging Cost	Transport Reqds
Rates:				$235/m³		$411/m²			$220/m³	
Units:	ft²	cm	m³	$	m²	$	m³	m³	$	# trucks
HIGH										
100	100000	18.40	1709	401,700	223	91,637	2044	34	457,[illegible]11	153
60	100000	18.7	1737	408,249	223	91,637	2072	34	463,[illegible]43	155
30	100000	23	2137	502,125	223	91,637	2471	34	551,[illegible]26	185
15	100000	21.2	1969	462,828	223	91,637	2304	34	514,338	172
10	100000	23.3	2165	508,674	223	91,637	2499	34	557,258	187
3	100000	25.5	2369	556,703	223	91,637	2703	34	602,221	202
0.3	100000	29	2694	633,114	223	91,637	3029	34	673,754	226
0.03	100000	32	2973	698,608	223	91,637	3307	34	735,068	246
MEDIUM										
100	100000	10	929	218,315	223	91,637	1263	34	285,432	96
60	100000	14.3	1328	312,190	223	91,637	1663	34	373,316	125
30	100000	17.2	1598	375,502	223	91,637	1932	34	432,586	145
15	100000	19	1765	414,799	223	91,637	2100	34	469,374	157
10	100000	20.2	1877	440,996	223	91,637	2211	34	493,900	166
3	100000	22.8	2118	497,758	223	91,637	2453	34	547,039	183
0.3	100000	26.6	2471	580,718	223	91,637	2806	34	624,703	209
0.03	100000	29.8	2768	650,579	223	91,637	3103	34	690,105	231
LOW										
100,60,30	100000	0	0	0	223	91,637	334	34	81,052	28
15	100000	0	0	0	223	91,637	334	34	81,052	28
10	100000	13.8	1282	301,275	223	91,637	1616	34	363,097	122
3	100000	18.4	1709	401,700	223	91,637	2044	34	457,111	153
0.3	100000	23.4	2174	510,857	223	91,637	2508	34	559,301	187
0.03	100000	27.2	2527	593,817	223	91,637	2861	34	636,966	213

TABLE B.11. Detail of Costs and Other Parameters for Remediation of a Uranium Hexafluoride Soil Site, Without Soil Washing (continued)

	Transport Costs	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor De no Labor	TOTAL LABOR	Occup. Dose
Rates:	$1325/ truck		Northwest Compact	Southeast Compact	Out-of-SE Compact			1.62 manhr/m³	4.07: manhr/,n²		0.1 mrem/ hr
Units:	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	person-
HIGH											
100	202,725	2078	2,933,856	9,863,166	19,842,265	10,879,762	12,032,93	2769	907	3677	368
60	205,375	2106	2,973,195	9,995,464	20,108,416	11,025,692	12,194,19	2814	907	3722	372
30	245,125	2505	3,537,048	11,891,738	23,923,254	13,117,347	14,507,35	3461	907	4369	437
15	227,900	2338	3,301,016	11,097,949	22,326,345	12,241,770	13,538,47	3191	907	4098	410
10	247,775	2533	3,576,386	12,024,036	24,189,405	13,263,276	14,668,61	3507	907	4414	441
3	267,650	2737	3,864,869	12,994,223	26,141,183	14,333,425	15,851,63	3838	907	4745	475
0.3	299,450	3063	4,323,820	14,537,702	29,246,283	16,035,935	17,733,88	4364	907	5272	527
0.03	325,950	3341	4,717,205	15,860,684	31,907,797	17,495,229	19,346,49	4816	907	5723	572
MEDIUM											
100	127,200	1297	1,832,376	6,158,816	12,390,024	6,793,739	7,516,323	1505	907	2412	241
60	165,625	1697	2,396,229	8,055,090	16,204,862	8,885,394	9,828,161	2152	907	3060	306
30	192,125	1966	2,776,502	9,333,973	18,777,659	10,296,045	11,387,89	2589	907	3496	350
15	208,025	2134	3,012,533	10,127,762	20,374,568	11,171,621	12,355,45	2859	907	3767	377
10	219,950	2245	3,169,888	10,656,955	21,439,174	11,755,339	13,001,82	3040	907	3948	395
3	242,475	2487	3,510,822	11,803,539	23,745,820	13,020,060	14,398,96	3431	907	4339	434
0.3	276,925	2840	4,009,111	13,479,316	27,117,071	14,868,500	16,442,48	4003	907	4911	491
0.03	306,075	3137	4,428,723	14,890,497	29,956,020	16,425,080	18,163,47	4485	907	5392	539
LOW											
100,60,30	37,100	368	521,090	1,748,876	3,518,309	1,929,425	2,139,214	0	907	907	91
15	37,100	368	521,090	1,748,876	3,518,309	1,929,425	2,139,214	0	907	907	91
10	161,650	1650	2,330,665	7,834,593	15,761,276	8,642,178	9,559,836	2077	907	2984	298
3	202,725	2078	2,933,856	9,863,166	19,842,265	10,879,762	12,032,93	2769	907	3677	368
0.3	247,775	2542	3,589,499	12,068,136	24,278,122	13,311,919	14,721,48	3522	907	4429	443
0.03	282,225	2895	4,087,788	13,743,913	27,649,374	15,160,358	16,765,00	4094	907	5001	500

TABLE B.12. **Detail of Costs and Other Parameters for Remediation of a Sealed Source Manufacturer Soil Site, With Soil Washing**

	Contaminated Area	Soil Depth	Soil Vol.	Soil Excavation Cost	Floor Area Removed	Floor Demo. & Excavation	Total Soil Vol.	Total Concrete Vol.	Soil Washing Cost	Waste Packaging Cost	Transport
Rates				$235/m³		$411/m²				$220/m³	
Units	ft²	cm	m³	$	m²	m²	m³	m³	$	m³	# trucks
HIGH											
100	5000	3.00	14	3,275	11	4,582	31	2	5,800	3,072	2
60	5000	4.3	20	4,694	11	4,582	37	2	7,000	3,603	2
30	5000	5.5	26	6,004	11	4,582	42	2	8,000	4,093	2
15	5000	7	33	7,641	11	4,582	49	2	8,000	4,707	2
10	5000	7.3	34	7,968	11	4,582	51	2	9,600	4,829	2
3	5000	8.6	40	9,388	11	4,582	57	2	10,800	5,361	2
0.3	5000	11	51	12,007	11	4,582	68	2	12,900	6,342	3
0.03	5000	12.7	59	13,863	11	4,582	76	2	14,400	7,037	3
MEDIUM											
100	5000	0	0	0	11	4,582	17	2	5,400	1,845	1
60	5000	2.5	12	2,729	11	4,582	28	2	5,400	2,867	1
30	5000	4.5	21	4,912	11	4,582	38	2	7,100	3,685	2
15	5000	6	28	6,549	11	4,582	45	2	7,100	4,298	2
10	5000	6.4	30	6,986	11	4,582	46	2	8,800	4,461	2
3	5000	7.7	36	8,405	11	4,582	52	2	10,000	4,993	2
0.3	5000	10.2	47	11,134	11	4,582	64	2	12,200	6,015	3
0.03	5000	12	56	13,099	11	4,582	72	2	13,800	6,750	3
LOW											
100,60,30	5000	0	0	0	11	4,582	17	2	5,400	1,845	1
3	5000	3.6	17	3,930	11	4,582	33	2	6,300	3,317	2
0.3	5000	7.3	34	7,968	11	4,582	51	2	9,600	4,829	2
0.03	5000	9.7	45	10,588	11	4,582	62	2	11,800	5,810	2

TABLE B.12. Detail of Costs and Other Parameters for Remediation of a Sealed Source Manufacturer Soil Site, With Soil Washing (continued)

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Soil Excavation Labor	Floor Demo Labor	Soil Washing Labor	TOTAL LABOR	Occup. Dose
Rates	$1325/ truck		Northwest Compact	Southeast Compact	Out-of-SE Compact			1.62 manhr/m³	4.07 manhr/m²	0.17 manhr/ m³		0.1 mrem/hr
Units	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	man-hr	Person-mrem
HIGH												
100	2,650	14	20,772	66,276	133,331	73,460	92,838	23	45	5	73	7
60	2,650	16	24,181	77,742	156,398	86,107	108,636	32	45	6	84	8
30	2,650	19	27,328	88,326	177,690	97,781	123,110	41	45	7	94	9
15	2,650	21	31,262	101,556	204,305	112,374	139,954	53	45	8	106	11
10	2,650	22	32,049	104,202	209,628	115,293	144,922	55	45	9	109	11
3	2,650	24	35,458	115,667	232,694	127,940	160,720	65	45	10	120	12
0.3	3,975	29	41,753	136,835	275,279	151,289	191,095	83	45	12	140	14
0.03	3,975	32	46,211	151,829	305,443	167,827	211,684	96	45	13	154	15
MEDI												
100	1,325	8	12,904	39,816	80,101	44,274	57,426	0	45	3	48	5
60	1,325	13	19,461	61,866	124,460	68,595	85,498	19	45	5	69	7
30	2,650	17	24,706	79,506	159,946	88,053	110,981	34	45	6	86	9
15	2,650	20	28,640	92,736	186,562	102,646	127,825	45	45	8	98	10
10	2,650	20	29,689	96,264	193,659	106,537	134,016	48	45	8	101	10
3	2,650	23	33,098	107,730	216,725	119,184	149,814	58	45	9	112	11
0.3	3,975	27	39,655	129,779	261,084	143,506	181,411	77	45	11	133	13
0.03	3,975	31	44,375	145,655	293,022	161,017	203,224	90	45	12	148	15
LOW												
100,60,	1,325	8	12,904	39,816	80,101	44,274	57,426	0	45	3	48	5
3	2,650	15	22,346	71,568	143,977	79,297	100,075	27	45	6	78	8
0.3	2,650	22	32,049	104,202	209,628	115,293	144,922	55	45	9	109	11
0.03	2,650	26	38,343	125,369	252,212	138,642	174,072	73	45	11	129	13

TABLE B.13. Detail of Costs and Other Parameters for Remediation of a Generic R&D Facility Soil Site, With Soil Washing

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Soil Washing Cost	Waste Packaging Cost	Transport
Rates				$235/m³		$411/m²				$220/m³	
Units	ft²	cm	m³	$	m²	$	m³	m³	$	$	# trucks
HIGH											
100	5000	3.00	14	3,275	11	4,582	31	2	23,730	3,072	2
60	5000	4.5	21	4,912	11	4,582	38	2	25,060	3,685	2
30	5000	6.2	29	6,768	11	4,582	46	2	26,580	4,380	2
15	5000	7	33	7,641	11	4,582	49	2	26,700	4,707	2
10	5000	7.8	36	8,514	11	4,582	53	2	28,100	5,034	2
3	5000	11.5	53	12,553	11	4,582	70	2	31,330	6,546	3
0.3	5000	20.4	95	22,268	11	4,582	111	2	39,130	10,184	4
0.03	5000	24.9	116	27,180	11	4,582	132	2	43,120	12,023	5
MEDIUM											
100	5000	0	0	0	11	4,582	17	2	21,000	1,845	1
60	5000	2.5	12	2,729	11	4,582	28	2	23,350	2,867	1
30	5000	4.5	21	4,912	11	4,582	38	2	25,060	3,685	2
15	5000	6	28	6,549	11	4,582	45	2	25,200	4,298	2
10	5000	6.4	30	6,986	11	4,582	46	2	26,580	4,461	2
3	5000	8.2	38	8,951	11	4,582	55	2	28,480	5,197	2
0.3	5000	16.4	76	17,902	11	4,582	93	2	35,710	8,549	3
0.03	5000	22.3	104	24,342	11	4,582	120	2	40,840	10,961	4
LOW											
100,60,30,10	5000	0	0	0	11	4,582	17	2	21,070	1,845	1
3	5000	3.6	17	3,930	11	4,582	33	2	24,300	3,317	2
0.3	5000	8.3	39	9,060	11	4,582	55	2	28,480	5,238	2
0.03	5000	18.6	86	20,303	11	4,582	103	2	37,610	9,448	4

TABLE B.13. Detail of Costs and Other Parameters for Remediation of a Generic R&D Facility Soil Site, With Soil Washing (continued)

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor Demo Labor	Soil Washing Labor	TOTAL LABOR	Occup. Dose
Rates	$1325/ truck		Northwest Compact	Southeast Compact	Out-of-SE Compact			1.62 manhr/m³	4.07 manhr/ m²	0.17 manhr/m³		0.1 mrem/hr
Units	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	man-hr	person-mrem
HIGH												
100	2,650	14	20,772	66,276	133,331	73,460	110,768	23	45	5	73	7
60	2,650	17	24,706	79,506	159,946	88,053	128,941	34	45	6	86	9
30	2,650	20	29,164	94,500	190,110	104,591	149,551	47	45	8	100	10
15	2,650	21	31,262	101,556	204,305	112,374	158,654	53	45	8	106	11
10	2,650	23	33,360	108,612	218,500	120,157	169,037	59	45	9	113	11
3	3,975	30	43,064	141,245	284,150	156,153	215,139	87	45	12	144	14
0.3	5,300	46	66,405	219,742	442,067	242,738	324,202	154	45	19	218	22
0.03	6,625	55	78,206	259,431	521,912	286,517	380,047	187	45	23	255	26
MEDIU												
100	1,325	8	12,904	39,816	80,101	44,274	73,026	0	45	3	48	5
60	1,325	13	19,461	61,866	124,460	68,595	103,448	19	45	5	69	7
30	2,650	17	24,706	79,506	159,946	88,053	128,941	34	45	6	86	9
15	2,650	20	28,640	92,736	186,562	102,646	145,925	45	45	8	98	10
10	2,650	20	29,689	96,264	193,659	106,537	151,796	48	45	8	101	10
3	2,650	24	34,409	112,139	225,597	124,049	173,909	62	45	9	116	12
0.3	3,975	39	55,915	184,462	371,093	203,823	274,541	123	45	16	185	18
0.03	5,300	50	71,388	236,500	475,779	261,222	347,247	168	45	20	234	23
LOW												
100,60,	1,325	8	12,904	39,816	80,101	44,274	73,096	0	45	3	48	5
3	2,650	15	22,346	71,568	143,977	79,297	118,075	27	45	6	78	8
0.3	2,650	24	34,672	113,021	227,371	125,022	175,031	62	45	9	117	12
0.03	5,300	43	61,684	203,866	410,129	225,226	302,470	140	45	18	203	20

TABLE B.14. Details of Costs and Other Parameters for Remediation of a Dry ISFSI Soil Site, With Soil Washing

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Soil Washing Cost	Waste Packaging Cost	Transport Reqds
Rates:				$235/m³		$411/m²				$220/m³	
Units:	ft²	cm	m³	$	m²	$	m³	m³	$		# trucks
HIGH											
100	500	3.00	1	327	43	17,564	65	7	12,500	7,196	3
60	500	4.5	2	491	43	17,564	66	7	12,600	7,258	3
30	500	6.2	3	677	43	17,564	67	7	12,700	7,327	3
15	500	7	3	764	43	17,564	67	7	12,800	7,360	3
10	500	7.8	4	851	43	17,564	68	7	12,900	7,393	3
3	500	11.5	5	1,255	43	17,564	69	7	13,100	7,544	3
0.3	500	20.4	9	2,227	43	17,564	74	7	13,900	7,908	3
0.03	500	24.9	12	2,718	43	17,564	76	7	14,400	8,091	3
MEDIUM											
100	500	0	0	0	43	17,564	64	7	12,300	7,074	3
60	500	2.5	1	273	43	17,564	65	7	12,400	7,176	3
30	500	4.5	2	491	43	17,564	66	7	12,600	7,258	3
15	500	6	3	655	43	17,564	67	7	12,700	7,319	3
10	500	6.4	3	699	43	17,564	67	7	12,800	7,335	3
3	500	8.2	4	895	43	17,564	68	7	12,900	7,409	3
0.3	500	16.4	8	1,790	43	17,564	72	7	13,700	7,744	3
0.03	500	22.3	10	2,434	43	17,564	74	7	14,200	7,985	3
LOW											
100,60,30,	500	0	0	0	43	17,564	64	7	12,300	7,074	3
3	500	3.6	2	393	43	17,564	66	7	12,500	7,221	3
0.3	500	8.3	4	906	43	17,564	68	7	12,900	7,413	3
0.03	500	18.6	9	2,030	43	17,564	73	7	13,800	7,834	3

TABLE B.14. Details of Costs and Other Parameters for Remediation of a Dry ISFSI Soil Site, With Soil Washing (continued)

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor Demo Labor	Soil Washing Labor	TOTAL LABOR	Occup. Dose
Rates:	$1325/truck		Northwest Compact	Southeast Compact	Out-of-SE Compact			1.62 manhr/m³	4.07 manhr/m³	0.17 manhr/m³		0.1 mrem/hr
Units:	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	man-hr	Person-mrem
HIGH												
100	3,975	33	47,236	155,276	312,377	171,629	213,192	2	174	11	187	19
60	3,975	33	47,629	156,599	315,038	173,089	214,976	3	174	11	189	19
30	3,975	33	48,075	158,098	318,055	174,743	216,985	5	174	11	190	19
15	3,975	33	48,285	158,804	319,474	175,521	217,983	5	174	11	191	19
10	3,975	34	48,495	159,509	320,893	176,299	218,982	6	174	12	191	19
3	3,975	34	49,465	162,773	327,459	179,899	223,336	9	174	12	194	19
0.3	3,975	36	51,799	170,622	343,250	188,557	234,130	15	174	13	202	20
0.03	3,975	37	52,979	174,591	351,235	192,935	239,683	19	174	13	206	21
MEDIUM												
100	3,975	32	46,449	152,630	307,054	168,711	209,623	0	174	11	185	18
60	3,975	33	47,105	154,835	311,489	171,143	212,530	2	174	11	187	19
30	3,975	33	47,629	156,599	315,038	173,089	214,976	3	174	11	189	19
15	3,975	33	48,023	157,922	317,700	174,548	216,761	5	174	11	190	19
10	3,975	33	48,128	158,275	318,409	174,937	217,310	5	174	11	190	19
3	3,975	34	48,600	159,862	321,603	176,688	219,431	6	174	12	192	19
0.3	3,975	35	50,750	167,094	336,153	184,666	229,439	12	174	12	198	20
0.03	3,975	36	52,297	172,298	346,621	190,406	236,564	17	174	13	203	20
LOW												
100,60,30	3,975	32	46,449	152,630	307,054	168,711	209,623	0	174	11	185	18
3	3,975	33	47,393	155,805	313,441	172,213	213,866	3	174	11	188	19
0.3	3,975	34	48,626	159,950	321,781	176,786	219,543	6	174	12	192	19
0.03	3,975	36	51,327	169,035	340,056	186,806	232,009	14	174	12	200	20

TABLE B.15. Detail of Costs and Other Parameters for Remediation of a Test Reactor Soil Site, With Soil Washing

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Soil Washing Cost	Waste Packaging Cost	Transport Reqds
Rates:				$235/m^3		$411/m^2				$220/m^3	
Units:	ft^2	cm	m^3	$	m^2	m^2	m^3	m^3	$	$	# trucks
HIGH											
100	5000	3.00	14	3,275	186	76,364	293	28	55,600	31,981	11
60	5000	4.5	21	4,912	186	76,364	300	28	56,900	32,595	11
30	5000	6.2	29	6,768	186	76,364	307	28	58,400	33,289	12
15	5000	7	33	7,641	186	76,364	311	28	58,600	33,616	12
10	5000	7.8	36	8,514	186	76,364	315	28	59,800	33,943	12
3	5000	11.5	53	12,553	186	76,364	332	28	63,000	35,456	12
0.3	5000	20.4	95	22,268	186	76,364	373	28	70,900	39,094	14
0.03	5000	24.9	116	27,180	186	76,364	394	28	74,900	40,933	14
MEDIUM											
100	5000	0	0	0	186	76,364	279	28	53,000	30,755	11
60	5000	2.5	12	2,729	186	76,364	290	28	55,100	31,777	11
30	5000	4.5	21	4,912	186	76,364	300	28	56,099	32,595	11
15	5000	6	28	6,549	186	76,364	307	28	56,200	33,208	12
10	5000	6.4	30	6,986	186	76,364	308	28	58,400	33,371	12
3	5000	8.2	38	8,951	186	76,364	317	28	59,800	34,107	12
0.3	5000	16.4	76	17,902	186	76,364	355	28	67,300	37,459	13
0.03	5000	22.3	104	24,342	186	76,364	382	28	72,600	39,870	14
LOW											
100,60,30,10	5000	0	0	0	186	76,364	279	28	53,000	30,755	11
3	5000	3.6	17	3,930	186	76,364	295	28	56,100	32,227	11
0.3	5000	8.3	39	9,060	186	76,364	317	28	60,200	34,148	12
0.03	5000	18.6	86	20,303	186	76,364	365	28	69,300	38,358	13

TABLE B.15. **Detail of Costs and Other Parameters for Remediation of a Test Reactor Soil Site, With Soil Washing (continued)**

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor Demo Labor	Soil Washing Labor	TOTAL LABOR	Occup. Dose
Rates:	$1325/ truck		Northwest Compact	Southeast Compact	Out-or-SE Compact			1.62 manhr/m³	4.07 manhr/m²	0.17 manhr/m³		0.1 mrem/hr
Units:	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	man-hr	person-mrem
HIGH												
100	14,575	145	206,255	690,067	1,388,246	761,523	943,318	23	756	50	829	83
60	14,575	148	210,189	703,297	1,414,861	776,116	961,461	34	756	51	841	84
30	15,900	151	214,647	718,291	1,445,025	792,654	983,375	47	756	52	855	86
15	15,900	153	216,745	725,347	1,459,220	800,437	992,559	53	756	53	862	86
10	15,900	154	218,843	732,403	1,473,414	808,220	1,002,7	59	756	54	868	87
3	15,900	161	228,547	765,036	1,539,065	844,216	1,047,4	87	756	56	899	90
0.3	18,550	178	251,888	843,533	1,696,982	930,801	1,157,9	154	756	63	973	97
0.03	18,550	186	263,689	883,223	1,776,827	974,580	1,212,5	187	756	67	1011	101
MEDIUM												
100	14,575	140	198,387	663,608	1,335,016	732,337	907,031	0	756	47	804	80
60	14,575	144	204,944	685,657	1,379,374	756,658	937,203	19	756	49	824	82
30	14,575	148	210,189	703,297	1,414,861	776,116	960,660	34	756	51	841	84
15	15,900	151	214,123	716,527	1,441,476	790,709	978,930	45	756	52	853	85
10	15,900	152	215,172	720,055	1,448,574	794,600	985,621	48	756	52	857	86
3	15,900	155	219,892	735,931	1,480,512	812,112	1,007,2	62	756	54	872	87
0.3	17,225	170	241,398	808,254	1,626,008	891,886	1,108,1	123	756	60	940	94
0.03	18,550	181	256,871	860,291	1,730,694	949,285	1,181,0	168	756	65	989	99
LOW												
100,60,30,	14,575	140	198,387	663,608	1,335,016	732,337	907,031	0	756	47	804	80
3	14,575	146	207,829	695,359	1,398,892	767,360	950,555	27	756	50	834	83
0.3	15,900	155	220,155	736,813	1,482,286	813,085	1,008,7	62	756	54	873	87
0.03	17,225	174	247,167	827,658	1,665,043	913,289	1,134,8	140	756	62	958	96

TABLE B.16. Detail of Costs and Other Parameters for Remediation of a Research Reactor Soil Site, With Soil Washing

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Soil Washing Cost	Waste Packaging Cost	Transport Reqds
Rates:				\$235/m³		\$411/m³				\$220/m³	
Units:	ft²	cm	m³	\$	m²	\$	m³	m³	\$	\$	# trucks
HIGH											
100	500	3.00	1	327	65	26,727	99	10	18,800	10,887	4
60	500	4.5	2	491	65	26,727	100	10	19,000	10,948	4
30	500	6.2	3	677	65	26,727	100	10	19,100	11,018	4
15	500	7	3	764	65	26,727	101	10	19,100	11,050	4
10	500	7.8	4	851	65	26,727	101	10	19,200	11,083	4
3	500	11.5	5	1,255	65	26,727	103	10	19,600	11,234	4
0.3	500	20.4	9	2,227	65	26,727	107	10	20,400	11,598	4
0.03	500	24.9	12	2,718	65	26,727	109	10	20,700	11,782	4
MEDIUM											
100	500	0	0	0	65	26,727	98	10	18,600	10,764	4
60	500	2.5	1	273	65	26,727	99	10	18,800	10,866	4
30	500	4.5	2	491	65	26,727	100	10	19,000	10,948	4
15	500	6	3	655	65	26,727	100	10	19,000	11,010	4
10	500	6.4	3	699	65	26,727	101	10	19,100	11,026	4
3	500	8.2	4	895	65	26,727	101	10	19,200	11,099	4
0.3	500	16.4	8	1,790	65	26,727	105	10	19,600	11,435	4
0.03	500	22.3	10	2,434	65	26,727	108	10	20,500	11,676	4
LOW											
100,60,30,10	500	0	0	0	65	26,727	98	10	18,600	10,764	4
3	500	3.6	2	393	65	26,727	99	10	18,800	10,911	4
0.3	500	8.3	4	906	65	26,727	101	10	19,200	11,104	4
0.03	500	18.6	9	2,030	65	26,727	106	10	19,700	11,525	4

TABLE B.16. Detail of Costs and Other Parameters for Remediation of a Research Reactor Soil Site, With Soil Washing (continued)

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor Demo Labor	Soil Washing Labor	TOTAL LABOR	Occup. Dose
Rates:	$1325/ truck		Northwest Compact	Southeast Compact	Out-of-SE Compact			1.62 manhr/m³	4.07 manhr/m²	0.17 manhr/m³		0.1 mrem/hr
Units:	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	man-hr	person-mrem
HIGH												
100	5,300	49	70,915	234,909	472,579	259,467	321,509	2	265	17	284	28
60	5,300	50	71,308	236,232	475,240	260,927	323,393	3	265	17	285	28
30	5,300	50	71,754	237,731	478,256	262,580	325,402	5	265	17	286	29
15	5,300	50	71,964	238,437	479,676	263,359	326,301	5	265	17	287	29
10	5,300	50	72,173	239,142	481,095	264,137	327,299	6	265	17	288	29
3	5,300	51	73,144	242,406	487,660	267,737	331,854	9	265	17	291	29
0.3	5,300	53	75,478	250,255	503,452	276,395	342,647	15	265	18	298	30
0.03	5,300	54	76,658	254,224	511,437	280,773	348,000	19	265	19	302	30
MEDIU												
100	5,300	49	70,128	232,263	467,255	256,549	317,940	0	265	17	281	28
60	5,300	49	70,783	234,468	471,691	258,981	320,948	2	265	17	283	28
30	5,300	50	71,308	236,232	475,240	260,927	323,393	3	265	17	285	28
15	5,300	50	71,701	237,555	477,902	262,386	325,078	5	265	17	286	29
10	5,300	50	71,806	237,907	478,611	262,775	325,627	5	265	17	287	29
3	5,300	50	72,278	239,495	481,805	264,526	327,748	6	265	17	288	29
0.3	5,300	52	74,429	246,727	496,355	272,504	337,356	12	265	18	295	29
0.03	5,300	53	75,976	251,931	506,823	278,244	344,881	17	265	18	300	30
LOW												
100,60,3	5,300	49	70,128	232,263	467,255	256,549	317,940	0	265	17	281	28
3	5,300	50	71,072	235,438	473,643	260,051	322,183	3	265	17	284	28
0.3	5,300	50	72,305	239,583	481,983	264,623	327,860	6	265	17	288	29
0.03	5,300	52	75,006	248,668	500,258	274,644	339,926	14	265	18	297	30

TABLE B.17. Details of Costs and Other Parameters for Remediation of a Power Reactor Soil Site, With Soil Washing

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Soil Washing Cost	Waste Packaging Cost	Transport Reqds
Rates:				\$235/m³		\$411/m²				\$220/m³	
Units:	ft²	cm	m³	\$	m²	\$	m³	m³	\$	\$	# trucks
HIGH											
100	2000	3.00	6	1,310	465	190,910	702	71	133,000	77,378	26
60	2000	4.5	8	1,965	465	190,910	705	71	134,000	77,624	26
30	2000	6.2	12	2,707	465	190,910	708	71	134,000	77,901	27
15	2000	7	13	3,056	465	190,910	710	71	134,000	78,032	27
10	2000	7.8	14	3,406	465	190,910	711	71	135,000	78,163	27
3	2000	11.5	21	5,021	465	190,910	718	71	136,000	78,768	27
0.3	2000	20.4	38	8,907	465	190,910	735	71	139,000	80,223	27
0.03	2000	24.9	46	10,872	465	190,910	743	71	141,000	80,959	28
MEDIU											
100	2000	0	0	0	465	190,910	697	71	132,000	76,888	26
60	2000	2.5	5	1,092	465	190,910	701	71	133,000	77,297	26
30	2000	4.5	8	1,965	465	190,910	705	71	134,000	77,624	26
15	2000	6	11	2,620	465	190,910	708	71	134,000	77,869	27
10	2000	6.4	12	2,794	465	190,910	709	71	134,000	77,934	27
3	2000	8.2	15	3,580	465	190,910	712	71	135,000	78,228	27
0.3	2000	16.4	30	7,161	465	190,910	727	71	137,000	79,569	27
0.03	2000	22.3	41	9,737	465	190,910	738	71	140,000	80,534	27
LOW											
100,60,3	2000	0	0	0	465	190,910	697	71	132,000	76,888	26
3	2000	3.6	7	1,572	465	190,910	703	71	133,000	77,476	26
0.3	2000	8.3	15	3,624	465	190,910	712	71	135,000	78,245	27
0.03	2000	18.6	35	8,121	465	190,910	731	71	137,000	79,929	27

TABLE B.17. Details of Costs and Other Parameters for Remediation of a Power Reactor Soil Site, With Soil Washing (continued)

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor Demo Labor	Soil Washing Labor	TOTAL LABOR	Occup. Dose
			Northwest Compact	Southeast Compact	Out-of-SE Compact							
Rates:	$1325/ truck							1.62 manhr/m³	4.07 manhr/m²	0.17 manhr/m³		0.1 mrem/hr
Units:		m³	$	$	$	$	$	man-hr	man-hr	man-hr	man-hr	person-mrem
HIGH												
100	34,450	352	497,518	1,669,603	3,358,831	1,841,984	2,279,032	9	1891	119	2019	202
60	34,450	353	499,091	1,674,895	3,369,477	1,847,821	2,286,769	14	1891	120	2024	202
30	35,775	354	500,875	1,680,893	3,381,543	1,854,437	2,295,730	19	1891	120	2030	203
15	35,775	355	501,714	1,683,715	3,387,221	1,857,550	2,299,323	21	1891	121	2032	203
10	35,775	355	502,553	1,686,537	3,392,899	1,860,663	2,303,916	23	1891	121	2035	203
3	35,775	358	506,435	1,699,591	3,419,159	1,875,062	2,321,535	35	1891	122	2047	205
0.3	35,775	365	515,771	1,730,990	3,482,326	1,909,695	2,364,510	61	1891	125	2077	208
0.03	37,100	368	520,492	1,746,865	3,514,264	1,927,207	2,388,048	75	1891	126	2092	209
MEDII												
100	34,450	349	494,371	1,659,019	3,337,539	1,830,310	2,264,557	0	1891	118	2009	201
60	34,450	351	496,993	1,667,839	3,355,283	1,840,038	2,276,786	8	1891	119	2017	202
30	34,450	353	499,091	1,674,895	3,369,477	1,847,821	2,286,769	14	1891	120	2024	202
15	35,775	354	500,665	1,680,187	3,380,123	1,853,659	2,294,832	18	1891	120	2029	203
10	35,775	354	501,085	1,681,598	3,382,962	1,855,215	2,296,628	19	1891	120	2030	203
3	35,775	356	502,973	1,687,949	3,395,738	1,862,220	2,305,713	25	1891	121	2036	204
0.3	35,775	362	511,575	1,716,878	3,453,936	1,894,130	2,344,544	49	1891	124	2064	206
0.03	35,775	366	517,764	1,737,693	3,495,811	1,917,089	2,374,044	67	1891	125	2083	208
LOW												
100,60	34,450	349	494,371	1,659,019	3,337,539	1,830,310	2,264,557	0	1891	118	2009	201
3	34,450	352	498,147	1,671,720	3,363,090	1,844,319	2,281,727	11	1891	120	2021	202
0.3	35,775	356	503,078	1,688,301	3,396,447	1,862,609	2,306,162	25	1891	121	2037	204
0.03	35,775	363	513,883	1,724,639	3,469,550	1,902,691	2,354,426	56	1891	124	2071	207

TABLE B.18. Detail of costs and Other Parameters for Remediation of a Rare Metals Extraction Soil Site, With Soil Washing

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Soil Washing Cost	Waste Packaging Cost	Transport Reqds
Rates:				$235/m³		$411/m²				$220/m³	
Units:	ft²	cm	m³	$	m²	$	m³	m³	$	$	# trucks
HIGH											
100	100000	0.80	74	17,465	279	114,546	492	42	95,500	52,673	18
60	100000	1.1	102	24,015	279	114,546	520	42	98,800	55,125	19
30	100000	1.2	111	26,198	279	114,546	530	42	101,000	55,943	19
15	100000	1.4	130	30,564	279	114,546	548	42	101,000	57,578	20
10	100000	1.5	139	32,747	279	114,546	557	42	106,000	58,395	20
3	100000	2	186	43,663	279	114,546	604	42	115,000	62,483	21
0.3	100000	2.6	242	56,762	279	114,546	660	42	125,000	67,388	23
0.03	100000	3.1	288	67,678	279	114,546	706	42	134,000	71,476	24
LOW											
100	100000	0.2	19	4,366	279	114,546	437	42	82,900	47,768	16
60	100000	0.4	37	8,733	279	114,546	455	42	86,500	49,403	17
30	100000	0.6	56	13,099	279	114,546	474	42	90,000	51,038	18
15	100000	1.1	102	24,015	279	114,546	520	42	90,000	55,125	19
10	100000	1.1	102	24,015	279	114,546	520	42	98,800	55,125	19
3	100000	1.3	121	28,381	279	114,546	539	42	102,000	56,760	19
0.3	100000	2	186	43,663	279	114,546	604	42	115,000	62,483	21
0.03	100000	2.6	242	56,762	279	114,546	660	42	125,000	67,388	23

TABLE B.18. Detail of costs and Other Parameters for Remediation of a Rare Metals Extraction Soil Site, With Soil Washing (continued)

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor Demo Labor	Soil Washing Labor	TOTAL LABOR	Occup. Dose
Rates:	$1325/ truck		Northwest Compact	Southeast Compact	Out-of-SE Compact			1.62 manhr/m³	4.07 manhr/ m²	0.17 manhr/m³		0.1 mrem/hr
Units:	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	man-hr	person-mrem
HIGH												
100	23,850	239	339,010	1,136,530	2,286,418	1,253,986	1,558,020	120	1134	84	1338	134
60	25,175	251	354,745	1,189,449	2,392,879	1,312,358	1,630,018	166	1134	88	1388	139
30	25,175	254	359,990	1,207,089	2,428,366	1,331,815	1,654,676	181	1134	90	1405	140
15	26,500	262	370,481	1,242,368	2,499,340	1,370,729	1,700,917	211	1134	93	1438	144
10	26,500	265	375,726	1,260,008	2,534,826	1,390,187	1,728,375	226	1134	95	1455	145
3	27,825	284	401,951	1,348,207	2,712,261	1,487,473	1,850,990	301	1134	103	1538	154
0.3	30,475	306	433,422	1,454,045	2,925,182	1,604,217	1,998,387	391	1134	112	1638	164
0.03	31,800	325	459,648	1,542,244	3,102,616	1,701,503	2,121,002	467	1134	120	1721	172
LOW												
100	21,200	217	307,539	1,030,691	2,073,497	1,137,242	1,411,622	30	1134	74	1239	124
60	22,525	225	318,029	1,065,971	2,144,471	1,176,157	1,461,363	60	1134	77	1272	127
30	23,850	232	328,519	1,101,250	2,215,445	1,215,071	1,516,404	90	1134	81	1305	131
15	25,175	251	354,745	1,189,449	2,392,879	1,312,358	1,633,218	166	1134	88	1388	139
10	25,175	251	354,745	1,189,449	2,392,879	1,312,358	1,633,218	166	1134	88	1388	139
3	25,175	258	365,235	1,224,728	2,463,853	1,351,272	1,691,134	196	1134	92	1422	142
0.3	27,825	284	401,951	1,348,207	2,712,261	1,487,473	1,860,990	301	1134	103	1538	154
0.03	30,475	306	433,422	1,454,045	2,925,182	1,604,217	1,873,387	391	1134	112	1638	164

TABLE B.19. Details of Cost and Other Parameters for Remediation of a Uranium Fuel Fabrication Soil Site, With Soil Washing

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Soil Washing Cost	Waste Packaging Cost	Transport Reqds
Rates:				$235/m³		$411/m²				$220/m³	
Units:	ft²	cm	m³	$	m²	$	m³	m³	$	$	# trucks
HIGH											
100	50000	18.40	855	200,850	446	183,273	1524	68	289,000	149,024	50
60	50000	18.7	869	204,125	446	183,273	1537	68	292,000	150,250	51
30	50000	21.2	985	231,414	446	183,273	1654	68	314,000	160,469	54
15	50000	23	1068	251,062	446	183,273	1737	68	314,000	167,827	57
10	50000	23.3	1082	254,337	446	183,273	1751	68	332,000	169,053	57
3	50000	25.5	1184	278,352	446	183,273	1853	68	352,000	178,046	60
0.3	50000	29	1347	316,557	446	183,273	2016	68	383,000	192,353	65
0.03	50000	32	1486	349,304	446	183,273	2155	68	409,000	204,615	69
MEDIUM											
100	50000	10	465	109,158	446	183,273	1133	68	215,000	114,688	39
60	50000	14.3	664	156,095	446	183,273	1333	68	253,000	132,265	45
30	50000	17.2	799	187,751	446	183,273	1468	68	279,000	144,119	49
15	50000	19	883	207,399	446	183,273	1551	68	279,000	151,477	51
10	50000	20.2	938	220,498	446	183,273	1607	68	305,000	156,382	53
3	50000	22.8	1059	248,879	446	183,273	1728	68	328,000	167,010	56
0.3	50000	26.6	1236	290,359	446	183,273	1904	68	362,000	182,542	62
0.03	50000	29.8	1384	325,289	446	183,273	2053	68	390,000	195,623	66
LOW											
100,60,30	50000	0	0	0	446	183,273	669	68	127,000	73,812	25
15	50000	7	325	76,410	446	183,273	994	68	249,000	102,425	35
10	50000	13.8	641	150,637	446	183,273	1310	68	249,000	130,221	44
3	50000	18.4	855	200,850	446	183,273	1524	68	289,000	149,024	50
0.3	50000	23.4	1087	255,429	446	183,273	1756	68	333,000	169,462	57
0.03	50000	27.2	1263	296,908	446	183,273	1932	68	367,000	184,995	62

TABLE B.19. Details of Cost and Other Parameters for Remediation of a Uranium Fuel Fabrication Soil Site, With Soil Washing (continued)

	Transport Cost	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor Demo Labor	Soil Washing Labor	TOTAL LABOR	Occup. Dose
Rates:	$1325/		Northwest	Southeast	Out-of-SE			1.62	4.07	0.17		0.1
Units:	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	man-hr	person-
HIGH												
100	66,250	677	957,192	3,215,516	6,468,829	3,547,179	4,435,576	1385	1815	259	3458	346
60	67,575	683	965,060	3,241,976	6,522,059	3,576,365	4,473,588	1407	1815	261	3483	348
30	71,550	729	1,030,624	3,462,473	6,965,645	3,819,581	4,780,287	1595	1815	281	3691	369
15	75,525	763	1,077,830	3,621,231	7,285,027	3,994,696	4,986,383	1731	1815	295	3841	384
10	75,525	768	1,085,698	3,647,691	7,338,257	4,023,882	5,038,070	1753	1815	298	3866	387
3	79,500	809	1,143,395	3,841,728	7,728,612	4,237,912	5,309,082	1919	1815	315	4049	405
0.3	86,125	874	1,235,185	4,150,424	8,349,632	4,578,414	5,739,721	2182	1815	343	4340	434
0.03	91,425	930	1,313,862	4,415,020	8,881,935	4,870,272	6,107,890	2408	1815	366	4589	459
MED												
100	51,675	521	736,896	2,474,647	4,978,381	2,729,974	3,403,768	752	1815	193	2760	276
60	59,625	601	849,666	2,853,901	5,741,348	3,148,305	3,932,564	1076	1815	227	3118	312
30	64,925	655	925,721	3,109,678	6,255,908	3,430,436	4,289,504	1294	1815	250	3359	336
15	67,575	689	972,927	3,268,436	6,575,289	3,605,551	4,494,275	1430	1815	264	3508	351
10	70,225	711	1,004,398	3,374,274	6,788,211	3,722,294	4,657,672	1520	1815	273	3608	361
3	74,200	759	1,072,585	3,603,591	7,249,540	3,975,239	4,976,600	1716	1815	294	3824	382
0.3	82,150	830	1,172,243	3,938,747	7,923,790	4,344,927	5,445,251	2002	1815	324	4140	414
0.03	87,450	889	1,256,165	4,220,983	8,491,580	4,656,243	5,837,878	2242	1815	349	4406	441
LOW												
100,6	33,125	336	474,639	1,592,659	3,204,038	1,757,112	2,174,322	0	1815	114	1929	193
15	46,375	466	658,219	2,210,050	4,446,078	2,438,116	3,095,599	527	1815	169	2511	251
10	58,300	592	836,554	2,809,802	5,652,631	3,099,662	3,871,094	1038	1815	223	3076	308
3	66,250	677	957,192	3,215,516	6,468,829	3,547,179	4,435,576	1385	1815	259	3458	346
0.3	75,525	770	1,088,321	3,656,510	7,356,000	4,033,610	5,050,299	1761	1815	298	3874	387
0.03	82,150	841	1,187,978	3,991,666	8,030,251	4,403,298	5,517,625	2047	1815	328	4190	419

TABLE B.20. Detail of Costs and Other Parameters for Remediation of Uranium Mill Soil Site, With Soil Washing

	Contaminated Area	Soil Depth	Soil Volume	Soil Excavation Cost	Floor Area Removed	Floor Demo & Excavation	Total Soil Volume	Total Concrete Volume	Soil Washing Cost	Waste Packaging Cost	Transport Reqds
Rates:				$235/m³		$411/m²				$220/m³	
Units:	ft²	cm	m³	$	m²	$	m³	m³	$	$	# trucks
HIGH											
100	880000	18.40	15042	3,534,956	186	76,364	15321	28	2,230,000	1,348,254	451
60	880000	18.70	15288	3,592,592	186	76,364	15566	28	2,266,000	1,369,837	458
30	880000	21.20	17331	4,072,885	186	76,364	17610	28	2,551,000	1,549,691	518
15	880000	23.00	18803	4,418,696	186	76,364	19082	28	2,650,000	1,679,186	562
10	880000	23.30	19048	4,476,331	186	76,364	19327	28	2,803,000	1,700,769	569
3	880000	25.50	20847	4,898,989	186	76,364	21125	28	3,046,000	1,859,040	622
0.3	880000	29.00	23708	5,571,399	186	76,364	23987	28	3,439,000	2,110,837	706
0.03	880000	32.00	26161	6,147,750	186	76,364	26439	28	3,768,000	2,326,662	778
MED											
100	880000	10.00	8175	1,921,172	186	76,364	8454	28	1,340,000	743,943	249
60	880000	14.30	11691	2,747,276	186	76,364	11969	28	1,794,000	1,053,293	353
30	880000	17.20	14061	3,304,416	186	76,364	14340	28	2,099,000	1,261,924	422
15	880000	19.00	15533	3,650,227	186	76,364	15812	28	2,247,000	1,391,419	466
10	880000	20.20	16514	3,880,767	186	76,364	16793	28	2,448,000	1,477,749	494
3	880000	22.80	18639	4,380,272	186	76,364	18918	28	2,743,000	1,664,798	557
0.3	880000	26.60	21746	5,110,318	186	76,364	22025	28	3,155,000	1,938,176	648
0.03	880000	29.80	24362	5,725,093	186	76,364	24641	28	3,509,000	2,168,390	725
LOW											
100,6	880000	0.00	0	0	186	76,364	279	28	53,000	24,526	9
15	880000	7.00	5723	1,344,820	186	76,364	6001	28	1,021,000	528,118	177
10	880000	13.80	11282	2,651,217	186	76,364	11560	28	1,731,000	1,017,322	341
3	880000	18.40	15042	3,534,956	186	76,364	15321	28	2,230,000	1,348,254	451
0.3	880000	23.40	19130	4,495,542	186	76,364	19409	28	2,795,000	1,707,963	571
0.03	880000	27.20	22237	5,225,588	186	76,364	22515	28	3,226,000	1,981,341	663

TABLE B.20. Detail of Costs and Other Parameters for Remediation of a Uranium Mill Soil Site, With Soil Washing (continued)

	Transport Costs	Disposal Volume	Disposal Charges			Average Disposal Cost	TOTAL COSTS	Excavation Labor	Floor Demo Labor	Soil Washing Labor	TOTAL LABOR	Occup. Dose
Rates:	$1325/		Northwest	Southeast	Out-or-SE			1.62	4.07	0.17		0.1
Units:	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	man-hr	person-
HIGH												
100	597,575	6128	8,651,358	29,091,491	58,524,930	32,089,260	39,876,409	24369	756	2605	27729	2773
60	606,850	6227	8,789,830	29,557,181	59,461,783	32,602,931	40,514,573	24766	756	2646	28168	2817
30	686,350	7044	9,943,761	33,437,928	67,268,892	36,883,527	45,819,817	28077	756	2994	31827	3183
15	744,650	7633	10,774,59	36,232,066	72,890,011	39,965,556	49,534,452	30461	756	3244	34461	3446
10	753,925	7731	10,913,06	36,697,756	73,826,864	40,479,228	50,289,616	30858	756	3286	34900	3490
3	824,150	8450	11,928,52	40,112,813	80,697,120	44,246,152	54,950,695	33772	756	3591	38119	3812
0.3	935,450	9595	13,544,02	45,545,859	91,627,073	50,238,987	62,372,036	38407	756	4078	43241	4324
0.03	1,030,850	10576	14,928,74	50,202,755	100,995,604	55,375,702	68,725,328	42380	756	4495	47631	4763
MED												
100	329,925	3382	4,774,147	16,052,181	32,293,043	17,706,457	22,117,861	13244	756	1437	15437	1544
60	467,725	4788	6,758,910	22,727,066	45,721,271	25,069,082	31,207,740	18939	756	2035	21730	2173
30	559,150	5736	8,097,471	27,228,733	54,777,517	30,034,574	37,335,427	22779	756	2438	25973	2597
15	617,450	6325	8,928,301	30,022,871	60,398,636	33,116,603	41,099,062	25163	756	2688	28607	2861
10	654,550	6717	9,482,189	31,885,629	64,146,048	35,171,289	43,708,719	26753	756	2855	30363	3036
3	738,025	7567	10,682,27	35,921,606	72,265,442	39,623,109	49,225,567	30196	756	3216	34168	3417
0.3	858,600	8810	12,436,25	41,820,342	84,132,248	46,129,615	57,268,072	35229	756	3744	39729	3973
0.03	960,625	9856	13,913,28	46,787,698	94,125,348	51,608,778	64,048,249	39467	756	4189	44412	4441
LOW												
100,60,	11,925	111	158,419	529,193	1,064,606	584,073	749,887	0	756	47	804	80
15	234,525	2401	3,389,429	11,395,285	22,924,512	12,569,742	15,774,569	9271	756	1020	11047	1105
10	451,825	4624	6,528,123	21,950,917	44,159,849	24,212,963	30,140,691	18276	756	1965	20998	2100
3	597,575	6128	8,651,358	29,091,491	58,524,930	32,089,260	39,876,409	24369	756	2605	27729	2773
0.3	756,575	7763	10,959,22	36,852,985	74,139,148	40,650,452	50,481,896	30991	756	3299	35046	3505
0.03	878,475	9006	12,713,19	42,751,721	86,005,954	47,156,958	58,544,726	36023	756	3828	40607	4061

TABLE B.21. Detail of Costs and Other Parameters for Remediation of Uranium Hexafluoride Facility Soil Site, With Soil Washing

	Contaminated	Soil	Soil	Soil	Floor	Floor Demo	Total	Total	Soil	Waste	Transport
Rates:				$235/m³		$411/m²				$220/m³	
Units:	ft²	cm	m³	$	m²	$	m³	m³	$	$	# trucks
HIGH											
100	100000	18.40	1709	401,700	223	91,637	2044	34	388,000	187,330	63
60	100000	18.7	1737	408,249	223	91,637	2072	34	393,000	189,782	64
30	100000	21.2	1969	462,828	223	91,637	2304	34	437,000	210,220	71
15	100000	23	2137	502,125	223	91,637	2471	34	450,000	224,936	76
10	100000	23.3	2165	508,674	223	91,637	2499	34	747,000	227,388	76
3	100000	25.5	2369	556,703	223	91,637	2703	34	513,000	245,374	83
0.3	100000	29	2694	633,114	223	91,637	3029	34	575,000	273,987	92
0.03	100000	32	2973	698,608	223	91,637	3307	34	632,000	298,513	100
MEDIUM											
100	100000	10	929	218,315	223	91,637	1263	34	240,000	118,658	40
60	100000	14.3	1328	312,190	223	91,637	1663	34	316,000	153,811	52
30	100000	17.2	1598	375,502	223	91,637	1932	34	367,000	177,520	60
15	100000	19	1765	414,799	223	91,637	2100	34	375,000	192,235	65
10	100000	20.2	1877	440,996	223	91,637	2211	34	420,000	202,045	68
3	100000	22.8	2118	497,758	223	91,637	2453	34	466,000	223,301	75
0.3	100000	26.6	2471	580,718	223	91,637	2806	34	533,000	254,366	86
0.03	100000	29.8	2768	650,579	223	91,637	3103	34	589,000	280,527	94
LOW											
100,60,30	100000	0	0	0	223	91,637	334	34	63,500	36,906	13
15	100000	7	650	152,821	223	91,637	985	34	150,000	94,133	32
10	100000	13.8	1282	301,275	223	91,637	1616	34	307,000	149,724	51
3	100000	18.4	1709	401,700	223	91,637	2044	34	388,000	187,330	63
0.3	100000	23.4	2174	510,857	223	91,637	2508	34	467,000	228,206	77
0.03	100000	27.2	2527	593,817	223	91,637	2861	34	543,000	259,272	87

TABLE B.21. Detail of Costs and Other Parameters for Remediation of Uranium Hexafluoride Facility Soil Site, With Soil Washing (continued)

	Transport	Disposal	Disposal Charges			Average	TOTAL	Excavation	Floor	Soil	TOTAL	Occup.
Rates:	$1325/		Northwest	Southeast	Out-of-SE			1.62	4.07	0.17		0.1
Units:	$	m³	$	$	$	$	$	man-hr	man-hr	man-hr	man-hr	person
HIGH												
100	83,475	827	1,202,958	4,042,045	8,131,601	4,458,868	5,611,009	2769	907	347	4024	402
60	84,800	838	1,218,694	4,094,964	8,238,062	4,517,240	5,684,708	2814	907	352	4074	407
30	94,075	931	1,349,823	4,535,958	9,125,233	5,003,671	6,299,431	3191	907	392	4490	449
15	100,700	997	1,444,235	4,853,474	9,763,997	5,353,902	6,723,299	3461	907	420	4789	479
10	100,700	1009	1,459,971	4,906,393	9,870,457	5,412,274	7,087,672	3507	907	425	4839	484
3	109,975	1090	1,575,364	5,294,468	10,651,168	5,840,333	7,357,022	3838	907	460	5205	520
0.3	121,900	1220	1,758,944	5,911,860	11,893,208	6,521,337	8,216,974	4364	907	515	5787	579
0.03	132,500	1332	1,916,298	6,441,052	12,957,814	7,105,055	8,958,312	4816	907	562	6286	629
MED												
100	53,000	514	762,366	2,560,305	5,150,705	2,824,459	3,546,068	1505	907	215	2627	263
60	68,900	674	987,908	3,318,815	6,676,640	3,661,121	4,603,659	2152	907	283	3342	334
30	79,500	782	1,140,017	3,830,368	7,705,759	4,225,381	5,316,539	2589	907	328	3825	382
15	86,125	849	1,234,429	4,147,884	8,344,522	4,575,612	5,735,407	2859	907	357	4124	412
10	90,100	893	1,297,371	4,359,561	8,770,365	4,809,099	6,053,877	3040	907	376	4323	432
3	99,375	990	1,433,745	4,818,194	9,693,023	5,314,987	6,693,058	3431	907	417	4756	476
0.3	113,950	1131	1,633,060	5,488,505	11,041,524	6,054,363	7,628,034	4003	907	477	5388	539
0.03	124,550	1250	1,800,905	6,052,978	12,177,103	6,676,995	8,413,288	4485	907	527	5920	592
LOW												
100,60	17,225	143	237,852	796,329	1,602,019	878,733	1,088,001	0	907	57	964	96
15	42,400	403	605,012	2,031,112	4,086,099	2,240,741	2,771,731	1053	907	167	2128	213
10	67,575	656	961,682	3,230,616	6,499,206	3,563,834	4,481,045	2077	907	275	3259	326
3	83,475	827	1,202,958	4,042,045	8,131,601	4,458,868	5,611,009	2769	907	347	4024	402
0.3	102,025	1012	1,465,216	4,924,033	9,905,944	5,431,731	6,831,455	3522	907	426	4856	486
0.03	115,275	1154	1,664,531	5,594,344	11,254,445	6,171,107	7,774,107	4094	907	486	5487	549

ATTACHMENT E

DETAILED GROUNDWATER INFORMATION

ATTACHMENT E

DETAILED GROUNDWATER INFORMATION

Cost Analysis of Remediating Existing Groundwater Contamination at NRC Licensed Sites

Introduction

The cost analysis was undertaken to estimate the total cost of reducing existing groundwater contamination, at NRC licensed sites, to various dose objectives. The dose objectives evaluated were: 1) 25 mrem/y total effective dose equivalent (TEDE), 2) 15 mrem/y TEDE, 3) 3 mrem/y TEDE, and background.

The goal of this cost analysis is to determine the costs associated with reducing the concentration of radionuclides in groundwater, at a composite NRC-licensed site, to concentrations that result in a dose of 25, 15, and 3 mrem/y TEDE to an individual who drinks 2 liters of groundwater per day. The composite site contamination concentration (and other generic site variables) was based on an analysis of contaminated groundwater at NRC-licensed sites with existing groundwater contamination. The analysis also evaluated the differential cost of further reducing the concentration of radionuclides in groundwater at the composite NRC-licensed sites to background concentrations.

NRC-licensed sites with existing groundwater contamination (Table C.E.2) can be divided into two types; 1) sites where the groundwater is contaminated primarily with uranium, and 2) sites where the groundwater is contaminated primarily with man-made beta particle radioactivity (at NRC-licensed sites these are H-3, Sr-90, or Tc-99).

The analysis evaluates the costs of reducing the existing concentration of radionuclides in groundwater at the composite NRC-licensed sites to the TEDE dose objectives and the total cost of providing replacement water. The physical aspects of the composite sites evaluated were derived from a review of data from NRC-licensed sites known to have groundwater contamination (Table C.E.2).

The analysis looked at the technical aspects of remediating the existing contamination, using available technology, and estimating the total cost to reduce the contamination to each identified level.

Assumptions Used

The groundwater dose pathway is the only significant exposure pathway operating at each site. The groundwater contamination plume remains within a controlled area for the duration of regulatory concern, and no offsite individual is affected by the plume.

Assumptions for composite Sr-90 site.

Dose Reduction (mrem/y)	Initial Plume Size[1] (ft)	Initial Ave. Conc. (pCi/l)	Final Ave. Conc. (pCi/l)	Years	Generic Assumptions
					$K_d = 20$
25 to 15	75x150	2625	2000	1	Hydraulic Cond. = 100 ft/day
25 to 3	same	2625	500	12	Porosity = 0.35
25 to background[2]	same	2625	8	68	

[1]Area of plume that is at the initial average concentration or greater
[2]MCL of 8 pCi/l

Assumptions for composite uranium site.

Dose Reduction (mrem/y)	Initial Plume Size[1] (ft)	Initial Ave. Conc. (pCi/l)	Final Ave. Conc. (pCi/l)	Years	Generic Assumptions
					$K_d = 15$
25 to 15	500x1000	1333	800	26	Hydraulic Cond. = 100 ft/day
25 to 3	same	1333	200	148	Porosity = 0.35
25 to background[2]	same	1333	30	459	

[1]Area of plume that is at the initial average concentration or greater
[2]Proposed MCL of 30 pCi/l

The values used in the tables in Chapter 6.4 and in Chapter 8 of Appendix C for the cases in going from 15-3 mrem/y were obtained by interpolation of the results presented in the tables above.

Cost Estimate Modeling

The cost estimates were done using the Cost of Remedial Action (CORA) model version 3.0 (EPA). This code calculates the capital and first year operations and maintenance (O&M) costs for various remedial actions that could be taken at a contaminated site.

Explanation of Cost Categories

Capital Costs

One time costs for site development, technology design, and construction costs of building a pump and treat remediation system. Value obtained from applying EPA's CORA model to a composite NRC-licensed Sr-90 or uranium site.

O&M Costs

First year technology operation and maintenance costs for a pump and treat remediation system. Value obtained from applying EPA's CORA model to a composite NRC-licensed Sr-90 or uranium site. Value multiplied by number of years required to meet remediation goal in the groundwater. Out-year estimates were not discounted.

The remedial actions considered here were pump and treat of contaminated groundwater and supplying water. The cost modules considered for the pump and treat remedial action were:

1) Removal (aggressive pumping)
2) Treatment (ion exchange)
3) Disposal of wastes
4) Effluent release from the system
5) Groundwater monitoring
6) Site health & safety
7) Site administration

Additional costs were incurred from:

1) Start-up (capital)
2) Insurance (capital and O&M)
3) Permitting (capital and O&M)
4) Construction services (capital)
5) Contingencies (capital and O&M)

The costs to supply water were based on a scenario of 25 people living above the contaminated groundwater plume therefore having to install a 100-ft deep well outside the plume and distributing the water to 6 households. Capital costs included costs to install the system and operate and maintain it for 1000 years for uranium case. For Sr-90, operation is for 286 years.

For background information, a list of indicators for potential subsurface soil groundwater contamination used by the NRC as part of their groundwater contamination considerations is included in Table C.E.1.

Table C.E.1

List of Indicators for Potential Subsurface Soil Groundwater Contamination

Based on the experience gained from operational and decommissioning NRC-licensed facilities, the following is a list of potential indicators for groundwater contamination at decommissioning facilities:

<u>High Potential</u> - If a site has a history of or currently has:

- Unlined lagoons, pits, canals, or surface-drainage ways that received radioactively contaminated liquid effluent.

- Lined lagoons, pits, canals, or surface drainage ways that received radioactively contaminated liquid effluent, where the lining has leaked, ruptured, or where overflow has occurred.

- Septic systems, dry wells, or injection wells that received radioactively contaminated liquid effluent.

- Storage tanks, waste tanks, and/or piping (above or below ground) that held or transported radioactively contaminated fluids and are known to have leaked.

- Liquid or wet radioactive waste buried onsite (i.e., burial under 10 CFR 20.302 or 20.304 (or the current 10 CFR 20.2002)).

- An accident or spill onsite where radioactive material was released exterior to a building.

- Wet bulk waste (e.g., sludge or tailings) stored exterior to buildings or used as backfill.

- Containerized-liquid waste, stored exterior to buildings, that has leaked.

<u>Medium Potential</u> - If a site has a history of or currently has:

- Surface water or atmospheric discharge of radioactive effluents.

- Radioactive contamination detected on the roof of a building.

- Radioactive contamination detected in the floor cracks or sump of a building.

Table C.E.1 (continued)

- An accident or spill onsite, where liquid radioactive material was released to the interior of a building.
- The presence of greater than 10-year-old underground storage tank or underground piping that held radioactively contaminated fluids, not known to have leaked, but never tested.
- A history of incineration of radioactive waste exterior to buildings onsite.
- Dry bulk waste (i.e., sludge or tailings) stored exterior to buildings or used as backfill.
- Solid containerized waste, stored exterior to buildings, that has leaked.

Low Potential - If a site has a history of or currently has:

- Less than 10-year-old underground storage tanks or underground piping that has held radioactively contaminated fluids and is known not to have leaked.
- Dry bulk waste stored inside of the buildings.
- A sealed-source-only license.

The potential for groundwater contamination at any of these sites is conditioned by certain site characteristics such as depth to groundwater, amount of yearly precipitation and hydraulic conductivity, and by certain source characteristics such as half-life, solubility, and distribution coefficient.

Table C.E.2

Groundwater Contamination at NRC Licensed Facilities

Examples of reported* radionuclide concentrations in groundwater at NRC-licensed facilities, not including uranium milling and mining sites

SDMP Sites	
Safety Light	696 Bq (18,800 pCi)/l strontium-90 6770 Bq (183,000 pCi)/l tritium
Westinghouse - Waltz Mill	9 Bq (250 pCi)/l strontium-90
UNC - Wood River Junction	0.28 Bq (7.5 pCi)/l strontium-90
RMI	22,000 Bq (600,000 pCi)/l technetium-99 12,000 μg/l enriched uranium
Sequoyah Fuels	20,300 μg/l natural uranium
Fansteel	48 Bq (1300 pCi)/l gross beta 930 Bq (25,000 pCi)/l natural uranium
Cimmarron	83 Bq (2250 pCi)/l enriched uranium
Nuclear Metals	100 μg/l depleted uranium
Engelhard	48 Bq (1300 pCi)/l gross alpha
Whittaker	43 Bq (1160 pCi)/l gross beta 2.8 Bq (76 pCi)/l gross alpha
B&W - Apollo	4.7 Bq (126 pCi)/l gross beta 1.7 Bq (47 pCi)/l gross alpha
Other Material Sites	
Cintichem	0.9 Bq (24 pCi)/l strontium-90
NFS - Erwin	37 Bq (10,000 pCi)/l enriched uranium
GE - Wilmington	3.7 Bq (1000 pCi)/l enriched uranium
ABB/CE - Hematite	11 Bq (300 pCi)/l gross beta
Siemens	2.5 Bq (68 pCi)/l gross beta 3.2 Bq (87 pCi)/l gross alpha

Table C.E.2 (continued)	
Reactor Sites	
TMI-2	18,500 Bq (500,000 pCi)/l tritium
Big Rock Point	1500 Bq (40,000 pCi)/l tritium
Dresden-1	850 Bq (23,000 pCi)/l tritium
Yankee-Rowe	300 Bq (8000 pCi)/l tritium
Humboldt Bay	96 Bq (2600 pCi)/l tritium
D.C. Cook	63 Bq (1700 pCi)/l tritium

[a]Data were reported in units used here.

APPENDIX D

TERMINATION SURVEY CONSIDERATIONS AND DETAILED ANALYSIS OF COSTS OF TERMINATION SURVEYS

APPENDIX D

D.1 Introduction

Survey cost estimates were developed for four reference facilities. The specific information regarding each facility was obtained from the Pacific Northwest National Laboratory (PNNL), previous Environmental Survey and Site Assessment Program (ESSAP) survey reports, or the corresponding NUREG documents describing each facility. For each facility, the "affected" areas, as defined in NUREG/CR-5849 (NRC, 1992A), were estimated based on reference facility descriptions. It should be noted that for the purpose of survey planning, the areas considered as affected were larger than the area actually decontaminated.

D.2 Modifications Made in Response to Public Comments

A number of public comments, noted in Appendix H, were received on survey methods and costs. The estimates of survey costs at various alternative residual dose levels for the four facilities are presented in the following section based on survey methods described below.

D.3 Overall Survey Methodology Approach

D.3.1 Bases of Survey Techniques

The costs of radiological surveys for license termination are based on survey techniques which a licensee would use in the decommissioning of its facility. Methodologies for conducting surveys are based on the approaches recommended in the Multi-Agency Radiological Site Survey Manual (MARSSIM) (MARS, 1996) developed jointly by the NRC, EPA, DOE, and DOD and published for public comment in December 1996. These methodologies are based on the analyses contained in NUREGs-1505, 1506, and 1507 (NRC, 1995a, b, c). Based on this survey methodology, cost estimates for carrying out the surveys are estimated based on appropriate instrumentation and labor costs.

D.3.2 Dose Conversion Factors

Dose conversion factors are used in the determination of costs by converting the concentration of the principal contaminant radionuclide to a dose that corresponds to the alternative residual dose levels being considered. Dose conversion factors for Co-60, Cs-137, Th-232, and natural uranium for several exposure scenarios (as described in NUREG/CR-5512 (NRC, 1992b) are contained in Appendix C.

D.3.3 Instrumentation

The instruments considered for performing the final survey were standard commercially available instruments currently used by ESSAP. These instruments include large area gas proportional detectors, GM detectors, ZnS and NaI scintillation detectors coupled with ratemeter-scalers.

D.4 Survey Costs

D.4.1 Labor Cost

The labor costs for the decommissioning activities, including the overhead costs, were provided to the Oak Ridge Institute for Science and Education (ORISE) by the NRC. These hourly rates were $22.99, $36.82, $70.99, and $105.99 for secretarial support, health physics technician, supervisor, and project management, respectively. In estimating man-hours necessary to complete the survey, time was also allowed for daily instrument check-outs, QA activities, etc., based on ESSAP field survey experience. In estimating total man-hours, project management and clerical times were also considered in the planning and report preparation phases of activities.

D.4.2 Analytical Cost

In order to represent average costs of commercially available radiochemistry analyses, cost tables from sources other than ESSAP were also considered. These included the Eberline and the International Technology (IT) Corporation. Additional information was obtained from M. H. Chew and Associates, Inc., which is compiling similar types of information for the Department of Energy.

D.4.3 Special Services

The only item applicable to these cost estimates is the cost of land survey. The cost of such contracts was estimated based on similar subcontracts by ESSAP and by contacting a local engineering/land surveying firm.

D.5 Detailed Survey Analysis for Reference Facilities

D.5.1 Survey Cost Estimate Introduction and Assumptions

To facilitate survey design and assure that the number of survey data points for a specific site is relatively uniformly distributed among areas of similar contamination potential, the reference site is divided into survey units which have a common history or other characteristics, or are naturally distinguishable from other portions of the site.

The limitation on survey unit size for Class 1 and Class 2 areas ensures that each area is assigned an adequate number of data points. Because the number of data points—determined by the nonparametric statistical tests—is independent of the survey unit size, the survey coverage in an area is determined by dividing the fixed number of data points obtained from the statistical tests by the survey unit area.

Survey units are limited in size, based on classification and site-specific conditions. One important factor in assigning survey units is the relative homogeneity of the surveyed area. The suggested maximum areas for survey units, used for this cost estimate exercise, are provided below. It should be stressed that these survey unit sizes may be altered based on site conditions with reasonable justification.

Typical Maximum Survey Unit Sizes

Area	Typical Maximum
Class 1	
Structures	200 m^2 floor area
Land areas	10,000 m^2
Class 2	
Structures	200 to 1,000 m^2
Land areas	10,000 m^2
Class 3	
Structures	no limit
Land areas	no limit

The indoor and outdoor scan coverages for each of the survey unit classifications are 100% for Class 1, 50 to 100% for Class 2, and 10% for Class 3. For this cost estimate, it is assumed that 75% of Class 2 areas are scanned.

The number of samples for Class 1 areas is determined either by nonparametric statistics or based on the hot spot potential. The number of samples for Class 2 and Class 3 areas are determined solely by nonparametric statistics. A reference area is needed for all radionuclides that are present in background and for radionuclides that are assessed using gross measurement techniques—such as surface activity measurements using a gas proportional detector.

Survey costs are estimated for alternative residual dose levels of 100, 60, 25, 15, and 3 mrem/y. These cost estimates are derived from methodology presented in MARSSIM (MARS, 1996) and NUREGs-1505, 1506, and 1507 (NRC, 1995a, b, c). An explanation of the methodology and parameters for each of the alternative residual dose criteria for the reference facilities are presented in the following sections.

In developing survey cost estimates for alternative residual dose levels of 100, 60, 25, 15, and 3 mrem/y, the only parameters that change at these dose levels are the DCGL and standard deviation. The classification and number of survey units remain the same for the alternate residual dose levels, therefore the scan coverage will remain the same for each dose level. The number of samples required at each dose level will likely change due to the change in the DCGL relative to the scan MDC—the area factor will also get larger as the DCGL is decreased, resulting in more samples to satisfy the potential for small areas of elevated activity. Similarly, the area factor will also get smaller as the DCGL is increased, resulting in fewer samples necessary to satisfy the potential for small areas of elevated activity.

The following discussion of cost estimates made for each of the alternative residual dose levels is somewhat repetitive for the various levels, but it is done so that the survey methods and costs can be understood as each dose level is considered.

D.5.2 Power Reactor

Although the power reactor may be contaminated with many different fission and activation product radionuclides, the two contaminants that deliver greater than 95% of the dose are Co-60 and Cs-137. Based on Appendix C, these radionuclides are assumed to be present at a ratio of Co-60 to Cs-137 of approximately 3-to-1.

D.5.2.1 Survey Cost Estimate for 100 mrem/y

Surface Activity and Soil Concentration Dose Conversion Guideline Levels (DCGLs)

For the Appendix C concentration ratio for Co-60 to Cs-137, the gross activity DCGL for surface activity is 40,900 dpm/100 cm^2 total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the total beta surface activity. Using the same assumptions, the combined DCGL for Co-60 is 18.3 pCi/g. Compliance with the soil DCGL will be demonstrated based on the Co-60 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

<u>Surface Activity</u>
The expected background for beta surface activity measurements is 2,000 $\pm$ 600 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 17,000 dpm/100 cm^2
Class 2	Standard deviation is 10,000 dpm/100 cm^2
Class 3	Standard deviation is 600 dpm/100 cm^2

<u>Soil Concentrations</u>
Co-60 is not expected to be present in background.

Class 1	Standard deviation is 7.3 pCi/g
Class 2	Standard deviation is 7 pCi/g
Class 3	Standard deviation is 0.2 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 6 (from nonparametric statistics).

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements is 425 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126 cm^2 gas proportional detector. The scan MDC for the floor monitor is 3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 60% of the floor areas in the power reactor facility.

Number of Surface Activity Measurement:Indoor Areas and Exterior Paved Areas and Structures (based on nonparametric stats or driven by hot spot potential)

Because the scan MDCs are sufficiently below the DCGL, the number of samples in Class 1 areas will be determined by nonparametric statistics.

The number of surface activity measurements per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 6250. It is assumed that an additional 2302 (includes 550 measurements from exterior surfaces) measurements are collected based on scan results for a total of 8552 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

It should be recognized that the outdoor areas include both soil areas and exterior building surfaces and paved areas. It is general practice for surface activity measurements to be performed on outdoor surfaces such as exterior structures and paved areas.

Reference Areas

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Because Co-60 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is not needed.

For exterior paved areas, it is assumed that all measurements are performed on asphalt in a reference area. The number of measurements equals 6 (from nonparametric statistics).

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Co-60 is approximately 5 pCi/g.

Exterior paved surfaces and building surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor is 3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 40% of the exterior paved areas.

Number of Soil Samples

Because the NaI scan MDC is less than the DCGL (5 vs. 18.3 pCi/g), the number of samples in Class 1 areas will not be driven by the potential for small areas of elevated activity.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 270. It is assumed that an additional 117 samples are collected based on scan results for a total of 387 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1, 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.2.2 Survey Cost Estimate for 60 mrem/y

Surface Activity and Soil Concentration Dose Conversion Guideline Levels (DCGLs)

For the concentration ratio from Appendix C for Co-60 to Cs-137, the gross activity DCGL for surface activity is 24,500 dpm/100 cm^2 total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the total beta surface activity. Under the same assumptions, the combined DCGL for Co-60 is 11 pCi/g. Compliance with the soil DCGL will be demonstrated based on the Co-60 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

Surface Activity
The expected background for beta surface activity measurements is 2,000 $\pm$ 600 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 10,400 dpm/100 cm^2
Class 2	Standard deviation is 7500 dpm/100 cm^2
Class 3	Standard deviation is 600 dpm/100 cm^2

Soil Concentrations
Co-60 is not expected to be present in background.

Class 1	Standard deviation is 4.4 pCi/g
Class 2	Standard deviation is 4 pCi/g
Class 3	Standard deviation is 0.2 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 6 (from nonparametric statistics).

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements is 425 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor is 3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 60% of the floor areas in the power reactor facility.

Number of Surface Activity Measurement:Indoor Areas and Exterior Paved Areas and Structures
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDCs are sufficiently below the DCGL, the number of samples in Class 1 areas will be determined by nonparametric statistics.

The number of surface activity measurements per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 6484. It is assumed that an additional 2302 (includes 550 measurements from exterior surfaces) measurements are collected based on scan results for a total of 8786 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

It should be recognized that the outdoor areas include both soil areas and exterior building surfaces and paved areas. It is general practice for surface activity measurements to be performed on outdoor surfaces such as exterior structures and paved areas.

Reference Areas

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Because Co-60 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is not needed.

For exterior paved areas, it is assumed that all measurements are performed on asphalt in a reference area. The number of measurements equals 6 (from nonparametric statistics).

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Co-60 is approximately 5 pCi/g.

Exterior paved surfaces and building surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor is 3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 40% of the exterior paved areas.

Number of Soil Samples

Because the NaI scan MDC is less than the DCGL (5 vs. 11 pCi/g), the number of samples in Class 1 areas will not be driven by the potential for small areas of elevated activity.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 270. It is assumed that an additional 117 samples are collected based on scan results for a total of 387 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1, 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.2.3 Survey Cost Estimate for 25 mrem/y

Surface Activity and Soil Concentration Dose Conversion Guideline Levels (DCGLs)

For the Appendix C concentration ratio for Co-60 to Cs-137, the gross activity DCGL for surface activity is 10,200 dpm/100 cm^2 total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the total beta surface activity. Under the same assumptions, the combined DCGL for Co-60 is 4.6 pCi/g. Compliance with the soil DCGL will be demonstrated based on the Co-60 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

Surface Activity
The expected background for beta surface activity measurements is 2,000 $\pm$ 600 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 6720 dpm/100 cm^2
Class 2	Standard deviation is 5400 dpm/100 cm^2
Class 3	Standard deviation is 600 dpm/100 cm^2

Soil Concentrations
Co-60 is not expected to be present in background.

Class 1	Standard deviation is 2.3 pCi/g
Class 2	Standard deviation is 2 pCi/g
Class 3	Standard deviation is 0.2 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 10 (from nonparametric statistics).

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements is 425 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor is 3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 60% of the floor areas in the power reactor facility.

Number of Surface Activity Measurement:Indoor Areas and Exterior Paved Areas and Structures
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDCs are sufficiently below the DCGL, the number of samples in Class 1 areas will be determined by nonparametric statistics.

The number of surface activity measurements per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 9355. It is assumed that an additional 2302 (includes 550 measurements from exterior surfaces) measurements are collected based on scan results for a total of 11,657 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

It should be recognized that the outdoor areas include both soil areas and exterior building surfaces and paved areas. It is general practice for surface activity measurements to be performed on outdoor surfaces such as exterior structures and paved areas.

Reference Areas

It is assumed that all background soil samples, if necessary, are collected from an off-site reference area. Because Co-60 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is not needed.

For exterior paved areas, it is assumed that all measurements are performed on asphalt in a reference area. The number of measurements equals 10 (from nonparametric statistics).

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Co-60 is approximately 5 pCi/g.

Exterior paved surfaces and building surfaces will be scanned with both a floor monitor (573 cm^2) and a 126 cm^2 gas proportional detector. The scan MDC for the floor monitor is 3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 40% of the exterior paved areas.

Number of Soil Samples

Because the NaI scan MDC is just above the DCGL (5 vs. 4.6 pCi/g), the number of samples in Class 1 areas may be determined based on the potential for small areas of elevated activity. The area factor is 1.1 and corresponds to an area of approximately 300 m^2. When this acceptable elevated area is divided into the survey unit area (2000 m^2), the number of samples based on hot spot potential is 7. It is very unlikely that the number of samples necessary to satisfy the hot spot potential is going to be the driver because the nonparametric statistics should require more than 7 samples per survey unit.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 270 (252 in Class 2 and 3 areas). It is assumed that an additional 117 samples are collected based on scan results for a total of 387 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1, 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.2.4 Survey Cost Estimate for 15 mrem/y

Surface Activity and Soil Concentration Dose Conversion Guideline Levels (DCGLs)

The DCGL for Co-60 is 5170 dpm/100 cm^2 and for Cs-137 is 13,600 dpm/100 cm^2. For the concentration ratio from Appendix C for Co-60 to Cs-137, the gross activity DCGL for surface activity is 6,130 dpm/100 cm^2 total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the total beta surface activity. The soil concentration DCGL is 3.0 pCi/g for Co-60 and 10.7 pCi/g for Cs-137. For the concentration ratio from Appendix C, the combined DCGL for Co-60 is 2.75 pCi/g. Compliance with the soil DCGL will be demonstrated based on the Co-60 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

The estimated standard deviations for surface activity and soil concentrations in survey units are determined for each area classification. In large part, the estimated standard deviations were based on results of past survey experience. A general guide for Class 1 areas, it was assumed that the ratio of the standard deviation (σ) to the DCGL (Δ) increased as the DCGL was lowered from 100 to 3 mrem/y. For example, for DCGLs at 100 and 60 mrem/y, σ/Δ is 40%; for DCGL at 25 mrem/y, σ/Δ is 50%; for DCGL at 15 mrem/y, σ/Δ is 60%; and for DCGL at 3 mrem/y, σ/Δ is 70%. The standard deviations for Class 2 areas were estimated to be approximately 50 to 95% of the Class 1 standard deviations. The standard deviations for Class 3 areas are assumed to be equal to the standard deviation of background—where the contaminant is not present in background and nuclide-specific measurements are performed, the standard deviation of background, and therefore the standard deviation of the Class 3 area, is assumed to be near zero.

<u>Surface Activity</u>
The expected background for beta surface activity measurements is 2,000 $\pm$ 600 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 3700 dpm/100 cm^2
Class 2	Standard deviation is 3000 dpm/100 cm^2
Class 3	Standard deviation is 600 dpm/100 cm^2

<u>Soil Concentrations</u>
Co-60 is not expected to be present in background.

Class 1	Standard deviation is 1.7 pCi/g
Class 2	Standard deviation is 1.3 pCi/g
Class 3	Standard deviation is 0.2 pCi/g

Indoor Areas

<u>Survey Unit Classification</u>

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 9 (from nonparametric statistics).

Class 1 areas include the floor and lower walls in the Containment, Auxiliary, Fuel, Turbine, RadWaste, and Other Buildings. A total of 77 survey units, measuring 70 to 279 m^2, for a total surface area of 8488 m^2 will be scanned.

Class 2 areas include the floor and lower walls in the Containment, Auxiliary, Fuel, Turbine, RadWaste, Control and Other Buildings. A total of 223 survey units, measuring 133 to 501 m^2, for a total surface area of 38,790 m^2 will be scanned.

Class 3 areas include the upper walls and ceilings in the Containment, Auxiliary, Fuel, Turbine, RadWaste, Control and Other Buildings. A total of 35 survey units, measuring 260 to 5729 m^2, for a total surface area of 6,000 m^2 will be scanned.

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements is 425 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor is 3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 60% of the floor areas in the power reactor facility.

Number of Surface Activity Measurement:Indoor Areas and Exterior Paved Areas and Structures
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDCs are sufficiently below the DCGL, the number of samples in Class 1 areas will be determined by nonparametric statistics.

The number of surface activity measurements per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 6718. It is assumed that an additional 2302 (includes 550 measurements from exterior surfaces) measurements are collected based on scan results for a total of 9020 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

It should be recognized that the outdoor areas include both soil areas and exterior building surfaces and paved areas. It is general practice for surface activity measurements to be performed on outdoor surfaces such as exterior structures and paved areas.

Survey Unit Classification

Reference Areas

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Because Co-60 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is not needed.

For exterior paved areas, it is assumed that all measurements are performed on asphalt in a reference area. The number of measurements equals 9 (from nonparametric statistics).

The Class 1 area includes 1 soil survey unit area of 2000 m^2, with a total soil scan area of 2000 m^2. No Class 1 areas have been identified for exterior paved surfaces or building exteriors.

Class 2 areas include 4 soil survey units, each measuring 4180 m^2, with a total scan surface area of 12,540 m^2. Class 2 areas for exterior paved surfaces or building exteriors include 10 survey units, each measuring 1000 m^2, with a total scan surface area of 7500 m^2.

Class 3 areas include 10 soil survey units, each measuring 5574 m^2, with a total scan surface area of 5574 m^2. Class 3 areas for exterior paved surfaces or building exteriors include 20 survey units, each measuring 10,000 m^2, with a total scan surface area of 20,000 m^2.

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Co-60 is approximately 5 pCi/g.

Exterior paved surfaces and building surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor is 3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 40% of the exterior paved areas.

Number of Soil Samples

Because the NaI scan MDC is greater than the DCGL (5 vs. 2.75 pCi/g), the number of samples in Class 1 areas will be driven by the potential for small areas of elevated activity. The area factor is 1.8 and corresponds to an area of approximately 20 m^2. When this acceptable elevated area is divided into the survey unit area (2000 m^2), the number of samples based on hot spot potential is 100, which is going to be the driver for class 1 areas because the nonparametric statistics will require fewer than 100 samples per survey unit.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 272 (252 in Class 2 and 3 areas). It is assumed that an additional 117 samples are collected based on scan results for a total of 469 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1, 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.2.5 Survey Cost Estimate for 3 mrem/y

Surface Activity and Soil Concentration DCGLs (Δ's)

For the Appendix C concentration ratio for Co-60 to Cs-137, the gross activity DCGL for surface activity is 1220 dpm/100 cm^2 total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the total beta surface activity. Under the same assumptions, the combined DCGL for Co-60 is 0.55 pCi/g. Compliance with the soil DCGL will be demonstrated based on the Co-60 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

Surface Activity
The expected background for beta surface activity measurements is 2,000 ± 600 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 1400 dpm/100 cm^2
Class 2	Standard deviation is 900 dpm/100 cm^2
Class 3	Standard deviation is 600 dpm/100 cm^2

Soil Concentrations
Co-60 is not expected to be present in background.

Class 1	Standard deviation is 0.39 pCi/g
Class 2	Standard deviation is 0.27 pCi/g
Class 3	Standard deviation is 0.2 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 45 (from nonparametric statistics).

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements is 425 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor is 3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 60% of the floor areas in the power reactor facility.

Number of Surface Activity Measurement:Indoor Areas and Exterior Paved Areas and Structures
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDC is greater than the DCGL (3600 vs 1220 dpm/100 cm^2), the number of samples in Class 1 areas may be determined based on the potential for small areas of elevated activity. The area factor is 3.0 and corresponds to an area of approximately 4 m^2. When this acceptable elevated area is divided into each survey unit area, the total number of samples based on hot spot potential is 2155.

The number of surface activity measurements per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 6494 (3822 from Class 2 and 3 areas). It is assumed that an additional 2302 (includes 550 measurements from exterior surfaces) measurements are collected based on scan results for a total of 8796 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

It should be recognized that the outdoor areas include both soil areas and exterior building surfaces and paved areas. It is general practice for surface activity measurements to be performed on outdoor surfaces such as exterior structures and paved areas.

Reference Areas

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Because Co-60 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is not needed.

For exterior paved areas, it is assumed that all measurements are performed on asphalt in a reference area. The number of measurements equals 45 (from nonparametric statistics).

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Co-60 is approximately 5 pCi/g.

Exterior paved surfaces and building surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor is

3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 40% of the exterior paved areas.

Number of Soil Samples

Because the NaI scan MDC is greater than the DCGL (5 vs. 0.55 pCi/g), the number of samples in Class 1 areas will be driven by the potential for small areas of elevated activity. The area factor is 9.1 and corresponds to an area of approximately 1 m^2. When this acceptable elevated area is divided into the survey unit area (2000 m^2), the number of samples based on hot spot potential is 2000, which is going to be the driver for class 1 areas because the nonparametric statistics will require fewer than 2000 samples per survey unit.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 273 (252 from Class 2 and 3 areas). It is assumed that an additional 77 samples are collected in Class 2 and 3 areas based on scan results for a total of 2329 soil samples. Because of the close sample spacing due to the potential small areas of elevated activity, it is assumed that no additional samples will be collected in Class 1 areas based on scan results. The number of samples based on scans will be assumed based on 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.3 Sealed Source Manufacturer Facility

The contaminants include Co-60 and Cs-137; assume that the radionuclide ratio of Co-60 to Cs-137 is 3:1.

D.5.3.1 Survey Cost Estimate for 100 mrem/y

Surface Activity and Soil Concentration DCGLs

For the concentration ratio of 3 to 1 presented in Appendix C for Co-60 to Cs-137, the gross activity DCGL for surface activity is 40,900 dpm/100 cm^2 total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the total beta surface activity. Under the same assumptions, the combined DCGL for Co-60 is 18.3 pCi/g. Compliance with the soil DCGL will be demonstrated based on the Co-60 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

Surface Activity
The expected background for beta surface activity measurements is 2,000 ± 600 dpm/100 cm^2 (1σ).

Class 1 Standard deviation is 17,000 dpm/100 cm^2

Class 2 Standard deviation is 10,000 dpm/100 cm^2
Class 3 Standard deviation is 600 dpm/100 cm^2

Soil Concentrations
Co-60 is not expected to be present in background.

Class 1 Standard deviation is 7.3 pCi/g
Class 2 Standard deviation is 7 pCi/g
Class 3 Standard deviation is 0.2 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 6 (from nonparametric statistics).

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements is 425 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor is 3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 80% of the floor areas.

Number of Surface Activity Measurements
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDCs are sufficiently below the DCGL, the number of samples in Class 1 areas will be determined by nonparametric statistics.

The number of surface activity measurements per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 226. It is assumed that an additional 52 measurements are collected based on scan results for a total of 278 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Because Co-60 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is not needed.

<u>Instrumentation for Surface Scans</u>

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Co-60 is approximately 5 pCi/g.

<u>Number of Soil Samples</u>

Because there are no Class 1 areas, there is no need to determine the number of samples based on the potential for small areas of elevated activity.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 54. It is assumed that an additional 13 samples are collected based on scan results for a total of 67 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1, 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.3.2 Survey Cost Estimate for 60 mrem/y

Surface Activity and Soil Concentration DCGLs

For the dose concentration ratio of Appendix C for Co-60 to Cs-137, the gross activity DCGL for surface activity is 24,500 dpm/100 cm^2 total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the total beta surface activity. Using the same assumptions, the combined DCGL for Co-60 is 11 pCi/g. Compliance with the soil DCGL will be demonstrated based on the Co-60 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

<u>Surface Activity</u>
The expected background for beta surface activity measurements is 2,000 ± 600 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 10,400 dpm/100 cm^2
Class 2	Standard deviation is 7500 dpm/100 cm^2
Class 3	Standard deviation is 600 dpm/100 cm^2

Soil Concentrations
Co-60 is not expected to be present in background.

Class 1	Standard deviation is 4.4 pCi/g
Class 2	Standard deviation is 4 pCi/g
Class 3	Standard deviation is 0.2 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 6 (from nonparametric statistics).

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements is 425 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor is 3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 80% of the floor areas.

Number of Surface Activity Measurements
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDCs are sufficiently below the DCGL, the number of samples in Class 1 areas will be determined by nonparametric statistics.

The number of surface activity measurements per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 234. It is assumed that an additional 52 measurements are collected based on scan results for a total of 286 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Because Co-60 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is not needed.

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Co-60 is approximately 5 pCi/g.

Number of Soil Samples

Because there are no Class 1 areas, there is no need to determine the number of samples based on the potential for small areas of elevated activity.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 54. It is assumed that an additional 13 samples are collected based on scan results for a total of 67 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1, 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.3.3 Survey Cost Estimate for 25 mrem/y

Surface Activity and Soil Concentration DCGLs (Δ's)

For the dose concentration ratio in Appendix C for Co-60 to Cs-137, the gross activity DCGL for surface activity is 10,200 dpm/100 cm^2 total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the total beta surface activity. Under the same assumptions, the combined DCGL for Co-60 is 4.6 pCi/g. Compliance with the soil DCGL will be demonstrated based on the Co-60 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

Surface Activity
The expected background for beta surface activity measurements is 2,000 $\pm$ 600 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 6720 dpm/100 cm^2
Class 2	Standard deviation is 5400 dpm/100 cm^2
Class 3	Standard deviation is 600 dpm/100 cm^2

Soil Concentrations
Co-60 is not expected to be present in background.

Class 1	Standard deviation is 2.3 pCi/g
Class 2	Standard deviation is 2 pCi/g
Class 3	Standard deviation is 0.2 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 10 (from nonparametric statistics).

<u>Instrumentation for Surface Activity Measurements and Scans</u>

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements is 425 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor is 3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 80% of the floor areas.

<u>Number of Surface Activity Measurements</u>
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDCs are sufficiently below the DCGL, the number of samples in Class 1 areas will be determined by nonparametric statistics.

The number of surface activity measurements per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 322. It is assumed that an additional 52 measurements are collected based on scan results for a total of 374 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Because Co-60 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is not needed.

<u>Instrumentation for Surface Scans</u>

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Co-60 is approximately 5 pCi/g.

Number of Soil Samples

Because there are no Class 1 areas, there is no need to determine the number of samples based on the potential for small areas of elevated activity.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 54. It is assumed that an additional 13 samples are collected based on scan results for a total of 67 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1, 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.3.4 Survey Cost Estimate for 15 mrem/y

Surface Activity and Soil Concentration DCGLs

The DCGL for Co-60 is 5170 dpm/100 cm^2 and for Cs-137 is 13,600 dpm/100 cm^2. Using the dose concentration ratio of Appendix C for Co-60 to Cs-137, the gross activity DCGL for surface activity is 6,130 dpm/100 cm^2 total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the total beta surface activity. The soil concentration DCGL is 3.0 pCi/g for Co-60 and 10.7 pCi/g for Cs-137. For the dose concentration ratio of Appendix C, the combined DCGL for Co-60 is 2.75 pCi/g. Compliance with the soil DCGL will be demonstrated based on the Co-60 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

The estimated standard deviations for surface activity and soil concentrations in survey units are determined for each area classification. In large part, the estimated standard deviations were based on results of past survey experience. A general guide for Class 1 areas, it was assumed that the ratio of the standard deviation (σ) to the DCGL (Δ) increased as the DCGL was lowered from 100 to 3 mrem/y. For example, for DCGLs at 100 and 60 mrem/y, σ/Δ is 40%; for DCGL at 25 mrem/y, σ/Δ is 50%; for DCGL at 15 mrem/y, σ/Δ is 60%; and for DCGL at 3 mrem/y, σ/Δ is 70%. The standard deviations for Class 2 areas were estimated to be approximately 50 to 95% of the Class 1 standard deviations. The standard deviations for Class 3 areas are assumed to be equal to the standard deviation of background—where the contaminant is not present in background and nuclide-specific measurements are performed, the standard deviation of background, and therefore the standard deviation of the Class 3 area, is assumed to be near zero.

Surface Activity
The expected background for beta surface activity measurements is 2,000 $\pm$ 600 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 3700 dpm/100 cm^2
Class 2	Standard deviation is 3000 dpm/100 cm^2
Class 3	Standard deviation is 600 dpm/100 cm^2

Soil Concentrations

Co-60 is not expected to be present in background.

Class 1	Standard deviation is 1.7 pCi/g
Class 2	Standard deviation is 1.3 pCi/g
Class 3	Standard deviation is 0.2 pCi/g

Indoor Areas

Survey Unit Classification

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 9 (from nonparametric statistics).

Class 1 areas include the Hot Cell and Hold-up Tank (HUT) room—all surfaces (floors, walls, and ceilings) in the Hot Cell and the HUT floor and lower walls are considered to be Class 1. It is assumed that the ventilation system has been removed from the facility. A total of 2 survey units, measuring 60 and 128 m^2, for a total surface area of 188 m^2 will be scanned.

Class 2 areas include the floor and lower walls in the loading dock, dry waste handling area, liquid waste handling area, Isotope Shop, Shielded Work room, and equipment area. The upper walls and ceiling in the HUT are considered to be Class 2. A total of 7 survey units, measuring 50 to 300 m^2, for a total surface area of 736 m^2, will be scanned.

Class 3 areas consist of the remaining surfaces—floors, walls, and ceilings—on the ground level, basement, and second level. The upper walls and ceilings in the Class 2 rooms are classified as Class 3 areas. A total of 4 survey units, measuring 803 to 1738 m^2, for a total surface area of 550 m^2, will be scanned.

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements is 425 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor is 3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 80% of the floor areas.

Number of Surface Activity Measurements
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDCs are sufficiently below the DCGL, the number of samples in Class 1 areas will be determined by nonparametric statistics.

The number of surface activity measurements per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 299. It is assumed that an additional 52 measurements are collected based on scan results for a total of 351 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Survey Unit Classification

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Because Co-60 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is not needed.

No Class 1 areas have been identified.

Class 2 areas include the Waste Storage Area and Stack Plume area. The stack plume area is calculated to cover the radial area 30 m from the stack and is biased toward the southern end of the facility. Class 2 areas include 2 survey units, measuring 270 and 2500 m^2, with a total scan surface area of 2078 m^2 .

The Class 3 area consists of the immediate area around the perimeter of the building and includes 1 survey unit measuring 300 m^2, with a total scan area of 30 m^2 .

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Co-60 is approximately 5 pCi/g.

Number of Soil Samples

Because there are no Class 1 areas, there is no need to determine the number of samples based on the potential for small areas of elevated activity.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 54. It is assumed that an additional 13 samples are collected based on scan results for a total of 67 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1, 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.3.5 Survey Cost Estimate for 3 mrem/y

Surface Activity and Soil Concentration DCGLs

Using the Appendix C dose concentration ratio for Co-60 to Cs-137, the gross activity DCGL for surface activity is 1220 dpm/100 cm^2 total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the total beta surface activity. Using the same assumptions, the combined DCGL for Co-60 is 0.55 pCi/g. Compliance with the soil DCGL will be demonstrated based on the Co-60 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

Surface Activity
The expected background for beta surface activity measurements is 2,000 $\pm$ 600 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 1400 dpm/100 cm^2
Class 2	Standard deviation is 900 dpm/100 cm^2
Class 3	Standard deviation is 600 dpm/100 cm^2

Soil Concentrations
Co-60 is not expected to be present in background.

Class 1	Standard deviation is 0.39 pCi/g
Class 2	Standard deviation is 0.27 pCi/g
Class 3	Standard deviation is 0.2 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 23 (from nonparametric statistics).

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements is 425 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126 cm^2 gas proportional detector. The scan MDC for the floor monitor is 3600 dpm/100 cm^2 and 2000 dpm/100 cm^2 for the gas proportional detector. Gamma scans will also be performed over approximately 80% of the floor areas.

<u>Number of Surface Activity Measurements</u>
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDC is greater than the DCGL (3600 vs 1220 dpm/100 cm^2), the number of samples in Class 1 areas may be determined based on the potential for small areas of elevated activity. The area factor is 3.0 and corresponds to an area of approximately 4 m^2. When this acceptable elevated area is divided into each survey unit area, the total number of samples based on hot spot potential is 47.

The number of surface activity measurements per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 407 (215 from Class 2 and 3 areas). It is assumed that an additional 52 measurements are collected based on scan results for a total of 459 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Because Co-60 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is not needed.

<u>Instrumentation for Surface Scans</u>

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Co-60 is approximately 5 pCi/g.

<u>Number of Soil Samples</u>

Because there are no Class 1 areas, there is no need to determine the number of samples based on the potential for small areas of elevated activity.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 54. It is assumed that an additional 13 samples are collected based on scan results for a total of 67 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1, 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.4 Uranium Fuel Fabrication Facility

The contaminant is low enriched uranium (3% enriched U-235 by weight); the radionuclides of concern are U-238, U-235, and U-234.

D.5.4.1 Survey Cost Estimate for 100 mrem/y

Surface Activity and Soil Concentration DCGLs

The DCGL for 3% enriched uranium is 4,190 dpm/100 cm^2 for total alpha and 1,500 dpm/100 cm^2 for total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the alpha surface activity. The soil concentration DCGL is 18.9 pCi/g for U-238, 4.7 pCi/g for U-235, and 94.4 pCi/g for U-234—for a total U DCGL of 118 pCi/g. Compliance with the soil DCGL will be demonstrated based on the U-235 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

<u>Surface Activity</u>
The expected background for alpha surface activity measurements is 63 $\pm$ 30 dpm/100 cm^2 (1σ).

Class 1 Standard deviation is 1700 dpm/100 cm^2
Class 2 Standard deviation is 1200 dpm/100 cm^2
Class 3 Standard deviation is 30 dpm/100 cm^2

<u>Soil Concentrations</u>
The expected background concentration for U-235 in soil is 0.05 $\pm$ 0.03 pCi/g (1σ).

Class 1 Standard deviation is 1.9 pCi/g
Class 2 Standard deviation is 1.5 pCi/g
Class 3 Standard deviation is 0.03 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 6 (from nonparametric statistics).

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements for alpha activity is 130 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor for alpha is 400 dpm/100 cm^2 and 260 dpm/100 cm^2 for the gas proportional detector. Surface scans for beta activity will be performed in the same areas as alpha scans, but beta scans will not be used for correlating the scan MDC and hot spot sampling design. Gamma scans will also be performed over approximately 50% of the floor areas.

Number of Surface Activity Measurements
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDCs are sufficiently below the DCGL, the number of samples in Class 1 areas is determined by nonparametric statistics.

The number of surface activity measurements per survey unit for each classification based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 3684. It is assumed that an additional 1777 measurements are collected based on scan results for a total of 5461 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Since U-235 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is needed. (It should be noted that to measure U-235 at background levels with a gamma spectrometer will require long counts, e.g., greater than 4 hours). The number of measurements equals 6.

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for low enriched uranium is 75 pCi/g.

Number of Soil Samples

Because the NaI scan MDC is less than the DCGL (75 vs. 118 pCi/g), the number of samples in Class 1 areas will not be driven by the potential for small areas of elevated activity.

The number of soil samples per survey unit, for each classification, based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 475. It is assumed that an additional 574 samples are collected based on scan results for a total of 1049 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1, 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.4.2 Survey Cost Estimate for 60 mrem/y

Surface Activity and Soil Concentration DCGLs

The DCGL for 3% enriched uranium is 2,510 dpm/100 cm^2 for total alpha and 900 dpm/100 cm^2 for total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the alpha surface activity. The soil concentration DCGL is 11.3 pCi/g for U-238, 2.8 pCi/g for U-235, and 56.6 pCi/g for U-234—for a total U DCGL of 70.8 pCi/g. Compliance with the soil DCGL will be demonstrated based on the U-235 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

Surface Activity
The expected background for alpha surface activity measurements is 63 $\pm$ 30 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 1030 dpm/100 cm^2
Class 2	Standard deviation is 800 dpm/100 cm^2
Class 3	Standard deviation is 30 dpm/100 cm^2

Soil Concentrations
The expected background concentration for U-235 in soil is 0.05 $\pm$ 0.03 pCi/g (1σ).

Class 1	Standard deviation is 1.1 pCi/g
Class 2	Standard deviation is 1.0 pCi/g
Class 3	Standard deviation is 0.03 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 6 (from nonparametric statistics).

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements for alpha activity is 130 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor for alpha is 400 dpm/100 cm^2 and 260 dpm/100 cm^2 for the gas proportional detector. Surface scans for beta activity will be performed in the same areas as alpha scans, but beta scans will not be used for correlating the scan MDC and hot spot sampling design. Gamma scans will be performed over approximately 50% of floor areas.

Number of Surface Activity Measurements
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDCs are sufficiently below the DCGL, the number of samples in Class 1 areas is determined by nonparametric statistics.

The number of surface activity measurements per survey unit for each classification based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 3731. It is assumed that an additional 1777 measurements are collected based on scan results for a total of 5508 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Since U-235 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is needed. (It should be noted that to measure U-235 at background levels with a gamma spectrometer will require long counts, e.g., greater than 4 hours). The number of measurements equals 6.

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for low enriched uranium is 75 pCi/g.

Number of Soil Samples

Because the NaI scan MDC is slightly greater than the DCGL (75 vs. 70.8 pCi/g), the number of samples in Class 1 areas is likely not driven by the potential for small areas of elevated activity. The area factor is 1.07 and corresponds to an area of approximately 1,500 m^2. When this acceptable elevated area is divided into each survey unit area (2,183 m^2), the number of samples based on hot spot potential is 2 per survey unit. It is very unlikely that the number of samples necessary to satisfy the hot spot potential is going to be the driver because the nonparametric statistics should require more than 2 samples per survey unit. The total number of samples necessary to satisfy the potential for small areas of elevated activity is 12.

The number of soil samples per survey unit, for each classification, based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 490 (357 in Class 2 and 3 areas). It is assumed that an additional 574 samples are collected based on scan results for a total of 1064 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1, 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.4.3 Survey Cost Estimate for 25 mrem/y

Surface Activity and Soil Concentration DCGLs

The DCGL for 3% enriched uranium is 1,050 dpm/100 cm^2 for total alpha and 375 dpm/100 cm^2 for total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the alpha surface activity. The soil concentration DCGL is 4.7 pCi/g for U-238, 1.2 pCi/g for U-235, and 23.7 pCi/g for U-234—for a total U DCGL of 29.6 pCi/g. Compliance with the soil DCGL will be demonstrated based on the U-235 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

Surface Activity

The expected background for alpha surface activity measurements is 63 ± 30 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 500 dpm/100 cm^2
Class 2	Standard deviation is 400 dpm/100 cm^2
Class 3	Standard deviation is 30 dpm/100 cm^2

Soil Concentrations

The expected background concentration for U-235 in soil is 0.05 $\pm$ 0.03 pCi/g (1σ).

Class 1	Standard deviation is 0.6 pCi/g
Class 2	Standard deviation is 0.5 pCi/g
Class 3	Standard deviation is 0.03 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 7 (from nonparametric statistics).

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements for alpha activity is 130 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor for alpha is 400 dpm/100 cm^2 and 260 dpm/100 cm^2 for the gas proportional detector. Surface scans for beta activity will be performed in the same areas as alpha scans, but beta scans will not be used for correlating the scan MDC and hot spot sampling design. Gamma scans will also be performed over approximately 50% of the floor areas.

Number of Surface Activity Measurements
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDCs are sufficiently below the DCGL, the number of samples in Class 1 areas is determined by nonparametric statistics.

The number of surface activity measurements per survey unit for each classification based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 4177. It is assumed that an additional 1777 measurements are collected based on scan results for a total of 5954 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Since U-235 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is needed. (It should be noted that to measure U-235 at background levels with a gamma spectrometer will require long counts, e.g., greater than 4 hours). The number of measurements equals 7.

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for low enriched uranium is 75 pCi/g.

Number of Soil Samples

Because the NaI scan MDC is greater than the DCGL (75 vs. 29.6 pCi/g), the number of samples in Class 1 areas is likely not driven by the potential for small areas of elevated activity. The area factor is 2.5 and corresponds to an area of approximately 500 m^2. When this acceptable elevated area is divided into each survey unit area (2,183 m^2), the number of samples based on hot spot potential is 5 per survey unit. It is very unlikely that the number of samples necessary to satisfy the hot spot potential is going to be the driver because the nonparametric statistics should require more than 5 samples per survey unit. The total number of samples necessary to satisfy the potential for small areas of elevated activity is 30.

The number of soil samples per survey unit, for each classification, based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 553 (388 in Class 2 and 3 areas). It is assumed that an additional 574 samples are collected based on scan results for a total of 1127 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1, 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.4.4 Survey Cost Estimate for 15 mrem/y

Surface Activity and Soil Concentration DCGLs

The DCGL for 3% enriched uranium is 630 dpm/100 cm^2 for total alpha and 225 dpm/100 cm^2 for total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the alpha surface activity. The Level 2 soil concentration DCGL is 2.8 pCi/g for U-238, 0.71 pCi/g for U-235, and 14.2 pCi/g for U-234—for a total U DCGL of 17.7 pCi/g. Compliance with the soil DCGL will be demonstrated based on the U-235 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

The estimated standard deviations for surface activity and soil concentrations in survey units are determined for each area classification. In large part, the estimated standard deviations were based on results of past survey experience. A general guide for Class 1 areas, it was assumed that the ratio of the standard deviation (σ) to the DCGL (Δ) increased as the DCGL was lowered from 100 to 3 mrem/y. For example, for DCGLs at 100 and 60 mrem/y, σ/Δ is 40%; for DCGL at 25 mrem/y, σ/Δ is 50%; for DCGL at 15 mrem/y, σ/Δ is 60%; and for DCGL at 3 mrem/y, σ/Δ is 70%. The standard deviations for Class 2 areas were estimated to be approximately 50 to 95% of the Class 1 standard deviations. The standard deviations for Class 3 areas are assumed to be equal to the standard deviation of background—where the contaminant is not present in background and nuclide-specific measurements are performed, the standard deviation of background, and therefore the standard deviation of the Class 3 area, is assumed to be near zero.

Surface Activity
The expected background for alpha surface activity measurements is 63 ± 30 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 410 dpm/100 cm^2
Class 2	Standard deviation is 300 dpm/100 cm^2
Class 3	Standard deviation is 30 dpm/100 cm^2

Soil Concentrations
The expected background concentration for U-235 in soil is 0.05 ± 0.03 pCi/g (1σ).

Class 1	Standard deviation is 0.45 pCi/g
Class 2	Standard deviation is 0.35 pCi/g
Class 3	Standard deviation is 0.03 pCi/g

Indoor Areas

Survey Unit Classification

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 10 (from nonparametric statistics).

Class 1 areas include the floors, walls, and ceilings in the process buildings. A total of 133 survey units, each measuring 100 m^2, for a total surface area of 13,300 m^2 will be scanned.

Class 2 areas include the floors, walls and ceilings in the process buildings. A total of 46 survey units, 50% measuring 500 m^2, and 50% measuring 642 m^2, for a total surface area of 19,843 m^2, will be scanned.

Class 3 areas consist of the upper walls and ceilings for the process buildings. A total of 5 survey units, each measuring 5472 m^2, for a total surface area of 2736 m^2, will be scanned.

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements for alpha activity is 130 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor for alpha is 400 dpm/100 cm^2 and 260 dpm/100 cm^2 for the gas proportional detector. Surface scans for beta activity will be performed in the same areas as alpha scans, but beta scans will not be used for correlating the scan MDC and hot spot sampling design. Gamma scans will also be performed over approximately 50% of the floor areas.

Number of Surface Activity Measurements
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDCs are sufficiently below the DCGL, the number of samples in Class 1 areas is determined by nonparametric statistics.

The number of surface activity measurements per survey unit for each classification based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 5696. It is assumed that an additional 1777 measurements are collected based on scan results for a total of 7473 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Survey Unit Classification

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Since U-235 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is needed. (It should be noted that to measure U-235 at background levels with a gamma spectrometer will require long counts, e.g., greater than 4 hours). The number of measurements equals 9.

Class 1 areas include a total of 6 survey units, each measuring 2183 m^2 , with a total surface area of 13,098 m^2 that will be scanned.

Class 2 areas include a total of 15 survey units, each measuring 4948 m^2, with a total scan surface area of 55,665 m^2.

Class 3 areas include a total of 5 survey units, each measuring 26,196 m^2, with a total scan surface area of 13,098 m^2.

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for low enriched uranium is 75 pCi/g.

Number of Soil Samples

Because the NaI scan MDC is greater than the DCGL (75 vs. 17.7 pCi/g), the number of samples in Class 1 areas may be driven by the potential for small areas of elevated activity. The area factor is 4.2 (considering the weighted area factor for the isotopic ratios of 3% enriched uranium) and corresponds to an area of approximately 300 m^2. When this acceptable elevated area is divided into each survey unit area (2183 m^2), the number of samples based on hot spot potential is 8 (rounding up), which is likely not going to be the driver because the nonparametric statistics should require more than 8 samples per survey unit. The total number of samples necessary to satisfy the potential for small areas of elevated activity is 48.

The number of soil samples per survey unit, for each classification, based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 643 (434 in Class 2 and 3 areas). It is assumed that an additional 574 samples are collected based on scan results for a total of 1217 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1, 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.4.5 Survey Cost Estimate for 3 mrem/y

Surface Activity and Soil Concentration DCGLs

The DCGL for 3% enriched uranium is 130 dpm/100 cm^2 for total alpha and 50 dpm/100 cm^2 for total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the alpha surface activity. The soil concentration DCGL is 0.57 pCi/g for U-238, 0.14 pCi/g for U-235, and 2.83 pCi/g for U-234—for a total U DCGL of 3.5 pCi/g. Compliance with the soil DCGL will be demonstrated based on the U-235 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

Surface Activity
The expected background for alpha surface activity measurements is 63 $\pm$ 30 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 110 dpm/100 cm^2
Class 2	Standard deviation is 80 dpm/100 cm^2
Class 3	Standard deviation is 30 dpm/100 cm^2

Soil Concentrations
The expected background concentration for U-235 in soil is 0.05 $\pm$ 0.03 pCi/g (1σ).

Class 1	Standard deviation is 0.1 pCi/g
Class 2	Standard deviation is 0.07 pCi/g
Class 3	Standard deviation is 0.03 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 19 (from nonparametric statistics).

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 5 minute measurements for alpha activity is 51 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor for alpha is 400 dpm/100 cm^2 and 260 dpm/100 cm^2 for the gas proportional detector. Surface scans for beta activity will be performed in the same areas as alpha scans, but beta scans will not be used for correlating the scan MDC and hot spot sampling design. Gamma scans will also be performed over approximately 50% of the floor areas.

Number of Surface Activity Measurements
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDC is greater than the DCGL (400 vs 130 dpm/100 cm^2), the number of samples in Class 1 areas may be determined based on the potential for small areas of elevated activity. The area factor is 3.1 and corresponds to an area of approximately 12 m^2. When this acceptable elevated area is divided into each survey unit area (100 m^2), the number of samples based on hot spot potential is 8. It is very unlikely that the number of samples necessary to satisfy the hot spot potential is going to be the driver because the nonparametric statistics should require more than 8 samples per survey unit. The total number of samples necessary to satisfy the potential for small areas of elevated activity is 1064.

The number of surface activity measurements per survey unit for each classification based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 4416 (802 from Class 2 and 3 areas). It is assumed that an additional 1777 measurements are collected based on scan results for a total of 6193 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Since U-235 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is needed. (It should be noted that to measure U-235 at background levels with a gamma spectrometer will require long counts, e.g., greater than 4 hours). The number of measurements equals 11.

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for low enriched uranium is 75 pCi/g.

Number of Soil Samples

Because the NaI scan MDC is significantly greater than the DCGL (75 vs. 3.5 pCi/g), the number of samples in Class 1 areas will be driven by the potential for small areas of elevated activity. The area factor is 21.4 and corresponds to an area of approximately 8 m^2. When this acceptable elevated area is divided into each survey unit area (2,183 m^2), the number of samples based on hot spot potential is 273 per survey unit. The total number of samples necessary to satisfy the potential for small areas of elevated activity is 1638.

The number of soil samples per survey unit, for each classification, based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 527 (286 in Class 2 and 3 areas). It is assumed that an additional 574 samples are collected based on scan results for a total of 2509 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1, 1 additional sample per 200 m^2 of scanned area in Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.5 Rare Metal Extraction Facility

The contaminants are Th-232 and Ra-226—both assumed to be in secular equilibrium with their progeny.

D.5.5.1 Survey Cost Estimate for 100 mrem/y

Surface Activity and Soil Concentration DCGLs

The DCGL for Th-232 is 2,320 dpm/100 cm^2 for total alpha and 1550 dpm/100 cm^2 for total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the alpha surface activity. The soil concentration DCGL is 5.7 pCi/g for Th-232 and 3.3 pCi/g for Ra-226. Compliance with the soil DCGL will be demonstrated based on the Th-232 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

Surface Activity
The expected background for alpha surface activity measurements is 63 $\pm$ 30 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 960 dpm/100 cm^2
Class 2	Standard deviation is 800 dpm/100 cm^2
Class 3	Standard deviation is 30 dpm/100 cm^2

Soil Concentrations
The expected background concentration for Th-232 in soil is 1.0 $\pm$ 0.4 pCi/g (1σ).

Class 1	Standard deviation is 2.7 pCi/g
Class 2	Standard deviation is 2 pCi/g
Class 3	Standard deviation is 0.4 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 6 (from nonparametric statistics).

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements for alpha activity is 130 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor for alpha is 400 dpm/100 cm^2 and 260 dpm/100 cm^2 for the gas proportional detector. Surface scans for beta activity will be performed in the same areas as alpha scans, but beta scans will not be used for correlating the scan MDC and hot spot sampling design. Gamma scans will also be performed over approximately 50% of the floor areas.

<u>Number of Surface Activity Measurements</u>
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDC is less than the DCGL (400 vs 2320 dpm/100 cm^2), the number of samples in Class 1 areas will not be determined based on the potential for small areas of elevated activity.

The number of surface activity measurements per survey unit for each classification based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 2929. It is assumed that an additional 1051 measurements are collected based on scan results for a total of 3980 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Since Th-232 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is needed. The number of measurements equals 7.

<u>Instrumentation for Surface Scans</u>

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Th-232 is 5 pCi/g.

<u>Number of Soil Samples</u>

Because the NaI scan MDC is less than the DCGL (5 vs. 5.7 pCi/g), the number of samples in Class 1 areas will not be driven by the potential for small areas of elevated activity.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 173. It is assumed that an additional 197 samples are collected based on scan results for a total of 370 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1 and Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.5.2 Survey Cost Estimate for 60 mrem/y

Surface Activity and Soil Concentration DCGLs

The DCGL for Th-232 is 1,390 dpm/100 cm^2 for total alpha and 930 dpm/100 cm^2 for total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the alpha surface activity. The soil concentration DCGL is 3.4 pCi/g for Th-232 and 2 pCi/g for Ra-226. Compliance with the soil DCGL will be demonstrated based on the Th-232 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

Surface Activity
The expected background for alpha surface activity measurements is 63 ± 30 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 590 dpm/100 cm^2
Class 2	Standard deviation is 500 dpm/100 cm^2
Class 3	Standard deviation is 30 dpm/100 cm^2

Soil Concentrations
The expected background concentration for Th-232 in soil is 1.0 ± 0.4 pCi/g (1σ).

Class 1	Standard deviation is 1.8 pCi/g
Class 2	Standard deviation is 1.5 pCi/g
Class 3	Standard deviation is 0.4 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 6 (from nonparametric statistics).

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements for alpha activity is 130 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor for alpha is 400 dpm/100 cm^2

and 260 dpm/100 cm^2 for the gas proportional detector. Surface scans for beta activity will be performed in the same areas as alpha scans, but beta scans will not be used for correlating the scan MDC and hot spot sampling design. Gamma scans will also be performed over approximately 50% of the floor areas.

Number of Surface Activity Measurements
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDC is less than the DCGL (400 vs 1390 dpm/100 cm^2), the number of samples in Class 1 areas will not be determined based on the potential for small areas of elevated activity.

The number of surface activity measurements per survey unit for each classification based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 2987. It is assumed that an additional 1051 measurements are collected based on scan results for a total of 4038 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Since Th-232 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is needed. The number of measurements equals 8.

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Th-232 is 5 pCi/g.

Number of Soil Samples

Because the NaI scan MDC is greater than the DCGL (5 vs. 3.4 pCi/g), the number of samples in Class 1 areas may be driven by the potential for small areas of elevated activity. The area factor is 1.5 and corresponds to an area of approximately 300 m^2. When this acceptable elevated area is divided into each survey unit area (2324 m^2), the number of samples based on hot spot potential is 8 per survey unit. It is very unlikely that the number of samples necessary to satisfy the hot spot potential is going to be the driver because the nonparametric statistics should require more than 8 samples per survey unit. The total number of samples necessary to satisfy the potential for small areas of elevated activity is 32.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 190 (73 in class 2 and 3 areas). It is assumed that an additional 197 samples are collected based on scan results for a total of 387 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1 and Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.5.3 Survey Cost Estimate for 25 mrem/y

Surface Activity and Soil Concentration DCGLs

The DCGL for Th-232 is 580 dpm/100 cm^2 for total alpha and 390 dpm/100 cm^2 for total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the alpha surface activity. The soil concentration DCGL is 1.4 pCi/g for Th-232 and 0.84 pCi/g for Ra-226. Compliance with the soil DCGL will be demonstrated based on the Th-232 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

Surface Activity
The expected background for alpha surface activity measurements is 63 $\pm$ 30 dpm/100 cm^2 (1σ).

Class 1 Standard deviation is 320 dpm/100 cm^2
Class 2 Standard deviation is 300 dpm/100 cm^2
Class 3 Standard deviation is 30 dpm/100 cm^2

Soil Concentrations
The expected background concentration for Th-232 in soil is 1.0 $\pm$ 0.4 pCi/g (1σ).

Class 1 Standard deviation is 1.1 pCi/g
Class 2 Standard deviation is 1 pCi/g
Class 3 Standard deviation is 0.4 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 8 (from nonparametric statistics).

Instrumentation for Surface Activity Measurements and Scans

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements for alpha activity is 130 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor for alpha is 400 dpm/100 cm^2 and 260 dpm/100 cm^2 for the gas proportional detector. Surface scans for beta activity will be performed in the same areas as alpha scans, but beta scans will not be used for correlating the scan MDC and hot spot sampling design. Gamma scans will also be performed over approximately 50% of the floor areas.

<u>Number of Surface Activity Measurements</u>
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDC is less than the DCGL (400 vs 580 dpm/100 cm^2), the number of samples in Class 1 areas will not be determined based on the potential for small areas of elevated activity.

The number of surface activity measurements per survey unit for each classification based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 3865. It is assumed that an additional 1051 measurements are collected based on scan results for a total of 4916 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Since Th-232 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is needed. The number of measurements equals 13.

<u>Instrumentation for Surface Scans</u>

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Th-232 is 5 pCi/g.

<u>Number of Soil Samples</u>

Because the NaI scan MDC is greater than the DCGL (5 vs. 1.4 pCi/g), the number of samples in Class 1 areas will be driven by the potential for small areas of elevated activity. The area factor is 3.6 and corresponds to an area of approximately 8 m^2. When this acceptable elevated area is divided into each survey unit area (2324 m^2), the number of samples based on hot spot potential is 290 per survey unit. The total number of samples necessary to satisfy the potential for small areas of elevated activity is 1160.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 288 (93 in Class 2 and 3 areas). It is assumed that an additional 197 samples are collected based on scan results for a total of 1463 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1 and Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.5.4 Survey Cost Estimate for 15 mrem/y

Surface Activity and Soil Concentration DCGLs

The DCGL for Th-232 is 348 dpm/100 cm^2 for total alpha and 232 dpm/100 cm^2 for total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the alpha surface activity. The soil concentration DCGL is 0.85 pCi/g for Th-232 and 0.5 pCi/g for Ra-226. Compliance with the soil DCGL will be demonstrated based on the Th-232 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

The estimated standard deviations for surface activity and soil concentrations in survey units are determined for each area classification. In large part, the estimated standard deviations were based on results of past survey experience. A general guide for Class 1 areas, it was assumed that the ratio of the standard deviation (σ) to the DCGL (Δ) increased as the DCGL was lowered from 100 to 3 mrem/y. For example, for DCGLs at 100 and 60 mrem/y, σ/Δ is 40%; for DCGL at 25 mrem/y, σ/Δ is 50%; for DCGL at 15 mrem/y, σ/Δ is 60%; and for DCGL at 3 mrem/y, σ/Δ is 70%. The standard deviations for Class 2 areas were estimated to be approximately 50 to 95% of the Class 1 standard deviations. The standard deviations for Class 3 areas are assumed to be equal to the standard deviation of background—where the contaminant is not present in background and nuclide-specific measurements are performed, the standard deviation of background, and therefore the standard deviation of the Class 3 area, is assumed to be near zero.

Surface Activity
The expected background for alpha surface activity measurements is 63 ± 30 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 240 dpm/100 cm^2
Class 2	Standard deviation is 190 dpm/100 cm^2
Class 3	Standard deviation is 30 dpm/100 cm^2

Soil Concentrations
The expected background concentration for Th-232 in soil is 1.0 ± 0.4 pCi/g (1σ).

Class 1	Standard deviation is 0.91 pCi/g
Class 2	Standard deviation is 0.82 pCi/g

Class 3 Standard deviation is 0.4 pCi/g

Indoor Areas

<u>Survey Unit Classification</u>

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 10 (from nonparametric statistics).

Class 1 areas include the floors and walls in the process and miscellaneous buildings. A total of 78 survey units, each measuring 62 to 93 m^2, with a total surface area of 7161 m^2, will be scanned.

Class 2 areas include the floors and lower walls in the process and miscellaneous buildings. A total of 58 survey units, each 62 to 517 m^2, with a total surface area of 14,530 m^2, will be scanned.

Class 3 areas consist of the upper walls and ceilings for the process buildings and all surfaces in the outbuildings. A total of 13 survey units, each measuring 496 to 4647 m^2, with a total surface area of 1900 m^2, will be scanned.

<u>Instrumentation for Surface Activity Measurements and Scans</u>

Surface activity measurements will be performed with a gas proportional detector; the MDC for 1 minute measurements for alpha activity is 130 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor for alpha is 400 dpm/100 cm^2 and 260 dpm/100 cm^2 for the gas proportional detector. Surface scans for beta activity will be performed in the same areas as alpha scans, but beta scans will not be used for correlating the scan MDC and hot spot sampling design. Gamma scans will also be performed over approximately 50% of the floor areas.

<u>Number of Surface Activity Measurements</u>
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDC is just above the DCGL (400 vs 348 dpm/100 cm^2), the number of samples in Class 1 areas may be determined based on the potential for small areas of elevated activity. The area factor is 1.2 and corresponds to an area of approximately 25 m^2. When this acceptable elevated area is divided into each survey unit area, the total number of samples based on hot spot potential is 319. It is very unlikely that the number of samples necessary to satisfy the hot spot potential is going to be the driver because the nonparametric statistics should require more than 4 samples per survey unit.

The number of surface activity measurements per survey unit for each classification based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 4491 (1671 in Class 2 and 3 areas). It is assumed that an additional 1051 measurements are collected based on scan results for a total of 5542 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Survey Unit Classification

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an offsite reference area. Since Th-232 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is needed. The number of measurements equals 21.

Class 1 areas include a total of 4 survey units, each measuring 2324 m^2, with a total surface area of 9,296 m^2 that will be scanned.

Class 2 areas include 1 survey unit, measuring 929 m^2, with a total scan surface area of 697 m^2 .

Class 3 areas include a total of 4 survey units, each measuring 3718 to 7435 m^2, with a total scan surface area of 2600 m^2.

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Th-232 is 5 pCi/g.

Number of Soil Samples

Because the NaI scan MDC is greater than the DCGL (5 vs. 0.85 pCi/g), the number of samples in Class 1 areas may be driven by the potential for small areas of elevated activity. The area factor is 5.9 and corresponds to an area of approximately 3 m^2. When this acceptable elevated area is divided into each survey unit area (2324 m^2), the number of samples based on hot spot potential is 775, which is going to be the driver for class 1 areas because the nonparametric statistics will require fewer than 775 samples per survey unit. The total number of samples necessary to satisfy the potential for small areas of elevated activity is 3100.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 422 (136 in Class 2 and 3 areas). It is assumed that an additional 197 samples are collected based on scan results for a total of 3454 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1 and Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.5.5.5 Survey Cost Estimate for 3 mrem/y

Surface Activity and Soil Concentration DCGLs

The DCGL for Th-232 is 70 dpm/100 cm^2 for total alpha and 47 dpm/100 cm^2 for total beta. Compliance with the surface activity DCGL will be demonstrated by measuring the alpha surface activity. The soil concentration DCGL is 0.17 pCi/g for Th-232 and 0.1 pCi/g for Ra-226. Compliance with the soil DCGL will be demonstrated based on the Th-232 concentration as measured by gamma spectrometry.

Surface Activity and Soil Concentration Backgrounds and Standard Deviations (σ's)

<u>Surface Activity</u>
The expected background for alpha surface activity measurements is 63 $\pm$ 30 dpm/100 cm^2 (1σ).

Class 1	Standard deviation is 80 dpm/100 cm^2
Class 2	Standard deviation is 50 dpm/100 cm^2
Class 3	Standard deviation is 30 dpm/100 cm^2

<u>Soil Concentrations</u>
The expected background concentration for Th-232 in soil is 1.0 $\pm$ 0.4 pCi/g (1σ).

Class 1	Standard deviation is 0.52 pCi/g
Class 2	Standard deviation is 0.48 pCi/g
Class 3	Standard deviation is 0.4 pCi/g

Indoor Areas

Reference Area

It is assumed that all measurements are performed on concrete in a reference area. The number of measurements equals 38 (from nonparametric statistics).

<u>Instrumentation for Surface Activity Measurements and Scans</u>

Surface activity measurements will be performed with a gas proportional detector; the MDC for 10 minute measurements for alpha activity is 35 dpm/100 cm^2.

The surfaces will be scanned with both a floor monitor (573 cm^2) and a 126-cm^2 gas proportional detector. The scan MDC for the floor monitor for alpha is 400 dpm/100 cm^2 and 260 dpm/100 cm^2 for the gas proportional detector. Surface scans for beta activity will be performed in the same areas as alpha scans, but beta scans will not be used for correlating the scan MDC and hot spot sampling design. Gamma scans will also be performed over approximately 50% of the floor areas.

Number of Surface Activity Measurements
(based on nonparametric stats or driven by hot spot potential)

Because the scan MDC is greater than the DCGL (400 vs 70 dpm/100 cm^2), the number of samples in Class 1 areas may be determined based on the potential for small areas of elevated activity. The area factor is 5.7 and corresponds to an area of approximately 6 m^2. When this acceptable elevated area is divided into each survey unit area, the total number of samples based on hot spot potential is 1268.

The number of surface activity measurements per survey unit for each classification based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 3907 (975 in Class 2 and 3). It is assumed that an additional 1051 measurements are collected based on scan results for a total of 4958 direct surface activity measurements. The number of measurements based on scans will be assumed based on 1 additional measurement per 10 m^2 of scanned area in Class 1, 1 additional measurement per 50 m^2 of scanned area in Class 2 and Class 3 areas.

Outdoor Areas

Reference Area

It is assumed that all background soil samples, if necessary, are collected from an off-site reference area. Since Th-232 measurements will be used to demonstrate compliance with criteria for outdoor areas, a reference area is needed. The number of measurements equals 236.

Instrumentation for Surface Scans

Soil surfaces will be scanned with a NaI scintillation detector. The scan MDC for Th-232 is 5 pCi/g.

Number of Soil Samples

Because the NaI scan MDC is greater than the DCGL (5 vs. 0.17 pCi/g), the number of samples in Class 1 areas will be driven by the potential for small areas of elevated activity. The area factor is 29.4 and corresponds to an area less than 1 m^2. When this acceptable elevated area is divided into each survey unit area (2324 m^2), the number of samples based on hot spot potential is 2324 per survey unit. The total number of samples necessary to satisfy the potential for small areas of elevated activity is 9296.

The number of soil samples per survey unit based on nonparametric statistics—considering both the Wilcoxon Rank Sum and Quantile tests—is 2404 (1161 in Class 2 and 3 areas). It is assumed that an additional 197 samples are collected based on scan results for a total of 10,890 soil samples. The number of samples based on scans will be assumed based on 1 additional sample per 50 m^2 of scanned area in Class 1 and Class 2 areas, and 1 additional sample per 400 m^2 of scanned area in Class 3 areas.

D.6 Results

A breakdown of survey costs for each reference facility is provided in Tables D.1.1 through D.4.6. In Figures D.1 through 4, the increasing total cost is shown as a function of decreasing residual dose criteria for each reference facility. For the reference facilities, the increase in cost becomes apparent at 3 mrem/y and below.

D.7 Relative Costs of Conducting Other Radiological Surveys for Decommissioning

As part of the decommissioning process, the cost of surveys other than that of the final status survey should be considered; mainly, that associated with scoping, characterization, remediation control, and confirmatory surveys (MARS, 1996). The scoping survey provides preliminary data used in planning the next phases of the decommissioning activities. It is typically a 1-5% effort compared to that of a final survey.

The characterization survey may involve the greatest effort. In planning a characterization survey, it should be remembered that some of the survey data that are below the guideline values and are from unremediated areas may not have to be duplicated and could later be used as final survey results. However, without the specific condition of a given facility, it is difficult to estimate how much effort would be needed for a radiological characterization of that site. If there is extensive subsurface soil contamination, the cost of site characterization could be several times higher than that of a final survey. On the other hand, if contamination is limited to indoor areas, or if the outdoor soil contamination is only in the surface soil, the cost of radiological characterization could be less than or comparable to that of the final survey. Therefore, the cost of characterization surveys can range from 0.5 to 10 times that of the final survey or fall outside of this range. It should be noted that a poor characterization of a facility could result in a much more costly remediation effort.

The remediation control survey is intended to monitor the effectiveness of remediation efforts while they are in progress. It also assures that the workers, the public, and the environment are adequately protected against exposures to radiation and radioactive materials arising from remediation activities. It is estimated that remediation control surveys involve a 10-20% effort compared to that of a final survey. A confirmatory survey is performed to evaluate the adequacy and accuracy of the licensee's final survey and is typically a 5-15% effort compared to that of a final survey.

Although it is difficult to develop exact estimates, it is expected that the cost associated with each of these radiological surveys will increase at the low residual dose criteria. That increase in cost as a function of decreasing residual dose criteria is expected to follow a pattern similar to that of the final survey. Tables D.1.6, D.2.6, D.3.6, and D.4.6 illustrate possible costs of these surveys compared to that of the final survey.

D.8 References

MARS. 1996. Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). Draft for Public Comment. December 1996.

NRC. 1992a. Manual for Conducting Radiological Surveys in Support of License Termination, Draft Report. NUREG/CR-5849. Oak Ridge Associated Universities.

NRC. 1992b. Residual Radioactive Contamination From Decommissioning, Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent, Final Report. NUREG/CR-5512, Vol. 1. Battelle Memorial Institute, Pacific Northwest Laboratory.

NRC. 1995a. A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys. NUREG-1505. U.S. Nuclear Regulatory Commission, Washington, D.C.

NRC. 1995b. Measurement Methods for Radiological Surveys in Support of New Decommissioning Criteria. NUREG-1506. U.S. Nuclear Regulatory Commission, Washington, D.C.

NRC. 1995c. Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions. NUREG-1507. U.S. Nuclear Regulatory Commission, Washington, D.C.

Table D.1.1

Reference Facility: Power Reactor

Residual Dose Limit 100 mrem/yr	Structure Surveys Class 1 Affected/Non-Uniform	Structure Surveys Class 2 Affected/Uniform	Structure Surveys Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Uniform	Land Surveys Class 2 Affected/Uniform	Land Surveys Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	42000	2000	18720	55740
Total area (m^2) - Floor/Lower Wall	8488	51723	0	na	na	na
Total area (m^2) - U.Wall/Ceiling	0	10000	260015	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	2000	12540	5574
Scan area (m^2) - Floor/Lower Wall	8488	38792.25	0	na	na	na
Scan area (m^2) - U.Wall/Ceiling	0	7500	26001.5	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	5.31	32.33	70.00	3.333333333	20.9	9.29
(beta) Floors & L. Walls	28.29	129.31	0.00	na	na	na
(beta) U. Walls & Ceilings	0.00	50.00	173.34	na	na	na
Direct Measurements						
Number of Measurements	2551	5129	872	na	na	na
Survey Time (hr)	127.55	256.45	43.60	na	na	na
Soil Sampling						
No. of Samples	na	na	na	58	135	194
Collection Time (hr)	na	na	na	5.80	13.50	19.40
Survey Time						
Subtotal (hours)	181	468	287	9	34	29
Adjustment A - 25% (daily checks, breaks, repeats)	40	117	72	2	9	7
Adjustment B - 15% (data review)	24	70	43	1	5	4
Total (hours)	226	655	402	13	48	40
Analytical Cost ($)						
Soil Samples	na	na	na	4350	10125	14550
Smear Samples	944	1898	323	na	na	na
Subtotal	944	1898	323	4350	10125	14550
Final Survey Cost ($)						
Labor	8307	24129	14791	471	1773	1479
Analytical	944	1898	323	4350	10125	14550
Subtotal	9251	26027	15114	4821	11898	16029
Sup. Data Review/ Report Preparation	25377					
Total Cost - Final Survey	108518					
Other Survey Costs ($)						
Gridding - Indoor	173544					
Gridding - Outdoor	6452					
Scoping Survey	5426					
Characterization Survey	108518					
Remed. Control Survey	10852					
Confirmatory Survey	5426					
TOTAL SURVEY COSTS	$418,731					

Table D.1.2

Reference Facility: <u>Power Reactor</u>

	Structure Surveys			Land Surveys		
Residual Dose Limit 60 mrem/yr	Class 1 Affected/Non-Uniform	Class 2 Affected/Uniform	Class 3 Unaffected	Class 1 Affected/Non-Uniform	Class 2 Affected/Uniform	Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	42000	2000	16720	55740
Total area (m^2) - Floor/Lower Wall	8488	51723	0	na	na	na
Total area (m^2) - U.Wall/Ceiling	0	10000	260015	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	2000	12540	5574
Scan area (m^2) - Floor/Lower Wall	8488	38792.25	0	na	na	na
Scan area (m^2) - U.Wall/Ceiling	0	7500	26001.5	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	5.31	32.33	70.00	3.333333333	20.9	9.29
(beta) Floors & L. Walls	28.29	129.31	0.00	na	na	na
(beta) U. Walls & Ceilings	0.00	50.00	173.34	na	na	na
Direct Measurements						
Number of Measurements	[illegible]	[illegible]	872	na	na	na
Survey Time (hr)	127.55	268.15	43.60	na	na	na
Soil Sampling						
No. of Samples	na	na	na	58	135	194
Collection Time (hr)	na	na	na	5.80	13.50	19.40
Survey Time						
Subtotal (hours)	161	480	287	9	34	29
Adjustment A - 25% (daily checks, breaks, repeats)	40	120	72	2	9	7
Adjustment B - 15% (data review)	24	72	43	1	5	4
Total (hours)	226	672	402	13	48	40
Analytical Cost ($)						
Soil Samples	na	na	na	4350	10125	14550
Smear Samples	944	1984	323	na	na	na
Subtotal	944	1984	323	4350	10125	14550
Final Survey Cost ($)						
Labor	8307	24732	14791	471	1773	1479
Analytical	944	1984	323	4350	10125	14550
Subtotal	9251	26716	15114	4821	11898	16029
Sup. Data Review/ Report Preparation	25377					
Total Cost - Final Survey	109205					
Other Survey Costs ($)						
Gridding - Indoor	173544					
Gridding - Outdoor	6452					
Scoping Survey	5460					
Characterization Survey	109205					
Remed. Control Survey	10921					
Confirmatory Survey	5460					
TOTAL SURVEY COSTS	$420,248					

Table D.1.3

Reference Facility: Power Reactor

Residual Dose Limit 25 mrem/yr	Structure Surveys Class 1 Affected/Non-Uniform	Structure Surveys Class 2 Affected/Uniform	Structure Surveys Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Uniform	Land Surveys Class 2 Affected/Uniform	Land Surveys Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	42000	2000	16720	55740
Total area (m^2) - Floor/Lower Walls	8488	51723	0	na	na	na
Total area (m^2) - U.Wall/Ceiling	0	10000	260015	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	2000	12540	5574
Scan area (m^2) - Floor/Lower Walls	8488	38792.25	0	na	na	na
Scan area (m^2) - U.Wall/Ceiling	0	7500	26001.5	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	5.31	32.33	70.00	3.333333333	20.9	9.29
(beta) Floors & L. Walls	28.29	129.31	0.00	na	na	na
(beta) U. Walls & Ceilings	0.00	50.00	173.34	na	na	na
Direct Measurements						
Number of Measurements	3556	7229	872	na	na	na
Survey Time (hr)	177.80	361.45	43.60	na	na	na
Soil Sampling						
No. of Samples	na	na	na	58	135	194
Collection Time (hr)	na	na	na	5.80	13.50	19.40
Survey Time						
Subtotal (hours)	211	573	287	9	34	29
Adjustment A - 25% (daily checks, breaks, repeats)	53	143	72	2	9	7
Adjustment B - 15% (data review)	32	86	43	1	5	4
Total (hours)	296	802	402	13	48	40
Analytical Cost ($)						
Soil Samples	na	na	na	4350	10125	14550
Smear Samples	1316	2675	323	na	na	na
Subtotal	1316	2675	323	4350	10125	14550
Final Survey Cost ($)						
Labor	10897	29541	14791	471	1773	1479
Analytical	1316	2675	323	4350	10125	14550
Subtotal	12213	32216	15114	4821	11898	16029
Sup. Data Review/ Report Preparation	25377					
Total Cost - Final Survey	117667					
Other Survey Costs ($)						
Gridding - Indoor	173544					
Gridding - Outdoor	6452					
Scoping Survey	5883					
Characterization Survey	117667					
Remed. Control Survey	11767					
Confirmatory Survey	5883					
TOTAL SURVEY COSTS	$438,864					

Table D.1.4

Reference Facility: Power Reactor

Residual Dose Limit 15 mrem/yr	Structure Surveys Class 1 Affected/Non-Uniform	Structure Surveys Class 2 Affected/Uniform	Structure Surveys Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Uniform	Land Surveys Class 2 Affected/Uniform	Land Surveys Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	42000	2000	16720	55740
Total area (m^2) - Floor/Lower Wall	8488	51723	0	na	na	na
Total area (m^2) - U.Wall/Ceiling	0	10000	260015	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	2000	12540	5574
Scan area (m^2) - Floor/Lower Wall	8488	38792.25	0	na	na	na
Scan area (m^2) - U.Wall/Ceiling	0	7500	26001.5	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	5.31	32.33	70.00	3.333333333	20.9	9.29
(beta) Floors & L. Walls	26.29	129.31	0.00	na	na	na
(beta) U Walls & Ceilings	0.00	50.00	173.34	na	na	na
Direct Measurements						
Number of Measurements	3247	4901	872	na	na	na
Survey Time (hr)	162.35	245.05	43.60	na	na	na
Soil Sampling						
No of Samples	na	na	na	140	135	194
Collection Time (hr)	na	na	na	14.00	13.50	19.40
Survey Time						
Subtotal (hours)	196	457	287	17	34	29
Adjustment A - 25% (daily checks, breaks, repeats)	49	114	72	4	9	7
Adjustment B - 15% (data review)	29	69	43	3	5	4
Total (hours)	274	639	402	24	48	40
Analytical Cost ($)						
Soil Samples	na	na	na	14000	13500	19400
Smear Samples	1201	1813	323	na	na	na
Subtotal	1201	1813	323	14000	13500	19400
Final Survey Cost ($)						
Labor	10101	23541	14791	893	1773	1479
Analytical	1201	1813	323	14000	13500	19400
Subtotal	11302	25355	15114	14893	15273	20879
Sup. Data Review/ Report Preparation	25377					
Total Cost - Final Survey	128193					
Other Survey Costs ($)						
Gridding - Indoor	173544					
Gridding - Outdoor	6452					
Scoping Survey	6410					
Characterization Survey	128193					
Remed. Control Survey	12819					
Confirmatory Survey	6410					
TOTAL SURVEY COSTS	$462,020					

Table D.1.5

Reference Facility: Power Reactor

Residual Dose Limit 3 mrem/yr		Structure Surveys Class 1 Affected/Non-Uniform	Structure Surveys Class 2 Affected/Uniform	Structure Surveys Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Uniform	Land Surveys Class 2 Affected/Uniform	Land Surveys Class 3 Unaffected
Site Information							
	Total area (m^2) - Outdoor	na	na	42000	2000	16720	55740
	Total area (m^2) - Floor/Lower Wall	8488	51723	0	na	na	na
	Total area (m^2) - U.Wall/Ceiling	0	10000	260015	na	na	na
	Scan (% Area)	100	75	10	100	75	10
	Scan area (m^2) - Outdoor	na	na	na	2000	12540	5574
	Scan area (m^2) - Floor/Lower Wall	8488	38792.25	0	na	na	na
	Scan area (m^2) - U.Wall/Ceiling	0	7500	26001.5	na	na	na
Scanning	Survey Time (hr)						
(gamma)	Floors & Outdoor Areas	5.31	32.33	70.00	3.333333333	20.9	9.29
(beta)	Floors & L. Walls	28.29	129.31	0.00	na	na	na
(beta)	U. Walls & Ceilings	0.00	50.00	173.34	na	na	na
Direct Measurements							
	Number of Measurements	5521	4231	1044	na	na	na
	Survey Time (hr)	178.05	211.55	52.20	na	na	na
Soil Sampling							
	No. of Samples	na	na	na	2000	135	194
	Collection Time (hr)	na	na	na	200.00	13.50	19.40
Survey Time							
	Subtotal (hours)	210	423	296	203	34	29
	Adjustment A - 25% (daily checks, breaks, repeats)	52	106	74	51	9	7
	Adjustment B - 15% (data review)	31	63	44	31	5	4
	Total (hours)	294	592	414	285	48	40
Analytical Cost ($)							
	Soil Samples	na	na	na	350000	23625	33950
	Smear Samples	1303	1565	386	na	na	na
	Subtotal	1303	1565	386	350000	23625	33950
Final Survey Cost ($)							
	Labor	10807	21814	15235	10481	1773	1479
	Analytical	1303	1565	386	350000	23625	33950
	Subtotal	12110	23380	15621	360481	25398	35429
	Sup. Data Review/ Report Preparation	25377					
	Total Cost - Final Survey	497796					
Other Survey Costs ($)							
	Gridding - Indoor	173544					
	Gridding - Outdoor	6452					
	Scoping Survey	24890					
	Characterization Survey	497796					
	Remed. Control Survey	49780					
	Confirmatory Survey	24890					
	TOTAL SURVEY COSTS	$1,275,146					

Table D.1.6

Reference Facility: **Power Reactor**

		Residual Dose Limit (mrem/yr)				
		3	15	25	60	100
Scan time (min/ 100 m^2)	outdoor - gamma	10	10	10	10	10
	indoor - gamma	15	15	15	15	15
	floor/ l.wall - beta	20	20	20	20	20
	u. wall/ ceiling - beta	40	40	40	40	40
	floor/ l.wall - beta	20	20	20	20	20
	u. wall/ ceiling - beta	40	40	40	40	40
Direct Measurements (min/ location)	alpha/beta	3	3	3	3	3
Soil Sampling (samples/hr)		10	10	10	10	10
Analysis Cost ($/sample)	soil	175	100	75	75	75
	smear	0.37	0.37	0.37	0.37	0.37
Labor Rate ($/hr)	H.P. Technician	36.82	36.82	36.82	36.82	36.82
	H.P. Spervisor	70.99	70.99	70.99	70.99	70.99
Costs of Other Surveys (as a % of final survey costs)	Scoping Survey	5	5	5	5	5
	Characterization Survey	100	100	100	100	100
	Remed. Control Survey	10	10	10	10	10
	Confirmatory Survey	5	5	5	5	5

Total Survey Costs

	Power Reactor
3	$1,275,146
15	$462,020
25	$438,864
60	$420,248
100	$418,731

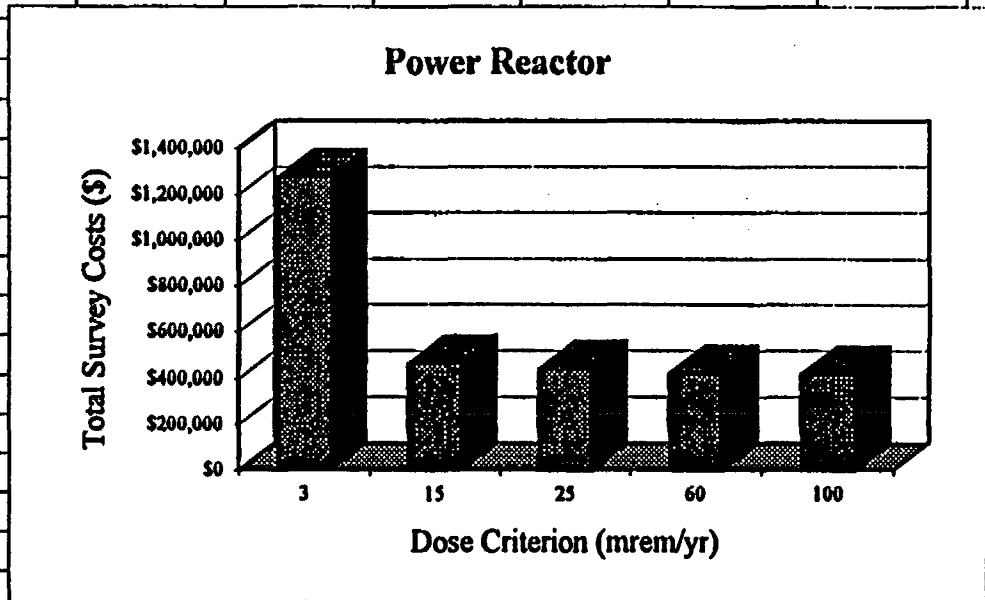

Figure D.1

Table D.2.1

Reference Facility: <u>Sealed Source Facility</u>

Residual Dose Limit 100 mrem/yr	Structure Surveys			Land Surveys		
	Class 1 Affected/Non-Uniform	Class 2 Affected/Uniform	Class 3 Unaffected	Class 1 Affected/Non-Uniform	Class 2 Affected/Uniform	Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	na	0	2770	300
Total area (m^2) - Floor/Lower Wall	163	853	2350	na	na	na
Total area (m^2) - U.Wall/Ceiling	25	128	3153	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	0	2077.5	30
Scan area (m^2) - Floor/Lower Wall	163	639.75	235	na	na	na
Scan area (m^2) - U.Wall/Ceiling	25	96	315.3	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	0.10	0.53	1.47	0	3.4625	0.05
(beta) Floors & L. Walls	0.54	2.13	0.78	na	na	na
(beta) U. Walls & Ceilings	0.17	0.64	2.10	na	na	na
Direct Measurements						
Number of Measurements	72	150	56	na	na	na
Survey Time (hr)	3.60	7.50	2.80	na	na	na
Soil Sampling						
No. of Samples	na	na	na	0	48	19
Collection Time (hr)	na	na	na	0.00	4.80	1.90
Survey Time						
Subtotal (hours)	4	11	7	0	8	2
Adjustment A - 25% (daily checks, breaks, repeats)	1	3	2	0	2	0
Adjustment B - 15% (data review)	1	2	1	0	1	0
Total (hours)	6	15	10	0	12	3
Analytical Cost ($)						
Soil Samples	na	na	na	0	3600	1425
Smear Samples	27	56	21	na	na	na
Subtotal	27	56	21	0	3600	1425
Final Survey Cost ($)						
Labor	227	557	369	0	426	101
Analytical	27	56	21	0	3600	1425
Subtotal	254	613	389	0	4026	1526
Sup. Data Review/ Report Preparation	25377					
Total Cost - Final Survey	32164					
Other Survey Costs ($)						
Gridding - Indoor	3223					
Gridding - Outdoor	836					
Scoping Survey	1609					
Characterization Survey	16092					
Remed. Control Survey	3218					
Confirmatory Survey	1609					
TOTAL SURVEY COSTS	$58,771					

Table D.2.2

Reference Facility: <u>**Sealed Source Facility**</u>

Residual Dose Limit 60 mrem/yr	Structure Surveys Class 1 Affected/Non-Uniform	Structure Surveys Class 2 Affected/Uniform	Structure Surveys Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Uniform	Land Surveys Class 2 Affected/Uniform	Land Surveys Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	na	0	2770	300
Total area (m^2) - Floor/Lower Wall	163	853	2350	na	na	na
Total area (m^2) - U.Wall/Ceiling	25	128	3153	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	0	2077.5	30
Scan area (m^2) - Floor/Lower Wall	163	639.75	235	na	na	na
Scan area (m^2) - U.Wall/Ceiling	25	96	315.3	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	0.10	0.53	1.47	0	3.4625	0.05
(beta) Floors & L. Walls	0.54	2.13	0.78	na	na	na
(beta) U. Walls & Ceilings	0.17	0.64	2.10	na	na	na
Direct Measurements						
Number of Measurements	22	158	56	na	na	na
Survey Time (hr)	3.60	7.90	2.80	na	na	na
Soil Sampling						
No. of Samples	na	na	na	0	48	19
Collection Time (hr)	na	na	na	0.00	4.80	1.90
Survey Time						
Subtotal (hours)	4	11	7	0	8	2
Adjustment A - 25% (daily checks, breaks, repeats)	1	3	2	0	2	0
Adjustment B - 15% (data review)	1	2	1	0	1	0
Total (hours)	6	16	10	0	12	3
Analytical Cost ($)						
Soil Samples	na	na	na	0	3600	1425
Smear Samples	27	58	21	na	na	na
Subtotal	27	58	21	0	3600	1425
Final Survey Cost ($)						
Labor	227	578	369	0	426	101
Analytical	27	58	21	0	3600	1425
Subtotal	254	636	389	0	4026	1526
Sup. Data Review/ Report Preparation	25377					
Total Cost - Final Survey	32208					
Other Survey Costs ($)						
Gridding - Indoor	3223					
Gridding - Outdoor	836					
Scoping Survey	1610					
Characterization Survey	18104					
Remed. Control Survey	3221					
Confirmatory Survey	1610					
TOTAL SURVEY COSTS	$58,811					

Table D.2.3

Reference Facility: **Sealed Source Facility**

Residual Dose Limit 25 mrem/yr	Structure Surveys Class 1 Affected/Non-Uniform	Structure Surveys Class 2 Affected/Uniform	Structure Surveys Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Uniform	Land Surveys Class 2 Affected/Uniform	Land Surveys Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	na	0	2770	300
Total area (m^2) - Floor/Lower Walls	163	853	2350	na	na	na
Total area (m^2) - U Wall/Ceiling	25	128	3153	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	0	2077.5	30
Scan area (m^2) - Floor/Lower Walls	163	639.75	235	na	na	na
Scan area (m^2) - U Wall/Ceiling	25	96	315.3	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	0.10	0.53	1.47	0	3.4625	0.05
(beta) Floors & L. Walls	0.54	2.13	0.78	na	na	na
(beta) U Walls & Ceilings	0.17	0.64	2.10	na	na	na
Direct Measurements						
Number of Measurements	102	216	56	na	na	na
Survey Time (hr)	5.10	10.80	2.80	na	na	na
Soil Sampling						
No. of Samples	na	na	na	0	48	19
Collection Time (hr)	na	na	na	0.00	4.80	1.90
Survey Time						
Subtotal (hours)	6	14	7	0	8	2
Adjustment A - 25% (daily checks, breaks, repeats)	1	4	2	0	2	0
Adjustment B - 15% (data review)	1	2	1	0	1	0
Total (hours)	8	20	10	0	12	3
Analytical Cost ($)						
Soil Samples	na	na	na	0	3600	1425
Smear Samples	38	80	21	na	na	na
Subtotal	38	80	21	0	3600	1425
Final Survey Cost ($)						
Labor	305	727	369	0	426	101
Analytical	38	80	21	0	3600	1425
Subtotal	342	807	389	0	4026	1526
Sup. Data Review/ Report Preparation	25377					
Total Cost - Final Survey	32467					
Other Survey Costs ($)						
Gridding - Indoor	3223					
Gridding - Outdoor	836					
Scoping Survey	1623					
Characterization Survey	16233					
Remed. Control Survey	3247					
Confirmatory Survey	1623					
TOTAL SURVEY COSTS	$59,252					

Table D.2.4

Reference Facility: Sealed Source Facility

Residual Dose Limit 15 mrem/yr	Structure Surveys			Land Surveys		
	Class 1 Affected/Non-Uniform	Class 2 Affected/Uniform	Class 3 Unaffected	Class 1 Affected/Non-Uniform	Class 2 Affected/Uniform	Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	na	0	2770	300
Total area (m^2) - Floor/Lower Wall	163	853	2350	na	na	na
Total area (m^2) - U Wall/Ceiling	25	128	3153	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	0	2077.5	30
Scan area (m^2) - Floor/Lower Wall	163	639.75	235	na	na	na
Scan area (m^2) - U Wall/Ceiling	25	96	315.3	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	0.10	0.53	1.47	0	3.4625	0.05
(beta) Floors & L. Walls	0.54	2.13	0.78	na	na	na
(beta) U. Walls & Ceilings	0.17	0.64	2.10	na	na	na
Direct Measurements						
Number of Measurements	93	202	56	na	na	na
Survey Time (hr)	4.65	10.10	2.80	na	na	na
Soil Sampling						
No. of Samples	na	na	na	0	16	19
Collection Time (hr)	na	na	na	0.00	4.80	1.90
Survey Time						
Subtotal (hours)	5	13	7	0	8	2
Adjustment A - 25% (daily checks, breaks, repeats)	1	3	2	0	2	0
Adjustment B - 15% (data review)	1	2	1	0	1	0
Total (hours)	8	19	10	0	12	3
Analytical Cost ($)						
Soil Samples	na	na	na	0	4800	1900
Smear Samples	34	75	21	na	na	na
Subtotal	34	75	21	0	4800	1900
Final Survey Cost ($)						
Labor	282	691	369	0	426	101
Analytical	34	75	21	0	4800	1900
Subtotal	316	766	389	0	5226	2001
Sup. Data Review/ Report Preparation	25377					
Total Cost - Final Survey	34074					
Other Survey Costs ($)						
Gridding - Indoor	3223					
Gridding - Outdoor	836					
Scoping Survey	1704					
Characterization Survey	17037					
Remed. Control Survey	3407					
Confirmatory Survey	1704					
TOTAL SURVEY COSTS	$61,984					

Table D.2.5

Reference Facility: Sealed Source Facility

Residual Dose Limit 3 mrem/yr	Structure Surveys Class 1 Affected/Non-Uniform	Structure Surveys Class 2 Affected/Uniform	Structure Surveys Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Uniform	Land Surveys Class 2 Affected/Uniform	Land Surveys Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	na	0	2770	300
Total area (m^2) - Floor/Lower Wall	163	853	2350	na	na	na
Total area (m^2) - U.Wall/Ceiling	25	128	3153	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	0	2077.5	30
Scan area (m^2) - Floor/Lower Wall	163	639.75	235	na	na	na
Scan area (m^2) - U.Wall/Ceiling	25	96	315.3	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	0.10	0.53	1.47	0	3.4625	0.05
(beta) Floors & L. Walls	0.54	2.13	0.78	na	na	na
(beta) U. Walls & Ceilings	0.17	0.64	2.10	na	na	na
Direct Measurements						
Number of Measurements	212	174	73	na	na	na
Survey Time (hr)	10.60	8.70	3.65	na	na	na
Soil Sampling						
No. of Samples	na	na	na	0	48	19
Collection Time (hr)	na	na	na	0.00	4.80	1.90
Survey Time						
Subtotal (hours)	11	12	8	0	8	2
Adjustment A - 25% (daily checks, breaks, repeats)	3	3	2	0	2	0
Adjustment B - 15% (data review)	2	2	1	0	1	0
Total (hours)	16	17	11	0	12	3
Analytical Cost ($)						
Soil Samples	na	na	na	0	8400	3325
Smear Samples	78	64	27	na	na	na
Subtotal	78	64	27	0	8400	3325
Final Survey Cost ($)						
Labor	588	619	413	0	426	101
Analytical	78	64	27	0	8400	3325
Subtotal	667	683	440	0	8826	3426

Sup. Data Review/ Report Preparation	25377
Total Cost - Final Survey	39417
Other Survey Costs ($)	
Gridding - Indoor	3223
Gridding - Outdoor	836
Scoping Survey	1971
Characterization Survey	19709
Remed. Control Survey	3942
Confirmatory Survey	1971
TOTAL SURVEY COSTS	$71,068

Table D.2.6

Reference Facility: **Sealed Source Facility**

		Residual Dose Limit (mrem/yr)				
		3	15	25	60	100
Scan time (min/ 100 m^2)	outdoor - gamma	10	10	10	10	10
	indoor - gamma	15	15	15	15	15
	floor/ l.wall - beta	20	20	20	20	20
	u. wall/ ceiling - beta	40	40	40	40	40
	floor/ l.wall - beta	20	20	20	20	20
	u. wall/ ceiling - beta	40	40	40	40	40
Direct Measurements (min/ location)	alpha/beta	3	3	3	3	3
Soil Sampling (samples/hr)		10	10	10	10	10
Analysis Cost ($/sample)	soil	175	100	75	75	75
	smear	0.37	0.37	0.37	0.37	0.37
Labor Rate ($/hr)	H.P. Technician	36.82	36.82	36.82	36.82	36.82
	H.P. Spervisor	70.99	70.99	70.99	70.99	70.99
Costs of Other Surveys (as a % of final survey costs)	Scoping Survey	5	5	5	5	5
	Characterization Survey	50	50	50	50	50
	Remed. Control Survey	10	10	10	10	10
	Confirmatory Survey	5	5	5	5	5

		Total Survey Costs
		Sealed Source Facility
	3	$71,068
	15	$61,984
	25	$59,252
	60	$58,811
	100	$58,771

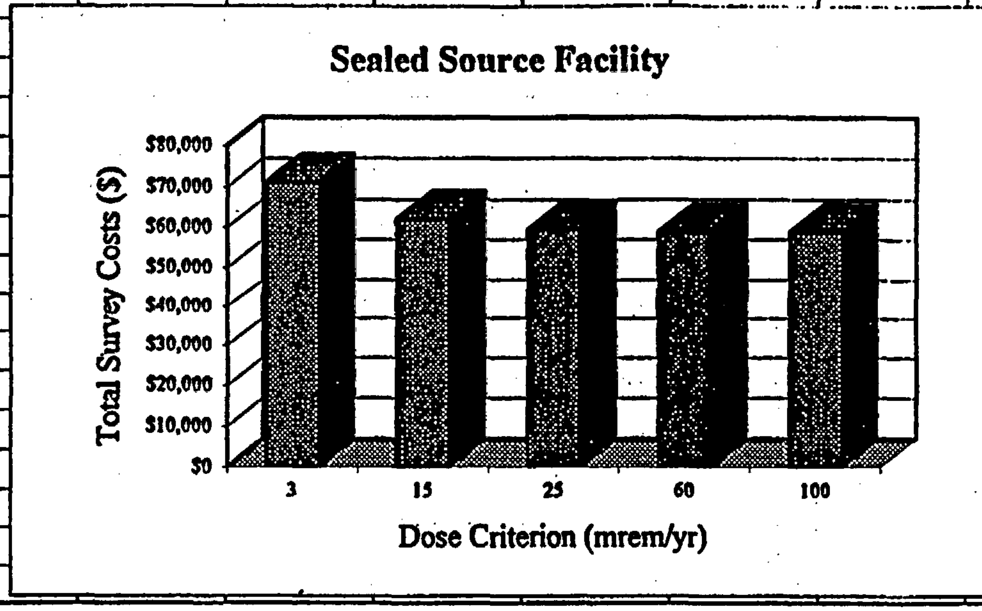

Figure D.2

Table D.3.1

Reference Facility: U Fuel Fabrication

Residual Dose Limit 100 mrem/yr	Structure Surveys Class 1 Affected/Non-Uniform	Structure Surveys Class 2 Affected/Uniform	Structure Surveys Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Uniform	Land Surveys Class 2 Affected/Uniform	Land Surveys Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	na	13098	74220	130980
Total area (m^2) - Floor/Lower Wall	12300	25124	0	na	na	na
Total area (m^2) - U.Wall/Ceiling	1000	1000	27360	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	13098	55665	13098
Scan area (m^2) - Floor/Lower Wall	12300	18843	0	na	na	na
Scan area (m^2) - U.Wall/Ceiling	1000	750	2736	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	7.69	15.70	0.00	21.83	92.775	21.83
(alpha/beta) Floors & L. Walls	82.00	125.62	0.00	na	na	na
(alpha/beta) U. Walls & Ceilings	13.33	10.00	36.48	na	na	na
Direct Measurements						
Number of Measurements	4130	1228	105	na	na	na
Survey Time (hr)	206.50	61.30	5.25	na	na	na
Soil Sampling						
No. of Samples	na	na	na	[illegible]	[illegible]	[illegible]
Collection Time (hr)	na	na	na	39.50	57.10	8.30
Survey Time						
Subtotal (hours)	310	213	42	61	150	30
Adjustment A - 25% (daily checks, breaks, repeats)	77	53	10	15	37	8
Adjustment B - 15% (data review)	46	32	6	9	22	5
Total (hours)	433	298	58	86	210	42
Analytical Cost ($)						
Soil Samples	na	na	na	29625	42825	6225
Smear Samples	1528	454	39	na	na	na
Subtotal	1528	454	39	29625	42825	6225
Final Survey Cost ($)						
Labor	15955	10960	2151	3161	7726	1553
Analytical	1528	454	39	29625	42825	6225
Subtotal	17483	11414	2190	32786	50551	7778

		Survey costs using in situ gamma spectrometry		
Sup. Data Review/ Report Preparation	25377	Conventional	Indoor survey cost	31087
Total Cost - Final Survey	147579	in situ costs	Total Cost - Final	167105
Other Survey Costs ($)		**Other Survey Costs ($)**		
Gridding - Indoor	63752		Gridding - Indoor	63752
Gridding - Outdoor	28160		Gridding - Outdoor	28160
Scoping Survey	7379		Scoping Survey	8355
Characterization Survey	36895		Characterization S	125329
Remed. Control Survey	22137		Remed. Control S	25068
Confirmatory Survey	7379		Confirmatory Surv	8355
TOTAL SURVEY COSTS	$313,281		TOTAL SURVEY C	$457,209

Table D.3.2

Reference Facility: U Fuel Fabrication

Residual Dose Limit 60 mrem/yr	Structure Surveys Class 1 Affected/Non-Uniform	Structure Surveys Class 2 Affected/Uniform	Structure Surveys Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Uniform	Land Surveys Class 2 Affected/Uniform	Land Surveys Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	na	13098	74220	130980
Total area (m^2) - Floor/Lower Wall	12300	25124	0	na	na	na
Total area (m^2) - U.Wall/Ceiling	1000	1000	27360	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	13098	55665	13098
Scan area (m^2) - Floor/Lower Wall	12300	18843	0	na	na	na
Scan area (m^2) - U.Wall/Ceiling	1000	750	2736	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	7.69	15.70	0.00	21.83	92.775	21.83
(alpha/beta) Floors & L. Walls	82.00	125.62	0.00	na	na	na
(alpha/beta) U. Walls & Ceilings	13.33	10.00	36.48	na	na	na
Direct Measurements						
Number of Measurements	[illegible]	[illegible]	105	na	na	na
Survey Time (hr)	206.50	63.65	5.25	na	na	na
Soil Sampling						
No. of Samples	na	na	na	[illegible]	[illegible]	[illegible]
Collection Time (hr)	na	na	na	39.50	68.60	8.30
Survey Time						
Subtotal (hours)	310	215	42	61	151	30
Adjustment A - 25% (daily checks, breaks, repeats)	77	54	10	15	38	8
Adjustment B - 15% (data review)	46	32	6	9	23	5
Total (hours)	433	301	58	86	212	42
Analytical Cost ($)						
Soil Samples	na	na	na	29625	43950	6225
Smear Samples	1528	471	39	na	na	na
Subtotal	1528	471	39	29625	43950	6225
Final Survey Cost ($)						
Labor	15955	11081	2151	3161	7803	1553
Analytical	1528	471	39	29625	43950	6225
Subtotal	17483	11552	2190	32786	51753	7778

		Survey costs using in situ gamma spectrometry		
Sup. Data Review/ Report Preparation	25377	Conventional	Indoor survey cost	31226
Total Cost - Final Survey	148920	in situ costs	Total Cost - Final	167105
Other Survey Costs ($)		**Other Survey Costs ($)**		
Gridding - Indoor	63752		Gridding - Indoor	63752
Gridding - Outdoor	28160		Gridding - Outdoor	28160
Scoping Survey	7446		Scoping Survey	8355
Characterization Survey	111690		Characterization S	125329
Remed. Control Survey	22338		Remed. Control S	25066
Confirmatory Survey	7446		Confirmatory Surv	8355
TOTAL SURVEY COSTS	$389,752		**TOTAL SURVEY C**	$457,348

Table D.3.3

Reference Facility: U Fuel Fabrication

	Structure Surveys			Land Surveys		
Residual Dose Limit 25 mrem/yr	**Class 1** Affected/Non-Uniform	**Class 2** Affected/Uniform	**Class 3** Unaffected	**Class 1** Affected/Non-Uniform	**Class 2** Affected/Uniform	**Class 3** Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	na	13098	74220	130980
Total area (m^2) - Floor/Lower Walls	12300	25124	0	na	na	na
Total area (m^2) - U.Wall/Ceiling	1000	1000	27360	na	na	
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	13098	55665	13098
Scan area (m^2) - Floor/Lower Walls	12300	18843	0	na	na	na
Scan area (m^2) - U.Wall/Ceiling	1000	750	2736	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	7.69	15.70	0.00	21.83	92.775	21.83
(alpha/beta) Floors & L. Walls	82.00	125.62	0.00	na	na	na
(alpha/beta) U. Walls & Ceilings	13.33	10.00	36.48	na	na	na
Direct Measurements						
Number of Measurements	[illegible]	[illegible]	[illegible]	na	na	na
Survey Time (hr)	226.50	65.95	5.25	na	na	na
Soil Sampling						
No. of Samples	na	na	na	[illegible]	[illegible]	[illegible]
Collection Time (hr)	na	na	na	42.70	61.70	8.30
Survey Time						
Subtotal (hours)	330	217	42	65	154	30
Adjustment A - 25% (daily checks, breaks, repeats)	82	54	10	16	39	8
Adjustment B - 15% (data review)	49	33	6	10	23	5
Total (hours)	461	304	58	90	216	42
Analytical Cost ($)						
Soil Samples	na	na	na	32025	46275	6225
Smear Samples	1676	488	39	na	na	na
Subtotal	1676	488	39	32025	46275	6225
Final Survey Cost ($)						
Labor	16986	11200	2151	3326	7963	1553
Analytical	1676	488	39	32025	46275	6225
Subtotal	18662	11688	2190	35351	54238	7778

		Survey costs using in situ gamma spectrometry	
Sup. Data Review/ Report Preparation	25377	Conventional — Indoor survey costs	32540
Total Cost - Final Survey	155284	In situ costs — Total Cost - Final S	220535
Other Survey Costs ($)		**Other Survey Costs ($)**	
Gridding - Indoor	63752	Gridding - Indoor	63752
Gridding - Outdoor	28160	Gridding - Outdoor	28160
Scoping Survey	7764	Scoping Survey	11027
Characterization Survey	116463	Characterization Su	165401
Remed. Control Survey	23293	Remed. Control Su	33080
Confirmatory Survey	7764	Confirmatory Surve	11027
TOTAL SURVEY COSTS	$402,481	**TOTAL SURVEY CO**	$565,522

Table D.3.4

Reference Facility: U Fuel Fabrication

Residual Dose Limit 15 mrem/yr	Structure Surveys Class 1 Affected/Non-Uniform	Structure Surveys Class 2 Affected/Uniform	Structure Surveys Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Uniform	Land Surveys Class 2 Affected/Uniform	Land Surveys Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	na	13098	74220	130980
Total area (m^2) - Floor/Lower Wall	12300	25124	0	na	na	na
Total area (m^2) - U.Wall/Ceiling	1000	1000	27360	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	13098	55665	13098
Scan area (m^2) - Floor/Lower Wall	12300	18843	0	na	na	na
Scan area (m^2) - U.Wall/Ceiling	1000	750	2736	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	7.69	15.70	0.00	21.83	82.775	21.83
(alpha/beta) Floors & L. Walls	82.00	125.62	0.00	na	na	na
(alpha/beta) U. Walls & Ceilings	13.33	10.00	36.48	na	na	na
Direct Measurements						
Number of Measurements	5684	1504	105	na	na	na
Survey Time (hr)	293.20	75.20	6.25	na	na	na
Soil Sampling						
No. of Samples	na	na	na	471	663	83
Collection Time (hr)	na	na	na	47.10	66.30	8.30
Survey Time						
Subtotal (hours)	396	227	42	69	159	30
Adjustment A - 25% (daily checks, breaks, repeats)	99	57	10	17	40	8
Adjustment B - 15% (data review)	59	34	6	10	24	5
Total (hours)	555	317	58	97	223	42
Analytical Cost ($)						
Soil Samples	na	na	na	70650	99450	12450
Smear Samples	2170	656	39	na	na	na
Subtotal	2170	656	39	70650	99450	12450
Final Survey Cost ($)						
Labor	20424	11577	2151	3553	8200	1553
Analytical	2170	656	39	70650	99450	12450
Subtotal	22594	12233	2190	74203	107650	14003

	Conventional		Survey costs using in situ gamma spectrometry	
Sup. Data Review/ Report Preparation	25377	Conventional	Indoor survey costs	37017
Total Cost - Final Survey	258250	in situ costs	Total Cost - Final $	381960
Other Survey Costs ($)		**Other Survey Costs ($)**		
Gridding - Indoor	63752		Gridding - Indoor	63752
Gridding - Outdoor	28160		Gridding - Outdoor	28160
Scoping Survey	12913		Scoping Survey	19098
Characterization Survey	193688		Characterization Su	286470
Remed. Control Survey	38738		Remed. Control Su	57294
Confirmatory Survey	12913		Confirmatory Surve	19098
TOTAL SURVEY COSTS	$608,413		**TOTAL SURVEY CO**	$892,849

Table D.3.5

Reference Facility: U Fuel Fabrication

Residual Dose Limit 3 mrem/yr	Structure Surveys Class 1 Affected/Non-Unifor	Class 2 Affected/Uniform	Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Unifor	Class 2 Affected/Uniform	Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	na	13098	74220	130980
Total area (m^2) - Floor/Lower Wall	12300	25124	0	na	na	na
Total area (m^2) - U.Wall/Ceiling	1000	1000	27360	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	13098	55665	13098
Scan area (m^2) - Floor/Lower Wall	12300	18843	0	na	na	na
Scan area (m^2) - U.Wall/Ceiling	1000	750	2736	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	7.69	15.70	0.00	21.83	92.775	21.83
(alpha/beta) Floors & L. Walls	82.00	125.62	0.00	na	na	na
(alpha/beta) U. Walls & Ceilings	13.33	10.00	36.48	na	na	na
Direct Measurements						
Number of Measurements	4944	1144	106	na	na	na
Survey Time (hr)	578.80	133.47	12.25	na	na	na
Soil Sampling						
No. of Samples	na	na	na	1911	515	83
Collection Time (hr)	na	na	na	191.10	51.50	8.30
Survey Time						
Subtotal (hours)	680	285	49	213	144	30
Adjustment A - 25% (daily checks, breaks, repeats)	170	71	12	53	36	8
Adjustment B - 15% (data review)	102	43	7	32	22	5
Total (hours)	952	399	68	298	202	42
Analytical Cost ($)						
Soil Samples	na	na	na	573300	154500	24900
Smear Samples	1829	423	39	na	na	na
Subtotal	1829	423	39	573300	154500	24900
Final Survey Cost ($)						
Labor	35043	14680	2512	10976	7437	1553
Analytical	1829	423	39	573300	154500	24900
Subtotal	36873	15104	2551	584276	161937	26453

	Conventional	Survey costs using in situ gamma spectrometry	
Sup. Data Review/ Report Preparation	25377	Indoor survey costs	54527
Total Cost - Final Survey	852570	In situ costs — Total Cost - Final Survey	1782440
Other Survey Costs ($)		**Other Survey Costs ($)**	
Gridding - Indoor	63752	Gridding - Indoor	63752
Gridding - Outdoor	28160	Gridding - Outdoor	28160
Scoping Survey	42628	Scoping Survey	89122
Characterization Survey	639427	Characterization Survey	1336830
Remed. Control Survey	127885	Remed. Control Survey	267366
Confirmatory Survey	42628	Confirmatory Survey	89122
TOTAL SURVEY COSTS	$1,797,052	**TOTAL SURVEY COS**	$3,711,319

Table D.3.6

Reference Facility: **U Fuel Fabrication**

		Residual Dose Limit (mrem/yr)				
		3	15	25	60	100
Scan time (min/ 100 m^2)	outdoor - gamma	10	10	10	10	10
	indoor - gamma	15	15	15	15	15
	floor/ l.wall - alpha/beta	40	40	40	40	40
	u. wall/ ceiling - alpha/beta	80	80	80	80	80
	floor/ l.wall - beta	20	20	20	20	20
	u. wall/ ceiling - beta	40	40	40	40	40
Direct Measurements (min/ location)	alpha/beta	7	3	3	3	3
Soil Sampling (samples/hr)		10	10	10	10	10
Analysis Cost ($/sample)	soil	300	150	75	75	75
	smear	0.37	0.37	0.37	0.37	0.37
Labor Rate ($/hr)	H.P. Technician	36.82	36.82	36.82	36.82	36.82
	H.P. Spervisor	70.99	70.99	70.99	70.99	70.99
Costs of Other Surveys (as a % of final survey costs)	Scoping Survey	5	5	5	5	5
	Characterization Survey	75	75	75	75	25
	Remed. Control Survey	15	15	15	15	15
	Confirmatory Survey	5	5	5	5	5

	Total Survey Costs
	U Fuel Fabrication
3	$1,797,052
15	$608,413
25	$402,481
60	$389,752
100	$313,281

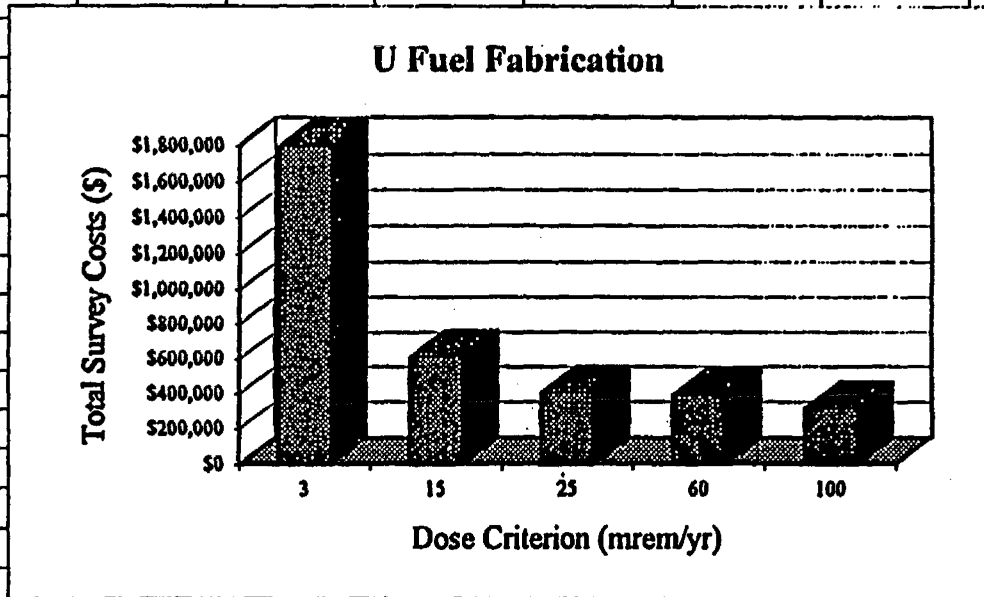

Figure D.3

Table D.4.1

Reference Facility: Rare Metal Extraction Facility

Residual Dose Limit 100 mrem/yr	Structure Surveys Class 1 Affected/Non-Uniform	Structure Surveys Class 2 Affected/Uniform	Structure Surveys Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Uniform	Land Surveys Class 2 Affected/Uniform	Land Surveys Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	na	9296	929	26023
Total area (m^2) - Floor/Lower Wall	7161	19373	0	na	na	na
Total area (m^2) - U.Wall/Ceiling	0	0	19026	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	9296	696.75	2602.3
Scan area (m^2) - Floor/Lower Wall	7161	14529.75	0	na	na	na
Scan area (m^2) - U.Wall/Ceiling	0	0	1902.6	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	4.48	12.11	0.00	15.49333333	1.16125	4.337166667
(alpha/beta) Floors & L. Walls	47.74	96.87	0.00	na	na	na
(alpha/beta) U. Walls & Ceilings	0.00	0.00	25.37	na	na	na
Direct Measurements						
Number of Measurements	244	140	134	na	na	na
Survey Time (hr)	122.15	70.05	6.80	na	na	na
Soil Sampling						
No. of Samples	na	na	na	290	31	49
Collection Time (hr)	na	na	na	29.00	3.10	4.90
Survey Time						
Subtotal (hours)	174	179	32	44	4	9
Adjustment A - 25% (daily checks, breaks, repeats)	44	45	8	11	1	2
Adjustment B - 15% (data review)	26	27	5	7	1	1
Total (hours)	244	251	45	62	6	13
Analytical Cost ($)						
Soil Samples	na	na	na	21750	2325	3675
Smear Samples	904	518	$0	na	na	na
Subtotal	904	518	$0	21750	2325	3675
Final Survey Cost ($)						
Labor	8988	9228	1858	2294	220	476
Analytical	904	518	$0	21750	2325	3675
Subtotal	9892	9747	1709	24044	2545	4151

	Conventional
Sup. Data Review/ Report Preparation	25377
Total Cost - Final Survey	77483
Other Survey Costs ($)	
Gridding - Indoor	43082
Gridding - Outdoor	3458
Scoping Survey	3873
Characterization Survey	19366
Remed. Control Survey	15493
Confirmatory Survey	3873
TOTAL SURVEY COSTS	$166,607

Survey costs using in situ gamma spectrometry

Conventional	
Indoor survey cost	21347
Total Cost - Final	40158
Other Survey Costs ($)	
Gridding - Indoor	43082
Gridding - Outdoor	3458
Scoping Survey	2008
Characterization S	30119
Remed. Control S	8032
Confirmatory Surv	2008
TOTAL SURVEY C	$150,211

Table D.4.2

Reference Facility: Rare Metal Extraction Facility

Residual Dose Limit 60 mrem/yr	Structure Surveys Class 1 Affected/Non-Uniform	Structure Surveys Class 2 Affected/Uniform	Structure Surveys Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Uniform	Land Surveys Class 2 Affected/Uniform	Land Surveys Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	na	9296	929	26023
Total area (m^2) - Floor/Lower Wall	7161	19373	0	na	na	na
Total area (m^2) - U.Wall/Ceiling	0	0	19026	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	9296	696.75	2602.3
Scan area (m^2) - Floor/Lower Wall	7161	14529.75	0	na	na	na
Scan area (m^2) - U.Wall/Ceiling	0	0	1902.6	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	4.48	12.11	0.00	15.49333333	1.18125	4.337166667
(alpha/beta) Floors & L. Walls	47.74	96.87	0.00	na	na	na
(alpha/beta) U. Walls & Ceilings	0.00	0.00	25.37	na	na	na
Direct Measurements						
Number of Measurements	2443	1459	134	na	na	na
Survey Time (hr)	122.15	72.95	8.80	na	na	na
Soil Sampling						
No. of Samples	na	na	na	303	35	49
Collection Time (hr)	na	na	na	30.30	3.50	4.90
Survey Time						
Subtotal (hours)	174	182	32	46	5	9
Adjustment A - 25% (daily checks, breaks, repeats)	44	45	8	11	1	2
Adjustment B - 15% (data review)	26	27	5	7	1	1
Total (hours)	244	255	45	64	7	13
Analytical Cost ($)						
Soil Samples	na	na	na	22725	2625	3675
Smear Samples	904	540	50	na	na	na
Subtotal	904	540	50	22725	2625	3675
Final Survey Cost ($)						
Labor	8988	9378	1658	2361	240	476
Analytical	904	540	50	22725	2625	3675
Subtotal	9892	9918	1709	25086	2865	4151

Sup. Data Review/ Report Preparation	25377		
Total Cost - Final Survey	78997		
Other Survey Costs ($)			
Gridding - Indoor	43082		
Gridding - Outdoor	3458		
Scoping Survey	3950		
Characterization Survey	19749		
Remed. Control Survey	15799		
Confirmatory Survey	3950		
TOTAL SURVEY COSTS	$168,984		

Survey costs using in situ gamma spectrometry

Conventional	Indoor survey cost	21518
	Total Cost - Final	40158
Other Survey Costs ($)		
	Gridding - Indoor	43082
	Gridding - Outdoor	3458
	Scoping Survey	2008
	Characterization S	30119
	Remed. Control S	8032
	Confirmatory Surv	2008
	TOTAL SURVEY C	$150,382

Table D.4.3

Reference Facility: <u>Rare Metal Extraction Facility</u>

Residual Dose Limit 25 mrem/yr	Structure Surveys			Land Surveys		
	Class 1 Affected/Non-Uniform	Class 2 Affected/Uniform	Class 3 Unaffected	Class 1 Affected/Non-Uniform	Class 2 Affected/Uniform	Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	na	9296	929	26023
Total area (m^2) - Floor/Lower Wall	7161	19373	0	na	na	na
Total area (m^2) - U.Wall/Ceiling	0	[illegible]	[illegible]	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	9296	696.75	2602.3
Scan area (m^2) - Floor/Lower Wall	7161	14529.75	0	na	na	na
Scan area (m^2) - U.Wall/Ceiling	0	0	1902.6	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	4.45	12.11	0.00	15.49333333	1.16125	4.337166667
(alpha/beta) Floors & L. Walls	47.74	96.87	0.00	na	na	na
(alpha/beta) U. Walls & Ceilings	0.00	0.00	25.37	na	na	na
Direct Measurements						
Number of Measurements	2813	1687	136	na	na	na
Survey Time (hr)	145.65	93.35	6.80	na	na	na
Soil Sampling						
No. of Samples	na	na	na	1369	65	49
Collection Time (hr)	na	na	na	135.90	5.50	4.90
Survey Time						
Subtotal (hours)	198	202	32	151	7	9
Adjustment A - 25% (daily checks, breaks, repeats)	49	51	8	38	2	2
Adjustment B - 15% (data review)	30.	30	5	23	1	1
Total (hours)	277	283	45	212	9	13
Analytical Cost ($)						
Soil Samples	na	na	na	101925	4125	3675
Smear Samples	1078	691	50	na	na	na
Subtotal	1078	691	50	101925	4125	3675
Final Survey Cost ($)						
Labor	10200	10429	1658	7804	343	476
Analytical	1078	691	50	101925	4125	3675
Subtotal	11277	11120	1709	109729	4468	4151
Sup. Data Review/ Report Preparation	25377					
Total Cost - Final Survey	167831					
Other Survey Costs ($)						
Gridding - Indoor	43082					
Gridding - Outdoor	3458					
Scoping Survey	8392					
Characterization Survey	125873					
Remed. Control Survey	33566					
Confirmatory Survey	8392					
TOTAL SURVEY COSTS	$390,593					

Survey costs using in situ gamma spectrometry

Conventional	Indoor survey costs	24106
	Total Cost - Final S	48904
Other Survey Costs ($)		
	Gridding - Indoor	43082
	Gridding - Outdoor	3458
	Scoping Survey	2445
	Characterization Su	36678
	Remed. Control Su	9781
	Confirmatory Surve	2445
	TOTAL SURVEY CO	$170,899

Table D.4.4

Reference Facility: Rare Metal Extraction Facility

Residual Dose Limit 15 mrem/yr	Structure Surveys Class 1 Affected/Non-Uniform	Structure Surveys Class 2 Affected/Uniform	Structure Surveys Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Uniform	Land Surveys Class 2 Affected/Uniform	Land Surveys Class 3 Unaffected
Site Information						
Total area (m^2) - Outdoor	na	na	na	9296	929	26023
Total area (m^2) - Floor/Lower Wall	7161	19373	0	na	na	na
Total area (m^2) - U.Wall/Ceiling	0	0	19026	na	na	na
Scan (% Area)	100	75	10	100	75	10
Scan area (m^2) - Outdoor	na	na	na	9296	696.75	2602.3
Scan area (m^2) - Floor/Lower Wall	7161	14529.75	0	na	na	na
Scan area (m^2) - U.Wall/Ceiling	0	0	1902.6	na	na	na
Scanning Survey Time (hr)						
(gamma) Floors & Outdoor Areas	4.48	12.11	0.00	15.49333333	1.16125	4.337166667
(alpha/beta) Floors & L. Walls	47.74	96.87	0.00	.na	na	na
(alpha/beta) U. Walls & Ceilings	0.00	0.00	25.37	na	na	na
Direct Measurements						
Number of Measurements	3658	1867	136	na	na	na
Survey Time (hr)	176.96	93.35	6.80	na	na	na
Soil Sampling						
No. of Samples	na	na	na	2307	[illegible]	[illegible]
Collection Time (hr)	na	na	na	330.70	8.60	6.10
Survey Time						
Subtotal (hours)	229	202	32	346	10	10
Adjustment A - 25% (daily checks, breaks, repeats)	57	51	8	87	2	3
Adjustment B - 15% (data review)	34	30	5	52	1	2
Total (hours)	321	283	45	485	14	15
Analytical Cost ($)						
Soil Samples	na	na	na	496050	12900	9150
Smear Samples	1309	691	50	na	na	na
Subtotal	1309	691	50	496050	12900	9150
Final Survey Cost ($)						
Labor	11813	10429	1658	17846	503	538
Analytical	1309	691	50	496050	12900	9150
Subtotal	13122	11120	1709	513896	13403	9688

	Conventional		Survey costs using in situ gamma spectrometry
Sup. Data Review/ Report Preparation	25377	Indoor survey costs	25951
Total Cost - Final Survey	588314	Total Cost - Final S	50044
Other Survey Costs ($)		**Other Survey Costs ($)**	
Gridding - Indoor	43082	Gridding - Indoor	43082
Gridding - Outdoor	3458	Gridding - Outdoor	3458
Scoping Survey	29416	Scoping Survey	2502
Characterization Survey	441236	Characterization Su	37533
Remed. Control Survey	117663	Remed. Control Su	10009
Confirmatory Survey	29416	Confirmatory Surve	2502
TOTAL SURVEY COSTS	$1,252,584	**TOTAL SURVEY CO**	$175,081

Table D.4.5

Reference Facility: Rare Metal Extraction Facility

Residual Dose Limit 3 mrem/yr		Structure Surveys Class 1 Affected/Non-Unifor	Structure Surveys Class 2 Affected/Uniform	Structure Surveys Class 3 Unaffected	Land Surveys Class 1 Affected/Non-Unifor	Land Surveys Class 2 Affected/Uniform	Land Surveys Class 3 Unaffected
Site Information							
	Total area (m^2) - Outdoor	na	na	na	8296	929	26023
	Total area (m^2) - Floor/Lower Wall	7161	19373	0	na	na	na
	Total area (m^2) - U.Wall/Ceiling	0	0	19026	na	na	na
	Scan (% Area)	100	75	10	100	75	10
	Scan area (m^2) - Outdoor	na	na	na	8296	696.75	2602.3
	Scan area (m^2) - Floor/Lower Wall	7161	14529.75	0	na	na	na
	Scan area (m^2) - U.Wall/Ceiling	0	0	1902.6	na	na	na
Scanning	Survey Time (hr)						
(gamma)	Floors & Outdoor Areas	4.48	12.11	0.00	15.49333333	1.16125	4.337166667
(alpha/beta)	Floors & L. Walls	47.74	96.87	0.00	na	na	na
(alpha/beta)	U. Walls & Ceilings	0.00	0.00	25.37	na	na	na
Direct Measurements							
	Number of Measurements	2861	1141	166	na	na	na
	Survey Time (hr)	730.20	228.20	33.20	na	na	na
Soil Sampling							
	No. of Samples	na	na	na	9718	463	709
	Collection Time (hr)	na	na	na	971.80	46.30	70.90
Survey Time							
	Subtotal (hours)	782	337	59	987	47	75
	Adjustment A - 25% (daily checks, breaks, repeats)	196	84	15	247	12	19
	Adjustment B - 15% (data review)	117	51	9	148	7	11
	Total (hours)	1095	472	82	1382	66	105
Analytical Cost ($)							
	Soil Samples	na	na	na	2915400	138900	212700
	Smear Samples	1351	422	61	na	na	na
	Subtotal	1351	422	61	2915400	138900	212700
Final Survey Cost ($)							
	Labor	40332	17381	3019	50893	2447	3878
	Analytical	1351	422	61	2915400	138900	212700
	Subtotal	41683	17803	3080	2966293	141347	216578

			Survey costs using in situ gamma spectrometry		
	Sup. Data Review/ Report Preparation	25377	Conventional	Indoor survey costs	62566
	Total Cost - Final Survey	3412160		Total Cost - Final Survey	147580
Other Survey Costs ($)			**Other Survey Costs ($)**		
	Gridding - Indoor	43082		Gridding - Indoor	43082
	Gridding - Outdoor	3458		Gridding - Outdoor	3458
	Scoping Survey	170608		Scoping Survey	7379
	Characterization Survey	2559120		Characterization Survey	110685
	Remed. Control Survey	682432		Remed. Control Survey	29516
	Confirmatory Survey	170608		Confirmatory Survey	7379
	TOTAL SURVEY COSTS	$7,041,468		**TOTAL SURVEY COS**	$411,845

Table D.4.6

Reference Facility: **Rare Metal Extraction Facility**

		Residual Dose Limit (mrem/yr)				
		3	15	25	60	100
Scan time (min/ 100 m^2)	outdoor - gamma	10	10	10	10	10
	indoor - gamma	15	15	15	15	15
	floor/ l.wall - alpha/beta	40	40	40	40	40
	u. wall/ ceiling - alpha/beta	80	80	80	80	80
	floor/ l.wall - beta	20	20	20	20	20
	u. wall/ ceiling - beta	40	40	40	40	40
Direct Measurements (min/ location)	alpha/beta	12	3	3	3	3
Soil Sampling (samples/hr)		10	10	10	10	10
Analysis Cost ($/sample)	soil	300	150	75	75	75
	smear	0.37	0.37	0.37	0.37	0.37
Labor Rate ($/hr)	H.P. Technician	36.82	36.82	36.82	36.82	36.82
	H.P. Spervisor	70.99	70.99	70.99	70.99	70.99
Costs of Other Surveys (as a % of final survey costs)	Scoping Survey	5	5	5	5	5
	Characterization Survey	75	75	75	25	25
	Remed. Control Survey	20	20	20	20	20
	Confirmatory Survey	5	5	5	5	5

Total Survey Costs

Rare Metal Extraction Facility

3	7041468
15	1252584
25	390593
60	168984
100	166607

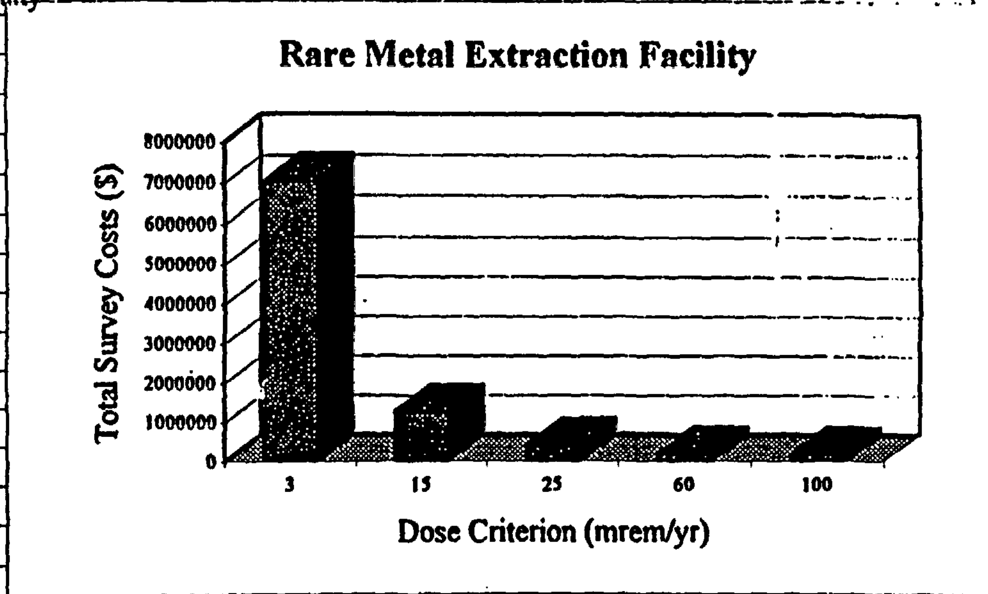

Figure D.4

APPENDIX E

SUMMARY OF DRAFT GEIS SCOPING PROCESS

APPENDIX E

E.1 Basis for Scoping Process

The Commission's regulations in 10 CFR Part 51 for complying with NEPA contain requirements for conducting a scoping process prior to preparation of an Environmental Impact Statement (EIS). Section 51.26 indicates that, whenever the NRC determines that an EIS will be prepared by NRC in connection with a proposed action, the NRC will publish a notice of intent in the Federal Register stating that a Generic Environmental Impact Statement (GEIS) will be prepared, and conduct an appropriate scoping process. Section 51.26 indicates that this scoping process may include the holding of a public scoping meeting as well as opportunity for written comment.

Section 51.27 contains requirements regarding the content of the notice of intent, in particular that it should describe the proposed action and, to the extent that sufficient information is available, also describe possible alternatives. In addition, the notice of intent is to describe the proposed scoping process, including the role of participants, whether written comments will be accepted, and whether a public scoping meeting will be held.

E.2 Scoping Activities Conducted

In accord with 10 CFR 51.26 and 10 CFR 51.27, a notice of intent announcing the scoping process was published in the Federal Register on June 18, 1993 (58 FR 33570). The notice of intent (referred to as an FRN) included a discussion of the proposed action, the bases for preparation of the GEIS, and the scoping process. The FRN also invited comment on the scope of the GEIS by describing then-current preliminary NRC staff views on the scope and major topics to be dealt with in the GEIS including: (1) the facilities to be considered; (2) the affected environment; (3) the regulatory alternatives to be considered; (4) the methods of analysis of regulatory alternatives; (5) impacts (both radiological and nonradiological) and costs associated with the regulatory alternatives; and (5) areas considered to be outside the scope of the GEIS. The FRN indicated that oral comment and discussion on the proposed action and alternatives could be presented at any of eight public scoping meetings. The eight public scoping meetings were held in Washington DC, San Francisco, Oklahoma City, and Cleveland during July 1993. In addition to the scoping meetings, the FRN also indicated that written comments on the proposed action and alternatives could be submitted to NRC by August 15, 1993 (as a result of written requests, the written public comment period was subsequently extended to September 20, 1993).

E.3 Scoping Comments Received

Oral comments presented at the scoping meetings and written comments submitted subsequent to the scoping meetings were received from members of the general public, interest groups, Federal agencies, licensees, and industry organizations. Section E.5, below, summarizes the conclusions reached in the scoping process based on the comments received.

Transcripts of the Scoping Meetings and copies of related letters are available for inspection or copying for a fee in the NRC Public Document Room, 2120 L Street, NW (Lower Level), Washington, DC.

E.4 Nature of Scoping Process

The Commission's regulations in 10 CFR Part 51.29(a) require that the scoping process will be used to: (1) define the proposed action which is to be the subject of the statement; (2) determine the scope of the statement and identify the significant issues to be analyzed in depth; (3) identify and eliminate from detailed study issues which are peripheral or are not significant or which have been covered by prior environmental review (discussion of issues in the EIS which are eliminated from detailed study would then include a brief presentation of why they are peripheral or will not have a significant effect on the quality of the human environment or a reference to their coverage elsewhere); (4) identify any environmental assessment and other environmental impact statements which are being or will be prepared that are related to but are not part of the scope of the statement under consideration; (5) identify other environmental review and consultant requirements related to the proposed action so that other required analyses and studies may be prepared concurrently and integrated with the EIS; (6) indicate the relationship between the timing of the preparation of environmental analyses and the Commission's tentative planning and decisionmaking schedule; (7) identify any cooperating agencies; (8) describe the means by which the EIS will be prepared, including any contractor assistance to be used.

The June 18, 1993, FRN (58 FR 33570) provided detailed description of the technical issues associated with Items (1) through (3), above, in Items (b) and (c) of the FRN on pages 33572 and 33573 by providing a proposed outline of the sections of the GEIS and preliminary NRC staff views on the scope and nature of the analyses to be conducted in those GEIS sections. These preliminary staff views were developed based on staff review of existing data and scientific information and also on the information presented in the seven public workshops on the Enhanced Participatory Rulemaking held between January and May of 1993. It is those Items (1) through (3), above, where the large majority of public comment was received during the scoping process, and it is those items where the principal determinations and conclusions regarding significant issues are discussed below in Section E.5. The FRN also presented information regarding Items (4) through (8), above, in items (d) through (g) on pages 33573 through 33574 of the FRN.

E.5 Summary of Conclusions of the Scoping Process

The Commission's regulations in 10 CFR 51.29(b) require that, at the conclusion of the scoping process used to perform the actions listed in 10 CFR 51.29(a) (listed in E.4 above), the NRC prepare a concise summary of the determinations and conclusions reached as a result of the scoping process, including the significant issues identified.

A number of public comments were received during the scoping process regarding the need for, general form of, and procedural aspects of a rule. These comments were not, strictly speaking, part of the GEIS scoping process and were not treated in the conclusions and determinations. These comments were treated more fully in the rulemaking development. In general, however, based on the comments received during the scoping process and as part of the rulemaking workshop process, most of which agreed that there should be a regulation which codifies residual radioactivity for decommissioning, the NRC is proceeding with a rulemaking to establish radiological criteria for decommissioning. Based on the scoping process, a proposed rule was issued for public comment in August 1994. NRC plans to issue a final rule in 1997. In accordance with 10 CFR Part 51 and with the National Environmental Policy Act, this GEIS is being prepared as part of that rulemaking action. Based on the scoping process, the GEIS is analyzing regulatory alternatives for establishing radiological criteria for decommissioning structures and lands of licensed facilities.

The following is a summary of the conclusions reached as a result of the GEIS scoping process as it related to the scope of this GEIS:

1. <u>Regulatory Alternatives</u>

Based on the comments received, the GEIS analyzes in detail the regulatory alternatives for establishing residual dose criteria and considers the impacts and costs associated with those alternatives. Chapter 2 indicates that the following regulatory alternatives are analyzed in this GEIS: (1) "no regulatory change"; (2) abandonment of facilities; (3) risk-based limits or goals; (4) use of best available technology; (5) return of the site to preexisting background conditions; and (6) restrictions on future use of the site.

The analysis of the regulatory alternatives includes impacts on public health and the environment and costs associated with the regulatory alternatives. The analysis of impacts include radiological and nonradiological impacts to workers, the public, and the environment, as well as societal, economic, land use, and other impacts. Costs include the costs of decontamination of buildings and structures, waste disposal, and radiation surveys. The details of the bases for the analyses and of how the analyses were performed are discussed below in Item 3. This includes the bases for the comparison of impacts and costs, the bases for the risk levels evaluated, how worker and public impacts are calculated, collective risks, ALARA considerations, and development of the bases for costs, including aspects of measurability at low dose levels.

2. <u>Method of Approach</u>

The scope of the facilities covered by the GEIS consists of licensed nuclear fuel cycle and non-fuel cycle facilities listed in Chapter 1 of this GEIS and described more fully in Chapter

3. In the GEIS analysis, reference facilities are analyzed, and reference contamination at the buildings and soils surrounding these facilities is estimated for a range of contamination levels to provide reasonable consideration of the incremental impacts and costs resulting from the regulatory alternatives.

The affected environment considered in Chapter 3 includes that affecting human health and safety, and in particular radiation exposure pathways resulting from occupancy of site buildings and from residential, agricultural, and recreational use of site lands, and of affected water sources, both on an unrestricted use basis and a restricted use basis. In addition, the affected environment includes consideration of waste disposal, nonradiological impacts on humans, impacts on biota, economic impacts, societal impacts, and land use impacts.

With regard to the technical approach, Chapters 4-6 (and Appendices B, C, and D) analyze the impacts on public health and the environment and costs associated with the regulatory alternatives using data as available for a set of reference facilities for a modeled set of reasonable pathways. The analysis of impacts includes radiological and nonradiological impacts to workers, the public, and the environment, as well as societal, economic, land use, and other impacts. Costs include the costs of decontamination of buildings and structures, waste disposal, and radiation surveys. The details of how the analyses were performed are discussed below in Item 3.

3. Analysis of Impacts, Costs, and Wastes

With regard to the bases for health risks from exposure to radioactive material, the NRC has generally followed the basic radiation protection recommendations of the ICRP and its U.S. counterpart, the NCRP, in formulating basic radiation protection standards.

Recommendations of the ICRP and the NCRP were relied on in the revision of 10 CFR Part 20, "Standards for Protection Against Radiation," which were implemented by licensees on or after January 1, 1994. The analysis in Chapter 4 with regard to impacts from exposure to radioactive materials continues this practice and bases the analysis on the estimates of the NCRP and ICRP. It is outside the scope of this GEIS to review other studies to establish a new basis for health effects from radiation exposure.

Risks specifically related to exposure to chemical hazards are outside the scope of this GEIS although licensees would continue to be required to meet the applicable standards set by Federal, State, or local agencies with jurisdiction over these matters. Nevertheless, a licensee would be required to meet such standards before the NRC would terminate its license.

With regard to the analysis of impacts in this GEIS, incremental radiological and nonradiological impacts from the regulatory alternatives are considered. Chapter 4 considers impacts to persons occupying the site following license termination based on several possible exposure pathways. These pathways are based on scenario and pathway analyses developed in NUREG/CR-5512 which was subject to significant public and peer technical review. In addition to these impacts, Chapter 4 of the GEIS also considers both radiological and nonradiological (e.g., industrial accidents) impacts to workers involved in the decontamination activities, which occur during decommissioning, and considers the radiological and nonradiological (e.g., transportation accidents) impacts to workers and the public as a result of transport and disposal of decommissioning wastes, and issues related to transfer of the waste as opposed to keeping it on site. Consideration of the need to site added LLW facilities is included in Chapter 4 and in Appendix G. Chapter 4 of the GEIS also considers incremental impacts on biota and the environment, on society, and on economics which may result from the regulatory alternatives.

With regard to the analysis of the costs associated with the regulatory alternatives, Chapter 5 of the GEIS considers decontamination costs, waste transport and disposal costs, costs of surveys, and related issues. Incremental costs are assessed for the regulatory alternatives. ALARA issues are considered in Chapters 6 and 7.

Development of specific actions related to LLW disposal actions is outside the scope of this GEIS and can be considered as part of issues related to 10 CFR Part 61.

4. Planning for, and Funding and Timing of Decommissioning

In considering whether these areas are in the scope of this GEIS, it is important to note the GEIS prepared in 1988 (NUREG-0586) to support the promulgation of rules on general decommissioning planning requirements considered these areas in detail and resulted in general requirements for decommissioning in the Commission's regulations in 10 CFR Parts 30, 40, 50, 70, and 72 for reactors, and for fuel cycle and non-fuel cycle facilities in the areas of planning, financial assurance, and timing.

Development of these requirements was based on an analysis in NUREG-0586 which assessed the decommissioning activities for a number of reference nuclear facilities. The analysis in NUREG-0586 considered activities necessary to carry out decommissioning at the reference facilities, including the engineering and planning necessary for decommissioning, decontamination of facilities, the dismantling of equipment and structures, disposal of radioactive wastes, and radiation surveys. Based on that analysis for each of the reference facilities, NUREG-0586 assessed potential radiation exposures to workers and to the public during the decommissioning process, costs of decommissioning, the effect on planning and timing of the half-lives of principal radionuclides, the waste volumes generated and disposed of, and other environmental consequences. The analysis considered both prompt decommissioning and decommissioning following a storage period. Based on the analysis in NUREG-0586, requirements for planning of decommissioning activities, establishment of funding methods, and timing for carrying out decommissioning were included in the 1988 rulemaking. Specific timing and planning requirements for certain facilities were modified in a 1994 rulemaking (59 FR 36026; July 15, 1994) and a 1996 rulemaking (61 FR 39278; July

29, 1996), however, the analysis of NUREG-0586 remained valid for use in these modifications.

The incremental costs and impacts associated with the regulatory alternatives being treated in this GEIS do not appear to significantly affect these above issues or to affect the nature of the requirements in the existing regulations. In any of the regulatory alternatives being considered in this GEIS, licensees must continue to plan for, secure funding for, and complete decommissioning in a timely manner according to the current requirements.

An area that can be affected by the considerations of this GEIS, and which is therefore discussed, is if significant additional funds beyond that considered in NUREG-0586 and the previous rulemaking are necessary to accommodate a regulatory alternative, as for example if significantly higher costs for survey measurements capability or waste disposal result from a particular alternative. These costs are considered in Chapters 5 and 6 of this GEIS.

5. Continued Liability for Facilities

As discussed in Item 4, under existing regulations in 10 CFR Parts 30, 40, 50, 70, and 72, licensees are responsible for planning for and providing funding for decommissioning, including planning and funding for disposal of the wastes associated with decommissioning. Under existing regulations in 10 CFR Part 61, the licensee is responsible for packaging waste in a manner which protects public health and safety, but licensed waste disposal facilities are responsible for safe handling and disposal of the wastes at the disposal site. Chapters 5, 6, and 7 discuss impacts and costs of different regulatory alternatives.

6. Recycle of Materials

In response, although the GEIS does not analyze recycle in detail, it does address the potential for future inadvertent recycle of soils or structures following decommissioning of a site. With regard to proposed release of contaminated materials such as equipment, components, piping, etc., the Commission plans to consider separately impacts and costs related to potential recycle of these materials from nuclear facilities to deal with cases where the licensee proposes to intentionally release material containing residual radioactivity for reuse or recycle. In the interim, the Commission will continue to review such actions on a case-by-case basis. The costs and impacts associated with recycle of such materials can be addressed on a separate basis without affecting the NEPA analysis of this GEIS.

7. Use of a GEIS vs. the Need to Prepare a Site-Specific EIS

This GEIS does not attempt to analyze site-specific issues which may arise in the licensing process involved with the decommissioning of specific facilities, rather its principal intent is to provide a decision analysis leading to establishment of technical requirements regarding acceptable residual radioactive contamination levels for decommissioning. These requirements would establish a single set of radiological criteria which would apply to the decommissioning of all sites, however they would also recognize the need for flexibility in applying these criteria because of constraints posed by site-specific conditions (e.g. geology, hydrology, meteorology, demographics, and radiation background levels) and to provide opportunity for meaningful participation by local communities in individual decommissioning actions and, therefore, as discussed in Chapter 7, would provide for site-specific implementation of the generic criteria.

8. Citizen Participation

Site-specific considerations arise in Chapters 4 and 5 of this GEIS, when analyzing impacts and costs associated with reference facilities, and in Chapter 6 when evaluating the regulatory alternatives. Based on these considerations, comment from affected parties is discussed in Chapter 7.

9. Waste Minimization

Analysis of the waste quantities generated, of problems related to disposal of these waste quantities, and of associated costs in Chapters 4, 5, and 6 and Appendix G of this GEIS illustrate the need for efforts to minimize waste generation at nuclear facilities. The need for provisions in facility design and procedures for operation to minimize contamination of the facility and the environment, to facilitate eventual decommissioning, and to minimize the generation of radioactive waste is discussed in Chapter 7.

APPENDIX F

ACCESS RESTRICTIONS FOR RESTRICTED USE OF FACILITIES THAT HAVE HAD THEIR LICENSES TERMINATED BY NRC

APPENDIX F

ACCESS RESTRICTIONS FOR RESTRICTED USE OF FACILITIES THAT HAVE HAD THEIR LICENSES TERMINATED BY NRC

Licensees may choose to only remediate a contaminated site sufficiently to allow restricted release of the site. Examples include situations where further remediation is determined to be not cost effective for the benefit received and/or further remediation is determined to cause net public harm or to be unfeasible with existing technology. Site use can be restricted by means of deed restrictions, simple access restrictions, and more complex engineered barriers. This Appendix discusses simple and relatively low cost access restrictions that could be used as part of a restricted use alternative. Deed restrictions, which can be very site specific in their application, are not discussed here. Engineered barriers can be very complex and site specific although a general discussion of stabilization and capping is contained in Section 6.6.7 of Appendix C. In order to show that a site has been remediated to ALARA, a licensee could further reduce dose to individuals on the site by installing inexpensive but effective technologies to prevent inadvertent access to the site. This section provides methods for representative low-cost technologies as well as cost estimates for those methods. The technologies evaluated in the section include installing a perimeter fence around the contaminated site, paving the contaminated site, and landscaping the site in a way to discourage access.

F.1 Perimeter Fence

One low cost but effective technology for restricting access to a site is a perimeter fence. For the purposes of this analysis, a cost estimate is developed for both a residential fence and a low-security industrial fence that are intended to only prevent unintentional access to the site. The residential chain link fence is six feet high, is made of 11-gauge wire and galvanized steel, and has 1-5/8" line posts every 10 feet, two-inch corner posts, and a 1-3/8" top rail. It is also assumed to have a six-foot high, four-foot wide gate every 1000 feet and to have a warning sign posted every 50 feet. The cost for installation of this fence is about $12.20 per linear foot, or $40.00 per linear meter (Means, 1993).

The industrial chain link fence is six feet high, is made of 6-gauge wire and galvanized steel, and has two-inch line posts every ten feet and a 1-5/8" top rail. It is also assumed that a set of double swing gates are in the fence every 1000 feet and that a warning sign is posted every 50 feet. The cost for installation of this fence is about $19.80 per linear foot, or $64.90 per linear meter (Means, 1993).

F.2 Paving and Surfacing

Another technology that can be used to minimize exposure of individuals to contaminated soil is to cover the contaminated land surface area with a material such as asphalt. This allows the possibility of reusing the site, such as for a parking area for vehicles. Cost estimates for installation of this technology range from about $11.9/m^2$ for a residential driveway-grade paved surface to $19.7/m^2$ for a highway-grade asphaltic concrete pavement (Means, 1993). The cost estimate for the driveway-grade paved surface includes estimates for grading the surface in preparation for paving, the lay-down of a stabilization (polypropylene) fabric, and the lay-down of a 2½-inch thick asphaltic concrete pavement. The cost estimate for the highway-grade paved surface includes for grading the surface in preparation for paving, installation of a 4-inch thick granular (1½-inch diameter stones) base course, lay-down of a 3-inch thick asphaltic concrete binder course, lay-down of a stabilization (polypropylene) fabric, and the lay-down of a 1½-inch thick asphaltic concrete wearing course.

In some cases, a more robust engineered barrier may be desired, such as to prevent burrowing animals and vegetation from accessing the contaminated soil. Cost estimates for such an engineered barrier, or multi-layered cap, were provided in Section 6.6.7 of Appendix C.

F.3 Landscaping

A low cost technology for preventing unintentional access to a site is to landscape the site with plants that discourage access. For this analysis, it is assumed that a barberry shrub is planted around the perimeter of the site. The barberry shrub is a prickly shrub with sour green or red berries and yellow flowers and is often used for hedges. It grows to a height of four to five feet and a width of about four feet. The cost of landscaping with the barberry shrub is estimated to be $3.90/ft, or $12.90/m, and includes purchase and planting of the shrub and preparation of the bedding area with peat moss.

F.4 Access Restriction Costs for Reference Facilities

Table F.1 provides estimates for the costs to implement site access restrictions for each of the reference facilities described in Section 4 of Appendix C. The capital costs are estimated using the unit costs discussed above. The average annual cost of maintenance was derived from the assumptions that the capital investment in the access restrictions depreciated by 5% each year, that the maintenance cost for the first year is 1% of the capital investment cost, and that maintenance costs increase by 10% each year thereafter. It is assumed that essentially the only wear and tear on the access restrictions are from natural environmental conditions. The assumed values for these parameters are, therefore, low relative to what they would be for actual operating equipment. Based on these assumptions, the lifetime of the access restrictions is about 30 years, and the annual maintenance cost reported in Table F.1 is the average annual maintenance cost over the 30-year period. If the paved surface were used as a parking lot, then annual maintenance costs would be expected to be significantly higher than shown in Table F.1, and the lifetime of the surface would be expected to be considerably less than 30 years.

Table F.1. Calculated Costs for Site Access Restrictions

Reference Facility	Perimeter Fence ($K)		Paved Surface ($K)		Landscaping ($K)	
	Capital	Annual Maintenance	Capital	Annual Maintenance	Capital	Annual Maintenance
Nuclear Power Plant	2.7 - 4.3	0.15 - 0.24	3.3 - 5.5	0.18 - 0.30	0.90	0.05
Uranium Fuel Fabrication Plant	15.4 - 25.1	0.84 - 1.38	110 - 180	6.0 - 9.9	5.0	0.27
Sealed Source Manufacturer	3.4 - 5.6	0.19 - 0.31	5.5 - 9.2	0.30 - 0.50	1.1	0.06
Rare Metals Extraction Plant	15.4 - 25.1	0.84 - 1.4	110 - 180	6.0 - 9.9	5.0	0.27
Uranium Mill	148 - 240	8.1 - 13.2	10,200-16,800	560 - 920	48	2.6

F.5 References

Means. 1993. Means Building Construction Cost Data. Kingston, Massachusetts.

APPENDIX G

EVALUATION OF THE PLANNED DISPOSAL CAPACITY FOR DECOMMISSIONING AND NORMAL OPERATION WASTE

APPENDIX G

G.1 Introduction and Background

The cost analyses performed in Appendix C of the GEIS assumed that the waste generated from the decommissioning of buildings and soils for most of the reference facilities was placed in low-level waste burial sites. Appendix G estimates the amount of available planned disposal capacity by compact and noncompact states and compares this capacity to the incremental amount of waste generated by decontaminating the structures and soils for all licensed facilities considering the regulatory alternatives and alternative residual dose criteria discussed in Chapter 2 of this GEIS.

G.2 Approach and Method

For the purpose of this study, the focus is placed on low-specific-activity waste usually present in large volumes. Such waste includes contaminated building rubble, soils, slag, ash, sands, etc., and tailings-like materials. For the lower alternative residual dose criteria considered in Appendix C (i.e., approximately 3 - 0.03 mrem/y), larger waste volumes would potentially occur and require disposal at approved disposal sites and could become a consideration with regard to available and planned disposal capacity to accommodate the resulting waste volume. Conversely, for the higher alternative residual dose criteria (approximately 3 to 100 mrem/y), lesser waste volumes could potentially occur. Other risk and cost considerations are discussed in Chapters 4 and 5, and in Appendices B, C, and D. This Appendix factors waste disposal capacity considerations into the development of acceptable residual dose criteria for decommissioning.

Inherent in this approach is the assumption that the total amount of activity (even when associated with very large waste volumes) is not expected to be a limiting factor for disposal. It is assumed that the total radioactivity present in such waste from decommissioning of lands and structures would be a small fraction of that contained in waste generated under routine and normal operations. In other words, it is assumed that the volume might be a limiting factor, rather than total activity or radionuclide concentrations. Because the GEIS determines the incremental impact of alternative residual dose criteria for lands and structures, this Appendix does not analyze waste volumes from disposal of metals and equipment. The decommissioning waste volume estimates of low specific activity waste are based on the information in Attachments C and D of Appendix C (to provide complete information on waste volume estimates, Appendix C of the draft GEIS is reproduced in this final GEIS as Attachment D to Appendix C) and, where appropriate, information provided by the low-level Compacts and unaffiliated States.

The estimated incremental waste volumes from decommissioning of lands and structures are compared to the overall volume of waste generated under normal operations and are also compared to waste disposal capacity provisions by the Compact regions or States. This comparison is performed for each of the nine Compacts and all unaffiliated States.

This Appendix also considers the Site Decommissioning Management Plan (SDMP) facilities identified by the NRC. The facilities have contaminated buildings, soils, slag, and groundwater and former waste disposal areas and tailing piles (NRC, 1993b).

G.3 Waste Generator Profiles and Population

Waste generators are grouped in this Appendix into five categories: nuclear power plants, test and research reactors, fuel cycle facilities, non-fuel cycle material facilities, and dry spent fuel storage facilities. Reference facilities for the categories of nuclear power plants, fuel cycle facilities, and non-fuel cycle facilities are described in Appendix C. As noted there, the number of reference facilities analyzed in this final GEIS have been reduced from the draft GEIS, but because this Appendix G is summarizing total quantities of waste and comparing it to waste compact capacities, it estimates volumes for all NRC-licensed facilities in the U.S. including those not analyzed in detail in Attachment C of Appendix C. However, a description of reference research and test reactors and spent fuel storage facilities, including waste volumes, can be found in Attachment D to Appendix C. Site Decommissioning Management Plan sites are discussed as a separate category. Low-level radioactive waste produced by these categories of waste generators is generated in diverse types of activities, including power production, fuel fabrication, materials testing, chemical production, drug research and testing, mineral processing, and basic and applied research in various scientific disciplines (e.g., physics, chemistry, medicine, and biology). The radioactivity contained in the waste originates from various sources, such as reactors (research and power), industrial facilities, ore extraction and processing, etc. Waste generators are licensed under Nuclear Regulatory Commission and Agreement State regulations governing the possession and use of radioactive materials.

There are over 22,000 licensees (issued by the Nuclear Regulatory Commission and Agreement States) authorized to possess and use radioactive materials (NRC, 1993a). Both NRC and Agreement State licensees generate waste. The following sections describe the operating and nonoperating nuclear power plants, fuel-cycle facilities, approved and pending independent spent fuel storage facilities, materials licensees, and operating and nonoperating research and test reactors licensed by the NRC that are considered in this appendix.

Using the NRC license program code data, the distribution of licensees is estimated to be as follows:

Category	NRC	Agreement-State
Academic	83	6,210
Medical	2,260	1,120
Industrial	4,060	7,880
Source Materials	166	n/a
Special Nuclear Materials	236	n/a

Sources: NUREG-1350, Vol. 5, NRC, 1993a; NRC license Management System output dated 11/9/93 (R1201005A).

Not all of these facilities have the potential of generating low-level radioactive waste. For example, the following tabulation summarizes the distribution of licensed facilities generating waste for selected Compacts and States. A review of NRC materials license program codes and results of surveys conducted by States and Compacts indicates that up to 25% of the licensees may generate low-level waste. In some States, however, it is less than two percent. Also, the number of licensees and those that generate waste are known to fluctuate from year-to-year. However, the number of facilities reporting to generate and ship waste is perhaps more reliable as it is based on survey data. If the number of licensees were updated to reflect current information (matching data sets, total number of licensees with those that generate waste), it is expected that the fraction of facilities generating waste might be lower still. Accordingly, this information is presented here for illustrative purposes only.

Selected State	Estimated Number of Licenses	Licensees Generating Waste		Year of LLW Data
		Number	Percent	
Southeast Compact	4,325	61	1.4	1990
Texas	1,801	26	1.4	1992
Appalachian Compact	1,776	300	17.0	1990/1991
New York	1,749	245	14.0	1992
Central Midwest	1,438	363	25.0	1992
Michigan	700	49	7.0	1992
New Jersey	661	72	11.0	1988
Massachusetts	476	104	22.0	1991
Maine	130	16	12.0	1992
Rhode Island	73	10	14.0	1989
Dist. of Columbia	67	15	22.0	1989

Sources: NRC, 1993a; NRC, 1988b; PADER, 1993; NYSERDA, 1993a; MDEP, 1992; Ebasco, 1990; SCC, 1991; MLLRWMB, 1992; Shuman, 1993; IDNS, 1993; DiPrete, 1989; Barry, 1989; MLLRWA, 1993.

Similarly, a low percentage of licensees have the potential for generating significant waste volumes during facility decommissioning. In many instances, decommissioning involves the use of simple decontamination methods, resulting in minimal waste generation. For other types of facilities (e.g., medical, academic, and industrial), the radioactive materials used are short-lived and would not require any significant decommissioning efforts. The same is true for licensees using sealed sources (e.g., industrial radiography and irradiation facilities). Such facilities are also not expected to generate any significant amounts of waste.

Tables G.3.1-G.3.6 provide a listing of facility numbers, locations, and types and also indicate the compact location (or unaffiliated State) in which the facility is located. Tables indicate whether the facility was operating or in decommissioning at the time of the reference used although, because the analysis that follows combines the waste volumes from all facilities both in operation and in decommissioning, the operational status of the facilities is for informational purposes and does not affect the analysis.

Table G.3-1 Nuclear Power Plants in Commercial Operation[a]

State and Compact Region[b]	Plant Name	No. of Units	Type	Net MWe
Alabama/SE	Browns Ferry	3	BWR	1065
	J.M. Farley	2	PWR	828
Arizona/SW	Palo Verde	3	PWR	1221
Arkansas/CE	Arkansas Nuclear	2	PWR	858
California/SW	Diablo Canyon	2	PWR	1087
	San Onofre	2	PWR	1080/436
Connecticut/NE	Haddam Neck	1	PWR	565
	Millstone-1	1	BWR	654
	Millstone-2/3	2	PWR	863/1142
Florida/SE	Crystal River-3	1	PWR	821
	St. Lucie	2	PWR	839
	Turkey Point-3/4	2	PWR	666
Georgia/SE	E.I. Hatch	2	BWR	766
	A.W. Vogtle	2	PWR	1100
Illinois/CM	Byron	2	PWR	1105
	Clinton	1	BWR	930
	Dresden-2/3	2	BWR	773
	Lasalle	2	BWR	1036
	Quad Cities	2	BWR	769
	Zion	2	PWR	1040
	Braidwood	2	PWR	1120
Iowa/MW	Duane Arnold	1	BWR	538
Kansas/CE	Wolf Creek	1	PWR	1135
Louisiana/CE	River Bend	1	BWR	936
	Waterford-3	1	PWR	1075
Maine/Unaf.	Maine Yankee	1	PWR	830
Maryland/AP	Calvert Cliffs	2	PWR	825
Massachusetts/Unaf.	Pilgrim	1	BWR	670
Michigan/Unaf.	Big Rock Point	1	BWR	67
	D.C.Cook	2	PWR	1060
	Fermi-2	1	BWR	1075
	Palisades	1	PWR	768
Minnesota/MW	Monticello	1	BWR	536
	Prairie Island	2	PWR	503
Mississippi/SE	Grand Gulf	1	BWR	1142
Missouri/MW	Callaway	1	PWR	1125

Table G.3-1 Nuclear Power Plants in Commercial Operation[a] (Continued)

State and Compact Region[b]	Plant Name	No. of Units	Type	Net MWe
Nebraska/CE	Cooper	1	BWR	764
	Fort Calhoun	1	PWR	478
New Jersey/NE	Hope Creek	1	BWR	1031
	Oyster Creek	1	BWR	620
	Salem	2	PWR	1106
New Hampshire/ Unaf.	Seabrook	1	PWR	1150
New York/Unaf.	J.A. Fitzpatrick	1	BWR	757
	R.E. Ginna	1	PWR	470
	Indian Point-2/3	2	PWR	970
	Nine Mile Point	2	BWR	610/1072
North Carolina/SE	Brunswick	2	BWR	790
	McGuire	2	PWR	1129
	Shearon Harris	1	PWR	860
Ohio/MW	Davis Besse	1	PWR	874
	Perry	1	BWR	1141
	Fermi-2	1	BWR	876
Pennsylvania/AP	Beaver Valley	2	PWR	810/833
	Limerick	2	BWR	1055
	Peach Bottom-2/3	2	BWR	1035/1051
	Susquehanna	2	BWR	1038
	Three Mile Island	1	PWR	808
South Carolina/SE	Catawba	2	PWR	1129
	Oconee	3	PWR	846
	Robinson-2	1	PWR	665
	V.C. Summer	1	PWR	885
Tennessee/SE	Sequoyah	2	PWR	1148
	Watts Bar-1	1	PWR	1125
Texas/Unaf.	South Texas Project	2	PWR	1250
	Comanche Peak	2	PWR	1150
Vermont/Unaf.	Vermont Yankee	1	BWR	504
Virginia/SE	North Anna	2	PWR	915
	Surry	2	PWR	781
Washington/NW	Washington Project-2	1	BWR	1095
Wisconsin/MW	Kewaunee	1	PWR	503
	Point Beach	2	PWR	485

(a) Commercially operating plants by the end of 1995 (Nuclear News, 1993a, NRC, 1996a).
(b) Key to low-level waste Compact regions: NW, Northwest,; MW, Midwest; NE, Northeast; AP, Appalachian; CE, Central Interstate; CM, Central Midwest; SE, Southeast; SW, Southwestern; and Unaf., unaffiliated States.

Table G.3-2 Formerly Operated Commercial Nuclear Power Plants[(a)]

Unit & Location	Type & Power (MWt)	D&D Option Status[(b)]	State or Compact
CVTR, Parr, SC	PTHW 65	SAFSTOR	Southeast
Dresden 1, Morris, IL	BWR 700	SAFSTOR	Central Midwest
Fort St. Vrain, Platteville, CO	HTGR 842	DECON	Rocky Mountain
Trojan, Portland, OR	PWR 3,411	Pending	Northwest
Humbolt Bay, Humbolt Bay, CA	BWR 200	SAFSTOR	Southwestern
Rancho Seco, Herald, CA	PWR 2,772	SAFSTOR	Southwestern
GE VBWR, Pleasanton, CA	BWR 50	SAFSTOR	Southwestern
San Onofre-1, San Clemente, CA	PWR 1,347	SAFSTOR	Southwestern
Pathfinder, Sioux Falls, SD	BWR 190	DECON	Southwestern
Lacrosse, Genoa, WI	BWR 165	SAFSTOR	Midwest
Yankee Rowe, MA	PWR 600	pending	Massachusetts
Peach Bottom 1, Peach Bottom, PA	HTGR 115	SAFSTOR	Appalachian
Three Mile Island 2, Londonderry, PA	PWR 2,772	DECON/SAFSTOR	Appalachian
Fermi 1, Lagoona Beach, MI	SCF 200	SAFSTOR	Michigan
Shoreham, Wading River, NY	BWR 2,436	DECON	New York
Indian Point 1, Buchanan, NY	PWR 615	SAFSTOR	New York

(a) Extracted from NRC, 1993a. Five plants under the custodial care of the AEC/DOE are excluded from this listing.

(b) Key to D&D options: SAFSTOR, facility placed in safe storage for decontamination at some future time; and DECON, facility, equipment, and site decontaminated for unrestricted release shortly after plant shutdown.

Table G.3-3 Location and Types of Research and Test Nuclear Reactors[a]

State & Location	Licensee	Type of Reactor	Low-Level Waste Compact
Washington			Northwest
Seattle	Univ. of Washing.	Argonaut[b]	
Pullman	Washington S. Univ.	Triga	
Oregon			Northwest
Corvallis	Oregon State Univ.	Triga Mark II	
Portland	Reed College	Triga Mark I	
Idaho			Northwest
Pocatello	Idaho State Univ.	AGN-201	
Utah			Northwest
Salt Lake City	Univ. of Utah	Triga Mark I	
California			Southwestern
San Ramon	Aerotest	Triga (Industrial)	
San Diego	General Atomics	Triga Mark I & F	
Pleasanton	General Electric	Nuclear Test	
Irvine	Univ. of Calif.	Triga Mark I	
Arizona			Southwestern
Tucson	Univ. of Ariz.	Triga Mark I	
Colorado			Rocky Mountain
Denver	U.S. Geological Survey	Triga Mark I	
New Mexico			Rocky Mountain
Albuquerque	Univ. of New Mex.	AGN-201	
Texas			Texas
Austin	Univ. of Texas	Triga Mark II	
College Station	Texas A&M	Triga/AGN-201	
Iowa			Midwest
Ames	Iowa S. University	UTR-10	
Missouri			Midwest
Rolla	Univ. of Missouri	Pool	
Columbia	Univ. of Missouri	Tank	
Wisconsin			Midwest
Madison	Univ. of Wisconsin	Triga	
Indiana			Midwest
West Lafayette	Purdue Univ.	Lockheed	
Ohio			Midwest
Columbus	Ohio S. Univ.	Pool	
Nebraska			Central Interstate
Omaha	Veterans Admin.	Triga	
Kansas			Central Interstate
Manhattan	Kansas State Univ.	Triga	
Arkansas			Central Interstate
Russellville	Arkansas Tech, Univ.	Triga	

Table G.3-3 Location and Types of Research and Test Nuclear Reactors[a] (Continued)

State & Location	Licensee	Type of Reactor	Low-Level Waste Compact
Illinois			Central Midwest
Urbana	Univ. of Illinois	Triga Lopra	
Michigan			Michigan
Ann Arbor	Univ. of Michigan	Pool	
Midland	Dow Chemical	Triga	
Pennsylvania			Appalachian
Univ. Park	Penn. State Univ.	Triga	
Massachusetts			Massachusetts
Worcester	Worcester Poly. Tech.	GE	
Lowell	Univ. of Lowell	GE Pool	
Cambridge	MIT	HWR	
Rhode Island			Rhode Island
Narragansett	RI AEC	Critical Assy.	
New York			New York
Ithaca	Cornell Univ.	Triga Mark II & Zero Power	
Buffalo	S. Univ. of NY	Pulstar	
Troy	Rensselaer Poly Tech.	Critical Assy.	
Bronx	Manhattan College	Tank	
Maryland			Appalachian
Bethesda	Armed Forces Radio-biology Institute	Triga	
Gaithersburg	NIST	Nuclear test	
College Park	Univ. of Maryland	Triga	
Virginia			Southeast
Charlottesville	Univ. of Virginia	Pool	
North Carolina			Southeast
Raleigh	NC State Univ.	Pulstar	
Georgia			Southeast
Atlanta	Georgia Tech.	Heavy Water	
Florida			Southeast
Gainesville	Univ. of Florida	Argonaut	

(a) Extracted from NRC, 1993a.
(b) Facilities that are pending or undergoing decommissioning.

Table G.3-4 Research and Test Nuclear Reactors Preparing for or Undergoing Decommissioning; Possession Only License[a]

State & Location	Licensee	Type of Reactor	Low-Level Waste Compact
Washington			
Seattle	Univ. of Washing.	Argonaut	Northwest
Utah			Northwest
Provo	Brigham Young Univ.	L-77	
Salt Lake City	Univ. of Utah	AGN-201	
California			Southwestern
Los Angeles	Univ. of Calif.	Argonaut	
Pleasanton	General Electric	GETR	
Pleasanton	General Electric	EVESR	
Texas			
Austin	Univ. of Texas	Pool	Texas Compact
District of Columbia	Catholic Univ.	AGN-201	Dist. of Columbia
Ohio			Midwest
Sandusky	NASA	Mock-up	
Plum Brook	NASA	Test	
Pennsylvania			Appalachian
Saxton	Saxton Nuclear Experiment Corp.	PWR	
Waltz Mill	Westinghouse	Test	
Virginia			Southeast
Charlottesville	Univ. of Virginia	Pool	
Lynchburg	Babcock & Wilcox	Pool	
Kansas			Central Interstate
Lawrence	Univ. of Kansas	Pool	
Arkansas			Central Interstate
Strickler	SEFOR	Na-cooled	
Massachusetts			Massachusetts
Watertown	Watertown Arsenal	Pool	

(a) Obtained from the Office of Nonpower Reactors and Decommissioning Directorate, November 1993, and NRC, 1993a.

Table G.3-5 Location of Fuel Fabrication, Uranium Hexafluoride Production, and Uranium Enrichment Facilities[a]

Location	Fuel Fabrication	Uranium Hexafluoride Production	Uranium Enrichment	Low-Level Waste Compact
Windsor, CT	ABB Combustion Engineering[b]			Northeast
Lynchburg, VA	Babcock & Wilcox (2)			Southeast
Wilmington, NC	General Electric			Southeast
Columbia, SC	Westinghouse			Southeast
Hematite, MO	ABB Combustion Engineering			Midwest
Erwin, TN	Nuclear Fuel Services			Southeast
Richland, WA	Siemens Nuclear Power			Northwest
San Diego, CA	General Atomics			Southwestern
Metropolis, IL		Allied-Signal		Central Midwest
Gore, OK		Sequoyah Fuels[b]		Central Interstate
Homer, LA			Louisiana Energy Services[c]	Central Interstate

(a) Extracted from NRC, 1993a.
(b) Facility under decommissioning.
(c) Louisiana Energy Services, NRC Docket No. 70-3070, June 1993.

Table G.3-6 Dry Spent Fuel Storage Facilities[a]

Power Plant/ Facility	Licensee & State	Licensing Status	Low-Level Waste Compact
Surry 1/2	Virginia Electric & Power Co., VA	approved	Southeast
H.B. Robinson	Carolina Power & Light Co., SC	approved	Southeast
Oconee 1/2/3	Duke Power Co., SC	approved	Southeast
Fort St. Vrain	Public Service Co. of Colorado, CO	approved	Rocky Mountain
Calvert Cliffs	Baltimore Gas & Electric Co., MD	approved	Appalachian
Brunswick	Carolina Power & Light Co., NC	pending	Southeast
Prairie Island	Northern States Power Co., MN	approved	Midwest
Rancho Seco	Sacramento Municipal Utility District, CA	pending	Southwestern
General Electric	Morris, IL	approved	Central Midwest
Point Beach 1/2	Wisconsin Electric and Power Co., WI	general license	Midwest
Davis-Besse	Toledo Edison Co., OH	general license	Midwest
Palisades	Consumer Power Co., MI	general license	Michigan

(a) Data extracted from NUREG-1350, Vol.5 (NRC, 1993a; 1996a) and DOE, 1990.

G.4 Estimated Quantities of Low-Level Waste Generated

For the population of waste generators discussed in Section G.3, this section provides estimates of the quantities of low-level waste generated from normal operations and from decommissioning of structures and lands.

G.4.1 Normal Operations Waste

Over the past recent years, the trend in normal operations waste generation rates has been generally downward (see tabulation below) in response to the volume allocations imposed by the disposal sites and higher disposal costs (DOE, 1988; 1989; 1990; 1991; 1992a; Lockheed, 1996). Over the past 13 years, annual waste generation rates have varied significantly, ranging from a high of about 2.7 million ft^3 to as low as 0.7 million ft^3.

National Low-Level Waste Generation Rates (ft^3)

1983	1984	1985	1986	1987	1988	1989	1990
2.71E+6	2.62E+6	2.68E+6	1.80E+6	1.84E+6	1.43E+6	1.63+6	1.14E+6

1991	1992	1993	1994	1995
1.37E+6	1.74E+6	7.92E+5	8.58E+5	6.89E+5

Table G.4-1 presents a breakdown of normal operation waste generation by Compact and nonmember states (unaffiliated). Table G.4-2 presents, for illustrative purposes, the total volume and total activity of all radioactive waste shipped for disposal by each of the five categories of waste generators from 1988 to 1992 (EG&G, 1989; 1990; 1991; 1992; 1993). This table captures all waste (i.e., Classes A, B, and C, brokered and nonbrokered). Typically, Class A waste constitutes over 95 percent of the volume but only about 3 to 13 percent of the activity of the waste (NRC, 1990).

G.4.2 Estimated Waste Volumes from Decommissioning of Structures and Lands at Reference Facilities

The estimates of total waste volume from decommissioning of structures and lands, given below, are based on information in Attachments C and D of Appendix C for the five categories of facilities indicated in Section G.3, the estimated number of sites to be decommissioned, and information provided by the low-level Compacts and unaffiliated States. The results presented here represent a broad estimate in that they are based on a number of assumptions regarding contamination levels and extent discussed in Appendix C, and assuming similar behavior by the licensed facilities categorized by the reference facilities.

Table G.4-1
Compacts and Non-Member States Low-Level Normal Operations Waste Generation Rates[a]

Compact/State	Waste Volumes (ft^3) 1988	1989	1990	1991	1992	5-Year Average
Appalachian	182,600	171,212	119,582	244,930	112,083	166,000
Central Int.	71,718	85,244	58,328	56,774	80,116	70,500
Central Midwest	114,655	143,353	102,977	104,302	287,219	150,500
Midwest	96,758	157,820	123,511	112,800	88,793	116,000
Northeast	88,209	102,439	87,018	106,207	91,064	95,000
Northwest	128,377	115,016	95,943	137,935	235,620	143,000
Rocky Mountain	3,076	10,215	4,481	4,783	37,481	12,000
Southeast	479,114	497,208	336,474	285,828	369,951	390,000
Southwestern	111,530	149,909	84,910	100,599	133,758	116,000
District of Columbia	909	925	539	1,206	1,598	1,000
Maine	6,330	15,634	6,865	5,209	8,789	8,500
Massachusetts	50,614	56,526	40,750	34,425	56,734	48,000
New Hampshire	486	27	1198	4,324	48	1,200
New York	73,020	96,642	73,394	99,254	70,272	82,000
Puerto Rico	0	0	0	0	0	0
Rhode Island	1,108	1,419	160	361	374	700
Texas	12,376	22,101	9,185	53,087	162,844	26,000
Vermont	7,247	172	0	17,138	6,090	7,700
Total	1.43E+6	1.63E+6	1.14E+6	1.37E+6	1.74E+6	____

(a) Extracted from DOE, 1989; 1990; 1991; 1992a; and EG&G, 1993.

Table G.4-2 Yearly Activity (Ci) and Waste Volumes (ft^3) of All Waste Shipped for Disposal[a]

Year	Academic	Government	Medical	Industrial	Utility	Total
1988						
Volume	4.94E+4	8.76E+4	2.42E+4	4.56E+5	8.11E+5	1.43E+6
Activity	2.26E+3	1.05E+4	8.60E+1	3.44E+4	2.13E+5	2.59E+5
1989						
Volume	6.61E+4	1.14E+5	3.47E+4	5.65E+5	8.47E+5	1.63E+6
Activity	1.94E+3	1.26E+4	1.49E+2	1.27E+5	7.25E+5	8.67E+5
1990						
Volume	4.86E+4	7.23E+4	2.28E+4	3.56E+5	6.42E+5	1.14E+6
Activity	1.09E+3	1.01E+4	5.95E+1	1.03E+5	4.33E+5	5.47E+5
1991						
Volume	4.80E+4	1.03E+5	2.86E+4	5.51E+5	6.37E+5	1.37E+6
Activity	4.72E+2	1.93E+4	7.00E+4	7.17E+4	7.08E+5	7.99E+5
1992						
Volume	4.43E+4	1.58E+5	2.62E+4	9.08E+5	6.06E+5	1.74E+6
Activity	1.72E+3	4.07E+4	3.97E+2	1.00E+5	8.57E+5	1.00E+6

(a) Includes Class A, B, and C, brokered, and nonbrokered waste. Data extracted from EG&G, 1989; 1990; 1991; 1992; 1993.

To convert volume to cubic meters, multiply cubic feet by 0.02832.
To convert activity in SI units, multiply Ci by 3.7×10^{10} Bq.

G.4.2.1 Nuclear Power Plants

Table G.4-3 presents estimates of low-specific activity waste volumes for nuclear power plants. In making overall volume estimates, Table G.4-3 includes waste volumes from both the operating and nonoperating power plants listed in Tables G.3-1 and G.3-2. For comparison purposes, the waste volumes are aggregated by Compact regions and unaffiliated States. Table G.4-3 estimates that nuclear power plants would produce approximately 1 million cubic feet of decommissioning waste.

G.4.2.2 Test and Research Reactors

The estimated amounts of low-specific activity waste for test and research reactors are shown in Table G.4-4. In making overall volume estimates, Table G.4-4 includes decommissioning waste volumes from both the operating and nonoperating test and research reactors listed in Tables G.3-3 and G.3-4. Table G.4-4 estimates that test and research reactors would produce approximately 0.15 million cubic feet of decommissioning waste.

G.4.2.3 Fuel Cycle Facilities

Table G.4-5 shows the estimated amounts of low-specific activity waste for the fuel cycle facilities listed in Table G.3-5. These facilities are estimated to produce approximately 0.66 million cubic feet of waste.

G.4.2.4 Non-Fuel Cycle Materials Facilities

Table G.4-6 presents the estimated volumes of low-specific activity waste resulting from decommissioning activities at non-fuel cycle materials facilities. For comparison, the waste volumes are aggregated by Compact regions and unaffiliated States. In total, non-fuel cycle materials facilities are estimated to produce about 5 million cubic feet of waste.

G.4.2.5 Dry Spent Fuel Storage

The amounts of low-specific activity waste generated during the decommissioning structures and lands for dry spent fuel storage facilities are shown in Table G.4-7. Based on Table G.3-6, the overall waste volumes in this section are based on the presence of 12 storage facilities. In total, this category is estimated to produce about 6E+3 ft^3 of waste.

Table G.4-3 Estimates of Low-Specific Activity Decommissioning Waste Volumes for Nuclear Power Plants[a]

Compact/State	Operating Plants	Non-Operating	Total No.	Waste Vol. (ft^3)
Appalachian	11	2	13	104,000
Central Int.	7		7	56,000
Central Midwest	13	1	14	112,000
Midwest	11	1	12	96,000
Northeast	8		8	64,000
Northwest	1	1	2	16,000
Rocky Mountain		1	1	8,000
Southeast	34	1	35	280,000
Southwestern	7	5	12	96,000
Maine	1		1	8,000
Massachusetts	1	1	2	16,000
Michigan	5	1	6	48,000
New Hampshire	1		1	8,000
New York	6	2	8	64,000
Texas	4		4	32,000
Vermont	1		1	8,000
Total	111	16	127	1.0E+6

(a) The number of operating and shutdown power plants are based on data presented in Tables G.3-1 and G.3-2. Waste volumes for decommissioning of structures and lands were taken from Appendix C and rounded off to 8,000 ft^3 per plant.

Table G.4-4 Estimates of Low-Specific Activity Decommissioning Waste Volumes for Test and Research Reactors[a]

Compact/State	Operating Reactors	D&D and Poss. Only	Total No.	Waste Vol. (ft^3)
Appalachian	4	2	6	15,000
Central Int.	3	2	5	12,500
Central Midwest	2		2	5,000
Midwest	6	2	8	20,000
Northwest	6	3	9	22,500
Rocky Mountain	2		2	5,000
Southeast	4	2	6	15,000
Southwestern	5	3	8	20,000
Massachusetts	3	1	4	10,000
Michigan	2		2	5,000
New York	4		4	10,000
Texas	2	1	3	7,500
Rhode Island	1		1	2,500
District of Columbia		1	1	2,500
Total	44	17	61	1.5E+5

(a) The number of operating and shutdown reactors is based on data presented in Tables G.3-3 and G.3-4. Waste volumes from decommissioning structures and lands were based on Attachments C and D of Appendix C and rounded off to 2,500 ft^3 per plant.

Table G.4-5 Estimates of Low-Specific Activity Decommissioning Waste Volumes for Fuel Cycle Facilities[a]

Compact/State	No. of Projected Facilities	Waste Vol. (ft^3)
Northeast	1	60,000
Southeast	4	240,000
Midwest	1	60,000
Northwest	1	60,000
Southwestern	1	60,000
Central Midwest	1	60,000
Central Int.	2	120,000
Total	11	6.6E+5

(a) The number of facilities is based on data presented in Table G.3-5. Waste volumes from decommissioning of structures and lands were based on Appendix C and rounded off to 60,000 ft^3 per site.

Table G.4-6 Estimates of Low-Specific Activity Decommissioning Waste Volumes for Materials Facilities[a]

Compact/State	Assumed No. of Licensees	% of Total Facilities	No. of D&D Sites	Waste Vol. (ft^3)
Appalachian	1,776	7.99	193	482,500
Central Int.	1,550	6.98	169	422,500
Central Midwest	1,438	6.47	156	390,000
Midwest	2,098	9.44	228	570,000
Northeast	893	4.00	97	242,000
Northwest	1,350	6.07	147	367,500
Rocky Mountain	882	3.96	96	240,000
Southeast	4,325	19.5	47	117,500
Southwestern	2,753	12.3	300	750,000
District of Columbia	67	0.30	7	17,500
Maine	130	6.00	14	35,000
Michigan	700	3.15	76	190,000
Massachusetts	476	2.14	52	130,000
New Hampshire	115	0.50	13	32,500
New York	1,749	7.87	190	475,000
Rhode Island	73	0.30	8	20,000
Texas	1,801	8.10	196	490,000
Vermont	43	0.20	5	12,500
Total	22,219		1,994	5E+6

(a) The number of licensees is based on NUREG-1350 Vol. 5 (NRC, 1993a) and survey data from States and Compacts provided in periodic survey reports and from the 1989 Governor's Certification package. The number of licensees generating decommissioning waste was based upon the number of facilities estimated in JFA, 1994, for this category. Waste volumes from decommissioning structures and lands were based on Appendix C, assuming 2,500 ft^3 per site.

Table G.4-7 Estimates of Low-Specific Activity Decommissioning Waste Volumes for Dry Spent Fuel Storage Facilities[a]

Compact/State	No. of Projected Facilities	Waste Vol. (ft^3)
Southeast	4	2,000
Rocky Mountain	1	500
Appalachian	1	500
Midwest	3	1,500
Southwestern	1	500
Michigan	1	500
Central Midwest	1	500
	-----	------
Total	12	6E+3

(a) The number of dry spent fuel storage facilities is based on DOE data, see Table 4-9 (DOE, 1990). Waste volumes are 500 ft^3 per site (Appendix C).

G.4.3 Sites in the Site Decommissioning Management Plan (SDMP)

Under the Site Decommissioning Management Plan (SDMP), the NRC has identified a number of facilities that warrant special attention. The SDMP program includes over 50 sites, however, the actual number of sites varies depending upon licensing actions and progress of clean up activities. The SDMP program classifies the sites into seven categories:

Category	No. of Sites
Metal Extraction	14
Fuel Cycle	6
Research	6
Byproduct	9
U-Catalyst	3
Mg-Th Alloy	3
Others	9

Some sites are known or suspected of having some groundwater contamination. The sites have contaminated buildings, soils, slag, process waste, and former waste disposal areas and tailing piles (NRC, 1993b,c; NRC, 1995; NRC, 1996b).The contaminants include uranium (47%), thorium (34%), byproduct materials (14%), and plutonium (5%). The greater waste volumes are associated with ore processors. Fourteen of the SDMP sites, contaminated primarily with thorium, are estimated to generate potentially large volumes of contaminated soil and rubble, ranging from 20,000 to 10 million ft^3.

Table G.4-8 presents the estimated waste volumes for the NRC's SDMP sites and Table G.4-9 presents waste volume estimates associated with the decontamination of specific SDMP sites (NRC, 1993b,c; NRC, 1995; NRC, 1996b). Based on these data, the SDMP sites are estimated to produce about 57 million cubic feet of waste.

It should be recognized that such facilities are in a class apart from the traditional categorization of waste generators. Essentially, most of the waste is associated with the movement and processing of large volumes of uranium- and thorium- bearing ores.

Table G.4-8 Summary Estimates of Low-Specific Activity Decommissioning Waste Volumes from NRC SDMP Sites[a]

Compact/State	No. of Projected Facilities	Waste Vol. (ft^3)
Appalachian[b]	13	5.4E+6
Midwest	12	2.6E+7
Northeast	3	4.7E+6
Central Interstate	5	1.6E+7
Massachusetts[c]	3	1.3E+5
Michigan	4	4.4E+6
Total	40	5.7E+7

(a) The number of SDMP sites is based on information provided in Table G.4-9.
(b) One site without data on waste volumes and characteristics omitted for the purpose of this estimate.
(c) One site without data on waste volumes and characteristics omitted for the purpose of this estimate.

G.5 Waste Capacity Projections

This section discusses the estimated current or planned waste disposal capacities for the unaffiliated States and Low-Level Waste Compacts (LLW Forum, 1993; 1996). Table G.5-1 summarizes this information, based on projections made by the Compacts or States.

Table G.4-9 Estimated Waste Volume From Selected SDMP Facilities[a]

Facility/State	Estimated Quantity	Nuclide	Material	Compact
U.S. Army, Aberdeen Proving Ground, MD	1.3E+5 kg	Dep.U	Soils	Appalachian
Babcock & Wilcox, Parks Township, PA	6.0E+5 ft^3	U/Th	Soils/Metals	Appalachian
BP Chemicals, Lima, OH	2.8E+6 ft^3	Dep.U	Soils/Sludge	Midwest
Cabot Comp.:				
- Boyertown, PA	2.5E+5 ft^3	U/Th	Soils	
	1.3E+4 tons	U/Th	Tailings	Appalachian
- Reading, PA	6.0E+4 ft^3	U/Th	Slag	" "
- Revere, PA	8.2E+5 ft^3	U/Th	Slag/Soils	" "
Chemetron Corp., Newburgh Heights, OH:				Midwest
- Bert Ave.	4.8E+5 ft^3	Dep.U	Soils	" "
- Harvard Ave.	1.6E+5 ft^3	Dep.U	Soils	" "
Dow Chemical:				
- Midland, MI	3.2E+5 ft^3	Th	Slag/Soils	Michigan
- Bay City, MI	1.1E+6 ft^3	Th	Slag/Soils	" "
Fansteel, Muskogee, OK	8.1E+5 ft^3	U/Th	Sludge/Soils	Central
Hartley & Hartley, Bay County, MI:				
- SCA	2.7E+6 ft^3	Th	Slag/Soils	Michigan
- MDNR	2.5E+5 ft^3	Th	Slag/Soils	" "
Heritage Minerals, Lakehurst, NJ	2.8E+6 ft^3	U/Th	Sands/Tailings	Northeast
Kerr-McGee:				
- Crescent, OK	5.0E+5 ft^3	U	Soils/Sludge	Central
- Cushing, OK	4.4E+6 ft^3	U/Th	Soils/Sludge	" "
U.S. Army, Lake City Independence, MO	3.4E+6 ft^3	Dep.U	Soils/Sands	Midwest
Magnesium Elektron, Flemington, NJ	7.0E+5 ft^3	U/Th	Sludge/Soils	Northeast
3M-Kerrick, Pine County, MN	2.0E+4 ft^3	U/Th	Metals/Debris	Midwest
Molycorp:				
- Washington, PA	1.6E+6 ft^3	Th/U	Soil/Slag	Appalachian
- York, PA	3.3E+5 ft^3	Th/U/Ra	Soils/Waste	" "
Nuclear Metals, Concord, MA	1.3E+5 ft^3	Dep.U	Soils/Sludge	Massachusetts
Metcoa, Pulaski, PA	4.6E+4 ft^3	Th	Soil/Slag	Appalachian
RMI Titanium, Ashtabula, OH	1.4E+6 ft^3	U/Tc/Dep.U	Soils/Rubble	Midwest

Table G.4-9 Estimated Waste Volume From Selected SDMP Facilities[a] (Continued)

Facility/State	Estimated Quantity	Nuclide	Material	Compact
Schott Glass Tech., Duryea, PA	2.7E+5 ft^3	U/Th	Soils/Glass	Appalachian
Shieldalloy,				
- Cambridge, OH	1.0E+7 ft^3	U/Th/Ra	Soils/Slag	Midwest
- Newfield, NJ	1.2E+6 ft^3	Th/U/Ra	Soils/Slag	Northeast
GSA, Boston, MA	4.3E+2 ft^3	U	Soils	Massachusetts
Whittaker Corp., Greenville, PA	1.1E+6 ft^3	U/Th/Ra	Slag/Soils	Appalachian
Horizons, Inc., Cleveland, OH	2.2E+4 ft^3	U/Th	Soils/Rubble	Midwest
Jefferson Proving Ground, IN	1.9E+6 ft^3	Dep. U	Soils	Midwest
Kaiser Aluminum Specialty, Tulsa, OK	3.4E+6 ft^3	Th	Soils/Slag	Central
Advanced Med. Syst., Cleveland, OH	8.1E+4 ft^3	Co/Dep.U	Slag/Solids	Midwest
Elkem Metals, Marietta, OH	8.1E+3 ft^3	U/Th	Soils	Midwest
Englehard Corp., Plainville, MA	Unknown	U	Sludge	Massachusetts
NE Ohio Reg. Sewer Dist., Cleveland, OH	5.3E+6 ft^3	Co	Soils/Sludge	Midwest
Permagrain, Quehanna, PA	1.2E+4 ft^3	Sr/Co	Soils/Rubble	Appalachian
Safety Light, Bloomsburg, PA	Unknown	H/Ra/Cs/Sr	Soils/Rubble	Appalachian
Sequoyah Fuels, Gore, OK	7.0+6 ft^3	U	Soils/Rubble	Central
Westinghouse, Waltz Mill, Madison, PA	Unknown	Sr/Co/Cs	Soils	Appalachian

(a) Partial listing extracted from updated report on Site Decommissioning Management Plan, SECY-93-179 (NRC, 1993b), NUREG-1444 (NRC, 1993c), Supplement 1 to NUREG-1444 (NRC, 1995), and SECY-96-207 (NRC, 1996b). Listing excludes five sites expected to be removed from SDMP program by mid-1997 and nine others recently removed from the SDMP program from 1994 to mid-1996.

G.5.1 Appalachian States Compact

The Appalachian States Low-Level Radioactive Waste Compact (Appalachian Compact) is comprised of four states, including Pennsylvania, Delaware, Maryland, and West Virginia. Pennsylvania is the host state for the disposal facility. The Appalachian Compact's disposal facility is designed to accommodate an annual waste generation of 235,000 ft^3. However, based on current waste generation rates, the annual average is lower, about 100,000 ft^3 (PADER, 1993). The facility is designed to accommodate about 3.1 million ft^3 over a 30-

year period. The design does not make special provisions for D&D waste. Based on a study conducted by the Compact, it is thought that the design basis provides an ample margin to handle future D&D waste. Most of the LWR D&D waste volume is assumed to be generated beyond the life of the planned LLW facility, assuming plant life extension.

G.5.2 Central Interstate Compact

The Central Interstate Low-Level Radioactive Waste Compact (Central Compact) consists of five states: Nebraska, Arkansas, Kansas, Louisiana, and Oklahoma. The State of Nebraska has been designated as the host state. The Central Compact generates about 25,000 ft^3 of waste per year. Initially, the disposal is planned to accommodate 500,000 ft^3, with authorized expansions in 250,000 ft^3 increments, up to the maximum design capacity. The facility will handle up to 2.5 million ft^3 of waste, including D&D waste. However, current volume estimates do not include provisions for D&D waste. The Compact requires that the disposal of D&D waste be addressed on a case-by-case basis and get legislative approval.

G.5.3 Central Midwest Compact

The Central Midwest Interstate Compact Low-Level Radioactive Waste Compact (Central Midwest Compact) is comprised of the States of Illinois and Kentucky. The State of Illinois has been chosen to host the disposal facility. The Central Midwest Compact is projected to generate about 50,000 ft^3 per year on average. The facility will be designed to handle about 5.5 million ft^3 over its 50-year life span (Chem-Nuclear, 1991). For planning purposes, D&D waste volumes have been estimated for various scenarios, with a volume of about 3.0 million ft^3 for the most likely scenario.

G.5.4 Midwest Interstate Compact

The Midwest Interstate Low-Level Radioactive Waste Compact (Midwest Compact) consists of six states: Indiana, Iowa, Minnesota, Missouri, Ohio, and Wisconsin. Ohio has been designated as the first alternate host state after Michigan left the Compact.

The Midwest Compact generates 125,000 ft^3 of waste per year, on average. The facility is designed for a capacity of 1.5 million ft^3, averaging approximately 75,000 ft^3 over the 20-year life of the facility (OLLRWAC, 1993). For planning purposes, D&D waste volumes have been estimated for various scenarios and, depending upon the scenario, the D&D and unusual waste volumes are estimated to be up to 1.7 million ft^3 (Baird, 1988).

G.5.5 Northeast Compact

The Northeast Interstate Compact Low-Level Radioactive Waste Compact (Northeast Compact) is comprised of the States of New Jersey and Connecticut. The Compact requires that each State develop the facilities needed to manage an equitable portion of the region's waste.

Table G.5-1
Estimated Low-Level Waste Disposal Capacity by Compacts and Non-Member States[(a)]

Compact/State	Assumed Generation (ft³/y.)	Facility Life or Projection (y.)	Planned Disposal/ Storage Capacity (10^6 ft³)	Provision for D&D (10^6 ft³)	Out-of-Region Waste (10^6 ft³)	Planned Capacity Waste (10^6 ft³)
Appalachian[(#)]	100,000	30	3.0	0.1	---	3.1
Central Interstate[(&)]	25,000	30	2.5	---	---	2.5
Central Midwest	50,000	50	2.5	3.0	---	5.5
Midwest Interstate	75,000	20	1.5	$\leq$1.7	---	3.2
Northeast:						
Connecticut	10,000	50	0.5	0.96	---	1.5
New Jersey[(@)]	37,000	50	1.0	1.7	---	2.7
Northwest	90,000	60	5.4	0.2	1.1	6.7
Rocky Mountain	16,000	60	0.96	0.14	---	1.1
Southeast	370,000	20	7.4	3.6	---	11.0
Southwestern	100,000	30	3.0	2.5	---	5.5
District of Columbia	1,000	n/a	---	---	---	---
Rhode Island[(+)]	500	n/a	---	---	---	---
Massachusetts	20,000	30	0.6	0.45	---	1.1
Michigan[(^)]	18,000	20	0.36	0.97	---	1.3
New Hampshire	500	n/a	---	---	---	---
New York[(*)]	72,000	60	4.3	(3.4)	---	4.3
Puerto Rico	0	n/a	---	---	---	---
Texas Compact[(")]	26,000	50	1.3	1.5	---	2.8
Maine	6,300	50	0.11	0.10	---	0.21
Vermont	5,900	50	0.11	0.18	---	0.29

(a) All values are rounded off. Footnotes continued on next page. See Section 5.0 for details and sources. Additional sources for update: Lockheed, 1996; NYSERDA, 1996; MLLRWA, 1996; TLLRWDA, 1996; MLLRWMB, 1996; SWLLRWC, 1996; WADOE, 1996; PADER, 1996; LADEQ, 1996; CTHWMS, 1996; NJLLRWDFSB, 1996; IDNS, 1996.

Table G.5-1 Footnotes:

(#)	Adjusted from prior estimates based on recent trends. Most of the D&D waste volume for LWRs assumed to occur beyond life of currently planned LLW disposal facility. All LWRs are assumed to obtain operating-life extensions.
(@)	The assumed yearly generation rate is based on an analysis for 1989-1993 waste disposal practices. The planned disposal volume is based on an "as-disposed" waste volume. For LWR D&D waste volumes, projections assume immediate dismantlement, minimal recycling/reuse, and no access to low-activity and high-volume rubble disposal facilities.
(&)	Planned capacity for disposal is 500,000 ft^3. This initial capacity is expandable in 250,000 ft^3 increments to a maximum capacity of 2.5E+06 ft^3. Total capacity includes provisions for D&D waste from LWRs.
(^)	Operational life span of LLW facility to be determined at discretion of volunteer community. Preliminary estimate for LWR D&D waste volume.
(+)	No plans are being made for developing an LLW facility. State is planning to join a compact or unaffiliated state.
(%)	Based on the "Expected Case." D&D waste volume from LWRs included in the projected yearly waste generation rate.
(*)	Compact awaiting congressional ratification. Waste from Maine and Vermont will be disposed of at the planned Texas LLW disposal facility. The assumed generation rate is based on 50-year projections for "as-disposed" waste volumes.

The State of Connecticut is projected to generate annually about 10,000 ft^3 of waste for disposal. Based on 50-year projections, the total waste disposal volume is expected to be 0.5 million ft^3, assuming a 20-year life extension for the currently operating power plants (CTHWMS, 1993). For planning purposes, the anticipated D&D waste volume has been estimated to be 0.96 million ft^3. The total waste volume is expected to be 1.5 million ft^3.

New Jersey is expected to generate about 37,000 ft^3 per year, based on a trend established over a five-year period (from 1989 to 1993). Over the projected operational life of the planned New Jersey disposal facility, the total disposal volume is expected to be 2.7 million ft^3, from all sources. For planning purposes, the D&D waste volume from LWRs is estimated to be about 1.7 million ft^3. This estimate assumes immediate dismantlement, minimal recycling/reuse, and no access to low-activity and high volume rubble disposal sites.

G.5.6 Northwest Compact

The Northwest Interstate Compact on Low-Level Radioactive Waste Management (Northwest Compact) consists of eight states: Alaska, Hawaii, Idaho, Montana, Oregon, Utah, Washington, and Wyoming. The Northwest Compact is also accepting waste, under contract, from the Rocky Mountain Compact, which is addressed separately below.
The Northwest Compact is one of the two remaining sited States, with its facility located in Richland, WA. The disposal site is slated to remain operational well into the next century (2063, based on DOE land-lease expiration date). The current license is due for renewal in May 1997. The U.S. Ecology site lease with the State of Washington is due for renewal in 2005. Assuming a waste generation rate of about 90,000 ft^3/y, it is deemed that the Compact will have a sufficient disposal capacity to handle its waste and that of the Rocky Mountain Compact. The Northwest Compact is expected to generate about 200,000 ft^3 from D&D activities. The additional waste volume from the Rocky Mountain Compact is estimated to total about 1.11 million ft^3, which includes a provision of 140,000 ft^3 for D&D (Nuclear Waste News, 1993a). The site's total capacity has been estimated to be about 30 million ft^3.

G.5.7 Rocky Mountain Compact

The Rocky Mountain Low-Level Radioactive Waste Compact (Rocky Mountain Compact) is comprised of three states: Colorado, Nevada, and New Mexico. The Rocky Mountain Compact was one of the three sited States with a facility located in Beatty, NV. However, the Beatty facility was closed at the end of 1992 (LLW Forum, 1993). The Rocky Mountain Compact has since made arrangements with the Northwest Compact to dispose of its waste at the Richland, WA, facility.

The Rocky Mountain Compact is expected to generate about 16,000 ft^3/y over the life of the agreement with the Northwest Compact. If the agreement with the Northwest Compact remains open for the life of the Richland facility, the Rocky Mountain Compact is expected to generate about 1.11 million ft^3 (Nuclear Waste News, 1993a).

G.5.8 Southeast Compact

The Southeast Interstate Low-Level Radioactive Waste Management Compact (Southeast Compact) consist of eight states: Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia. The Southeast Compact is one of the currently two sited States, with its facility located in Barnwell, SC. Since July 1, 1995, the disposal site has been accepting waste from all Compacts and States. The alternate host State is North Carolina, with its new facility expected to become operational at the turn of the century.

On average, the Southeast Compact generates annually about 370,000 ft^3 of waste. The Compact has estimated (under a base case analysis) that the new North Carolina site will be required to handle at least 7.4 million ft^3 over 20 years (Guichard, 1993). This volume includes a provision for 200,000 ft^3 to accommodate waste from nuclear power plant life extensions but does not include any D&D waste from power reactors. Other alternatives consider waste volumes ranging from 7.5 to 10.6 million ft^3. The facility design and development are based on 11 million ft^3. This volume includes 3.42 million ft^3 for D&D and excludes waste due to plant life extension.

G.5.9 Southwestern Compact

The Southwestern Low-Level Radioactive Waste Compact (Southwestern Compact) consists of four States: California, Arizona, North Dakota, and South Dakota. California is the host state for the disposal facility.

The Southwestern Compact generates annually about 100,000 ft^3 of waste. The Southwestern Compact is expected to generate about 5.5 million ft^3 over 30 years. This waste volume includes D&D waste, about 2.5 million ft^3.

G.5.10 New Hampshire

New Hampshire is an unaffiliated State. New Hampshire generators have produced varying amounts of waste over the past five years, ranging from 9 to 235 ft^3 annually, excluding that generated by the Seabrook nuclear power plant (Lockheed, 1996). For planning purposes, the State is assumed to generate annually about 500 ft^3 of waste.

G.5.11 Massachusetts

The State of Massachusetts is not affiliated with a low-level waste compact. Between 1988 to 1991, Massachusetts waste generators produced annually about 46,000 ft^3. The waste generated by the Yankee Rowe (shut down since 1991) and Pilgrim nuclear power station is being stored and, since July 1, 1995, has been shipped to Barnwell, SC, for disposal. The State is expected to generate about 600,000 ft^3 over the next 30 years, assuming a yearly generation rate of 20,000 ft^3 (MLLRWMB, 1993; MLLRWMB, 1992). The State is also anticipating that an additional 450,000 ft^3 will be generated by various D&D activities.

G.5.12 Rhode Island

Rhode Island is not affiliated with a low-level waste compact. Rhode Island generators have produced varying amounts of waste over the past five years, ranging from 6 to 374 ft^3 annually (Lockheed, 1996). For planning purposes, the State is assumed to generate annually about 500 ft^3 of waste. The State is not planning to build a disposal facility but is considering joining an LLW Compact or an unaffiliated State.

G.5.13 New York

The State of New York is not affiliated with a low-level waste compact. The State has been considering various waste management options, including the need to establish long-term waste storage capabilities, relying on a volunteer community to host a site, and using an existing site for storage and/or disposal purposes (NYSERDA, 1993b).

The State of New York generates annually about 72,000 ft^3 of waste (NYSLLRWSC, 1995). Current disposal plans are based on 30- and 60-year waste generation rates. It is anticipated that about 4.3 million ft^3 will be generated under the "expected-case" scenario. This waste volume includes an estimated 3.4 million ft^3 of D&D waste from LWRs.

G.5.14 Texas Compact - Pending

The State of Texas will operate a disposal facility for its own waste and that from the States of Maine and Vermont (Nuclear Waste News, 1993b). The Compact agreement has been ratified by all three States, however, the agreement has yet to be ratified by the U.S. Congress. A site has been located and a license application to design and operate the facility has been submitted to the appropriate State agency.

The State of Texas is projected to generate annually about 26,000 ft^3 of waste and 1.3 million ft^3 over the next 50 years (TLLRWDA, 1996). An additional 1.5 million ft^3 is expected from the decommissioning of various facilities over the next 50 years. These waste projections characterize "disposal" volumes.

The State of Vermont is projected to generate annually about 5,900 ft^3 of waste, for a total of about 290,000 ft^3 from all sources (VLLRWA, 1993; Stanton, 1993; TLLRWDA, 1996). As before, these waste projections characterize "disposal" volumes.

The State of Maine is expected to generate annually about 6,300 ft^3 of waste (TLLRWDA, 1996) and about 100,000 ft^3 from decommissioning (MDEP, 1992). Again, these waste projections characterize "disposal" volumes.

G.5.15 Michigan

In May 1990, the Michigan Low-Level Radioactive Waste Authority concluded that none of the three potential disposal sites met the siting criteria (MLLRWA, 1993). The three sited States warned that Michigan was out of compliance with the Federal Law and that access to the disposal sites would be terminated. Since November 1990, Michigan low-level waste generators have been storing their waste on site. In July 1991, the Midwest Compact Commission revoked Michigan's membership in the Compact. The State of Ohio became the host state for the Midwest Compact. Since July 1, 1995, Michigan waste generators have been able to ship waste to Barnwell, SC, for disposal. Meanwhile, Michigan is pursuing plans that rely on a volunteer community to host the disposal facility.

The State has estimated that 18,000 ft^3/y will be generated, for long-term projection purposes (MLLRWA, 1996). The waste volume from D&D activities of LWRs has been estimated to be about 970,000 ft^3. The operational life span of the planned disposal facility is expected to be about 20 years; a time frame which would be set at the discretion of the volunteer community.

G.5.16 District of Columbia

The District of Columbia is not affiliated with a low-level waste compact. District generators have produced varying amounts of waste over the last five years, ranging from <1 to 1,598 ft^3 annually (Lockheed, 1996). For planning purposes, the District is assumed to generate annually about 1,000 ft^3 of waste (LLW Forum, 1993; Barry, 1989). The District is not expected to site a facility because of the high population density, limited land space, and low waste volumes.

G.5.17 Puerto Rico

Over the past decade, the Commonwealth of Puerto Rico has not shipped any waste for disposal (EG&G, 1988-1993; Lockheed, 1996). The Commonwealth is not expected to site a disposal facility as waste volumes are very small (LLW Forum, 1993; CPR, 1990; Lockheed, 1996). The generators also rely on radioactive decay for short-lived radionuclides.

G.6 Onsite Waste Disposal

In the past, waste generators have disposed of certain waste on site under the provisions of 10 CFR Part 20.304. This provision was rescinded by the NRC in 1980 and replaced by requirements under 10 CFR 20.302 (45 FR 71761, October 30, 1980). Under Part 20.304, a licensee was authorized to dispose of low-specific activity waste not exceeding 1,000 times the amounts specified in Appendix C of 10 CFR 20.

It has been estimated by the NRC that about 100 licensees conducted burial under Part 20.304 (45 FR 71761, October 30, 1980). Under the requirements of Part 20.302, the licensees were required to obtain specific approval. Based on preliminary data, it is estimated that about 40 disposal requests have been authorized by the NRC (NMSS files, preliminary data). In addition, there are approximately another 30 pending applications in various stages of review and evaluation, while some have been denied or are being held up pending the submission of additional information from the applicants.

Based on preliminary NRC data, waste volumes have ranged from minimal (a few hundred cubic feet) to larger amounts (3 million ft^3). Most of the burials, however, involve waste volumes ranging from a few tens to several thousands of cubic feet. The waste materials include contaminated soils, sand, animal carcasses, ash, sludge, rubble, hardware, etc. Such materials were generated under normal operations, unusual occurrences, and decontamination activities initiated by the licensee. The radionuclides most often cited in applications include H-3, C-14, P-32, S-35, Cr-51, Mn-54, Fe-59, Co-58, Co-60, Zn-65, Ga-67, Tc-99m, I-125, I-131, Cs-134, and Cs-137. Radionuclide concentrations vary significantly, from a fraction to several hundreds of picocuries per gram.

If, under the implementation of a D&D Plan, a licensee were required to remove any materials buried on site, the total volume of excavated waste would be determined on a site-specific basis. The total volume would include the waste itself and some soil which has commingled with the waste.

G.7 Discussion and Summary

Table G.7-1 gives the estimated waste volumes for decommissioning of lands and structures at licensed facilities categorized by the reference facilities for all five waste sectors, across all States and Compacts. The total volume for these facilities is 6.8 million ft^3 (Table G.7-1 does not include the estimated waste volumes from SDMP sites).

Table G.7-2 compares the results shown in Table G.7-1 against planned disposal capacities of the Compact regions and States. A review of this information indicates the following with regard to incremental impacts of alternate residual dose criteria:

- The estimated waste volumes from decommissioning of lands and structures make up about 13% of the planned disposal capacity based on the assumptions of footnote (c) of Table G.7-2. As indicated in Attachments C and D of Appendix C, incremental waste volumes from decommissioning are estimated to vary by about a 40% decrease in going from 100-25 mrem/y and a 250% increase in going from 100-.03 mrem/y as compared to a range of 100 to 3 mrem/y. However, as already noted based on Attachments C and D of Appendix C, a very large cost is associated with a very small dose reduction in reducing the dose below 3 mrem/y, and so such a reduction is extremely unlikely (see footnote (c) to Table G.7-2) and need not be considered further. To simplify and bound this assessment, the analysis of waste disposal volumes has focused on examination of incremental effects of moving from a residual dose criteria from 100 to 3 and to 0.03 mrem/y and does not consider the incremental differences for the intermediate residual dose criteria examined in Chapters 4 through 6 of this GEIS. Incremental volumes and effects related to these intermediate residual dose criteria would be lower than the bounding values presented here.

  Therefore, the estimated incremental waste volumes from decommissioning of lands and structures corresponding to bounding alternative residual dose criteria being considered here would not have a significant effect on the overall amount of disposal capacity, making up about 13% of the total planned low-level waste disposal capacity, and making up approximately 25% or less of the planned disposal capacity for any of the regions.

- For four regions, the review in Section G.5 indicates that there are not definitive plans for the disposal of the waste due to both normal operation and decommissioning. The regions are the District of Columbia, New Hampshire, Puerto Rico, and Rhode Island.

- Although not addressed here, it is assumed that since the waste is characterized by low radionuclide concentrations, the total radioactivity is not expected to be a limiting factor for disposal. It is assumed that such waste would produce a small fraction of the activity contained in normal operation waste (see Section G.4).

- In establishing disposal capacity needs, Compacts and States have adopted varying approaches. Some do not include any specific provisions for D&D waste. Rather, the design basis incorporates ample margin to handle such waste. In other cases, the disposal of D&D waste will be addressed on a case-by-case basis. In other Compacts, the assumption is that D&D waste will be placed into another disposal facility. This is the case for waste that will be generated beyond the operational life of the currently planned disposal sites.

- The disposition of wastes from SDMP sites is highly site-specific and consists mostly of waste associated with movement and processing of larger volumes of uranium and thorium bearing ores and soil, and such wastes may not go to currently planned disposal sites. For example, this type of waste may either be stabilized in place or may be shipped to other disposal sites designed to handle large volumes of very low level waste. One such facility is Envirocare of Utah, Inc., located in Tooele County, Utah (NRC, 1993d). The facility is authorized to handle large quantities of bulk low-level waste, NORM waste, and mixed waste under specific restrictions. The restrictions include limits on nuclides, concentrations, and specifications on the physical and chemical properties of the waste. In addition, some of these facilities could be placed into restricted use, and as described in Appendix C, this would result in a reduction in soil volumes requiring disposal.

Table G.7-1
Total Waste Volume Summary from Decommissioning of Lands and Structures for Reference Facility Categories by Compacts and Non-Member States

	Waste Volume (10^6 ft^3)					
Compact/State	Power Plants	Research Reactors	Fuel Cycle	Materials	Dry Fuel Storage	Total Volume
Appalachian	0.104	0.015		0.483	0.0005	0.602
Central Interstate	0.056	0.013	0.120	0.423		0.611
Central Midwest	0.112	0.005	0.060	0.390	0.0005	0.568
Midwest	0.096	0.020	0.060	0.570	0.0015	0.748
Northeast	0.064		0.060	0.243		0.367
Northwest	0.016	0.023	0.060	0.368		0.466
Rocky Mountain	0.008	0.005		0.240	0.0005	0.254
Southeast	0.280	0.015	0.240	0.118	0.002	0.655
Southwestern	0.096	0.020	0.060	0.750	0.0005	0.927
District of Columbia		0.003		0.018		0.020
Maine	0.008			0.035		0.043
Massachusetts	0.016	0.010		0.130		0.156
Michigan	0.048	0.005		0.190	0.0005	0.244
New Hampshire	0.008			0.033		0.041
New York	0.064	0.010		0.475		0.549
Puerto Rico				0.000		0.000
Rhode Island		0.003		0.020		0.023
Texas	0.032	0.008		0.490		0.530
Vermont	0.008			0.013		0.021
Total	1.02	0.153	0.660	4.99	0.006	6.8

Table G.7-2
Estimated Low-Level Waste Disposal Capacity by Compacts and Non-Member States

Compact/State	Waste Volume (10^6 ft^3) Total Planned Capacity	Waste Volume (10^6 ft^3) Reference Facility Categories Total Waste Volume(e) Estimates(c)	Ratio Estimate Capacity(d)
Appalachian	3.10	0.60	0.19
Central Interstate	2.5	0.61	0.24
Central Midwest	5.5	0.57	0.10
Midwest	3.2	0.75	0.23
Northeast	4.2	0.37	0.09
Northwest	6.7	0.72	0.11
Rocky Mountain	(a)	---	---
Southeast	11.0	0.65	0.06
Southwestern	5.5	0.93	0.17
District of Columbia	---	0.02	---
Maine	(b)	---	---
Massachusetts	1.1	0.16	0.15
Michigan	1.3	0.24	0.18
New Hampshire	---	0.04	---
New York	4.3	0.55	0.13
Puerto Rico	---	0.00	---
Rhode Island	---	0.02	---
Texas	3.3	0.59	0.18
Vermont	(b)	---	---
Total	51.7	6.8	0.13

(a) Included in total for the Northwest Compact.
(b) Included in total for the Texas Compact.
(c) Numbers given are for total waste volume for decommissioning lands and structures at a residual dose criterion of 3 mrem/y. Incremental waste volumes would be approximately 40% of these values for residual dose criteria of 100 to 25 mrem/y and approximately 250% for the 100 - .03 mrem/y range. Because very large costs are incurred with very small dose reduction (i.e., 3 - .03 mrem/y), this is extremely unlikely to occur.
(d) Refer to (c), above, for explanation of ratio estimates.
(e) Does not include waste volumes estimated to be generated by NRC SDMP sites.

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APPENDIX H

SUMMARY OF COMMENTS ON DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT

APPENDIX H

SUMMARY OF COMMENTS ON DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT

H.1 Regulatory Alternatives and Approach

Comments

Some commenters agreed with the general content of the GEIS and stated that it sufficiently addressed all environmental, social, and economic impacts of the proposed rulemaking on radiological criteria for decommissioning and fulfilled NEPA requirements which eliminated the need for licensees' environmental reports or for site-specific NRC preliminary environmental reviews for decommissioning to both unrestricted or restricted release. Other commenters criticized the GEIS as being technically incomplete or inconsistent because there is a lack of documentation, there are apparent discrepancies in the analysis, it is not clear why existing decommissioning criteria provide inadequate protection of public health, and the conclusions were derived from flawed bases and analyses. Some commenters indicated that the ALARA process is used inappropriately, that determining whether the proposed decommissioning criteria will minimize overall public risk is impossible, and that the totality of impact must be reviewed and included in decisionmaking. Some commenters questioned the results of the GEIS regarding the costs, impacts, and conclusions reached as a result of the GEIS analysis and also questioned why Alternative 5a (maintenance of a license) was excluded from consideration in the GEIS.

Response

In response to the comment on the use of the results of the GEIS in site-specific licensing cases of either unrestricted or restricted use, Section 7.2.3 discusses the approach for such use. In response to comments criticizing the GEIS for the reasons noted, the responses contained in Section H.2.2 describe the modifications made to the GEIS to improve the analysis in detail and in clarity. It should be understood that this is a generic analysis which reviews a large potential pool of facilities and sites and therefore, of necessity, is broad in its analysis of costs and impacts. Nevertheless, despite the range of possible parameters, scenarios, and site-specific situations, Appendices B and C provide analysis of impacts and costs, and provide results which can be helpful for gaining insight in making decisions regarding the dose criterion, ALARA, the decommissioning objective, and whether restricted use should be permitted. The analyses of costs in Appendix C and the analysis of impacts in Appendix B consider a range of possible cases. Nevertheless, with the range of cases studied, it is believed that this GEIS provides sufficient supporting information for the issuance of a final rule, in particular based on the rationale in Chapter 7.2.2.

Alternative 5a was not analyzed in detail in the GEIS because it is outside the scope of the rulemaking supported by this rule which is intended to evaluate alternatives for establishing radiological criteria for decommissioning and license termination.

H.2 Analysis of Impacts and Costs

H.2.1 Reference Facilities

Comments

A number of comments were received that criticized the analysis of costs and risks as incomplete and inadequate and submitted information in support of those comments. In general, some of the major comments suggested, and provided data on, using additional data from actual decommissionings that should be included which would consider variations in site contamination characteristics, including the concentration and volume of contamination and the profile of the contamination with depth. Specific comments were received suggesting such additional data for reactors, fuel fabrication facilities, uranium mills, rare-earth facilities, sealed source manufacturers, and independent spent fuel storage installations.

Response

In response to the comment, the NRC has reviewed additional data from a number of operating facilities. These facilities include power reactors, research reactors, uranium fabrication plants, rare metal facilities, and sealed source manufacturers and broad R&D facilities. A discussion of that data, with the exception of uranium mills, is contained in the specific facility discussions in Appendix C. The results of that review are incorporated into the results of Appendix C. Because of the complexities associated with decommissioning mill facilities, they are excluded from the scope of this final GEIS (see Section 3.2.1).

H.2.2 Human Health Impacts; Dose/Mortality Modeling

H.2.2.1 Dose Modeling Approach

Comments

Several commenters had specific criticism of the calculational method for estimating doses, including that it employed models that were inappropriately conservative and that more realism was needed, that it did not take into account dose reduction by simple techniques such as tearing down buildings, that it lacked supporting data for comparison of individual versus collective dose, that it did not include alpha radiation, that it was inconsistent in its use of default assumptions, that it omits evaluation above 100 mrem, that it does not consider completely nonradiological impacts or collective dose, that using an average member of a critical group in calculations is inappropriate, or that the supporting technical basis had not been released for public review.

In particular, there were questions regarding the uranium dose modeling approach, including consistency in estimating doses to the bone and to the lung and in summing organ doses, the need to take into account that, for many source-material wastes, uranium is insoluble, use of 1:1 concentration ratios for residual uranium and its long-lived decay products which is too conservative because fuel cycle facilities process refined uranium (separated from its progeny), and ingrowth of daughter products from long-lived radionuclides.

Response

Based on examination of additional information for the facilities considered (see Appendix C) and by expanding the alternative uses for unrestricted release sites (see Appendix B), the modeling was refined to include a broader range of possible site-specific circumstances and impacts than in the draft GEIS. While there can be other approaches to reducing residual doses (such as tearing buildings down), or other approaches to dose modeling for specific circumstances beyond that used in Appendix B, these are not considered typical and would require justification on a case-specific basis. Finally, doses above 100 mrem/y were included in Appendices B and C evaluations. However, based on 10 CFR Part 20, 100 mrem/y was used as the highest alternative dose criterion because it is the NRC's public dose limit in 10 CFR Part 20.

H.2.2.2 Use of the Linear Nonthreshold Hypothesis in Analysis

Comments

Commenters stated that the use of the linear nonthreshold hypothesis was not appropriate in the GEIS analysis as a decisionmaking tool for setting standards, for reasons ranging from that it overestimates to that it underestimates the risk.

Response

Use of the linear nonthreshold model for estimating incremental health effects per radiation dose incurred is considered a reasonable assumption for regulatory purposes by international and national scientific bodies such as ICRP and NCRP. The principal international and national radiological protection criteria, including the NRC's, are based on this assumption as a measure of conservatism. NRC's policy regarding use of the linear nonthreshold model was stated in the preamble to the issuance of 10 CFR Part 20 (56 FR 23360; May 21, 1991) noting that the assumptions regarding a linear nonthreshold dose effect model are appropriate for formulating radiation protection standards. Although this matter continues to be the subject of further consideration at this time, there is not sufficient evidence to convince the NRC to alter its policy as part of this rulemaking.

A discussion of the basis for the analysis of dose and associated risk is contained in Appendix B.

H.2.2.3 Time Period for Analysis

Comments

Commenters were concerned that the time period for analysis in the GEIS was not appropriate. Some commenters objected to the time frame used for calculating dose and wanted it lengthened to better predict health effects over the hazardous life of each isotope. Other commenters wanted the time frame shortened. Other commenters questioned the 70-year time period as excessive when evaluating exposures of individuals living on site in that it exaggerates the real-world risks noting that the EPA uses a 30-year exposure period in its parallel radiation site cleanup standards, and there is no justification for the NRC's assuming a 70-year exposure period because it is highly unlikely that any person would, in fact, spend 70 years working or living on site after a facility is decommissioned.

Response

The GEIS uses time periods following license termination of 1000 years for estimating collective doses from soil and 70 years for estimating collective exposures in buildings which have previously been used for licensed activities. Doses are calculated assuming radioactive decay of principal radionuclides.

The use of 1000 years in estimating site exposures is reasonable based on the nature of the levels of radioactivity at decommissioned sites and the potential for changes in the physical characteristics at the site over long periods of time. Unlike analyses of situations where large quantities of long-lived radioactive material may be involved (e.g., a high-level waste repository) and where distant future calculations may provide some insight into long term consequences, in the analysis for decommissioning, where the consequences of exposure to residual radioactivity at levels near background are small and peak doses for radionuclides of interest in decommissioning occur within 1000 years, long term modeling thousands of years into the future of doses that are near background may be virtually meaningless. In 10 CFR Part 40, Appendix A makes reference to both a 200-year and 1000-year time frame. In 10 CFR Part 61, references to the design of a physical barrier rather than a calculation of exposure are made.

The use of a 70-year time period for calculating collective dose and risk following license termination for buildings that have been involved in licensed activities is a reasonable building lifetime. The use of these time periods is discussed in Appendix B.

H.2.2.4 Transfer of Risk -- Nonradiological Impacts and Waste Disposal Impacts

Comments

Commenters questioned the use of collective dose in the analysis indicating that the GEIS incorrectly uses collective versus individual dose.

Several commenters questioned whether the net risk from decommissioning adequately considers all risks involved, including real risks to the worker and public risks associated with cleanup activities and waste handling and transport, compared to hypothetical risks from radiation exposure, and also questioned whether transferring risk without minimizing total risk is appropriate; for example, risks incurred at offsite disposal sites cannot be used to offset risks at the site being decommissioned and whether transfer to another site can be justified as an option for adequate long-term protection of the public since there is no net reduction in dose. Some commenters favored a risk-based approach that, in addition to radiological impacts, considers other impacts, such as risks to remediation workers, risks, both radiological and nonradiological, from transportation and waste disposal, and risks of damage to ecosystems and wildlife.

Response

The GEIS uses a risk-based approach to obtain comparisons for selecting alternative dose and associated cost. It was recognized that various aspects of decommissioning risk, such as traffic accidents from shipping, radioactive waste, or industrial activities, are different from risks incurred from exposure to radiation. Nevertheless, to obtain some measure of overall risk balance of major decommissioning activities and their respective costs, a measure of risk equivalency is permissible (see Appendix B for risk translation of decommissioning activities). In this way, the overall risk versus cost could be compared to obtain cost-benefit ratios for the alternative residual doses evaluated and the ratios compared with a range of acceptable associated cost-benefit ratios (see Chapter 6 for such comparisons).

H.2.2.5 Effect of Chemicals

Comments

Commenters indicated that the GEIS fails to consider nonradioactive hazardous pollutants and the adequacy of funding to deal with them, and in particular the synergistic effects of nonradiation hazards and radiation hazards, and injuries and illnesses from exposures to chemicals and from conventional industrial hazards that might present the greatest risks to workers' health and safety.

Response

This GEIS is concerned with the cost-benefit impacts resulting from considering alternative dose rate criteria. The impacts from other aspects of decommissioning have already been considered in the FGEIS on the 1988 final rule (NUREG-0586). While there can be some small impacts resulting from nonradioactive (e.g., chemical decontamination) removal of radioactive contamination from structures in achieving alternative dose rate levels, their consideration is covered by other Federal and State regulations (e.g., Department of Labor, Environmental Protection Agency, etc.).

H.2.2.6 Radon

Comments

Commenters questioned the approach to radon in the draft GEIS and in the proposed rule with some indicating that the rule should specifically include reference to radon whereas other commenters stated that the rule should not include standards for radon or expressed concerns about the complications introduced by these considerations and the fact that background radon levels are so high.

Response

As discussed in Appendix A, wide variations in local concentrations of naturally-occurring radon have been observed in all regions of the United States, including in soils and buildings. These variations make it very difficult to distinguish between naturally-occurring radon and radon resulting from licensed material. Because of these variations and the limitation of measurement techniques, Sections 4.2.2 and 7.2.2 discuss the approach taken in the GEIS analysis and in conclusions regarding radon.

H.2.3 Nonhuman Impacts

Comments

Commenters indicated that all environmental impacts, not only risks to humans, need to be incorporated into the GEIS analysis and in site-specific decisions, and that because of the paucity of our understanding of ecosystems, a full case-by-case consideration of all environmental and social "aspects" for each site or facility should be included. There are situations whereby a slightly larger dose/risk of radiation exposure would be an acceptable tradeoff (i.e., major environmental disruption due to restoration efforts, safety risk to cleanup workers).

Response

In general, the scientific literature concludes that protecting humans against radiological exposure is sufficient to ensure protection of other flora and fauna, especially at the levels of exposure being considered in this GEIS and rulemaking. Thus, both the draft and final GEIS state that the protection being provided to human populations by the standards imposed in these regulations should be sufficient to protect environmental resources (see Attachment C to Appendix B and Section 4.3).

Other aspects of decommissioning, such as general disturbance of ground cover, use of chemicals, etc., are either not related specifically to the level of the residual dose criteria and thus are outside the scope of the GEIS or the effects will be temporary and populations would be reestablished to former levels as discussed in Section 5.3 of the draft GEIS (see Attachment C to Appendix B).

H.2.4 Impacts on Waste Disposal/Capacity

H.2.4.1 Limits on Capacity

Comments

Commenters were concerned about whether the analysis had appropriately considered the effect on disposal capacity, whether the full scope of impacts of the cleanup criteria had been considered, including the impact of future waste management regulations, and also that the GEIS analysis appears to be volume-based without any activity analysis.

Response

As noted in the response to Comment H.2.2.1, several of the assumptions, models, and approaches in Appendix C have been revised in response to public comments to include additional data and alternate waste disposal costs. A complete discussion of such revisions is contained in Appendix C. Based on those revisions, an updated analysis of disposal capacity is contained in Appendix G, including considerations of waste regulations and activity analysis.

H.2.4.2 NORM Waste

Comments

Commenters questioned the appropriateness of the GEIS analysis to NORM with regard to EPA and State and local government requirements, and with regard to the impact of high volume NORM wastes, including impacts on available waste disposal capacity.

Response

The criteria of the rule supported by this final GEIS apply to residual radioactivity from activities under a licensee's control and not to background radiation (which includes radiation from NORM). Issues related to NRC-licensed sites containing materials which occur in nature are discussed in more detail in Appendices A, C, and G. As noted in response to Comment H.2.4.1, above, Appendices C and G have been modified as appropriate to consider a range of waste volumes for remediation and disposal.

NRC's legislative and regulatory authority extends to those materials and facilities under the Atomic Energy Act of 1954, as amended, and not to naturally-occurring radioactive material (sometimes referred to as NORM), except as it is defined as source material in Section 40.4 of 10 CFR Part 40. The analysis of the GEIS applies to residual radioactivity from activities under a licensee's control and not to background radiation (which includes radiation from NORM). There is a wide variety of sites containing NORM subject to EPA jurisdiction and not licensed by the NRC. The extent to which the analysis in this GEIS would apply to these sites would be based on a separate evaluation. However, the considerations and analyses done in the GEIS regarding large fuel cycle and non-fuel-cycle facilities containing large quantities of naturally-occurring nuclides, such as uranium and thorium, are appropriate for certain NORM sites, and the broad provisions of Chapter 7 may be useful in considerations regarding NORM sites.

H.2.5 Methods and Costs for Decommissioning

H.2.5.1 Inaccuracy in Costs

Comments

Some commenters criticized the models used to estimate the costs and risks of waste handling (including soil washing), removal, and disposal, and in particular noted that the models for the reference facilities underestimated volumes of material and thus underestimated costs. Commenters also indicated that the costs for waste disposal should be reviewed in particular in recognition of uncertainty associated with various radioactive waste disposal options. Commenters also indicated that NRC should thoroughly reexamine the analysis of the survey costs of demonstrating compliance at cleanup levels marginally above background radiation.

Response

As discussed in response to Comment H.2.1, the models used to estimate the waste volumes and resultant costs have been reevaluated. That reevaluation is contained in Appendix C. It is recognized, as is discussed in Appendix G, that there is some uncertainty in waste disposal availability and costs. For purposes of this GEIS, which attempts to provide a generic analysis and illustration of trends in potential impacts and costs associated with alternative residual dose criteria, Appendix C contains waste disposal costs based on a review of available information. A specific site in its licensing activities related to the decommissioning of that site would evaluate specific waste disposal charges. With regard to survey costs, Appendix D contains an updated evaluation of the methods and costs of surveys based on current information regarding capabilities to measure residual radioactivity at the dose levels evaluated in this GEIS.

H.2.5.2 Cost of Compliance, Social Costs, and Other Costs

Comments

Commenters indicated that the NRC needs to consider other costs not included in the cost analysis; e.g., costs owing to limited available disposal capacity, increased NRC and State and local regulatory costs, SSAB costs, costs of extensive public comment and hearing procedures.

Commenters also noted that the full social cost of radiological exposure was not considered, e.g., costs of decommissioning are emphasized but not costs of morbidity or mortality over the full period of toxicity of residual radioactivity to both present and future members of the public.

Response:

Disposal capacity space in considering alternative dose levels is addressed in Appendix G and is evaluated based on current and planned waste disposal sites. The differences in cost for decommissioning to alternative dose levels and the mortalities averted for various alternative uses of the sites for the dose levels evaluated are also considered in Appendices B and C, and cost-benefit comparisons are presented in Appendix B. Reasonable expectation of facility buildings lasting 70 years after license termination and sites requiring consideration for 1000 years are included in these alternatives. While there are costs in terminating licenses to the government, states, and affected populations, these are not necessarily increased costs and are likely to decrease because of licensing uniformity and inclusion of restricted release alternatives and appropriate consideration of mitigation before terminating a license.

H.3 Results of Analysis

H.3.1 Completeness/Validity of Analysis and Suggested Alternative Cost-Benefit Analysis Approaches

Comments

Some commenters criticized the inclusion of considerations of cost-effectiveness, objecting to using cost in decisionmaking and that the completeness of decontamination or cleanup should be decided by some criterion that does not include any consideration of the costs to achieve them, i.e., the health, public welfare, and environment must be NRC's priority without regard to costs associated with decommissioning. Other commenters criticized the GEIS because, although they favored use of cost-benefit analyses in decisionmaking, they felt that the cost-benefit analysis was inadequate because it used an improper approach combining the building and soil analysis and that separate analyses of the cost-effectiveness of soil removal and building removal should be performed. A commenter illustrated that such separate analyses would clarify differences between costs and impacts of cleanup of soils and structures that were not obvious in the draft GEIS. Commenters also suggested deleting the "knee-in-curve" approach as not clearly illustrating the information regarding costs and impacts for cleanup of both soils and structures, and also suggested alternative values of the $/person-rem value used or indicated that the cost per mortality averted was high compared to other costs per risk in Federal regulations. They also felt that the GEIS analysis underestimated the amount of contamination at reference facilities as well as the costs of remediation and final site closeout surveys.

Response

The rationale for establishing a dose criterion is explained in Section 7.2.2 of Chapter 7. It indicates that considerations are given to health and safety issues and issues regarding expenditure of resources compared to the benefits obtained. NRC methods and policy regarding cost considerations are stated in NUREG/BR-0058, Rev. 2, and call for preparation of an appropriate regulatory analysis in support of regulatory decisions. NUREG/BR-0058 does note that costs cannot be considered for regulatory actions necessary to ensure adequate protection of the health and safety of the public; however, it further notes that costs can be a factor in those cases where there may be more than one way to reach a level of adequate protection. Thus, the analysis in the GEIS was prepared in support of the rulemaking to provide additional information to decisionmakers with regard to the rule criteria being considered.

Based on the comments and information received, additional information has been added to the GEIS. Data on contamination submitted by the commenters were reviewed, compared with other existing data, including that in the draft GEIS and incorporated into Appendix C, as appropriate. Appendix C thus considers additional soil contamination data as well as soil and building contamination levels comparable to those evaluated in the draft GEIS. It also considers the range of disposal costs and survey methods and costs presented in the draft GEIS as well as those suggested in the comments. The Commission agrees with the commenters that consideration of soil and buildings separately can provide added information. Thus, Appendices B and C have used the analysis of the draft GEIS, which contained the data for performing separate analyses, and has presented the data more clearly in its tables. In addition, the "knee-in-curve" figures, which provided general information about behavior of costs and impacts associated with cleanup, have been replaced with a set of tables in Appendix B and in Chapter 6.

With regard to comments on the $/person-rem value, the evaluation of regulatory alternatives in the GEIS has been done using the regulatory analysis framework presented in NUREG/BR-0058 and NUREG-1530. NUREG/BR-0058 provides a decisionmaking tool for deciding between regulatory alternatives. A value of $2000/person-rem is developed in NUREG-1530, which includes a review of costs of other Federal regulations, and used in NUREG-0058 as part of that decisionmaking tool.

H.3.2 Comparison of Costs and Benefits

Comments

Some commenters agreed that the analysis of the GEIS supports a 15 mrem/y residual dose criterion, which was recommended in Chapter 8 of the draft GEIS, and that such a level is attainable, provides a margin of safety, and isn't unjustifiably costly. However, most commenters did not agree that the analysis of the GEIS supports a 15 mrem/y criterion. Some opposed 15 mrem/y as being too high and indicated that the analysis supported alternatives that reduced the contamination level to lower levels, including preexisting background. Others opposed 15 mrem/y as being too low and indicated that an appropriate analysis would support alternatives which generally included increasing the limit to 25, 30, 50, or 100 mrem/y with further reduction based on ALARA.

Response

As discussed in response to previous comments, modifications to the GEIS analysis have been made with regard to the reference facilities, the dose modeling approach, and the overall cost-benefit analysis approach. The results of these modifications and the effect on the cost-benefit analysis are discussed in Chapter 7. Also discussed in Section 7.2.2 of Chapter 7 is the rationale for establishing a dose criterion for unrestricted use.

H.3.3 Restricted Use

Comments

Some commenters agreed with the concepts and analyses permitting restricted use of decommissioned sites because it may be financially impractical to reach unrestricted levels, especially if health and safety considerations do not warrant it and because restricted release allows realistic land uses to be considered. Some commenters opposed the concept of, and analysis of, any planned restricted release of decommissioned sites because of concerns over the durability and effectiveness of institutional controls to provide needed protection of public health and safety at decommissioned sites, and because licensees should accept responsibility for their actions and not place the burden on other parties.

Commenters also noted that the cost analysis should take into account institutional and engineering controls, including the costs of SSAB involvement in the restricted use process, that can be maintained to ensure that the costs of incremental reductions in residual radioactivity are truly proportional to the benefits achieved and should allow credit for soil covers in meeting the criteria for restricted use.

Response

Current NRC regulations pertaining to decommissioning, promulgated on June 27, 1988 (53 FR 24018), do not contain provisions for release of a facility for restricted use but limit a licensee's options in decommissioning to release of a facility for unrestricted use. Experience with decommissioning of facilities since 1988 has indicated that for certain facilities, achieving unrestricted use might not be appropriate because there may be net public or environmental harm in achieving unrestricted use, or because expected future use of the site would likely preclude unrestricted use, or because the cost of site cleanup and waste disposal to achieve unrestricted use is excessive compared to achieving the same dose criterion by restricting use of the site and eliminating exposure pathways. The input received from the rulemaking workshops held from January through May 1993 confirmed this experience and indicated that restricted use of a facility, if properly designed and if proper controls were in place, was a reasonable means for terminating licenses at certain facilities.

Current NRC-licensed sites which might request restricted use are largely industrial sites. It is reasonable for them to remain industrial because of their locations and previous siting considerations. Nevertheless, there may be instances where if a site had high cultural value, such considerations would be presented as part of the public process that is part of restricted use and could be considered as a socioeconomic effect under the ALARA process.

The proposed rule, and the analysis of the draft GEIS of environmental impacts, thus provided for both unrestricted and restricted use of sites. Appendix C and Appendix F provide additional information with regard to impacts and costs related to restricted use. Based on the analyses of Appendices B, C, F, and G, it would appear that release of certain facilities for restricted use is an appropriate option assuming the presence of the specific provisions described below to ensure that appropriate controls are in place so that the restrictions on use remain in effect.

An important question raised in the public comments relates to the durability of institutional controls, i.e., whether the controls provide reasonable assurance that the exposure will be limited to the dose criterion in the rule over the periods in question.

For many types of decommissioned sites released under restricted conditions where potential doses to an individual are caused by relatively short-lived nuclides, the radiation exposure that could potentially be received if controls were to fail will gradually decrease to below the unrestricted dose criterion so the restrictions on use would no longer be necessary. Examples of facilities with nuclides of this type include reactors or materials facilities for which the principal dose contributing nuclides after decommissioning are Co-60 or Cs-137 (half-lives 5.3 and 30 years, respectively), or other similarly short-lived nuclides. The Commission has considered the effectiveness of institutional controls for up to 100 years in similar contexts such as low-level waste disposal sites. Because decommissioned facilities will have contamination at much lower levels than low-level disposal sites, the Commission believes that institutional controls using relatively simple deed restrictions can provide reasonable assurance that the TEDE will be below the dose criterion in the rule with restrictions in place.

In a limited number of cases, in particular those involving large quantities of uranium and thorium contamination, the presence of long-lived nuclides at decommissioned sites will continue the potential for radiation exposure beyond the 100-year period. More stringent institutional controls should be required in these situations, such as legally enforceable deed restrictions and/or controls backed up by State and local government control or ownership, engineered barriers, and Federal ownership, as appropriate. Such Federal control is authorized under Section 151(b) of the National Waste Policy Act (NWPA). Requiring absolute proof that such controls would endure over long periods of time would be difficult and should not be required. Rather, institutional controls should be established by the licensee with the objective of lasting 1000 years to be consistent with the time-frame used for calculations (and discussed in Section IV.F.7 of the Supplementary Information to the final rule). Having done this, the licensee would be expected to demonstrate that the institutional controls could reasonably be expected to be effective into the foreseeable future.

To provide added assurance that the public will be protected, there should be financial assurance to provide that the controls remain in place and are effective over the period needed. Given these provisions, the use of reliable institutional controls is appropriate, and such controls will provide a high level of assurance that doses will not exceed the dose criterion for unrestricted use.

Although it is anticipated that failure of active and passive institutional controls with the appropriate provisions in place will be rare, it is recognized that it is not possible to preclude the failure of controls. Therefore, in the proposed rule, the Commission included a requirement that remediation be conducted so that there would be a maximum value ("cap") on the TEDE from residual radioactivity if the institutional controls were no longer effective in limiting the possible scenarios or pathways of exposure. The cap included in the proposed rule was 1 mSv/y (100 mrem/y), which is the public dose limit codified in 10 CFR Part 20. Public comments on the proposed rule suggested other values for the cap, both higher than and lower than the proposed value. The analysis of those comments, and their potential effect on the institutional controls used, is discussed in Section IV.B.3.4 of the Supplementary Information to the final rule.

Given the discussion above on the viability of controls and on the provisions for financial assurance and for a "cap", the provision for restricted use and institutional controls should provide a high level of assurance that public health and safety will be protected. Licensees seeking restricted use should be required to demonstrate, to NRC's satisfaction, that the institutional controls they propose are comparable to those discussed above, are legally enforceable, and are backed by financial assurance. Licensees should also be required to demonstrate that the cap will be met.

With regard to responsibility for cleanup, the need to fix responsibility for decommissioning of licensed sites is appropriate. The planning and financial assurance requirements adopted June 27, 1988 (53 FR 24018) recognized the responsibility of licensees to plan for the cleanup of their sites and to provide adequate financial assurance for that cleanup. Similarly in the proposed rule and in the draft GEIS, it was indicated that licensees would not be permitted to release a facility for unrestricted or restricted public use unless the dose criteria stipulated in the rule had been satisfied. As noted in Chapter 7 and in Appendices B and C, further cleanup to levels such as background is not generally reasonable because it results in very little additional health benefit with very large costs incurred and could result in an increase in the overall risk associated with cleanup of a particular site when all factors (e.g., estimated fatalities due to traffic accidents during transport of radioactive wastes) are considered. Therefore, for the reasons discussed in more detail in Chapter 7 and Appendices B and C, potential use of restrictions is considered appropriate to protect public health and safety and to permit release of the sites and termination of license.

H.3.4 Need for Groundwater Analysis

Comments

The GEIS does not adequately analyze the technical basis or costs of applying the EPA drinking-water standard as proposed and should provide a cost benefit analysis of imposing the EPA's drinking-water standard as proposed.

Response

Chapter 6 and Appendix C have been modified to include an analysis of impacts and costs associated with remediation of the site to reduce the dose from the groundwater pathway to alternative residual dose levels.

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11. ABSTRACT (200 words or less)

The action being considered in this Final Generic Environmental Impact Statement (GEIS) is an amendment to the Nuclear Regulatory Commission's (NRC) regulations in 10 CFR Part 20 to include radiological criteria for decommissioning of lands and structures at nuclear facilities. Under the National Environmental Policy Act (NEPA), all Federal agencies must consider the effect of their actions on the environment. To fulfill NRC's responsibilities under NEPA, the Commission is preparing this GEIS which analyzes alternative courses of action and the costs and impacts associated with those alternatives.

In preparing the final GEIS, the following approach was taken: (1) a listing was developed of regulatory alternatives for establishing radiological criteria for decommissioning; (2) for each alternative, a detailed analysis and comparison of incremental impacts, both radiological and nonradiological, to workers, members of the public, and the environment, and costs were performed; and (3) based on the analysis of impacts and costs, conclusions on radiological criteria for decommissioning were provided. Contained in the GEIS are results and conclusions related to achieving, as an objective of decommissioning ALARA, reduction to preexisting background, the radiological criterion for unrestricted use, decommissioning ALARA analysis for soils and structures containing contamination, restricted use and alternative analysis for special site-specific situations and groundwater cleanup.

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