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Vol. 1

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

Main Report

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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Background

The Nuclear Regulatory Commission (NRC) has the statutory responsibility for protecting health and safety and the environment related to the possession and use of source, byproduct, and special nuclear material under the Atomic Energy Act. The NRC believes that one portion of this responsibility is to assure safe and timely decommissioning of the nuclear facilities used in conjunction with NRC-licensed activities. This responsibility can be partially fulfilled by providing guidance to licensees on how to plan for and prepare their sites for decommissioning.

Once licensed activities have ceased, existing NRC regulations require licensees to decommission their facilities so that their licenses can be terminated and the property released for unrestricted use. This requires that radioactivity in buildings, equipment, soil, groundwater, and surface water resulting from the licensed operation be reduced to levels low enough to allow license termination. Licensees must then demonstrate by a site radiological survey that residual contamination in all facilities and environmental media has been properly reduced to acceptable levels. The NRC conducts confirmatory surveys, where appropriate, to verify that sites meet NRC radiological criteria for decommissioning.

The action considered in this final Generic Environmental Impact Statement (GEIS) is an amendment to the Nuclear Regulatory Commission's regulations in 10 CFR Part 20 to include radiological criteria for decommissioning of lands and structures at nuclear facilities.

Need for the Rulemaking Action

The 1988 amendments (53 FR 24018; June 27, 1988) to NRC's regulations do not contain explicit radiological criteria for decommissioning. Instead, the NRC has been continuing to use criteria and practices described in several NRC guidance documents which have been in use for a number of years. This approach ensures protection of public health and safety by guiding decommissioning decisions and generally keeping potential radiological doses to a small fraction of NRC's public dose limit given in 10 CFR Part 20. However, both the number and complexity of facilities that will require decommissioning are expected to increase. Therefore, the NRC believes that it is necessary for radiological criteria for decommissioning to be codified in its regulations to allow it to more effectively carry out its function of protecting public health and the environment at decommissioned sites by providing a clear and consistent regulatory basis for determining the extent to which radioactive contamination must be removed or reduced in lands and structures before a site can be released and the license terminated.

Purpose of this GEIS

Under the National Environmental Policy Act (NEPA), all Federal agencies must consider the effect of their actions on the environment. It is the intent of NEPA to have Federal agencies incorporate consideration of environmental issues into their decisionmaking process. To fulfill NRC's responsibilities under NEPA, the Commission has prepared this GEIS which analyzes alternative courses of action and the costs and impacts associated with those alternatives.

Scope of the Generic Environmental Impact Statement

This GEIS analyzes regulatory alternatives for establishing radiological criteria for decommissioning structures and lands of licensed facilities. The alternative regulatory courses of action analyzed in the GEIS include a "no regulatory change" alternative and rulemaking alternatives to amend the NRC's regulations in 10 CFR Part 20. These rulemaking alternatives include setting residual criteria at certain limits or goals using a risk basis, requiring that a site's residual contamination be returned to background conditions, requiring that there be restrictions on future use of sites, and requiring the use of best available remediation technologies.

The scope of the GEIS includes nuclear facilities licensed by the NRC that require decommissioning including those involved with the nuclear fuel cycle and those licensed to use nuclear material for other non-fuel cycle related purposes. The types of nuclear fuel cycle facilities that require decommissioning include nuclear power plants, nonpower reactors, fuel fabrication plants, uranium hexafluoride production plants, and independent spent fuel storage installations. Because of the complexities associated with decommissioning of mill facilities, they are excluded from the scope of the final GEIS. Non-fuel cycle facilities include universities, medical institutions, radioactive source manufacturers, and companies that use radioisotopes for industrial purposes (about 75% of NRC's non-fuel-cycle materials licensees use either sealed radioactive sources or small amounts of short-lived radioactive materials).

The scope of the GEIS considers both radiological and nonradiological impacts on human health and safety, including radiation exposure resulting from occupancy of site buildings and residence on site lands following decommissioning and license termination, and radiation exposure during decommissioning and waste transport for disposal. Nonradiological impacts on humans, such as those resulting from conventional workplace accidents and from traffic accidents during transport of decommissioning wastes for disposal, are also considered. Waste disposal impacts, as well as impacts on biota, economic impacts, societal impacts, and land use impacts are addressed.

The GEIS does not analyze site-specific issues which may arise in the decommissioning process. Instead, its principal intent is to provide a decision analysis leading to establishment of technical requirements for acceptable residual radioactive contamination levels for decommissioning. Depending on the particulars of the specific facility, portions of the GEIS analysis may be applicable to the NEPA process for a specific site.

Approach in Preparing the GEIS

In preparing the GEIS, the NRC has presented the decision bases, analyses, and conclusions and recommendations regarding regulatory alternatives for establishing radiological criteria for decommissioning. In summary, the approach is as follows:

(1) A reasonable listing is developed of alternative regulatory actions to establish radiological criteria for decommissioning. The regulatory alternatives considered are listed above.

(2) For each of the regulatory alternatives, the GEIS presents a detailed analysis and comparison of: (1) incremental impacts, both radiological and nonradiological, to workers, members of the public, and the environment, resulting from each alternative, and (2) the incremental costs associated with each regulatory alternative.

(3) Based on the analyses of impacts and costs, the GEIS provides conclusions on radiological criteria for decommissioning.

Conclusions

The following principal conclusions are presented in the GEIS:

(1) Definition of Decommissioning

The definition of decommissioning should provide that, at the end of operations and completion of decommissioning activities, the license must be terminated and the facility released for either unrestricted use or release of property under restricted conditions (see Item #2 below).

(2) Establishment of Radiological Criteria for Decommissioning

A tiered approach should be used for establishing radiological criteria for decommissioning. This tiered approach would combine elements of both unrestricted and restricted use alternatives. This tiered approach is outlined below.

a) Achieving, as an Objective of Decommissioning ALARA, Reduction to Pre-Existing Background - The objective of returning a site to preexisting background conditions is consistent with the concept of returning a site to the condition that existed before its use. However, the question of whether this objective as a goal of decommissioning, and in particular the ALARA aspects of decommissioning, should be codified by rule depends on a variety of factors, including cost, practicality of achieving the objective, and the type of facility involved. Decommissioning is expected to be relatively easy for a certain class of non-fuel-cycle nuclear facilities (i.e., those that use either sealed radioactive sources or small amounts of short-lived nuclides), because there is usually no residual radioactive contamination to be cleaned up and disposed of, or, if there is any, it should be localized or it can be quickly reduced to low levels by radioactive decay. Achieving an objective of returning these facilities to background would not appear to be an unreasonable objective of ALARA. However, in general, for those nuclear facilities where contamination exists in soils and/or structures, achieving an ALARA decommissioning objective of "return to a pre-existing background" is not reasonable from a net detriment standpoint or cost vs. impacts standpoint because detriments and costs of remediation and surveys tend to increase significantly at low levels, while benefits tend to decrease at criteria near background.

b) Setting a Residual Dose Criterion - Given the range of possible parameters, scenarios, and site specific situations, there is a wide range of cost-benefit results among the different facilities and within facility types and there is no unique algorithm which decisively is the most beneficial result for all facilities which could be established. National and international radiation standards setting bodies, including the International Commission on Radiation Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP), note in their most recent documents (ICRP 60 and NCRP No. 116) that, although the limit for the public dose should be 100 mrem/y from all man-made sources combined, it would seem appropriate that the amount of exposure that a person would receive from any one source should be held to a fraction of the limit to account for the potential that an individual may be exposed to more than one source of man-made radioactivity, thus limiting the potential that an individual would receive a dose at the public dose limit. Considering potential sources, the dose from decommissioned sources should be held to 25 percent of the public dose limit which would provide a sufficient and ample margin for protection of public health and safety.

c) Decommissioning ALARA Analyses - As indicated above, for the generic scenarios considered, there is a wide range of possible cost-benefit results for different facilities. Therefore, ALARA analyses should be part of the radiological criteria for decommissioning.

d) Restricted Use and Alternate Site Specific Cases - There can be situations where restricting site use to achieve a TEDE of 25 mrem/y is a more reasonable and cost-effective option than unrestricted use. In this manner, restrictions can provide protection of public health and safety at reasonable cost by limiting the time period that an individual spends onsite or restricting agricultural or drinking water use. For many facilities, the time period needed for restrictions can be fairly short, i.e., enough to allow radioactive decay to reduce radioactivity to levels which permit release for unrestricted use. Thus restricted use, accompanied by provisions which assure the restrictions remain in place, should have a part in a license termination approach. There may be several existing licensed sites where the public health and the environment may best be protected by alternate means and it may be reasonable to anticipate that there may be site specific special circumstances, not analyzed in this final GEIS because of their specific situation, which need particular analysis.

(3) Groundwater Cleanup

The provisions of item #2 above are intended to protect the public from radiation from all of the pathways that they could be exposed to from a decommissioned facility (e.g., direct exposure to radiation from material on the soil surface, ingestion of food grown in the soil and from fishing, inhalation of dust from soil surfaces, and drinking water obtained from surface waters and from groundwater). Such criteria would thus limit the amount of radiation that a person could potentially receive from all possible sources (i.e., "all-pathways") at a decommissioned facility.

Because equivalent doses received through any of these pathways would involve equivalent risks to the person exposed, it would appear that, with regard to the need to set a separate standard for groundwater, there appears to be no reason from the standpoint of protection of public health and safety to have a separate, lower, criterion for one of the pathways (e.g., drinking water) as long as, when combined, they don't exceed the total dose standard established in the rule. Thus, while it is evident that exposures from drinking contaminated groundwater need to be controlled and that the environmental integrity of the nation's groundwater resources needs to be protected, it is also evident that protection of public health and safety is fully afforded by limiting exposure to persons from all potential sources of radioactive material at a decommissioned facility.

As is noted in Item #2 above, given the range of possible parameters, scenarios, and site specific situations, licensees should consider, as appropriate, in an ALARA analysis site specific conditions which could impact groundwater dose estimates.

(4) Citizen Participation

The public should not only be fully informed of the decommissioning actions at a particular site but also be able to effectively participate in site decommissioning decisions. In particular, for a decommissioning where a licensee does not propose to meet the conditions for unrestricted use noted in Item #2 above, additional community involvement and advice should be sought through a variety of methods regarding the proposed decommissioning. In seeking that advice, there should be provisions for: 1) participation by representatives of a broad cross section of community interests who may be affected by the decommissioning; (2) an opportunity for a comprehensive, collective discussion on the issues by the participants represented; and 3) a publicly available summary of the results of all such discussions. Advice sought from affected parties should be considered in decommissioning planning.

It is recognized that special environmental or cultural issues may be associated with a particular decommissioning action which would require more stringent implementation of the requirements. Sites on or contiguous to historical sites or Native American lands that contain religious or sacred areas are examples of such special issues. These issues can best be handled on a site-by-site basis as part of the decommissioning plan review process, and as part of the NRC's environmental review under NEPA. Where necessary, the provisions for public comment and for seeking community involvement and advice would provide a mechanism for addressing these issues.

(5) Minimization of Contamination

There should be specific attention given to design features and procedures that facilitate decommissioning the site, reduce the amount of radioactive waste, and minimize the overall public risk associated with decommissioning.

Foreword

The information in this report is being considered by the U.S. Nuclear Regulatory Commission staff in the development of amendments to its regulations in 10 CFR Part 20 to include radiological criteria for decommissioning of lands and structures at nuclear facilities. This report documents the potential environmental consequences of proposed regulatory alternatives.

This report contains the analysis of environmental impacts for rulemaking on radiological criteria for decommissioning that is being considered by the NRC. The results, approaches and/or methods described in this NUREG are provided for information only.

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1. Introduction

1.1 Description of the Rulemaking Action

The action considered in this final Generic Environmental Impact Statement (GEIS) is an amendment to the Nuclear Regulatory Commission's regulations in 10 CFR Part 20 to include radiological criteria for decommissioning of lands and structures at nuclear facilities. This action would provide a clear and consistent regulatory basis for determining the extent to which radioactive contamination must be removed or reduced in lands and structures before a site can be released and the license terminated.

1.2 Background

The Nuclear Regulatory Commission (NRC) has the statutory responsibility for protecting health and safety and the environment related to the possession and use of source, byproduct, and special nuclear material under the Atomic Energy Act. The NRC believes that one portion of this responsibility is to assure safe and timely decommissioning of the nuclear facilities used in conjunction with NRC-licensed activities. This responsibility can be partially fulfilled by providing guidance to licensees on how to plan for and prepare their sites for decommissioning. Decommissioning was defined in amendments made in 1988 to the NRC's regulations ("General Requirements for Decommissioning of Nuclear Facilities," 53 FR 24018, June 27, 1988), in 10 CFR 30.4, 40.4, 50.2, 70.4, and 72.3, to mean to remove nuclear facilities safely from service and to reduce residual radioactivity to a level that permits release of the property for unrestricted use and termination of the license.

During licensed operations, radioactive contamination may be spread into various areas within the facility by the movement of water or other fluids containing the radioactive materials through or along piping, equipment, walls, floors, drains, etc. In addition, areas surrounding buildings could become contaminated by the movement of materials, equipment, and people into and out of the areas containing the radioactive material, although NRC's contamination control requirements tend to limit such spread of material. In addition to contamination, some licensed operations (for example, nuclear reactors) can produce radioactive materials through the process of activation.

The 1988 amendments to the NRC regulations, noted above, required licensees who had ceased licensed activities to decommission their facilities so that their licenses could be terminated and the property released for unrestricted use. This required that radioactivity in buildings, equipment, soil, groundwater, and surface water resulting from the licensed operation be reduced to levels low enough to allow license termination. Licensees would then demonstrate by a site radiological survey that residual contamination in all facilities and environmental media had been properly reduced to acceptable levels. The NRC conducts confirmatory surveys, where appropriate, to verify that sites meet NRC radiological criteria for decommissioning.

Nuclear facilities licensed by the NRC, or used by licensees in their activities, that require decommissioning include those that are part of the nuclear fuel cycle (activities related to the generation of electricity through nuclear power generation) and those used in licensed activities for purposes other than fuel cycle activities (e.g., health care, research, and manufacturing). The types of nuclear fuel cycle facilities that require decommissioning include nuclear power plants, nonpower (research and test) reactors, fuel fabrication plants, uranium hexafluoride production plants, and independent spent fuel storage installations. Some effort to reduce radioactive contamination to acceptable levels will generally be necessary at these facilities before the license can be terminated. Non-fuel-cycle materials facilities include universities, medical institutions, radioactive source manufacturers, and companies that use radioisotopes for industrial purposes. About 75% of NRC's non-fuel-cycle 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 removed and disposed of. Of the remaining 25 percent, a small number (e.g., radioactive source manufacturers, research and development laboratories, and radioactive ore processors) conduct operations that could produce substantial radioactive contamination in portions of the facility. As at fuel cycle facilities, efforts will be needed to reduce contamination levels at these facilities during decommissioning.

Several hundred NRC licenses are currently terminated each year. Most of these licenses cover limited operations that produce little or no radioactive contamination and do not present complex decommissioning problems or potential risks to public health or the environment from residual contamination.

1.3 Need for the Rulemaking Action

The current regulatory structure for decommissioning was described in Chapter 2 of the draft GEIS. Specifically, that chapter noted that the 1988 amendments (53 FR 24018, June 27, 1988) to current NRC regulations do not contain explicit radiological criteria for decommissioning and that subsequently, at present, the NRC continues to use on a case-by-case basis criteria and practices described in several NRC guidance documents, listed here, which have been in use for a number of years:

1. Policy and Guidance Directive FC 83-23, "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of License for Byproduct, Source, or Special Nuclear Material Licenses," August 1987 (most recent revision).

2. Branch Technical Position, "Disposal or Onsite Storage of Thorium and Uranium Wastes from Past Operations" (46 FR 52061, October 1981).

3. (a) Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors," June 1974.

(b) Letter to Stanford University from James Miller, Chief, Standardization and Special Projects Branch, Division of Licensing, Office of Nuclear Reactor Regulations, USNRC, April 21, 1982.

4. 40 CFR Part 141, "National Primary Drinking Water Standard," U.S. EPA.

5. "Persons Exposed to Transuranium Elements in the Environment" (42 FR 60956, November 1977), U.S. EPA.

This approach of using these criteria and guidance ensures protection of public health and safety by guiding decommissioning decisions and generally keeping potential radiological doses to a small fraction of NRC's public dose limit given in 10 CFR Part 20. However, more of the older and larger nuclear facilities are reaching the end of their useful lives and need to be decommissioned. Because both the number and complexity of facilities that will require decommissioning are expected to increase, the NRC believes it is necessary to codify, and provide consistency in, radiological criteria for decommissioning.

The NRC believes that radiological criteria for decommissioning should be codified in its regulations so the Commission can more effectively protect public health and the environment at decommissioned sites by providing for:

(1) more efficient use of NRC and licensee resources;

(2) consistent application across all types of licensees;

(3) a predictable basis for decommissioning planning;

(4) the elimination of protracted delays in decommissioning which result as licensees wait for generic regulatory criteria before proceeding with decommissioning of their facilities; and

(5) a reassessment of the basis for the residual contamination levels contained in existing guidance in light of changes in basic radiation protection standards and decommissioning experience gained during the past 15 years.

1.4 Purpose of This Environmental Impact Statement

Under the National Environmental Policy Act (NEPA), all Federal agencies must consider the effect of their actions on the environment. Section 102(1) of NEPA requires that the policies, regulations, and public laws of the United States be interpreted and administered in accordance with the policies set forth in NEPA. It is the intent of NEPA to have Federal agencies incorporate consideration of environmental issues into their decisionmaking process. NRC regulations implementing NEPA are contained in 10 CFR Part 51. To fulfill NRC's responsibilities under NEPA, the Commission is preparing this final GEIS which analyzes courses of action which NRC would take in establishing radiological criteria for decommissioning and the costs and impacts associated with those alternatives.

1.5 Activities Conducted in Preparation of the Final GEIS

In preparing this final GEIS, the NRC conducted a number of activities including:

(1) In accord with 10 CFR 51.26 and 10 CFR 51.27, a notice of intent announcing a GEIS 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 either by oral comment at any of eight public scoping meetings or by written 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) facilities to be considered; (2) affected environment; 3) regulatory alternatives to be considered; (4) methods of analysis of regulatory alternatives; (5) impacts (both radiological and nonradiological) and costs associated with the regulatory alternatives; and (6) areas considered to be outside the scope of the GEIS.

    Oral comments presented at the scoping meetings and written comments submitted subsequent to the scoping meetings came from members of the general public, interest groups, Federal agencies, licensees, and industry organizations. A summary was prepared of the comments received during the scoping process and of the determinations and conclusions reached, including the significant issues identified. This summary is contained in Appendix E.

(2) Based on the scoping process and analysis of alternative actions, the NRC issued the draft Generic Environmental Impact Statement (GEIS) on Radiological Criteria for Decommissioning (NUREG-1496) in August 1994 (NRC 1994a). This draft GEIS accompanied a proposed rule on radiological criteria for decommissioning which was also issued in August 1994 (59 FR 43200, August 22, 1994).

    Public comments, including those from the EPA, on both the proposed rule and on the draft GEIS were received during the public comment period which closed in January 1995. The comments received on the proposed rule and draft GEIS are summarized in NUREG/CR-5383 (NRC 1996). The comments received on the draft GEIS are presented in Appendix H of this final GEIS along with responses to the comments. In addition, Chapters 2-5 and Appendices A, B, C, D, and G of this final GEIS indicate how these comments were incorporated into the analysis of the final GEIS.

    As discussed in those chapters and appendices, the NRC has carefully considered the numerous comments made on the analysis of the draft GEIS. This was previously noted in a Federal Register notice issued in August 1995 (60 FR 40117, August 7, 1995), which announced that the NRC was delaying completion of this rulemaking to allow it to more fully consider the comments received. In addition, the Commission held a workshop in September 1995 (announced in August 1995, 60 FR 42193) which discussed survey methods appropriate for decommissioning.

1.6 Content of the Final Environmental Impact Statement

Based on the scoping process and the review of public comments received on the draft GEIS, this final GEIS analyzes regulatory alternatives for establishing radiological criteria for decommissioning structures and lands of licensed facilities. The scope of this GEIS includes the licensed nuclear fuel cycle and non-fuel-cycle facilities noted in Section 1.2 and described more fully in Chapter 3. This final GEIS considers environmental effects on human health and safety, especially radiation exposure resulting from occupancy of site buildings and residence on site lands after decommissioning and license termination, and radiation exposure during decommissioning activities and waste transport. In addition, nonradiological impacts on humans, impacts on biota, economic impacts, societal impacts, and land use impacts are addressed.

In the draft GEIS, a range of reasonable regulatory alternatives associated with the proposed action, including "no regulatory change," risk-based limits or goals, use of best available technology, return of the site to preexisting background conditions, and restrictions on future use of the site were analyzed to determine the impact and costs associated with the proposed action. In its evaluation of these regulatory alternatives, the draft GEIS considered each alternative's radiological and nonradiological impacts and the costs associated with implementation.

The results of the draft GEIS were that it was appropriate to consider a dose criterion for release of a decommissioned site for unrestricted use, and to also consider a dose criterion for restricted use of the site and that, in particular, a dose criterion of 15 mrem/y TEDE was generally not unduly burdensome or would not pose undue environmental harm. This final GEIS reviews and analyzes the public comments received on the dose criterion and on a range of alternative dose criteria suggested by the commenters.

The GEIS does not attempt to analyze site-specific issues which may arise in the decommissioning process; rather, its principal intent is to provide a decision analysis leading to establishment of technical requirements for acceptable residual radioactive contamination levels for decommissioning. However, depending on the particular regulatory alternative that is ultimately selected, portions of the GEIS analysis may be applicable to the NEPA process for a specific site. Application of the GEIS to the site-specific NEPA process is described in Chapter 7.

As described in the draft GEIS, certain issues have been analyzed previously in NUREG-0586, the "Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities" (NRC 1988). The issues from NUREG-0586 include: (1) planning necessary to conduct decommissioning operations safely; (2) assurance that sufficient funds are available to pay for decommissioning; (3) the time period in which decommissioning should be completed; and (4) whether facilities should not be abandoned but instead have remaining contamination reduced to appropriate levels. Requirements related to these issues were instituted in the 1988 amendments to the Commission's regulations noted above (53 FR 24018, June 28, 1988). Although this final GEIS does not analyze these issues in detail, it does consider how current issues being addressed could affect the conclusions made in NUREG-0586 (NRC 1988) and in the rulemaking. In addition, requirements were recently published in a separate rulemaking regarding timeliness of decommissioning for 10 CFR Parts 30, 40, and 70 licensees (59 FR 36026, July 15, 1994) which are not addressed in detail in this final GEIS.

The GEIS does not address the issues where licensees propose to release equipment, components, piping, and other similar material containing residual radioactivity intentionally for reuse or recycle either as part of decommissioning or ongoing operations. It is planned that these issues will be considered separately. Chapter 4 of this GEIS does note that the scenarios and assumptions used in the GEIS to estimate public doses from decommissioned lands and structures are considered sufficiently conservative that future inadvertent recycle of soils or structures following decommissioning of a site would not affect the conclusions made in this GEIS regarding public health.

1.7 Approach to Preparing the GEIS

In preparing this final GEIS, the NRC has presented the decision bases, analyses, and conclusions and recommendations regarding regulatory alternatives for establishing radiological criteria for decommissioning. In summary, the approach is as follows:

(1) As noted above, the draft GEIS presented and analyzed alternative regulatory actions to establish radiological criteria for decommissioning. The alternatives analyzed in the draft GEIS include continuation of existing decommissioning practices (i.e., the "no regulatory change" alternative) and rulemaking alternatives that could amend the NRC's regulations in 10 CFR Part 20, including setting residual criteria at certain limits or goals, requiring that a site's residual contamination be returned to background, requiring restrictions on the use of sites, and requiring the use of best available remediation technologies.

    The result of the draft GEIS was proposal of a dose criterion of 15 mrem/y TEDE for both unrestricted and restricted uses of sites as a value that would not cause undue environmental harm.

(2) Based on the public comments received on the results of the draft GEIS, this final GEIS presents a detailed analysis and comparison of: (1) incremental impacts, both radiological and nonradiological, to workers, members of the public, and the environment, resulting from alternative dose criteria and (2) incremental costs

associated with each alternative dose criterion. As described in chapters 4 and 5, and Appendices B and C, the analysis of impacts and costs considers in detail specific comments made by the commenters on the analysis approach, assumptions, parameters and methods used.

(3) Based on the analyses of impacts and costs, the final GEIS provides a conclusion regarding radiological criteria for decommissioning, in accord with the requirements of 10 CFR 51.72.

1.8 Structure of the GEIS

The GEIS has been prepared in accordance with requirements of NEPA and with Council on Environmental Quality (CEQ) regulations for preparation of environmental impact statements. In addition, the GEIS has been prepared in accordance with NRC's implementing regulations set forth in 10 CFR Part 51 and, in particular, the format requirements for an environmental impact statement in Appendix A to 10 CFR Part 51.

The GEIS is divided into two volumes. Volume 1 contains the summary and seven technical chapters which are listed and summarily described below.

Chapter 1 - "Introduction" describes the rulemaking action and presents background information, and the purpose, scope, and structure of the GEIS. In particular, it describes the general approach taken in preparing the GEIS.

Chapter 2 - "Regulatory Alternatives and Analysis Approach" describes specific regulatory alternatives analyzed in the final GEIS and the approach used in analyzing those alternatives.

Chapter 3 - "Description of the Affected Environment" describes the reference facility buildings and lands covered by the GEIS and the contamination levels existing at the facilities and sites when operations cease and decommissioning begins.

Chapter 4 - "Impacts for Each Reference Facility" evaluates the health impacts from both radiation exposure and traffic/construction accidents for each type of reference facility addressed in the GEIS. It also evaluates the other environmental impacts besides human health and includes biological, socioeconomic, and physical environmental impacts.

Chapter 5 - "Costs Associated with Each Reference Facility" assesses costs associated with the decontamination and disposal of residual radioactivity on building structures and in soil and the costs associated with termination surveys for each type of facility addressed in this GEIS.

Chapter 6 - "Comparison of Impacts and Costs for Regulatory Alternatives" compares costs and impacts for the regulatory alternatives.

Chapter 7 - "Conclusions and Recommendation Regarding Course of Action" describes the conclusions that can be drawn from the analysis of alternatives and, in accordance with 10 CFR 51.71(e), provides a recommendation on the action to be taken.

Volume 2 contains the following supporting appendices:

Appendix A: Background as an Alternative Residual Radioactivity Criterion for Decommissioning

Appendix B: Impact and Cost Analysis

Appendix C: Estimated Costs for Decontamination as a Function of Residual Radiation Dose Rate for Facilities and Soils

Appendix D: Termination Survey Considerations and Detailed Analysis of Costs of Termination Surveys

Appendix E: Summary of Draft GEIS Scoping Process

Appendix F: Access Restrictions for Restricted Use of Facilities That Have Had Their Licenses Terminated by the NRC

Appendix G: Evaluation of the Planned Disposal Capacity for Decommissioning and Normal Operation Waste

Appendix H: Summary of Comments on the Draft GEIS

2. Regulatory Alternatives and Analysis Approach

2.1 Regulatory Alternatives Analyzed

The National Environmental Policy Act requires all Federal agencies to consider the effect of their actions on the environment. The draft GEIS (NRC 1994a) analyzed the costs and impacts of five regulatory alternatives for establishing radiological criteria for decommissioning including:

(1) Alternative 1a - continue the current NRC practice of using existing NRC guidance on a case-by-case basis in decommissioning licensed facilities, and do not issue amended regulations containing explicit radiological criteria for decommissioning (the "no regulatory change" alternative).

Alternative 1b - retain the current values for the radiological criteria but codify them in a regulation.

(2) Alternative 2 - issue a rule containing radiological criteria leading to unrestricted use of sites on the basis of risk, either as a limit or a goal. This alternative has sub-alternatives corresponding to various levels of risk.

(3) Alternative 3 - issue a rule containing radiological criteria based on emphasizing the use of "best" available technology.

(4) Alternative 4 - issue a rule containing radiological criteria based on return to background levels.

(5) Alternative 5 - issue a rule similar to alternative 2, but allow restricted use of facilities and sites.

Not considered in the draft GEIS is an alternative in which a licensee would abandon or leave a facility after the end of operations without some facility and/or site remediation and survey or other demonstration that the levels of radioactivity have been reduced. In NUREG-0586, "Generic Environmental Impact Statement for Decommissioning of Nuclear Facilities," (NRC 1988) and in a 1988 rulemaking, "General Requirements for Decommissioning of Nuclear Facilities" (53 FR 24018), this alternative was considered and rejected because it could result in an unreasonable risk to the public. Thus, licensees are not permitted simply to abandon facilities without some actions to remediate the site and/or demonstrate that the site is safe. To enforce this prohibition, current NRC regulations in 10 CFR Parts 30, 40, 50, 70, and 72 require licensees, when their operations cease, to request license termination, to present a plan for reducing radioactivity, or to demonstrate that the radioactivity at their facilities has been reduced. These same regulations also require certain licensees to maintain funding provisions such as sureties or trust funds to ensure that adequate funds will be available for safe decommissioning.

2.2 Results of Draft GEIS Analysis of Alternatives and Preliminary Recommendation Regarding Alternatives

The draft GEIS indicated that because of problems associated with Alternatives 1a and 1b, separate detailed analyses of their impacts and costs were not made in the GEIS. Continued retention of current criteria and guidance either on a case-by-case basis (Alternative 1a) or in amended regulations (Alternative 1b) would require a detailed reassessment of their scientific basis. As was described more fully in discussions of the other regulatory alternatives, the draft GEIS contained an evaluation of impacts and costs for a range of residual radioactivity levels. Because the levels permissible under current guidance are encompassed by that range, the analysis was considered sufficient to address the "no regulatory change" approach and, therefore, a separate analysis of Alternatives 1a and 1b was not performed in the draft GEIS.

In Alternative 2, a revised and uniform risk basis for radiological criteria would be used for release of facilities to unrestricted use. This basis would use a risk limit or a risk goal approach. The draft GEIS noted that because residual dose criteria are measures of risk, both the risk limit and goal approaches of Alternative 2 are evaluated in terms of residual dose. For both the risk limit and risk goal approach, the draft GEIS evaluated incremental impacts for a subset of residual radioactivity dose/risk criteria to persons living and/or working on the site after the license is terminated. These levels included a range of 100 mrem/y to 0.03 mrem/y which correspond to a range of lifetime risks of excess fatal cancer of approximately 2 in 1000 to 1 in 1,000,000. The draft GEIS also evaluated incremental impacts to persons involved in the decommissioning of the site and the transport of wastes to achieve these residual dose criteria, as well as the incremental costs to achieve these dose levels.

Based on its detailed analysis of impacts and costs of the range of dose criteria considered, the results of the draft GEIS were that generally the cost of achieving a 15 mrem/y limit would not be unduly burdensome on licensees. Thus, the preliminary recommendation of the draft GEIS was that 15 mrem/y, based on the cost-benefit analysis of the draft GEIS as well as on other considerations indicated, including level of risk and considerations related to exposures to multiple sources, was an appropriate dose criterion for unrestricted use.

The draft GEIS also noted that in those cases where 15 mrem/y may present an unreasonable burden, release of the site with restrictions placed on its use represents a means for providing similar levels of protection but reducing the impact and cost.

As also noted in the draft GEIS, in addition to setting a limit, it is reasonable that licensees should also reduce contamination below the 15 mrem/y limit to levels that are as low as reasonably achievable (ALARA). Use of ALARA allows reduction in the contamination remaining by taking into account economics and concomitant risk reduction for site-specific situations. The analyses in the draft GEIS indicate that there may be reductions in impacts which could be achieved below 15 mrem/y at reasonable cost for some facilities.

Alternative 3, in which radiological criteria are based on what is achievable using the "best" available technology during decommissioning, was not recommended by the draft GEIS. In the alternative, a site would be released for unrestricted use only if residual radioactivity remaining at the site cannot be removed or measured using this technology. This objective would be technology driven. The draft GEIS found that since the objective of the alternative is technology driven, impact and cost are not factors. In fact, application of the best available technology at some sites could result in higher rather than lower impacts. Although in theory a technology-based criteria could lead to removal of all radioactivity, there are difficulties related to such removal such as increased impacts from the removal and transport. A technology-based regulation could also result in disagreements between the licensee and the NRC over which technology is best for a particular site, leading to cleanup delays and misdirected resources. Moreover, technologies are likely to change in the future, potentially resulting in further ambiguity.

Alternative 4, which would establish criteria requiring the removal of all radioactivity attributable to licensed activities, was examined in detail in the draft GEIS. A site would be released for unrestricted use only after all radioactivity has been removed and background levels have been achieved. As part of the analyses of Alternative 4, Appendix A of the draft GEIS (which was printed separately as NUREG-1501 (NRC 1994b)) reviewed in detail sources of natural background in the U.S. As noted there, sources of natural background are highly variable between locations (spatial) and also over time at the same place (temporal). NUREG-1501 also analyzed costs associated with surveys to demonstrate that a dose criterion of "0" mrem/y above background had been achieved.

As discussed in the draft GEIS, a "return-to-background" regulatory alternative which requires removal of all residual radioactivity attributable to licensed activities would have a dose criterion value of "0" mrem/y above background. A "0" mrem/y above background alternative was not explicitly studied, but impacts and costs were analyzed for residual dose criteria ranging from 100 mrem/y to 0.3 mrem/y above background. However, impacts and costs for a "0" mrem/y above background alternative can be analyzed by inference based on information collected for the dose range of 100 mrem/y to 0.3 mrem/y above background. According to data in the draft GEIS, the rate of reduction in health impacts below 3 mrem/y tends to become smaller or negative (a detriment). This trend in the data is expected to continue to "0" mrem/y and suggests that there is not necessarily a further health and safety benefit in establishing a return-to-background alternative that is on the order of "0" mrem/y above background. The results in the draft GEIS also suggest that expenditures made to reduce impacts to a dose criterion of "0" mrem/y above background may be very large.

A significant consideration in determining the effectiveness of a return-to-background alternative is whether available radiological survey instruments and procedures can measure "0" mrem/y above background at NRC-licensed sites being decommissioned. This determination must account for the sensitivity of the measurement technique in the presence of widely varying radiation levels of background. Information contained in NUREG-1501 and Appendix D of the draft GEIS indicates that significant resources and sophisticated measurement techniques must be applied to measure very low concentrations of residual radioactivity in the presence of background.

In conclusion, when health impacts and cost are taken into account for a "0" mrem/y above background regulatory alternative for the principal radionuclides studied, decommissioning costs increase significantly but health impacts are not necessarily reduced. Furthermore, due to technological limitations with available radiological measurement techniques in the dose rate range of 3 mrem/y to 0.03 mrem/y above background, a "0" mrem/y above background regulatory alternative could present significant implementation difficulties. Thus, the preliminary recommendation of the draft GEIS that the sites not be required to be returned to background is also recommended in this GEIS, although it is recognized that this should be a general objective of a decommissioning ALARA analysis when reasonable.

Alternative 5 would establish criteria that would allow for land use restrictions after decommissioning to ensure protection of humans and the environment by limiting exposure to residual radioactivity. In the restricted use mode, the NRC license would be terminated as part of decommissioning, but restrictions would apply to future use of the site.

This alternative would be a departure from NRC's requirements implemented in 10 CFR Parts 30, 40, 50, 70, and 72 in the 1988 amendments noted above (53 FR 24018), which require that sites be released for unrestricted use following completion of decommissioning activities and termination of a license. Restricted use after termination of the NRC license is not an option in those amendments which instead define decommissioning as a process that reduces residual radioactivity to a level that "permits release of the property for unrestricted use and termination of license." In addition, each of the 10 CFR Parts indicates that the NRC will terminate a license if the NRC determines that the licensee's premises are "suitable for release for unrestricted use."

The draft GEIS provided a preliminary recommendation that restricting site use could provide considerable flexibility in the regulatory process, particularly in view of the potential range of site-specific situations. This alternative would allow for additional options for reducing impacts and costs, particularly when the impacts of decontaminating a site exceed the impacts associated with unrestricted use of a site at the residual levels of radioactivity being considered, or when decontamination costs become financially prohibitive at these levels. The restricted use alternative could provide additional flexibility in optimizing the expenditure of resources to protect public health and safety.

On the other hand, the draft GEIS noted the restricted use alternative raises the question of the permanency of the restrictions. It is important to ensure that the restrictions will remain in place in the future, especially for sites contaminated with long-lived radionuclides. The preliminary conclusion of the draft GEIS was that restrictions can be viable, but the operation and maintenance costs of these restrictions need to be funded.

Public comments were received on the restricted use mode questioning its applicability, appropriateness, and durability. Other comments were received favoring restricted use but suggesting that it be allowed in more circumstances and that the dose criterion be raised from the preliminary recommendation of 15 mrem/y in the draft GEIS.

In response to these comments, this final GEIS contains an analysis of restricted use taking into account both the specific comments made on restricted use and the general comments made on the draft GEIS and discussed elsewhere in this final GEIS.

2.3 Public Comments on Preliminary Recommendations of Draft GEIS

A number of comments were received from members of the public on the preliminary recommendation of the draft GEIS. These comments addressed a variety of concerns including a general disagreement with the recommendation of 15 mrem/y itself (some commenters thought the recommended dose criterion should have higher values, including 25, 30 or 100 mrem/y, and some commenters thought the recommended dose criterion should be lower, including a dose criterion of "0" mrem/y). Other commenters disagreed with the overall approach used in making the recommendation. Some of these commenters stated a cost analysis should not be used at all in deciding upon the criterion, while others agreed with the cost-benefit approach but disagreed with the method of analysis itself. These commenters disagreed with the approach in the draft GEIS which combined soils and structures in one analysis, and one commenter provided data and analysis illustrating a separate analysis for soils and structures. Some commenters provided specific comments on specific parameters and assumptions used in the draft GEIS, including such things as cost of waste disposal, cost of surveys, and the volumes and extent of contamination used for the reference facilities. The comments received on the draft GEIS are summarized in NUREG/CR-5383 (NRC 1996). A summary of the comments and the responses to these comments are provided in Appendix H of this final GEIS.

2.4 Final GEIS Method of Analysis of Public Comments on Draft GEIS Recommendations

2.4.1 Introduction

The public comments on the recommendations of the draft GEIS were considered in detail in the analysis of the final GEIS. Based on the comments received, Alternatives 1 and 3 were not considered further in the final GEIS. Alternatives 2, 4, and 5 were reevaluated in the final GEIS based on the comments received by reconsidering the alternative dose criteria of the draft GEIS for unrestricted and restricted use to various alternative dose levels. The bases for selecting the alternative residual dose criteria evaluated are discussed in Chapters 3 and 7 of the final GEIS.

Chapters 4 and 5 illustrate the kinds of impacts and costs considered for these alternative residual dose criteria. Based on these analyses, Chapter 6 compares the incremental costs incurred and risk reduction obtained in achieving these alternative residual dose criteria as a means of evaluating Regulatory Alternatives 2 and 5. Specific areas where the comments (described in Section 2.3, above) are addressed are described in Chapters 4, 5, 6, and 7 and in Appendices B, C, D and H.

Impacts evaluated include: (1) radiation exposure to members of the general public that live on or work on the site after decommissioning; (2) radiation exposures to decontamination workers that perform site decommissioning activities and to transport workers and the public resulting from transport of decommissioning waste to licensed disposal sites; and (3) nonradiological impacts such as conventional workplace and transportation accidents that could occur during decommissioning.

Costs expected to be sensitive to radiological criteria for decommissioning include the costs of decontamination of soil and building materials, the cost of disposal of the contaminated waste, and the cost of performing radiological surveys to demonstrate that the desired levels of residual radioactivity have been achieved.

The analysis of cost versus impacts was performed in the following three steps:

1. Reference facilities were defined and characterized for the NRC licensees expected to be affected by the rulemaking.

2. For each reference facility and for alternative residual dose criteria, impacts and decommissioning costs were estimated.

3. Each regulatory alternative has an implied risk reduction which can be expressed in terms of residual dose. Based on the impacts and costs evaluated in step 2, each regulatory alternative was assessed by comparing the impacts and costs of these implied risk reductions for the reference facilities.

2.4.2 Identification of Reference Facilities

To account for differences in the facilities covered by this rulemaking, the draft GEIS used reference facilities in estimating impacts and costs. This use of reference facilities is similar to the approach used in NUREG-0586 (NRC 1988) which supported the rulemaking on decommissioning funding, planning, and timing. These reference facilities were considered to be sufficiently representative of facilities licensed by NRC to serve as a basis for assessing impacts and costs associated with the regulatory alternatives being evaluated. Reference facilities are divided into fuel cycle and non-fuel-cycle groups. Fuel cycle facilities include power, test, and research reactors; uranium fuel fabrication plants; uranium hexafluoride conversion facilities; and independent spent fuel storage installations (ISFSI). Non-fuel-cycle facilities include sealed source manufacturers, research and development laboratories, and rare metal refineries.

Based on the evaluation and results of the draft GEIS, the final GEIS has simplified the analysis by consolidating the reference facilities and reducing the number to be analyzed but still maintaining the validity of the analysis. This consolidation was done by combining facilities by common characteristics of contaminant radionuclides. Uranium mills (land and structures), which were considered in the draft GEIS, are no longer considered in the final GEIS (see Section 3.2.1). (For reference purposes, Appendix C of the draft GEIS has been included as Attachment D to Appendix C of this final GEIS and includes information on the 10 reference facilities of the draft GEIS.)

2.4.3 Determination of Impacts and Costs of Decommissioning for Reference Facilities

Each reference facility discussed in Chapter 3 is characterized by a unique configuration of radioactive contamination resulting from its operation. Differential impacts and costs of decommissioning related to residual dose criteria are determined by estimating the impacts and costs associated with reducing the contamination at the reference facility to the residual dose criteria.

2.4.3.1 Factors Affecting Impacts and Costs.

In assessing the impacts and costs corresponding to each residual dose criterion, it was necessary first to identify the major factors affecting impacts and costs of decommissioning and then to determine which of those factors are sensitive to the specific value of the residual dose criterion.

As discussed in Chapter 3, the level of residual contamination in NRC-licensed facilities varies widely, and hence the extent and complexity of the cleanup can show large variations. Remediation for cleanup can be very simple at facilities where only sealed sources or short-lived radionuclides are handled. Decontamination actions at small research reactors or small laboratories can be straightforward, while extensive remediation may be required at large reactors, fuel production facilities, or rare-earth processing facilities. Although residual contamination and decommissioning complexity can vary, major decommissioning activities remain the same. These are:

1. Engineering and planning;
2. Radiological characterization survey;
3. General cleanup of facility, system draining, etc.;
4. For components, equipment, ductwork, piping, etc.:
   (a) Decontamination and disassembly;
   (b) Transport and disposal of any wastes;
5. For concrete, other building materials, and soil:
   (a) Decontamination and removal of contaminated materials (if necessary);
   (b) Shipment and disposal of contaminated materials and soil (if necessary);
6. Interaction with regulatory agencies;
7. Termination survey.

For approximately 75 percent of NRC licensees whose decommissioning would involve only the shipment of sealed sources or allowing short-lived radionuclides to decay, the impacts and costs associated with decommissioning would be limited to those associated with items #6 and #7 which should not be significant.

Items #1, #3, #4, and #6 are largely insensitive to the level of the residual dose criterion for structures and lands. For example, the impacts and costs associated with the removal of a large steam generator at a power reactor should be the same regardless of the residual dose criterion for lands and structures. Therefore, impacts and costs related to these items are not sensitive to the residual dose criterion selected or to the choice of the regulatory alternative and, accordingly, are not addressed in the GEIS. These overall impacts and costs are presented in NUREG-0586, "Generic Environmental Impact Statement for Decommissioning of Nuclear Facilities," (NRC 1988) prepared in support of a 1988 rulemaking "General Requirements for Decommissioning of Nuclear Facilities" (53 FR 24018).

The impacts and costs of items #2, #5, and #7 are sensitive to the residual radioactivity criteria for lands and structures. The required sensitivity of survey instruments and the extensiveness of sampling and laboratory analyses needed depend on the level of the residual dose criterion, and these affect the costs of decommissioning. Also, the quantity of building materials and soil requiring remediation is a function of the residual dose criterion. Both the impacts and costs of decommissioning are obviously sensitive to these quantities.

Therefore, the assessment of impacts illustrated in Chapter 4 and the assessment of costs illustrated in Chapter 5 focus on incremental impacts and costs associated with cleaning, removing, and disposing of concrete and soil and on radiological surveys required to assess the site and demonstrate compliance. In particular, those chapters focus on the differential in impacts and costs resulting from the promulgation of alternative residual dose criteria for lands and structures.

The impacts and costs of decontaminating buildings and soils to various levels of residual radioactivity are difficult to analyze because of a lack of relevant data. Decommissioning studies previously conducted by Battelle under contract with the NRC (NRC, 1977; 1978a-c; 1979 a-d; 1980a-b) did not relate decommissioning impacts and costs to residual contamination levels. In addition, survey costs at very low levels of radioactivity are uncertain.

Accordingly, in support of this GEIS, new studies of the impacts and costs associated with items #2, #5, and #7, are presented in Appendices C and D. Based on the information contained in these appendices, representative contamination levels in structures and soils at the reference facilities are quantified and summarized in Chapter 3. Chapter 4 presents illustrations of the results of the evaluation of the health impacts and other consequences associated with the decontamination of the reference facilities to alternative residual dose criteria. Chapter 5 presents illustrations of the results of the evaluation of the costs associated with the decontamination and radiological survey of the reference facilities to alternative residual dose criteria.

2.4.3.2 Impact Analysis.

Impacts were evaluated quantitatively, wherever possible, and qualitatively when quantitative analyses were not possible or warranted by the magnitude of the effects. Human health effects were evaluated quantitatively. These evaluations included the following:

- impacts to people residing on the site after decommissioning and license termination and, therefore, subject to radiation exposure principally caused by residual radioactivity in soil;
- impacts to people working in site buildings after decommissioning and license termination and therefore subject to radiation exposure principally caused by residual radioactivity on building surfaces;
- impacts to workers who are exposed to radioactivity as they perform the decommissioning activities and transport waste resulting from decommissioning to licensed disposal sites;
- impacts to workers performing decontamination and transporting waste to disposal sites who are subject to conventional decommissioning-related work-place and traffic accidents during decommissioning; and
- impacts to members of the public who are exposed to radioactivity and traffic accidents resulting from the transportation of waste to licensed disposal sites.

Quantitative impacts are described in more detail and are estimated in Chapter 4 and in Appendix B.

Other environmental impacts evaluated qualitatively in Chapter 4 include the following:

- impacts to plant and animal populations;
- socioeconomic impacts, including land use changes;
- impacts on the physical environment, including noise, aesthetics, and impacts on surface water and groundwater; and
- impacts on low-level waste disposal capacity.

These impacts were evaluated and discussed in NUREG-0586 (NRC 1988). Many of the same issues and conclusions are relevant to the present evaluation because decommissioning an entire facility encompasses activities associated with removing residual radioactivity from structures and soil. The qualitative impact evaluation in the GEIS uses some of the information contained in NUREG-0586 (NRC 1988).

2.4.3.3 Cost Analysis.

Decommissioning costs expected to be sensitive to residual radioactivity criteria are associated with cleaning, removal, and disposal of contaminated concrete and soil, and the performance of the radiological surveys needed to demonstrate that the target residual criterion has been achieved. Illustrations of these results are presented in Chapter 5 for each reference facility and for each rulemaking alternative. The analyses of decontamination costs and survey costs are described in detail in Appendices C and D, respectively.

2.4.3.4 Evaluation of Implementation of Regulatory Alternatives.

The impact and cost associated with the various alternative residual dose levels which can be obtained by the different regulatory alternatives are considered and are discussed in Chapter 6.

3. Description of the Affected Environment

3.1 Introduction

The affected environment and population include approximately 7,000 NRC-licensed and 15,000 Agreement State-licensed nuclear facilities, several thousand workers engaged in decontamination activities, local residents and communities, and the natural environment in the vicinity of the licensed facilities. The facilities, located throughout the United States and the Territories, include small laboratories in office or health unit complexes, large laboratories in major industrial buildings, and large power reactor units where most of the radiation is confined to the buildings. They also include large fuel cycle or non-fuel-cycle facilities with radiation contamination occurring in structures and on adjacent facility lands.

3.2 NRC-Licensed Facilities

The final GEIS analyzes the impacts and costs associated with alternative residual dose criteria for decommissioning. When a nuclear facility operates, it can generate radioactive contamination. Decommissioning operations reduce the contamination to an acceptable level. This section describes the NRC-licensed facilities covered by this GEIS and the nature and the level of contamination existing at these facilities at the end of their operations which must be subsequently reduced during decommissioning.

Because of the variety of facilities, the draft GEIS and this final GEIS use reference facilities in analyzing impacts and costs associated with regulatory alternatives. This use of reference facilities is similar to the approach used in NUREG-0586 (NRC 1988) which supported the rulemaking on decommissioning funding, planning, and timing. These reference facilities of the draft GEIS were considered to be sufficiently representative of those licensed by the NRC to support an assessment of the impacts and costs associated with the regulatory alternatives being considered.

As described in Appendix C, public comments were received which questioned the accuracy of the reference facilities of the draft GEIS. Specifically, these comments indicated that the volume of contaminated material and the extent of the contamination; i.e., the profile of the contamination with depth in the soil and concrete, was not accurate. These comments indicated that the volumes of waste in the draft GEIS were underestimated and that the contamination profile in the soil was deeper than that estimated in the draft GEIS. This chapter of the GEIS describes how the reference facilities and associated contamination levels have considered the public comments received.

3.2.1 Facilities Covered

As previously discussed, the radiological criteria in the amendments in 10 CFR Part 20 would apply to the decommissioning of nearly all of the facilities and sites licensed by the NRC. The licensed nuclear facilities that will require decommissioning and would be affected by this action include the following:

1. Facilities involved in the nuclear fuel cycle:
   a. nuclear power plants
   b. nonpower (research and test) reactors
   c. fuel fabrication plants
   d. uranium hexafluoride production plants
   e. independent spent fuel storage installations

2. Non-fuel-cycle nuclear materials facilities. These materials licensees include universities, medical institutions, radioactive source manufacturers, and companies that use radioisotopes for industrial purposes. About 75 percent of NRC's approximately 7,000 materials licensees use either sealed radioactive sources or small amounts of short-lived radioactive materials. Decommissioning of these facilities should be relatively easy since there is usually little or no residual radioactive contamination to be cleaned up and disposed of. Of the remaining 25 percent, a small number (e.g., radioactive source manufacturers, radiopharmaceutical producers, and radioactive ore processors) conduct operations that could produce considerable radioactive contamination in portions of the facility.

The amended Part 20 would not apply to the disposition of uranium mill or mill tailings, low-level waste, or high-level waste because these have already been addressed in separate regulatory actions.

The draft GEIS described the reference fuel cycle and non-fuel cycle facilities considered in the analysis. These descriptions have not changed in the final GEIS although the final GEIS does consider the comments on contamination volumes and extent in Section 3, below.

As noted above, this final GEIS has consolidated the reference facilities to simplify the analysis and the results while maintaining their validity. Specifically, the reference power reactor is used in the final GEIS as reference for the power reactor, test reactor, research reactor and ISFSI because the principal containment nuclides contributing to the residual dose (Co 60 and Cs 137) are common for these facilities and the power reactor is a representative analysis for these cases. The uranium fabrication facility is used as the reference for both the fabrication and the hexafluoride plant. The sealed source manufacturer and broad R&D facility are treated in one analysis. The remaining reference facility is the rare metal processing facility. Of the 7000 NRC licensed facilities which must terminate their licenses, these reference facilities are considered to be the approximately 500-700 facilities which can have low to medium to significant contamination. These reference facilities and the contamination levels used in this final GEIS are described in detail in Appendix C. A summary of the contamination is contained in Table 3-1 of this chapter.

With regard to uranium mills, there are currently regulations applicable to remediation of both inactive tailings sites, including vicinity properties, and active uranium and thorium mills. Under the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978, as amended, EPA has the authority to set cleanup standards for uranium mills and, based on that authority, issued regulations in 40 CFR Part 192 which contain remediation criteria for these facilities. NRC's regulations in 10 CFR Part 40, Appendix A, apply to the decommissioning of its licensed facilities and conform to EPA's standards for uranium mills. At ISLs, the decommissioning activities are similar to those at uranium mills and consist mainly of the cleanup of byproduct material as defined in Section 11e.(2) of the Atomic Energy Act of 1954, as amended.

Thus, applicable cleanup standards already exist for soil cleanup of radium in 10 CFR Part 40, Appendix A, Criterion 6(6). Radium is the main contaminant at mills in the large areas (50 to 1000 acres for uranium mills) where windblown contamination from the tailings pile has occurred, and at ISLs (in holding ponds). These standards require that the concentration of radium in those large areas not exceed the background level by more than 5 pCi/gm in the first 6 inches of soil, and 15 pCi/gm for every 6 inches below the first 6 inches. Cleanup of radium to these concentrations would generally result in doses higher than the lower alternative residual doses being considered in the GEIS, although, in actual practice, cleanup of uranium mill tailings results in radium levels lower than the 10 CFR Part 40 standards, and radium is usually removed to background levels during cleanup of uranium and thorium to the levels in existing NRC guidance documents.

However, in other mill and ISL site areas proximate to locations where radium contamination exists (e.g., under the mill building, in a yellow cake storage area, under/around an ore pad, and at ISLs in soils where spray irrigation has occurred as a means of disposal), uranium or thorium would be the radionuclide of concern. A difficulty in applying 10 CFR Part 40, Appendix A, as a standard for uranium and thorium, is that it does not have any cleanup standards for soil contamination from radionuclides other than radium. Application of the the alternative residual doses being considered in the GEIS to these areas (while retaining the 10 CFR 40, Appendix A, standard for radium) could result in a situation where the cleanup standard of that small portion of the mill site would be different than the standard for the large windblown tailings areas where radium is the nuclide of concern. This would result in situations of differing criteria being applied across essentially the same areas and would be a problem for contamination existing both in uranium mill soils and buildings. Thus, based on the practical problems of applying the criteria being analyzed in this final GEIS to mill and ISL facilities, these facilities have been excluded from the scope of this final GEIS.

The draft GEIS noted that the large majority of NRC's 7,000 materials licensees use either sealed radioactive sources or small amounts of short-lived radioactive materials in their business operations. Typically, these facilities can be categorized in the following manner:

1. A sealed source is defined in 10 CFR Part 30 as any byproduct material that is encased in a capsule designed to prevent leakage or escape of the byproduct material. Sealed source users, licensed pursuant to 10 CFR Part 30, include medical users of sealed sources (teletherapy, brachytherapy), users of industrial gauges, well loggers, radiographers, and irradiators. Nuclides contained in the capsules and used by sealed source users include Co-60, Cs-137, I-125, Ir-192, Sr-90, and Am-241. The sealed sources are designed and tested according to the requirements of industrial standards and radiation safety criteria set out in the regulations to prevent leakage.

As a result of the nature of the sealed source design, testing, and operation, it is expected that contamination of facility structures and soils would not result from routine operations.

Recent experience indicates that the frequency of leakage of sealed sources is very low. Leaking sources are taken out of service and returned to another specific licensee (typically the manufacturer) for disposal. Sealed source contamination would most likely be contained within the device or otherwise localized, and remediation would be straightforward and localized. When operations using the sealed source cease, the sealed source would be returned to a specific licensee authorized to possess the source or sent to licensed disposal site for proper disposal. It is expected that decontamination of the building or of soils would not be needed. Currently, 10 CFR 30.36 requires that sealed source licensees properly dispose of the source, submit NRC Form 314, and either conduct a radiation survey or demonstrate that the premises are suitable for license termination by other means.

2. Licensees using short-lived byproduct radionuclides are licensed pursuant to 10 CFR Part 30 and use short-lived nuclides for specific reasons, primarily in the area of medical diagnostics. Short-lived nuclides licensed for such use include Tc-99m, I-131, and I-123.

   The nature of operations using short-lived nuclides, makes the contamination of facility structures and soils unlikely. Contamination (if any) would likely be confined to localized areas in buildings. Any such contamination would be diminished by radioactive decay, and no long-term contamination would remain after license termination. Cleanup would be straightforward and localized. The predominant means for decommissioning of facilities that use short-lived nuclides is "decay-in-storage." In terminating the license, the licensee follows the same procedure required under 10 CFR 30.36 as noted above for sealed sources; i.e., any byproduct material is properly disposed of, NRC Form 314 is submitted indicating disposition of any licensed material, and either a radiation survey is conducted or there is a demonstration that the premises are suitable for license termination by other means (e.g., by calculation of the reduction in activity by radioactive decay). Based on use of "decay in storage" for the short-lived nuclides, and the time involved in submitting the information necessary to terminate a license, it is expected that licensed material would reach sufficiently low levels such that decontamination of the building or of soils would not be needed.

Based on the preceding discussion, decommissioning of these facilities should be relatively easy because there is usually little or no radioactive contamination to be cleaned up and disposed of. As noted above, decommissioning operations will generally consist of disposing of a sealed source or allowing licensed short-lived nuclides to decay in storage, submitting NRC Form 314, and demonstrating compliance with the requirements for license termination. Because the impacts and costs for these facilities are expected to be minimal, detailed reference facilities are not characterized, and impacts and costs are not analyzed in

Chapters 4 and 5. However, information from those chapters is used to provide a qualitative analysis of impacts and costs for this class of facilities in Section 7.2.2.

3.2.2 Contamination Distribution

The operation of reference facilities discussed above results in radionuclide contamination at the facility requiring cleanup to reach acceptable levels. This GEIS analysis focuses on the contamination levels in the reference facility building materials and in site soil, in those cases where contamination occurs.

3.2.2.1 Building Material Contamination Distribution.

Section 4 of Appendix C describes reference contamination levels on and within concrete and other building material surfaces for each of the reference facilities. Contamination on building surfaces occurs as a result of system leaks, minor spills, tracking of contamination, etc. The radionuclide contamination can spread readily onto the concrete surfaces and can also spread into the concrete either by diffusion directly into the concrete or by seepage into cracks in the concrete.

Analysis of impacts and costs of removal of concrete must consider both the level of contamination on the concrete surface and the profile of that contamination with concrete depth. This must be done to estimate the volume of material requiring removal and disposal to attain alternative residual dose criteria, and to estimate impacts and costs associated with removing and disposing of that material.

To estimate surface contamination levels on concrete surfaces, the draft GEIS assessed information on contamination levels in nuclear facilities, such as the Battelle series of reports on the technology, safety, and costs of decommissioning (NRC 1978a-c; 1979a-d; 1980a-b; 1992b), existing information on contamination levels including a study of source terms at operating facilities (NUREG/CR-4289) (NRC 1986), information from the Site Decommissioning Management Plan contained in NUREG-1444 (NRC 1993), and engineering judgment as to the areal extent and level of this contamination where detailed information is not available. The draft GEIS assessed the available data on distribution of radionuclides on concrete surfaces within the reference facilities and also presented information on the concentration profiles of the contaminants with depth of concrete. The concentration profiles were based on actual data where 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.

Comments were received on the draft GEIS criticizing the assessment of concrete contamination on surfaces and with depth. However, in reviewing the comment letters and the current data, significant data to modify the analysis of building material contamination distribution was not found (see Appendix C). Hence, the analysis of building contamination in Appendix C of the final GEIS is largely the same as the draft GEIS.

3.2.2.2 Soil Radionuclide Contamination Distribution.

The draft GEIS also described and analyzed reference contamination levels on and under soil surfaces for each of the reference facilities. Contamination may occur in onsite soils outside building structures as a result of spills or specific operating methods. The extent of this contamination depends on the nature of operations. In addition, the distribution of contamination with depth of soil varies greatly because soil is a widely varied 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 terms and penetration time requires considerable additional information on soil composition (clay, sand, humus), particle size distribution, pH, ion-exchange capacity, cumulative rainfall, and other factors.

Like the analysis for concrete, the analysis of impacts and costs of removal of soil must consider both the level of contamination on the soil surface and the profile of that contamination with soil depth. Both factors must be known to estimate the volume of material requiring removal and disposal to attain alternative residual dose criteria and the impacts and costs associated with removing and disposing of that material.

To estimate soil surface contamination levels, the draft GEIS assessed previous reports on the level and location of contamination in nuclear facilities, such as the Battelle series of reports on decommissioning technology, safety, and costs noted in Section 3.2.2.1, existing information on contamination levels including NUREG/CR-4289 (NRC 1986) which contains source terms from operating facilities, NUREG-1444 (NRC 1993), and engineering judgment as to the areal extent and level of this contamination where detailed information is not available. The draft GEIS presented available data on distribution of radionuclides on soil surfaces at the reference facilities.

As noted in the draft GEIS, little information is available on penetration of radionuclides into the soil or resultant profiles of contamination distribution with depth in soil. For the purposes of the draft GEIS, profiles of the contamination of the radionuclides in the soil were estimated based on the soil model of NUREG/CR-5512 (NRC 1992c).

Comments were received on the draft GEIS criticizing the assessment of soil contamination on surfaces and, in particular, with depth. These comments indicated that soil contamination is more extensive than indicated in the draft GEIS, that soil contamination occurs for a variety of reasons, and that the profile of the contamination with depth is more complex than the diffusion model estimated for the reference facilities in the draft GEIS. These commenters indicted that because the containment depth profile is more pronounced than the draft GEIS estimates, larger soil volumes are required to be removed to reach the lower dose criteria, and thus, it costs more to achieve the alternative dose criteria than estimated in the draft GEIS.

Appendix C of this final GEIS assesses the information presented in these comments and also considered other available data to confirm the accuracy of the information provided in the public comment letters. Based in the analysis of Appendix C, this final GEIS includes in its analysis of impacts and costs a range of soil contamination levels, volumes, and profiles. This range includes the data in the draft GEIS (as still being representative of cases of relatively simple soil contamination) as well as contamination levels comparable to those suggested in the public comments.

3.2.2.3 Summary of Radionuclide Distribution at Reference Facilities.

Based on the above analyses of surface source terms and profiles of contamination with depth, source terms in the final GEIS for the reference facilities are developed according to the following general model:

1. The extent and profile of radionuclide surface and volumetric contamination levels in concrete and other building materials in various areas of the reference facilities are estimated;

2. For reactors, the extent and profile of the activated concrete in the reactor building are estimated;

3. Contamination levels in cracks and corners, and in other potential contamination hot spots in concrete and other building materials, are estimated;

4. The extent and profile of radionuclide surface and volumetric contamination levels in various areas of the onsite soils and soils beneath the facility buildings at the reference facilities are estimated.

Based on the discussion in this chapter and the analyses of Appendix C, and using the general model described above, the estimated areas of contamination and the principal dose contributing radionuclides in buildings and soils for each reference facility are summarized in Table 3.1. Table 3.1 also summarizes the building surface contamination levels used in the analyses of impacts and costs. Profiles of contamination with depth of concrete and soil are given in Appendix C.

3.3 Human and Natural Environments

3.3.1 Human Health and Safety

Impacts on human health and safety include both radiological and nonradiological health effects both on those who are involved in or exposed to activities occurring as part of the decommissioning process (such as decontamination of buildings or transport of wastes), and on those who occupy site buildings or lands following decommissioning and license termination.

3.3.2 Socioeconomic Environment

Locations of the facilities range from rural areas with a few residents per square mile to urban areas with populations of several million persons. Population data, including the location of the nearest residents and local population distribution within 80 km are required as part of licensing and will be available for the site-specific environmental review prior to decommissioning.

Although the facility sites are industrial, surrounding land uses may be industrial, agricultural, commercial, residential, range land, forest, or open-space.

The draft GEIS analyzed collective radiological exposure and resultant health impacts based on assumed post-decommissioning use of the facility. As noted above, there is a variety of potential post-decommissioning and license termination cases of these sites.

Public comments on the draft GEIS questioned the analysis of risk to populations, the length of exposure time, issues of transfer of risk, etc. This final GEIS includes the facility use characteristics of the draft GEIS, and also includes a range of alternate post-decommissioning uses of the site and the buildings. These uses are described in detail in Appendix B.

3.3.3 Biological Environment

3.3.3.1 Flora.

The areas of surface contamination will be within the facility boundaries and will usually have been disturbed to some degree during the licensed operations. Existing vegetation may be natural or introduced and include grasses, shrubs, and trees. Some of the areas may qualify as wetlands, especially in the vicinity of drainages and stormwater control basins.

3.3.3.2 Fauna.

Animals using the sites for habitat (resident or forage) may include small mammals, reptiles and amphibians, birds, and invertebrates. Species present at individual sites will depend on the ecological zone, site characteristics, and degree of human activity in the area.

3.3.4 Physical Environment

3.3.4.1 Soils.

Soils on the sites can be expected to include the full range of soil series found in the United States. Most of the sites requiring decontamination will have been disturbed to some degree during construction and operation of the facility. Contamination of these soils is generally most concentrated at the surface but may extend to several feet or more in depth at some sites.

3.3.4.2 Meteorological.

Meteorological conditions will be representative of those found throughout the United States. Major sites maintain monitoring stations and air quality records.

3.3.4.3 Water Resources.

Some of the facilities maintain surface water impoundments or drainage and stormwater control structures for compliance with State and Federal water quality standards. At some sites, impounded water may be contaminated and require treatment.

3.3.4.4 Cultural Resources.

Because of past operations and disturbance of the facility sites, it is expected that any cultural or historic resources present will either have been identified in site surveys or inadvertently removed.

3.3.4.5 Low-level Waste Storage Capacity.

Low-level waste generated by the decommissioning process will be disposed of in planned low-level waste burial facilities. The disposal capacity planned by the various compacts and States totals about 52 x 10^6 ft^3 (Appendix G). The waste volumes from decommissioning of lands and structures will fill up some of this planned capacity.

TABLE 3.1
Total and Contaminated Surface Areas for Structures and Soils at Reference Sites[1]

Reference Facility	Structures Radionuclide Activity[2], dpm/100 cm^2	Structures Surface Areas				Soil Surface Area, ft^2	
		ft^2		% Contaminated			
		Floor	Wall	Floor	Wall	Total Site	Contaminated
PWR	7.5×10^6 Co60 2.4×10^6 Cs137	250,000	300,000	10	2	50×10^6	3,000
Uranium Fuel Fab	18,000 U	240,000	240,000	50	5	4.7×10^6	100,000
Sealed Source Manufacturer	102,000 Co60 33,300 Cs137	6,000	4,600	10	5	40,000	5,000
Rare Metal Extraction	18,000 Thorium	150,000	180,000	40	10	740,000	100,000

(1) The estimated surface areas listed above (reproduced from Appendix C) are based on limited information and in many cases represent an engineering judgment based on the size of the building structural facilities and types of operation. These estimates are considered to be conservatively large, i.e., they probably overestimate the actual areas involved.

(2) Radionuclide activity shown is for building surfaces. Radionuclide activity for soil surfaces is given in Appendix C.

4. Impacts for Each Reference Facility

4.1 Purpose

This analysis evaluated human impacts over a range of residual dose rate levels for each of four reference facilities. The four reference facilities include a power reactor, uranium fuel fabrication facility, sealed source manufacturer, and rare metals processor. Chapter 3 describes the reference facilities, and Appendix C gives additional detail.

This analysis also evaluated environmental consequences other than those directly affecting human health. These include impacts on the biological, socioeconomic, and physical environments both from the decontamination activities and from residual radiation levels.

4.2 Human Health Impacts

4.2.1 Human Health Impacts Resulting from Decommissioning

This section provides an overview of the analysis of the impacts of those decommissioning activities necessary to bring the reference facilities into compliance with the residual dose criteria. The complete bases and the detailed results of the impact analyses are provided in Appendix B. As discussed in Chapter 2, this evaluation analyzes impacts and costs for each reference facility for a range of possible residual dose criteria. These residual dose criteria represent the exposure to an individual at the site following decommissioning. The criteria selected for these detailed analyses include: 100, 60, 25, 15 and 3 mrem per year. Consideration of the impacts of a limit of "0" above background are discussed in Appendix A. The impacts are as follows:

1. Impacts on persons living on the site after decommissioning and license termination - Individuals residing on the site after completion of decommissioning and termination of the facility license may be exposed via a variety of potential pathways. As described in NUREG/CR 5512 (NRC 1992c), the pathways include: (1) external exposure to contaminated soil both indoors and outdoors, (2) internal exposure both indoors and outdoors due to inhalation of contaminated material that is resuspended, (3) direct and inadvertent ingestion of soil, (4) ingestion of drinking water from a source of groundwater contaminated by migration of radionuclides in soil, (5) ingestion of vegetable products grown in contaminated soil and/or irrigated with contaminated groundwater, (6) ingestion of food products from animals that consume contaminated feed and/or drink contaminated water, and (7) ingestion of fish products from a source of water contaminated with surface runoff from the site.

2. Impacts on persons working in the facility after decommissioning and license termination - Individuals working in the facility after completion of decommissioning and termination of the facility license may be exposed through a variety of potential pathways. As described in NUREG/CR-5512, the pathways include: (1) external exposure to surface sources, (2) inhalation of resuspended

surface contamination, and (3) inadvertent ingestion of surface contamination.

3. Impacts on persons resulting from decommissioning operations to reduce building and soil contamination to acceptable levels - These impacts have both radiological and nonradiological sources and affect both the public and decontamination workers. This human health impact is a result of the actions taken at each reference facility to reduce the building and soil contamination levels to achieve compliance with the alternative residual dose criteria specified above. The impacts are as follows:

   a. Radiological impacts to workers during decontamination and cleanup activities at the facility - These impacts are based upon the dose rates to which the workers are subjected and the collective effort required to reduce the residual contamination levels.

   b. Radiological impacts to workers and the general public incurred during transport and disposal of waste material generated during decontamination to a licensed disposal facility - These impacts are based upon the total volume of waste, number of shipments, and the collective exposure incurred in making a shipment of such radioactive waste.

   c. Nonradiological impacts (specifically, fatal transportation accidents) on workers and the general public incurred during transport of waste generated during decontamination to a licensed disposal facility - These impacts are based upon the total volume of waste, number of shipments, the distance to the disposal site, and the rate of fatal vehicular accidents.

   d. Nonradiological impacts (specifically, fatal construction accidents) on workers during decontamination and cleanup activities at the facility - These impacts are based upon the collective effort required to reduce the residual contamination levels and the rate of fatal construction accidents.

The GEIS does not include the radiological exposure impacts on offsite populations from routine and accidental decommissioning releases. These were addressed in NUREG-0586 (NRC 1988). Since decontaminating building surfaces and soil is a fraction of the entire decommissioning process, the impacts resulting from this part would be smaller than those described in NUREG-0586.

Also not specifically addressed in the GEIS are the impacts from future inadvertent recycling of contaminated building rubble and soil following decommissioning of a site. One could postulate that both building rubble and soil containing residual radioactivity could be inadvertently recycled into new construction material or used as fill, thus causing radiation exposures. Although the analysis in this GEIS does not specifically take this recycling into account, the building occupancy and onsite residency scenarios and assumptions used in the GEIS to estimate public doses from decommissioned lands and structures are considered sufficiently conservative to encompass recycling of such material. The exposure mechanisms are the same, and the resulting individual doses could only be less than those evaluated because the contamination of the recycled material will be reduced through dilution with other raw materials. Thus, future inadvertent recycling of soils or structures following decommissioning of the reference sites would not affect the conclusions made in this GEIS regarding public health.

Although this GEIS quantifies the impacts from transporting decommissioning waste to a low-level waste disposal site, the GEIS does not consider in detail the impacts from the permanent placement of waste in the disposal facility. These impacts have already been described in the Final Environmental Impact Statement on 10 CFR Part 61 (NRC 1982). Waste from decommissioning of lands and structures is a component of the entire waste placed within a disposal facility; therefore, the impact from this waste is a fraction of the entire disposal facility's impact. Because the estimated exposures from the entire waste disposal facility in the Part 61 GEIS are lower than those for the activities associated with decommissioning for the reference facilities illustrated in Tables 4.1 - 4.8, they would not affect the conclusions made regarding decommissioning impacts and costs in this GEIS. In addition, the analysis contained in Section 4.3.5, below, indicates that the incremental effect of alternative residual dose criteria for lands and structures for the reference facilities should not result in the need for additional disposal capacity beyond that planned.

4.2.2 Analysis of Radiological and Nonradiological Human Health Impacts

In assessing human health impacts from decommissioning, the analysis considers risks to individuals expressed either in terms of mrem/year when radiation exposure is involved or in accident rates when nonradiological impacts are involved. The assessment also considers collective risk to the population engaged in various activities related to the decommissioning which result in both long-term and short-term impacts. These impacts are accrued differently with respect to the alternative residual dose criteria. Working and living on site after license termination results in long-term exposure to residual dose levels; therefore collective risk is reduced with decreasing residual dose criteria. The four decontamination-related impacts listed in item #3 of Section 4.2.1 result from short-term activities and consist of both radiological and nonradiological risks. In these cases, the activities necessary to achieve lower residual dose criteria result in an increase in collective risk to those engaged in those activities. Because these long-term and short-term impacts take place over different time periods and may affect different persons, a precise comparison or balancing is difficult. Nevertheless, the analysis in this GEIS estimates the individual risks and collective risks for these impacts separately and also presents a total collective risk for these disparate impacts. This approach is considered reasonable in that it permits assessments and conclusions to be made about all of the impacts that may result from a particular decommissioning alternative.

Individual and collective risks are determined by estimating the risk to individuals engaged in the activities listed in Section 4.2.1, the total number of persons engaged in those activities, and the time period over which the activities take place. Details of the methods for assessing the individual and collective risks for the activities are indicated in Section B.3 of Appendix B, and assumptions regarding numbers of persons, time periods for activities, and other parameters needed to assess collective risk from an activity are summarized in Tables A.1, A.2.1 to A.2.4, and A.3.1 to A.3.4 of Attachment A to Appendix B.

For the impacts associated with working or living on the site following license termination, the analysis assumes exposure of individuals to the residual dose limit, corrected for radioactive decay, over a 1,000-year time period for soil and a 70-year time period for buildings which is assumed to be the life span of the building following license termination. Analysis of costs and impacts of building demolition are described in NUREG-0586 (NRC 1988).

For the impacts on workers involved in decontamination operations to reduce contamination in structures and soils to the residual dose levels, the analysis is based upon the reference contamination levels in each reference facility, as given in Chapter 3 and in Appendix C. Appendix C shows the amount of concrete that must be removed to achieve the alternative residual radioactivity criteria. Based on that information, the evaluation determines the time spent and radiation exposure received in decontaminating the surfaces to these levels and in removing and transporting the contaminated concrete to a disposal site. Additionally, the analysis assesses the decontamination and transportation impacts for soil contamination.

The radionuclides used in the analysis of impacts in this section (and of costs in Chapter 6) are Co-60, Cs-137, U-nat, and Th-232. Dose conversion factors for these nuclides are calculated for several different pathways of exposure based on the analysis procedures of NUREG/CR-5512 (NRC, 1992c) which contains the NRC's technical bases for translating contamination levels to annual total effective dose equivalent. The radionuclides Co-60 and Cs-137 are of the type found in certain of the facilities listed in Chapter 3, including power reactors, research and test reactors, ISFSIs, sealed source manufacturers, and R&D facilities. U-nat and Th-232 are of the type found at certain of the fuel cycle and non-fuel-cycle facilities listed in Chapter 3, including uranium fuel fabrication plants, UF_6 plants, and rare earth processors. While other radionuclides are also present at these facilities, the impacts and costs resulting from analysis of these radionuclides are considered sufficiently representative of the reference facilities for the generic analysis of this final GEIS.

Specific consideration is given here to issues regarding radon. Radon is a radioactive gas formed by the radioactive decay of radium. Radium is a member of the uranium-238 radioactive decay chain. Radionuclides from this decay chain are found in natural background in various concentrations in most soils and rocks. Estimation of radon dose is a consideration here only at those facilities which have been contaminated with radium as a result of licensed activities.

Because of natural transport of radon gas in outdoor areas due to diffusion and air currents, doses from exposure to radon in outside areas due to radium in the soil are negligible. Within buildings, wide variation in local concentrations of naturally occurring indoor radon, well in excess of the lower alternative residual dose criteria being considered in this final GEIS, have been observed in all regions of the United States. The dominant factor in determining indoor radon levels are the design features of any structures at a site where radium is present in the soil. Certain structural features, including energy saving measures that reduce air exchange with the outside, can have the effect of trapping radon gas within a building, thus allowing buildup of radon to elevated levels. In addition, indoor radon levels can vary significantly over time due to seasonal changes and the rate of air flow in rooms.

Another variable in radon levels is introduced by the use of radon mitigation techniques in buildings which can have the effect of reducing radon levels by deliberate venting of the gas to outside areas. In many parts of the country, local building codes have been enacted for the purpose of reducing radon levels in homes, in particular in areas where there are high levels of naturally occurring radium and radon.

The variations in radon levels described above make it very difficult to distinguish between naturally occurring radon and radon resulting from licensed material. In addition, it is impractical to predict prospective doses from exposure to indoor radon due to problems in predicting the design features of future building construction. Because of these variations and the limitation of measurement techniques, it is not practical to distinguish between radon from licensed activities at a dose comparable to the lower alternative residual dose criteria considered in this GEIS and radon which occurs naturally. Therefore, the GEIS does not address this pathway explicitly in calculating doses at the reference facilities, but focuses on the concentrations and impacts of radon precursors.

4.2.3 Results

Based upon the analyses in Appendix B, estimates of impacts are presented for illustrative purposes for each reference facility in Tables 4.1 through 4.8. These results are presented separately for soils and structures to highlight different impact considerations that arise. Only a combined analysis for soil and structure was presented in the draft GEIS (although sufficient information was presented there for doing separate analysis). The results presented in Tables 4.1 - 4.8 illustrate the kinds of information presented in Appendix B. For structures, the analysis is for an industrial setting and illustrate impacts resulting from a specific case of reducing the residual dose below 60 mrem/y. For soil, the analysis is for a residential setting for a diffusion profile (the same as the draft GEIS) for unwashed soil. All illustrations are for unrestricted use for high contamination levels. For the impacts incurred as a result of exposure to radiation (columns 2, 3, and 4), the table entries are estimated mortalities from radiation-induced cancer and are based on the cancer-to-dose relationships developed in the UNSCEAR and BEIR V reports (UNSCEAR 1988, BEIR 1990). For impacts incurred as a result of construction accidents while performing decontamination activities (column 5) or from traffic accidents while transporting waste (column 6), the table entries are estimated accident mortalities and are based on published statistical data on accident rates. For each reference facility, the tables show the impacts as follows:

Column 1 - Residual dose rate criteria

Column 2 – Estimated mortalities for the public from radiation exposure while living on site following completion of decommissioning (soil contamination, Tables 4.1-

4.4)

Column 2 - Estimated mortalities for the public from radiation exposure while working on site following completion of decommissioning (structure contamination, Tables 4.5-4.8)

Column 3 - Estimated mortalities for workers from radiation exposure while performing decontamination activities

Column 4 - Estimated mortalities for workers and the public from radiation exposure while transporting those waste materials generated during decommissioning operations

Column 5 - Estimated mortalities for workers from fatal construction accidents while performing decontamination activities

Column 6 - Estimated mortalities for workers and the public from fatal traffic accidents while transporting those waste materials generated during decommissioning operations

Column 7 - Estimated total mortalities from radiation exposure and accidents

Column 8 - Estimated mortalities from short-term decommissioning activities (decommissioning plus transportation) - total of Columns 3, 4, 5, and 6

Results presented in Tables 4.1 through 4.8 are shown as calculated output and do not indicate precision to the number of significant figures shown.

4.2.4 Summary

Estimates of incremental impact reduction (i.e., incremental impact averted) realized in setting alternative dose criteria are considered in Chapter 6, as are considerations of costs involved in achieving the incremental reductions in impact.

4.2.5 Uncertainties in Assessing Generic Impacts for Reference Facilities

There are several sources of uncertainty in the evaluation of the incremental impacts related to alternative residual radioactivity criteria. Of particular concern are the difficulties in making a generic evaluation of reference contamination levels on and within concrete and other building material, including contamination levels in cracks in the concrete and contamination hot spots. Another uncertainty in this generic evaluation stems from assumptions made about the areal extent and depth profile for soil contamination at reference facilities. These uncertainties are dealt with in the GEIS in the following manner:

1. Information about the level and location of contamination in concrete and other building material in nuclear facilities has been reviewed, and reference contamination levels are developed in the GEIS based on these data and on engineering judgment. These contamination levels may vary for specific sites. Reference contamination levels in concrete, based on an estimate of the range of contamination likely to occur in the buildings at the reference facilities, provide a reasonable estimate of the likely range of impacts that may result from decontamination operations at such facilities.

2. Information about concrete and other building material decontamination methods (including high-pressure water jet) and removal processes (including scabbling) has been reviewed and then used in the analysis of staff time necessary to remove contaminated concrete and soil removal.

3. Information as to the level and location of contamination in soil in nuclear facilities has been reviewed, and reference contamination levels are developed in the GEIS based on these data and on engineering judgment. These contamination levels may vary for specific sites. The available information is limited; therefore, three sets of reference soil contamination levels have been developed for each of the reference facilities. The analysis evaluated these contamination levels, referred to as "high," "medium," and "low" soil contamination, to bound the problem and to estimate the range of impacts that may result from differing soil contamination levels. Such an evaluation is presented for the cost of soil removal in Appendix C. Appendix B uses the results of Appendix C but only for the high contamination case which is considered sufficiently representative. Based on the preceding, Chapter 6 presents a summary of the results of the analysis presented in Appendix B.

4.3 Other Environmental Consequences

Environmental consequences other than those directly affecting human health were also evaluated in Section 5.3 of the draft GEIS (NRC 1994a) (for ease of reference, that section of the draft GEIS is included in this final GEIS as Attachment C to Appendix B). These included impacts on the biological, socioeconomic, and physical environments both from the decontamination activities and from residual radiation levels. Specifically addressed were the physical and radiological impacts on plant and animal populations; land use changes; social, economic, and cultural resource impacts; noise; aesthetics; and impacts on planned low-level waste disposal capacity.

Impacts were previously evaluated for the entire decommissioning process and are described in NUREG-0586 (NRC 1988). Since the decontamination of building structures and areas of contaminated soils is a component of decommissioning, some of the same activities and impacts were discussed in that document. This GEIS focuses on both the costs and environmental effects attributable to activities required to achieve the residual dose criteria indicated in Section 4.2.1.

4.3.1 Biological Environment

During the decommissioning process, biological components of the environment may be affected by the physical removal of contaminated soils from site areas outside of structures and by exposure to any residual radiation. Estimated area of soil contamination for each category of reference facility are given in Table 3.1.

Decontamination activities would include physical removal of the contaminated soils to depths of a few inches to a foot or more, followed by conditioning and revegetating of the disturbed area. Where warranted, site surveys for State or Federally listed or candidate threatened or endangered species would be made prior to any land disturbance outside of the facility structures.

Analysis of the effects on these environmental components in the draft GEIS was qualitative because radionuclide impact analysis on human health will usually bound the impact on biota, and because the range of residual dose criteria being considered in the draft (and final) GEIS is well below the exposures where effects were observed on biota (SC&A 1993). Also, issues related to biota may be very site-specific and will need to be addressed in an EIS prepared for a specific facility.

4.3.2 Socioeconomic Environments

Human social, cultural, and economic institutions exist in the vicinity of the nuclear facility during the time that the facility is operating. These institutions could be affected by specific decommissioning actions and the alternative regulatory approaches being considered, and new social, cultural, and economic institutions may come to exist following license termination. The analysis of the impacts on these environments in Attachment C to Appendix B is qualitative because, for the range of doses being considered, the differential impact on these institutions is not significant. Also, the socioeconomic impacts will be very site-specific and do not lend themselves to generic analysis. Attachment C to Appendix B does not specifically include the impacts on Native American tribal land use. The GEIS evaluation is based on reference facilities, which means that the average or more typical case is characterized. Tribal use is very specific, and impacts can most properly be assessed on a case-by-case basis. Impacts on Native American tribal use of site lands would be better addressed in an environmental impact statement or environmental assessment for a specific facility at the time of decommissioning of that facility.

4.3.3 Physical Environment

The physical environment (water, noise levels, air quality, aesthetics, and low-level waste capacity) could be affected by specific decommissioning actions and the alternative regulatory approaches being considered as part of license termination. Except for low-level waste capacity, analysis of the impacts on these components in Attachment C to Appendix B is qualitative because, for the range of doses being considered, the differential impact on these physical environments is not significant. Also, most of these impacts will be very site-specific and do not lend themselves to generic analysis. However, quantitative analysis of the adequacy and utilization of low-level waste capacity is provided. In addition, quantitative analysis of groundwater, which is also highly site specific, was not included in the draft GEIS, however Chapters 6 and 7 and Appendix C of this final GEIS provide a quantitative analysis of remediation activities associated with groundwater (see Section 4.3.5).

4.3.3.1 Low-Level Waste Disposal Capacity.

The draft GEIS analysis assumed that the waste generated from the decontamination of buildings and soils for most of the reference facilities will be placed in offsite low-level waste disposal facilities. An analysis was performed which estimated the amount of available and planned disposal site capacity by compact and noncompact States. These data were compared to the estimated incremental quantities of waste generated by decontaminating the structures and soils for all of the licensed facilities. In performing this analysis, each licensed facility was assumed to generate the same amount of waste as the corresponding reference facility described in the GEIS. A review of this analysis is contained in Appendix G of this final GEIS (see Section 4.3.5). The NRC has identified a number of facilities (47 sites) that warrant special attention. These sites are included in NRC's Site Decommissioning Management Plan (SDMP) program (NRC 1993) and encompass contaminated buildings, soil, slag, former waste disposal areas, and tailing piles. These facilities are a distinct and separate category because much of their waste results from moving and processing large volumes of uranium- and thorium-bearing ores and their impact on disposal capacity is discussed in Appendix G.

4.3.4 Unavoidable Adverse Impacts

The conclusions of the draft GEIS were as follows:

4.3.4.1 Biological Environment.

No adverse impacts to any components of the biological environment are expected at residual dose levels of 100 mrem/y or less.

4.3.4.2 Land Use.

Certain land uses such as housing, schools, etc., may be precluded at the higher proposed levels of residual radiation. The effects of this would be local and could include higher land prices and less desirably located sites being used for these purposes.

4.3.4.3 Socioeconomic.

Land use restrictions at the higher proposed levels of residual radiation could preclude future industrial or commercial development of the site, thus reducing local employment and the tax base. This could cause a reduction in the local economy and services.

4.3.4.4 Noise and Aesthetics.

The levels of residual radiation allowable under the standards are not expected to result in noise or aesthetic impacts.

4.3.4.5 Low-Level Waste Disposal Capacity.

The incremental effect of alternative residual dose criteria for lands and structures for licensed facilities in the reference facility categories should not result in the need for additional disposal capacity beyond that planned. SDMP wastes do require significant capacity.

4.3.5 Public Comments on Consequences in the Biological, Socioeconomic, and Physical Environments

The public comments on the impacts on the biological and socioeconomic environments and the noise and esthetic aspects of the physical environment were not substantial enough to cause revision to the preliminary recommendations of the draft GEIS.

There were two areas where there was extensive comment. One was in the area of groundwater contamination. Some commenters indicated that there is no reason for the separate groundwater standard included in the proposed rule and indicated that the all-pathways standard was sufficient and also that the proposed rule and draft GEIS did not include an analysis of impacts and costs to support such a separate standard. Other commenters, including the EPA, indicated that such a standard is appropriate to protect groundwater. In addition, there was also comment on the analysis of low-level waste disposal capacity of Appendix G of the draft GEIS. Commenters suggested that the volumes for the reference facilities of the draft GEIS underestimated the actual volumes and that the disposal capacity would be overtaxed by the decommissioning volumes resulting from achieving the dose criterion of the proposed rule.

In response to comments on the separate groundwater standard, Section 6.4 and Appendix C contain additional evaluation and analysis of the comments. In response to the comments on low-level capacity, Appendix G contains an updated analysis of the volumes and affect on capacity. That analysis is summarized below.

The disposal capacity planned for the compacts and States is estimated to total about 52×10^6 ft^3 (Table 4.9). Waste volumes from decommissioning of licensed facilities categorized by the reference facilities are estimated to total approximately 7×10^6 ft^3 at a residual dose criteria of 3 mrem/y (Table 4.10). This total was developed by taking the estimated volumes of building material and soil requiring disposal from each of the reference facilities (Appendix C) and multiplying by the number of facilities in those reference facility categories (see Appendix G). For conservatism, the volumes corresponding to high soil contamination given in Appendix C were used. Also, for conservatism the analysis of incremental volume effects has focused on the 100 to 3 mrem/y range and does not consider intermediate differences. As indicated in Attachments C and D of Appendix C, incremental waste volumes from decommissioning are estimated to vary by a 40 percent decrease in going from 100-25 mrem/y and a 250 percent increase in going from 100-.03 mrem/y as compared to the 100 to 3 mrem/y range. 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 such a reduction is extremely unlikely. Waste from normal facility operations also goes to the licensed disposal sites, is mixed with decommissioning wastes, and contributes to the filling up of capacity. Currently, the annual average waste generation from normal operations is estimated to be about 0.7×10^6 ft^3 (see Appendix G, Section G.4.1). The disposition of SDMP sites, as estimated in Appendix G, consists mainly of wastes associated with movement and processing of large volumes of uranium- and thorium-contaminated soil, and such wastes may not go directly to 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 radioactive waste. Also, some of these facilities could be placed into restricted use and, as described in Appendix C, this would result in reduction of soil volumes requiring disposal.

Based on the above estimates, overall the estimated total waste volumes from decommissioning of lands and structures at the licensed facilities categorized by the reference facilities are about 13 percent of the total planned low-level waste disposal capacity (Table 4.11). While this analysis concludes that the incremental effect of alternative residual dose criteria for lands and structures should not result in the need for additional disposal capacity beyond that planned, there may be potential lags in the development and operation of regional compact disposal facilities. These may have an effect on site-specific decommissionings and result in the need for such actions as delaying completion of decommissioning at a particular facility. Impacts and costs would be analyzed as part of a decommissioning plan at a specific facility. In general, alternative residual dose criteria for lands and structures should not be the cause of such lags, and hence the alternative criteria would not cause the need for such site-specific analysis of impacts or costs.

4.4 Comparison of Short-Term Uses and Long-Term Productivity

Decontamination and decommissioning of the site will make the lands available for other uses. Sites with restrictions on future uses because of residual radiation levels may be committed to wildlife habitat, open-space, industrial use, short-term recreation, or other similar uses.

Table 4.1

Statistical Mortality - Power Reactor Case 2

Residual Dose Limit (mrem/y)	Mortality from Radiation Exposure			Mortality from Accidents			Short Term Fatalities (Decon & Transportation)
	Living Onsite	Perform Decon	Transport Waste	Perform Decon	Transport Waste	TOTAL	
100	5.34e-05	1.97e-06	1.31e-04	1.65e-06	1.82e-04	3.70e-04	3.17e-04
60	3.95e-05	2.77e-06	1.74e-04	2.33e-06	2.43e-04	4.62e-04	4.22e-04
30	2.74e-05	3.56e-06	2.18e-04	2.99e-06	3.04e-04	5.55e-04	5.28e-04
25	1.85e-05	3.75e-06	2.18e-04	3.15e-06	3.04e-04	5.47e-04	5.28e-04
15	1.30e-05	4.23e-06	2.18e-04	3.56e-06	3.04e-04	5.42e-04	5.29e-04
10	1.01e-05	4.68e-06	2.61e-04	3.93e-06	3.65e-04	6.45e-04	6.34e-04
3	6.44e-06	6.95e-06	3.48e-04	5.83e-06	4.86e-04	8.54e-04	8.47e-04
1	2.42e-06	1.23e-05	6.09e-04	1.03e-05	8.51e-04	1.49e-03	1.48e-03

Table 4.2

Statistical Mortality - Uranium Fuel Fabrication Facility Case 2 & 2A

Residual Dose Limit (mrem/y)	Mortality from Radiation Exposure			Mortality from Accidents			
	Living Onsite	Perform Decon	Transport Waste (Truck)	Perform Decon	Transport Waste (Truck)	TOTAL	Short Term Fatalities (Decon & Transportation)
100	1.86e-01	1.45e-04	6.60e-07	1.22e-04	1.00e-02	1.96e-01	1.03e-02
60	1.11e-01	1.56e-04	7.08e-07	1.31e-04	1.08e-02	1.23e-01	1.10e-02
30	5.57e-02	1.68e-04	7.68e-07	1.41e-04	1.17e-02	6.77e-02	1.20e-02
25	4.65e-02	1.71e-04	7.80e-07	1.44e-04	1.19e-02	5.86e-02	1.22e-02
15	2.79e-02	1.79e-04	8.16e-07	1.51e-04	1.24e-02	4.06e-02	1.27e-02
10	1.86e-02	1.86e-04	8.44e-07	1.56e-04	1.28e-02	3.18e-02	1.32e-02
3	5.57e-03	2.02e-04	9.20e-07	1.70e-04	1.40e-02	1.99e-02	1.44e-02
0.3	1.86e-03	2.28e-04	1.04e-06	1.92e-04	1.58e-02	1.81e-02	1.62e-02

Table 4.3

Statistical Mortality - Sealed Source Case 2

Residual Dose Limit (mrem/y)	Mortality from Radiation Exposure			Mortality from Accidents			Short Term Fatalities (Decon & Transportation)
	Living Onsite	Perform Decon	Transport Waste	Perform Decon	Transport Waste	TOTAL	
100	8.91e-05	1.26e-06	8.70e-05	1.06e-06	1.22e-04	3.00e-04	2.11e-04
60	6.59e-05	1.78e-06	1.31e-04	1.49e-06	1.82e-04	3.82e-04	3.16e-04
30	4.56e-05	2.28e-06	1.31e-04	1.91e-06	1.82e-04	3.63e-04	3.17e-04
25	3.09e-05	2.40e-06	1.31e-04	2.02e-06	1.82e-04	3.48e-04	3.17e-04
15	2.17e-05	2.71e-06	1.74e-04	2.28e-06	2.43e-04	4.44e-04	4.22e-04
10	1.68e-05	2.99e-06	1.74e-04	2.52e-06	2.43e-04	4.40e-04	4.23e-04
3	1.07e-05	4.45e-06	2.61e-04	3.73e-06	3.65e-04	6.45e-04	6.34e-04
1	4.03e-06	7.88e-06	3.92e-04	6.62e-06	5.47e-04	9.57e-04	9.53e-04

Table 4.4

Statistical Mortality - Reference Rare Metal Extraction Plant Case 1 & 1A

Residual Dose Limit (mrem/y)	Mortality from Radiation Exposure			Mortality from Accidents			
	Living Onsite	Perform Decon	Transport Waste (Truck)	Perform Decon	Transport Waste (Truck)	TOTAL	Short Term Fatalities (Decon & Transportation)
100	1.86e-01	1.20e-06	8.00e-09	1.01e-06	1.22e-04	1.86e-01	1.24e-04
60	1.11e-01	4.04e-06	2.00e-08	3.40e-06	3.04e-04	1.12e-01	3.11e-04
30	5.57e-02	6.18e-06	3.20e-08	5.19e-06	4.86e-04	5.62e-02	4.98e-04
25	4.65e-02	6.53e-06	3.20e-08	5.49e-06	4.86e-04	4.69e-02	4.98e-04
15	2.79e-02	7.24e-06	3.60e-08	6.08e-06	5.47e-04	2.84e-02	5.61e-04
10	1.86e-02	7.60e-06	3.60e-08	6.38e-06	5.47e-04	1.91e-02	5.61e-04
3	5.57e-03	1.27e-05	6.00e-08	1.07e-05	9.12e-04	6.51e-03	9.35e-04
0.3	1.86e-03	1.55e-05	7.20e-08	1.30e-05	1.09e-03	2.98e-03	1.12e-03

Table 4.5							
Statistical Mortality - Power Reactor Structures Case 3							
Residual Dose Limit (mrem/y)	Mortality from Radiation Exposure			Mortality from Accidents			Short Term Fatalities (Decon & Transportation)
	Working Onsite	Perform Decon	Transport Waste	Perform Decon	Transport Waste	TOTAL	
100	7.68e-02	2.60e-03	4.79e-04	3.79e-04	6.69e-04	8.09e-02	4.12e-03
60	4.61e-02	2.60e-03	4.79e-04	3.79e-04	6.69e-04	5.02e-02	4.12e-03
30	2.30e-03	3.30e-03	5.22e-04	4.81e-04	7.30e-04	7.34e-03	5.03e-03
25	2.30e-03	3.30e-03	5.22e-04	4.81e-04	7.30e-04	7.34e-03	5.03e-03
15	2.30e-03	3.30e-03	5.22e-04	4.81e-04	7.30e-04	7.34e-03	5.03e-03
10	2.30e-03	3.30e-03	5.22e-04	4.81e-04	7.30e-04	7.34e-03	5.03e-03
3	2.34e-03	4.00e-03	6.09e-04	5.84e-04	8.51e-04	8.38e-03	6.05e-03
1	7.79e-04	4.00e-03	6.09e-04	5.84e-04	8.51e-04	6.82e-03	6.05e-03

Table 4.6							
Statistical Mortality - Uranium Fuel Fabrication Facility Structures Case 2							
Residual Dose Limit (mrem/y)	Mortality from Radiation Exposure			Mortality from Accidents			
	Working Onsite	Perform Decon	Transport Waste	Perform Decon	Transport Waste	TOTAL	Short Term Fatalities (Decon & Transportation)
100	2.10e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	2.10e-01	0.00e+00
60	2.10e-01	0.00e+00	0.00e+00	0.00e+00	0.00e+00	2.10e-01	0.00e+00
30	3.50e-06	0.00e+00	0.00e+00	0.00e+00	0.00e+00	3.50e-06	0.00e+00
25	3.50e-06	2.39e-03	8.70e-05	3.48e-04	3.65e-04	3.19e-03	3.19e-03
15	3.50e-06	2.39e-03	8.70e-05	3.48e-04	3.65e-04	3.19e-03	3.19e-03
10	3.50e-06	2.39e-03	8.70e-05	3.48e-04	3.65e-04	3.19e-03	3.19e-03
3	3.50e-06	2.39e-03	8.70e-05	3.48e-04	3.65e-04	3.19e-03	3.19e-03
1	3.50e-06	2.39e-03	8.70e-05	3.48e-04	3.65e-04	3.19e-03	3.19e-03

Table 4.7

Summary Costs for SS Manuf ($M)
Structures Case 3
Disposal Cost - $50/ft3

Residual Dose Limit (mrem/y)	Facility Decon	Survey	TOTAL
100	$0.029	$0.027	$0.056
60	$0.029	$0.027	$0.056
30	$0.040	$0.027	$0.067
25	$0.040	$0.027	$0.067
15	$0.040	$0.027	$0.067
10	$0.040	$0.027	$0.067
3	$0.040	$0.027	$0.067
1	$0.040	$0.027	$0.067

Table 4.8							
Statistical Mortality - Rare Metal Extraction Facility Structures Case 2							
Residual Dose Limit (mrem/y)	Mortality from Radiation Exposure			Mortality from Accidents			
	Working Onsite	Perform Decon	Transport Waste	Perform Decon	Transport Waste	TOTAL	Short Term Fatalities (Decon &
100	1.75e-01	2.39e-03	2.03e-04	3.49e-04	8.51e-04	1.79e-01	3.79e-03
60	1.05e-01	2.39e-03	2.03e-04	3.49e-04	8.51e-04	1.09e-01	3.79e-03
30	5.25e-02	2.39e-03	2.03e-04	3.49e-04	8.51e-04	5.63e-02	3.79e-03
25	3.94e-05	4.31e-03	2.47e-04	6.29e-04	1.03e-03	6.26e-03	6.22e-03
15	3.94e-05	4.31e-03	2.47e-04	6.29e-04	1.03e-03	6.26e-03	6.22e-03
10	3.94e-05	4.31e-03	2.47e-04	6.29e-04	1.03e-03	6.26e-03	6.22e-03
3	3.94e-05	4.31e-03	2.47e-04	6.29e-04	1.03e-03	6.26e-03	6.22e-03
1	3.94e-05	4.31e-03	2.47e-04	6.29e-04	1.03e-03	6.26e-03	6.22e-03

Table 4.9
Estimated Low-Level Waste Disposal Capacity by Compacts and Non-Member States[a]

Compact/State	Assumed Generation (ft^3/y.)	Facility Life or Projection (yr.)	Planned Disposal/ Storage Capacity (10^6 ft^3)	Provision for D&D (10^6 ft^3)	Out-of-Region Waste (10^6 ft^3)	Planned Capacity Waste (10^6 ft^3)
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
TOTAL						52.4

(a) See Appendix G for details and sources.

Table 4.10

Total Waste Volume Summary from Decommissioning of Lands and Structures for Reference Facility Categories by Compacts and Non-Member States(a)

	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

(a) See Appendix G for details

Table 4.11

Comparison of Estimated Low-Level Waste Disposal Capacity and Decommissioning Waste Volumes(a)

Compact/State	Waste Volume (10^6 ft^3)		Ratio Estimate Capacity(d)
	Total Planned Capacity	Reference Facility Categories Total Waste Volume Estimates(b,c)	
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	(e)	---	---
Southeast	11.0	0.65	0.06
Southwestern	5.5	0.93	0.17
District of Columbia	---	0.02	---
Maine	(f)	---	---
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	(f)	---	---
Total	51.7	6.8	0.13

(a) See Appendix G for details.
(b) Numbers given are for total waste volume for decommissioning lands and structures at a residual dose criteria of 3 mrem/y. Incremental waste volumes would be approximately 40 percent less than these values for residual dose criteria of 100 to 25 mrem/y and approximately 250 percent more than these values 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 not likely to occur.
(c) Does not include SDMP estimates from NUREG-1444 (NRC 1993).
(d) Refer to (b), above, for explanation of ratio estimates.
(e) Included in total for the Northwest Compact.
(f) Included in total for Texas.

5. Costs Associated with Each Reference Facility

5.1 Introduction

Operation of each of the nuclear facilities identified in Chapter 3 results in varying levels of contamination. This contamination must be cleaned up as part of decommissioning to reach acceptable levels. Costs are incurred to achieve this acceptable level. Each of the regulatory alternatives being considered requires various expenditures.

Costs associated with the different rulemaking alternatives are considered in the GEIS to determine the incremental costs associated with reducing the level of contamination at the reference facilities to a range of potentially acceptable residual dose criteria. These residual dose criteria represent the exposure to an individual at the site following decommissioning. The alternative residual dose criteria used in these analyses include: 100, 60, 25, 15, and 3 mrem per year.

In assessing the differential in cost related to alternative residual dose criteria, it is necessary to first consider the major factors in the cost of decommissioning. Following this, the analysis evaluates the sensitivity of these factors to the dose criteria.

5.2 Major Costs of Decommissioning Sensitive to Alternative Residual Criteria

Section 2.4.3.1 lists the major decommissioning activities that are necessary at reference facilities to reduce the contamination to acceptable levels. As discussed, not all these costs are sensitive to alternative residual criteria for lands and structures. Section 2.4.3.1 lists the following decommissioning activities with costs that are sensitive to the alternative residual criteria:

1. Radiological characterization surveys;

2. Cleaning, removal, packaging, transportation, and disposal of concrete, other building materials, and soil; and

3. Termination surveys.

This assessment of the costs of decontaminating the reference facilities to alternative residual dose criteria focuses on the costs of these three activities and the differential in these costs for alternative residual dose criteria.

The difficulty in making a generic evaluation of contamination levels on and within concrete and other building material, including contamination levels in cracks in the concrete and contamination hot spots, complicates the assessment of costs. Another notable complication for this generic evaluation regards assumptions concerning the depth profile for soil contamination at reference facilities. Previous studies on technology, safety, and costs of decommissioning prepared by Battelle for the NRC (NRC 1977; 1978a-c; 1979a-d; 1980a-b) did not relate decommissioning costs to precise residual contamination levels. In addition, evaluation of costs of termination surveys at the low contamination levels proposed in the rulemaking alternatives raises questions about the ability to detect and discriminate radionuclides at very low levels.

Appendix C presents the results of analyses prepared in response to public comments on the draft GEIS to provide a technical basis for developing differential costs for cleaning, removal, packaging, transportation, and disposal of concrete, other building materials, and soil, while Appendix D gives the basis for radiological characterization and termination survey costs. The following sections summarize the analyses in those appendices.

5.2.1 Cost Methodology for Concrete and Other Building Material Removal and Disposal

Section 4 of Appendix C describes reference contamination levels on and within concrete and other building material surfaces for the reference facilities. Sources of information used to develop this information include previous reports on contamination levels in nuclear facilities (NRC 1977, 1978a-c, 1979a-d, 1980a-b, 1986, 1992b, 1993) and, where detailed information is not available, engineering judgment regarding the extent of this contamination.

Sections 6.1 - 6.3 of Appendix C describe the concrete and other building material decontamination and removal techniques most likely to be used at the reference facilities, and the extent of contamination removal by these techniques. These techniques include surface cleaning by nondestructive means, as well as mechanical concrete removal methods such as chipping away surface layers. For these removal methods, costs are based upon the following:

1. The number of hours of direct staff labor necessary to remove contaminated concrete and, based on the unit cost of labor for concrete removal, the cost of direct staff labor;

2. Cost of overhead staff time during concrete removal;

3. Cost of materials used in the removal process;

4. Volumes of contaminated material requiring disposal because of removal of contaminated concrete and the resultant cost of transportation and disposal of the concrete and other waste materials generated during the removal process.

Based on these contamination levels and decontamination and removal techniques, tables of labor hours, waste volumes, number of waste shipments, and total cost entailed in achieving the alternative residual dose criteria are presented in Section 7, and Attachment C, of Appendix C.

5.2.2 Cost Methodology for Soil Removal and Disposal

Section 5 of Appendix C describes the reference facility soil contamination levels and depth profiles and is based on a review of information and engineering judgment regarding the level and location of contamination on site soil outside facility buildings. These contamination levels may vary for specific sites. The information available is limited; therefore, three sets of reference soil contamination levels have been developed for each of the reference facilities. For analysis purposes, only the high contamination level is used because this is considered sufficiently representative.

Sections 6.4 - 6.6 of Appendix C describes the soil decontamination and removal techniques that could be used to reduce radioactivity at the reference facilities and the extent of contamination removal by these techniques. This information is based on soil decontamination techniques effective in reducing contamination, namely soil excavation and disposal, and soil washing. For these soil contamination removal methods, the following information forms the cost basis:

1. The number of hours of direct staff labor necessary to remove contaminated soil and, based on the unit cost of labor for soil removal, the cost of direct staff labor;

2. Cost of overhead staff time during soil removal;

3. Cost of materials used in the removal process;

4. Volumes of contaminated soil requiring disposal and the resultant cost of transportation and disposal of the contaminated soil.

Based on these soil contamination depth profiles and the decontamination and removal techniques, Section 7 and Attachment C of Appendix C contain tables of the labor hours, waste volumes, number of waste shipments, and total cost needed to achieve the alternative residual dose criteria.

5.2.3 Survey Cost Methodology

Appendix D presents the cost of radiological surveys for alternative residual dose criteria for instruments and analytical methods routinely used in radiological surveys at nuclear facilities. Appendix D develops costs of radiological surveys for the reference facilities using the following information:

1. The survey methodology of NUREG/CR-1505, 1506, and 1507 (NRC 1995a-c) and of the draft survey manual prepared jointly by the NRC, the EPA, the Department of Energy (DOE), and the Department of Defense (DoD) entitled "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)" (MARS 1996). These documents are described in Appendix D. For each of the reference facilities, costs were determined for "affected" areas. Affected areas were larger than the areas actually decontaminated.

2. Instruments and analytical methods used in the performance of surveys are standard, commercially available equipment and techniques used in performing surveys.

3. Costs included labor to perform the survey, analytical costs, and overhead.

5.3 Results

Based on the discussion in Section 5.2 and Appendices C and D, estimates of costs are presented for illustration purposes for each reference facility in Tables 5.1 through 5.8. These results are presented separately for soils and structures to highlight different cost considerations that arise. Only a combined analysis for soil and structure was presented in the draft GEIS (although sufficient information was presented there for doing separate analysis). The results presented in Tables 5.1 - 5.8 illustrate the kinds of information presented in Appendix C. For structures, the analysis is for an industrial setting and illustrate costs resulting from a specific case of reducing the residual dose below 60 mrem/y. For soil, the analysis is for a residential setting for a diffusion profile (the same as the draft GEIS) for unwashed soil. All illustrations are for unrestricted use for high contamination levels. The costs are provided for each of the residual dose criteria being considered. For each reference facility, the tables show the costs as follows:

Column 1 - Residual dose rate criteria.

Column 2 - Costs for labor (both direct and indirect) and equipment and supplies necessary to remove contaminated soil and for packaging, transportation, and disposal of the resulting waste materials at a licensed disposal facility (soil contamination, Tables 5.1-5.4).

Column 2 - Costs for labor (both direct and indirect) and equipment and supplies necessary to remove contamination on the floors and walls of the facility and for packaging, transportation, and disposal of the resulting waste materials at a licensed disposal facility. (structure contamination, Tables 5.5-5.8).

Column 3 - Costs for labor (both direct and indirect) and equipment and supplies necessary to conduct the appropriate surveys in facility structures and on facility soils. As noted in Appendix D, this value includes the estimated cost of scoping, characterization, remediation, control, termination, and confirmation surveys.

Column 4 - The total costs associated with decommissioning the facility to the specified residual dose criteria.

Each of the tables has more than one set of costs to include the effect of different possible waste disposal costs.

As discussed in Chapter 3, other costs will be incurred as part of decommissioning, and many of them may be large, such as steam generator removal at a reactor. However, these costs are not included in the tables because they are not relevant to consideration of alternative dose criteria for lands and structures. These costs were discussed in NUREG-0586 (NRC 1988).

Considerations of incremental cost along with an analysis of incremental impact reduction realized (i.e., risk averted) in reaching alternative dose criteria are combined to determine the costs involved in achieving incremental reductions in risk and are presented in Chapter 6.

Results presented in Tables 5.1 through 5.8 are shown as calculated output and do not indicate precision to the number of significant figures shown. Values of "0" or "*" shown in the tables indicate no analysis was performed at that dose level, and information in the tables at those dose levels should be ignored.

5.4 Uncertainties in Assessing Generic Costs

There are several sources of uncertainty in evaluating the costs of alternative residual radioactivity criteria. Of particular concern are the difficulties in making a generic evaluation of reference contamination levels on and within concrete and other building material, including contamination levels in cracks in the concrete and contamination hot spots. Another uncertainty in this generic evaluation arises from assumptions about the areal extent and depth profile for soil contamination at reference facilities. In addition, there are issues involving the detection capability of radiological surveys at the lower residual dose criteria. These uncertainties are dealt with in the GEIS in the following manner:

1. Information about the level and location of contamination in concrete and other building material in nuclear facilities has been reviewed, and reference contamination levels are developed in the GEIS based on these data and on engineering judgment. These contamination levels may vary for specific sites. Reference contamination levels in concrete are based on an estimate of the range in which contamination is likely to occur in the buildings at the reference facilities. These levels are thought to provide a reasonable estimate of the likely range of impacts that may result from decontamination operations at such facilities.

2. Information on concrete and other building material decontamination methods (including high-pressure water jet) and removal processes (including scabbling) has been reviewed and that information has been used in the analysis of staff time necessary to remove contaminated concrete and soil removal.

3. Information about the level and location of contamination in soil in nuclear facilities has been reviewed, and reference contamination levels based on these data and on engineering judgment are developed in the GEIS. These contamination levels may vary for specific sites. The information available is limited; therefore, three sets of reference soil contamination levels have been developed for each of the reference facilities. The analysis evaluated these contamination levels, referred to as "high," "medium," and "low" soil contamination, to bound the problem and to provide an estimate of the range of costs that may result from differing soil contamination levels. The results presented in Section 5 use the "high" soil contamination case of Appendix C, which is considered sufficiently representative, along with the survey cost results of Appendix D, to estimate total costs. For the "high" soil contamination case (see Appendix C), the results of the analysis indicate that some onsite soil must be removed to achieve all of the alternative residual radioactive dose levels being considered.

4. In determining the costs and practicality of termination surveys at the low levels of contamination contemplated in this rulemaking, the GEIS used the survey methodology described in Appendix D. This is considered a reasonable estimate of the range of costs for the surveys necessary to verify compliance with the residual dose criteria.

Based on the above, Tables 5.1 through 5.8 provide illustrations which parallel those presented in Chapter 4 (Tables 4.1 to 4.8) and present estimates of costs for the reference facilities that are analyzed separately for soil and structures.

Table 5.1

Summary Costs for Power Reactor
Case 2
Disposal Cost - $50/ft3

Residual Dose Limit (mrem/y)	Soil Removal	Survey	TOTAL
100	$57,908	$106,000	$163,908
60	$81,360	$106,000	$187,360
25	$109,564	$106,000	$215,564
15	$122,700	$147,000	$269,700
3	$201,022	$961,000	$1,162,022

Table 5.2

Summary Costs for Uranium Fuel Fabrication Facility Case 2 & 2A
Disposal Cost - $50/ft3

Residual Dose Limit (mrem/y)	Soil Removal	Survey	TOTAL
100	$4,191,303	$184,000	$4,375,303
60	$4,501,813	$238,000	$4,739,813
25	$4,956,224	$248,000	$5,204,224
15	$5,189,533	$445,000	$5,634,533
3	$5,838,617	$1,599,000	$7,437,617

Table 5.3			
Summary Costs for Sealed Source Case 2 Disposal Cost - $50/ft3			
Residual Dose Limit (mrem/y)	Soil Removal	Survey	TOTAL
100	$37,167	$32,000	$69,167
60	$52,653	$32,000	$84,653
25	$69,856	$32,000	$101,856
15	$79,588	$35,000	$114,588
3	$129,820	$43,000	$172,820

Table 5.4			
Summary Costs for Rare Metal Extraction Facility Case 1 & 1A Disposal Cost - $50/ft3			
Residual Dose Limit (mrem/y)	Soil Removal	Survey	TOTAL
100	$35,627	$71,000	$106,627
60	$117,502	$73,000	$190,502
25	$189,639	$272,000	$461,639
15	$210,439	$1,130,000	$1,340,439
3	$367,995	$6,844,000	$7,211,995

Table 5.5

Summary Costs for Power Reactor ($M)
Structures Case 3
Disposal Cost - $50/ft3

Residual Dose Limit (mrem/y)	Facility Decon	Survey	TOTAL
100	$1.324	$0.315	$1.639
60	$1.324	$0.315	$1.639
30	$1.690	$0.315	$2.005
25	$1.690	$0.315	$2.005
15	$1.690	$0.315	$2.005
10	$1.690	$0.315	$2.005
3	$2.057	$0.315	$2.372
1	$2.027	$0.403	$2.430

Table 5.6

Summary Costs for Uranium Fuel Fabrication Facility ($M)
Structures Case 2
Disposal Cost - $50/ft3

Residual Dose Limit (mrem/y)	Facility Decon	Survey	TOTAL
100	$0.000	$0.129	$0.129
60	$0.000	$0.152	$0.152
30	$0.000	$0.154	$0.154
25	$1.013	$0.154	$1.167
15	$1.013	$0.163	$1.176
10	$1.013	$0.163	$1.176
3	$1.013	$0.198	$1.211
1	$1.013	$0.198	$1.211

Table 5.7			
Summary Costs for SS Manuf ($M) **Structures Case 3** **Disposal Cost - $50/ft3**			
Residual Dose Limit (mrem/y)	Facility Decon	Survey	TOTAL
100	$0.029	$0.027	$0.056
60	$0.029	$0.027	$0.056
30	$0.040	$0.027	$0.067
25	$0.040	$0.027	$0.067
15	$0.040	$0.027	$0.067
10	$0.040	$0.027	$0.067
3	$0.040	$0.027	$0.067
1	$0.040	$0.027	$0.067

Table 5.8

Summary Costs for Rare Metal Extraction Facility ($M)
Structures Case 2
Disposal Cost - $50/ft3

Residual Dose Limit (mrem/y)	Facility Decon	Survey	TOTAL
100	$1.281	$0.096	$1.377
60	$1.281	$0.096	$1.377
30	$1.281	$0.096	$1.377
25	$2.277	$0.119	$2.396
15	$2.277	$0.123	$2.400
10	$2.277	$0.123	$2.400
3	$2.277	$0.197	$2.474
1	$2.277	$0.197	$2.474

6. Comparison of Impacts and Costs

This Chapter summarizes the impacts and costs associated with obtaining various dose levels for release considerations for the reference facilities considered. The impacts and costs presented here use the impacts and costs tables illustrated in Chapters 4 and 5 (and presented in more detail in Appendices B, C, and D). Appendix H discusses the resolution of comments on the draft GEIS concerning the parameters modeled and any changes that have been made in the draft GEIS considerations. The impacts and costs associated with achieving various dose levels have been treated separately for structures and soils. The draft GEIS combined the analysis of structures and soils and was not sufficiently sensitive to the significant differences that can occur in cost-benefit considerations. Modeling considerations for structures have been left essentially unchanged from those considered in the draft GEIS. However, modeling considerations for soil have been broadened to include both those already considered in the draft GEIS, which afford one measure of actual situations, and also more extreme (but possible) situations which represent more bounding forms of actual situations. For reference purposes, the modeling considerations for soil and structures presented in detail in the draft GEIS Appendix C are included in this final GEIS as Attachment D to Appendix C. The cost-benefit analysis performed in Appendix B uses the high soil contamination case of Appendix C, a subset of the contaminant scenarios presented in Appendix C, and is considered to be sufficiently representative for performing a reasonably bounding analysis for generic cost-impact considerations.

Summaries of these cost-benefit results for the reference facility types considered are presented separately for soil and structures in Sections 6.2 and 6.3 for both unrestricted and restricted use situations for a variety of situations considered. The situations considered are described in Section 6.1 and presented in greater detail in Appendices B and C.

Section 6.4 is a summary of the impacts and costs associated with groundwater remediation for the alternative dose criteria being considered. When NRC's proposed rule was issued, it included a requirement that, in addition to the all-pathways dose criterion, licensees also had to demonstrate that radioactivity levels in groundwater, that was a potential source of drinking water, did not exceed the limits of EPA's 40 CFR 141. This proposed requirement was added at the request of EPA and specific comments were requested as to its appropriateness; no specific analysis of the environmental impacts and cost-benefit of this requirement was done in the draft GEIS (NRC 1994a). Section 6.4 of this Chapter provides a summary of an analysis of the impacts and costs associated with alternative doses from the groundwater pathway. The analysis is presented in detail in Section 8 of Appendix C.

6.1 Overall Cost-Benefit Analysis of Dose Criterion for Unrestricted Use

Tables 6.1 to 6.8 show the summarized results of the analyses of impacts and costs for soil and concrete removal. The results are indicated in terms of millions of dollars per estimated cancer mortality averted. In considering these results, the NRC uses the decisionmaking guidance of NUREG/BR-0058 (NRC 1995d) and NUREG-1530 (NRC 1995e). NUREG-1530 recommends that $2000 per person-rem be the value used by NRC in making decisions between regulatory alternatives. The $2000 per person-rem value is derived from studies reviewed by NUREG-1530 which arrive at $3 million per estimated mortality as representative of the studies reviewed. Tables 6.1 - 6.8 provide an indication of the range of results for different assumptions used in the analyses.

6.1.1 Summary of Assumption Used in the Analysis

1. Variation in contamination depth profiles This analysis was performed in response to public comments indicating that data and experience from additional actual facilities should be used in estimating the extent of contamination. Thus the soil contamination analysis contains both the profiles from the draft GEIS, which are used to provide an indication of the results for fairly simple types of contamination, and also more complex and deeper profiles added as a result of review of the public comments and of data from actual decommissionings. The effect of this variation is to provide a range in the volumes of soil requiring remediation. These two profile types are generally indicated in the tables as "diffusion," and "mixing/landfill," or "real world" respectively.

2. Alternative unrestricted land uses Because a variety of possible land uses could occur after the facilities are released for unrestricted use, the tables show results for a set of alternative public uses of the site. The effect of this variation is the possible range of collective exposures which can occur and the resultant variation in net health impacts that can occur. The alternative unrestricted land uses included in the tables are residential farming, industrial use, and dense residential use. The alternative unrestricted building uses included in the tables are office use, industrial use, and residential use.

3. Burial charges A set of different burial charges for different possible situations and materials are included in the tables.

4. Remediation Methods Alternative soil remediation methods are indicated in the tables for either soil washing followed by transport or soil transport without washing. The impact of these alternative remediation methods is a range in the volumes of soil requiring transport which affects both costs and the impacts associated with cleanup.

A description of the analytical methods, assumptions, and parameters is presented in Sections B.2 - B.3 of Appendix B and in Attachment A to Appendix B.

6.2 Results of Analysis for Unrestricted Use

The results of the analyses discussed above are presented in Tables 6.1 - 6.8 for the reference cases. These tables summarize the significant results presented in Attachment B of Appendix B. Results for unrestricted use of soil at the reference facilities are in Tables 6.1 - 6.4 and include analyses of several alternative cases, including type of soil profile, method of soil disposal, and type of post-license termination site use (e.g., residential farming, industrial use, high density dwelling use). Results for unrestricted use of structures at the reference facilities are in Tables 6.5 - 6.8 and include analyses of several alternative cases, including building location and type of post-license termination use (e.g., office use, industrial use, residential use).

The results presented in Tables 6.1 - 6.8 show a wide range of cost-benefit ratios among facility types as well as within facility type and are sensitive to the assumptions and parameters used in the analyses. Such results do not provide a quantitative basis for optimizing the selection of a cost-benefit ratio that can be implemented on a generic basis. Nevertheless, the following trends can be seen that provide guidance for overall cost-benefit considerations.

(a) For unrestricted use, based on consideration of a range of potential site-specific situations, modeling uncertainties, and a range of justifiable cost-benefit ratios, no definitive conclusion can be made on a generic basis which would distinguish between acceptable alternative residual radioactivity levels in the 15-25 mrem/y range.

(b) For soils, levels less than 25 mrem/y generally result in a cost-benefit ratio not considered reasonably justifiable under NRC's regulatory framework as described in NUREG/BR-0058.

(c) For structures, levels less than 25 mrem/y show more tendency to be reasonably justifiable under NRC's regulatory framework as described in NUREG/BR-0058.

6.3 Results of Analysis for Restricted Use

Tables 6.1 - 6.8 indicate that incremental costs to achieve unrestricted use can be quite high. Appendices B and C indicate that by restricting site use (and therefore eliminating certain exposure pathways), the quantity of material which must be removed and disposed of can be reduced and therefore the costs can also be reduced while reducing exposures through elimination of pathways.

6.3.1 Cost Estimating Bases For Access Restrictions

Licensees may choose to 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, or where it can cause net public or environmental harm, or where it is unfeasible with existing technology. Deed restrictions which contain limitations on public use of sites can be the means for restricting use of a site and eliminating exposure pathways. However, aside from deed restrictions, in order to show that such a site has been remediated to levels that are ALARA, installing inexpensive but effective technologies to prevent inadvertent access to the contaminated soil areas on the site can also be a method for reducing dose to individuals on the site. This section provides cost estimates for representative low-cost technologies that may accomplish this. The technologies evaluated in the section include installing a perimeter fence around the contaminated area, paving the contaminated area, and landscaping the area in a way to discourage access.

6.3.1.1 Perimeter Fence.

One low cost but effective technology for restricting access to a contaminated site area is a perimeter fence. For the purposes of this analysis, a cost estimate is developed for both a residential and a low-security industrial fence that are intended to only prevent unintentional access to the area. 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, 2" 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).

6.3.1.2 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 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.

6.3.1.3 Landscaping.

An additional low cost technology for preventing unintentional access to a site area is to landscape the area with plants that discourage access. For this analysis, it is assumed that a barberry shrub is planted around the perimeter of the area. 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 per linear foot, or $12.90 per linear meter, and includes purchase and planting of the shrub and preparation of the bedding area with peat moss.

6.3.2 Access Restriction Costs for Reference Facilities

Table 6.9 provides estimates for the costs to implement contaminated site area access restrictions for each of the reference facilities described in Chapter 3. 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 6.9 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 6.9, and the lifetime of the surface would be expected to be considerably less than 30 years. Using one of these low cost technologies may further reduce the restricted site dose from soil from 25 mrem/y to essentially zero and illustrates that such ALARA considerations should be included as part of site specific overall ALARA considerations.

Overall, based on the discussion in Section 6.3.1, on costs of soil removal in Appendix C, and on the impacts presented in Appendix B, the incremental cost-benefit ratio associated with reducing doses to less than 25 mrem/y by restricting site use is estimated to have a wide range depending on the site specific approach to restricted use, but can range from values less than $3 million per estimated mortality averted to values in excess of $50 million per estimated mortality averted for the reference facilities studied. The larger values would generally occur if it were necessary to remove, transport, and dispose of soil to reach lower dose levels while smaller values would result if measures such as those described above and deed restrictions were used. The wide range illustrates the need for site specific ALARA analyses for sites considering restricted use.

6.4 Analysis of Groundwater Remediation

In Section 6.2 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). 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). 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 illustrate potential ALARA considerations at levels below 25 mrem/y.

6.4.1. 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.

6.4.1.1 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.

6.4.1.2 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 make 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 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 (see Appendix C). 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 in NUREG/CR-5512 (NRC 1992c), 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 6.10 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 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 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 6.11 and 6.12 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 6.11 and 6.12, 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 6.13, Column 2, and the cost benefit analysis is shown in Column 4.

Table 6.1
Cost-Benefit for Soil Cleanup at Reference Power Reactor
(in incremental $M/estimated mortality averted)[1]

Unrestricted Use

Case 1 - Diffusion into the soil; $50/ft3 burial cost for soil; soil removal after soil washing; unrestricted use with resident farmer use of the site
Case 1A- Same as Case 1, but with industrial use of the site
Case 1B- Same as Case 1, but with residential high density dwelling use of the site

Case 2 - Diffusion into the soil, $50/ft3 burial cost for soil; no soil washing; unrestricted use with resident farmer use of the site
Case 2A- Same as Case 2, but with industrial use of the site
Case 2B- Same as Case 2, but with residential high density dwelling use of the site

Case 3 - Real world soil profile data; $50/ft3 burial cost for soil; soil removal after soil washing; unrestricted use with resident farmer use of the site
Case 3A- Same as Case 3, but with industrial use of the site
Case 3B- Same as Case 3, but with residential high density dwelling use of the site

Case 4 - Real world soil profile data; $50/ft3 burial cost for soil; no soil washing; unrestricted use with resident farmer use of the site
Case 4A- Same as Case 4, but with industrial use of the site
Case 4B- Same as Case 4, but with residential high density dwelling use of the site

Dose Reduction (mrem/y)	Cases 1, 2, 3, 4	Cases 1A, 2A, 3A, 4A	Cases 1B, 2B, 3B, 4B
100-60	800 - neg[2]	210 - neg	42 - 170
60 -25	800 - neg	220 - neg	43 - 2000
25 - 15	10000 - neg	2600 - neg	510 - neg
15 - 3	neg	neg	4000 - neg

Notes:
1) A number of cases were evaluated in Appendix C. This summary table includes those cases considered most representative for decision-making regarding unrestricted site use. A complete listing of cases can be found in Attachment A to Appendix B

2) neg = there is a net negative health effect

Table 6.2
Cost-Benefit for Soil Cleanup at Reference Uranium Fuel Fabrication Facility
(in incremental $M/estimated mortality averted)[1]

Unrestricted Use

Case 1 - Diffusion into the soil; $50/ft3 burial cost for soil; soil removal after soil washing; unrestricted use with resident farmer use or industrial use of the site

Case 2 - Diffusion into the soil; $50/ft3 burial cost for soil; no soil washing; unrestricted use with resident farmer or industrial use of the site
Case 2A- Same as Case 2, but with $10/ft3 burial cost for soil
Case 2B- Same as Case 2, but with residential high density dwelling use of the site

Case 5 - Real world soil profile data; $50/ft3 burial cost for soil; soil removal after soil washing; unrestricted use with resident farmer or industrial use of the site

Case 6 - Real world soil profile data; $50/ft3 burial cost; no soil washing; resident farmer or industrial use of the site
Case 6A- Same as Case 6, but with $10/ft3 burial cost for soil
Case 6B - Same as Case 6, but with residential high density dwelling use of the site

Dose Reduction (mrem/y)	Case 6	Cases 6A, 5, 6B	Case 2	Cases 1, 2A, 2B
100 - 60	34	7 - 20	5	1 - 3
60 - 25	250	36 - 94	7	2 - 4
25 - 15	670	64 - 210	24	5 - 18
15 - 3	neg[2]	280 - neg	87	17 - 71

Notes:

1) A number of cases were evaluated in Appendix C. This summary table includes those cases considered most representative for decision-making regarding unrestricted site use. A complete listing of cases evaluated can be found in Attachment A to Appendix B.

2) neg = there is a net negative health effect

Table 6.3
Cost-Benefit for Soil Cleanup at Referenced Sealed Source Manufacturer/Broad R&D Facility
(in incremental $M/estimated mortality averted)[1]

Unrestricted Use

Case 1 - Diffusion into the soil; $50/ft3 burial cost for soil; soil removal after soil washing; unrestricted use with resident farmer use of the site
Case 1A- Same as Case 1, but with industrial use of the site
Case 1B- Same as Case 1, but with residential high density dwelling use of the site

Case 2 - Diffusion into the soil; $50/ft3 burial cost for soil; no soil washing; unrestricted use with resident farmer use of the site
Case 2A- Same as Case 1, but with industrial use of the site
Case 2B- Same as Case 1, but with residential high density dwelling use of the site

Case 3 - Real world soil profile data; $50/ft3 burial cost; soil removal after soil washing; unrestricted use with resident farmer use of the site
Case 3A- Same as Case 3, but with industrial use of the site
Case 3B- Same as Case 3, but with residential high density dwelling use of the site

Case 4 - Real world soil profile data; $50/ft3 burial cost; no soil washing; unrestricted use with resident farmer use of the site
Case 4A- Same as Case 4, but with industrial use of the site
Case 4B- Same as Case 4, but with residential high density dwelling use of the site

Dose Reduction (mrem/y)	Cases 1, 2, 3, 4	Cases 1A, 2A, 3A, 4A	Cases 1B, 2B, 3B, 4B
100 - 60	380 - neg[2]	100 - neg	21 - 63
60 - 25	500 - neg	140 - neg	23 - 1900
25 - 15	940 - neg	250 - neg	50 - neg
15 - 3	neg	neg	440 - neg

Notes:

1) A number of cases were evaluated in Appendix C. This summary table includes those cases considered most representative for decision-making regarding unrestricted site use. A complete listing of cases can be found in Attachment A to Appendix B
2) neg = there is a net negative health effect

Table 6.4
Cost-Benefit for Soil Cleanup at Reference Rare Metal Extraction Facility
(in incremental $M/estimated mortality averted)[1]

Unrestricted Use

Case 1 - Diffusion into the soil; $50/ft3 burial cost for soil; no soil washing; unrestricted use with resident farmer use of the site
Case 1A- Same as Case 1, but with $10/ft3 burial cost for soil
Case 1B1- Same as Case 1, but with industrial use of the site
Case 1B2- Same as Case 1, but with high density dwelling use of the site
Case 1C - Same as Case 1, but with use of in-situ surveys

Case 2 - Real world profile data; $50/ft3 burial cost; no soil washing; resident farmer use of the site
Case 2A- Same as Case 2, but with $10/ft3 burial cost
Case 2B1- Same as Case 2, but with industrial use of the site
Case 2B2- Same as Case 2, but with high density dwelling use of the site
Case 2C - Same as Case 2, but with use of in-situ surveys

Dose Reduction (mrem/y)	Case 2	Cases 2A, 2B1, 2C	Cases 1, 1A, 1B1	Cases 1B2, 1C, 2B2
100 - 60	13	4 - 13	1	1 - 2
60 - 25	30	11 - 27	3 - 4	1 - 3
25 - 15	110	58 - 69	29 - 48	1 - 11
15 - 3	580	210 - 440	160 - 270	16 - 49

Notes:

1) A number of cases were evaluated in Appendix C. This summary table includes those cases considered most representative for decision-making regarding unrestricted site use. A complete listing of cases can be found in Attachment A to Appendix B

Table 6.5
Cost-Benefit for Structures Cleanup at Reference Power Reactor
(in incremental $M/estimated mortality averted)

Unrestricted Use

Case 1 - Bioshield contamination; $350/ft3 burial cost for concrete; 50 persons working in bioshield area after decommissioning and license termination

Case 1A- Same as Case 1, but with 20 persons working in bioshield area after decommissioning and license termination

Case 2 - Floor and wall contamination; $350/ft3 burial cost for concrete; office use of the facility (210 persons using contaminated areas of facility[(1)])

Case 3 - Floor and wall contamination; $350/ft3 burial cost for concrete; industrial use of facility (22 persons using contaminated areas of facility[(1)])

Case 4 - Floor and wall contamination; $350/ft3 burial cost of concrete; residential use of the facility (25 persons using contaminated areas of facility[(1)])

Dose Reduction (mrem/y)	Cases 1,1A	Case 2[2]	Cases 3,4[2]
100-60	8 - 16	<2	<10
60-25	12 - 24	2	10
25-15	14 - 28	5	30
15-3	74 - 160	9	50

Notes:

1) See Table A.1 of Attachment A of Appendix B.

2) See Section B.3.1.2 of Appendix B for bases of analyses. Impacts and costs are developed for scabbling individual concrete layers but do not include costs and impacts of removal of contamination in wet spots and cracks because they are highly site specific and thus do not lend themselves to generic analyses. Such impacts and costs could be taken into account in a site specific analysis

Table 6.6

Cost-Benefit for Structures Cleanup at Reference Uranium Fuel Fabrication Facility
(in incremental $M/estimated mortality averted)

Unrestricted Use

Case 1 - Floor and wall contamination; $350/ft3 burial cost for concrete, office use of the facility (1000 persons using contaminated areas of facility[1])

Case 2 - Floor and wall contamination; $350/ft3 burial cost for concrete; industrial use of facility (80 persons using contaminated areas of facility[1])

Case 3 - Floor and wall contamination; $350/ft3 burial cost for concrete; residential use of facility (120 persons using contaminated areas of facility[1])

Dose Reduction (mrem/y)	Case 1[2]	Cases 2,3[2]
100-60	<1	<10
60-25	1	10
25-15	2	20
15-3	3	30

Notes:

1) See Table A.1 of Attachment A of Appendix B.

2) See Section B.3.1.2 of Appendix B for bases of analyses. Impacts and costs are developed for scabbling individual concrete layers but do not include costs and impacts of removal of contamination in wet spots and cracks because they are highly site specific and thus do not lend themselves to generic analyses. Such impacts and costs could be taken into account in a site specific analysis

Table 6.7

Cost-Benefit for Structures Cleanup at Reference Sealed Source Manufacture/Broad R&D Facility
(in incremental $M/estimated mortality averted)

Unrestricted Use

Case 1 - Floor and wall contamination; $350/ft3 burial cost for concrete; office use of the facility (5 persons using contaminated areas of facility[(1)])

Case 2 - Floor and wall contamination; $350/ft3 burial cost for concrete; industrial use of facility (<1 person using contaminated areas of facility[(1)])

Case 3 - Floor and wall contamination; $350/ft3 burial cost for concrete; residential use of the facility (<1 person using contaminated areas of facility[(1)])

Dose Reduction (mrem/y)	Case 1[2]	Cases 2,3[2]
100-60	<2	<5
60-25	2	5
25-15	5	12
15-3	9	20

Notes:

1) See Table A.1 of Attachment A to Appendix B.

2) See Section B.3.1.2 of Appendix B for bases of analyses. Impacts and costs are developed for scabbling individual concrete layers but do not include costs and impacts of removal of contamination in wet spots and cracks because they are highly site specific and thus do not lend themselves to generic analyses. Such impacts and costs could be taken into account in a site specific analysis

Table 6.8

Cost-Benefit for Structures Cleanup at Reference Rare Metal Extraction Facility
(in incremental $M/estimated mortality averted)

Unrestricted Use

Case 1 - Floor and wall contamination; $350/ft3 burial cost for concrete; office use of the facility (500 persons using contaminated area of facility[1])

Case 2 - Floor and wall contamination; $350/ft3 burial cost for concrete; industrial use of facility (40 persons using contaminated areas of facility[1])

Case 3 - Floor and wall contamination; $350/ft3 burial cost for concrete; residential use of facility (60 persons using contaminated areas of facility[1])

Dose Reduction (mrem/y)	Case 1[2]	Cases 2,3[2]
100-60	<1	<10
60-25	1	10
25-15	3	30
15-3	5	60

Notes:
1) See Table A.1 of Attachment A to Appendix B.

2) See Section B.3.1.2 of Appendix B for bases of analyses. Impacts and costs are developed for scabbling individual concrete layers but do not include costs and impacts of removal of contamination in wet spots and cracks because they are highly site specific and thus do not lend themselves to generic analyses. Such impacts and costs could be taken into account in a site specific analysis

Table 6.9

Calculated Costs for Site Access Restrictions

Reference Facility	Perimeter Fence ($000)		Paved Surface ($000)		Landscaping ($000)	
	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

Table 6.10

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 6.11

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 6.12

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 6.13

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

7. Conclusions

7.1 Introduction

As discussed in Section 1.4, this GEIS is being prepared to fulfill NRC's responsibilities under NEPA, and the draft and final GEIS have been developed in accordance with 10 CFR 51 which contains NRC's regulations implementing NEPA.

In accordance with 10 CFR Part 51, the NRC prepared and issued NUREG-1496, Volumes 1 and 2, "Draft Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for Decommissioning of NRC-Licensed Nuclear Facilities" (draft GEIS) (NRC 1994a) which contained analyses and presented conclusions and the preliminary recommendation regarding regulatory alternatives and the establishment of radiological criteria for decommissioning. The draft GEIS provided a basis for rulemaking in 10 CFR Part 20 of the NRC's regulations to provide specific radiological criteria for the decommissioning of soils and structures at sites under its jurisdiction.

The draft GEIS was issued with the NRC's proposed rulemaking on radiological criteria for decommissioning and comments were requested on both the proposed rule and on NUREG-1496 in the Federal Register notice issuing that rule (59 FR 43200, August 22, 1994). The public comment closed on January 22, 1995. Public comments received on the draft GEIS are summarized in NUREG/CR-6353 (NRC 1996).

In accordance with 10 CFR 51.90 and 10 CFR 51.91, this final GEIS includes the comments received on the draft GEIS and responses to those comments (see Appendix H), reconsiders the regulatory alternatives presented in the draft GEIS (Chapter 2), and includes a supplement to the analyses of the draft GEIS (Chapters 3 - 6, and Appendices B - G) based on the public comments received. The results of those activities are included in Chapters 1 - 6 and are summarized in Section 7.2 below. Based on the analyses in this final GEIS, appropriate regulatory alternatives have been analyzed in detail to the extent feasible in a generic analysis, and conclusions regarding the overall approach for license termination (see Section 7.2 below) have been made which will achieve the requirements of NEPA.

7.2 Conclusions

7.2.1 Discussion

Chapters 1 - 6 describe the supplementation and modification of the analyses of the draft GEIS based on the public comments received. As is discussed in those chapters, given the range of possible parameters, scenarios, and site specific situations, both the draft GEIS and the final GEIS find that there is a wide range of cost-benefit results among the different facilities and within facility types and that there is no unique algorithm which decisively is the most beneficial result for all facilities. Nevertheless, the following section summarizes the results of this final GEIS.

7.2.2 Summary of Results

Despite the difficulties noted in Section 7.2.1, the following summarizes Chapters 1 - 6 and how the results of these chapters can be helpful for insight in making decisions regarding dose criteria, ALARA, objectives of decommissioning, restricted use and potential exemptions, groundwater cleanup, citizen participation, minimization of contamination, and relationship between the GEIS and site-specific decommissioning actions:

1) Achieving, as an objective of decommissioning ALARA, Reduction to Pre-Existing Background). The objective of returning a site to preexisting background conditions is consistent with the concept of returning a site to the radiological condition that existed before its use. However, the question of whether this objective as a goal of decommissioning ALARA should be codified by rule depends on a variety of factors, including cost, practicality (e.g., measurability) of achieving the objective, and the type of facility involved.

As noted in Section 7.3.1, decommissioning is expected to be relatively easy for a certain class of nonfuel-cycle nuclear facilities (i.e., those that use either sealed radioactive sources or small amounts of short-lived nuclides), because there is usually no residual radioactive contamination to be cleaned up and disposed of, or if there is any, it should be localized or it can be quickly reduced to low levels by radioactive decay. Decommissioning operations will generally consist of disposing of a sealed source or allowing licensed short-lived nuclides to decay in storage, submitting form NRC-314, and demonstrating (either through radiation survey or other means such as calculation of reduction of the contamination level by radioactive decay) compliance with the requirements for license termination. Because contamination at these facilities is expected to be negligible or to decay to negligible levels in a short time, achieving an objective of returning these facilities to background would not appear to be an unreasonable objective of ALARA.

However, in general, for those nuclear facilities where contamination exists in soils and/or structures, the analyses in Chapters 1 - 6 of this final GEIS shows, in a manner similar to the draft GEIS, that achieving an ALARA decommissioning objective of "return to a pre-existing background" is not reasonable as it may result in net detriment or because cost cannot be justified because detriments and costs associated with remediation and surveys tend to increase significantly at low levels, while risk reduction from radiation exposure from criteria near background is marginal.

2) Establishment of Dose Criterion. As noted in Section 7.2.1, given the range of possible parameters, scenarios, and site specific situations, both the draft GEIS and the final GEIS find that there is a wide range of cost-benefit results among the different facilities and within facility types and that there is no unique algorithm which decisively is the most beneficial result for all facilities which could be set as a residual dose criterion.

In consideration of such a constraint, national and international radiation standards setting bodies, including ICRP and NCRP note in their most recent documents (ICRP 60 and NCRP

No. 116) that, although the limit for the public dose should be 100 mrem/y from all man-made sources combined, it would seem appropriate that the amount that a person would receive from a single source, should be further reduced to be a fraction of the limit to account for the potential that an individual may be exposed to more than one source of man-made radioactivity, thus limiting the potential that an individual would receive a dose at the public dose limit. NCRP No. 116, Chapter 15, notes that no single source or set of sources under one's control should result in an individual being exposed to more than 25 mrem/y. This fraction was presented as a simple alternative to having a site operator (where a site could expose individuals to levels greater than 25 mrem/y) investigate all man-made exposures that an individual at the site would be exposed to so as to demonstrate that the total dose does not exceed 100 mrem/y. The clear implication in this simple alternative is that if individual sources are constrained to 25 mrem/y that NCRP believes it likely, given the potential for multiple exposures, that the public dose limits will be met. Further reductions considering ALARA would be still be considered by NCRP No. 116.

ICRP 60, Section 5.5.1, in discussing the principles of constraints and limits, notes that it is appropriate to select dose constraints applied to each source to allow for contributions from other sources so as maintain doses below the 100 mrem/y limit. ICRP 60 does not contain numerical guidance on dose constraints for particular practices, but notes that cumulative exposures to individuals from existing sources near 100 mrem/y are rarely a problem primarily because of the widespread use of source-related dose constraints. Further explanation of the fundamental concepts of ICRP 60 are contained in the paper "The ICRP Principles of Radiological Protection and Their Application to Setting Limits and Constraints for the Public from Radiation Sources," by Professor Roger Clarke, Chairman of the ICRP. The paper notes that the constraint approach derives from the optimization principle of radiation protection in which, for any source, individual doses should be ALARA and also be constrained by restrictions on doses to individuals (i.e., dose constraints). The paper further notes that a constraint is an individual related criterion applied to a single source in order to ensure that the overall dose limits are not exceeded, and that a dose constraint would therefore be set at a fraction of the dose limit as a boundary on the optimization of that source. Based on the principles presented in the paper, the constraint recommended in the paper for a decommissioned site is 30 mrem/y and that further optimization through the ALARA principle is appropriate. As is the case for NCRP No. 116, the implication of the paper and ICRP 60 is that the constraint level is a boundary on the dose from this source and is sufficient to assure that members of the public are not exposed to levels in excess of the public dose limit. The rationale for this is expressed in Section 5.5.1 of ICRP 60 where it is noted that the critical exposed group is not normally exposed to the constraint level from more than one source although they may be exposed to some dose level less than the constraint level from more than one source.

In its review of how the principles and recommendations of the ICRP, NCRP, and Federal Radiation Protection Guidance (FRG) are relevant to the proposed NRC rule, NRC's Advisory Committee on Nuclear Waste noted that 15 mrem/y represented an unnecessarily conservative fraction of the 100 mrem/y annual limit. Although it agreed that the need to partition the annual recommended dose limit among several sources from which a person is likely to be exposed appears justifiable, and noted that no explicit guidance from the various national and international bodies on this subject exists, ACNW stated that a value of 25 percent or 30 percent of the 100 mrem/y limit appears more justified and appropriate based on the likelihood that no more than 3 or 4 separate regulated sources will affect the critical group at any instance. ACNW further noted that the selection of 15 mrem/y that represents about 1/7 of the annual limit assumes that a person will encounter a simultaneous dose from seven different regulated sources and that this appears to be unjustified, particularly because the ALARA principle accompanies all such NRC regulatory actions.

The recommendations of the above organizations can be summarized as suggesting that a constraint value be set as part of the process of optimizing the dose from a particular source and that this constraint value should be set as a boundary value below which further optimization or ALARA principles should be employed. The recommendations also appear to suggest that setting a source constraint of 25 - 33 percent of the annual dose limit of 100 mrem/y is appropriate and adequate to ensure that the dose limit is met, and do not tend to lend support to 15 mrem/y as a means of expressing the appropriate fraction to constrain the dose from an individual source because it is not likely that a critical group will be exposed to as many as seven sources. Consequently, the constraint value should be set using a more reasonable approach.

NUREG/CR-5512 provides an analysis of exposure pathways for critical groups at decommissioned facilities. The principle limiting scenarios include: (a) full time residence and farming at a decommissioned site, (b) exposure while working in a decommissioned building, and (c) renovation of a newly decommissioned building. These principle limiting exposure scenarios tend to be conservative in their estimate of doses and also tend to be somewhat mutually exclusive; i.e., a person living near a decommissioned nuclear facility would only receive a dose near the constraint level if living patterns assumed full-time residency and farming at the site. These living patterns would make it difficult for the member of this critical group to also be a member of the critical group from other licensed or decommissioned sources. Conversely, a person having less residency than a full time farmer (e.g., apartment dweller, homeowner who works away from the site) might receive doses from other sources but would receive less than the constraint value from the decommissioned site because the exposure time and the number of pathways would be reduced. Thus, given the assumptions regarding living patterns made in evaluating compliance with the constraint level, it is difficult to envision an individual receiving levels approaching constraint levels for more than one licensed or decommissioned source. It is also likely that individuals at a decommissioned site will actually be exposed to doses substantially below the constraint level because cleanup is a coarse removal process. For example, the Appendix C indicates that, for the reference cases analyzed, removal of a layer of concrete by scabbling will result in doses at levels from 2 to more than 10 times lower than a constraint value. In addition to consideration of decommissioned sources, it is also difficult to envision that an individual would come in contact with more than a relatively minimal number of other sources as part of normal living patterns. For example, the NCRP in NCRP No. 93, "Ionizing Radiation Exposure of the Population of the United States," September 1987, reviewed likely radiation exposures to the public from consumer products, air emissions, and fuel cycle facilities (including nuclear power plants) and found that, in general, exposure to the public is in the few mrem/y range. Recent experience on nuclear power plant emissions and dose commitments (NUREG/CR-2850) tends to support the conclusions of NCRP No. 93 on power plant exposures.

This generic evaluation of various sources, including decommissioned sources, supplemented by the recommendations of the standards setting bodies and advisory committee noted above, suggests that the 15 mrem/y value may be too restrictive for its intended purpose of constraining doses from this category of sources in establishing an appropriate boundary constraint, and rather leads to a conclusion that 25 percent of the public dose limit is a sufficient and ample fraction to use as a limitation or constraint for decommissioned sources in that it provides a sufficient and ample margin of safety for protection of public health and safety. It is recognized that this conclusion reflects a judgment regarding the likelihood of individuals being exposed to multiple sources with cumulative doses approaching 100 mrem/y rather than an analysis based on probability distributions for such exposures. Thus, a dose criterion of 25 mrem/y, distinguishable from background, should be established.

To provide some perspective on the conservatism of a 25 mrem/y dose criterion, it should be noted that, as described in Appendix A, this dose level is small when compared to the average level of natural background radiation in the United States (about 300 mrem/y) and the variation of this natural background across the United States. In addition, there is uncertainty associated with estimating risks at such dose levels. This uncertainty occurs because evidence of radiation dose health effects has only been observed at high dose levels (20,000 mrem and above) and significant uncertainty in risk estimation is introduced when extrapolating to the very low dose levels being considered in this rulemaking. The health effects resulting from even a dose of 100 mrem are uncertain. The BEIR Committee stated in its 1990 report (BEIR 1990) that "Studies of populations chronically exposed to low-level radiation, such as those residing in regions of elevated natural background radiation, have not shown consistent or conclusive evidence of an associated increase in the risk of cancer."

With regard to radon, variations in radon levels, described in Section 4.2.2, make it very difficult to distinguish between naturally occurring radon and radon resulting from licensed material. In addition, it is impractical to predict prospective doses from exposure to indoor radon due to problems in predicting the design features of future building construction. Because of these variations and the limitation of measurement techniques, it is not practical to distinguish between radon from licensed activities at a dose comparable to the 25 mrem/y dose criterion discussed above and radon which occurs naturally. Therefore implementation of a 25 mrem/yr dose criterion should not be expected to demonstrate that radon from licensed activities is indistinguishable from background on a site-specific basis. Instead, this may be considered to have been demonstrated on a generic basis when radium, the principal precursor to radon, meets the requirements for unrestricted release, without including doses from the radon pathway.

In some instances it may not be reasonable to achieve levels of residual concentrations of radon precursors within the dose criterion for unrestricted use. As discussed in Item #5 below, for cases such as these, restricting site use through institutional controls could be considered as a means to limit the doses from precursors by limiting access to the site. Under such restricted use provisions, these doses should be further reduced based on ALARA principles which should consider the practicality of including as part of controls the use of radon mitigation techniques in existing or future structures.

3) Decommissioning ALARA analysis for soil contamination. Soil contamination can exist onsite at nuclear facilities because of a variety of reasons including small spills or leaks, deposition from airborne effluents, burial or placement in the ground onsite of system byproducts or other waste materials, or large leaks. The level of soil contamination for the large majority of NRC-licensed facilities (>6000) is either zero or is minimal. Certain facilities (e.g., power reactors, fuel facilities, industrial facilities) may have greater soil contamination, and certain of these facilities have been identified as having extensive soil contamination (albeit generally at relatively low levels) and have been placed in the Site Decommissioning Management Plan (SDMP) (see NUREG-1444). These sites warrant specific NRC attention regarding their decommissioning.

As indicated above, for the generic scenarios considered, the results of Chapters 1 - 6 in this final GEIS evaluation indicate that there is a wide range of possible cost-benefit ratios. Nevertheless, there appears to be a strong indication that removing and transporting soil to waste burial facilities to achieve exposure levels at the site at or below a 25 mrem/y unrestricted use dose criterion is generally not cost-effective when evaluated against the range normally considered justifiable under NRC's regulatory framework presented in NUREG/BR-0058 and NUREG-1530 (see Section 6.1). Further, even for a range of cleanup levels at or above a 25 mrem/y criterion there can also be cases where costs are unreasonable in comparison to benefits realized.

In actual situations, it is likely that even if no specific analysis of ALARA were required for soil removal that the actual dose will be reduced to below 25 mrem/y because of the nature of the removal process. For example, the process of soil excavation is a coarse removal process that is likely to remove large fractions of the remaining radioactivity;

4) Decommissioning ALARA analysis for structures containing contamination. Contamination of building floors and walls can exist at nuclear facilities for a variety of reasons including system leaks, spills, tracking, and activation. The large majority of NRC licensed facilities (>6000) have zero or limited building contamination. Contamination in general does not penetrate the surface of concrete and can be readily removed by water jets or concrete scabbling. If the building is reused for some new industrial, office, or other use after license termination, persons can be in fairly direct contact with the decommissioned floors and walls.

As indicated above, for the range of generic situations considered, the results of Chapters 1 -

6 of this final GEIS evaluation indicate that there is a wide range of possible cost-benefit ratios. Nevertheless, there appears to be more of a tendency than for soil that cleanup of concrete to levels at or below 25 mrem/y can be cost effective in certain cases when compared against the regulatory alternatives decisionmaking guidelines of NUREG/CR-0058 and NUREG-1530.

In actual situations, it is likely that even if no specific analysis of ALARA were required for concrete removal that the actual dose will be reduced to below 25 mrem/y because of the nature of the removal process. For example, as is also noted above for soil removal, the process of scabbling of concrete removes a layer of concrete which likely contains a large fraction of the remaining radioactivity.

To reflect the analyses of Chapters 1 - 6, in any ALARA analysis conducted to support decisions about a site specific cleanup, all detriments potentially resulting from the cleanup activities should be taken into consideration in balancing costs and benefits, e.g., traffic mortalities which might occur as contaminated waste is transported away from the site (e.g., see Appendix B).

5) Restricted use and Exemptions from Rule Criteria. As illustrated in Chapters 1 - 6, there can be situations where restricting site use to achieve a TEDE of 25 mrem/y is a more reasonable and cost-effective option than unrestricted use. In this manner, restrictions can provide protection of public health and safety at reasonable cost by limiting the time period that an individual spends onsite or restricting agricultural or drinking water use. For many facilities, the time period needed for restrictions can be fairly short, i.e. long enough to allow radioactive decay to reduce radioactivity to levels which permit release for unrestricted use. For example, at reactors, manufacturing facilities, or broad scope licensees where the principal contaminants can have half-lives of 5 - 30 years (Co-60, Cs-137) restricting site use for about 10 - 60 years can result in achieving unrestricted use levels. Thus restricted use, accompanied by provisions which assure the restrictions remain in place, can have a part in a license termination approach. Considerations for assuring that restrictions remain in place were discussed in the draft GEIS and included provisions for legally enforceable institutional controls, financial assurance to provide that the controls remain in place, and a "cap" on the level of radioactivity allowable in the unlikely event that controls should fail.

For restricted use, Chapter 6 suggests that while removal of soil to levels below 25 mrem/y may not be cost-effective, other simple and less costly measures, such as fencing or landscaping may be cost-effective and should be considered as part of the ALARA process.

The draft GEIS and Chapters 1 - 6 analyze impacts and costs associated with alternative regulatory actions for nuclear facilities licensed by the NRC. The preamble to the proposed rule (59 FR 43200) discussed the fact that there may be several existing licensed sites where the health and the environment may best be protected by means other than the decommissioning activities analyzed in Chapters 1 - 6, and that these facilities might seek exemptions (under §20.2301) from the criteria of the rule. Based on the analysis of

Chapters 1 - 6 of this final GEIS, for the very large majority of NRC licensed sites (>6000), it continues to be reasonable to envision that the unrestricted and/or restricted use regulatory alternatives analyzed here will provide appropriate and achievable criteria for decommissioning. Nevertheless, it is also reasonable to continue to anticipate that there may be certain difficult sites that present unique decommissioning problems, not analyzed in this final GEIS because of their specific situation, which need particular analysis and for which the public health and safety may best be protected by alternate means. It is preferable to codify provisions for these sites under the aegis of a rule rather than require licensees of these facilities to seek an exemption process outside the rule as was contemplated in the proposed rulemaking. These circumstances and the need for such analyses are expected to be rare and should require Commission approval.

As is noted in Section 3.2.1, radiological criteria for lands and structures at mill facilities are considered to be outside the scope of this Final GEIS because of the complexities associated with decommissioning of these facilities.

6) Groundwater Cleanup. The NRC proposed rule included separate requirements for groundwater protection, but there was not detailed separate analysis of groundwater cleanup in the draft GEIS. Public comments on the proposed rule, including EPA comments supporting the separate requirement, were received on the impacts and costs associated with groundwater cleanup. Chapter 6, and Appendix C, contain further technical analyses of costs and impacts associated with groundwater remediation.

The analyses of the draft GEIS and of Chapters 1 - 6 of this final GEIS in support of the proposed rule analyzed impacts and costs of regulatory alternatives which would contain criteria (an individual dose criterion for unrestricted use, ALARA, and restricted use) to protect the public from radiation from all of the pathways that they could be exposed to from a decommissioned facility (e.g., direct exposure to radiation from material on the soil surface, ingestion of food grown in the soil and from fishing, inhalation of dust from soil surfaces, and drinking water obtained from surface waters and from groundwater). Such criteria would thus limit the amount of radiation that a person could potentially receive from all possible sources at a decommissioned facility, i.e., it is an "all-pathways" standard.

Because equivalent doses received through any pathways of exposure would involve equivalent risks to the person exposed, it would appear that, with regard to the need to set a separate standard for groundwater, there is no reason from the standpoint of protection of public health and safety to have a separate, lower, criterion for one of the pathways (e.g., drinking water) as long as, when combined, they don't exceed the total dose standard established in the rule. A standard imposed on a single pathway, such as drinking water, may have been appropriate in the past for site cleanups when a dose-based standard for decommissioning did not exist. It may also be appropriate for chemical contamination when no total limit on exposure exists. But the presence of an overall TEDE criterion for all radionuclides combined and on all pathways of exposure combined, including drinking water, would remove the need for such a single-pathway standard. This is a better and more uniform method for protecting public health and safety than, as was contained in NRC's proposed rule, setting separate requirements using the MCLs contained in 40 CFR 141. This is because the MCL requirements do not cover all radionuclides, and do not provide a consistent risk standard for different radionuclides. Therefore, it would appear that an overall single TEDE criterion should be adopted in the final rule.

Thus, while it is evident that exposures from drinking contaminated groundwater need to be controlled, and that the environmental integrity of the nation's groundwater resources needs to be protected, it is also evident that protection of public health and safety is fully afforded by limiting exposure to persons from all potential sources of radioactive material (TEDE) at a decommissioned facility. There is, therefore, no compelling reason to impose a separate limit on dose from the drinking water pathway and separate groundwater requirements need not be set in NRC's rulemaking. Nevertheless it should be made clear that, because of the importance of protecting this resource as a source of potential public exposure, the groundwater pathway is clearly included as part of the all-pathways unrestricted use dose criterion. Further separate protection of the resource, per se, cannot be effected unilaterally as part of this final GEIS but might be the subject of some future EPA action.

In actual situations, based on typical operational practices of most nuclear facilities and based on the behavior of radionuclides in the environment, for the very large majority of sites, concentrations of radionuclides in the groundwater will be well below the dose criterion of this final rule and in fact would be either below or only marginally above the MCLs codified in 40 CFR 141 as referenced in the proposed NRC rule. For example, the large majority of NRC licensees either use sealed sources or have very short-lived radionuclides; the potential for contamination from these facilities reaching groundwater is highly unlikely. Even for facilities like reactors or certain industrial facilities, whose major contaminants are relatively short-lived nuclides like Co-60 or Cs-137, the migration of these nuclides through soil is so slow as to preclude groundwater contamination of any significance. In addition, it is not anticipated that there would be decommissioned nuclear facilities located near enough to public water treatment facilities such that treatment facilities would be affected by the potential groundwater contamination from decommissioned facilities

As further analyzed in Chapter 6 and Appendix C, cost and practicality is reviewed in this final GEIS to determine whether such analyses can provide additional information regarding decisions on issues such as ALARA levels, including how, and to what level, ALARA efforts should be made in groundwater cleanup, and if, and in what manner, restrictions on use should be considered. Analysis of impacts to populations, and the cost of remediating those impacts, is particularly important for groundwater because this resource can be used for public uses away from the site being decommissioned. The analysis in Appendix C draws from NRC's experience and the public comments regarding contaminated sites. In particular with regard to groundwater remediation, potential methods considered include removal of soil to preclude prospective contamination, pump and treat process for the cleanup of existing groundwater contamination, and the supply of alternate sources of drinking water, as well as administrative costs of predicting and measuring levels in the plume of contaminated groundwater.

Given the range of possible parameters, scenarios, and site specific situations, Section 7.2.1 notes that there is a wide range of cost-benefit results and there is no unique algorithm which decisively is an ALARA result for all facilities. This finding is especially true for groundwater contamination where the behavior of radionuclides in soil and in the aquifer is highly site specific, and much more so than, for example, behavior in concrete. The results of the overall considerations of Section 6.4 of Chapter 6 for all pathways are thus applicable to the groundwater component, with certain specific findings for the groundwater component; e.g., removing soil to doses less than the dose criterion of 25 mrem/y is not generally likely to be cost effective when evaluated against the range normally considered justifiable under the regulatory framework described in NUREG/BR-0058 and NUREG-1530 (see Section 6.1). However, there was more of a tendency that sites where there can be both groundwater contamination and a relatively large population obtaining all their drinking water from the site plume would be potentially cost-effective to treat. Thus, licensees should consider their site specific conditions under which an ALARA analysis could identify the need to consider reducing the dose below the unrestricted use dose criterion.

(7) Citizen Participation

The public should not only be fully informed of the decommissioning actions at a particular site but also be able to effectively participate in site decommissioning decisions. In particular, for a decommissioning where a licensee does not propose to meet the conditions for unrestricted use noted in Item #2 above, additional community involvement and advice should be sought through a variety of methods regarding the proposed decommissioning. In seeking that advice, there should be provisions for: 1) participation by representatives of a broad cross section of community interests who may be affected by the decommissioning; (2) an opportunity for a comprehensive, collective discussion on the issues by the participants represented; and 3) a publicly available summary of the results of all such discussions. Advice sought from affected parties should be considered in decommissioning planning.

It is recognized that special environmental or cultural issues may be associated with a particular decommissioning action which would require more stringent implementation of the requirements. Sites on or contiguous to historical sites or Native American lands that contain religious or sacred areas are examples of such special issues. These issues can best be handled on a site-by-site basis as part of the decommissioning plan review process, and as part of the NRC's environmental review under NEPA. Where necessary, the provisions for public comment and for seeking community involvement and advice would provide a mechanism for addressing these issues.

In particular, it is also recognized that environmental justice issues will need to be considered during individual site reviews, consistent with the Commission's procedures on environmental justice.

(8) Minimization of Contamination

There should be specific attention given to design features and procedures that facilitate decommissioning the site, reduce the amount of radioactive waste, and minimize the overall public risk associated with decommissioning.

(9) Relationship between the Generic Environmental Impact Statement and Site-Specific Decommissioning Actions

This GEIS evaluates the environmental impacts associated with the remediation of several types of NRC-licensed facilities to a range of alternative residual radioactivity levels. The generic analysis will likely encompass the impacts that will occur in most Commission decisions to decommission an individual site where the licensee proposes to release the site for unrestricted use. Therefore, the GEIS can be useful in satisfying the NRC's obligations under the National Environmental Policy Act in regard to individual decommissioning decisions that meet the 25 mrem/y criterion for unrestricted use. However, it is reasonable to still initiate an environmental assessment in regard to any particular site, for which a categorical exclusion is not applicable, to determine if the generic analysis encompasses the range of environmental impacts at that particular site.

In cases where a license is terminated and the site is released under restricted use conditions, licensees would demonstrate that land use restrictions or other types of institutional controls will provide reasonable assurance that the 25 mrem/y limit can be met. The types of controls and their contribution to providing reasonable assurance that 25 mrem/y can be met for a particular site will differ for each site in this category. Similarly, Item #5 above notes there may be other site specific special circumstances, not analyzed in this final GEIS because of their specific situation, which need particular analysis. Therefore, the environmental impacts for these cases cannot be analyzed on a generic basis and an independent environmental review should be conducted for each site-specific decommissioning decision where land use restrictions or institutional controls are relied on by the licensee or where other alternate analysis is necessary.

The GEIS indicates that the decommissioning for certain classes of licensees (e.g., licensees using only sealed sources) will not individually or cumulatively have a significant effect on the human environment. Therefore, for these categories of licensees, the decommissioning of these types of licenses should be actions eligible for categorical exclusion from the Commission's environmental review process.

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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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