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Final
Environmental Impact Statement
on 10 CFR Part 61 "Licensing Requirements for Land Disposal of Radioactive Waste"

Summary and Main Report

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety and Safeguards

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ABSTRACT

The three-volume final environmental impact statement (FEIS) is prepared to guide and support publication of a final regulation, 10 CFR Part 61, for the land disposal of low-level radioactive waste. The FEIS is prepared in response to public comments received on the draft environmental impact statement (DEIS) on the proposed Part 61 regulation. The DEIS was published in September 1981 as NUREG-0782. Public comments received on the proposed Part 61 regulation separate from the DEIS are also considered in the FEIS. The FEIS is not a rewritten version of the DEIS, which contains an exhaustive and detailed analysis of alternatives, but rather references the DEIS and presents the final decision bases and conclusions (costs and impacts) which are reflected in the Part 61 requirements. Four cases are specifically considered in the FEIS representing the following: past disposal practice, existing disposal practice, Part 61 requirements, and an upper bound example.

The Summary and Main Report are contained in Volume 1. Volume 2 consists of Appendices A - Staff Analysis of Public Comments on the DEIS for 10 CFR Part 61, and Appendices B - Staff Analysis of Public Comments on Proposed 10 CFR Part 61 Rulemaking. Volume 3 contains Appendices C-F, entitled as follows: Appendix C - Revisions to Impact Analysis Methodology, Appendix D - Computer Codes Used for FEIS Calculations, Appendix E - Errata for the DEIS for 10 CFR Part 61 and last, Appendix F - Final Rule and Supplementary Information.

FOREWARD

In September 1981, NRC published the Draft Environmental Impact Statement on 10 CFR Part 61: "Licensing Requirements for Land Disposal of Radioactive Waste" (NUREG-0782). This draft environmental impact statement (EIS) contains an exhaustive and detailed analysis of a wide range of alternatives. Based upon NRC analysis of public comments on both the draft EIS and upon the proposed Part 61 regulation itself (Federal Register Notice 46 FR 38081, July 24, 1981), no new alternatives or principles were identified which required analysis. No major changes were required for several requirements of the Part 61 regulation, including the overall performance objectives which should be achieved in the land disposal of low-level radioactive waste, administrative and procedural requirements for licensing a land disposal facility, and the requirements for financial assurance. Many clarifying and explanatory changes were, however, required with respect to specific rule provisions.

Given this conclusion and public comments suggesting that the number of alternatives considered in the EIS be reduced to a smaller, more understandable number, NRC has chosen not to republish the extensive analysis of alternatives as presented in the draft EIS. Rather, NRC has refined the EIS impact analysis methodology based upon public comments and has grouped the alternatives analyzed onto four major alternatives which present the basis for decisions made regarding the Part 61 requirements.

This final EIS is therefore not a revision of the draft EIS but a stand-alone statement which uses the draft EIS as a resource and reference document. Refinements made to the draft EIS assumptions and impact analysis methodology are noted and used in the final EIS. NRC hopes that in this way, the final EIS will be of a more managable size and the alternatives analyzed and conclusions reached presented in more of a concise, understandable manner.

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List of Preparers

The overall responsibility for the preparation of this draft environmental impact statement was assigned to the Low-Level Waste Licensing Branch, Division of Waste Management, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission. The statement was prepared with technical assistance from the firm of Dames and Moore, White Plains, New York.

Nuclear Regulatory Commission Staff

Preparers

R. Dale Smith, Chief
Low-Level Waste Licensing Branch
Kitty S. Dragonette
Paul H. Lohaus
George C. Pangburn
G. W. Roles

Contributors

Timothy C. Johnson
Mary Jo Seemann
James A. Shaffner
David L. Siefken
Derek Widmayer

Special Contributors

Willste CRESS Central Dictation Unit
- Carole Finan
- Jeannette Kiminas
- Pauline Rock
- Charline Simon
- Irene Suissa

Cathy S. Bromberg, Secretary, Low-Level Waste Licensing Branch
Robert Fonner, Attorney, Office of the Executive Legal Director

Dames and Moore Staff

Others contributing significantly to this environmental impact statement included personnel of the firm of Dames and Moore, Inc. (D&M) of White Plains, New York. The D&M contribution was directed by Dr. Oktay I. Oztunali.

OPTIONR & GRWATRR Codes

Oktay I. Oztunali
C. Joseph Pitt

Input on I-129 & C-14

Oktay I. Oztunali
Leslie Skoski
Kim D. Petschek

SUMMARY

1.0 PURPOSE, SCOPE, AND NEED OF THE FINAL EIS

The action being considered in this final environmental impact statement is the issuance of a new regulation, Part 61, to the U.S. Nuclear Regulatory Commission (NRC) rules in Title 10, Code of Federal Regulations (10 CFR). Part 61 provides licensing procedures, performance objectives, and technical requirements for the issuance of licenses for the land disposal of "low-level" radioactive waste (LLW). Specifically, the regulations establish performance objectives for land disposal of waste; technical requirements for the siting, design, operations, and closure activities for a near-surface disposal facility; technical requirements on waste form that waste generators must meet for near-surface disposal of waste; classification of waste; institutional requirements; financial requirements; administrative and procedural requirements for licensing a LLW disposal facility; and a manifest system.

1.1 Purpose

NRC has a two-fold purpose in preparing this final EIS. First, it is to fulfill NRC's responsibility under the National Environmental Policy Act of 1969 (NEPA). Second, NRC has prepared this final EIS to document the decision processes applied in the development of Part 61. NRC has analyzed alternative courses of action and requirements were selected with consideration of costs, environmental impacts and health and safety effects to current and future generations.

1.2 Scope

This final EIS analyzes requirements for the land disposal of radioactive waste and specifically, near-surface disposal. Near-surface disposal involves disposal in the approximate uppermost 30 meters of the earth's surface. Burial deeper than 30 meters may also be involved with near-surface disposal technologies. This final EIS does not analyze other methods of disposal such as ocean disposal. It is also not a generic EIS in that it does not analyze all of the issues involved in the disposal of LLW. Rather, this final EIS provides the decision analysis for requirements in Part 61.

1.3 Need for the Proposed Action

Current NRC regulations for licensing radioactive materials do not contain sufficient technical standards or criteria for the disposal of licensed materials as waste. Comprehensive standards, technical criteria, and licensing procedures are needed to ensure the public health and safety and long-term environmental protection in the licensing of new disposal sites. They are also needed with respect to operation of the existing sites and with respect to final closure and stabilization of all sites. The development of these regulations has been in response to needs and requests expressed by the public, Congress, industry, the States, the Commission and other federal agencies for codification of regulations for the disposal of LLW.

1.4 EIS Scoping Process

NRC has conducted scoping activities for the Part 61 rule and this final EIS since 1978. Public participation in the development of Part 61 and analyses of the major scoping activities and public comments are discussed in detail in Appendix C of the draft EIS which has been published as NUREG-0782.

In addition, proposed 10 CFR Part 61 was published in the Federal Register on July 24, 1981 for 90 days public comment which was extended to January 14, 1982 to coincide with the 90 day comment period for the draft EIS. The availability of the draft EIS was announced on October 22, 1981.

2.0 COMMENTS ON DRAFT EIS AND RULE

Public comments received on both the proposed rule and draft EIS have been used in preparing this final EIS. A total of 107 different persons submitted comments on the proposed rule and 42 on the draft EIS. The concerns expressed by all commenters are discussed in detail in staff analyses of comments which are contained in Appendices A (draft EIS) and B (rule) of this final EIS. The major concerns are summarized in the supplementary information section of the proposed final Part 61 rule contained in Appendix F of this final EIS. The staff's consideration of these comments and actions taken in response to them are set out in the various chapters and appendices of this final EIS.

2.1 Comments on the Draft EIS

Of the 42 comment letters received on the draft EIS, 21 came from States or State agencies, 8 from federal agencies or national laboratories, 5 from utilities, 3 from industry, 2 from individuals, 2 from disposal firms, and 1 from an individual radiation safety worker.

The tone of the letters was overwhelmingly supportive of the goals and the results of the 10 CFR 61 rulemaking effort. Criticism of the draft EIS was generally constructive in nature. Of the 42 letters received, 29 contained items which required a response by the staff. The remaining 13 letters in one form or another acknowledged receipt of the draft EIS but contained no items requiring a response.

2.2 Comments on Proposed Part 61 Rule

The rule commenters represented a variety of interests. The topics addressed a wide range of issues and all parts of the rule. The general response was quite favorable. Almost half (47) expressed explicit support of the rule or its overall approach. Many expressed the view that the rule provides a needed and adequate framework for establishing additional low-level waste disposal capacity. Support was expressed by almost every sector. Only 15 commenters expressed outright opposition to the rule or some significant part of the rule. Most (9) were individuals. No State group or current disposal site operator expressed opposition. Most of the remaining commenters (47) either offered constructive comments without taking a general position on the rule or offered support with reservations about one or more aspects of the rule.

3.0 APPROACH AND METHOD OF ANALYSIS USED FOR PREPARATION OF THE FINAL EIS

3.1 Approach Used for Preparation of the Final EIS

The approach NRC has followed in preparation of this final EIS is to present, in a concise manner, the final decision bases and conclusions (costs and impacts) which are reflected in the requirements of Part 61. NRC has chosen not to republish the exhaustive and detailed analysis of alternatives presented in the draft EIS. Rather, in response to public comments, NRC has reduced the number of alternatives analyzed to a more manageable and understandable number and has used the draft EIS as a resource and reference document in preparing this final EIS.

The changes made to the proposed Part 61 rule and draft EIS in response to public comments did not involve identification of major new alternatives or principles which required analysis. However, in the final EIS, an improved method of cost analysis, a more refined analysis of the impacts of waste classification, and analysis of a new pathway (trench overflow and leachate treatment) were added.

Thus, NRC has concentrated in this final EIS on preparing a final analysis of the costs and impacts of a continuation of existing near-surface disposal practices (the no action alternative) and the changes in costs and impacts that would result from application of improvements to existing practices established by Part 61. An analysis of the unmitigated costs and impacts of implementation of the final requirements selected for Part 61 is also presented.

The final EIS is being published in three separate volumes. Volume one consists of this summary and the main text. The main text consists of six chapters described in greater detail below. Volume 2 contains Appendices A-B which set out details of the analysis of public comments on the draft EIS and proposed Part 61 Rule. Volume 3 contains Appendices C-F which set out other supporting technical information to that contained in the main text.

Chapter one of the main text is an introduction which describes the proposed action and presents the purpose, scope, need and structure of the EIS. Chapter two presents background information about LLW and describes the affected environment. Chapter three presents and analyzes major comments filed on the draft EIS. Chapter four describes the method of analysis, impact measures used, alternatives analyzed and the results of the analysis of alternatives. Chapter five presents final conclusions and a discussion of the final requirements selected. Finally, Chapter six presents the typical and unmitigated impacts of the application of the final requirements selected for the Part 61 rule.

3.2 Performance Versus Prescriptive Requirements

In Chapter two of the draft EIS (§ 2.2), NRC analyzed the basic type of requirements which should be developed and set out in Part 61 (i.e., performance objective or prescriptive requirements). Based on this analysis, the preferred approach selected and followed by NRC in the preparation of Part 61 was to develop both performance objective and prescriptive requirements. Overall performance objectives were developed to define the level of safety that should be achieved in the land disposal of LLW. Minimum technical performance requirements were also developed for each of the major components of a LLW disposal

system that should be considered in all cases in the disposal of LLW to help ensure that the overall performance objectives for land disposal would be met. Finally, prescriptive requirements were established where they were deemed necessary and where sufficient technical information and rationale were available to support them.

Based on public comments on the Part 61 rule and draft EIS and NRC's analysis of these comments (the comments were supportive of this combined approach), NRC has made no change to this approach and it has been followed in the development of the final Part 61 rule.

3.3 Performance Objectives for Land Disposal

In chapter three of the draft EIS (§ 3.2), NRC reviewed the need for performance objectives to ensure safety and environmental protection in the disposal of LLW. In evaluating the level of safety and environmental protection which should be achieved, NRC identified four components for which performance objectives should be established. These were:

(1) Long-term protection of the public health and safety (and the environment);

(2) Protection of an inadvertent intruder;

(3) Protection of workers and the public during operation of a LLW disposal facility; and

(4) Long-term stability of the disposal site after closure to eliminate the need to actively maintain and care for a disposal facility over the long term.

Based on public comments filed on the rule and draft EIS, no new areas were identified which should be addressed in the Part 61 rule as overall performance objectives for land disposal of LLW. Commenters supported development of performance objectives in the above four areas.

3.4 Technical, Financial and Other Requirements

In § 3.2 of chapter three of the draft EIS, NRC also identified four principal components which collectively make up a LLW disposal system. Each of these was specifically addressed in the development of the technical requirements and includes:

(1) Site Characteristics - The geohydrological, geomorphological, climatological and other natural characteristics of the site where the disposal facility is located;

(2) Design and Operation - The methods by which the site is utilized, the disposal facility designed, the methods of waste emplacement and closure of the site;

(3) Waste Form and Packaging - The characteristics of the waste and its packaging; and

(4) Institutional Controls - The actions which involve a government agency maintaining surveillance, monitoring and control over access and utilization of the site after closure.

Specific technical requirements for each of these components were developed in chapters four, five, six and seven of the draft EIS. In addition, NRC analyzed the need for changes to existing administrative and procedural requirements that are applied by NRC in the licensing of LLW disposal facilities (Chapter eight of the draft EIS) and the need for financial assurance requirements (Chapter 9 of the draft EIS).

Based on public comments filed on the rule and draft EIS, no new major areas were identified in addition to the above that should be addressed in the development of the technical requirements. New topics identified by commentors which should be addressed in the Part 61 rule and EIS fell into one of the above areas.

3.5 Method of Analysis

The overall method of analysis followed in this final EIS for determination of the technical requirements is as follows:

(1) First, the costs and impacts from the generation, transport, and disposal of waste at a reference near-surface disposal facility are calculated (Alternative 1). This analysis is reflective of past disposal practices and is termed the "base case" analysis.

(2) Second, a range of three alternatives to the base case are evaluated with respect to their incremental change in mitigating potential impacts and cost over the base case. One represents today's practices and is the no action alternative (Alternative 2). The second represents the Part 61 requirements and is the preferred alternative (Alternative 3). The third represents application of extensive improvements over today's practices (Alternative 4).

(3) Third, a comparative evaluation of the alternatives is conducted based on the impacts (radiological and other impacts) and costs, of each alternative. Based on the evaluation and public comments, conclusions are reached on the final requirements to be codified through the Part 61 rulemaking action.

(4) Finally, application of the requirements selected and incorporated into the final Part 61 rule is evaluated to assess typical unmitigated impacts of LLW disposal following the preferred requirements. The disposal of waste according to Part 61 is analyzed on a regional basis at four regionally operated sites and the typical impacts and costs are determined. The analysis also helps assess the applicability of the Part 61 requirements to the wide range in site and waste characteristics expected in the regional disposal of LLW.

Based on public comments no change has been made to the overall method of analysis. The number of alternatives analyzed has been reduced to a more manageable number and NRC has presented the results in a clearer, more concise manner.

3.6 Description of Impact Measures Used and Exposure Pathways Analyzed

NRC has used the same impact measures and with one exception, analyzed the same exposure pathways in this final EIS as in the draft EIS. In response to public comments, a new pathway, trench overflow and leachate treatment, has been added and a more refined analysis of the impacts of waste classification was performed. Also, in response to public comments, the cost analysis has been calculated in a more realistic manner. These changes have not affected the overall conclusions reached based on the analyses in the draft EIS.

3.6.1 Impact Measures

Table S.1 lists the specific impact measures used in this final EIS. The impact measures used include short-term radiological exposures, long-term radiological exposures, costs, energy use and land use. They were categorized as they apply to waste processing activities at a waste generator facility, during transportation to the disposal location and during and after disposal at the disposal facility. As in the draft EIS, NRC has concentrated on long-term radiological exposures and costs.

Table S.1 Impact Measures Used in Analyses

Waste Management Phase	Impact Measure
Waste processing	Costs Energy use Occupational exposures due to waste processing Population exposures due to waste incineration
Waste transportation	Costs Energy use Occupational exposures Population exposures
Waste disposal	Costs Energy use Land use Occupational exposures Exposures to individuals and populations due to: o operational accidents o ground-water migration o inadvertent human intrusion o overland flow o leachate treatment

3.6.2 Risk From LLW Disposal Facility Operation

Several commenters suggested that NRC quantify the risks associated with operation of a LLW disposal facility. In the draft EIS, NRC expressed radiological impacts associated with operation of a near-surface disposal facility in terms of exposures to individuals and populations. NRC did not convert or express these exposures in terms of risks because of the difficulty of accurately assessing risks to future populations from exposures incurred at future times and the small number of individuals involved who could receive a potential exposure. Based on a reexamination of this issue, NRC does not plan to express doses in terms of risk in the final EIS. This would involve new work and time to prepare which is not warranted given the urgent need for Part 61 and the limited additional information which would be provided. In the draft EIS, NRC compared calculated doses on a common basis to existing standards which are expressed in terms of dose quivalent. The same approach has been followed in the final EIS. NRC has, however, attempted to express the overall impacts of Part 61 in the final EIS in a clearer manner so that comparison of alternatives and unmitigated impacts are easier to discern and understand.

To place in perspective the potential risk associated with the various doses calculated in this final EIS, NRC has summarized below dose response relationships as set forth in ICRP publication 26. The reader can use these to estimate the level of risk associated with doses calculated for the various alternatives.

In the draft EIS, doses were presented for the whole body and six organs (bone, liver, thyroid, kidney, lung and gastro-intestinal tract). In the final EIS, doses are generally presented only for the whole body, thyroid and bone. This has been done in response to public comments to simplify reporting of impacts and since the whole body, thyroid and bone are generally of most significance with respect to the radionuclides involved.

ICRP-26 states that "the risk factors for different tissues are based on the estimated likelihood of inducing fatal malignment disease, non-stochastic changes, or substantial genetic defects expressed in liveborn descendants." The risk factors summarized below, as taken from ICRP-26, are expressed as overall mortality risk factors, except as noted.

For uniform whole body irradiation, the ICRP concludes that for individuals, the mortality risk factor for radiation-induced cancers is about 1×10^{-4} chance of developing a fatal cancer per one rem dose. This is stated as an average for both sexes and all ages. A 500-mrem dose would then equate to a risk of potentially developing a fatal cancer of about 5×10^{-5}. For bone, the risk factor is lower, 5×10^{-6} potential cancers per rem dose. Likewise for thyroid, the overall mortality risk factor is lower, 5×10^{-6} potential cancers per one rem dose.

3.6.3 Exposure Pathways

As in the draft EIS, NRC has concentrated on long term radiological exposures. These could involve activities such as man potentially contacting the waste after disposal (i.e., inadvertent human intrusion into the disposal facility), potential leaching and transport of the waste through the groundwater; intrusion and dispersion by plants and animals; long-term erosion of the site with eventual uncovering of the waste and surface water and air transport; and release of

gaseous decomposition products from the waste containing radioactive species (e.g., tritiated methane gas). These are discussed in § 4.2.3 of Chapter 4 of the final EIS.

3.6.4 Costs

Costs are calculated and separated in this EIS into three components:

(1) Processing costs - those costs associated with processing and packaging wastes prior to disposal;

(2) Transportation costs - those costs associated with transferring the waste to the disposal facility; and

(3) Disposal facility costs - those costs associated with design and operation of a disposal facility over a 20-year period as well as postoperational (closure and institutional control) costs. Closure and institutional control costs are calculated as the total funds that would have to be collected over the operating life of the site and invested in a sinking fund in order to pay for the projected level of postoperational activities.

Additional information is contained in § 4.2.3 of Chapter 4. Appendix C also describes the present value analysis used to calculate disposal facility costs.

4.0 DESCRIPTION OF ALTERNATIVES

In the draft EIS, a broad range of waste form properties, facility design, operating procedures and institutional control alternatives, directed at helping to ensure that the performance objectives would be met were analyzed. A large number of specific cases or combinations of alternatives were analyzed in the draft EIS. The extent and detail of these analyses and difficulty in their summarization and thus understanding were pointed out in the public comments. Rather than repeat each of the alternative cases here, NRC has selected four representative alternatives to present the costs and impacts of the Part 61 requirements which are described below.

Based on analysis of the public comments, NRC has also not repeated the analyses which led to derivation of the performance objectives. The costs and impacts of meeting the performance objectives are reflected in each alternative analyzed. In addition, based on public comments, NRC has not repeated the extensive analyses that led to the key technical principles which should be addressed in the near-surface disposal of waste (i.e., long-term stability, contact of water with waste and intruder controls). Rather, NRC has concentrated on showing the incremental changes in costs and impacts resulting from application of the Part 61 requirements over those practices in effect today.

In the analysis, NRC assumed a reference disposal facility site located in a humid environment and having moderately permeable soils. The site is assumed to be operated for 20 years and have a capacity of up to one million m^3 of waste. As part of the analysis, variations are considered in which the site soils are assumed to be either very permeable (sandy) or very impermeable (clayey).

4.1 Alternative 1 - The Base Case Alternative Reflecting Past Practices

This alternative represents the level of control and costs which has been historically applied in the disposal of LLW. This historical level of costs and impacts serves as a basis against which improvements and changes can be evaluated and compared on a common basis. The analysis of the base case alternative also shows what the costs and impacts would be if the current controls at existing sites were relaxed.

The base case alternative reflects past practices with respect to poor waste form characteristics and properties and an absence of facility design or operational practices directed at long term stability. In the past, it was believed that only a "good site" was needed for waste disposal. No credit was given to waste form or containers. The site is thus assumed to have been selected in accordance with currently accepted site requirements. Since a site would not have been licensed in the past without adequate health physics procedures, accepted health physics practices and procedures are assumed to be carried out through the operators radiation safety program. Other assumptions made for this case are set out in § 4.3.1 of Chapter 4 of the final EIS.

4.2 Alternative 2 - The No Action Alternative Reflecting Today's Practices

This alternative characterizes and reflects today's practices in the near-surface disposal of LLW. As the industry gained experience and as regulatory agencies acted with respect to identified problems in past operations, changes and modifications were made in past disposal practices. These included limits on the contents, type and form of waste acceptable for disposal and improvements in design and operational practices. Several waste streams including evaporator bottoms, resins, and filter sludge waste containing greater than 1 uCi/cm^3 of radionuclides with a half life exceeding 5 years are required to be stabilized prior to disposal. These are mainly assumed to be stabilized by means of containers providing stability. Concentrated liquids from power plants are solidified. A limit of 10 nCi/gm is placed upon the transuranic content of received waste. In addition, several design and operational improvements are carried out to reduce contact of waste by water and to improve site stability. These include compaction of backfill material and trench caps, use of a permeable backfill, use of a thick (2m) clay cap and improved surface drainage to reduce infiltration. Care is taken during operations to maintain occupational exposures to accepted levels and higher activity wastes presenting greater external occupational hazard are placed on the bottom of disposal trenches and shielded with lower activity waste.

Other assumptions made for this case are set out in § 4.3.2 of Chapter 4 of the final EIS.

4.3 Alternative 3 - The Preferred Alternative Reflecting Part 61

Alternative 3 reflects the final Part 61 requirements as established by the draft EIS analysis and as modified based on public comments.

In the draft EIS, NRC analyzed (in addition to the improvements already in effect at the existing sites) a broad range of other alternatives which could be applied to reduce radiological impacts. The relative incremental change in impacts and costs for each alternative was calculated and compared in arriving

at the requirements selected for Part 61. This extensive analysis of alternatives is principally set out in Chapters 4, 5 and 6 of the draft EIS. Also based on the analyses in the draft EIS, three key principles were identified which are of primary significance in ensuring the performance objectives will be met over the long term. No new aspects were identified in the public comments. These principles are:

(1) Long-term stability of the disposal facility and disposed waste. Stability helps reduce trench cover collapse, subsidence, water infiltration and the need to care for the facility over the long term;

(2) The presence of liquids in waste and the contact of water with waste both during operations and after the site is closed. Water is the primary vehicle for waste transport and its presence in and contact with waste can contribute to accelerated waste decomposition and increased potential for making the waste available for transport off site; and

(3) Institutional, engineering and natural controls that can be readily applied to reduce the likelihood and impacts of inadvertent intrusion.

The following chart summarizes the relative importance of each in helping to achieve the performance objectives.

PRINCIPLE	PERFORMANCE OBJECTIVES			
	Migration	Maintenance	Intruder	Operations
Long term stability	Reduces water infiltration and potential for migration	Reduces need for long-term maintenance	Reduces likelihood and impacts of inadvertent intrusion	Reduces occupational hazards and offsite releases in accident
Reduce contact of water with waste	Reduces potential for migration	Reduces need for active maintenance	Reduces waste degradation-thus intruder impacts	Reduces occupational hazards and offsite releases
Institutional and other intruder controls	Custodial care reduces potential for water infiltration	Assures proper maintenance	Reduces likelihood and impact of inadvertent intrusion	Reduces occupational hazards

Based on the EIS analyses and public comments, several technical requirements have been identified for codification into Part 61. Concentration limits are established for important radionuclides as well as transuranic radionuclides

which determine the disposal requirements for the waste. Waste is divided into three waste classes: Class A, Class B and Class C. All higher activity wastes (Class B and Class C) are required to be stabilized. Stability can be provided by the waste form as generated, processing of the waste to a stable form or by placement in a container or structure that provides stability. Lower activity compressible wastes (Class A) are required to be disposed of in separate disposal units from stable Class A, B and C wastes. Class C wastes, which present greater long-term potential hazard to an inadvertent intruder, are required to be disposed of on the bottom of disposal units. Disposal facility design and operation directed at reducing water contact with waste and achieving long-term stability is the same as the previous no action alternative. The only major operational difference is the segregation of compressible Class A wastes from stable Class A, B and C wastes.

Specific assumptions made for this case are set out in § 4.3.3 of Chapter 4 of the FEIS. One important assumption is that (except for Cs-137) all Class C concentration limits, as set out in the proposed rule, are raised by a factor of 10 to correspond to limits in the final Part 61 rule. Class B and C wastes are stabilized by a combination of solidification and use of containers providing stability.

4.4 Alternative 4 - Upper Bound Requirements (All Stable Alternative)

In the draft EIS, NRC analyzed many alternatives providing greater controls in disposal at much higher costs. These were rejected by NRC based on cost/impact considerations. Alternative 4 analyzes a number of these alternatives which could be required and applied in the disposal of LLW. Because of the overall importance of long-term stability in reducing impacts and long term costs, the alternatives selected are directed at ways to achieve long term stability. The principal alternative analyzed is to place all Class A unstable waste into a stable form, principally through waste packaging. The other alternatives considered involve use of several facility design and operation options to achieve stability including grouted disposal, disposal into grouted concrete-walled trenches or extreme compaction. Other assumptions for these cases are set out in §§ 4.3.4 and 4.4.5 of Chapter 4 of the final EIS.

5.0 REGULATORY ANALYSIS - CONCLUSIONS AND COMPARATIVE EVALUATION

This section presents the final conclusions drawn from a comparative evaluation of the alternatives The final conclusions are presented as the basic principles and concepts that should be set out as the minimum technical requirements in the Part 61 rule.

This section has been divided into 2 major subsections. The first subsection presents the results of Alternative 1 (the Base Case). The second subsection presents and compares Alternative 2 (The No Action Alternative), Alternative 3 (The Preferred Alternative) and Alternative 4 (Upper Bound Requirements).

5.1 Results of Alternative 1 (The Base Case Reflecting Past Practices)

Table S.2 summarizes the differences in costs and impacts for each alternative. Principal conclusions for Alternative 1 include:

Table S.2 Results of the Alternatives Analysis

	1 Base Case	2 No Action	3 Preferred (Part 61)	4 Upper Bound
I. Long-Term Individual Exposures (mrem/yr):				
Intruder-construction				
o 100 yrs - Body	2.30E+3*	1.79E+3	1.84E+2	1.75E+1
Bone	4.49E+3	1.80E+3	1.87E+2	1.77E+1
Thyroid	2.16E+3	1.78E+3	1.84E+2	1.74E+1
o 500 yrs - Body	1.14E+2	2.61E+0	3.02E+0	3.07E+0
Bone	1.55E+3	1.16E+1	1.63E+1	1.67E+1
Thyroid	2.70E+1	2.29E+0	2.42E+0	2.45E+0
Intruder-agriculture				
o 100 yrs - Body	2.68E+3	2.21E+3	2.02E+2	0.
Bone	3.64E+3	2.32E+3	2.08E+2	0.
Thyroid	2.60E+3	2.17E+3	2.01E+2	0.
o 500 yrs - Body	6.66E+1	2.77E+0	3.04E+0	3.09E+0
Bone	6.41E+2	7.19E+0	9.17E+0	9.38E+0
Thyroid	3.93E+1	9.08E+0	9.02E+0	9.23E+0
Boundary Well				
o Body	1.58E+2	4.39E-1	1.11E-1	1.09E-1
o Bone	5.61E+0	4.49E-2	3.70E-2	1.47E-2
o Thyroid	1.50E+3	1.11E+1	4.16E+0	3.31E+0
Surface water				
o Body	3.16E-2	2.90E-4	1.44E-4	8.80E-5
o Bone	4.92E-2	4.29E-4	3.37E-4	1.36E-4
o Thyroid	2.16E+1	1.50E-1	5.99E-2	4.77E-2
II. Short-Term Whole Body Exposures (total man-mrem over 20 yrs):				
Occupational				
o Waste processing	**	+3.75E+5	+5.75E+5	+6.15E+5
o Waste transport	7.58E+6	4.99E+6	4.97E+6	4.97E+6
o Waste disposal	3.33E+6	2.15E+6	2.14E+6	2.15E+6
To population				
o Waste processing	**	+0.	+1.26E+2	+8.93E+1
o Waste transport	7.49E+5	4.78E+5	4.76E+5	4.84E+5
III. Costs (total $ over 20 yrs):				
Waste generation and transport				
o Waste processing	**	+9.53E+7	+1.18E+8	+2.86E+8
o Waste transport	2.64E+8	1.73E+8	1.72E+8	1.70E+8

Table S.2 (Continued)

	1 Base Case	2 No Action	3 Preferred (Part 61)	4 Upper Bound
Waste disposal				
o Design & op.	3.25E+8	3.41E+8	3.50E+8	3.42E+8
o Post operational#	4.55E+7	4.55E+7	3.57E+7	1.38E+7
o Total disp. fac. cost	3.71E+8	3.87E+8	3.86E+8	3.56E+8
o Unit disp. fac. cost ($/m^3)	3.71E+2	5.97E+2	5.95E+2	5.64E+2
IV. Total waste generation, transport, and disposal cost incremental to base case (total $ over 20 yrs):	--	+2.03E+7	+4.10E+7	+1.77E+8
V. Waste Volume (m^3):				
Volume acceptable	1.00E+6	6.47E+5	6.48E+5	6.31E+5
o Unstable	7.47E+5##	4.42E+5##	4.23E+5	0.
o Stable - Regular	2.52E+5##	2.05E+5##	2.21E+5	6.27E+5
o Stable - Layered	0.	0.	3.47E+3	3.83E+3
Volume not acceptable	0.	2.56E+4	2.20E+4	2.20E+4

*The notation 2.30E+3 means 2.30 x 10^3.

**In this EIS, population exposures due to waste processing by waste generators, occupational exposures due to waste processing by waste generators, and costs due to waste processing by waste generators are presented as impacts and costs in addition to those associated with the base case.

#Postoperational costs are presented as an upper bound level of costs for a site having moderately permeable soils. In the analysis, ranges of costs are calculated depending upon site-specific conditions and uncertainties regarding the ability of the disposal facility to function as planned. As discussed in the text, the uncertainties in the calculated postoperational costs decrease for each successive case.

##Although much of the waste is or has been stabilized, the fact that for these two cases all the stable waste is disposed comingled with unstable waste tends to negate the potential gain of waste stabilization. The result is about the same as if all waste was in an unstable form.

(1) The disposal facility is calculated to accept one million m^3 of waste over its 20-year lifetime. No waste shipped for disposal is determined to be unacceptable for near-surface disposal.

(2) Long-term environmental impacts for the base case are calculated to be high. Potential impacts to an inadvertent intruder are projected to be 2.3 rem (whole body) and 4.5 rem (bone) at 100 years following the end of the two-year facility closure period. At 500 years, potential inadvertent intruder exposures are reduced, but are still on the order of 0.6 to 1.6 rems to the bone. These exposures at 500 years are due to the relatively longer lived radionuclides.

Groundwater impacts, which are considered over a time period of 10,000 years following disposal facility closure, are also high. As shown, thyroid exposures are on the order of 1.5 rem at the boundary well and 22 mrem at the surface water location. These exposures are principally due to migration of I-129. Whole body exposures are also relatively high at the boundary well--160 mrem--and are principally due to the migration of tritium.

It is not likely that doses to actual individuals would ever be this high, notwithstanding the conservatism of the analysis. For one thing, potholes and depressions created by the unstable site conditions would be filled in by the site owner, thus reducing the percolation. In addition, groundwater movement of radionuclides would almost certainly be detected through monitoring wells long before appreciable exposures could be received by the public. A more important point is that a considerable amount of effort and cost to the site owner may be required to prevent such potential exposures from occurring. This is discussed in more detail below.

(3) Short-term environmental impacts include exposures to radiation workers during waste processing, transport and disposal, as well as population exposures due to waste processing and transport. All impacts are given in units of man-millirem and are summed over the 20 years of site operation. Occupational exposures due to waste processing by waste generators, population exposures due to waste processing by waste generators and costs due to waste processing by waste generators are not calculated for the base case. They are calculated for the other cases and are presented as incremental impacts from the base case. The base case represents conditions in which little or no waste processing is performed other than that required to meet safety requirements for transportation and disposal facility waste handling operations.

(4) A base case transportation cost of $264 million is estimated for transportation of about 50,000 m^3 of waste per year over 20 years ($264 per m^3 of waste).

(5) Disposal design and operational costs are calculated to be on the order of $325/m^3 (9.20/ft^3).

(6) Postoperational costs are projected to be quite high--i.e., on the order of $46 million for the reference disposal facility site. At a site having very impermeable soil and assuming that a bathtub condition exists requiring extensive leachate pumping and treatment, postoperational costs

could climb to $58 million. These costs are the total costs that would have to be collected from disposal facility customers over the operating life of the disposal facility in order to pay for the projected postoperational activities. Better than 90% of the post-operational funds collected would be for the 100-year institutional control period. These costs translate to a charge to a disposal facility customer ranging from $1.29 to $1.64/ft^3.

The sheer magnitude of the funds that would be needed to be collected over 20 years to ensure long-term care deserves special consideration. High potential ground-water doses are estimated, and to prevent such potential exposures from occurring, a considerable amount of active site maintenance would be expected on the part of the site owner. It is difficult to predict how long this extensive site maintenance would be required or how much it would actually cost, although it is seen that many millions of dollars could be potentially involved. It is therefore judged to be inappropriate to assume that sufficient postoperational funds would in fact be collected. The disposal facility may close prematurely and prior to collection of sufficient funds. There is also no assurance that the extensive kinds of maintenance activities that would be required would actually be carried out in a timely manner, leading to a self-perpetuating situation. Finally, extensive site maintenance activities can lead to offsite releases of quantities of radionuclides.

In conclusion, the environmental and long-term cost impacts of this case are clearly excessive and reversion to disposal fascility practices typified by this alternative is an unacceptable alternative. Leaving a disposal facility in a condition so that extensive active maintenance activities are required to ensure public health and safety could result in a considerable financial burden to the site owner and to future generations. Such active maintenance activities can continue for long time periods, and in fact tend to become self-perpetuating. Active maintenance activities such as leachate pumping and treatment represent a large source of expense without a tangible corresponding economic gain.

5.2 Comparison of Alternatives 2 (No Action), 3 (Preferred) and 4 (Upper Bound)

5.2.1 Long-Term Individual Exposures

In comparing the no action and preferred (Part 61) alternatives, it is seen that both intruder and groundwater exposures for the no action alternative are reduced over the base case. This is principally due to the low concentration (10 nCi/gm limit) of transuranic radionuclides disposed and the improved stability of the disposal facility. The added operational practices, however, for the preferred (Part 61) alternative of segregating stable waste streams from unstable waste streams and placing certain high activity waste streams at the bottom of the disposal cells further reduces potential intruder exposures at 100 years for the Part 61 case by an order of magnitude. Although a new requirement, waste segregation is an operational practice that has been and is currently being carried out for particular waste streams at existing sites. Thus, implementing this alternative on a more extensive basis is well within current waste disposal technology. Similarly, the new requirement of layering (or other special handling) of certain waste streams has long been a standard practice at disposal facilities and so this practice is also judged to be well within current waste disposal technology. Further reduction in impacts are

observed for the upper bound all stable alternative in which all waste streams are stabilized prior to disposal. Other design and operation options analyzed for this upper bound alternative are discussed later in this section.

At 500 years, comparable intruder impacts (ranging from 2 to 17 mrem/yr are observed for all three cases. In fact, due to the raise in the near-surface transuranic disposal limits for the Part 61 and all stable alternatives from 10 to 100 nCi/gm, intruder impacts for these two alternatives are slightly higher than those for the no action case. As discussed in § 4.4 of Chapter 4, however, even this small difference in impacts is probably exaggerated. Waste streams containing transuranic nuclides in concentrations between 10 and 100 nCi/gm are required in the last two cases to be layered. Waste streams disposed with a minimum of 5 meters of cover (earth and/or low activity waste streams) would still be difficult to contact after 500 years. In addition, the analysis conservatively takes no credit for the reduction in exposures that would result from stabilized waste forms which would tend to reduce potential airborne dispersion and plant root uptake.

With respect to groundwater impacts, as shown, the impacts for the Part 61 case are about a factor of three lower than the no action case for exposures to the thyroid and a factor of about four lower for exposures to the whole body. For the all stable case potential exposures are somewhat lower than the Part 61 case. Most of the radioactivity contributing to the calculated impacts is contained in the stabilized waste streams. One of the main purposes of stabilizing such high activity waste is to provide structural support for disposal cell covers, thus reducing trench cover subsidence and minimizing contact of waste by percolating water. If, however, the stabilized waste streams are disposed comingled with other unstable waste streams (as is the situation for the no action case), then much of the benefit to be achieved by waste stabilization can be lost. This is illustrated in § 4.4 of Chapter 4 by the variations in the no action and Part 61 case analysis in which reduced effectiveness was assumed for improved covers over disposal cells containing unstable waste streams. In the no action case, the increased percolation from comingled disposal raised the calculated thyroid impacts to 41 mrem/yr at the site boundary well. A similar assumption for the Part 61 case raised the calculated thyroid impacts at the boundary well to only 7.8 mrem/yr.

The results of the analysis also suggest that waste stabilization reduces the dependence upon the site to minimize radiological impacts. This is an important consideration, since there will always be some uncertainty associated with measurements and predictions of site geohydrological properties. A stabilized disposal site reduces the concern regarding the impact of these uncertainties on the potential radiological exposures arising from waste disposal.

The staff also notes that for both the no action and Part 61 case, there is still a possibility (although small) of a water accumulation problem at a disposal site having very impermeable soils. The relative radiological impacts and costs of this phenomenon, however, are much reduced for the Part 61 case as compared to the no action case. The potential for such impacts is believed to be reduced to minimum levels for the all stable case. This is presented in Chapter 4.

5.2.2 Short-Term Whole Body Exposures

Occupational exposures due to waste processing for the no action alternative are calculated to increase over the base case. This is due to the increased waste processing performed for this case. Occupational exposures due to waste transportation and waste disposal are reduced over the base case. This is principally due to the reduced volume of waste delivered to the disposal facility resulting from increased use of volume reduction techniques. Population exposures due to waste incineration are calculated to be zero for the no action alternative. Releases are only assumed to occur from waste incineration and no volume reduction through incineration is assumed for the no action alternative. Population whole body exposures due to waste transportation are reduced over that of the base case, which is again a result of the increased use of volume reduction for this case.

Occupational exposures for the preferred Part 61 alternative are higher than the no action case due to processing additional volumes of waste into a stable form or package. Such potential exposures, however, are difficult to determine since they are facility-specific and are based on the type of processing performed, facility design and layout, and on other factors. Population exposures for the Part 61 alternative follow a similar pattern. Population exposures due to waste incineration are small. Population exposures due to waste transport are slightly increased due to the slightly increased volume of waste transported to the disposal facility. Occupational exposures due to waste transport and waste disposal are about the same as those of the previous case.

Occupational exposures for the all stable alternative are judged to be greater than the Part 61 case. The difference in occupational exposures for waste processing for this case and the previous case are entirely due to the additional waste stabilization requirements. As shown, this difference is not significant.

5.2.3 Costs

Waste processing costs are estimated to be increased by $95 million for the no action alternative over the base case. These costs are presented as total costs over 20 years, the assumed lifetime of the disposal facility. These additional costs are due to the requirements to stabilize higher activity wastes prior to disposal and the volume reduction activities assumed. Waste processing costs are also increased for the preferred Part 61 alternative by an additional $23 million. This increase is due to stabilizing additional volumes of waste into a stable form or package and the additional volume reduction activities assumed. Costs for stabilization would be incurred only by disposal facility customers generating the high activity waste and not by small waste generators who mainly generate waste with only low levels of activity. Waste processing costs are significantly increased for the upper bound all stable alternative due to the placement of all wastes into a stable form or package. This cost increase would be borne by all waste generators and is the principal reason this alternative was not selected.

Transportation costs are reduced for the no action, preferred and upper bound alternatives over the base case due to the smaller volume of waste shipped but do not vary much from one case to the other.

Relative to the base case, disposal facility design and operating costs for the no action alternative have increased from $325 million to $341 million. This corresponds to an increase in unit costs from $\$325/m^3$ ($9.20) to about $\$527/m^3$ ($\$14.93/ft^3$). This increase is due to the many improvements in site operation for the no action case relative to the base case (and also to the reduced volume of waste delivered to the disposal facility for the no action case). These same improvements, however, result in lower long term post-operational costs which are projected to be on the order of $23 million for the reference site, assuming that the disposal facility functions as planned. Given the uncertainties associated with long-term disposal site stability for this case, a series of upper bound analyses was also calculated for this case assuming reduced effectiveness of disposal site covers and different disposal site conditions. Postoperational costs in these variations were calculated to range from $40 million (permeable site soils) to $46 million (moderately permeable site soils) to $58 million (impermeable site soils).

With regard to the no action case, the preferred Part 61 case results in increased design and operational costs due to segregation of stable wastes and layering of certain higher activity wastes. Improved stability results in lower institutional control and post-operational costs. A low level of maintenance is projected to be required for stable waste streams, since these waste streams are segregated from unstable waste streams. A higher level of maintenance is projected for unstable waste streams. Total post-operational costs for the preferred case are projected to be about $21 million for the reference site, assuming that the site functions as planned. This translates to a unit post-operational charge to be paid by disposal facility customers of $\$31.94/m^3$ ($\$0.90/ft^3$). These costs include costs for a five-year observation and maintenance period following disposal facility closure. In a series of upper bound variations similar to (but more conservative than) those performed for the no action case, upper bound post-operational costs for the Part 61 case ranged from $33 million (for a site with very permeable soils) to $36 million (for a site with moderately permeable soils) to $44 million (for a site with very impermeable soils)

Post operational costs for the all stable alternative are the lowest of the four cases considered. The uncertainty regarding the actual levels of costs is also the lowest of the four cases.

In conclusion, relative to the no action case, costs incurred for the Part 61 case are projected to include increased waste processing costs, somewhat increased disposal facility design and operation costs, and decreased post-operational costs. (These costs do not include the cost savings to disposal facility customers for raising the near-surface transuranic disposal limit from 10 to 100 nCi/gm. This cost savings could be as much as $19 million over 20 years.) Most of these additional costs are attributed to additional waste processing costs associated with stabilizing some additional high activity waste streams. Thus, these costs would only be incurred by disposal facility customers generating the high activity waste and not by small waste generators such as hospitals who mainly generate waste with only low levels of activity. The additional disposal facility design and operation costs are associated with the additional disposal facility operating practices for the Part 61 case of segregating unstable waste streams from stable waste streams, and of layering certain high activity (Class C) waste streams. Of these additional disposal facility costs, segregation costs are projected to be incurred by all disposal

facility customers. These costs are estimated to run at about an additional \$12.30/m³ (\$0.35/ft³) in design and operations costs. Costs for layering certain high activity waste streams are projected to be only incurred by disposal facility customers generating the high activity streams.

Due to the increased disposal facility stability for the Part 61 case, the level of long-term site maintenance is reduced for the Part 61 case in comparison to the no action case. Corresponding long-term institutional control costs to be borne by the site owner are also reduced, as are the uncertainties associated with projecting such costs. This means that the funds collected from the disposal facility cutomers to provide for post-operational activities could be reduced. Thus, lower post-operational costs to the disposal facility customers are projected for the Part 61 case.

The annual cost differential between the all stable case and both the no action case and the Part 61 case is projected to be greater. These additional costs are principally due to the increased costs to stabilize all waste streams. Such costs would be passed on to all disposal facility customers. Conversely, disposal facility design and operating costs for the all stable case would be reduced relative to the Part 61 case (there would be no waste segregation charge). Post-operational costs would be less than either of the other two cases.

The fact that the large additional costs that are projected to occur for the all stable case would be expected to be passed on to all disposal facility customers is believed to be significant. Many disposal facility customers are small entities such as hospitals or small research facilities. The waste generated by such facilities is generally of very low activity, and requiring stabilization of all waste could add up to \$450/m³ (\$12.74/ft³) in total disposal costs to be borne by such small entities. Rather than stabilizing all wastes, another option might be to provide stability through variations in disposal facility design and operation--e.g., through such possible techniques as grouted disposal, disposal into concrete-walled trenches, or extreme compaction. The additional disposal facility design and operating costs for these alternatives are projected to run at about \$80, \$369, and \$28 respectively per m³ of unstable waste disposed. Post-operational costs, however, would be reduced. Such possible techniques would also have to be developed and tested for specific disposal facilities, since past experience regarding these techniques at low-level waste disposal facilities has ranged from occasional to none. In addition, there are some occupational safety concerns regarding some of the above alternatives.

NRC staff thus judges that the preferred alternative is the one representing the final Part 61 requirements. Although the Part 61 case involves somewhat higher costs than the no action case, the potential in the Part 61 case for minimizing long-term environmental releases and costs to the site owner is enhanced. Greater protection is provided to site owners against excessive long-term costs and also provided to disposal site customers against premature closure of the disposal facility. Minimum environmental impacts and costs to the site owner are associated with the all stable case. NRC staff, however, believe that there are sufficient uncertainties associated with the cost impacts to disposal facility customers that it cannot be implemented generically at this time. This decision may change in the future, depending upon cost considerations and the application of newer waste management technologies. During licensing of specific disposal facilities, however, special attention will be given to the possibility of leachate accumulation within disposal cells.

At specific sites where such a possibility can occur, additional measures intended to eliminate this possibility will be considered.

6. WASTE CLASSIFICATION

The waste classification system developed for the Part 61 regulation follows directly from the performance objectives and technical criteria. It is intended to ensure as far as possible on a non-site-specific basis that the Part 61 requirements are met.

Three classes of waste are established:

1. Wastes for which there are no stability requirements but which must be disposed of in a segregated manner from other wastes. These wastes, termed Class A "segregated" wastes, are defined in terms of maximum allowable concentrations of certain isotopes and certain minimum requirements on waste form and packaging that are necessary for safe handling.

2. Wastes which need to be placed in a stable form and disposed in a segregated manner from unstable waste forms. These wastes, termed Class B "stable" wastes are also defined in terms of allowable concentration of isotopes and requirements for a stable waste form as well as minimum handling requirements.

3. Wastes which need to be placed into a stable form, disposed in a segregated manner from nonstable waste forms, and disposed of so that a barrier is provided against potential inadvertent intrusion after institutional controls have lapsed. These wastes are termed Class C "intruder protected" wastes and are also defined in terms of allowable concentrations of isotopes and requirements for disposal by deeper burial or some other barrier.

Finally, a "fourth" class of waste is established which is that waste which exceeds the classification limits and is generally considered unacceptable for near-surface disposal. Disposal of this waste at near-surface disposal facilities would require case-by-case determinations.

A significant number of comments and issues were raised with respect to the waste classification system. Major issues raised related to:

- Calculated waste classification limits;
- Isotopes considered;
- Volume reduction;
- Compliance;
- De minimis levels for waste;
- Classification by total hazard; and
- Manifest tracking system

6.1 Calculated Waste Classification Limits

The numerical basis for the limits calculated for the three waste classes is presented in Chapter 7, Volume 2, of the draft EIS. The principal basis used for setting the classification limits was limiting exposures to a potential

inadvertent intruder, although a number of other considerations went into setting the values--principally long-term environmental concerns, disposal facility stability, institutional control costs, and financial impacts to small entities. Waste classification represents a combination of waste form, radioisotope characteristics, radioisotope concentrations, the method of emplacement, and to some extent the site characteristics.

A number of comments were received on the calculated limits for Class C waste. NRC staff has evaluated these comments and has concluded that a rise in the Class C limits by a factor of 10 is warranted for all radionuclides. This is due to consideration of (1) the reduced likelihood of significant intruder exposures with incorporation of passive warning devices at the disposal facility, (2) the difficulty of contacting waste disposed of at greater depths, and (3) average concentrations in waste which would be expected to be considerably less than peak concentrations. The effect of the change in the Class C concentration is analyzed in Chapter 5 and summarized below.

Two cases are analyzed. In the first case, Class C limits are assumed which correspond to those established for the final Part 61 rule. For example, the limit for disposal of alpha-emitting (except Cm-242) transuranic radionuclides by near-surface disposal is set at 100 nCi/gm. The results of this case are obtained from the "preferred case" (Alternative 3) analysis presented earlier. The second case corresponds to Class C limits which were proposed for the draft Part 61 rule.

Only slight differences are observed between the two cases. Most of the differences in the calculated impact measures appear to be derived from the slightly reduced volume of waste delivered to the disposal facility for the case corresponding to the limits established in the proposed Part 61 rule. A reduced amount of waste processing is also projected for the proposed rule case relative to the final rule case. Unit disposal costs are slightly raised for the proposed rule case, however, which is due to the reduced volume of waste delivered to the disposal facility.

6.2 Isotopes Considered for Waste Classification Purposes

In the draft EIS, a total of 23 different radionuclides were considered in the numerical analysis. These nuclides were nearly all moderately or long-lived radionuclides. Based upon these 23 radionuclides, concentration limits were proposed in the draft EIS for 11 individual radionuclides plus alpha-emitting transuranics, enriched uranium and depleted uranium. In response to public comments, limits for ^{135}Cs, enriched uranium, and depleted uranium have been eliminated, as have been limits for ^{59}Ni and ^{94}Nb except as contained in activated metal. A separate limit is provided for ^{242}Cm, a transuranic nuclide with a 162.9 day half-life.

These changes are principally in response to comments on proposed Part 61 regarding the costs and impacts of compliance with the waste classification requirements. In particular, many commenters were concerned that they would have to directly measure every isotope in every waste package. This would be difficult since measurement of many of the listed isotopes--which would usually be present only in trace quantities--could not be performed except by complex radiochemical separation techniques by laboratories. Commenters were concerned that costs and personnel radiation exposures would be significantly increased.

Thus to ease the burden of compliance, the number of isotopes treated generically in the waste classification table was reduced to those judged to be needed on a generic basis for waste classification purposes. Other isotopes may be added later either generically or in specific waste streams.

6.3 Volume Reduction

Some commenters were concerned that the waste classification requirement would discourage volume reduction. This concern is believed to be alleviated by the increase in the Class C waste disposal limits. As an illustration, the volumes of waste determined to be unacceptable for near-surface disposal under extreme volume reduction conditions (waste spectrum 4) may be compared against the proposed and final Part 61 limits.

These comparative volumes are as follows:

	Unacceptable Volumes (m^3)	Percent of Total Generated
Proposed Part 61 Limits	9.42 E+3	4
Final Part 61 Limits	1.93 E+3	1

6.4 Compliance with Waste Classification

Many commenters on the draft Part 61 rule were concerned regarding acceptable procedures for determining compliance with the waste classification requirements. It was recognized in the draft EIS that developing a reasonable approach to compliance would be an important consideration. A balance is needed between the need for knowledge of waste contents and practical limitations in measurement. Based upon discussions with licensees and other interested parties, and comments on the draft EIS, a draft technical position paper has been prepared.

The staff's position is that all licensees must carry out a compliance program to assure proper classification of waste. Licensee programs to determine radionuclide concentrations and waste classes may, depending upon the particular operations at the licensee's facility, range from simple programs to very complex ones. In general, more sophisticated programs would be required for licensees generating Class B or Class C waste, for licensees generating waste for which minor process variations may cause a change in classification, or for licensees generating waste for which there is a reasonable possibility of the waste containing concentrations of radionuclides which exceed limiting concentration limits for near-surface disposal. Some licensees, such as nuclear power facilities, are expected to employ a combination of methods.

There are four basic programs, however, which may be potentially used either individually or in combination by licensees:

- Materials accountability;
- Classification by source;

- Gross radioactivity measurements; or
- Direct and "inferential" measurement of individual radionuclides.

6.5 "De minimis" Levels of Radioactive Waste

Over one-fourth of all commenters on the draft EIS endorsed the concept of setting levels for wastes below which there is no regulatory concern, the so-called "de minimis" level. The fundamental concern of practically all commenters appeared to be not whether a generic or a case-by-case approach should be taken, but rather that action to develop de minimis standards should be taken as soon as possible.

NRC staff believes that the current policy of examining waste streams on a case-by-case basis to establish "de minimis" levels will result in the quickest and best results. It is recognized that setting generic limits is a desirable goal, and NRC plans to work toward this goal over the next few years. Meanwhile, NRC staff believes that the process of examining a few specific waste streams will facilitate the development of generic requirements and is accelerating its efforts on setting standards for disposal of wastes by less restrictive means. In this regard, NRC staff is willing to accept petitions for rulemaking from licensees for declaring certain waste streams to be of no regulatory concern.

6.6 Classification by Total Hazard

Several commenters were concerned with materials which may be present in low-level radioactive waste which may be chemically toxic or hazardous. Some suggested that the Commission's waste classification system incorporate a "total hazard" approach that would consider both the radiological and chemical hazard of wastes. One commenter considered the EIS deficient in that it did not consider the health impact of hazardous chemicals in LLW. At least one comment did not favor the total hazard approach because of the very complex classification system that the commenter perceived would result.

The Commission has stated publicly on several occasions that if it were technically feasible to classify waste by total hazard, then it would make eminently good sense to do so. NRC does not now know of any scheme for such classification. The Commission will be studying the chemical toxicity of low-level waste, with special emphasis on identifying any licensees who generate hazardous wastes subject to requirements of the Environmental Protection Agency. We will look then at what could be done, perhaps through processing, to minimize the hazard.

Furthermore, the Commission believes that the technical provisions of Part 61 generally meet or exceed those expected in the Environmental Protection Agency's rules for the disposal of hazardous wastes. Although it is not the Commission's intent to allow disposal of hazardous wastes in a radioactive waste disposal facility, as is noted in the regulation, the Commission recognizes that such wastes may be present in low-level radioactive wastes. It is the Commission's view that disposal of these combined wastes in accordance with the requirements of Part 61 will adequately protect the public health and safety. Such hazardous wastes are expected to be such a small percentage of the total volume that dilution by other wastes would greatly minimize any risks. The Commission intends to work closely with the Environmental Protection Agency to assure

continued compatibility. Further, EPA in its response to a resolution of the Conference of Radiation Control Program Directors indicated their willingness to work with other Federal agencies to address this problem.

6.7. Manifest Tracking System

Based on analyses in the draft EIS a new proposed section was added to 10 CFR Part 20 (§ 20.311) which established a manifest tracking system for LLW. The system addressed the need for providing information on the classification and characteristics of waste shipped for disposal, for improved accountability of wastes and for helping establish a better data base about LLW.

The manifest required by § 20.311 is consistent with DOT shipping paper requirements and the same document may be used by licensees to meet requirements of both agencies. Section 20.311 requires more comprehensive information about the waste being shipped, e.g., specific nuclides in the waste and their quantities, waste chemical content, and waste form. No significant changes were made to the manifest requirements based on public comments. Copies of proposed Part 61 were distributed to all NRC licensees and copies were also made available to all Agreement States for their licensees. Only 29 letters commented on the manifest system. Based on these comments, several clarifying changes were made to the proposed requirements. Because of the minor nature of the comments received, NRC did not redo the analyses presented in draft EIS. No new alternatives were identified in the comments which would require changes to that analysis or final conclusions derived.

7.0 FINANCIAL ASSURANCE REQUIREMENTS

No significant changes have been made to the financial assurance requirements as proposed in 10 CFR Part 61 based on public comments. These requirements are intended to ensure that: (1) a licensee has sufficient financial resources to construct and operate the facility and to provide for final closure and post closure care; and (2) a licensee provides financial assurance for the active institutional control period after the site is closed and stabilized.

One of the major points raised by a variety of commenters was that the proposed regulation failed to address financial responsibility for unanticipated contingencies at a LLW disposal site. These comments cover two different time periods--the post-closure period, when the original licensee is still responsible at the site, and the institutional control period, when the license has been transferred to the landowner of the site for a period of up to one hundred years. In the case of the post-closure care period, the licensee would be responsible for all activities at the site found necessary by the Commission to protect the public health and safety. Financial responsibility for activities during the institutional control period are a matter to be worked out between the site owner (i.e., the state or federal government) and the licensee in its lease or other legally binding arrangement.

Several commenters considered that the rule should resolve the issue of financial responsibility for contingencies by requiring liability insurance or specific language that licensees would be required to indemnify property owners in case of off-site migration. Although not proposed in the original rule, the staff evaluation of these public comments indicates there is a need for

licensees to provide financial responsibility for liability coverage for off-site bodily injury and property damage. The four existing LLW disposal facilities currently carry this type of liability coverage. The Commission has not established a third party liability requirement in Part 61, however, since the Commission's only statutory framework for establishing such a requirement is Section 170 of the Atomic Energy Act, also known as the "Price-Anderson" Act which is designed to cover "catastrophic events." The Commission believes this coverage would be in excess of the risk at a low-level waste facility. The Commission will strongly encourage licensees to continue to carry third party liability insurance coverage through the conventional insurance market.

8.0 ADMINISTRATIVE AND PROCEDURAL REQUIREMENTS

No significant changes were made in the administrative and procedural requirements for licensing a LLW disposal facility. Because of this, no additional analysis of these requirements beyond that contained in the draft EIS was included in the final EIS. One change was made to the provisions for State and tribal participation in the NRC licensing process to provide for a more parallel evaluation of proposals by states and Indian tribes for participation in the NRC licensing process. The time required for submittal of such proposals from the state in which the site is located was reduced from 120 days to 15 days after tendering of the application. For Indian tribes and other States not covered above, the time was changed to 120 days after tendering.

As set out in the draft EIS, the life cycle of a disposal facility can be divided into five phases. These are shown and briefly described in Figure S.1.

9.0 UNMITIGATED IMPACTS OF FINAL PART 61 RULE

Both direct and indirect environmental impacts will occur as a result of the final Part 61 rule. The direct effects of the action fall upon those segments of the human environment whose conduct of affairs will be affected by the change in regulatory requirements including: generators and processors; transporters; disposal facility operators; federal agencies and the states; and the public.

The indirect impacts of the final Part 61 rule involving its effect on air and water quality, biota and social impacts are determined based on application of the performance objectives and minimum technical requirements of the rule to four reference disposal facility sites located on a regional basis. By applying these requirements to a reference facility design and analyzing the benefits and residual impacts, an estimate of the "real world" effects of the rule is provided

9.1 Environmental Consequences Occurring Directly as a Result of the Final Part 61 Rule

9.1.1 Beneficial Impacts

The requirements of the Part 61 regulation are expected to result in beneficial impacts to the public in three major areas. First, the implementation and enforcement of the rule will improve the performance of future LLW disposal

facilities and thereby reduce the potential hazards of LLW disposal. Although the benefits of the rule's requirements may not be immediately apparent, the staff believes that in the long term these requirements will improve stability and will lessen the potential for radionuclide migration and the need for active long-term maintenance of facilities.

Second, the requirements of the Part 61 rule should assure that near-surface disposal remains a safe viable option for the disposal of LLW. Therefore, the public can be assured of the continued availability of goods and services whose provision results in generation of LLW. Among these goods and services are electricity from nuclear power plants, medical diagnostic aids based on nuclear technology, research into causes and cures of debilitating diseases such as cancer, and research into new applications of nuclear technology.

Finally, the Part 61 rule provides public benefits in the form of more explicit provisions for participation in the licensing process for future LLW disposal facilities. Licensing requirements and procedures have heretofore been fragmented and somewhat difficult for interested citizens to fathom. These procedures are consolidated in the rule, and expanded provisions for participation by state and tribal governments are set out under Subpart F of the rule.

Figure S.1 Life Cycle and Financial Assurances for a Disposal Facility Following the Final 10 CFR Part 61

Time in years	Activity	Form of financial assurance
1-2 yrs	Site Selection and Characterization	Licensee responsible for costs incurred
1-2 yrs	Licensing Activities	Licensee responsible for costs incurred including license fee
		Site closure plan including cost estimates for closure is submitted as part of license application
		Lease arrangement with long-term care arrangements for financial responsibility between licensee and state submitted for review to NRC for adequacy
		Licensee obtains adequate short-term sureties to provide for closure
20-40 yrs	License Issued; Site is in Active Operation; Waste Received	Short-term sureties in place for closure: NRC periodically reviews and requires updating to account for changes in inflation, site conditions, etc.
		NRC periodically reviews revisions to lease arrangements to ensure that arrangements for financial responsibilities for long-term care are adequate

Time in years	Activity	Form of financial assurance
1-2 yrs	Site Closure and Stabilization	Costs covered from short-term sureties, if necessary; otherwise, licensee performs activities
		Lease arrangement between site owner and operator for long-term care is still in effect
5-15 yrs	Observation and Maintenance	Licensee still responsible for all further costs during this period, with short-term assurances still in place
100 yrs	License Transferred to Site Owner; "Active Institutional Control Period"	Terms and conditions of lease are met, and either state or licensee provides funds to pay for all required and necessary activities of this period

9.1.2 Adverse Impacts

The staff does not expect that implementation of the rule will be without adverse public impacts. Three primary impacts are expected to occur.

The first of these impacts will be residual environmental and human health hazards resulting from LLW disposal. Despite the provisions of the Part 61 rule, the variables and processes involved in LLW disposal are sufficiently complex that unmitigated impacts cannot be avoided. These may include occupational exposure, migration of radionuclides, and subsequent offsite exposures. (Section 9.2 discusses these unmitigated impacts.) It should be noted, however, that these impacts are not impacts caused by the rule, but rather impacts which are considered beyond the capability of the rule to eliminate entirely.

Achieving reductions in impacts from LLW disposal will not be without costs in an economic sense. Implementing the requirements of the Part 61 rule will involve costs to the disposal facility operators, waste transporters, and waste generators. These costs, of course, will be passed on to the public in the form of increased prices for goods and services whose provision involves the generation of LLW. It is not expected that the passing on of these costs will create a significant incremental change to the consumer, but rather will appear along with many other costs of doing business in aggregate price increases. These anticipated increased costs can also be balanced against the likely costs, which would be significantly higher, that could result without the promulgation of a uniform series of criteria for waste disposal. The current lack of such criteria is believed by many to significantly contribute to the current shortage of disposal capacity.

Finally, implementation and enforcement of the provisions of the Part 61 rule will require the allocation of federal and state resources during the operational and postoperational periods of a LLW disposal facility. To the extent that these public resources are allocated to regulation of LLW disposal, they

are unavailable for other purposes. Conversely, to the extent that the public incurs this cost, it reduces (within limits) the costs of LLW disposal in terms of human health hazards and environmental impacts.

9.2 Environmental Consequences Occurring Indirectly as a Result of the Final Part 61 Rule

To estimate these impacts, the performance objectives and minimal technical criteria established in the final rule are applied to four reference disposal facilities assumed to be constructed on four hypothetical regional sites. Through this analysis, the residual or unmitigated impacts that could occur even with the application of the Part 61 requirements are addressed.

9.2.1 Hypothetical Regional Sites

For the purposes of this final EIS, the conterminous U.S. has been divided into four regions having boundaries based upon the existing five NRC regions (NRC Regions IV and V are treated as one region for purposes of analysis). A disposal facility is assumed to be located at a hypothetical site within each region. Each site has been developed from a number of sources and is meant to be consistent with the basic disposal facility siting considerations set forth in the final Part 61 rule and the generic environmental characteristics within that region. The regional sites are intended to be representative of reasonable realistic sites--i.e., sites that could be licensed under the Part 61 rule--but are not intended to represent the "best" sites that could be located within the regions.

The disposal facilities and waste forms situated at the four regional sites are intended to provide an example of potential impacts associated with disposal of waste according to the minimum requirements of the final Part 61 regulation. These should not be interpreted as representing the best or the only designs or waste forms which could be implemented in compliance with the rule. There are a number of ways in which the Part 61 requirements may be met for a specific disposal facility, and compliance with the Part 61 rule, as well as measures which may be implemented to reduce potential impacts to levels as low as reasonably achievable, would be evaluated on a case-by-case basis. The examples, rather, are intended to illustrate an upper bound range of impacts from implementation of the rule, with the expectation that actual impacts from implementation of the rule at existing or future disposal facilities would be less.

9.2.2 Results of the Regional Analysis

The section is divided into 4 subsections as follows: 9.2.2.1, Long-Term Radiological Impacts; 9.2.2.2, Short-Term Radiological Impacts; 9.2.2.3, Costs; and 9.2.2.4, Other Impacts (including non-quantifiable impacts such as impacts to biota and cultural resources). Quantifiable impact measures are summarized on Table S.3.

9.2.2.1 Long-Term Radiological Impacts

Long-term radiological impacts for the regional case study as summarized on Table S.3 include potential individual and population intruder impacts, erosional impacts, and groundwater impacts. Individual inadvertent intruder

Table S.3 Summary of Quantifiable Impact Measures for Regional Analysis

	NE Site		SE Site		MW Site		SW Site
	low perc.	high perc.	low perc.	high perc.	low perc.	high perc.	
I. Long-Term Individual Exposures (mrem/yr):							
Intruder-construction							
° 100 yrs - Body	1.82E+2*		1.97E+2		2.24E+2		1.27E+2
Bone	1.83E+2		2.01E+2		2.28E+2		1.67E+2
Thyroid	1.82E+2		1.97E+2		2.24E+2		1.24E+2
° 500 yrs - Body	2.39E+0		3.36E+0		3.68E+0		1.45E+1
Bone	7.92E+0		1.85E+1		2.16E+1		1.71E+2
Thyroid	2.15E+0		2.66E+0		2.91E+0		6.76E+0
Intruder-agriculture							
° 100 yrs - Body	1.95E+2		2.18E+2		2.49E+2		1.38E+2
Bone	2.01E+2		2.23E+2		2.56E+2		1.46E+2
Thyroid	1.94E+2		2.17E+2		2.47E+2		1.37E+2
° 500 yrs - Body	2.87E+0		3.32E+0		3.53E+0		6.03E+0
Bone	8.19E+0		1.01E+1		1.04E+1		2.07E+1
Thyroid	8.58E+0		9.87E+0		1.09E+1		9.96E+0
Boundary well							
° Body	6.78E-3 -	8.57E-3	2.61E-2 -	5.59E-2	7.90E-3 -	1.04E-2	3.84E-3
° Bone	6.44E-3 -	1.25E-2	3.13E-2 -	1.04E-1	9.65E-3 -	1.75E-2	1.42E-2
° Thyroid	4.29E+0 -	4.97E+0	5.02E+0 -	9.38E+0	4.66E+0 -	5.33E+0	7.82E-1
Surface water							
° Body	**		1.50E-4 -	3.76E-4	**		***
° Bone	**		2.90E-4 -	1.02E-3	**		***
° Thyroid	**		7.23E-2 -	1.35E-1	**		***

Table S.3 Summary of Quantifiable Impact Measures for Regional Analysis (Continued)

	NE Site		SE Site		MW Site		SW Site
	low perc.	high perc.	low perc.	high perc.	low perc.	high perc.	
II. Short-Term Whole Body Exposures (total man-mrem over 20 yrs):							
Occupational							
° Process by waste generator#	+1.70E+5		+2.40E+5		+1.70E+5		+1.50E+5
° Process by regional process center	1.81E+5		7.25E+4		1.08E+5		9.13E+4
° Waste transport	4.70E+6		5.91E+6		4.26E+6		4.48E+6
° Waste disposal	2.06E+6		2.58E+6		1.73E+6		1.66E+6
To population							
° Process by waste generator#	+1.26E+2		+1.51E+2		+1.23E+2		+5.83E+1
° Process by regional process center	0.		0.		0.		0.
° Waste transport	3.79E+5		5.86E+5		6.07E+5		1.07E+6
III. Costs (total $ over 20 yrs):							
Waste generation and transport							
° Process by waste generator#	+2.20E+7		+2.90E+7		+2.10E+7		+1.60E+7
° Process by regional process center	5.29E+7		2.10E+7		3.14E+7		2.66E+7
° Waste transport	1.22E+8		2.04E+8		2.01E+8		3.05E+8
Waste disposal							
° Design & op.	3.51E+8		3.54E+8		3.42E+8		3.29E+8
° Postoperational							
Closure	3.87E+6		3.87E+6		3.87E+6		3.87E+6
Obs. & maint.	1.13E+6 -	1.42E+6	1.14E+6 -	1.43E+6	1.11E+6 -	1.39E+6	5.86E+5
Inst. Control	1.57E+7 -	3.86E+7	1.57E+7 -	3.06E+7	1.54E+7 -	2.96E+7	9.32E+6
Total post op.	2.07E+7 -	4.38E+7	2.07E+7 -	3.59E+7	2.04E+7 -	3.49E+7	1.38E+7
° Total disp. cost	3.72E+8 -	3.95E+8	3.75E+8 -	3.90E+8	3.62E+8 -	3.77E+8	3.43E+8
° Unit cost ($/m^3)	5.70E+2 -	6.06E+2	5.03E+2 -	5.24E+2	7.06E+2 -	7.34E+2	6.79E+2

Table S.3 Summary of Quantifiable Impact Measures for Regional Analysis (Continued)

	NE Site		SE Site		MW Site		SW Site
	low perc.	high perc.	low perc.	high perc.	low perc.	high perc.	
IV. Waste Volume (m^3):							
Volume acceptable	6.52E+5		7.17E+5		4.95E+5		4.88E+5
° Class A unstable	4.25E+5		4.72E+5		3.12E+5		3.25E+5
° Class A stable	1.56E+5		1.73E+5		1.27E+5		1.28E+5
° Class B	6.76E+4		6.70E+4		5.33E+4		3.26E+4
° Class C	3.26E+3		4.34E+3		2.97E+3		2.18E+3
Volume not acceptable	1.69E+4		2.80E+4		1.82E+4		1.67E+4

*The notation 1.82E+2 means 1.82×10^2.

**Less than $1. \times 10^{-6}$ millirem/year.

***Impacts at the surface water body are not given for the southwest site due to the intermittent nature of the nearest stream to the site and the extreme depth to groundwater at the site.

#In this EIS, population exposures due to waste processing by waste generators, occupational exposures due to waste processing by waste generators, and costs due to waste processing by waste generators are presented as impacts and costs in addition to those associated with a no action case (i.e., continuance of current disposal practices).

impacts are calculated for two scenarios for two time periods (100 and 500 years) following transfer of the disposal facility to the site owner for the whole body, bone, and thyroid.

As shown, the limiting individual inadvertent intruder impacts are to the bone although in all cases the Part 61 performance objective for inadvertent intrusion is met.

Potential impacts from groundwater migration are listed for three different organs (whole body, bone, and thyroid) for two different biota access locations:

1. A well (boundary well) located at the site boundary which is assumed to be used by a few individuals;

2. A small stream (surface water access) located down-gradient of the disposal facility and assumed to be used by a small population of about 300 persons.

As shown in Table S.3, the highest exposures due to ground-water migration are to the thyroid, although in all cases the Part 61 performance objective for environmental releases is met. The estimated impacts reflect the differing volumes of waste streams and corresponding radionuclide inventories within each regional facility, as well as the differing environmental characteristics of each regional site.

For the high percolation northeast case, it is possible that the disposal cells containing unstable waste could accumulate water and fill up like a bathtub. This could lead to overflow of the disposal cells.

Leachate accumulation impacts are, therefore, calculated for the northeast site to demonstrate representative impacts that could potentially occur from such a situation. Waterborne impacts are calculated assuming that 425,000 gallons of leachate annually overflow the unstable waste disposal cells. This overflow is assumed to be carried to a nearby stream where contaminated water is consumed by an individual. The impacts to the surrounding population from processing the leachate through an evaporator are also calculated. The results of this calculation are as follows:

	Body	Bone	Thyroid
Individual dose from disposal cell overflow (mrem/yr)	6.64E+1	1.14E+2	4.37E+1
Population dose from leachate treatment (man-millirem/yr)	1.98E+2	7.40E-1	1.98E+2

It would appear that additional efforts to achieve site stability and reduce percolation would be called for at sites in which there is a potential for water accumulation problems.

9.2.2.2 Short-Term Radiological Impacts

Short-term radiological impacts are also summarized in Table S.3. Included are (1) potential impacts to populations (in man-mrem) from transporting waste to the regional facilities, (2) potential occupational impacts (in man-mrem) associated with processing, transporting, and disposing of waste within the region, and (3) potential impacts from incinerating small volumes of waste at the waste generator's facilities.

As shown, transportation impacts over 20 years range from about 380 to 1,070 man-rems, or about 19 to 54 man-rems per year.

Occupational impacts are listed as total impacts over 20 years for waste processing, transportation to the disposal facility, and waste disposal. Waste processing occupational exposures are presented as additional exposures to those associated with a "no action" situation. That is, these exposures are presented as incremental exposures to those that would be received if existing disposal practices and facility license conditions were continued.

Also included are the occupational exposures that are estimated to be associated with operation of regional processing centers. This waste processing is assumed to consist of compaction of compressible waste streams by large compactor/shredders.

9.2.2.3 Costs

Costs, including waste processing, transport, and disposal costs are listed in Table S.3. Similarly to occupational exposures, costs due to processing the waste by the waste generator are presented as additional costs to those associated with a continuation of existing disposal facility practices and license conditions. These costs include costs for waste volume reduction as well as for waste stabilization.

Waste disposal costs are set out into design and operational costs and postoperational costs, where postoperational costs include costs to waste customers (over 20 years of operation) for providing for: (1) facility closure, (2) a 5-year observation and maintenance period, and (3) 100 years of institutional control. Also shown are total disposal costs as well as unit ($\$/m^3$) costs.

As shown, the largest total design and operational costs are for the northeast and southeast sites, due to the larger volumes of waste delivered to these two sites. The southwest site is projected to experience a low level of postoperational costs, due to the semiarid nature of the site.

Postoperational costs for the northeast, southeast, and midwest sites are presented in Table 6.5 as a range from a reasonable to a worst case, corresponding to the variation in percolation into the disposed unstable waste streams. A low level of postoperational costs is projected for the stable waste streams. A moderate (reasonable case) to high (worst case) level of postoperational costs, however, is assumed for the unstable waste streams.

The presentation of the worst case here is believed to be very conservative, since it discounts improvements in disposal facility operations which could be implemented to help to reduce water contact with the unstable waste streams. It also discounts the increased use of compaction for the compressible waste streams. Such compaction would tend to retard the rate of subsidence and slumping associated with the unstable waste disposal cells.

Unit costs are seen to vary widely depending upon the assumed design and operating practices carried out at the particular disposal facility as well as the volumes of waste delivered to the facility. For example, the design and operation of the southeast site is essentially the same as the midwest facility. However, the volume of waste delivered to the midwest facility is much less than the southeast facility, while the design and operational costs are only slightly less. This is because capital costs to construct the disposal facility are much less dependent upon the volumes of waste delivered to the facility than the operating costs. Many of the same expenses to design, build, and operate the facility would be incurred whether a high or a low volume of waste was received.

9.2.2.4 Other Impacts

Air Quality

Nonradiological impacts to air quality due to LLW management and disposal would principally arise from two sources: combustion of fossil fuels during processing, transporting, and disposing of waste and (2) particulate matter (dust) released into the air due to earth moving activities at the disposal facility. It is believed that implementation of the Part 61 regulation would have little if any effect upon overall air quality.

Biota

The operation of a disposal facility would involve acquiring and fencing in up to a few hundred acres of land. During this process, impacts to biota could result from destruction of habitat. Such impacts would again not be caused by the fact that the facility is used for waste disposal, but arise from the decision to change the land from one use to another. Similar types of impacts would result from other land uses involving construction such as a small industrial concern, a school, a farm, and so forth. Implementation of the Part 61 rule is expected to have little effect on the potential for impacts to biota.

Land Use

Possible future use of a LLW disposal facility after it has closed is greatly influenced and somewhat circumscribed by the presence of the disposed waste. This does not mean that land used for LLW disposal is permanently excluded from productive use. Rather, as long as care was taken to restrict activities to those which would not involve excavating into the disposed waste or bringing contamination to the surface, there may be a number of useful purposes the facility surface may be put to. These could possibly include use of the facility for golf courses, recreational areas, or light industry.

It is difficult to assess the influence of the Part 61 regulation on this land use. A range of land uses may be estimated, using the regional analysis as a guide. Land use for each of the regions is shown below.

Land Use ($m^2 \times 10^5$)			
Northeast	Southeast	Midwest	Southwest
2.26	2.49	1.72	1.69

<u>Energy Use</u>

One way in which the effects of a proposed action can be quantified is to estimate the total energy requirements associated with that action. In terms of LLW management and disposal, this would be a difficult project given the large number of waste generators, the many different types and forms of LLW, and the many possible processing techniques that could be used.

The estimated increase in energy use due to the Part 61 regulation is listed below in gallons of equivalent fuel for each region for the range of post operational activities projected.

Energy Use (gal $\times 10^5$)			
Northeast	Southeast	Midwest	Southwest
+0.83 - +0.96	+1.11 - +1.31	+0.90 - +1.00	+0.66

<u>Social Impacts</u>

In general, social impacts due to promulgation of the final Part 61 regulation are difficult to address. These impacts are very site-specific and would include such aspects as the effect of bringing a labor force into an area on local utilities, schools, and other services. These types of impacts are typically of most concern during the siting, construction, and operation of large facilities such as a large nuclear power plant. A low-level waste disposal facility is by comparison a very small operation, and the final Part 61 regulation is not expected to result in any significant incremental changes in social impacts associated with operation of LLW disposal facilities.

Chapter 1

INTRODUCTION

1.1 PURPOSE, SCOPE, AND NEED OF THE FINAL EIS

1.1.1 Description of the Proposed Action

The action being considered in this final environmental impact statement (final EIS) is the issuance of a new regulation, Part 61, to the U.S. Nuclear Regulatory Commission (NRC) rules in Title 10, Code of Federal Regulations (10 CFR). The new Part 61 provides licensing procedures, performance objectives and technical requirements for licensing the land disposal of "low-level" radioactive waste (LLW).

There are four principal purposes to the regulation:

- o Establish performance objectives for the land disposal of radioactive waste;
- o Establish the technical requirements for disposal of radioactive waste by near-surface disposal including limits on the form and content of waste acceptable for near-surface disposal;
- o Establish the administrative and procedural requirements which NRC will follow in licensing the land disposal of radioactive waste; and
- o Establish a manifest system.

1.1.2 Purpose

NRC has a two-fold purpose in preparing this EIS. First, it is to fulfill NRC's responsibilities under the National Environmental Policy Act of 1969 (NEPA) (Ref. 1). NRC has also prepared this EIS to demonstrate the decision process and bases applied in the establishment of technical requirements and licensing procedures included in the Part 61 regulation. It is the intent of NEPA to have federal agencies incorporate environmental values into the decision-making process to assure a thorough consideration of such values. NRC has considered and analyzed alternative courses of action and requirements were selected with full consideration of public views and the environmental, health, and safety effects to current and future generations.

1.1.3 Scope

This EIS analyzes requirements for the land disposal of radioactive waste and specifically near-surface dispoal. Near-surface disposal involves disposal in the uppermost crust of the earth, generally within 30 meters of the earth's surface. Near-surface disposal technology may also involve burial at depths greater than 30 meters. This EIS does not address other methods of disposal such as ocean disposal.

This EIS is not a generic EIS. It does not attempt to analyze all of the issues that are involved in the disposal of LLW. Rather, it is specific to providing a decision analysis leading to the establishment of the technical requirements and procedures for licensing the disposal of LLW. Only issues that are germane to this decision process are analyzed and considered.

1.1.4 Need For The Proposed Action

Current NRC regulations for licensing radioactive materials do not contain sufficient technical standards or criteria for the disposal of licensed materials as waste. Comprehensive standards, technical criteria and licensing procedures are needed to ensure the public health and safety and long-term environmental protection in the licensing of new disposal sites. They are also needed with respect to operation of the existing sites and with respect to final closure and stabilization of all sites. The development of these regulations has been in response to needs and requests expressed by the public, Congress, industry, the States, the Commission and other federal agencies for codification of regulations for the disposal of LLW. Respondents to the advance notice of proposed rulemaking published on October 25, 1978 strongly supported the Commission's development of specific standards and requirements for the disposal of LLW.

1.1.5 Scoping For The Final EIS

NRC has conducted scoping activities for the Part 61 rule and this EIS since 1978. Included have been:

(1) Public comments in response to an Advance Notice of Proposed Rulemaking on the LLW Disposal Regulation (10 CFR Part 61) published in the Federal Register on October 25, 1978 (Ref. 2);

(2) Public comments on a preliminary draft of 10 CFR Part 61 dated November 5, 1979 (Ref. 3). On February 28, 1980, the Commission also published a Notice of Availability of the November 5, 1979 preliminary draft regulation, announcing its availability for public review and comment (Ref. 4). Copies of the draft regulation were distributed to all of the states;

(3) During the summer and fall of 1980, four regional workshops were held on Part 61 sponsored by the Southern States Energy Board, the Western Interstate Energy Board, the Midwest Regional Office of the Council of State Governments and the New England Regional Commission (Refs. 5, 6, 7, and 8). The workshops provided an opportunity for open dialogue among representatives of the states, public interest groups, the industry, and others on the issues to be addressed through the Part 61 rulemaking. These workshops were particularly useful in formulating our positions on the more judgmental aspects of the rule and underlying assumptions (such as the length of time we should assume that active governmental controls could reasonably be relied on);

(4) Input from the State Planning Council, the National Governors Association, the National Council of State Legislators, and the National Conference of State Radiation Control Program Directors;

(5) A Natural Resources Defense Council Petition for Rulemaking (Ref. 9);

(6) Discussions with industry, public interest groups, state and federal agencies, and others;

(7) Licensing experience and current LLW management techniques at existing disposal sites;

(8) Programs of the Environmental Protection Agency to develop standards for LLW disposal and regulations for disposal of nonradioactive solid and chemically hazardous wastes; and

(9) The results of federal, state, and other organization's studies and technical data on LLW management and disposal.

Public participation in the development of Part 61 and analyses of the major scoping activities and public comments are discussed in detail in Appendix C of the draft EIS (Ref. 10).

In addition, proposed 10 CFR Part 61 was published on July 24, 1981 for public comments (Ref. 11). The 90-day comment period was extended to January 14, 1982 to coincide with the 90-day comment period for the draft EIS. The availability of the draft EIS was announced on October 22, 1981. Public comments received on both the rule and draft EIS have been used in preparing this final EIS. The analysis of comments is contained in Appendices A and B.

1.2 STRUCTURE AND APPROACH FOR PREPARATION OF THE FINAL EIS

1.2.1 Structure of the Final EIS

This final EIS has been prepared in accordance with requirements of the National Environmental Policy Act (NEPA), following Council on Environmental Quality (CEQ) regulations (Ref. 12) for preparation of environmental impact statements and following NRC implementing regulations set out in Title 10, Code of Federal Regulations, Part 51, "Licensing and Regulatory Policy and Procedures for Environmental Protection."

The EIS is divided into three volumes. Volume 1 contains the summary and six chapters which are listed and summarily described below:

Chapter 1 - "Introduction" describes the proposed action and presents the purpose, scope, need and structure of the EIS. It also describes how NRC has utilized data prepared and presented in the draft EIS and comments filed on the draft in preparing this final statement.

Chapter 2 - "Description of the Affected Environment" presents background information about LLW, describes the affected environment, and reviews the historical basis for the Part 61 rule.

Chapter 3 - "Analysis of Comments on the Draft EIS" summarizes the major comments received, changes made and actions taken by the staff in response to the comments.

Chapter 4 - "Analysis of Alternatives" describes the pathways of exposure analyzed, impact measure used, specific alternatives analyzed and presentation of results.

Chapter 5 - "Conclusions and Discussion of Requirements" presents final conclusions and requirements derived from the analysis of alternatives.

Chapter 6 - "Unmitigated Impacts of Final Part 61 Rule" presents the typical and unmitigated impacts of the Part 61 rule based on analysis of disposal of waste on a regional basis following the final requirements in Part 61.

Volumes 2 and 3 contain a series of supporting appendices.

Volume 2

Appendix A - Staff Analysis of Public Comments on the Draft EIS for 10 CFR Part 61
Appendix B - Staff Analysis of Public Comments on Proposed 10 CFR Part 61 Rulemaking

Volume 3

Appendix C - Revisions to Impact Analysis Methodology
Appendix D - Computer Codes Used for Final EIS Calculations
Appendix E - Errata for the Draft EIS for 10 CFR Part 61
Appendix F - Proposed Final Rule and Supplementary Information

1.2.2 Method of Preparation

The approach NRC has followed in preparation of this final EIS is to present, in a concise manner, the final decision bases, conclusions (costs and impacts) of NRC's analysis of LLW disposal as reflected in the requirements of Part 61. NRC has chosen not to republish the exhaustive and detailed analysis of alternatives presented in the draft EIS.

Based on public comments received and NRC's analysis of those comments (see Chapter 3 and Appendices A and B of this final EIS) no new alternatives or principles were identified which required analysis. No major changes are required for several specific requirements of Part 61 including the overall performance objectives which should be achieved in the land disposal of LLW, administrative and procedural requirement for licensing a LLW disposal facility and the requirements for financial assurance. Many clarifying and explanatory changes are, however, required with respect to specific rule provisions. Several changes are also made with respect to the EIS relating to the method of cost analysis used, certain analyses of the impacts of waste classification, and a new pathway (trench overflow and leachate treatment) is analyzed.

Given this conclusion and the public comments that the number of alternatives should be reduced to a smaller understandable number, NRC has chosen not to republish the extensive analysis of alternatives as presented in the draft EIS. Rather, NRC has grouped the alternatives analyzed into 4 major alternatives which present the basis for decisions made regarding requirements included in Part 61.

NRC has concentrated its efforts in this final statement on analysis of those areas where changes have been made based on public comments and to present a clearer analysis of the costs and impacts of alternative technical requirements for the near-surface disposal of LLW which can be applied to ensure the overall performance objectives are met. Thus, the final EIS concentrates on analysis of the costs and environmental impacts from continuation of existing practices in near-surface disposal of waste (the no action alternative) and from application of improvements to existing practices that would be implemented due to requirements established by Part 61. Finally, this EIS collectively considers all the final Part 61 requirements and presents the typical and unmitigated impacts of the final Part 61 rule. This is accomplished through analysis of the disposal of LLW at a grouping of regional sites that are operated in compliance with the Part 61 requirements.

The draft EIS, thus, serves as a resource and reference document to the final EIS. Changes made to the draft EIS and assumptions used in the analyses based on public comment are noted and used in the final EIS. Other changes to the draft which are not critical to the analyses are presented in errata to the draft EIS in Appendix E. In this way, the analyses and conclusion of the final EIS reflect the work presented in the draft EIS and any changes and modifications made based on public comment. NRC staff hope that by presenting a more concise statement of the alternatives analyzed, changes made based on public comments and final conclusions, the final EIS will be of more manageable size, easier to understand and the costs for publication and distribution will be reduced.

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Chapter 2

DESCRIPTION OF THE AFFECTED ENVIRONMENT

This chapter has been prepared to describe the affected environment and to provide the reader with background information about LLW and about the historical basis for the requirements in the Part 61 regulation. In preparing this EIS, the staff has assumed a basic level of knowledge about the structure of matter, radioactivity and radioactive decay. The reader is referred to references 1 and 2 as well as any high school or college physics or physical science textbook for background information on these topics. The reader is also referred to NCRP Report No. 39 (Ref. 3) for background information about basic radiation protection criteria.

2.1 DESCRIPTION OF THE AFFECTED ENVIRONMENT

The environment affected or potentially affected by the generation, transport, and disposal of LLW encompasses the whole of the nuclear industry and much of society. It consists of all the industries, hospitals, private individuals, and governmental agencies and laboratories that generate LLW through the use of radioactive materials as a normal part of their day-to-day activities and functions. It consists of those involved in supplying waste processing and packaging services at waste generator facilities, and transporting waste from waste generators to disposal facilities. It consists of those involved in the ownership, operation, and long-term control of the disposal facilities. It involves the various regulatory agencies such as NRC, the Department of Transportation (DOT) and the state radiation control programs that license, regulate, and inspection all waste management phases to assure an adequate level of safety. It consists of society: the individuals, small population groups, and the general population that can be potentially affected by the various activities involved in the generation and disposal of waste. Finally, it consists of the natural environment including the ground and surface water, the atmosphere, and various plant and animal species that would be affected by site-specific activities. Additional details regarding specific parts of the affected environment are contained in the following sections.

2.2 LOW-LEVEL WASTE

The term "low-level waste" serves as a general term for a very wide range of radioactive wastes. All industries; hospitals; medical, educational, or research institutions; private or government laboratories; or facilities forming part of the nuclear fuel cycle (e.g., nuclear power plants, fuel fabrication plants) utilizing radioactive materials as a part of their normal operational activities generate so-called low-level radioactive waste just as they generate other types of hazardous and nonhazardous wastes. LLW consists of the radioactive materials themselves and other materials which have been in contact with radioactive material and are contaminated or suspected of being contaminated. Because of the wide range in the types of activities and in specific purposes of application, LLW is generated in many waste types, forms, and amounts. It ranges from trash that is only suspected of being contaminated to highly radioactive material such as activated structural components from nuclear power reactors. The form of the generated waste can be solid, liquid, or gaseous. It can consist of a wide range of chemical forms and can be shipped in a number of different types of packages.

2.3 VOLUME OF LLW GENERATED

Currently, about 85,000 m^3 (3 million ft^3) of LLW is generated and disposed of at the commercial LLW disposal sites annually. Based on projections of LLW volume prepared by NRC for the waste streams considered in this EIS, about 3.62 million m^3 (128 million ft^3) will be generated during the period 1980-2000. Of this, about 65% of the waste is projected to be generated by fuel cycle sources and 35% by nonfuel cycle sources.

2.4 LLW GENERATORS

LLW is generated by more than 20,000 companies, institutions, laboratories, and government facilities licensed by the NRC or Agreement States to use radioactive materials as a normal part of their day-to-day activities. This includes fuel cycle facilities such as nuclear power plants, uranium hexafluoride conversion plants and fuel fabrication facilities; institutional waste generators, such as colleges and universities, medical schools, private physicians and hospitals; and industrial generators such as research and development labs, manufacturing companies, pharmaceutical suppliers and quality control labs. Most of the activity disposed of at the commercial sites is generated by less than 100 licensees.

2.4.1 Fuel Cycle Facilities

The LLW produced by commercial nuclear power plants can be divided into six basic categories: ion exchange resins, concentrated liquids, filter sludges, compactible trash, noncompactible trash and nonfuel irradiated reactor components. Ion exchange resins are used in reactors to remove dissolved radioactivity from liquid streams. When spent, they are exchanged and the spent resins are placed into a shipping container (usually referred to as a liner) where excess water is removed (dewatering) prior to transfer to a disposal site. In some cases the spent resins may be solidified with binders such as cement or synthetic polymers. Resin waste in shipping containers is usually transported in a cask or overpack that is shielded for radiation protection purposes. Concentrated liquid waste is produced by the evaporation of a wide variety of reactor liquid streams. These concentrated liquids are solidified in various materials such as cement, placed in a shipping container, and shipped to a disposal site. Filter sludge is waste produced by precoat filters and consists of powdered filter material. It is used to remove suspended and dissolved material from liquid streams. Filter sludge waste is generally dewatered and placed into a container for disposal. Compactible and noncompactible trash consists of everything from paper towels, plastic, and glassware to metallic components such as pipes and contaminated tools. Nonfuel irradiated components consist of fuel channels, control rods, and in-core instrumentation that has been exposed to in-core neutron flux.

Other fuel cycle waste streams include process waste and trash from uranium hexafluoride and fuel fabrication plants. This can include calcium fluoride generated in hydrogen fluoride gas scrubbers, filter sludges and paper, plastic, equipment and other trash. These are generally packaged in 55 gallon drums or larger containers and shipped for disposal.

2.4.2 Nonfuel Cycle Facilities

Institutional waste generators use radioactive materials in many diverse applications including analytical instruments, diagnosis and therapy, research and instruction. The type of waste generated generally falls into six groups: liquid scintillation vials, liquids, biological wastes, trash, accelerator targets and sealed sources. Liquid scintillation vials are made of glass or plastic and contain organic solvents and small amounts of radioactivity. They are ususally packaged in 55-gallon drums with absorbent material for disposal. Absorbed liquids consist of organic and aqueous liquids generated by various preparatory and analytical procedures involving radioactive material. They are absorbed on media such as diatomaceous earth and packaged in 55-gallon or smaller drums. Biological wastes consist of animal carcasses, tissues and culture media used in research programs. It is usually treated with lime and packaged in 55-gallon drums for disposal. Institutional trash consists mostly of paper, rubber, plastic, broken labware and disposable syringes. Sealed sources consist of radioactive material that has been encapsulated to contain and prevent leakage of the material. Sealed sources are packaged in a shielded container for transport and are sometimes disposed of in toner tubes or caissons backfilled with concrete.

The use of radioactive materials and resulting wastes produced by industrial waste generators are diverse and can consist of: sealed sources, compactible trash, radioisotope production wastes, and a range of biological, scintillation and absorbed liquids similar to those generated by medical and educational institutions.

2.5 DISPOSAL OF LLW

Waste is disposed of by a method generally known as shallow land or near surface disposal (NSD). This method of waste disposal consists of placing packaged waste into excavated trenches. The filled trenches are backfilled with soil, capped, and mounded to facilitate rainwater runoff.

The operators of the disposal facilities offer the essential services of providing a licensed and controlled site for disposal of radioactive waste. Presently, there are 6 commercial sites: 3 operating and 3 closed. One of the operating sites, located at Barnwell, South Carolina, is operated by Chem-Nuclear Systems, Inc. The other two operating sites, located at Beatty, Nevada and Richland, Washington are operated by U.S. Ecology, Inc. The commercial sites are summarized in Table 2.1 below. The Department of Energy (DOE) also operates 14 sites throughout the country for the disposal of wastes generated from certain defense and all DOE research and development activities. These 14 sites are not subject to NRC or Agreement State regulatory jurisdiction.

2.6 FEDERAL AND STATE RESPONSIBILITIES IN COMMERCIAL LLW DISPOSAL

There are five key federal agencies that administer programs regarding the management and disposal of LLW. These include the Nuclear Regulatory Commission (NRC), the Environmental Protection Agency (EPA), the U.S. Geological Survey (USGS) in the Department of Interior, the Department of Energy (DOE), and the Department of Transportation (DOT).

Table 2.1 Commercial Waste Disposal Sites

Location	Operator	Originally Licensed By (Year)	Currently Licensed By	Operational Status
Beatty, Nevada	U.S. Ecology, Inc.	AEC (1962)	State	Open
Maxey Flats Kentucky	U.S. Ecology, Inc.*	Kentucky (1962)	State	Closed
West Valley, New York	Nuclear Fuel Services, Inc.	New York (1963)	State	Closed
Richland, Washington	U.S. Ecology, Inc.	AEC (1965)	State and NRC**	Open
Sheffield, Illinois	U.S. Ecology, Inc.	AEC (1967)	NRC	Closed
Barnwell, S. Carolina	Chem-Nuclear Systems, Inc.	South Carolina, (1971)	State and NRC**	Open

*U.S. Ecology was the operator while the site was open. Currently, Hittman, Inc. maintains the site as a caretaker for the State of Kentucky.
**NRC licenses only special nuclear material.

NRC has regulatory responsibility for use of source, byproduct, and special nuclear material including control of LLW disposal at licensed facilities. NRC carries out its responsibilities in compliance with overall federal radiation protection guidance and environmental standards established by the Environmental Protection Agency. EPA was charged with this responsibility in the Reorganization Plan Number Three of 1970. The U.S. Geological Survey is responsible for basic research in the geological sciences and assists in the development of basic data for application in the development of criteria. The U.S. Department of Transportation has the primary responsibility for regulating waste containers and other aspects of the interstate transport of radioactive waste. The Department of Energy carries out federal responsibilities for the research, development, and transfer of LLW disposal technology to commercial industry.

In discharging its responsibilities, NRC is permitted by the Atomic Energy Act to relinquish part of its regulatory authority over source, byproduct, and special nuclear material to the states. States which have assumed regulatory authority are termed Agreement States and currently, there are 26 such Agreement States. Licensing of commercial LLW disposal facilities is part of the NRC's authority which may be assumed by an Agreement State. Of the six commercial disposal facilities which have operated in the United States, five of these facilities are located in Agreement States and are principally regulated by the Agreement States (See Table 1.1).

2.7 REGULATORY PROGRAM FOR LLW DISPOSAL

Existing NRC regulations for commercial LLW disposal in licensed disposal facilities are principally contained in a few paragraphs in 10 CFR Part 20 (§20.302). The requirements mainly describe in general terms the type of information to be included in an application for a disposal facility and require that LLW disposal facilities must be sited on land owned by the state or federal government. In practice, this requirement has been met through lease conditions between the disposal facility operator and state landlords which provide that the States assume responsibility for long-term control and surveillance of the facility site after closure. Licensing of the six commercial sites has, therefore, been performed by NRC or the Agreement States on a case-by-case basis following these general requirements in Part 20 or compatible provisions in Agreement State regulations.

Other NRC regulations, Part 30 ("Rules of General Applicability to Domestic Licensing of Byproduct Material"), Part 40 ("Domestics Licensing of Source Material"), and Part 70 ("Domestic Licensing of Special Nuclear Material")-- apply to possession of licensed material by a disposal facility licensee. Part 2 ("Rules of Practice for Domestic Licensing Proceedings") contains general requirements for NRC licensing proceedings. Part 51 ("Licensing and Regulatory Policy and Procedures for Environmental Protection") contains requirements for compliance with the National Environmental Policy Act of 1969 (NEPA).

To the extent that a new regulation such as Part 61 represents a change in NRC's radiation protection program for source, byproduct, and special nuclear material, it is necessary that the Agreement States cooperate in the formulation of compatible regulations and revise their existing regulations as necessary. Current NRC regulations regarding NRC's relationship with the Agreement States are contained in 10 CFR Part 150.

2.8 BRIEF HISTORY OF LLW DISPOSAL

The disposal of commercial LLW by near surface disposal generally followed from the practices and procedures utilized by the Atomic Energy Commission (AEC) at national laboratories involved in atomic energy research and development and defense programs. Activities in the programs involving use of radioactive materials generated quantities of radioactive waste and means had to be developed for their disposal.

Two principal methods of disposal were utilized: near surface disposal (NSD) and ocean disposal. The practice of NSD was quickly adopted as the preferred disposal practice. This technique could be utilized near the point where the waste was being generated, avoiding unnecessary transportation which might jeopardize the security of the project in the event of a transportation accident. In addition, NSD proved to be a fairly cost-effective technique as it employed practices commonly used in sanitary landfill operations and did not require unusual equipment or construction techniques.

With the growth of commercial applications, the AEC announced in 1960 that regional land burial sites for commercial LLW should be established on federal- or state-owned land and that the sites should be operated by private contractors subject to government licensing authority. With this announcement, the AEC indicated that its disposal sites would only be available for commercial

use until adequate disposal capacity was established in the private sector. As an interim measure, pending designation of regional commercial waste sites, the AEC also announced that disposal sites at Idaho Falls, Idaho and Oak Ridge, Tennessee would continue to accept commercial wastes for disposal.

At the same time, the AEC also initiated a phase-out of sea disposal operations by placing a moratorium on the issuance of new sea disposal licenses. Existing licenses remained in effect and were phased out. The last disposal of commercial wastes at sea took place in June 1970.

In September 1962, the AEC licensed the first commercial land burial site at Beatty, Nevada and, during the period 1962-1971, five additional commercial sites were licensed by the AEC or Agreement States resulting in a regional distribution of commercial disposal sites as shown in Table 1.1. In May 1962, the AEC withdrew its program of interim acceptance of commercial waste at Idaho Falls and Oak Ridge.

2.9 HISTORICAL BASIS FOR LLW DISPOSAL REGULATIONS

Over the past 35 years, considerable experience has been gained at both government and commercial disposal facilities. This section reviews the historical record of past disposal practice to see which practices have worked well, areas where improvements are needed and the level of performance of existing sites. This material has been taken from NUREG/CR-1759, "Review of Low-Level Radioactive Waste Disposal History" (Ref. 4).

In general, the overall performance of the existing LLW disposal facilities has been marginal to very good. Problems have been encountered at several sites although these problems have not resulted in any threat to the public health and safety. Of most significance have been problems with site instability which have led to maintenance problems at the three closed sites. The problems have thus, involved economic and social resource commitments not originally anticipated to care for and maintain the sites. The instability experienced at these sites also makes prediction of long term performance difficult as well as the need to commit funds and personnel to correct areas of instability to ensure that problems of public health and safety significance do not develop. The experiences at these sites point out that a combination of unstable waste forms, specific site characteristics and certain design and operational practices led to problems of instability. They also point out problems with respect to financial assurance and institutional control of the sites. Each is discussed in further detail below.

2.9.1 Closed Sites

Maxey Flats

The difficulties experienced at the Maxey Flats site were caused by a number of interrelated factors, including site characteristics, waste form, site design and operation, and institutional considerations. Although the difficulties have not caused significant off-site exposures, they have resulted in considerable expenditures of money by the Commonwealth of Kentucky to maintain the site in a safe condition. These expenditures were neither planned for nor funded for while the disposal facility was operating. They have also resulted in uncertainties in predicting the levels of future impacts and required maintenance.

Siting factors contributing to the difficulties included a humid environment coupled with a complex site geology. The low permeability of most of the site soils, along with the humid environment and site operational practices, has resulted in a water accumulation problem (the "bathtub" effect) in many of the disposal trenches.

In addition, numerous fractured formations exist in the subsurface media. In general, the locations and extent of fractured formations cannot be ascertained, and they raise the possibility of subsurface migration of radionuclides. Consequently, they significantly increased the difficulty of predicting the long term performance of the site.

The waste form has probably been one of the most significant factors leading to the current difficulties. The waste farms sent to Maxey Flats reflected the general practices of the times. Licensees were encouraged to send all suspect wastes for disposal. Waste minimization or volume reduction were not required on a technical or economic base. Most of the waste that was disposed into the site is believed to have been either composed of very easily degradable material or packaged so that large void spaces existed within the waste or between the waste and the packaging. Frequently, these easily degradable waste streams contained little or no radioactivity. Some of the waste packages (such as cardboard and fiberboard boxes) were often easily degradable. The wastes often contained chemical agents that helped to further increase waste degradation and leaching of radionuclides.

As the waste material degrades and compresses, a process which is accelerated by contact by water, additional voids are produced. This leads to settlement of the disposal trench contents, followed by subsidence or slumping of the disposal trench covers. This increases the percolation of water into the disposal trenches, accelerating the cycle. This slumping and subsidence is frequently quite sudden.

Initially, much of this slumping would be expected to be caused by compression of the wastes packaged in weak or easily degradable containers. Over the short term, longer lasting but still degradable rigid containers such as wooden boxes, 55-gallon drums, and steel liners would be expected to help reduce subsidence. The rigid containers initially provide some structural support to the trench covers, and act to "bridge" voids within the disposal trench and waste packages. Eventually, however, this structural support is lost as the rigid containers rust or rot out, leading to disposal trench settling at rates which are difficult to predict.

Site design and operating practices also contributed to the rapid waste degradation, subsequent slumping of the trench covers, and influx of precipitation. The site design and operating practices also reflected the general practices of the times. The waste was emplaced within the disposal trenches with little or no attempt to segregate wastes according to characteristics such as chemical content or the relative stability of the waste packages. In general, little compaction was given to the disposed waste, backfill, and trench covers other than that provided by driving over the disposal trenches with heavy trucks. Given all these factors, considerable void spaces are believed to have existed within the trenches which promoted rapid settling. Another factor was that water was frequently allowed to stand in the open disposal trenches while they were being actively filled. This again helped to promote rapid waste degradation and settling.

Another operational problem involved handling practices which led to several incidences of contamination of site grounds and equipment. This contamination was caused by small leaks and spills from packaged wastes delivered to the site. Although some contamination is probably unavoidable, the surface contamination problems at Maxey Flats have also been caused by past onsite solidification of bulk shipments of low activity liquids shipped to the site for disposal and by deposition from an evaporator installed to treat trench leachates pumped from trenches. Of principal importance, this site surface contamination has complicated assessment of the relative contribution of each of the possible routes of radioactivity release from the site, and consequently may have reduced the effectiveness of the environmental monitoring program at the site.

Institutional considerations have principally involved insufficient planning for site closure, funding for closure and for long-term care, and appreciation of the levels of activities and expenditures that could be needed to address major subsidence and disposal trench instability problems and leachate management.

Given this experience, it is clear that unless adequate steps are taken to achieve long term site stability (i.e., reduce subsidence of the disposal trenches through mechanical or other means of stabilization and installation of trench covers that will prevent infiltration) the process of leachate production and need for treatment will continue to occur. At the same time, instability makes it difficult to predict long term site performance and uncertain high costs are involved to care for the site over an uncertain long time frame.

West Valley

The difficulties experienced at West Valley were also caused by a number of interrelated factors, including waste form and site design and operations. Here again, the major problem has been site instability caused by disposal of compressible wastes, void spaces between waste and packaging, no segregation of wastes during emplacement, voids created through backfilling operations, and no real compaction of backfill or trench caps. These factors coupled with a humid environment and low permeability soils led to trench cap subsidence and collapse, infiltration of precipitation and accumulation of leachate within disposal trenches. Remedial actions to place and compact thicker trench caps were required and have retarded infiltration. Liquids pumped from trenches were treated. Such active maintenance activities caused by site instability are probably more expensive than if the site had been designed and operated so that only minor maintenance (e.g., filling of small depressions, cutting the grass) were required. Again, in this case, although there has been no hazard to the public health and safety, large unanticipated expenditures of funds have been required to place the site into a stable condition. The ability of remedial actions to provide long term stability is uncertain and additional funds may be required over the long term.

Sheffield

The performance of the Sheffield site has shown some of the same types of instability problems as Maxey Flats and West Valley. Although little or no leachate pumping activities are required at the site, trench subsidence and slumping problems have been observed which are generally similar to those

experienced at the Maxey Flats and West Valley sites. Much of the waste was easily degradable or was packaged with large void spaces within the waste containers. Void spaces also existed between disposed waste packages, and there was limited compaction of backfill and disposal trench covers. The subsidence and trench cover slumping has led to increased infiltration of rain and surface water, leading to increased maintenance requirements. The need for maintenance resulting from this instability would appear to be significantly less than that at West Valley or Maxey Flats. This is mostly due to the nature of the site soils, which are more permeable than those at the other two sites, and consequently there is less potential for a water accumulation problem. The site operator has taken steps to address and mitigate the above concerns.

Still, it is apparent that significant expenses will be required over several years for site stabilization and care. As in the case of Maxey Flats and West Valley, these expenses were not planned for at the time that the facility was opened and the site was opened and operated without specific criteria for the condition the site would be in upon transfer to the State (the degree of site stability after closure, the level of maintenance required over the long-term, etc.) During operations, the site operator prepared a site utilization plan, which included provisions for site surface water management and erosion control, but waste disposal was terminated prior to complete implementation of the plan. Such a plan was not, however, made a condition of license operation at the time the facility was originally licensed. Although funds were collected for "perpetual care" as a surcharge on received waste, the amount of funds collected will be insufficient to close and stabilize the site by today's standards. There was no provision to formally corrolate and update the amount of funds that would have to be collected with the amount of site maintenance expected.

2.9.2 Operating Sites

Barnwell

There have been no problems identified with performance of the disposal facility. As is the case of the Beatty and Richland sites, the problems experienced are unrelated to the operation of the site or its ability to isolate radioactive wastes. They have related to the receipt of improperly packaged waste, improperly solidified waste and waste containing excess free liquid. An inspection program has been instituted to address this problem. Also, as is the case at the Beatty and Richland sites, since operations started, a number of changes and improvements to site operations have been implemented in response to operational experiences.

Many of these improvements have involved operational procedures, including methods of disposal trench construction, health physics, and environmental monitoring. An example of an improvement in disposal trench construction implemented since operations began is the current practice of replacing the top few feet of sandy surface soil with compacted clay. Many of the waste form and packaging requirements implemented at the site have been imposed within the last few years and are intended to help improve transportation safety, occupational safety during handling at the disposal site and to improve overall stability of the site.

An improvement in institutional requirements has been the adoption into both the State and NRC license of more specific requirements on site closure. These

requirements include development by the site operator of a preliminary closure and stabilization plan. A requirement that adequate funding arrangements for closure and long-term care be made is also part of the closure license conditions.

Richland

There have been no problems identified with the performance of the disposal facility. Due to natural site characteristics, there have been no problems with groundwater migration from the site and no problems are expected in the future. Potential long-term problems with wind erosion of site soils have been greatly mitigated and possibly eliminated through engineering means -- i.e., by the depth of cover placed over the disposed waste and the license requirement for trench stabilization against wind erosion.

The problems that have been experienced at the site are unrelated to the operation of the site or to the ability of the site to isolate radioactive waste, but are a result of violations of transportation regulations by waste shippers and transporters. Wastes have been received at the site improperly packaged and in damaged packages.

The current license for the site is very detailed, containing specific requirements on waste form, operational health physics, and trench design and construction, which can be inspected against. Perhaps most importantly, the site license contains specific requirements on preparation for site closure. The site operator is required to prepare a preliminary site closure and stabilization plan addressing site closure, the conditions of the site upon transfer to the site owner, and arrangements for funding for closure and long-term care.

Beatty

There have been no problems identified with performance of the disposal facility. The difficulties that have been experienced are unrelated to the ability of the site to isolate radioactive waste. Problems were encountered with respect to diversion of waste from the disposal site by site employees which resulted from earlier inadequate management control over site personnel that existed at the site at the time the problems were occurring. (Subsequent to the diversion problem, site management changed hands, and there have been no such diversion problems since.) Recent problems with waste shipments similar to those experienced at Barnwell and Richland can be attributed to a large degree to waste generator and shipper practices.

As the site has been operated, a number of license conditions and improvements have been added in response to the above problems and experiences. For example, although liquids in bulk quantities were once received at the site for subsequent solidification and disposal, this practice has been discontinued. With few exceptions, receipt of liquids at the site is prohibited. Some of the requirements instituted after the diversion problems included increased security (additional fencing and access control), additional trench construction requirements (including a requirement to survey trench boundaries and reference the surveys to a benchmark), and improved recordkeeping requirements that waste normally be emplaced within three working days of receipt. Other, more recent requirements are intended to help address the problems with leaky waste packages being delivered to the site.

Unlike the Barnwell and Richland facilities, there are no requirements in the site disposal license for preparing and implementing a specific site closure and stabilization plan. The State believes, however, that this is compensated by a strong lease with the site operator. This lease was renegotiated in 1979 and the site operator agreed to post a bond against closure costs. In addition, a sinking fund exists for long-term care of the site. This fund is fed through sources such as fines on transportation violators as well as a surcharge on received waste.

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Chapter 3

ANALYSIS OF COMMENTS ON THE DRAFT ENVIRONMENTAL IMPACT STATMENT

3.1 INTRODUCTION

The draft EIS for 10 CFR 61 was issued in September 1982 as NUREG-0782. The public comment period for the document ended on January 14, 1982, and during this period 50 commenters provided written comments to NRC. Of the 50 comments received by the Commission, 8 contained no reference to the draft EIS but were limited instead to comment on the proposed 10 CFR 61. These eight comments were considered and analyzed as part of the staff analysis of comments on the rule. Therefore, the discussion in this chapter is limited to the comments of the remaining 42 commenters. All of the written comments (including the 8 mentioned above) are available for review at the NRC Public Document Room, 1717 H Street NW., Washington, D. C. and are filed under PR-61 (46 FR 51776).

Of the 42 comments received on the draft EIS, 21 came from states or state agencies. Although many of the these commenters had no comment on the draft EIS, several submitted extensive comments. Federal agencies and/or national laboratories submitted 8 of the 42 comments, and these included some of the most extensive comments received by the staff.

Other commenters responding to the draft EIS are categorized below:

- Utilities - 5 commenters
- Industry - 3 commenters
- Individuals - 2 commenters
- Brokers/Disposal firms - 2 commenters
- Radiation Safety Personnel - 1 commenter

As comment letters were received they were docketed by the staff and then reviewed to determine the specific comment items requiring responses. Each such item was numbered marginally, and a response to that item was prepared by an individal reviewer. Individual reviewers also identified additional work or analysis for the draft EIS which was prompted by the preparation of comment responses. The comments received and the responses prepared for them are presented in Appendix A.

3.2 ANALYSIS OF COMMENTS

As noted above, 42 comment letters were recieved by NRC on the draft EIS. The tone of the letters was overwhelmingly supportive of the goals and the results of the 10 CFR 61 rulemaking effort. Criticism of the proposed rule and the draft EIS was generally constructive in nature. Of the 42 letters received, 29 contained items which required a response by the staff. The remaining 13 comments in one form or another acknowledge receipt of the draft EIS but contained no items requiring a response.

Public comments were received on the rule as well. A total of 107 different persons submitted comments on proposed 10 CFR Part 61. The commenters represented a variety of interests. The topics addressed a wide range of issues and all parts of the rule. The general response was quite favorable. Almost half (47) expressed explicit support of the rule or its overall approach. Many expressed the view that the rule provides a needed and adequate framework for establishing additional low-level waste disposal capacity. Support was expressed by almost every sector. Only 15 commenters expressed outright opposition to the rule or some significant part of the rule. Most (9) were individuals. No State group or current disposal site operator expressed opposition. Most of the remaining commenters (47) either offered constructive comments without taking a general position on the rule or offered support with reservations about one or more aspects of the rule. The staff analysis of rule comments is contained in Appendix B and specific comments and staff action taken in response to specific comments are set out in the various chapters and appendices of the final EIS.

In 29 comment letters on the draft EIS, the staff identified 235 items which required responses. For purposes of summary presentation in this chapter, these items were assigned to categories based on the major divisions of the rule. Two other categories not based on the rule--scope of the draft EIS and Editorial and Other Comments--were added to assure completeness. The following listing gives a breakdown of comment items by category:

	Category	Number of Comment Items
1.	Scope of the draft EIS	42
2.	Performance Objectives	3
3.	Technical Requirements: Site Suitability	7
4.	Technical Requirements: Design, Operations & Closure	16
5.	Technical Requirements: Waste Classification	46
6.	Technical Requirements: Waste Characteristics	14
7.	Technical Requirements Institutional Requirements	12
8.	Financial Assurances	9
9.	Records, Reports, Tests & Inspections	0
10.	Amendments to 10 CFR	1
11.	Editorial and Other	85
	Total	235

In the following sections, the significant comments under each category will be discussed. Along with this discussion the staff's analysis and conclusions as to changes or additional work in the final EIS are presented. As noted earlier, each comment item has been specifically addressed and is contained in Appendix A. In addition, the staff's actions taken in response to specific comment items are set out in the various chapters and appendices of the final EIS.

3.2.1 Editorial and Other Comments

This category was the largest in terms of the number of comment responses required, 85 in all. However, most of the comments dealt with typographical errors, organization or format and had no significant effect on the analyses in the draft or final EIS. The majority of the comment items are listed in Appendix E of this volume, "Errata for the draft EIS for 10 CFR Part 61."

3.2.2 Waste Classification

The staff received 46 comments on the treatment in the draft EIS of the rule's technical requirement on waste classification. Most of the commenters were concerned with the limits on waste concentrations set forth in the rule and on the assumptions and bases supporting these limits. For example, several of the commenters noted that for various reasons--among them, unrealistically conservative assumptions, decay of short half-life radionuclides and the low probability of inadvertent intrusion--the values derived in the draft EIS for Table 1 were unnecessarily restrictive. These commenters also noted that the data base upon which these values were developed contained uncertainties and that the draft EIS did not explicitly evaluate the effect of these uncertainties. It was suggested that upon review of these and other factors that the concentration limits should be relaxed by at least one order of magnitude.

The staff acknowledges that there are uncertainties in the radioactive waste data base. Despite these uncertainties, however, the staff believes that the data base is the most complete yet prepared for low-level waste. The staff also believes that the uncertainties do not preclude making an intelligent decision on the requirements to be included in Part 61. The data base and assumptions are conservative, although an effort has been generally made to avoid over-conservatism.

With respect to the comments on the restrictiveness of the concentration limits in Table 1, the staff has reevaluated the calculations that establish the waste classification concentration limits to eliminate unnecessarily conservative assumptions. Based on this reevaluation the concentration limits for Class C waste in Table 1 have been raised.

Five parties commented on the proposed Part 61 limits on near-surface disposal of transuranic (TRU) radionuclides. In the draft rule these limits were set at 10 nanocuries per gram (nCi/gm) of waste. In general, these commenters supported a relaxation of this limit, although one commenter only suggested that options for disposal of transuranic nuclides above 10 nCi/gm should be addressed. Several arguments were advanced in support of this position, one being that TRU content in wastes from nuclear power plants is typically well below 10 nCi/gm and only occasionally in the 10-100 nCi/gm range. Another noted that the current limit (10 nCi/gm) is essentially unenforceable in that current measurement techniques make it very difficult if not impossible to certify that waste contains less than 10 nCi/gm. However, it would be much less difficult to certify that waste contains less than 100 nCi/gm. In response to these and other arguments, the staff reevaluated the analyses for disposal of waste containing transuranic nuclides and, as a result, the disposal limits for Class C waste have been raised to 100 nCi/gm for long-lived alpha emitting transuranic nuclides. For Class A wastes, the limit remains at 10 nCi/gm.

Several commenters expressed support for setting concentration levels for wastes below which there is no regulatory concern, the so-called "de minimis" level. The staff considered this action during the development of the draft Part 61 and the draft EIS, but decided that setting de minimis levels on a waste stream specific basis was preferable to establishing a generic limit. The staff is of the same opinion at this time and therefore, has not included de minimis levels in the final Part 61 and final EIS. However, NRC intends to accelerate its schedule for development of de minimis levels. In the development of these levels, the staff is willing to accept petitions for rulemaking from licensees for declaring certain waste streams to be of no regulatory concern.

The issue of total hazard in determining a waste classification system was also addressed by several commenters. (In this regard, a waste classification system based on "total hazard" is meant to consider in addition to radiological hazard, the chemical, biological, or other nonradiological hazards in waste material.) The problem which the staff has found in dealing with nonradiological hazard is that to the staff's knowledge there is no accepted consistent way to numerically compare radiological and nonradiological hazards. There are hundreds of thousands of different chemicals in existence, and the level of knowledge of the effects of these chemicals on the human body is much less understood than the effects of radioactive material. Nonetheless, there are key provisions of the rule which were developed to minimize potential nonradiological hazards associated with low-level waste. In addition, NRC plans to coordinate with EPA on this matter.

Finally, several commenters raised questions about compliance with the waste classification system proposed in the rule and draft EIS. These commenters questioned the ability of regulators to accurately inspect against the generator's certifications, and the use of scaling factors, among other aspects. The staff believes that licensees can economically and effectively carry out proper waste classification programs. At present the staff has identified four basic programs which may be used either individually or in combination by licensees to determine radionuclide concentrations in waste: materials accountability; classification by source; gross radioactivity measurements; and direct measurement of individual radionuclides including scaling some radionuclides based upon measurement of others. (These methods are discussed in the final EIS.) Routine detailed measurements on all waste packages are not considered necessary or desirable by the staff. To assist licensees, the staff is preparing written guidance on the methods by which compliance with the waste classification system can be shown.

3.2.3 Scope of EIS

Forty-two of the comments received fell under this category. Most of these comments simply asked why a certain subject was not included in the draft EIS, why it was treated the way it was or other similar questions. As these types of comments were very specific and did not affect the overall EIS to a substantive degree, they are not discussed in this summary. Rather, the staff has excerpted those comments on scope which are most substantive or which have affected the final EIS to the greatest degree.

The major comment raised on the scope of the draft EIS described the document as "...inadequate as an environmental full-disclosure statement..." and

criticized the document for reading "...as though a serious public health and radiological protection problem were being addressed whereas, in truth, the shallow land burial of low-level nuclear waste is essentially a non-problem in these respects." In preparing the draft EIS the staff sought to explore a broad range of alternatives in order to systematically develop the proposed Part 61 rule and to demonstrate the decision process behind that development. The staff also sought to assure that the Commission's mandate under the Atomic Energy Act and the National Environmental Policy Act were met. In both cases the staff feels that the document meets the objectives and notes that this commenter was alone among 50 others in suggesting that the draft EIS was inadequate.

The staff also believes that low-level radioactive waste, if not managed and disposed of properly, may indeed jeopardize public health and safety and the environment in addition to posing long-term economic burdens. Similarly, the staff does not believe that LLW can be dismissed as a "non-problem" and any attempt to do so is, at the very least, inappropriate.

Another commenter, the Environmental Protection Agency (EPA) found the draft EIS to be deficient in the absence of discussion in the draft EIS of the "...potential environmental impact and health risk from the non-radioactive chemical, hazardous and toxic materials in the LLW." In preparing the draft EIS, the staff concentrated on the public health and safety aspects and environmental impacts of the radiological hazard of LLW, although it was recognized that chemical and other hazards may accompany this waste. The staff believes that efforts to consider these other hazards are not readily attainable and would in fact delay the Part 61 rulemaking effort needlessly. The staff believes that the technical provisions of Part 61 generally meet or exceed those expected in EPA's rules for the disposal of hazardous wastes. Although it is not NRC's intent to allow disposal of hazardous wastes in a radioactive waste disposal facility, as is noted in the regulation, the Commission recognizes that small amounts of such wastes may be present in low-level radioactive wastes. It is NRC's view that disposal of these combined wastes in accordance with the requirements of Part 61 will adequately protect public health and safety and environmental quality. In addition, NRC plans to study the chemical toxicity of various types of low-level waste in the interim and to examine what steps could be taken to minimize the non-radiological hazard of LLW.

A third comment on the scope of the draft EIS noted that the document failed to specify "...in a clear, concise and meaningful way, the costs and benefits associated with the various alternative actions considered." Several commenters raised this issue in different ways and the staff, upon review of the draft EIS, recognize the difficulty in following the large number of alternatives analyzed. Therefore, the final EIS contains summary alternatives which combine various waste form and processing options; facility design options and operational procedures. These summary alternatives (four in number) are evaluated against one another to arrive at the preferred alternatives for inclusion in the final version of Part 61. The staff feels that this treatment is responsive to concerns such as the one mentioned earlier in this paragraph and also affords the interested reader an opportunity to more critically examine the decision process which led to the final provisions of Part 61.

Two commenters felt that the draft EIS should include a discussion of the hazard or risk associated with operation of a low-level waste disposal facility in order to place the impact analysis in its proper perspective. Upon review of this comment the staff decided to hold with its original decision not to attempt to quantify risk of LLW disposal facility operation. This decision was based on consideration of the substantial new work and delay in preparation of Part 61 which a risk assessment would require. In addition, the staff felt that this significant expenditure of work and the consequent delay in rulemaking was not warranted given the limited additional information which would be provided by expressing exposure in terms of risk. The draft EIS contained a comparison of calculated doses (impacts) to existing standards, and in the final EIS the staff has attempted to express these impacts in a clearer manner. In addition, a section has been included in the summary which provides dose response relationships as set forth in ICRP Publication No. 26. The reader can use these to estimate the level of risk associated with doses calculated for the various alternatives.

Another commenter felt that the draft EIS throughout placed undue emphasis on practices in use in the late 1960's to early 1970's as reference points for evaluating proposed Part 61 requirements. The staff recognizes that significant improvements have been made by the regulatory agencies and site operators in the requirements imposed on disposal facility operations and believes that the draft EIS contained adequate recognition of this fact. In the final EIS, as mentioned earlier, four summary alternatives have been identified by the staff for comparative evaluation. These alternatives include an alternative which specifies past disposal practices and one which specifies current practices. Each of these alternatives are then evaluated against the projected costs and impacts of implementation of Part 61. No further changes are planned in the final EIS as a result of this comment.

Finally, one commenter noted that the draft EIS and Part 61 "...fail to accurately address realistic concerns and place realistic conditions on the operation of a radioactive waste disposal site at an arid location." The staff in preparing the draft EIS and Part 61 did not attempt to regionalize the analysis. Rather, the effort was intended to arrive at a regulation which would be applicable in any climatic region. The staff believes that the Part 61 requirements for achieving long-term stability will be effective at both humid and arid sites. Specific measures to be used at specific sites will be reviewed on a site-specific basis. No further changes are planned in the final EIS as a result of this comment.

3.2.4 Facility Design, Operation and Closure

The staff received 16 comments which were placed in this category. The comments were specific in nature and had little, if any, effect on the final EIS. In general, the comments dealt with the layout of disposal facilities, design of disposal unit covers, and occupational exposures.

One of the commenters inquired as to the availability of decontainerized disposal as an option for low-activity waste. The staff considered this option and has not precluded it from use under Part 61.

Several commenters raised questions regarding cost assumptions in the draft EIS: salaries, environmental monitoring costs and closure and decommissioning

costs. In general, these commenters felt that the cost assumptions were too low. Two commenters also suggested that more realistic cost projections could be made by incorporating the concept of time value of money. The staff made inquiries of these commenters and incorporated revised cost figures into the final EIS. Although these revised figures did to some extent alter the analysis of the final EIS, the conclusions of the analysis were not changed.

3.2.5 Waste Characteristics

The staff received 14 comments by various parties on the technical requirements related to waste characteristics. Several of the major comments are discussed below.

One commenter felt that container limits on gaseous radioactive wastes are excessively conservative and should be justified in the draft EIS. The staff based its 100 Ci limit on license conditions for disposal of gaseous wastes now in effect at the Hanford and Barnwell disposal sites. The 100 Ci limit appears generally consistent with an accident evaluation assuming a dropped package producing occupational exposures to site workers. The DOT limits, however, are established based upon accident doses to the public. For gaseous waste forms the occupational exposure case is the limiting condition. The Commission has studies underway to determine whether higher limits would be appropriate. Such limits would be proposed in a future rulemaking.

Another commenter requested that criteria be given by NRC to reasonably assure that wastes will meet the 150 year stability requirement. Since the draft EIS was published, the staff has reconsidered this requirement and removed it to be in keeping with the desire to avoid prescriptive requirements where possible. Staff technical positions prepared to provide guidance on this subject, however, state that to the extent that it is practicable, waste forms or containers should be designed to maintain gross physical properties and identity for over 300 years.

3.2.6 Institutional Requirements

Twelve comments were received by the staff on this part of the draft EIS. Several of these major comments are discussed below. It should be noted, however, that none of these comments resulted in substantive changes to the methodology, findings or conclusions of the draft EIS.

One commenter noted that the differences between the responsibilities of Agreement and non-Agreement States were not clearly identified and questioned whether a non-Agreement State could provide surveillance during operational, closure and institutional control periods if that state in fact owned the disposal facility. The staff noted that the responsibilities of Agreement and non-Agreement States are in fact different with respect to licensing of a LLW disposal facility. Agreement States would have responsbility for licensing and regulatory control of sites, while in the case of non-Agreement States, this responsibility would rest with the NRC for byproduct, source and special nuclear materials. With respect to surveillance, monitoring, institutional and other land ownership responsbilities, however, both Agreement and non-Agreement States would have the same responsibilities as landowners and NRC believes both can administer acceptable programs.

Another comment noted that Part 61 should permit transfer of land to federal ownership during site operation or after closure. The staff noted that the proposed Part 61 does not preclude transfer of land ownership from a state to the federal government. Present laws, however, contain no specific provisions for such transfers and each case would have to be worked out on an individual basis.

A third comment questioned the assumption in the draft EIS that records may not be available in 100 years noting that our society has commonly preserved records for over 300 years. In preparing the analysis of institutional controls, NRC did not intend to imply that records would only last for 100 years. Rather, the staff assumed that active institutional controls can only be relied on for 100 years, although they may last much longer. The staff also assumed that passive institutional controls such as records would last for much longer than 100 years.

3.2.7 Financial Assurances

The staff received 9 comments on this portion of the draft EIS. The comments received were specific in nature and, although they had some effect on the final EIS, there was no substantive effect on the conclusions of the analysis.

3.2.8 Site Suitability

Seven comments were received by the staff on the technical requirements for site suitability. The comments considered most significant by the staff are discussed below.

One commenter felt that the draft EIS "...fails to emphasize the need to prevent significant movement of pollutants from the disposal site to underlying ground water." The commenter also suggested that ideally the disposal site should be in an area having a substantial thickness of clay or that trenches should have impervious bottoms and sides.

The staff believes that the draft EIS contains adequate emphasis on the movement of radionuclides from the disposal site to underlying groundwater. (Indeed, several commenters felt that the draft EIS placed too much emphasis on this pathway.) With respect to the second comment on siting in areas having a substantial thickness of clay, the staff has attempted throughout the draft EIS to avoid prescriptive requirements. The siting criteria in the rule strive to eliminate undesirable characteristics yet allow siting in almost any part of the country, so long as an applicant can demonstrate that the site will meet the performance objectives and technical requirements of the rule. Requiring an applicant to locate only in an area having a substantial thickness of clay would limit the siting options open to the applicant and would give little credit to other aspects of the disposal "system," i.e., waste form, site design, operational procedures, etc. With respect to the use of trenches having engineered impervious bottoms and sides, this suggestion would in the staff's opinion only lead to other problems, i.e., the "bathtub effect," which would in turn lead to trench overflow and the need for trench leachate pumping and treatment. This comment has not resulted in any change to the final EIS.

Another comment on site suitability noted that the draft EIS and the proposed Part 61 rule assume that "...in the event of early release of radionuclides from disposal containers, or from decontainerized disposal that site design... should be capable of preventing radionuclide migration out of the disposal trenches... (but) the proposed regulations provide no fail-safe assurance that this will be the case." The draft EIS and 10 CFR 61 do not provide fail-safe assurances that waste released from a container will not migrate from the trenches into the surrounding groundwater and environment. Rather, both the rule and the draft EIS are based on the interaction of waste form, site characteristics, site design and site operation and closure as a system which will provide a reasonable assurance that the performance objectives of Subpart C will be realized.

One commenter felt that NRC would be basing its decision on site suitability on the ability of sites to fit NRC computer models and that the realities of site complexity make it unlikely that present models will be adequate to the task. The staff's findings on suitability of a proposed site will not be based solely on computer modeling although such modeling will be a basic tool in site evaluation. Existing models are believed to be adequate for non-complex sites and new or improved models are being developed.

3.2.9 Performance Objectives

The staff received 3 comments on this aspect of the draft EIS. Two of the three comments received are discussed below.

One commenter noted that ALARA considerations are mentioned through the draft EIS, but do not receive any treatment in the performance objectives of the rule. The staff considered this comment as well as similar ones made on the rule itself and determined that it is NRC's intent that ALARA apply to the performance objectives addressing releases of radioactivity to the environment and safety during operation. Accordingly, the rule has been amended to include specific reference to ALARA in the performance objectives for protection of populations (§61.41) and safety during operations (§61.43).

A second commenter took issue with NRC's approach in the draft EIS and proposed Part 61 of specifying performance objectives and technical requirements rather than only performance objectives. The staff believes the approach taken was appropriate for several reasons. One is that a rule based only on performance objectives would take longer to prepare and would require significantly greater time in licensing due to the large number of factors needed to be considered in determining compliance. Moreover, while this approach might be workable, it would not allow for establishment of more detailed prescriptive requirements in those areas where specific guidance is known to be needed. Finally, the comments received on Part 61 and the draft EIS have overwhelmingly supported the combined approach of performance objectives and minimum technical requirements set forth in the rule.

3.2.10 Amendments to Other Parts of 10 CFR

The staff received only one comment on this subject area, and inasmuch as it did not have any effect on the final EIS, it is not discussed here.

3.2.11 Records, Reports, Tests and Inspections

No comments were received on this part of the draft EIS.

Chapter 4

ANALYSIS OF ALTERNATIVES

4.1 BACKGROUND AND INTRODUCTION

The draft EIS contained a detailed analysis of a broad range of alternative waste form properties and alternative disposal facility design and operating practices. In fact, more than 70 specific cases were analyzed numerically in Chapters 4, 5, and 6 of the draft EIS, while several other alternatives which could not be readily analyzed numerically were analyzed on a subjective basis. This analysis served two objectives. First, based upon the results of this analysis, several performance objectives and technical criteria were developed for codification into the proposed Part 61 regulation. Second, the analysis served to review, and provide an estimate of the relative effectiveness of, many of the improvements in low level waste disposal technology that had been developed over the past years.

The four basic performance objectives developed for near-surface of low level waste include:

1. Protect the public health and safety (and the environment) over the long term;

2. Protect the potential inadvertent intruder;

3. Ensure operational and public health and safety during the short-term operational phase; and

4. Ensure long-term stability to eliminate the need for long-term maintenance after operations cease.

Technical criteria were then developed to help ensure that the performance objectives will be met. Key principles were identified which are of primary significance in ensuring that the performance objectives will be met. These are:

1. Long-term stability of the disposal facility and disposed waste. Stability helps to reduce disposal unit cover collapse, subsidence, water infiltration, and the need to care for the facility over the long-term.

2. The presence of liquids in waste and the contact of water with waste both during operations and after the site is closed. Water is the primary vehicle for waste transport and its presence in and contact with waste can contribute to accelerated waste decomposition and increased potential for making the waste available for transport offsite.

3. Institutional, engineering, and natural controls that can be readily applied to reduce the likelihood and impacts of inadvertent intrusion.

A review of the comments received on the draft EIS indicated few, if any, major objections to the overall performance objectives and most of the technical criteria. There were, in fact, several laudatory comments on the draft EIS. There were, however, a number of comments on specific technical details of the analysis, such as the assumed costs for environmental monitoring. (Revisions to the technical details of the analysis methodology are discussed in Appendix C of this final EIS.) In addition, there was some concern that the large number of cases considered and the extreme level of detail was confusing and difficult to follow.

In response, the analysis for the final EIS is considerably simplified over that for the draft EIS. Four cases (and minor variations on them) are presented for numerical analysis which are representative of the following:

1. Past disposal practice (base case alternative)
2. Current disposal practice (no action alternative)
3. Part 61 requirements (preferred alternative)
4. Upper bound requirements (all stable alternative)

A detailed description of each alternative and variation thereof follows, which is then followed by a presentation and comparative evaluation of the results of the analysis. First, however, a brief review of the assumptions, data base, and impact measures calculated is presented.

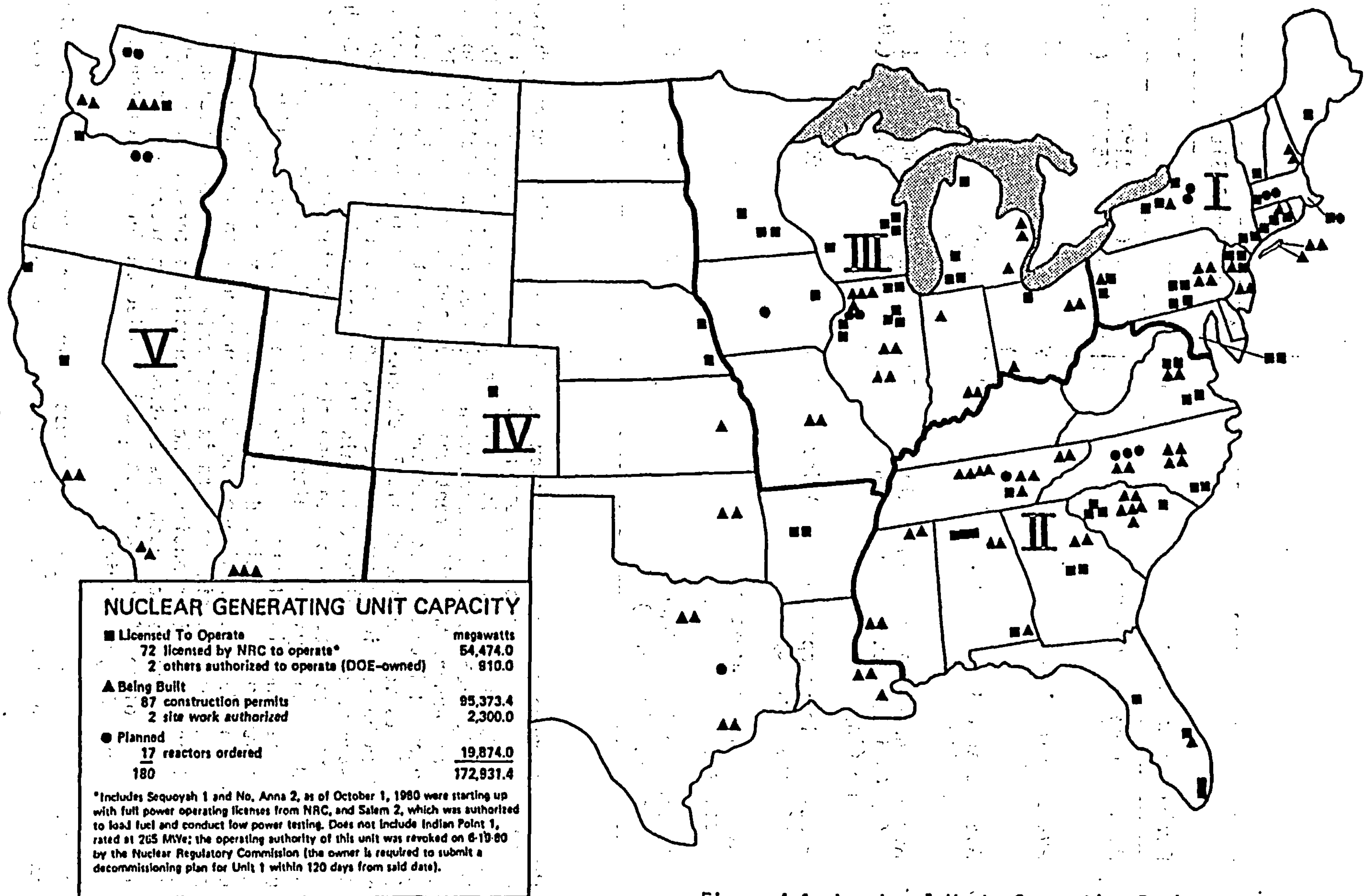
4.2 CALCULATIONAL METHODOLOGY

This discussion of the calculational methodology used for the final EIS is presented in three sections: (1) information base for analysis, (2) use of reference waste volume and disposal facility, and (3) impact measures. Further background information may be obtained from consulting the draft EIS and Appendix C of this final EIS.

4.2.1 Information Base for Analysis

To perform the alternative analyses, an information base was developed which involved three main components: alternative disposal facility environments, alternative waste characteristics, and alternative disposal facility designs and operating practices. Based upon this information base, an analysis methodology was developed to calculate impacts and compare alternatives.

First, the continental United States was assumed to be divided into four regions as shown in Figure 4.1. The four regions considered correspond to the five U.S. Nuclear Regulatory Commission regions and are termed the northeast region (NRC Region I), the southeast region (NRC Region II), the midwest region (NRC Region III), and the western region (NRC Regions IV and V). In each region, a hypothetical regional disposal facility site is characterized. (The site in the western region is generally termed the southwest site.) These sites, while not representing any particular location within a region or any existing or possibly planned site, reflect typical environmental conditions within the regions. This allows consideration in the calculational methodology of a wide range of environmental conditions such as the amount of rainfall or the average distance from the waste generator to the disposal facility. A list of some of the various regional site's environmental properties is presented below.



BECAUSE OF SPACE LIMITATIONS, SYMBOLS DO NOT REFLECT PRECISE LOCATIONS

Figure 4.1 Low-Level Waste Generation Regions

Environmental Property	Regional Sites NE	SE	MW	SW
Mean average temperature °C (°F)	8°C (46°F)	17°C (63°F)	11°C (51°F)	14°C (57°F)
Average wind speed km/hr	16.6	13	17	25
Average annual precipitation mm (in)	1,034 (41)	1,168 (46)	777 (30.5)	485 (19)
Average annual natural percolation (PERC) into groundwater system mm (in)	74 (2.9)	180 (7.1)	50 (2.0)	1 (.04)
Precipitation-evaporation (PE) index of site vicinity	136	91	93	21
Average silt context of site soils (%)	65	50	85	65
Average cation exchange capacity (meq/100g)	15	10	12	5

The next component of the information base involved considering and characterizing a wide range of waste types, waste forms, and processing options. In previous studies on LLW management and disposal, the disposed waste was usually assumed to be a mostly uncharacterized mass with little attempt to distinguish, in a quantitative manner, the different waste types and forms. In this EIS, however, LLW is separated into 37 waste streams and each waste stream is characterized in terms of its volumes and physical, chemical, and radiological properties as projected to be routinely generated during the years 1980 through 2000. The 37 waste streams so considered in this EIS are listed in Table 4.1. Each waste stream represents a type of waste generated by a particular type of waste generator and having physical, chemical, radiological, and other characteristics unique to that individual stream. The most important radionuclides present in each waste stream are identified and the geometric mean of the range of activity concentrations for each radionuclide is determined from available data. For some waste streams, sufficient data is available to represent radionuclide concentrations as a distribution. The radionuclides considered are shown in Table 4.2. The volumes of each waste stream are considered on a regional basis. That is, the volume of the waste stream is projected for each of the above regions over a 20 year period.

Furthermore, six generic alternative waste form, processing, and packaging options are considered. These generic processing options, called "waste spectra,"

Table 4.1 Waste Streams Considered in Analyses

Waste Stream	Symbol
<u>Group I: LWR* Process Wastes</u>	
PWR** Ion Exchange Resins	P-IXRESIN
PWR Concentrated Liquids	P-CONCLIQ
PWR Filter Sludges	P-FSLUDGE
PWR Filter Cartridges	P-FCARTRG
BWR*** Ion Exchange Resins	B-IXRESIN
BWR Concentrated Liquids	B-CONCLIQ
BWR Filter Sludges	B-FSLUDGE
<u>Group II: Trash</u>	
PWR Compactible Trash	P-COTRASH
PWR Noncompactible Trash	P-NCTRASH
BWR Compactible Trash	B-COTRASH
BWR Noncompactible Trash	B-NCTRASH
Fuel Fabrication Compactible Trash	F-COTRASH
Fuel Fabrication Noncompactible Trash	F-NCTRASH
Institutional Trash (large facilities)	I-COTRASH
Institutional Trash (small facilities)	I+COTRASH
Industrial SS# Trash (large facilities)	N-SSTRASH
Industrial SS Trash (small facilities)	N+SSTRASH
Industrial Low Act. Trash (large facilities)	N-LOTRASH
Industrial Low Act. Trash (small facilities)	N+LOTRASH
<u>Group III: Low Specific Activity Wastes</u>	
Fuel Fabrication Process Wastes	F-PROCESS
UF_6 Process Wastes	U-PROCESS
Institutional LSV## Waste (large facilities)	I-LIQSCVL
Institutional LSV Waste (small facilities)	I+LIQSCVL
Institutional Liquid Waste (large facilities)	I-ABSLIQD
Institutional Liquid Waste (small facilities)	I+ABSLIQD
Institutional Biowaste (large facilities)	I-BIOWAST
Institutional Biowaste (small facilities)	I+BIOWAST
Industrial SS Waste	N-SSWASTE
Industrial Low Activity Waste	N-LOWASTE
<u>Group IV: Special Wastes</u>	
LWR Nonfuel Reactor Core Components	L-NFRCOMP
LWR Decontamination Resins	L-DECONRS
Waste from Isotope Production Facilities	N-ISOPROD
Tritium Production Waste	N-TRITIUM
Accelerator Targets	N-TARGETS
Sealed Sources	N-SOURCES
Industrial High Activity Waste	N-NIGHACT
MOX† Facility Decontamination Waste	F-PUDECON

*LWR: Light Water Reactor
**PWR: Pressurized Water Reactor
***BWR: Boiling Water Reactor
#SS: Source and Special Nuclear Material
##LSV: Liquid Scintillation Vial
†MOX: Mixed Oxide (PuO_2+UO_2)

Table 4.2 Radionuclides Considered in Analyses

Isotope	Half Life (years)	Radiation Emitted	Principal Means of Production
H-3	12.3	β	Fission; Li-6 (n, α)
C-14	5730	β	N-14 (n, p)
Fe-55	2.60	X	Fe-54 (n, γ)
Co-60	5.26	β, γ	Co-59 (n, γ)
Ni-59	80,000	X	Ni-58 (n, γ)
Ni-63	92	β	Ni-62 (n, γ)
Sr-90	28.1	β	Fission
Nb-94	20,000	β, γ	Nb-93 (n, γ)
Tc-99	2.12×10^5	β	Fission, Mo-98 (n, γ), Mo-99 (β^-)
I-129	1.17×10^7	β, γ	Fission
Cs-135	3.0×10^6	β	Fission; daughter Xe-135
Cs-137	30.0	β, γ	Fission
U-235	7.1×10^8	α, β, γ	Natural
U-238	4.51×10^9	α, γ	Natural
Np-237	2.14×10^6	α, β, γ	U-238 (n, 2n), U-237 (β^-)
Pu-238	86.4	α, γ	Np-237 (n, γ), Np-238 (β^-); daughter Cm-242
Pu-239	24,400	α, γ	U-238 (n, γ), U-239 (β^-), Np-239 (β^-)
Pu-240	6,580	α, γ	Multiple n-capture
Pu-241	13.2	α, β, γ	Multiple n-capture
Pu-242	2.79×10^5	α	Multiple n-capture; daughter Am-242
Am-241	458	α, γ	Daughter Pu-241
Am-243	7950	α, β, γ	Multiple n-capture
Cm-243	32	α, γ	Multiple n-capture
Cm-244	17.6	α, γ	Multiple n-capture

represent relative levels of waste processing activities applied to the 37 waste streams characterized. The waste spectra have been developed to limit the number of waste form and packaging alternatives that would have to be analyzed, since an infinite number of possible combinations of various waste streams and processing options are available. The first four waste spectra are described in detail in Appendix D of the draft EIS. Minor revisions to the spectra for the final EIS, as well as a description of waste spectra 5 and 6, are contained in Appendix C of this final EIS. A condensed description of the 6 waste spectra is included in this chapter as Figure 4.2.

Briefly, waste spectrum 1 characterizes past and, in some cases, existing waste management practices. Waste spectrum 2 characterizes improvements in the form of the waste through processing and reduction in waste volume with relatively modest expenditures of time and money. Of the 6 waste spectra, waste spectrum 2 most closely resembles existing waste management practices, which are currently in a marked state of change due to state initiatives, a lack of disposal capacity, and economic considerations. Waste spectrum 3 characterizes further waste form improvements and volume reduction at further increased costs, including incineration of most combustible waste streams. Waste spectrum 4 characterizes the maximum volume reduction and improved waste forms that can currently be practically achieved. Waste spectrum 5 characterizes (for most waste streams) use of containers providing structural support to achieve waste form stability rather than processing to a solid form. For purposes solely of analysis in this EIS, costs and other properties associated with such containers are assumed to be those associated with a high integrity container (HIC), a recently developed and marketed waste packaging option. Waste spectrum 6 is a combination of waste spectra 1 and 2, and characterizes a condition in which compressible waste streams are subjected to improved compaction, but high activity waste streams are disposed for the most part in an unstable waste form. Waste spectrum 6 is believed to represent current and future waste management practices assuming there are no requirements on achieving stable waste forms.

The waste spectra can be used singly or in combinations to represent a particular alternative requirement.

The third component of the information base involved characterizing a number of alternative disposal facility designs and operating practices with respect to their costs, operational exposures, and other factors. These alternatives are developed in Appendix F to the draft EIS as updated by Appendix C of this final EIS. Included are alternatives which will reduce potential impacts to inadvertent intruders, reduce ground-water migration and long-term social impacts, improve operational safety, or combinations thereof. The alternatives characterized include the following:

Deeper trenches	Improved monitoring
Thicker trench covers	Moisture barriers
Increased backfill thickness	Sand backfill
Layered waste disposal	Improved surface water drainage
Slit trenches	
Caisson disposal	Weather shielding
Concrete walled trenches	Stacked waste emplacement
Grouting	Waste segregation
Engineered intruder barriers	Decontainerized disposal
Improved compaction	Dynamic compaction

Figure 4.2 Summary Description of Waste Spectra

Waste Spectrum 1 This spectrum assumes a continuation of past and in some cases existing waste management practices. Some of the light water reactor (LWR) wastes are solidified; however, no processing is done on organics, combustible wastes, or streams containing chelating agents. LWR resins and filter sludges are assumed to be shipped to disposal sites in a dewatered form. LWR concentrated liquids are assumed to be concentrated in accordance with current practices, and are solidified with various media designated as solidification scenario A.* No special effort is made to compact trash. Institutional waste streams are shipped to disposal sites after they are packaged in currently utilized absorbent materials. Resins from LWR decontamination operations are solidified in a medium with highly improved characteristics (solidification scenario C).*

Waste Spectrum 2 This spectrum assumes that LWR process wastes are solidified using improved solidification techniques (solidification scenario B).* Prior to solidification, LWR concentrated liquids are additionally reduced in volume to 50 weight percent solids through use of an evaporator/crystallizer. In the case of cartridge filters, the solidification agent fills the voids in the packaged waste but does not increase the volume. Liquid scintillation vials are crushed at large facilities and packed in absorbent material. All compactible trash streams are compacted, most at the source of generation and some at the disposal facility. Liquids from medical isotope production facilities are solidified using solidification scenario C procedures.

Waste Spectrum 3 In this spectrum, LWR process wastes are solidified assuming that further improved solidification agents are used (solidification scenario C). LWR concentrated liquids are first evaporated to 50 weight percent solids. All possible incineration of combustible material (except LWR process wastes) is performed; some incineration is done at the source of generation and some at the disposal site. All incineration ash is solidified using solidification scenario C procedures.

Waste Spectrum 4 This spectrum assumes extreme volume reduction. All waste streams amenable to evaporation or incineration with fluidized bed technology are calcined and solidified using solidification scenario C procedures; LWR process wastes, except cartridge filters, are calcined in addition to the streams incinerated in Spectrum 3. All noncombustible wastes are reduced in volume at the disposal site or at a central processing facility using a large hydraulic press. This spectrum represents the maximum volume reduction that can be currently achieved.

Figure 4.2 (continued)

Waste Spectrum 5 This spectrum incorporates for most waste streams high integrity containers (HICs) to achieve a stable waste form. Relative to waste spectrum 1, all waste streams other than activated metals which had previously been in an unstable form are stabilized using HICs. Activated metals are stabilized by filling interstitial voids in a waste container with a noncompressible material. LWR concentrated liquids are solidified assuming solidification scenario B procedures, while waste from medical isotope production facilities is assumed to be solidified using solidification scenario C. Wastes from tritium manufacturing facilities are also placed into HICs. All compressible waste streams are compacted into HICs, most at the source of generation and some at a regional processing center assumed to be colocated with the disposal facility.

Waste Spectrum 6 This waste spectrum represents overall waste characteristics projected to result without requirements for waste stability and considering the increasing costs for waste disposal. Similarly to waste spectrum 1, most higher activity waste streams are disposed in an unstable manner. LWR resins and filter sludges are shipped in a dewatered form. Pressurized water reactor (PWR) cartridge filters, LWR nonfuel reactor core components, and LWR noncompressible trash are also packaged in a nonstable manner. LWR concentrated liquids are reduced in volume to 50 weight percent solids and solidified. Similarly to waste spectrum 2, all compressible waste streams are compacted. Most are compacted at the source of generation and some at a regional processing center assumed to be colocated with the disposal facility.

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* Solidification scenario A: half of a waste stream is solidified in urea-formaldehyde, the other half in cement.
Solidification scenario B: half of a waste stream is solidified in cement, the other half in vinyl ester styrene.
Solidification scenario C: 100% of a waste stream is solidified in vinyl ester styrene.

Other disposal alternatives were also briefly examined. These included potential land based methods (e.g., intermediate depth disposal, mined cavities) as well as other potential disposal methods (e.g., ocean disposal). Many of the alternatives were selected for further detailed analysis in the draft EIS.

4.2.2 Use of Reference Waste Volume and Disposal Facility

From the above, it can be seen that when considering the effects of alternative regional, waste form, and facility design and operation characteristics on the magnitude of the impact measures calculated, an extremely large number (thousands) of possible permutations can be considered. To enable development of performance objectives and technical requirements for LLW disposal, the number of these permutations needed to be controlled and analyzed on a systematic basis. NRC, therefore, adopted use of: (1) a reference waste volume distribution, and (2) a reference disposal facility site and design.

As discussed in Appendix D of the draft EIS, the reference waste volume distribution is obtained through averaging all the waste volumes assumed to be generated in each of the waste streams for each of the four regions, and normalizing these volumes to one million m^3 of waste for waste spectrum one. This allows the effects of alternative waste spectra and alternative disposal facility designs and operating practices to be compared on a common basis.

To help provide conservative bounds to the potential costs and impacts of waste disposal, the reference disposal facility is assumed to be sited in a humid eastern environment. NRC staff anticipates that over the next 20 years, over three-quarters of the waste generated in the United States will be generated in humid environments--i.e., in the eastern and humid midwestern sections of the country. Regional disposal of waste (e.g., from state compacts) therefore implies that most of the waste generated in humid environments would also be disposed in humid environments. For this EIS, the reference disposal facility is assumed to have environmental characteristics corresponding to the southeast regional site, although either the northeast regional site or the midwest regional site could have been used for this purpose.

The reference facility is sized to accept a relatively large quantity of waste--i.e., up to about 50,000 m^3 of waste per year over a 20-year operating life, or up to a total volume of one million m^3. This corresponds to approximately one-quarter of the total volume of LLW projected in the United States to the year 2000.

The reference facility site minimally meets all of the site suitability requirements set out in the draft Part 61 rule. The facility is also assumed to be operated in compliance with minimum radiation safety practices required by provisions of 10 CFR Part 20, as well as most of the criteria in the NRC Branch Technical Position on Site Closure and Stabilization. (See Appendix I of the draft EIS.) The facility is described in detail in Appendix E of the draft EIS. A brief description follows.

The disposal facility is assumed to be operated for profit by a small corporation which is engaged in other nuclear-related business activities in addition to operating the disposal facility. The disposal area at the reference facility

includes 58 disposal trenches with dimensions of 180 m (591 ft) long, 30 m (100 ft) wide, and 8 m (26 ft) deep. The rather large trench sizes assumed are representative of recent trends at existing disposal sites. A 100-foot buffer zone encircles the disposal area and lies between the disposal area and the disposal site boundary. Support facilities and structures at the site include (1) an administration building, (2) a health physics/security building, (3) a warehouse, (4) a garage, (5) a waste activities building, and (6) a storage shed. All structures at the site are one-story metallic structures on concrete pad foundations.

Shipments of radioactive waste arrive by truck and are processed onto the site on a first-come, first-served basis. Accompanying the shipments are manifest documents--termed radioactive shipment records (RSRs)--which describe the contents of the shipment. Arriving shipments are inspected for compliance with applicable federal regulations and waste acceptance criteria established as conditions in the disposal facility license.

Waste is randomly emplaced in the trench, sometimes using cranes and forklifts, and for the base case (see Section 4.4) backfilled with dirt removed during trench excavation. Random waste emplacement results in a trench volume use efficiency of about 50 percent. Waste is emplaced to within one meter of the top of the trench. Earthen fill is then backfilled into the trench until the trench cover approximately corresponds to the original grade of the site surface. A one-meter thick earthen cap is then placed upon the backfill and is mounded. The earthen cap is then covered with natural overburden material. The overburden is then reseeded to promote growth of a short-rooted grass cover.

After a 20-year operating period, closure of the facility is assumed to require approximately two years and involves dismantling and decontamination of site buildings, disposal of wastes produced during dismantlement and decontamination operations, and final site seeding and contouring. The licensee also makes a final survey of the disposal area to make sure that direct radiation levels are at essentially background levels. Following closure, the disposal license with the site operator is terminated and the license for the site is transferred to the site owner. For this EIS, the site owner is assumed to be a state agency.

4.2.3 Impact Measures

The impact measures considered in this EIS include short-term radiological exposures, long-term radiological exposures, costs, energy use, and land use. These impact measures are listed in Table 4.3.

Of these, the principal impact measures considered involved long-term radiological exposures and costs. Long-term radiological exposures could involve activities such as man potentially contacting the waste after disposal (i.e., inadvertent human intrusion into the disposal facility); potential leaching and transport of the waste through the ground water; intrusion and dispersion by plants and animals; long-term erosion of the site with eventual uncovering of the waste leading to surface water and air transport; and release of gaseous decomposition products from the waste containing radioactive species (e.g., tritiated methane gas). Further discussion is provided below.

Table 4.3 Impact Measures Used in Analyses

Waste Management Phase	Impact Measure
Waste processing	Costs Energy use Occupational exposures due to waste processing Population exposures due to waste incineration
Waste transportation	Costs Energy use Occupational exposures Population exposures
Waste disposal	Costs Energy use Land use Occupational exposures Exposures to individuals and populations due to: o operational accidents o ground-water migration o inadvertent human intrusion o overland flow o leachate treatment

Human Intrusion Exposure Pathways. Intrusion into disposed waste may be either deliberate or inadvertent. A deliberate intrusion event implies that the intruder knows of the potential hazard of the disposed waste but for some reason deliberately chooses to ignore the hazard. (For example, the intruder could be seeking something of possible value in the disposed waste.) NRC believes that deliberate intrusion into the disposal facility cannot reasonably be protected against, and it is not considered further. After the facility closes, however, and assuming a removal or breakdown of active institutional control and surveillance over the facility, one or a few individuals could inadvertently disturb waste at the disposal facility through such activities as constructing a house. In this case the intruder is unaware of the presence of the waste or the possibility of a health hazard.

Intrusion into a closed waste disposal facility, assuming a breakdown in or removal of institutional controls, has been examined in detail in studies by a number of industry, national laboratory, and federal agency contractor investigators. These studies analyzed a range of intrusion exposure pathways ranging from potentially trivial events to events which could cause relatively significant exposures.

Based on a review of the pathways considered by these investigators, NRC selected a limited number for analysis in the EIS. (Refer to Chapter 4 of the draft EIS.) The events are conservatively assumed to occur based upon consideration of typical human activities. NRC recognizes the hypothetical nature of such events and that they may never occur. Given their hypothetical nature, NRC has assumed reasonably conservative (but not overly conservative) actions on the part of the intruder. In addition, some judgment was also made as to the likelihood and extent of the events occurring depending upon specific waste forms and disposal practices.

The intrusion events considered are discussed in detail in Chapter 4 and Appendix G of the draft EIS. Briefly, the events involve consumption of water from a well drilled at the site, plus two scenarios in which the intruder contacts waste directly. The former is discussed as part of the forthcoming discussion on groundwater migration.

The two scenarios involving direct contact of waste by an intruder are termed the intruder-construction scenario and the intruder-agriculture scenario. The intruder-construction scenario involves exposures to workmen involved in constructing a house directly on the disposal facility, thus contacting and dispersing the disposed waste. Exposures can result from airborne dispersal of a soil/waste mixture (leading to exposures due to immersion in a contaminated cloud as well as from inhalation) and from direct gamma radiation. The intruder-agriculture scenario involves an individual or several individuals living in the house thus constructed and consuming food grown in a small on-site garden. Exposures can result from airborne dispersion of a soil/waste mixture, direct gamma radiation, and ingestion of contaminated foodstuffs.

The extent to which the above two scenarios occur is dependent upon the condition of the waste at the time the waste is contacted. This is further a function of time, the original waste form, and disposal site operating practices. For example, the extent that the above two scenarios would occur would be significantly reduced if: (1) the waste was in a form recognizable as something other than dirt, or (2) the waste was disposed at a sufficient depth so

that contact from normal surface activities such as housing construction is unlikely. In the first case, since it is believed that the most likely cause of human intrusion is a bureaucratic mistake, it is believed that activities such as housing construction would not proceed if workers dug up hunks of waste material. Rather, workers would stop while land records are investigated and the mistake discovered. This abbreviated version of the intruder-construction scenario is called the intruder-discovery scenario, and potential exposures would be much less than those of the full intruder-construction scenario. In this event, the intruder-agriculture scenario would not occur. In the second case, it is believed that if the waste is disposed at sufficient depth below the earth's surface, then it would be much less likely that the waste is contacted in any case, whether the intruder-construction and intruder-agriculture scenarios occur, or just the intruder-discovery scenario occurs.

In this EIS, therefore (see the draft EIS for additional background), the following is taken to occur at the end of the institutional control period:

- If stable waste streams are segregated from unstable waste streams, then the intruder-agriculture and intruder-construction scenarios are applied to the unstable waste streams and the intruder-discovery scenario is applied to the stable waste streams.

- If unstable waste streams are <u>not</u> segregated from stable waste streams, then the intruder-agriculture and intruder-construction scenarios are applied to all waste streams.

- If waste streams are stable and layered (placed at the bottom of a disposal cell), then only a fraction of the intruder-discovery scenario is applied to the stable and layered streams.

The effectiveness of waste stability and waste layering as a means of reducing intruder exposures, however, is only assumed to last for a period of 500 years. After 500 years, no credit is given to waste form for reducing intruder exposures. Waste is assumed to have an appearance similar to ordinary dirt and the intruder-construction and intruder-agriculture scenarios proceed normally.

A somewhat similar situation exists for layered waste. The full effectiveness of layering is only assumed to last for 500 years. After 500 years, the layered waste is assumed to be contacted in a similar manner as unlayered unstable waste at 100 years. However, waste disposed so that at least 5 meters of earth or low activity waste covered it would still be undoubtably difficult to contact even at 500 years. As much as a factor of 10 credit for layered waste is believed possible at 500 years, although no such credit is taken in the analysis methodology. The effect on the calculated impacts of taking such credit is explored in the ensuing analysis, however.

<u>Ground-Water Migration</u>. Potential impacts due to long-term releases to ground water are given major consideration in this EIS. To analyze potential ground water migration impacts from near-surface radioactive waste disposal, NRC staff has adopted use of a model reference waste disposal facility located in a humid environment. Movement of radionuclides from the disposed waste and through ground water has been modeled based upon calculational procedures derived from Darcy's Law. As depicted in Figure 4.3, a disposal cell (or group of disposal cells) is assumed to be located within an unsaturated zone of thickness Zo.

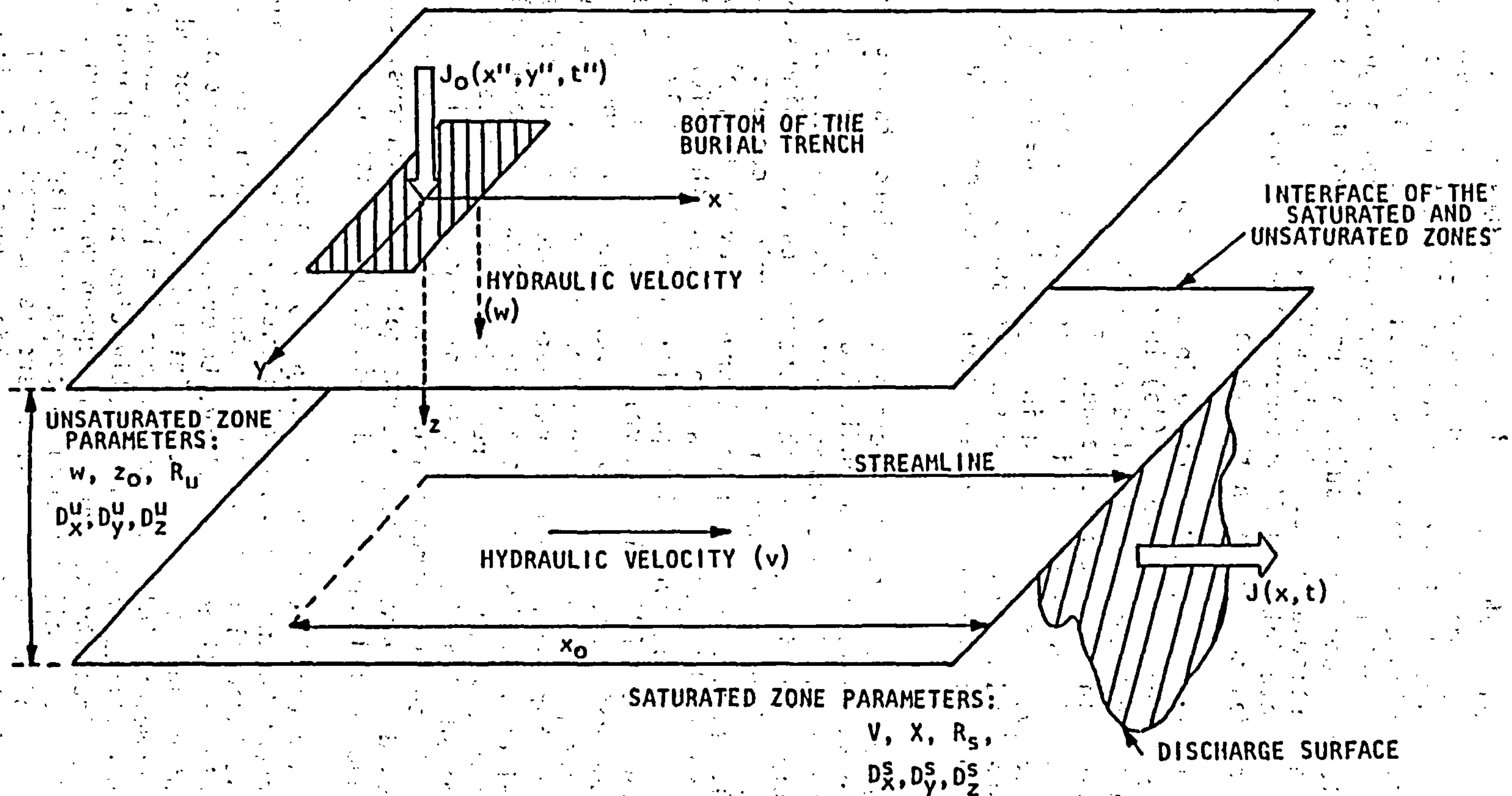

Figure 4.3 Geometry of Ground Water Scenario

Both the unsaturated zone and the underlying saturated zone (aquifer) are assumed to be stationary, homogeneous, and isotropic, and the fluid moving through these zones is assumed to be incompressible and of constant viscosity. The disposal cell is filled with a heterogeneous mixture of waste streams ranging from streams having very low activity to streams having relatively high activity. Each waste stream contains a particular suite of radioisotopes and, if contacted by water, leaches at a particular rate. Precipitating water striking a covered disposal cell may percolate into and flow through the cell and leach out a portion of the radionuclides contained in the waste.

The source term of each radioisotope in the disposed waste leaving the bottom of the disposal cell is given by (Jo) in Curies/year. The radioactive source moves down through the unstaturated zone with hydraulic velocity (w), and mixes with the water in the saturated zone. The water in the saturated zone, carrying the radiocontaminants with it, is then assumed to flow horizontally with hydraulic velocity (v). As illustrated in Figure 4.3, the contaminated ground water can be visualized as crossing a discharge surface at some arbitrary distance (x) downstream of the disposal cell(s), having a radionuclide activity equal to J (in Ci/yr).

The source term (Jo), and the factors that go into its determination, are discussed more extensively in Appendix G of the draft EIS. It is a somewhat complicated function of site environmental conditions, disposal facility design and operating practices, waste characteristics (including waste leaching characteristics, radionuclide concentrations, chemical content, and structural stability), and the potential for intrusion by humans, plants, or animals. To provide a reasonable yet conservative analyses, the reference site is assumed to experience a relatively high precipitation rate (1.17 m/yr) and a high natural percolation rate (PERC = 180 mm/yr). The percolation of water into disposal cells at the reference facility is a variable depending upon facility design and operating practices and waste form. For example, unstable waste forms would result in higher percolation of rainwater into disposal cells (due to subsidence of disposal cell covers), while improved thicker disposal cell covers and compaction techniques would reduce percolation. If the unstable waste streams were disposed mixed with the stable waste streams, then all of the waste streams would experience high percolation rates. However, if the unstable waste streams were disposed segregated from the unstable waste streams, then only the unstable waste streams would experience the higher percolation.

Percolation rates into disposal cells may also be increased through intrusion by inadvertent humans, deep-rooted plants, and burrowing animals. During the active institutional control period, the site owner would be expected to survey and maintain the disposal facility, to prevent inadvertent intrusion by humans, and to control and limit potential intrusion by deep-rooted plants and burrowing animals. However, following the active institutional control period, breakdowns in such surveillance and control activities are postulated to occur. Therefore, for disposal facility designs which depend upon improved covers to reduce percolation (e.g., a walled trench, a compacted clay cap), a reduction in the effectiveness of these disposal covers is assumed at a time 100 years following license termination. The extent of this reduction in effectiveness is discussed in Appendix G of the draft EIS. Briefly, however, 90% of the disposal area experiences percolation equal to twice the previously assumed value for that

case. The remaining 10% experiences even higher percolation, the specific value of which depends upon the case considered.

As another example, the leaching of radionuclides from the disposed waste depends upon the radionuclide content, whether the waste is solidified, and the chemical content of the waste. Unsolidified waste streams are assumed to leach at a fraction corresponding to leach fractions measured under totally saturated conditions at the Maxey Flats, Kentucky and West Valley, New York disposal facilities. Solidified waste forms are assumed to leach at lower rates based upon an approximation derived from experimental data. However, increased leaching of solidified waste forms is assumed if chelating agents or organic chemicals are present. If wastes containing chelating agents or organic chemicals are disposed in a segregated manner from other waste streams, then the higher leaching fractions are only applied to the segregated streams; otherwise, the higher leaching fraction is applied to all solidified streams.

Radionuclide leaching is also varied in this EIS by considering disposal designs which reduce the amount of leaching. The amount of leaching is assumed to be proportional to the amount of water contacting the waste and to the contact time of the water with the waste. Disposal designs that increase the speed that percolating water flows past the waste reduce the quantity of radionuclides leached for two reasons: (1) by reducing the amount of water having sufficient time to dissolve the wastes into the water retained between successive infiltration events, and (2) by reducing the amount of water retained between successive infiltration events. This may be accomplished by using high porosity, low specific retention backfill materials such as a very coarse backfill (such as sand and gravel) rather than a very fine-grained backfill (such as clay).

After the radionuclides have left the disposal cell, the movement of radionuclides through ground water may be estimated by a number of calculational techniques--many of which may be extremely complicated and require a great deal of site-specific information. Given the generic nature of this analysis, however, a simple approximation in this EIS is used which allows rapid consideration and comparison of a number of alternatives. This approximation solves the Darcy's Law differential equations in terms of error functions. Basically, however, the disposed waste is modeled as 10 distributed sources or sectors as shown in Figure 4.4. Movement of radionuclides out of the sectors and to a biota access location is calculated principally as a function of the ground-water travel time from the sector to the access location, the Peclet number (basically the distance to the access location divided by the longitudinal dispersivity of the medium), and the retardation coefficients of the medium.

Actual values for retardation coefficients at a specific site would be a strong function of site soil and environmental conditions. Since a generic rather than a site-specific analysis is being performed in this EIS, retardation coefficients must be assumed rather than measured. In this EIS, 5 sets of retardation coefficients are assumed which correspond to those which would be expected from a range of soil conditions. These 5 sets are shown in Table 4.4. The first set corresponds to retardation coefficients for very permeable sandy soils, the fifth set corresponds to very impermeable clayey soils, and the third set corresponds to moderately permeable soils having a moderate clay content.

It can be seen that the retardation coefficients for some radionuclides--i.e., ^{3}H, ^{14}C, ^{99}Tc, and ^{129}I--are relatively low and do not appreciably vary under

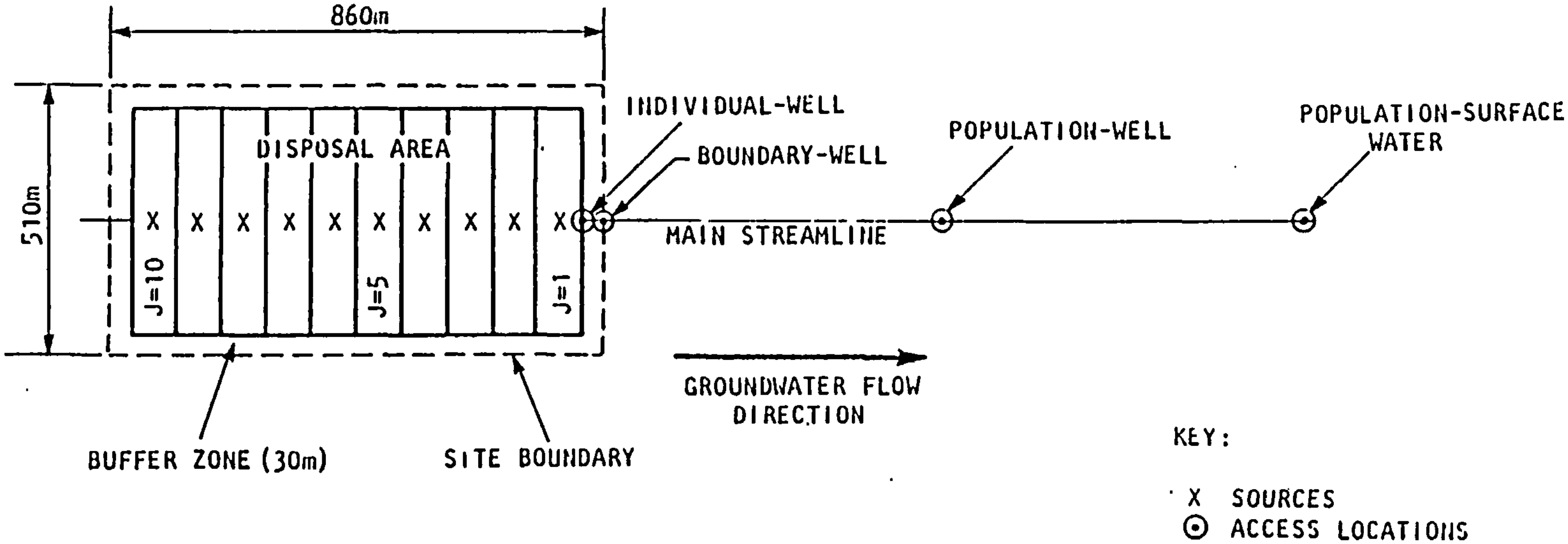

Figure 4.4 Geometric Relationships of Disposal Area and Ground Water Access Locations

Table 4.4 Sets of Retardation Coefficients Used in Impacts Analysis

	Assumed Retardation Coefficients				
Nuclide	Set 1	Set 2	Set 3	Set 4	Set 5
H-3	1	1	1	1	1
C-14	10	10	10	10	10
Fe-55	630	1290	2640	5400	11050
Ni-59†	420	860	1750	3600	7350
Co-60	420	860	1750	3600	7350
Sr-90	9	18	36	73	146
Nb-94	1000	2150	4640	10000	21500
Tc-99	2	3	4	5	6
I-129	2	3	4	5	6
Cs-137†	85	173	350	720	1460
U-235†	840	1720	3520	7200	14730
Np-237	300	600	1200	2500	5000
Pu-238†	840	1720	3520	7200	14730
Cm-243†	300	600	1200	2500	5000
Am-241†	300	600	1200	2500	5000

†Coefficients for other isotopes of these elements are assumed to be the same.

different soil conditions. For other radionuclides, the retardation coefficients are sufficiently large that the travel time of the radionuclide to a biota access point may be on the order of thousands of years. Within that time, considerable radioactive decay can occur. The result of this is that the ground-water migration exposures calculated in this EIS are mainly dominated by the above four isotopes. Tritium is relatively short-lived but is present in the disposed waste in relatively large quantities and is very mobile in the environment. The latter three isotopes are present in much smaller quantities, but are long-lived and are also assumed to be environmentally mobile.

At an actual site, retardation coefficients and other environmental properties may be measured. There will be some uncertainties with these environmental properties, however. In addition, no site soils will be completely homogeneous, although it is recognized that it is desirable during siting activities to select a site having as simple a substrata as is practical. Finally, although site selection would be geared to avoiding discontinuities, it is always possible that there will exist features such as continuous sand lenses or fractured formations.

For the above reasons, it makes sense in this generic analysis to concentrate on the above four nuclides which are expected to be very mobile in the environment. These nuclides move equal to or at about the speed of groundwater. The significance of this is that actions taken on a generic basis to control disposal of mobile isotopes will also control disposal of the less mobile isotopes. That is, if movement of the mobile isotopes can be minimized (and the mobility of these isotopes are less dependent on specific site environmental conditions), then movement of the less mobile isotopes such as Cs-137, whose mobility would be normally expected to be less but would be a stronger function of site environmental conditions, would also be minimized.

The retardation coefficients assumed for the reference disposal site correspond to set 3 on Table 4.4 (soils with moderate permeability). However, lower retardation coefficients (set 2) are assumed for radionuclides contained in waste streams assumed to contain or be contacted by chelating agents or organic chemicals. That is, if waste streams containing chelating agents or organic chemicals are segregated from other waste streams, then the second set of retardation coefficients is applied to the streams containing the chemical agents and the third set is applied to the other waste streams. If no segregation is performed, then the second set is applied to all waste streams.

Radionuclide concentrations are then determined as a function of time at four principal downstream biota access locations:

1. a well located on the disposal facility and potentially used by an inadvertent intruder following the end of the active institutional control period;

2. a well located at the site boundary which is assumed to be used by a few individuals;

3. a well assumed to be located approximately 500 meters down gradient from the disposal facility and used by a small population of about 100 persons; and

4. a small stream located about one kilometer down gradient from the disposal facility and assumed to be used by a small population of about 300 persons.

Once the concentrations at the biota access locations are determined, potential exposures from consumption and use of the water may be determined for seven organs. These include whole body, bone, liver, thyroid, kidney, lung, and the gastro-intestinal (GI) tract.

As discussed earlier, the calculational procedure first estimates the source term Jo, in curies/year, leaving the disposal cell. However, the concentrations of radionuclides at the biota access locations are also determined by the volume of water with which the released and migrating radionuclides are diluted. All other considerations being equal, the larger the volume of water with which the radionuclides are diluted, the lower the concentration of the radionuclides in the water. The dilution volume is a site-specific variable, and is dependent upon the attributes of the aquifer (thickness, flow rate, dispersivity, etc.), the distance from the release point (the further away from the release point, the greater the mixing that would likely occur), and man-made perturbations such as pumping water from a well.

Given the generic nature of the analysis in this EIS, reasonable yet conservative assumptions are made regarding the dilution volumes. For the first two biota access locations (intruder well and boundary well), released radionuclides are assumed to be diluted by a volume of water equal to that provided by natural percolation of rainwater upon the disposal area (about 87 acres). (At the reference facility, this volume of water is equal to 63,400 m^3.) Of this volume, the individual using the contaminated water is assumed to withdraw 7700 m^3/year (3.84 gpm), which represents the basic annual needs of a single person living in a rural area.

For the population well, the dilution volume is assumed to correspond to the annual volume of water withdrawn from a water well pumping at a rate of 100 gpm (200,000 m^3/yr). Small farming communities that utilize ground water for their needs usually have wells that range from 100 gpm to 1,000 gpm depending on the population. For the surface water access location, a stream is assumed having a flow rate of about 5 ft^3/sec (4.5×10^6 m^3/yr). A stream having a flow rate of much below this value is unlikely to be used for human consumption.

For flexibility in the analysis, some of the environmental properties associated with the reference disposal facility are assumed to be variable. This provides an insight in the generic analysis of the sensitivity of the results to site parameters. In the EIS, the reference site parameters are assumed to range from very permeable soil conditions to very impermeable soil conditions, with the reference case being moderately permeable soil conditions. The differing environmental characteristics assumed include:

Environmental Characteristics	Site with Perm. Soil	Site with Mod. Perm. Soil (Ref. Site)	Site with Impermeable Soil
Retardation coefficient set	2	3	4
Speed of percolating water (m/hr)*	1120	112	11.2
Ground water travel time from bottom of waste to aquifer (yrs)	<<1	10	60
Ground water travel time (yrs)** to:			
intruder well	32	42	92
boundary well	56	66	116
population well	390	400	450
surface water access	790	800	850

*Assuming that site soils are used as backfill

**From the first sector closest to the access locations

Other Long-Term Release Pathways. There may be other potential pathways for long-term release of radionuclides to the environment from disposed waste. These pathways include:

- o Gaseous releases from decomposing waste;
- o Plant and animal intrusion; and
- o Wind and surface water erosion and transport.

NRC staff believes, however, that the most significant pathway is ground water migration. Gaseous releases do not have a large impact and can be reduced by assuring stable site conditions. Impacts from plant and animal intrusion are site-specific and can be reduced through engineering designs applied to reduce ground water migration and potential intruder exposures. Erosion is a slow, long-term process which can be controlled through proper siting and good operational techniques. These pathways are discussed in more detail in the draft EIS, particularly Appendix M.

Costs. Costs are calculated over 20 years operation of the disposal facility and are separated in this EIS into three components:

- o processing costs
- o transportation costs
- o disposal facility costs.

Waste processing costs include costs associated with processing (e.g., compaction, solidification) and packaging wastes prior to disposal. Processing costs are separated into those associated with processing by waste generators and those which could result from transfer of the waste to a centralized regional processing center prior to disposal. Transportation costs are costs associated

with transferring the waste to the disposal facility. For the reference facility, transportation costs are calculated based upon an average transport distance of 400 miles.

Disposal facility costs are separated into (1) design and operation costs and (2) postoperational costs. Design and operation costs are those costs associated with siting, designing, constructing, and operating the facility over 20 years. These costs are a function of the alternative disposal facility designs considered in the EIS. Design and operating costs are calculated using a present value analysis described in Appendix C of this final EIS. In the analysis, a discount rate of 15% is used. (Appendix C illustrates the sensitivity of the design and operating costs to other values of the discount rate.)

Postoperational costs are divided into closure costs, observation and maintenance costs, and institutional control (long-term care) costs. Closure costs are calculated assuming that adequate funds for closure are provided for by the licensee through use of an investment fund (represented as a surcharge on received waste). The availability of funds for closure is assumed to be ensured by some manner of surety mechanism which is assumed to annually cost 1.5% of the principal. Observation and maintenance costs cover costs that would be borne by the disposal facility operator during the time period following site closure and prior to transfer of the license to the site owner (which marks the beginning of the institutional control period). For convenience, these costs are calculated as if a certain sum of money were set aside each year by the site operator for this purpose. These costs are of course assumed to be passed on to the disposal facility customer. Institutional control costs are calculated based on the assumption that a state-operated sinking fund is established and that a surcharge is levied upon the waste received at the disposal facility on a cost-per-waste-volume arrangement. Costs are calculated assuming a 10% interest rate and a 9% average inflation rate. All post-operational costs are calculated as costs to a disposal facility customer.

Short-Term Radiological Impacts. Short-term radiological impacts include occupational exposures during waste processing, waste transportation, and waste disposal. These are calculated as whole body exposures. Whole body exposures to populations due to waste processing activities involving waste incineration are also calculated. Finally, radiological impacts due to possible water accumulation problems at a disposal facility are calculated. These could involve disposal cell overflow into a nearby stream where the water is consumed and used by an individual, or airborne releases due to evaporation of accumulated leachate. In this EIS, impacts from overflow are calculated as exposures to an individual (in millirem) while impacts due to leachate evaporation are calculated as exposures to the population surrounding the disposal facility (in man-millirem). A description of the methodology used to calculate impacts due to water accumulation is provided in Appendix C.

Other Impact Measures. Other impact measures estimated include land use (in m^2) and energy use (in equivalent gallons of fuel oil).

4.3 DESCRIPTION OF ALTERNATIVE CASES

This section presents a description of the four principal cases considered in this final EIS.

4.3.1 Past Practices (Base Case Alternative)

This first case is meant to provide a representation of past disposal practices. This case provides a baseline of costs and other impact data against which today's practices and improvements to today's practices may be evaluated. If through this historical perspective former poor practices can be identified, then much of the job of developing Part 61 requirements becomes one of identifying common-sense methods of avoiding such poor practices.

Basically, the disposal facility is assumed to be sited according to the siting requirements contained in the proposed Part 61 regulation and operated with adequate operational safety. However, the combination of poor waste form and inadequate disposal facility operating practices results in high long-term potential environmental releases as well as high costs and maintenance activities during the institutional control period. This approach follows since in the past it was believed that only a "good site" was needed for waste disposal. No credit was given to waste form or containers to reduce impacts. Safety during operations was generally given greater emphasis than long-term costs and radiological impacts. The fact that extensive maintenance activities would be involved was tolerated since it was believed that as long as the disposal facility was operating, there was little need to consider the economic impacts of these maintenance activities after the disposal facility closed.

The assumptions made for this case include the following:

1. The waste disposed into the facility is composed of mostly structurally unstable waste forms. This is represented in the analysis by waste spectrum 1. In this case, for example, light water reactor ion-exchange resins and filter sludge are shipped to the disposal facility in a dewatered form. Several other high activity waste streams are also shipped to disposal facilities in an unstable form, and no special effort is made to compact compressible waste streams.

2. The design and operation of the facility are not directed toward minimizing contact of waste by water through achieving long-term site stability. Waste is randomly emplaced into the disposal cell and then backfilled with earth originally excavated from the disposal cell. A relatively thin (1 m thick) cover (cap) is then emplaced over the backfill. This cap is also composed of the originally excavated soil and is also subjected to indifferent compaction techniques. There is no segregation of waste containing compressible material nor segregation of waste containing chelating or other chemical agents.

3. There are no radionuclide disposal limits, so anything (other than high level waste) that can be transported to the site is disposed of at the site. Thus, the site contains relatively high concentrations of toxic radionuclides having long half lives.

4. There are some operational rules of thumb at the site to reduce operational exposures which involve preferential emplacement of waste packages exhibiting high surface radiation levels. Such preferential

disposal might involve disposal at the bottom of the disposal cells or disposal at trench corners. However, this practice is not generalized to include waste packages containing high concentrations of radionuclides which may not exhibit high surface radiation levels. These could include, for example, waste packages containing large quantities of tritium or transuranic radionuclides.

5. The reference disposal facility is assumed to be operated for 20 years, after which the site is closed and the site license is transferred to the site owner, which for purposes of analysis is assumed to be a state. The site closure period is assumed to last two years, and there is also assumed to be no intervening period between the end of the closure period and transfer of the license to the site owner (no observation and maintenance period).

4.3.2 Current Disposal Practices (No Action Alternative)

This case provides a representation of current disposal practices. It represents the improvements in disposal facility design and operating practices, as well as improvements in waste form and packaging requirements, that have been implemented at disposal facilities over the last several years.

The assumptions made for this case include the following:

1. A limit of 10 nCi/gm is placed upon the transuranic content of received waste. License conditions at currently operating disposal facilities generally allow transuranic nuclides in waste up to the 10 nCi/gm limit as long as the transuranics exist as trace contaminants homogeneously distributed through the waste. Surface-contaminated materials are generally given a more strict interpretation. In practice, homogeneously contaminated waste streams such as ion exchange resins are occasionally found to exceed the 10 nCi/gm limit, almost always due to the shorter lived transuranic isotopes. In such cases, waste generators will either dilute such waste with lower activity waste (still remaining a homogeneous mixture), thus lowering the transuranic content to less than 10 nCi/gm, or allow the short lived radionuclides to decay prior to shipment. These subtleties of license interpretation and waste management practices are accounted for in the analysis by (for purposes of waste classification only) decaying Pu-241 concentrations within light water reactor process waste streams and isotope production waste to its alpha-emitting daughter equivalents. No such decay is performed for trash or other waste streams which cannot be assumed to be homogeneously contaminated.

2. Several waste streams having radionuclide concentrations exceeding one $\mu Ci/cm^3$ of any radionuclide having a half life exceeding 5 years are required to be stabilized prior to disposal. These waste streams include light water reactor ion exchange resins, filter sludge, and cartridge filters, as well as waste from medical isotope production facilities. Waste stabilization may be carried out by any of a number of methods. Such methods could include processing the waste into a stable form (e.g., solidification with a media such as cement, asphalt or vinyl ester styrene), placing the waste into a container providing

structural support (e.g., use of a high integrity container), or special disposal facility design. For this EIS, waste solidification is estimated to cost in the range of $1280 to $1450 per m^3 of input waste. Use of a high integrity container to achieve stabilization is estimated to cost in the neighborhood of $450 per m^3 of waste. For purposes solely of analysis in this case study, compliance with the waste stabilization requirement for this case is assumed to be principally achieved by solidification of some waste streams (e.g., LWR concentrated liquids, isotope production facility waste, some LWR ion exchange resins and filter sludge) and by emplacement of other waste streams (e.g., most LWR ion exchange resins and filter sludge) into HICs prior to disposal. All things equal, most waste generators would be expected to adopt the least expensive approach to meeting a particular requirement. All compressible waste streams are compacted, either at the waste generator's facility or at a centralized processing center.

3. Several improvements are made in the ability of the disposal facility to minimize contact of waste by water and to improve long-term site stability. Waste emplaced into the disposal cells is backfilled with a very permeable material such as sand or gravel. An improved cover is placed over the disposal cells. This improved cover may take a number of forms. For purposes of cost/impact analysis, the improved cover in this EIS is assumed to consist of a 2 meter thick earthern cover having a high clay content. The backfill and disposal cell cover are compacted by improved compaction techniques such as use of vibratory compactors or sheepsfoot rollers. (The compaction technique which would be used for an actual site would be dependent upon site specific soil and environmental conditions.)

4. There is no segregation of unstable waste streams. However, there is segregation of waste streams containing chelating or chemical agents.

5. As in Case 1, there is assumed to be operating practices involving preferential emplacement of waste packages having high surface radiation levels. However, there is assumed to be no such similar operating practices for layering of other high activity wastes.

6. As in the preceding case, the site is operated for 20 years, followed by a two-year closure period prior to transfer of the site license to the site owner. Again, no observation and maintenance period is assumed.

4.3.3 Part 61 Requirements (Preferred Alternative)

This case provides a representation of disposal practices which would minimally meet the requirements of the final Part 61 regulation. In this case, waste streams determined to be acceptable for near-surface disposal are classified into three waste classes: Class A, Class B, and Class C. A summary of the classification limits assumed in the analysis for this case is presented as Table 4.5. This case is summarized below:

1. All higher activity (Class B and Class C) waste streams are required to be stabilized prior to disposal. As the previous case, possible waste stabilization methods could include processing the waste into a stable waste form (solidification), placing the waste into a container providing structural support (e.g., an HIC), or by special

Table 4.5 Waste Classification Limits Assumed for the Part 61 Case

Isotope	Class Limits ($\mu Ci/cm^3$) Class A	Class B	Class C
H-3	4.0E+1*	**	**
C-14#	8.0E-1	8.0E-1	8.0E+0
Fe-55	7.0E+2	**	**
Ni-59#	2.2E+0	2.2E+0	2.2E+1
Co-60	7.0E+2	**	**
Ni-63#	3.5E+0	7.0E+1	7.0E+2
Nb-94#	2.0E-3	2.0E-3	7.0E+2
Sr-90	4.0E-2	1.5E+2	7.0E+3
Tc-99	3.0E-1	3.0E-1	3.0E+0
I-129	8.0E-3	8.0E-3	8.0E-2
Cs-135	8.4E+1	8.4E+1	8.4E+2
Cs-137	1.0E+1	4.4E+1	4.6E+3
U-235	4.0E-2	4.0E-2	4.0E-1
U-238	5.0E-2	5.0E-2	5.0E-1
TRU	1.0E+1##	1.0E+1##	1.0E+2##
Pu-241	3.5E+2##	3.5E+2##	3.5E+3##

*The notation 4.0E+1 means 4.0×10^1.
**No limit is set for these isotopes and classes.
#For activated metals, the limits for these isotopes are raised by a factor of 10.
##The limits for these isotopes are given in units of nCi/gm rather than $\mu Ci/cm^3$

disposal facility design. As before, it is assumed that some waste streams are solidified and other are emplaced into high integrity containers. This is assumed solely for this case analysis in order to achieve a common basis for comparison with the previous case (i.e., if different stabilization techniques were assumed for this case than for the previous case, then the results of the two cases could not be conveniently compared and the cost/impact attributes of the Part 61 rule easily assessed).

2. Concentration limits for disposal are placed upon a number of radionuclides. For example, a limit of 100 nCi/gm is placed upon alpha-emitting transuranic elements (except for Cm-242). Concentrations less than 10 nCi/gm are treated as Class A waste, while concentrations between 10 and 100 nCi/gm are treated as Class C waste.

3. Disposal facility design is the same as the previous case, with the exception of segregation of compressible waste. That is, compressible (unstable) Class A waste streams are disposed in separate disposal units segregated from stable Class A, Class B, and Class C waste

streams. Waste streams containing chemical or chelating agents are segregated from other waste streams.

4. High activity (Class C) waste streams, which may include waste streams with or without high surface radiation readings, are preferentially placed upon the bottom of the disposal units.

5. As in the previous case, the site is assumed to be operated for 20 years, followed by a two-year closure period. However, a 5-year observation and maintenance period is assumed between the end of the closure period and transfer of the site license to the site owner.

4.3.4 Upper Bound Requirements (All Stable Alternative)

This case explores some possible variations on waste disposal in which all wastes are stabilized. In this case, stability is assumed to be principally achieved through waste form and packaging, the principal means of doing this being emplacement of waste into high integrity containers. Costs and other impacts associated with other possible ways to stabilize the unstable waste streams are also explored. Other assumptions are as follows:

1. Limiting concentration limits for waste classification and disposal are placed upon radionuclides in the same manner as the previous case. However, since all waste streams are to be stabilized, the Class A limits listed in Table 4.5 are all assumed for this case to be set equal to zero.

2. The disposal facility design is the same as the previous case. However, since all waste streams are stabilized, there is no segregation of compressible waste. Segregation is carried out, however, for waste streams containing chemical or chelating agents.

3. High activity (Class C) waste are preferentially layered upon the bottom of the disposal units.

4. As in the previous case, the site is operated for 20 years, followed by a two-year closure period. A five-year observation and maintenance period exists between the end of the closure period and transfer of the license to the site owner.

4.4 RESULTS OF THE CASE ANALYSIS

The results of the four cases analyzed in this chapter are presented in Table 4.6.

4.4.1 Past Disposal Practices (Base Case Alternative)

In this case, the disposal facility is calculated to accept one million m^3 of waste over its 20-year lifetime. All waste is assumed to be mixed together during disposal and no waste is determined to be unacceptable for near-surface disposal. Of this waste, almost 75% of the waste is in an unstable waste form. The rest of the waste, including such waste streams as solidified concentrated liquids, is considered to be inherently stable. The practice of codisposal of

unstable and stable waste forms, however, plus the inadequate site operations, tends to negate the potential gain brought about by the stable waste streams. The results are about the same as if all waste was in an unstable form.

Long-term environmental impacts for the base case are projected to be high. As shown in Table 4.6, potential impacts to an inadvertent intruder are projected to be on the order of 2.2 to 4.5 rem at a time period equal to 100 years following the end of the two-year facility closure period. At this time, much of the potential exposures are due to the presence of gamma-emitting isotopes having short to moderate half lives (e.g., Cs-137). At 500 years, potential inadvertent intruder exposures have been reduced, but are still on the order of 0.6 to 1.6 rems to the bone. These exposures are due to the relatively longer lived radionuclides such as Pu-239. This level of inadvertent intruder exposure can persist for long time periods. At 1000 years following site closure, for example, potential inadvertent intruder exposures are in the range of 0.5 to 1.1 rem to the bone.

Offsite impacts that could occur from the above intrusion events are also listed in Table 4.6. For this case, recall that impacts due to potential inadvertent intrusion would naturally be expected to be largest for the persons directly contacting the disposed waste. However, a portion of the contaminated soil/waste mixture may be transported offsite. Waterborne impacts involve impacts that could result if rainwater washed the contamination down to a nearby stream and the water in the stream is consumed and used by an individual. As shown, these calculated impacts run at about 0.7 millirem/yr to be bone. Airborne impacts are to the surrounding population. Both airborne and waterborne impacts are calculated at 100 years following closure and transfer of the license to the site owner.

Groundwater impacts are considered over a 10,000 year time period following disposal facility closure and are also high. As shown, thyroid exposures are on the order of 1.5 rem at the intruder and boundary wells, 470 mrem at the population well and 22 mrem at the surface water location. These exposures are principally due to migration of I-129. Whole body exposures are also relatively high at the boundary well--160 mrem--and are principally due to the migration of tritium.

These high levels of impacts are caused by a number of interrelated factors. Much of the waste is in an easily compressible, readily degradable waste form with relatively high leaching characteristics. All waste streams are randomly disposed together into the disposal facility, and rather indifferent backfilling techniques are performed, resulting in much void volume in the interstistial spaces between disposed waste packages. The disposal cell covers are composed of originally excavated soil and are relatively thin (1 m thick). Little or no compaction is performed on the backfill and disposal cell covers other than that provided by the weight of waste delivery vehicles. As a result of the above, severe subsidence problems are assumed to occur. The facility is assumed to be characterized by potholes and subsidence depressions, leading to concentrated sources of rainwater infiltration. Percolation into the waste cells is assumed to be twice as high (360 mm/yr) as the surrounding undisturbed soils.

It is not likely that doses to actual individuals could ever be this high, however, notwithstanding the conservatism of the analysis. For one thing, potholes and depressions would be filled in by the site owner, thus reducing

Table 4.6 Results of the Case Analysis

	Base case	No action case	Part 61 case	Upper bound case
I. Long-Term Individual Exposures (mrem/yr):				
Intruder-construction				
o 100 yrs - Body	2.30E+3*	1.79E+3	1.84E+2	1.75E+1
Bone	4.49E+3	1.80E+3	1.87E+2	1.77E+1
Thyroid	2.16E+3	1.78E+3	1.84E+2	1.74E+1
o 500 yrs - Body	1.14E+2	2.61E+0	3.02E+0	3.07E+0
Bone	1.55E+3	1.16E+1	1.63E+1	1.67E+1
Thyroid	2.70E+1	2.29E+0	2.42E+0	2.45E+0
Intruder-agriculture				
o 100 yrs - Body	2.68E+3	2.21E+3	2.02E+2	0.
Bone	3.64E+3	2.32E+3	2.08E+2	0.
Thyroid	2.60E+3	2.17E+3	2.01E+2	0.
o 500 yrs - Body	6.66E+1	2.77E+0	3.04E+0	3.09E+0
Bone	6.41E+2	7.19E+0	9.17E+0	9.38E+0
Thyroid	3.93E+1	9.08E+0	9.02E+0	9.23E+0
Intruder well				
o Body	3.06E+1	8.50E-2	2.15E-2	2.11E-2
o Bone	5.61E+0	4.53E-2	3.72E-2	1.58E-2
o Thyroid	1.50E+3	1.11E+1	4.16E+0	3.31E+0
Boundary well				
o Body	1.58E+2	4.39E-1	1.11E-1	1.09E-1
o Bone	5.61E+0	4.49E-2	3.70E-2	1.47E-2
o Thryoid	1.50E+3	1.11E+1	4.16E+0	3.31E+0
Population well				
o Body	7.90E-1	6.57E-3	3.33E-3	2.02E-3
o Bone	1.13E+0	1.04E-2	8.24E-3	3.41E-3
o Thyroid	4.74E+2	3.51E+0	1.32E+0	1.05E+0
Surface water				
o Body	3.16E-2	2.90E-4	1.44E-4	8.80E-5
o Bone	4.92E-2	4.29E-4	3.37E-4	1.36E-4
o Thyroid	2.16E+1	1.50E-1	5.99E-2	4.77E-2

Table 4.6 (continued)

	Base case	No action case	Part 61 case	Upper bound case
II. Other Long-Term Exposures:				
Offsite releases from intrusion				
o Waterborne (mrem/yr)				
Body	1.21E-1	9.67E-2	1.16E-2	4.46E-4
Bone	6.80E-1	2.34E-1	2.42E-2	1.14E-3
Thyroid	2.84E-3	2.32E-3	4.78E-4	1.07E-5
o Airborne (man-mrem/yr)				
Body	5.87E+1	1.82E+0	2.39E-1	9.05E-3
Bone	9.66E+2	1.19E+1	2.25E+0	6.16E-2
Thyroid	5.93E-1	5.09E-1	8.62E-2	2.34E-3
III. Short-Term Whole Body Exposures (total man-mrem over 20 yrs):				
Occupational				
o Process by waste generator	**	+2.50E+5	+4.50E+5	+4.90E+5
o Process by regional process center	0.	1.25E+5	1.25E+5	1.25E+5
o Waste transport	7.58E+6	4.99E+6	4.97E+6	4.97E+6
o Waste disposal	3.33E+6	2.15E+6	2.14E+6	2.15E+6
To population				
o Process by waste generator	**	+0.	+1.26E+2	+8.93E+1
o Process by regional process center	0.	0.	0.	0.
o Waste transport	7.49E+5	4.78E+5	4.76E+5	4.84E+5
IV. Costs (total $ over 20 yrs):				
Waste generation and transport				
o Process by waste generator	**	+5.90E+7	+8.20E+7	+2.14E+8
o Process by regional process center	0.	3.63E+7	3.63E+7	7.17E+7
o Waste transport	2.64E+8	1.73E+8	1.72E+8	1.70E+8

Table 4.6 (continued)

	Base case	No action case	Part 61 case	Upper bound case
IV. Costs (total $ over 20 yrs): (cont'd)				
Waste disposal				
o Design & op.	3.25E+8	3.41E+8	3.50E+8	3.42E+8
o Post operational				
Closure	3.87E+6	3.87E+6	3.87E+6	3.87E+6
Obs. & maint.	0.	0.	1.13E+6	5.86E+5
Inst. control	4.16E+7	1.90E+7	1.57E+7	9.32E+6
Total post op.	4.55E+7	2.29E+7	2.07E+7	1.38E+7
o Total disp. cost	3.71E+8	3.64E+8	3.71E+8	3.56E+8
o Unit cost ($/m³)	3.71E+2	5.61E+2	5.73E+2	5.64E+2
V. Energy Use (equivalent gallons of fuel oil):	**	-2.40E+6	-1.42E+6	+4.30E+6
VI. Land Use (m²):	3.47E+5	2.25E+5	2.25E+5	2.19E+5
VII. Waste Volume (m³):				
Volume acceptable				
o Unstable	7.47E+5#	4.42E+5#	4.23E+5	0.
o Stable - Regular	2.52E+5#	2.05E+5#	2.21E+5	6.27E+5
o Stable - Layered	0.	0.	3.47E+3	3.83E+3
o Total volume acceptable	1.00E+6	6.47E+5	6.48E+5	6.31E+5
Volume not acceptable	0.	2.56E+4	2.20E+4	2.20E+4

*The notation 2.30E+3 means 2.30×10^3.

**In this EIS, population exposures due to waste processing by waste generators, occupational exposures due to waste processing by waste generators, costs due to waste processing by waste generators, and energy use are presented as impacts and costs in addition to those associated with the base case.

#Although much of the waste is or has been stabilized, the fact that for these two cases all the stable waste is disposed comingled with unstable waste tends to negate the potential gain of waste stabilization. The result is about the same as if all waste was in an unstable form.

the percolation. In addition, ground-water movement of radionuclides would almost certainly be detected through monitoring wells long before appreciable exposures could be received by the public. A more important point is that a considerable amount of effort and cost to the site owner may be required to prevent such exposures from occurring. This is discussed in more detail later.

The above impacts are calculated for the reference disposal facility site assuming soils with moderate permeability and moderate ion exchange capacity. It is also useful to consider variations on the environmental properties of the reference disposal facility site. These variations were discussed in Section 4.2.3 and are referred to as a variation assuming very impermeable site soil conditions and a variation assuming very permeable site soil conditions. Relative to the reference site, the impermeable site variation assumes greater contact time between waste and percolating water, longer groundwater travel times to biota access locations, and higher isotopic retardation coefficients. The permeable site variation assumes, relative to the reference site, shorter contact time between waste and percolating water, shorter groundwater travel times to biota access locations, and lower isotopic retardation coefficients.

The results of this analysis is shown in Table 4.7. Listed are groundwater impacts from the boundary well, population well, and surface water access location. Also listed are impacts due to potential leachate accumulation as well as waste disposal costs.

Impacts listed in Table 4.7 for trench overflow/leachate treatment require some interpretation. As discussed, ground-water migration impacts may be calculated for a variety of disposal site environmental conditions. The reference disposal site assumes moderately permeable soil conditions. For sites having very impermeable soils, however, and assuming unstable disposal cell conditions leading to severe cell cover subsidence and slumping problems, it is more likely that the rate of percolation into a disposal cell will exceed the rate of percolation through the bottom of the disposal cell and into the groundwater. If this happens, the trench may fill up with water like a bathtub. This phenomenon has been in fact observed at both the Maxey Flats, Kentucky and West Valley, New York disposal facilities. It is possible that the disposal cell may even fill up to the point that the disposal cell overflows, leading to environmental releases and human exposures.

In Table 4.7, impacts are approximated assuming that one million gallons of contaminated leachate per year overflows the disposal cells and is carried down to a nearby stream. The water in this stream is then assumed to be consumed and used by an individual. The impacts are calculated in a very conservative manner (for example, no credit is taken for radioactive decay during facility operations) and as shown are rather high--on the order of 6 rem/yr. Similarly to the groundwater case, however, it is unlikely that the site owner or the appropriate health department (state or federal) would ever allow such impacts to occur. Rather, a remedial action program would be implemented in which leachate would be removed from the disposal cells and processed. Annual impacts from processing one million gallons of leachate by evaporation are also shown. Impacts are calculated as annual exposures (in man-millirem/yr) to the surrounding population. Such remedial action programs, involving leachate treatment and solidification as well as restabilization of the disposal site to reduce infiltration are anticipated to last several years.. Such actions are also

Table 4.7 Variations on the Base Case Analysis

	Ref. site	Imperm. site	Perm. site
Groundwater Impacts (mrem/yr):			
Boundary well			
o Body	1.58E+2	3.09E+0	1.45E+2
o Bone	5.61E+0	1.34E+1	2.98E+0
o Thyroid	1.50E+3	1.44E+3	4.74E+2
Population well			
o Body	7.90E-1	1.88E+0	9.94E-2
o Bone	1.13E+0	9.24E+0	1.94E-1
o Thyroid	4.74E+2	1.11E+3	4.74E+1
Surface water			
o Body	3.16E-2	8.65E-2	5.38E-3
o Bone	4.92E-2	3.58E-1	1.31E-2
o Thyroid	2.16E+1	6.21E+1	2.16E+0
Leachate Accumulation Impacts:			
Disposal cell overflow (mrem/yr)			
o Body	0.	6.38E+3	0.
o Bone	0.	2.28E+3	0.
o Thyroid	0.	5.97E+3	0.
Leachate treatment (man-mrem/yr)			
o Body	0.	6.26E+4	0.
o Bone	0.	7.53E+1	0.
o Thyroid	0.	6.26E+4	0.
Waste Disposal Costs (total $ over 20 yrs):			
Design and op.	3.25E+8	3.25E+8	3.25E+8
Post operational			
o Closure	3.87E+6	3.87E+6	3.87E+6
o Obs. and maint.	0.	0.	0.
o Inst. control	4.16E+7	5.42E+7	3.68E+7
o Total post op	4.55E+7	5.80E+7	4.07E+7
Total disposal costs	3.71E+8	3.83E+8	3.66E+8
Unit cost ($/m^3)	3.71E+2	3.83E+2	3.66E+2

anticipated to be quite expensive for the site owner. (A further discussion on costs is provided below.)

Short-term environmental impacts include exposures to radiation workers during waste processing, transport, and disposal, as well as population exposures due to waste processing and transport. All impacts are given in units of man-millirem and are summed over the 20 years of site operation.

Population exposures from processing wastes at waste generating facilities are not calculated for the base case as the base case is meant to represent conditions in which little or no waste processing is performed other than that required to meet safety requirements for transportation and disposal facility waste handling operations. In addition, such impacts are already considered as part of licensing such facilities. (This EIS is interested in the incremental exposures above the base case exposures.) Potential impacts from processing wastes at a regional processing center are also zero for the base case. (No regional waste processing is assumed to occur for the base case.)

Total transportation population exposures are an estimated 749,000 man-millirem for 20 years delivery of waste to the disposal facility. This exposure was calculated assuming an average waste transport distance of 400 miles (one way) and an assumed population dose of 0.018 man-millirem per shipment per mile. In addition, each shipment is assumed to make one stop during the 400-mile trip, resulting in a population dose of 2.0 man-mrem per shipment stopover. The total population exposed is assumed to be 1.5×10^5 persons during transit and 500 persons per stopover.

Short-term occupational exposures are calculated as the total exposures over 20 years of (1) waste processing activities, (2) waste transportation, and (3) waste disposal. Occupational exposures from normal waste handling and packaging to meet Department of Transportation (DOT) transportation requirements and to meet safety requirements at disposal facilities (e.g., specific packaging criteria for biological wastes, solidification of liquids) are not estimated for the base case. These would be expected to vary widely among the many thousands of NRC and Agreement State licensees. However, additional potential exposures due to the additional waste treatment processes considered in the subsequent cases are estimated as part of the impacts of these cases. Occupational exposures due to waste transportation are estimated as about 7.58 man-millirem per m^3 of waste transported. Again, as no waste processing activities are assumed to take place at a regional processing center for the base case, no occupational doses due to waste processing at the regional center are calculated.

Disposal facility occupational exposures are calculated as approximately 167,000 man-millirem/year, or about 3.33 man-millirem per m^3 of waste disposed. Assuming a total exposed working crew of about 50 persons, this calculates as an average estimated 3.33 rem per year per individual worker, which is an approximate upper bound of the general range of occupational exposures currently experienced at operating disposal facilities.

Costs are divided into processing costs, transportation costs, and disposal costs, and are presented as total costs over 20 years of disposal facility operation. For the base case, minimal waste processing is assumed to occur. The actual costs experienced by a waste generator are a function of many

variables, including the characteristics of the waste processed, the volume of the waste processed, and the design of the waste processing equipment, if any. Processing costs are presented in this EIS as additional costs to those associated with the base case.

Transportation costs may vary widely for different waste generators depending upon the distance from the waste generator to the disposal facility and the characteristics of the waste disposed. Information regarding the assumptions used to determine these costs are provided in Appendix C of the draft EIS. For this final EIS, a base case transportation cost of $264 million is estimated for transportation of about 50,000 m^3 of waste per year over 20 years ($264 per m^3 of waste).

As shown in Tables 4.6 and 4.7, disposal costs are divided into (1) disposal costs charged for facility design and operation, and (2) post-operational costs. Disposal design and operation costs are calculated to be on the order of $325/$m^3$ (9.20/ft^3). Postoperational costs are calculated as the total amount of money that would have to be collected over the operating life of the site to have sufficient funds to close the site and to carry out a particular level of site care. In the base case, post-operational costs required to be collected from disposal facility customers are projected to be quite high--i.e., on the order of $45.5 million for the reference disposal facility site. For a site having very impermeable soils so that a large-scale leachate accumulation problem could exist (and as currently exists at some formerly operated disposal facilities), postoperational costs would be even higher--i.e., on the order of $58 millon. Better than 90% of the postoperational funds thus collected would be for the 100-year institutional control period. These costs translate to a charge to a disposal facility customer of from $1.29/$ft^3$ to $1.64/$ft^3$. These changes assume a total waste volume of one million m^3; if only 500,000 m^3 of waste was delivered, the post-operational change would range from approximately $2.58/$ft^3$ to $3.28/$ft^3$.

The shear magnitude of the funds that would need to be collected over 20 years to ensure long-term care for the base case deserves special consideration. As discussed earlier, significant potential ground water impacts are estimated. These large calculated impacts result from the assumed practice of indiscriminately disposing of easily compressible, degradable waste streams (which frequently have only very low levels of contamination) with higher activity waste streams. These easily degradable waste streams (e.g., trash) frequently contain chemicals which may increase leaching and reduce retardation of radionuclides during migration through ground water. As discussed earlier, these calculated levels of exposures are not likely to be actually realized. However, to <u>prevent</u> such potential exposures from occurring, a considerable amount of active site maintenance could be expected on the part of the site owner. It is difficult to predict how long this extensive site maintenance would be required or how much it would cost, although it is seen that many millions of dollars could be potentially involved.

It could be argued that it would be a simple matter to merely charge sufficient postoperational fees to provide for the required care. However, this concept has a number of drawbacks, including:

- o There is no assurance that sufficient funds will be available for long-term care, or that funds collected will not be spent for other purposes. For example, the disposal facility may close prematurely and prior to collection of sufficient funds.

- There is no assurance that the extensive kinds of maintenance activities that would be required would actually be carried out in a timely manner. For example, at a site with very impermeable soils, subsidence could lead to disposal trenches filling up with water (the bathtub scenario) which could potentially be ignored until large expenditures were required to rectify the problem.

- Extensive site maintenance activities can lead to releases of quantities of radionuclides offsite. For example, if extensive water management activities such as removal and evaporation of large quantities of trench leachate are required, then offsite exposures will result.

Leaving a disposal facility in a condition so that extensive active maintenance activities are required to ensure public health and safety could result in a considerable financial burden to the site owner and to future generations. Such active maintenance activities can continue for long time periods, and in fact tend to become self-perpetuating. Active maintenance activities such as leachate pumping and treatment represent a large source of expense without a tangible corresponding economic gain. Under such conditions, human nature dictates a tendency to try and maintain the site spending as little money as possible, and without addressing more expensive measures to eliminate the need for such active maintenance. This is believed to be especially true if insufficient funds were collected during the operating life of the site. In such a case, funds for maintaining the site would need to be provided by funds appropriated through the legislative process. Experience has shown that it would probably prove to be much easier to yearly appropriate the minimal amount of funds necessary to maintain the status quo than to appropriate sufficient funds to stabilize the site. This is true even if the yearly maintenance costs following stabilization would be expected to be reduced.

Also shown in Table 4.6 is the estimated land area (347,000 m^2, or about 86 acres) required to dispose of approximately one million m^3 of waste. In this EIS, energy use is presented in incremental gallons of equivalent fuel from that associated with the base case.

4.4.2 Current Disposal Practices (No Action Alternative)

This case represents the level of costs and impacts resulting from a continuation of current waste management practices.

In this case, a total of 670,000 m^3 of waste is generated. This reduced volume of waste relative to the previous case is due to the greatly increased use of volume reduction techniques projected to be utilized now and in the future. These volume reduction techniques are utilized on compressible trash streams as well as on light water reactor process liquids. Of this volume, 25,600 m^3 of waste is classified as being unacceptable. This waste includes the L-DECONRS and N-SOURCES waste streams, which are projected for the purposes of this EIS to contain high concentrations of transuranic nuclides. (For further information on the assumed radionuclide content of these streams consult Chapter 4 and Appendix D of the draft EIS.) Small portions of LWR process waste streams (ion-exchange resins, filter sludge, and concentrated liquids) are also determined to be unacceptable, as is most of the F-PUDECON waste stream. These waste streams are determined to be unacceptable for near-surface disposal mainly based upon their transuranic content.

Of the waste accepted (647,000 m^3), about 32% is or has been stabilized prior to disposal. Again, however, stable and unstable waste streams are disposed comingled, which negates much of the benefit provided by the stable waste. Of the waste streams stabilized according to the 1 $\mu Ci/cm^3$ criteria, most are assumed to be stabilized using high integrity containers. Some are stabilized through solidification.

As shown in Table 4.6, individual intruder exposures are reduced over the previous base case alternative. This reduction in intruder exposures is principally due to the 10 nCi/gm limit on transuranic radionuclides. As shown, the potential waste volume-weighted inadvertent intruder exposures are still somewhat high at 100 years--on the order of 1.8 to 2.3 rem--but drop to only a few millirem by 500 years. As before, much of the calculated exposure at 100 years is due to short to moderately lived gamma-emitting isotopes. These decay away rather quickly, however.

As would be expected, impacts to surrounding populations due to intrusion are also reduced over the previous base case.

Relative to the previous case, groundwater impacts are also greatly reduced. These impacts run at approximately 11 mrem/yr to the thyroid at the intruder and boundary wells, 3.5 mrem/yr at the population well, and 1.6 mrem/yr at the surface water access location. Whole body exposures have also been greatly reduced from the previous case--i.e., 0.4 mrem/yr at the boundary well as opposed to the previous 158 mrem/yr.

It is possible that these impacts are nonconservative. As commenters on the proposed Part 61 rule and EIS have noted, it is difficult to judge the effectiveness of improved disposal cell covers when disposal cells are filled with compressible waste. Although a number of improvements in waste form and packaging are implemented, resulting in stabilization of many of the higher activity waste streams, all waste streams are still disposed intermingled together. Given the possibility of slumping and subsidence associated with the presence of the unstable waste streams, it is possible that too much credit has been given to the improved disposal cell covers to reduce percolation into the disposal cells. Assuming that only reduced credit could be taken, calculated groundwater impacts would be increased.

For the impacts listed in Table 4.6 for the reference site no action case, percolation through the improved disposal cell covers was assumed to be 60 mm over the first 100 years following closure of the disposal facility and transfer of the facility license to the site owner. This percolation is assumed to increase at the end of this time period, due to the possibility of a breakdown or removal of institutional controls and to the possibility of intrusion by burrowing animals and deep-rooted plants. Ten percent of the disposal cells are assumed to experience percolation equal to 180 mm while the remaining 90% are assumed to experience a percolation equal to 120 mm. This is equal to an average percolation rate into the disposal cells after 100 years of 126 mm.

The effects of assuming increased percolation into the disposal cells is modeled by assuming a percolation rate equivalent to that associated with the base case disposal cell covers assuming improved compaction. As discussed above, these base case covers are relatively thin (1 m thick) and have only a small to moderate clay content. In this high percolation case, percolation into the disposal cells is taken to be 270 mm both during and after the 100-year institutional control period.

The effect of increased percolation into the disposed waste compared to the reference site no action case is shown in Table 4.8, as are two variations on the higher percolation case assuming impermeable and permeable site soil conditions, respectively. As shown, boundary well whole body impacts for the reference site are raised from less than one mrem/yr to nearly 9 mrem/yr. Thyroid impacts at the boundary well are raised from about 11 mrem/yr to about 41 mrem/yr. Thyroid exposures at the population well and surface water access location are similarly raised. Higher exposures are calculated for the two variations on the reference site environmental conditions.

The impacts listed in Table 4.8 for trench overflow/leachate treatment again require some interpretation. Given the soil conditions at the reference disposal site it is not likely that such a water accumulation problem would occur. The listed impacts would only be for the case if the disposal facility was sited in very impermeable soils. In this case, the impacts from trench overflow and leachate treatment are somewhat reduced over the previous case. Some of this reduction in calculated impact is due to the fact that some volumes of waste have been determined to be unacceptable for near-surface disposal. In addition, some of the waste streams in this case have been stabilized by solidification or by using high integrity containers.

Much of the impacts thus calculated are due to tritium, and it is useful to examine the potential reduction in such impacts if waste streams containing large quantities of tritium (the N-TRITIUM and N-TARGET streams) are placed into high integrity containers prior to disposal. If this is the case the leachate accumulation impacts are reduced to the following:

	Body	Bone	Thyroid
Disposal cell overflow (mrem/yr)	3.55E+2	5.85E+2	2.68E+2
Leachate treatment (man-mrem/yr)	2.90E+2	1.22E+0	2.90E+2

As can be seen, the potential difference in impacts is about an order of magnitude.

Short-term whole body occupational and populational exposures exhibit a number of changes relative to the base case. For example, occupational exposures due to waste processing are calculated to increase over the base case. This is naturally due to the increased waste processing performed for this case. Some of these additional impacts are due to the requirement to stabilize LWR processing wastes containing radionuclides having half lives greater than 5 years and in concentrations greater than one microcurie per cubic centimeter. However, a very significant portion of these additional occupational exposures are due

Table 4.8 Variations on the No Action Case Analysis

	Ref. site low perc.	Ref. site high perc.	Imperm. site high perc.	Perm. site high perc.
Groundwater Impacts (mrem/yr):				
Boundary well				
o Body	4.39E-1	8.83E+0	1.48E+0	8.13E+1
o Bone	4.49E-2	1.65E-1	4.75E-1	8.88E-1
o Thyroid	1.11E+1	4.08E+1	1.29E+2	1.29E+2
Population well				
o Body	6.57E-3	2.41E-2	2.35E-1	2.80E-2
o Bone	1.04E-2	3.82E-2	3.52E-1	5.76E-2
o Thyroid	3.51E+0	1.29E+1	1.29E+2	1.29E+1
Surface water				
o Body	2.90E-4	1.09E-3	1.03E-2	1.53E-3
o Bone	4.29E-4	1.68E-3	1.39E-2	3.92E-3
o Thyroid	1.60E-1	5.87E-1	5.87E+0	5.88E-1
Leachate Accumulation Impacts:				
Disposal cell overflow (mrem/yr)				
o Body	0.	0.	5.56E+3	0.
o Bone	0.	0.	5.85E+2	0.
o Thyroid	0.	0.	5.47E+3	0.
Leachate treatment (man-mrem/yr)				
o Body	0.	0.	6.21E+4	0.
o Bone	0.	0.	7.32E+1	0.
o Thyroid	0.	0.	6.21E+4	0.
Waste Disposal Costs (total $ over 20 years):				
Design and op.	3.41E+8	3.41E+8	3.41E+8	3.41E+8
Post operational				
o Closure	3.87E+6	3.87E+6	3.87E+6	3.87E+6
o Obs. and maint.	0.	0.	0.	0.
o Inst. control	1.90E+7	4.16E+7	5.42E+7	3.68E+7
o Total post op.	2.29E+7	4.55E+7	5.80E+7	4.07E+7
Total disposal costs	3.64E+8	3.87E+8	3.99E+8	3.82E+8
Unit cost ($/m^3)	5.61E+2	5.97E+2	6.15E+2	5.89E+2

to compaction of compressible waste streams. Such compaction techniques are used as a cost-saving device by licensees and are unrelated to the waste stabilization requirement. In this case, a portion of the exposures due to waste compaction are assumed to be due to operation of a regionalized center for compacting compressible wastes generated by small entities.

Occupational exposures due to waste transportation and waste disposal are significantly reduced over the base case. This is principally due to the reduced volume of waste delivered to the disposal facility resulting from increased use of volume reduction techniques.

Population exposures due to waste incineration are calculated to be zero. Population whole body exposures due to waste transportation are reduced over that of the base case, which is again a result of the increased use of volume reduction for this case.

Waste generation and transportation costs show both increases and decreases relative to the base case. As expected, waste processing costs have increased, both due to the requirement for stabilization of some wastes as well as compaction of compressible waste streams. Costs due to processing at the regional processing center are entirely due to volume reduction considerations. None of these costs are due to the waste stabilization requirement. Transportation costs, due to the lower volume of waste delivered to the disposal facility, are reduced over the base case.

Relative to the base case, total disposal facility design and operation costs over 20 years have increased from \$325 million to \$341 million. This increase is due to the many improvements in site operation assumed for the existing case relative to the base case. These improvements include segregation of waste containing chemical agents (no segregation of unstable waste, however), use of a sand/gravel backfill, improved disposal cell covers, and improved compaction of backfill and disposal cell covers. The \$341 million in design and operation costs, when divided by the total volume of waste delivered to the disposal facility, corresponds to about \$527/m^3 (\$14.93/ft^3). Much of this high unit cost relative to the base case is chiefly the result of the lowered volume of waste delivered to the disposal facility. If these same costs were divided by one million m^3, which is the volume of waste assumed for the base case, unit costs would only be about \$341/m^3 (\$9.66/ft^3), or about \$16/m^3 (\$0.45/ft^3) greater than the base case.

Postoperational costs for this case are rather difficult to determine. Although a number of improvements in facility design and operating practices are incorporated, the fact that stable waste streams are still disposed mixed with unstable waste streams may still result in subsidence and slumping problems during the institutional control period. Therefore, postoperational costs are shown in Tables 4.5 and 4.7 as a range of costs. In this case, total postoperational costs for the reference facility (total funds that would have to be collected from waste generators over 20 years in order to provide for site closure and for the assumed amount of long-term care) are again projected to range from \$22.9 million to \$45.5 million. Due to the reduced volume of waste delivered to the disposal facility, unit costs to the disposal facility customer would be in the range of \$35.39/m^3 to \$70.32/m^3 (\$1.00/ft^3-\$1.99/ft^3). For

sites having a potential for leachate accumulation, postoperational costs are projected to range up to $58 million, or $89.64/m^3$ ($2.54/ft^3$). The uncertainty regarding these costs is a direct result of the uncertainty over the long-term stability of the site.

Both land use and energy use are calculated to be decreased over the base case. Land use for this case drops from 347,000 m^2 to 225,000 m^2. This is due to the reduced volume of waste delivered to the disposal facility. Relative to the base case, many of the compressible waste streams have been compacted. In addition, some 25,600 m^3 of waste have been determined to be unacceptable for disposal for this case. This is due to 10 nCi/gm limit on transuranic waste disposal assumed for this case.

Energy use is very difficult to estimate. Relative to the base case, however, energy use associated with waste processing would be increased while energy use associated with waste transport and disposal facility operations would be decreased. To the extent that post-operational costs are reduced for this case relative to the base case, energy use associated with post-operational activities (closure, institutional control) would also be reduced.

4.4.3 Part 61 Requirements (Preferred Alternative)

This case represents the level of costs and impacts resulting from implementation of the requirements in the final Part 61 regulation.

In this case, a total of 670,000 m^3 of waste is generated. Of this volume, 22,000 m^3 (3%) of waste is classified as being unacceptable for near-surface disposal. This waste again includes the L-DECONRS and N-SOURCES streams plus small portions of LWR process waste streams (e.g., ion-exchange resins, filter media, etc.). Of the remaining 650,000 m^3 of waste accepted at the disposal facility, 423,000 m^3 (63%) is classified as Class A unstable waste, 221,000 m^3 (33%) is classified as stable Class A and Class B waste, and 3,500 m^3 (1%) is classified as Class C (layered) waste. Similar to the no action case, the Class B and Class C waste streams are assumed to be stabilized through emplacement into high integrity containers and through solidification.

As shown in Table 4.6, intruder impacts at 100 years are considerably reduced over the previous case. This results from the practice of stabilizing higher activity waste and segregating them from unstable Class A waste, and from layering Class C waste. Impacts at 500 years are comparable to but slightly higher than those of the no action case. This slight increase in intruder impacts at 500 years is due to the raise in the limit for transuranic waste disposal from 10 nCi/gm to 100 nCi/gm for alpha-emitting transuranics and 3500 nCi/gm for Pu-241. Recall that in the no action case, the transuranic disposal limit was assumed to be 10 nCi/gm for all transuranic nuclides. For the Part 61 case, the limit for Class A disposal of transuranic waste is assumed to be 10 nCi/gm for alpha-emitting radionuclides and 350 nCi/gm for Pu-241 (a beta emitter). Above these limits waste must be stabilized and disposed at greater depths (layered). An overall limit for near-surface disposal is set at 100 nCi/gm for alpha-emitting transuranic radionuclides and 3500 nCi/gm for Pu-241.

This increase in impacts, however small, is probably overconservative. As discussed previously in this chapter, after 500 years, no credit is taken for the reduction in intruder impacts provided by layering waste streams. This is probably overconservative, since at least some of the effectiveness should be still retained. Assuming a factor of 10 credit for layered waste results in the following impacts for this case at 500 years.

	Body	Bone	Thryoid
Intruder-construction scenario (mrem/yr)	2.37E+0	1.09E+1	2.04E+0
Intruder-agriculture scenario (mrem/yr)	2.52E+0	6.70E+0	7.75E+0

Ground water impacts are also reduced over the no action case. In this case, thyroid impacts run at about 4.4 mrem/yr at the intruder and boundary wells, 1.3 mrem/yr at the population well and less than 0.1 mrem/yr at the surface water access location. Most of these impacts are from migration of the segregated stable waste streams. This means that efforts to reduce such impacts can proceed with a reasonable potential for success.

The beneficial effects of segregating stable high activity waste streams from unstable low activity waste streams are also shown in Table 4.9. In Table 4.6 and in the reference site low percolation case shown in Table 4.9, the improved disposal cell covers placed over both the stable and unstable disposal cells are assumed to be reasonably effective. In the high percolation cases in Table 4.9, however, this effectiveness is only assumed to be effective for the covers over the disposal cells containing stable wastes. Little or no such improvement is assumed for the disposal cells containing unstable wastes. To summarize, the average percolation rates assumed in the analysis are given by the following:

	Average percolation into disposal cells (mm)			
	high perc. case		low perc. case	
Time period	Unstable	Stable	Unstable	Stable
During institutional control period	270	30	60	30
After institutional control period	270	72	126	72

As shown in Table 4.9, impacts for the reference site high percolation case are not significantly raised over the reference site low percolation case, and are less than those calculated for the no action case.

Table 4.9 Variations on the Part 61 Case Analysis

	Ref. site low perc.	Ref. site high perc.	Imperm. site high perc.	Perm. site high perc.
Groundwater Impacts (mrem/yr):				
Boundary well				
o Body	1.11E-1	1.48E-1	1.03E-1	1.36E+0
o Bone	3.70E-2	1.27E-1	3.58E-1	7.11E-1
o Thyroid	4.16E+0	7.77E+0	2.46E+1	2.46E+1
Population well				
o Body	3.33E-3	8.70E-3	8.18E-2	1.20E-2
o Bone	8.24E-3	2.79E-2	2.52E-1	4.44E-2
o Thyroid	1.32E+0	2.45E+0	2.45E+1	2.46E+0
Surface water				
o Body	1.44E-4	3.89E-4	3.39E-3	7.69E-4
o Bone	3.37E-4	1.23E-3	9.80E-3	3.13E-3
o Thyroid	5.99E-2	1.12E-1	1.12E+0	1.12E-1
Leachate Accumulation Impacts:				
Disposal cell overflow (mrem/yr)				
o Body	0.	0.	6.65E+1	0.
o Bone	0.	0.	1.14E+2	0.
o Thyroid	0.	0.	4.48E+1	0.
Leachate treatment (man-mrem/yr)				
o Body	0.	0.	1.78E+2	0.
o Bone	0.	0.	6.71E-1	0.
o Thyroid	0.	0.	1.78E+2	0.
Waste Disposal Costs (total $ over 20 years):				
Design and op.	3.50E+8	3.50E+8	3.50E+8	3.50E+8
Post operational				
o Closure	3.87E+6	3.87E+6	3.87E+6	3.87E+6
o Obs. and maint.	1.13E+6	1.42E+6	1.42E+6	1.42E+6
o Inst. control	1.57E+7	3.04E+7	3.86E+7	2.73E+7
o Total post op.	2.07E+7	3.57E+7	4.39E+7	3.26E+7
Total disposal costs	3.71E+8	3.86E+8	3.94E+8	3.83E+8
Unit cost ($/m^3)	5.73E+2	5.96E+2	6.08E+2	5.91E+2

Again, the level of impacts listed for trench overflow/leachate treatment are unlikely to be achieved, but are included to illustrate the level of impacts that could result at a site having very impermeable soils. This also ignores the reduction in percolation that would result from improved disposal cell covers. Credit is taken for waste stabilization, however. In this case, the water accumulation problem only exists for disposal cells containing unstable waste streams. A proportionately lower volume of leachate is generated under such conditions.

Short-term whole body occupational exposures for this case are generally similar to those of the no action case. Since higher volumes of waste are processed by waste renerators, occupational exposures due to waste processing are higher than the no action case. Some of the additional occupational exposures from waste processing are due to the somewhat increased use of volume reduction technologies relative to the no action case, and are unrelated to exposures achieved from waste stabilization. This increased use of volume reduction technologies for the Part 61 case is attributable to the assumed raise in the transuranic disposal limit relative to the no action case. Occupational exposures due to waste transport and waste disposal are about the same as those of the previous case.

Population exposures follow a similar pattern. Population exposures due to waste incineration are very small but are increased over the previous case. This is in keeping with the expectation that at least some waste generators over the next twenty years will install and use incinerators to process compressible waste streams. All such incineration is projected to be carried out by the waste generators at the waste generator's facilities. Population exposures due to waste transport are slightly increased due to the slightly increased volume of waste transported to the disposal facility.

Waste generation and transport costs show a similar pattern to the calculated occupational exposures. Relative to the previous case, total waste processing costs are estimated to be raised by about $23 million. Most of these additional costs are due to stabilizing higher activity waste streams prior to disposal. Some of the additional waste processing costs for this case are due to the somewhat increased use of volume reduction technologies by waste generators. In addition, the waste processing costs include costs for stabilizing small volumes of waste streams which for the no action case were determined to be unacceptable for near-surface disposal. The potential savings to waste generators that would result from disposal by near-surface disposal rather than some alternative means (such as geologic repository) have not been included in the calculations. Costs due to volume reduction at the regional processing facility are essentially the same as the no action case. Essentially the same costs are calculated for waste transportation as were calculated for the no action case.

Waste disposal costs are divided into design and operation costs and post-operational costs. Relative to the no action case, design and operation costs are somewhat increased while the institutional control component of post-operational costs are reduced. The increased design and operation costs are due to the additional operational practice of segregating Class A unstable waste and layering Class C waste.

Post-operational costs are divided into closure, observation and maintenance, and institutional control. Closure costs are the same as the previous case.

Observation and maintenance costs are costs passed on to the disposal facility customer which would be required to fund a 5-year observation and maintenance program carried out by the site operator. This five-year period follows the closure period and is used to ensure the disposal facility is in a stable condition prior to transfer of the disposal facility to the site owner. These costs are presented in Table 4.9 as a range of costs.

Institutional control costs, similarly to observation and maintenance costs, are presented as a range to reflect uncertainties in long-term maintenance requirements. A low level of maintenance is projected to be required for stable waste streams, since these waste streams are segregated from unstable waste streams. A higher level of maintenance is projected for unstable waste streams. Since the degree and timing of the slumping and subsidence expected to be associated with disposal cells containing unstable waste streams is uncertain, the level of maintenance required for the unstable waste disposal cells is projected to range from a moderate to a high level of maintenance. This is believed to be conservative. It does illustrate a basic quandary regarding low-level waste disposal. The waste streams having the least radioactivity contribute the most to long-term maintenance and institutional control costs. The fact that these unstable waste streams are segregated from the stable waste streams, however, greatly reduces the environmental consequences of such disposal cell instability.

As shown in Table 4.9, total postoperational costs for the Part 61 case are projected to range from \$20.1 million to \$35.7 million for the reference disposal site. This translates to a unit postoperational charge to be paid by disposal facility customers of from \$31.94/m^3 (\$0.90/ft^3) to \$55.09/m^3 (\$1.56/ft^3). Higher postoperational costs would be associated with a site having very impermeable soils. For the preceeding no action case, total postoperational costs were projected to range from \$22.9 million to \$45.5 million. These costs did not include costs for an observation and maintenance period following disposal facility closure, and reduced to unit postoperational costs of from \$35.39/m^3 (\$1.00/ft^3) to \$70.32/m^3 (\$1.99/ft^3).

The differences between postoperational costs for the Part 61 versus the no action case are probably even larger than those calculated. This is because the environmental consequences of the uncertainty over the effectiveness of improved disposal cell covers is much more significant in the no action case than in the Part 61 case. In the no action case, potential increased percolation due to disposal cell subsidence over time is projected to effect all waste streams. In the Part 61 case, such potential increased percolation due to disposal cell subsidence is projected to only effect low activity unstable waste streams. Thus, postoperational costs are lower for the Part 61 case.

Land use is the same as the previous case. Somehwat more extensive volume reduction activities are carried out for the Part 61 case as were carried out for the no action case. Conversely, an additional 3600 m^3 of waste is accepted at the disposal facility relative to the no action case. The result is similar waste volumes being disposed for the two cases, resulting in similar land use requirements. Energy use is still reduced relative to the base case but increased relative to the no action case. Relative to the no action case, somewhat less energy use would be expected for post-operational activities. These reductions are counterbalanced by the expected increase in energy use associated with disposal operations (i.e., for waste segregation and for layering) and for waste processing activities.

4.4.4 Upper Bound Requirements (All Stable Alternative)

This case illustrates the costs and impacts associated with a case representing an extreme level of disposal facility stabilization. This may be accomplished in a number of different ways but for this case, waste streams which for the Part 61 case were disposed in an unstable manner are assumed to be emplaced into high integrity containers. The result is that all waste is disposed in a stable manner.

In this case, 653,000 m^3 of waste are generated, of which 22,000 m^3 (3%) of waste is determined to be unacceptable for near-surface disposal. Of the remaining 631,000 m^3, none of the waste is disposed in an unstable manner. (That is, the volume of Class A unstable waste is zero.) About 627,000 m^3 of waste is disposed as stable Class A and Class B waste and 3,800 m^3 (3%) is classed as Class C (layered) waste.

As shown, the intruder and groundwater exposures are the lowest of the four cases considered. Since all waste is stable, potential intruder exposures at 100 years are limited to those received during accidental discovery of the waste (the intruder-discovery scenario). Exposures due to the intruder-agriculture scenario are therefore not received. Intruder exposures at 500 years, however, are very similar to those observed for the previous case. Again, these exposures are possibly overconservative since no credit is taken after 500 years for the effectiveness of intruder barriers to reduce exposures to Class C layered waste.

Groundwater impacts are estimated to be in the range of 3.3 mrem/yr to the thyroid at the intruder and boundary wells, 1 mrem/yr at the population well, and about 0.05 mrem/yr at the surface water access location. These impacts are believed to be conservative, however. Since all waste streams are stable, there is believed to be support against significant subsidence of disposal cell covers. Given this, it is believed that further improvements in reducing percolation can be implemented with some confidence of their success. These could include, for example, barriers against deep-rooted plants and burrowing animals. It is believed that without a stable disposal site, such improved disposal covers would likely be ineffective. The conclusion is that if one wishes to lower potential long-term radiological impacts to levels as low as reasonably achievable, then disposal site stability is a place to start.

Other potential long-term impacts are also reduced. For example, offsite intruder impact at 100 years is reduced by one to two orders of magnitude over the previous case. Impacts at a site having very impermeable soils from trench overflow and leachate treatment are estimated to be zero for this case. Since all waste streams are disposed in a stable manner, the possibility of leachate accumulation problems at a site are judged to be remote.

Occupational exposures for this case are judged to be somewhat greater than the previous case. The difference in occupational exposures for waste processing for this case and the previous case are entirely due to the additional waste stabilization requirements. As shown, this difference is not significant.

Waste processing costs are significantly increased over the previous case. These increased costs are principally due to emplacement of Class A unstable waste streams into high integrity containers at an assumed average cost of \$450 per cubic meter of waste (\$12.74/ft^3).

Waste disposal costs are reduced relative to the previous case. Since all wastes are stable, there is no disposal change for segregated disposal of unstable waste streams. Post-operational costs are the lowest of the four cases considered.

As shown, land use for this all stable case is somewhat reduced--i.e., to 219,000 m^2--over the previous two cases. This is because the increased use of waste stabilization techniques for this case has resulted in somewhat decreased volumes of waste being delivered to the disposal facility. Energy use, on the other hand, is increased significantly over the previous three cases. This is again due to the increased use of waste stabilization techniques for this case.

4.4.5 Variations to the All Stable Alternative

In the previous case an option was considered in which all unstable waste streams are emplaced within containers providing structural support. The cost for such a container was estimated in this EIS to be on the order of $\$450/m^3$ based on cost estimates for a high integrity container currently being marketed. Another option could be to incinerate compressible waste streams and solidify the resulting ashes prior to disposal. This option is also projected at this time to be rather expensive--i.e., on the order of $\$927$ per m^3 of solidified waste--although with the current interest in volume reduction technology these costs could be reduced in the future.

Another option might be to provide stability through variations in disposal facility design and operation--e.g., through such possible techniques as grouted disposal, disposal into grouted concrete-walled trenches, or extreme compaction. Such possible techniques would have to be developed and tested for a specific disposal facility, since past experience regarding these techniques at low-level waste disposal facilities has ranged from occasional to none. Nonetheless, the projected costs (and some other impact measures) associated with these alternatives may be briefly considered.

For these alternatives, stable waste is assumed to segregated into stable and unstable waste streams, and stable waste streams are assumed to be disposed in the same method as the all stable and Part 61 cases. Unstable waste streams, however, are assumed to be subjected to more extensive alternative disposal practices. These alternatives include (also see Appendix F of the draft EIS):

1. Disposal into concrete-walled trenches. In this case, waste packages are stacked into concrete-walled disposal trenches. The interstitial spaces between the waste packages are grouted, and finally a concrete cap is poured over the grouted waste mass. This is followed by a compacted thick clay cap which is mounded and seeded to promote growth of a short-rooted grass cover.

2. Use of cement grout. In this case, waste packages are stacked into standard excavated disposal cells and cement grout is poured into the interstitial spaces between the waste packages. This is followed by a compacted thick clay cap which is mounded and seeded to promote growth of a short-rooted grass cover.

3. Use of extreme compaction techniques. This case is represented by a technique termed dynamic consolidation (or dynamic compaction). In this case, the unstable waste is assumed to be randomly emplaced in the disposal cells, backfilled, and a thin (e.g., one meter) earthen cover emplaced over the disposed waste. A large (5-40 ton) weight is then dropped from a significant height (e.g, 20-100 ft) several times over a limited area. At the site, an optimum weight and drop height would first be determined. Then, a crane would drop the weight a number of times at several locations in a pattern across the disposal cell cover surface. Depressions left by the weight are filled in and additional passes over the disposal cell surface may be made as desired and depending upon site-specific conditions. A clay cap would then be placed over the compacted earth/waste mass, mounded, and seeded.

The disposal costs estimated for the above three alternatives are compared below, compared with those associated with the Part 61 case. The disposal costs are divided into (1) design and operation costs, and (2) post-operational costs. Costs are also divided into costs for disposal of unstable waste streams as well as for all waste streams (total costs). Unit costs are based upon an unstable waste volume of 423,000 m^3 and a total disposed waste volume of 648,000 m^3. Post-operational costs for the Part 61 case are based on those projected in Table 4.6 for the reference disposal site assuming a moderate level of post-operational activities and costs. These respective costs are:

	Design and Op. Cost		Post-Operational Cost		Total Cost	
Case	Unstable Waste	All Waste	Unstable Waste	All Waste	Unstable Waste	All Waste
Part 61	228* (539)**	350 (540)	15.9 (37.6)	20.7 (31.9)	244 (577)	371 (573)
Walled Trench	384 (908)	507 (782)	9 (21.3)	13.8 (21.3)	393 (929)	521 (804)
Grout	262 (619)	384 (593)	9 (21.3)	13.8 (21.3)	271 (641)	398 (614)
Extreme compaction	240 (567)	363 (560)	9 (21.3)	13.8 (21.3)	249 (589)	377 (582)

*Units are $ x 10^6 (total over 20 years operation)
**Units are $ per m^3 of disposed waste.

As shown for the above three alternatives, stabilizing unstable waste streams by implementing special disposal practices is projected to raise facility design and operation costs. Conversely, post-operational costs would be reduced.

Total disposal costs for the three alternatives considered are still, however, larger than the total disposal costs for the reference site Part 61 case.

The above costs for the reference site Part 61 case are for a situation in which a moderate level of post-operational activities and costs are projected. This is believed to be a reasonable projection; however, it is also useful to inspect a worst case (i.e., unlikely) condition in which a high-level of post-operational costs and activities are estimated in the Part 61 case for unstable waste disposal.

These estimated worst case costs are given for three site environmental conditions: the reference site assuming moderately permeable soils, a variation on the reference site assuming very permeable soils, and a variation on the reference site assuming very impermeable soils. These costs are given below:

	Design and Op. Cost		Post-Operational Cost		Total Cost	
Case	Unstable Waste	All Waste	Unstable Waste	All Waste	Unstable Waste	All Waste
Mod. perm. site soils (Ref. site)	228* (539)	350 (540)	30.9 (73.1)	35.7 (55.1)	259 (612)	386 (596)
Perm. site soils	228 (539)	350 (540)	27.8 (65.7)	32.6 (50.3)	256 (605)	383 (591)
Imperm. site soils	228 (539)	350 (540)	39.1 (92.4)	43.9 (67.8)	267 (631)	394 (608)

*Units are $ x 10^6 (total over 20 years operation)
**Units are $ per m^3 of disposed waste.

Assuming a worst case situation, the total disposal costs for the site assuming very impermeable conditions are comparable to the costs for the grout alternative. Even more interesting, the total disposal costs for each of the variations on disposal facility site soil conditions are greater than the total disposal costs for the extreme compaction alternative.

The above appears to imply that techniques such as grouting waste packages or extreme compaction may be cost-effective methods to reduce post-operational costs associated with segregated unstable waste streams. However, it must be also observed that experience with the above three alternatives at low-level waste disposal facilities has ranged from little to none. There has been some experience both in the United States and abroad with use of concrete walled disposal cells. However, to NRC staff's knowledge, there has been no prior experience with either grouting or extreme compaction at low-level waste disposal facilities, although there is experience with extreme compaction at nonradioactive solid waste landfills.

There are other drawbacks as well. Use of the concrete-walled trench or grouted disposal of waste are projected to raise occupational exposures at the disposal facility (compared to the Part 61 case) by about 65 man-rem per year. Conversely, there is expected to be few additional occupational exposures due to waste handling for the extreme compaction alternative. The principal drawback to this compaction technique is the potential for expulsion of contaminated soil and waste. Depending upon the characteristics of the soil, the weight employed, and the drop height, depressions having depths of up to several feet may be produced. Care would have to be taken so that the dropped mass did not penetrate the cover material to the point that the waste is contacted and/or expelled into the air. This would cause a contamination problem for personnel and equipment, not to mention an airborne hazard both onsite and offsite. One way to reduce the potential for airborne spread of contamination would be to restrict the mass of the weight and the dropping height. However, this would also diminish the effectiveness of the compaction technique in that the depth of compaction would be reduced.

4.5 SUMMARY AND CONCLUSIONS

The preceding section of this chapter analyzed four LLW disposal case alternatives: a base case, a no action (existing disposal practices) case, a preferred (Part 61) case, and an upperbound case in which all waste is disposed in a stable manner. The results of the analysis of the cases have been presented in Table 4.6. Of these four cases, the base case is representative of disposal practices carried out several years ago. The environmental and long-term cost impacts of this case are clearly excessive and reversion to disposal facility practices typified by this case is an unacceptable alternative. The impacts listed in Table 4.6 for the remaining three cases are condensed, renormalized, and presented as Table 4.10. This allows a reference point to summarize some salient points raised by the previous analysis.

The impact measures are listed in Table 4.10 in three sections: (1) long-term individual exposures (in millirem/yr), (2) short-term whole-body exposures in addition to those associated with the no action case (in man-millirem/yr), and (3) total costs (in dollars over 20 years of disposal facility operations) in addition to those costs associated with the no action case.

Long-Term Individual Exposures

Impacts to a potential inadvertent intruder are given as waste volume-weighted impacts to the bone for the two intruder scenarios considered (intruder-construction and intruder-agriculture) for time periods equal to 100 and 500 years following closure of the site and transfer of the site license to the site owner. As shown for the no action case, intruder impacts run at about 2 rems after 100 years.

Table 4.10 Condensed Renormalized Comparison of the No Action, Part 61, and All Stable Cases

Impact Measures	No action case	Part 61 case	Upper bound case
I. Long-Term Individual Exposures (mrem/yr):			
Intruder-construction			
o 100 yrs - Bone	1.80E+3*	1.87E+2	1.77E+1
o 500 yrs - Bone	1.16E+1	1.63E+1	1.67E+1
Intruder-agriculture			
o 100 yrs - Bone	2.32E+3	2.08E+2	0.
o 500 yrs - Bone	7.19E+0	9.17E+0	9.38E+0
Boundary well			
o Body	4.39E-1	1.11E-1	1.09E-1
o Bone	4.39E-2	3.70E-2	1.47E-2
o Thyroid	1.11E+1	4.16E+0	3.30E+0
II. Short-Term Whole Body Exposures (man-millirem/yr):			
Total Occupational Exposures	**	+8.50E+3	+1.10E+4
Total Population Exposures	**	-9.50E+1	+3.05E+2
III. Total Annual Costs ($/yr)	**	+1.45E+6	+8.95E+6

*The notation 1.80E+3 means 1.80 x 10^3.

**Total occupational exposures, total population exposures, and total annual costs are given as increments to those exposures and costs associated with the no action case.

Given the added operational practices of segregating stable waste streams from unstable waste streams and placing certain high activity waste streams at the bottom of the disposal cells, potential intruder exposures at 100 years for the Part 61 case are reduced by an order of magnitude. Waste segregation is an operational practice that has been and is currently being carried out for particular waste streams, so implementing this alternative is well within current waste disposal technology. Similarly, layering (or other special handling) of certain waste streams has long been a standard practice at disposal facilities, and so this alternative is also judged to be well within current waste disposal technology. Further reductions in impacts are observed for the all stable case in which all waste streams are stabilized prior to disposal.

At 500 years, however, comparable intruder impacts (ranging from 10 to 17 mrem/yr) are observed for the three cases. In fact, due to the raise in the transuranic disposal limits for the last two cases from 10 to 100 nCi/gm, intruder impacts for the Part 61 and all stable cases are slightly higher than those for the no action case. As discussed in Section 4.4, however, even this small difference in impacts is probably exaggerated. Waste streams containing transuranic nuclides in concentrations between 10 and 100 nCi/gm are required in the last two cases to be layered. As discussed earlier, waste streams disposed with a minimum of 5 meters cover of earth and/or low activity waste streams would still be difficult to contact after 500 years. In addition, the analysis conservatively takes no credit for the reduction in exposures that would result in stabilized waste forms which would tend to reduce potential airborne dispersion and plant root uptake.

Groundwater impacts for the three cases are shown for three organs at a well assumed to be located down gradient of the disposed waste at the boundary of the disposal facility. In the analysis, an individual is assumed to pump contaminated water from the well and use it for consumption and other purposes such as irrigating crops. The impacts are listed as the maximum calculated potential impacts over 10,000 years following disposal facility closure. As shown, the impacts for the Part 61 case are about a factor of three lower than the no action case for exposures to the thyroid and a factor of about four lower for exposures to the whole body. For the all stable case potential exposures are somewhat lower than the Part 61 case, but the reduction is not as much as previously.

There is more to the above calculated impacts, however, then is apparent at first glance. As observed in Section 4.4 for the no action and Part 61 cases, most of the radioactivity contributing to the calculated impacts is contained in the stabilized waste streams. One of the main purposes of stabilizing such high activity waste is to provide structural support for disposal cell covers, thus reducing trench cover subsidence and minimizing contact of waste by percolating water. If, however, the waste streams thus stabilized are disposed comingled with other unstable waste streams (as is the situation for the no action case), then much of the benefit to be achieved by waste stabilization can be lost. This was illustrated in Section 4.4 by the variations in the no action and Part 61 case analysis in which reduced effectiveness was assumed for improved covers over disposal cells containing unstable waste streams. For the no action case, in which all waste is disposed comingled, the increased percolation raised the calculated thyroid impacts at the reference site to 41 mrem/yr. For the Part 61 case, the increased percolation into the unstable waste disposal cells

raised the calculated thyroid impacts at the reference site to only 7.8 mrem/yr, or better than 5 times less than the no action case.

It is recognized that the above is only a generic analysis and that actual percolation rates into disposal cells at an actual facility (and associated impacts) would need to be determined on a site-specific basis. The point, however, is that at the present time there is interest in developing improved methods of reducing the contact of waste by water, including improved disposal facility designs and disposal cell covers, with the aim of further reducing potential waste disposal impacts to levels as low as reasonably achievable. One example is the work conducted by the Department of Energy to develop biological barriers against intrusion by burrowing animals and deep-rooted plants. The effectiveness of current or possible future improved methods to reduce percolation into disposed waste, however, is believed to be linked to the degree of structural support provided by the disposed waste and backfill. Putting it another way, a stable disposal situation gives methods designed to reduce percolation a chance of working. Otherwise their long-term effectiveness is in doubt.

The analysis also suggests that waste stabilization reduces the dependence upon specific site characteristics to minimize radiological impacts. This was illustrated by the variations in the analysis performed for the no action and Part 61 cases. This is an important consideration, since there will always be some uncertainty associated with measurements and predictions of site geohydrological properties. A stabilized disposal site reduces the concern regardiing the impact of these uncertainties on the potential radiological exposures arising from waste disposal.

It may also be noted that for both the no action and Part 61 case, there is still a possibility (however small) of a water accumulation problem at a disposal site having very impermeable soils. The relative radiological impacts and costs of this phenomenon, however, are much reduced for the Part 61 case relative to the no action case. The potential for such impacts is believed to be reduced to minimum levels for the all stable case.

Short-Term Whole Body Exposures

Short-term whole body exposures are presented as yearly exposures (in man-millirem/ yr) in addition to those associated with the no action case. These exposures persist only during the 20-year period of operation of the disposal facility. Two such potential exposures are listed: total occupational exposures and total exposures to population.

Total occupational exposures are the sum of occupational exposures received

function of the layout of the waste generating facility, the type of waste processing performed and design of the waste processing equipment, and on several other factors. The most important consideration at a specific facility is often the level of management attention to reducing exposures.

Somewhat larger total occupational exposures are projected to occur for the all stable case. This relatively small difference between the Part 61 case and the all stable case is due to the assumption that high integrity containers (or some other container providing structural support) are used to stabilize unstable waste streams. As long as one is merely substituting once container for another, there would be expected to be little difference in occupational exposures received.

Total population exposures include potential exposures to populations from incineration of combustible waste at waste generating facilities, possible compaction of combustible waste at a regional processing facility, and transport of waste to the disposal facility. These are calculated as additional exposures in man-millirem/year and as shown, very little difference is projected from those exposures expected for the no action case.

Total Annual Costs

Total annual costs are presented as total annual costs that would be incurred by waste generators in addition to those associated with the no action case. Summed are total annual costs for waste processing, waste transport, and waste disposal. Costs for waste disposal include a basic disposal charge (design and operation costs) as well as a charge to disposal facility customers for post-operational activities (closure, observation, and institutional control).

Relative to the no action case, costs incurred for the Part 61 case are projected to include increased waste processing costs, somewhat increased disposal facility design and operation costs, and decreased post-operational costs. (These costs do not include the cost savings to disposal facility customers for raising the near-surface transuranic disposal limit from 10 to 100 nCi/gm.) Most of these additional costs are attributed to additional waste processing costs associated with stabilizing some additional high activity waste streams. Thus, these additional costs would only be incurred by disposal facility customers generating the high activity waste and not by small waste generators such as hospitals who mainly generate waste with only low levels of activity. The additional disposal facility design and operation costs are associated with the additional disposal facility operating practices for the Part 61 case of segregating unstable waste streams from stable waste streams, and of layering certain high activity (Class C) waste streams. Of these additional disposal facility costs, segregation costs are projected to be incurred by all disposal facility customers. These costs are estimated to run at about an additional $12.30/m^3 ($0.35/ft^3) in design and operations costs. Costs for layering certain high activity waste streams are projected to be only incurred by disposal facility customers generating the high activity streams.

Due to the increased disposal facility stability for the Part 61 case, the level of long-term site maintenance is reduced for the Part 61 case relative to the no action case. Corresponding long-term institutional control costs to be borne by the site owner are also reduced. This means that the funds collected from the disposal facility customers to provide for post-operational activities

could be reduced. Thus, lower post-operational costs to the disposal facility customer are projected for the Part 61 case.

The annual cost differential between the all stable case and both the no action case and the Part 61 case is projected to be more significant. These additional costs are principally due to the increased costs to stabilize all waste streams. Such costs would be passed on to all disposal facility customers. Conversely, disposal facility design and operating costs for the all stable case would be reduced relative to the Part 61 case (there would be no waste segregation charge). Post-operational costs would be less than either of the other two cases.

The fact that the large additional costs that are projected to occur for the all stable case would be expected to be passed on to all disposal facility customers is believed to be significant. Many disposal facility customers are small entities such as hospitals or small research facilities. The waste generated by such facilities is generally of very low activity.

One has to be concerned about the impact of such additional costs on small entities, although it is also possible that the magnitude of the estimated costs is exaggerated. In the all stable case, all Class A unstable waste streams were assumed to be stabilized by emplacement into containers providing structural support. Such containers are estimated in this EIS to cost on the order of \$450 per m^3 of waste, which is based upon estimated costs for high integrity containers. At the time these unit cost estimates were developed, however, there was only one company marketing high integrity containers. Since that time, additional companies are marketing high integrity containers. It may very well be that given business competition and future manufacturing savings, future costs for high integrity containers (or some equivalent container providing structural support) may be significantly reduced.

Another option might be to provide stability through variations in disposal facility design and operation--e.g., through such possible techniques as grouted disposal, disposal into concrete-walled trenches, or extreme compaction. The additional disposal facility design and operating costs for these alternatives are projected to run at about \$80, \$369, and \$28 respectively per m^3 of unstable waste disposed. Post-operational costs, however, would be reduced. Such possible techniques would also have to be developed and tested for specific disposal facilities, since past experience regarding these techniques at low-level waste disposal facilities has ranged from occasional to none. In addition, there are some occupational safety concerns regarding some of the above alternatives.

Conclusion

In conclusion, NRC staff judge that the generically preferred cage is the one representing the Part 61 requirements. Although the Part 61 case involves somewhat higher costs than the no action case, the potential in the Part 61 case for minimizing long-term environmental releases and costs to the site owner is enhanced. Minimum environmental impacts and costs to the site owner are associated with the all stable case. However, NRC staff belive that there are sufficient uncertainties associated with the cost impacts to disposal facility customers that it cannot be implemented generally at this time. This decision may change in the future, depending upon cost considerations and the maturation of newer waste management technologies. During licensing of specific disposal

facilities, however, special attention will be given tp the possibility of leachate accumulation within disposal cells. At specific sites where such a possibility can occur, additional measures intended to eliminate this possibility will be considered.

Chapter 5

CONCLUSIONS AND DISCUSSION OF REQUIREMENTS

This Chapter presents the final conclusions reached as part of the Part 61 rulemaking action. The final conclusions are presented as the basic principles and concepts that should be set out as the minimum requirements in the final Part 61 rule. The performance objectives derived as a result of the analyses are first addressed, followed by the principal technical requirements which follow from the performance objectives. These are followed by a discussion of waste classification requirements, which are then followed by a discussion and analysis of the final administrative, procedural, and financial requirements.

In preparing this chapter, use is made of the comparative analysis performed in the previous chapter, the analyses performed in the draft EIS, comments received on the draft EIS and comments received on the proposed Part 61 rule. Thus, also highlighted in this chapter are any significant modifications incorporated into the final Part 61 rule due to comments received on the proposed Part 61 rule. Although technically, this final EIS need only consider public comments received on the draft EIS, it is believed in keeping with the spirit of this EIS as a decision and information document to indicate the impact of comments on the proposed Part 61 rule on the final Part 61 EIS and rule.

In developing these conclusions, NRC considered and applied several criteria. The principal criteria used include whether the requirement would: (1) reduce short- and long-term health, safety and environmental impacts without major new short-term increases in the costs for disposal; (2) reduce uncertainty and long-term costs for disposal; (3) contribute significantly to helping ensure that the performance objectives would be met; (4) establish minimum technical requirements leaving maximum flexibility in how specific designs and operating practices could be applied by an applicant or licensee; and (5) establish specific controls where needed based on past experience and present knowledge.

5.1 PERFORMANCE OBJECTIVES VERSUS PRESCRIPTIVE REQUIREMENTS

In developing specific regulations for LLW disposal, two basic types of requirements can be established: performance objectives and prescriptive requirements.

A performance objective regulation would establish the overall objectives that should be achieved in the disposal of LLW and leave flexibility in how the objectives would be achieved. The performance objectives would establish general technical requirements on the design and operation of an LLW disposal facility and would include a standard or standards to specify the level of radiological hazard which should not be exceeded at an LLW disposal facility.

A prescriptive regulation would set out specific detailed requirements for the design and operation of an LLW disposal facility. Prescriptive standards would specify the particular practices, designs, or methods which are to be employed--for example, the thickness of the cover material over a shallow land burial disposal trench, or the maximum slope of the trench walls.

Based on the analysis in Chapter 2 of the draft EIS (§ 2.2), the preferred approach selected and followed by NRC in the preparation of the proposed Part 61 was to develop both performance objectives and prescriptive requirements. Overall performance objectives were developed to define the level of safety that should be achieved in the land disposal of LLW. Minimum technical performance requirements were also developed for each of the major components of an LLW disposal system that should be considered in all cases in the disposal of LLW to help ensure that the overall performance objectives for land disposal would be met. Finally, prescriptive requirements were established where they were deemed necessary and where sufficient technical information and rationale were available to support them.

Based on public comments on the Part 61 rule, draft EIS, and NRC's analysis of these comments, NRC has made no change to this approach. It has been followed in the development of the final Part 61 rule.

5.2 DEVELOPMENT OF PERFORMANCE OBJECTIVES

As part of the analysis performed in the draft EIS, NRC analyzed a range of alternative performance objectives for low-level radioactive waste disposal. This analysis involved an extensive series of case studies plus an extensive examination of the case study results. From the analysis NRC staff identified four such overall performance objectives:

1. Protect public health and safety (and the environment) over the long term;

2. Protect the inadvertent intruder;

3. Protect workers and the public during the short-term operational phase; and

4. Long-term stability to eliminate the need for active long-term maintenance after operations cease;

There were few comments from the public on the overall numerical analysis performed in the draft EIS to arrive at the preferred performance objectives. There were, however, some comments on the specific details of the analysis such as assumptions on environmental monitoring costs. Based upon the comments, NRC made a number of revisions to the numerical inputs to the impact analysis methodology including an improved method of cost analysis, a more extensive analysis of the impacts of waste classification and analysis of a new pathway (trench overflow and leachate treatment). The effect of the revisions to the analysis methodology had no effect on the overall conclusions but, rather, confirmed NRC's original conclusions. To provide greater clarity, an effort was made to reduce the number of cases considered and this resulted in the analysis performed in Chapter 4 of this final EIS. Based on public comments on the proposed rule, no new areas were identified which should be addressed in the Part 61 rule as overall performance objectives for land disposal of LLW. Commenters generally supported development of performance objectives in the above four areas.

One rule commenter challenged the performance objectives in Part 61 as being premature in advance of relevant EPA standards and beyond the agency's authority to the extent that they are not already embodied in 10 CFR Part 20 and that they are unduly stringent and unsupported. With respect to this comment, EPA, under its ambient environmental standards setting authority assigned by Reorganization Plan No. 3 of 1970 has the authority to prepare a standard that will set limits for releases of radioactivity to the general environment from disposal facilities. Presently there is no such EPA standard. In the absence of such a standard, the Commission examined a range of limits which bound that expected for the EPA standard and selected a proposed performance objective that establishes a release limit for the site boundary, a regulatory action within the limits of NRC authority. In a rulemaking action, the Commission is not solely limited to existing standards in Part 20 and the Commission does not intend to withdraw any portion of the rule that may be related to the performance objectives.

With regard to the specific performance objective for releases to the environment, the Environmental Protection Agency commented that the establishment of an individual exposure limit at the site boundary for releases as proposed in §61.41 is appropriate. They stated that the 25 mrem/yr limit is in the correct range of values (1 to 25 mrem/yr was analyzed by the Commission) which should encompass any future EPA standard for low-level waste disposal facilities. Based on the analysis, NRC does not anticipate any need to change the technical requirements of Part 61 to meet a future EPA standard. In their comments, EPA stated their opinion that it was inappropriate to apply the EPA drinking water standard as proposed in §61.41. Accordingly, this part of the performance objective has been deleted. However, this does not diminish the Commission's concern over protecting sources of drinking water. The Commission will assess the potential impact on drinking water supplies as part of its licensing review.

Reaction to the proposed performance objective to protect potential inadvertent intruders was mixed. There were some who felt the proposed 500 mrem whole body dose to the intruder was too high, some felt that it was the right value for a standard, and others felt that higher values were in order. Those that felt that the standard should be higher suggested values of 5 rem or 25 rem to correspond to limits for occupational exposure or one-time exposures to workers from potential accidents. A number of commenters, in their comments about considering the probability that intrusion will occur, expressed concern about weighting too heavily the protection against inadvertent intrusion in determining disposal requirements for waste. Based on these comments, the Commission believes that the primary concern of those who feel that the intruder protection objective is too restrictive is the effect that this has on the concentrations of certain nuclides that are acceptable for disposal in a near-surface facility and the need to meet waste form requirements such as stability for some wastes. With this in mind, and in response to other comments, the Commission has reevaluated the calculations that establish the waste classification concentration limits to eliminate unnecessarily conservative assumptions with the result that the analysis is more realistic and the limits for several important isotopes have been raised. With this action, the Commission believes that most of the concerns of those who encouraged higher exposure limits or less emphasis on protection of intruders will have been met.

With respect to those who suggested that lower limits would be appropriate, there were no compelling arguments or technical demonstrations presented that persuaded the Commission to lower the dose limit for intruders.

The EPA commented that it was not appropriate to state the 500 mrem (whole body) dose limit as a regulatory limit in the Part 61 rule, since the licensee would not be able to monitor or demonstrate compliance with a specific dose limit that applies to an event that might occur hundreds of years from now. They did recognize use of the 500 mrem whole body dose limit as the basis for determining the concentration limits in Table 1 of Part 61. Noting that, given ALARA, actual exposures to an inadvertent intruder would be lower than 500 mrem per year, the 500 mrem dose limit has been deleted from the performance objective but has been retained as the basis of the waste classification concentration limits.

EPA asked for a clarification of the intent of the performance objective in §61.43 as it pertains to effluents from the site. This performance objective states that operations at the land disposal facility must be conducted in compliance with the standards for radiation protection set out in Part 20. Part 20 contains standards for concentrations of radioisotopes in air and water released from a licensed facility. Section 61.41 sets forth limits on concentrations of radioisotopes released from a land disposal facility which are lower than those in Part 20. It is the Commission's intent that the provisions of Part 20 will apply to all aspects of radiation protection during operation except for releases of radioactivity from the site which will be governed by the more stringent requirements of §61.41. The rule has been modified to clarify this point.

Commenters pointed out a need to be clearer in the rule on how the principle of maintaining radiation exposures to a level that is as low as reasonably achievable (ALARA) will be handled. The Commission intends that the ALARA principle apply to the performance objectives for long-term environmental release and protection of individuals during site operations. It cannot apply to the intruder performance objective, since Part 61 sets out requirements for intrusion protection which are beyond the disposal facility licensee's control. Appropriate changes have been made in §§66.41 and 61.43 to reflect the ALARA principle.

Based upon the EIS analysis, and comments provided on the proposed Part 61 rule, the following performance objectives were derived for the final Part 61 rule:

5.2.1 Protection of the General Population From Releases of Radioactivity

Concentrations of radioactive material which may be released to the general environment in ground water, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment to levels as low as is reasonably achievable.

5.2.2 Protection of Individuals from Inadvertent Intrusion

Design, operation, and closure of the land disposal facility must ensure protection of any individual inadvertently intruding into the disposal site

and occupying the site or contacting the waste at any time after active institutional controls over the disposal site are removed.

5.2.3 Protection of Individuals During Operations

Operations at the land disposal facility must be conducted in compliance with the standards for radiation protection set out in Part 20 of this chapter, except for releases of radioactivity in effluents from the land disposal facility, which shall be governed by §61.41 of this part. Every reasonable effort shall be made to maintain radiation exposures as low as is reasonably achievable.

5.2.4 Stability of the Disposal Site After Closure

The disposal facility must be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate to the extent practicable the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required.

5.3 TECHNICAL REQUIREMENTS

Based upon the analyses for the performance objectives, a number of technical requirements were developed to help ensure that the performance objectives would be met. These technical requirements are set forth in Subpart D of the Part 61 rule. They specifically addressed the four principal components which collectively make up an LLW disposal system. These are:

(1) Site Characteristics - The geohydrological, geomorphological, climatological and other natural characteristics of the site where the disposal facility is located.

(2) Design and Operation - The methods by which the site is utilized, the disposal facility design, the methods of waste emplacement and closure of the site.

(3) Waste Form and Packaging - The characteristics of the waste and its packaging.

(4) Institutional Controls - The actions, including assurance of adequate financial resources, which involve a government agency maintaining surveillance, monitoring, and control over access and utilization of the site after closure.

Based on public comments filed on the rule and EIS, no new major areas were identified in addition to the above that should be addressed in the development of the technical requirements. New topics identified by commenters which should be addressed in the EIS fell into one of the above areas.

The technical requirements set forth in the proposed rule were generally derived either directly from the analysis to determine the performance objectives or were developed based upon past experience and existing good practices. A given technical requirement frequently helps to ensure that more than one performance objective will be met.

Most of the technical requirements can be related to three key principles that are of most significance in assuring the performance objectives are met. These three principles are:

1. Long-term stability of the disposal facility and disposed waste. Stability helps reduce trench cap collapse, subsidence, water infiltration, and the need to actively care for the facility over the long term.

2. The presence of liquids in waste and the contact of water with waste both during operations and after the site is closed. Water is the primary vehicle for waste transport and its presence in and contact with waste can contribute to accelerated waste decomposition and increased potential for making the waste available for transport offsite.

3. Institutional, engineering and natural controls that can be readily applied to reduce the likelihood and impacts of inadvertent intrusion.

The following chart summarizes the relative importance of each in helping to assure achievement of each of the performance objectives.

	Performance Objectives			
	Migration	Maintenance	Intruder	Operations
Long-term stability of waste and facility	Reduces water infiltration and thus the potential for migration.	Reduces uncertainty and need for long-term maintenance. Reduces long-term care costs.	Reduces likelihood for inadvertent intrusion. Reduces impacts to inadvertent intruder.	Reduces potential occupational Reduces off-site releases in the event of an accident
Contact of water with waste	Reduces potential for migration and off-site transport of waste.	Reduces need for active maintenance during and after operations.	Reduces waste degradation and thus impact to intruder.	Reduces potential hazards. Reduces potential for offsite releases.
Institutional and other intruder controls	Custodial care during institutional control reduces potential for water infiltration.	Assures proper maintenance.	Reduces likelihood for inadvertent intrusion. Reduces impacts to inadvertent intruder.	Reduces potential occupational hazards.

As discussed below, safety during disposal facility operations and proper disposal facility siting are also important considerations.

5.3.1 Stability

In translating these principles into technical requirements, NRC found that in general many were already being addressed in one way or another at one or more of the existing operating sites. For example, methods to improve site stability which are either already being carried out or may be readily implemented include improved, more stable waste forms and packaging for higher activity wastes, reducing void spaces between packaging placed in trenches, compaction of backfill material and trench covers, and use of institutional controls to continue to maintain and control site access after active operations cease.

The preferred alternative selected as a technical requirement will result in the least disruption of existing practices and will leave maximum flexibility in how stability can be achieved. The preferred alternative is to require that higher activity wastes must be placed into a stable form and disposed in a segregated manner from unstable waste. Lower activity wastes which are also stable may be emplaced with the higher activity stable waste. This is a desirable practice since it helps to reduce long-term environmental releases as well as operational exposures at the disposal facility.

Waste segregation is estimated to cost an approximate \$12.30/m^3 (\$0.35/ft^3) in additional disposal costs. Offsetting these additional costs will be the reduced need to change customers costs for long-term care. These reduced costs charged to the disposal facility customer can range from \$3.40/m^3 (\$0.10/ft^3) to \$21.80/m^3 (\$0.62/ft^3). Stability of the waste form can be achieved by several means:

1. The waste form as generated may already be stable (results in no increase in costs over those today);

2. Processing the waste to a stable form through techniques such as improved stable packaging, use of high integrity containers, or waste solidification. (The costs for this can range from negligible additional costs for stable packaging to an approximate additional \$450/m^3 for high integrity containers up to about an additional \$2000/m^3 in solidification costs. The costs are believed to be conservatively high. In addition, the industry is generally already moving toward this alternative in response to license conditions in effect at existing operating sites and it is, therefore, not a significant change from existing practices);

3. Use of engineering design at the disposal facility. Many engineering design alternatives which can provide stability are possible including caissons filled with concrete and concrete-walled trenches. (The cost for a concrete-walled trench including use of concrete grout as a backfill material was estimated to cost an approximate additional \$232/m^3 (\$6.60/ft^3) in total disposal costs.)

Given the need for waste stability and the requirement that Class B and Class C waste be stabilized, an obvious question is how does one comply with the technical details of the requirement. For example, for how long must a waste remain stable and what constitutes a stable waste form? Based upon the draft EIS analysis and other considerations, NRC proposed a number of specific requirements in the proposed Part 61 rule regarding waste stability. These included a statement that the requirements were intended to provide stability

for at least 150 years, that a stable waste form maintain its physical dimensions within 5 percent, and that the stability of the waste be maintained under a compressive load of 50 psi. There was also a statement that void spaces within waste containers be reduced to the extent practicable. Several comments were received on these draft requirements.

NRC staff has reviewed the 150-year stability requirement with respect to the scenarios used to calculate the waste classification values. The property of stability contributes to meeting successfully the performance objectives set forth in Part 61. A waste that is stable for a long period helps assure the long-term stability of the site, eliminating the need for active maintenance after the site is closed. This stability helps to assure against water infiltration due to failure of the disposal unit covers and, with the improved leaching properties implicit in a stable waste form, minimizes the potential for radionuclide migration in groundwater. Stability also plays an important role in protecting an inadvertent intruder, since the stable waste form is recognizable for a long period of time and minimizes any effects from dispersion of the waste upon intrusion.

The 150-year period was initially chosen to approximate the active life of a near-surface disposal facility, along with the periods of post closure observation and institutional control. At the end of this period, the intrusion scenario is based on the intruder readily recognizing any uncovered waste as something out of the ordinary with the result that no further attempts at construction or agriculture would be attempted. When other aspects of the performance objectives are considered, however, a longer design life is called for. The waste should continue to maintain its gross physical properties and maintain a measure of its identity for several hundred years more to provide site stability and to keep the Class B waste recognizable and unsuited to the construction and agriculture scenarios postulated. Consistent with the objective of avoiding prescriptive requirements where possible, the 150-year specification has been removed from the requirement. It is the NRC staff's belief, that to the extent that it is practicable, waste forms or containers should be designed to maintain gross physical properties and identity over 300 years, approximately the time required for Class B waste to decay to innocuous levels. This is reflected in the draft Low-Level Waste Licensing Branch Technical Position on Waste Form (Ref. 1).

A number of commenters on the proposed rule indicated that the proposed requirement that a stable waste form maintain its physical dimensions within five percent was overly restrictive and impossible to achieve due to the impracticality of filling containers to 95 percent capacity. Commenters also noted that asphalt and polymeric solidification agents would be incapable of meeting this requirement because of their visoelastic creep properties. Commenters also observed that the limit could entail added expenses.

Upon review of the proposed requirement, NRC staff has concluded that there is not sufficient basis at this time to support a strict numerical limit in the Part 61 rule on deformation of stable waste. The five percent value has been removed from this requirement. NRC staff will instead address the issue through technical positions on waste form. The intent will be to work through existing waste solidification capabilities with the aim of steadily improving such capabilities over time. In the meantime, reliance will be placed on the

requirements that void spaces within packages must be minimized and the requirements that wastes must be emplaced in a manner that permits void spaces between containers to be filled.

Several commenters objected to the specific requirement that the stability of the waste be maintained under a compressive load of 50 pounds per square inch (psi). Most felt that the specific requirement should be deleted and replaced by a more general requirement to reflect actual disposal site conditions and operations.

In response to these comments, the 50 psi specification has been removed from the rule. The specification was based on conservatively assuming maximum burial depths up to 45 feet and a waste or overburden density of 150 lb/ft^3. Testing performed on acceptable solidified waste specimens indicate that a 50 psi compressive strength should be easily obtained. NRC staff believes that while this is achievable, some latitude should be allowed for the design of waste forms and containers to reflect site conditions where burial depths may be less.

There was some question regarding the rule statement that void spaces within waste containers should be reduced to the extent practicable. Several requested specific criteria on how this would be met and if filler materials were needed. Two felt that economics would drive waste generators to package the maximum volume of waste into a container and that this requirement in the rule is unnecessary.

Due to the highly variable nature of wastes, NRC staff believes that it is not possible or desirable to include specific criteria for minimizing voids. To the extent that void spaces can contribute to eventual instability of the waste, they should be eliminated or reduced as much as possible. This might be done in some cases by filling void spaces with other wastes or inert materials. No change was made to the requirement.

Since the rule permits the stability of waste to be achieved by placing the waste in a suitable container for disposal, a number of comments addressed the properties such a container should exhibit and the uses to which it should be put. It was suggested that the Commission reexamine design criteria for a high integrity container for highly dispersible forms, and one suggested that such a container should be used for both high and low concentration wastes. A major supplier of waste solidification technology questioned whether the use of a container reflected the concepts of reducing potential exposures to levels as low as reasonably achievable (ALARA).

NRC staff has prepared a technical position on waste form criteria, including design criteria for such a container. Draft copies have been made available to interested parties for their review and comment (Ref. 1). In short, the technical position states that the container must provide equivalent assurance of stability as a stable waste form or product. It should be designed, to the extent that it is practicable, to maintain gross physical properties and identity over 300 years, under the conditions of disposal. The staff believes that the use of containers to achieve stability is consistent with the concept of ALARA and the use of the best available technology. Occupational exposures in using such containers are expected to be similar to or less than waste solidification, either with mobile or installed systems.

NRC also evaluated in the draft EIS a number of facility design and operational improvements that are in many cases currently being applied at the existing operating sites to improve long-term site stability. These include waste placement, backfill, and compaction of backfill and trench covers. The use of specific design and operational techniques would be evaluated for a specific facility on a case-by-case basis as part of licensing that facility.

In general, however, the overall objective is that waste placement and backfill procedures should improve rather than reduce site stability. Comments on the draft rule and EIS indicated that NRC staff was not sufficiently clear regarding this point. The draft requirement in paragraph (4) of section 61.52(a) was that wastes must be emplaced in an orderly manner. Several commenters objected to this requirement because of perceived increased operational exposures.

The requirement that was proposed was intended to assure that the placement of packages into a disposal unit did not destroy the integrity of the package (in order to minimize the possibility of releases of contamination) and also to minimize the void spaces between packages so that this would not be a contributor to site instability. It has been a common practice at waste disposal facilities to dump some wastes over the edge of a disposal trench with the packages falling and tumbling to the trench bottom where they ended up in a random arrangement. This practice jeopardizes package integrity and does not permit access to voids between packages so that they could be backfilled. The assumption by the commenters that orderly emplacement necessitates increased handling by site operators which results in higher radiation exposures is not necessarily the case. Lifting and stacking devices are currently in use for low-level waste disposal that permit remote lifting and emplacement in the disposal trench without increased occupational exposure. The resulting emplacement meets the intent of protection of packaging integrity and access to void spaces. In any case, one of the penalties of not achieving site stability is increased exposures to site maintenance personnel over the institutional control period. Since the term "orderly" was subject to misinterpretation, the requirement has been rewritten to remove the term and to specify the objectives of waste emplacement.

Several commenters on the proposed Part 61 regulation pointed out the stability problems (slumping, subsidence, etc.) that could still be associated with disposal units containing the segregated and unstable Class A waste. It is true that relative to the disposal cells containing stable waste, greater site instability and increased maintenance (and cost) during the institutional control period would be expected. However as addressed in Chapter 4, the level of activity in the unstable waste disposal units would be much less than in the stable waste disposal units. Waste segregation reduces the long-term impacts associated with the total site.

NRC's preferred solution in terms of minimizing groundwater migration and reducing institutional control maintenance activities would be to extend waste stability requirements to all waste. However, much of the waste generated by licensees is of very low activity and furthermore generated by small entities. Based upon the waste form and disposal facility design alternatives considered in the EIS, NRC staff concluded that extending waste stability requirements to

include all waste would have too great of an economic impact to require generically at this time, particularly to small entities. NRC staff, therefore, intends that the site operator give particular attention to means of achieving greater stability to the design of that portion of the facility used for disposal of Class A waste. Innovative designs should be considered in order to provide long-term stability of the site, considering the inherent instability of the Class A waste and the potential for water accumulation problems where there is potential for such problems to occur. Increased emphasis on identifying waste streams that may be disposed by less restrictive means ("de minimis waste") will also have a beneficial effect.

5.3.2 Contact with Water

A number of specific requirements relating to site characteristics, disposal facility designs and operating practices, and waste forms and packages are established in the Part 61 rule which are directed at reducing the contact of waste by water, both during operations and over the long term after closure (see Sections 61.50, 61.51, 61.52, 61.56, and 61.59). These include requirements that the site be free of areas of flooding or frequent ponding, and provide sufficient depth to the water table so that ground-water intrusion into the waste will not occur. They also include design features such as trench covers being designed to minimize water infiltration, to direct rainwater away from trenches and to prevent waste from sitting in rainwater in open trenches. Waste form requirements address the disposal of liquid waste.

A discussion of requirements related to (1) site characteristics, (2) disposal facility design and operating practices, and (3) waste form and packages is provided below.

Site Characteristics. Minimum requirements for disposal site suitability (set forth in section 61.50 of the Part 61 rule) are primarily directed at site characteristics to be avoided rather than setting forth areas which would be desired. The siting requirements were developed based on past history and recommendations from groups such as the U.S. Geological Survey (USGS), and are believed to represent, for the most part, simple common sense. (See Appendix E of the draft EIS.) The requirements can be paraphrased as follows:

1. The disposal site shall be capable of being characterized, modeled, analyzed, and monitored.

2. Projected population growth and future developments should not affect the ability of the site to meet the performance objectives.

3. Avoid areas having economically significant natural resources.

4. The disposal site must be generally well drained and free of areas of flooding or frequent ponding. Avoid waste disposal in a 100-year floodplain, coastal high-hazard area, or wetland.

5. Minimize upstream drainage areas.

6. Sufficient depth to the water table must be provided so that ground-water intrusion, perennial or otherwise, into the waste will not occur. Exceptions will be considered if diffusion is the predominant means of radionuclide movement.

7. Any ground water discharge to the surface within the disposal site must not originate within the hydrogeologic unit used for disposal.

8. Avoid areas of tectonic processes such as faulting, seismic activity, or vulcanism which occur with such frequency and extent that either the performance objectives are compromised or defensible modeling and prediction of long-term impacts are precluded.

9. Avoid areas of surface geologic processes such as mass wasting, erosion, slumping, land sliding, or weathering which could either cause the performance objectives to be compromised or preclude defensible modeling and prediction of long-term impacts.

10. Avoid areas where nearby facilities or activities could cause the performance objectives to be compromised or significantly mask the environmental monitoring program.

A discussion of NRC's intent regarding these site suitability requirements, as well as applicant procedures for site selection and characterization which are acceptable to NRC staff, is presented in NUREG-0902 (Ref. 2). This discussion on site suitability requirements is presented below along with public comments received on these requirements. (Approximately two dozen commenters offered comments on various aspects of the proposed disposal site suitability requirements.)

The first requirement implies that the proposed site should be geologically and hydrologically simple. Eight comments were received on this requirement primarily directed at the perceived vagueness of the requirement--i.e., what does it mean to be capable of being characterized, modeled, analyzed, and monitored? Since site characterization investigations can sample only a small fraction of the surface area or subsurface volume of the disposal site, NRC intends that the site characteristics must be such that these limited investigations can adequately define the site characteristics spatially across the disposal site. Since most modeling tends to homogenize the hydrogeologic units and average the hydrologic properties for such units, the site characteristics should vary within a sufficiently narrow range so that the input to the modeling is representative of the hydrogeologic units and the assumptions underlying the modeling are valid. For example, the hydrogeclogic unit used for disposal should not have continuous permeable or impermeable anomalies such as faults or fracture zones, sand lenses, weathered horizons, or karstic features that provide preferential pathways for or barriers to ground-water flow.

The first requirement also implies that natural processes affecting the disposal site should be occurring at a consistent and definable rate such that the modeling of the site will represent both present and anticipatable site conditions after closure. Finally, since monitoring programs can sample only a small fraction of the surface area or subsurface volume of the disposal site, site characteristics must be such that a reasonable number of monitoring points can adequately monitor site performance.

The second requirement, related to population growth, is tied to the potential for eventual use of the site. Disposal sites should be located in an area

which has low population density and limited population growth potential. Consideration should be given to the potential for future land use activities, such as residential, industrial, agricultural, and recreational development, that could adversely affect the disposal site.

The third requirement, related to known natural resources, includes such resources as mineral, coal or hydrocarbon deposits, geothermal energy sources, timber and water resources. The requirement applies to resource recovery that may occur at the ground surface, in the hydrogeologic units used for disposal and isolation, and at greater depths which require excavation or drilling through the disposal units. Potential indirect effects caused by nearby resource development, such as increased infiltration rates or steepened hydraulic gradients, should be evaluated. The primary concerns with respect to the presence of exploitable natural resources are the likelihood of inadvertent intrusion through resource development as well as the effects of such development on the performance of the site after the period of active institutional control.

The fourth requirement consists of two components. The first component, related to drainage crossing the disposal site, primarily applies to the disposal site after construction of the near-surface disposal facility. However, natural areas of poor drainage or frequent ponding can be indicative of seasonally high ground-water levels and should be so noted by the applicant. In addition, areas of flash flooding, such as arroyos or dry washes, should be avoided. The second component, related to avoidance of the 100-year floodplain, coastal high-hazard area or wetland, implements Executive Order 11988, Floodplain Management Guidelines (Ref. 3). This requirement can be applied to the disposal site at the site selection phase.

Commenters raised questions on the siting requirements related to surface water drainage. These can be summarized as (1) definition of certain terms such as upstream drainage areas, coastal high-hazard area and wetland, and (2) the adequacy of the exclusion of waste disposal based on the 100-year floodplain.

The 100-year floodplain is defined in the Executive Order (Ref. 3) as the lowland and relatively flat areas adjoining inland and coastal waters, including floodprone areas of offshore islands, including at a minimum, that area subject to a one percent or greater chance of flooding in any given year. A coastal high-hazard area is defined as the area subject to high velocity waters including, but not limited to, hurricane wave wash or tsunamis. Wetlands are defined as those areas that are inundated or saturated by surface water or ground water at a frequency and a duration sufficient to support and under normal circumstances do, or would, support a prevalence of vegetation or aquatic life that requires saturated or seasonally-saturated soil conditions for growth and reproduction. Wetlands generally include swamps, tidal flats, marshes, bogs, and similar areas.

The 100-year floodplain is that land which would be inundated by a flood having a 1 in 100 chance of occurring in any particular year. The Commission feels the major hazard due to flooding is associated with the period of site operations when disposal units are open. Because of other provisions of the rule, the disposal units will be open a comparatively short time. Once closed, the covers and site drainage system will provide protection against the effects of

flooding. The Commission considers 300 or 500-year floodplains to be unnecessarily restrictive; and questions whether an adequate data base or standard methods of determining such floodplains exist.

The fifth requirement, related to upstream drainage areas contributing flow across the disposal site, can be applied to the site at the site selection phase. The staff will consider engineering modifications or diversion of natural drainage to lessen potential impacts to the upstream drainage area if these changes are long-term (equivalent to the duration of the radiological hazard) and will not require ongoing active maintenance. The staff anticipates that diversions of perennial streams would not, in most cases, be acceptable. The consideration of upstream drainage areas should include the impact of potential modifications by others to the upstream drainage area, such as land clearing and cultivation or development of roads, which may occur after the near-surface disposal facility is in operation.

The sixth requirement, related to the depth of the water table, indicates that with few exceptions, near-surface disposal of low-level radioactive wastes will be in unsaturated soil deposits. Exceptions could include dry disposal in engineered facilities or structures either completely below, partially below, or completely above natural site grade. Alternatively, as indicated in the wording of the requirement, waste disposal may be below the water table at some sites if it can be conclusively shown that site characteristics will result in molecular diffusion being the predominant means of radionuclide movement and the rate of movement wll result in the performance objective being met. In no case, however, should waste disposal occur within the zone marked by fluctuations of the water table.

At sites where disposal will be above the water table, seasonal fluctuations of the water table and capillary fringe both prior and subsequent to waste disposal must be considered. The bottoms of the disposal units must be, at all times, above the saturated zone in order to limit the water contacting the wastes to that small portion which infiltrates through covers in disposal areas. Reducing the contact time of the water with the waste by using freely-draining granular backfill should be considered. In addition, the accumulation of water in the disposal unit (the bathtub effect) must be avoided. This can normally be accomplished if the bottom of the disposal unit can drain at least as readily as water can infiltrate into the disposal unit through the cover or sides and if there is no capillary rise of water into the disposal units from the underlying soil deposits.

For sites where disposal will be below the water table, the hydrogeologic unit used for disposal should have hydraulic properties (e.g., hydraulic conductivity and effective porosity) which essentially preclude ground-water flow. The hydraulic conductivity, as tested in-situ, should typically be less than 10^{-6} cm/sec. The effective porosity would be expected to be on the order of 0.01. Hydrogeologic units which meet these conditions generally cannot be tested by normal techniques requiring addition or withdrawal of water in wells. Methods of determining that molecular diffusion is the prevalent mechanism of solute transport include age-dating of ground water by isotopic ratios and radioisotopic methods to show that there has been no active circulation of ground water within the unit during the length of time determined by the age-dating.

The seventh requirement, related to ground-water discharge, stipulates that the hydrogeologic unit used for disposal will not discharge ground water to the ground surface within the disposal site. Surface-water features sustained by ground-water discharge, such as perennial and ephemeral streams, springs, seeps, swamps, marshes, and bogs, should not be present at the proposed disposal site. This requirement will result in a travel time for most dissolved radionuclides at least equal to the travel time of the ground water from the disposal area to the site boundary. In addition, this requirement should provide sufficient space within the buffer zone to implement remedial measures, if needed, to control releases of radionuclides before discharge to the ground surface or migration from the disposal site. The staff prefers long flow paths from the disposal site to the point of ground-water discharge in order to increase the amount of decay of the radionuclides, increase the hydrodynamic dispersion within the aquifer, and increase the likelihood of retardation of reactive radionuclides in the aquifer.

The eighth and ninth requirements, related to tectonic and geomorphic processes, respectively, can be applied to the disposal site at the site selection phase. These requirements relate primarily to the stability of the disposal site. The natural processes affecting the disposal site should be occurring at a consistent and definable rate. In addition, these processes should not occur at a frequency, rate, or extent which can significantly change the stability of the site or the ability of the disposal site to isolate low-level radioactive wastes during the duration of the radiological hazard (approximately 500 years). Changes which occur due to these processes should not invalidate the results of any modeling and prediction of long-term impacts.

The tenth requirement, related to effects of nearby facilities or activities, is included so that the evaluation of any proposed disposal site will include not only the impacts of that disposal site on its surroundings but also the impacts of the surroundings on the disposal site. For example, damming of downstream rivers, blasting associated with quarrying activities, subsidence and/or earth-fissuring caused by ground-water withdrawals, and ground-water rises associated with heavy irrigation may adversely affect the ability of the site to meet the performance objectives.

Several commenters suggested that radioactive waste disposal facilities could be co-located with hazardous waste disposal facilities. The Commission does not object to this as long as the facilities are separated from one another and the wastes are not comingled. The provisions of this requirement pertaining to nearby facilities not adversely impacting the ability of the site to meet the performance objectives or significantly masking the environmental monitoring program would have to be met.

<u>Disposal facility design and operating practices</u>. The requirements established in the Part 61 rule regarding disposal facility design and operating practices are primarily intended to minimize the contact of waste by water. As such, they complement requirements intended to improve overall site stability. That is, requirements which are intended to minimize contact of waste by water generally also help improve site stability, and vice versa.

Requirements for disposal site design relating to contact of waste by water include:

- Site design features must be aimed at avoiding the need for continuing active maintenance.

- Site design (and operation) must be compatible with the site closure plan.

- Site design must complement and improve the site's natural characteristics.

- The design of disposal cell covers must minimize to the extent practicable water infiltration, must direct percolating or surface water away from the disposed waste, and must resist degradation by surface geologic processes and biotic activity.

- Surface features must be designed to minimize water erosion.

- The disposal site must be designed to eliminate the contact of waste by water during storage, the contact of waste by standing water during disposal, and the contact of waste by percolating or standing water after disposal.

The above requirements are design objectives. That is, NRC staff realize the difficulties in proving that a given design will absolutely prevent or eliminate an occurrence. However, the design should work toward achieving such prevention or elimination, coming as close as practicable. Unfortunately, NRC was apparently not quite clear on this point, and many commenters interpreted NRC's intention as requiring absolute prevention, which was correctly pointed out by commenters as being impossible to demonstrate. This point will be clarified in the final Part 61 rule.

Requirements for disposal facility operation and closure relating to contact of waste by water include:

- Unstable Class A waste must be disposed in a segregated manner from other wastes so that there is no interaction between segregated disposal units.

- Void spaces between waste packages must be filled with earth or other material to reduce future subsidence within the fill.

- The boundaries of each disposal unit must be locatable.

- A buffer zone of land must be maintained between any disposed waste and the disposal site boundary.

- Adequate closure and stabilization measures must be carried out as each disposal unit is filled and covered.

- Active waste disposal operations must not have an adverse effect on completed closure and stabilization measures.

Many of these requirements are straightforward and received little or no comment except possibly for suggested clarifications or improved wording. Other requirements are directly related to disposal site stability and are discussed above.

There were some more significant comments, however, on facility operation and these included the need for segregation during transportation, the meaning and intent of the term "interaction," and the need for segregation in arid sites.

The intent of the rule is not to prohibit waste from more than one class from being shipped on the same transport vehicle. Consistent with appropriate transportation regulations, NRC staff has no objection to comingling different classes of waste in transport.

In identifying the need to clarify the term "interaction," commenters noted that it was vague and unenforceable, could include migration, and could be physical or chemical interaction.

The intent of the rule is to protect Class B and C wastes. Class A wastes could interact with other wastes directly through the release of absorbed liquids, solvents, or other mobile components that might be present in Class A waste. Indirect interaction could result from degradation of Class A waste and its lack of stability. Consolidation of Class A wastes would provide a less stable support which could contribute to failure of the disposal unit cover leading to increased precipitation infiltration and surface water intrusion. The degree to which these interactions could occur depends to a large extent on site-specific characteristics and NRC staff does not believe that it is appropriate to set a prescriptive requirement in this area in the rule. The wording of this requirement has been changed to define the purpose for the segregation and minimization of interaction between the segregated wastes.

The State of Washington regulates the disposal site located in an arid region near Richland, Washington. The State suggested that without the likelihood of ground water or surface water being factors at arid sites, segregation of Class A wastes seems to be unnecessary. They also suggested that comingling Class A and B wastes would dilute the Class B wastes and have potential benefit.

The State's observations may have some merit for arid sites but are difficult to adopt in a rule that must address sites located in all parts of the country. NRC staff anticipated the need to consider alternative disposal requirements and included proposed §61.54, "Alternative requirements for design and operations" to provide for consideration of such alternatives. In any case, waste segregation will have a beneficial effect on reducing potential slumping and wind erosion at an arid site, two points with which the State reported that they were concerned.

Waste form and packaging. The requirements in the Part 61 rule regarding waste form and packaging are primarily focused in two areas: safety during disposal site operations and site stability. The former is discussed below under "Safety During Operations." The latter requirements related to waste form stability have been discussed previously and also serve the beneficial effect of reducing contact of waste by water. An additional waste form requirement related to contact of waste by water is the rule's limitation on free standing liquid.

Several commenters addressed the proposed limitation of free standing liquid which would require that such liquids be reduced to as low a level as is reasonably achievable, but in no case to exceed 1%. Further, the proposed

rule stated that the liquid should be non-corrosive. There were no requests to increase the value. However, one waste solidification service supplier recommended a limit of zero, while the State of South Carolina recommended implementing the limits in the license for the Barnwell disposal facility, i.e., 0.5% for solidified waste and 1% for waste in high integrity containers. Several commenters asked for a definition of the term "non-corrosive."

NRC staff has reexamined the proposed limit on free standing liquid and has concluded that existing waste solidification technology can produce a waste form that essentially contains no free standing liquid. In order to compensate for potential condensation of water vapor sealed in containers, NRC staff believes that a limit of 0.5% by volume is appropriate for solidified wastes. For dewatered products, such as ion exchange resins that are in a container designed to ensure stability, it is very difficult to ensure that such products would meet a 0.5% requirement following transport to a burial site. Therefore, for dewatered products, a limit of 1% by volume should be allowed to account for settling during the transport period. The non-corrosive properties of the liquids will be defined and discussed in a staff technical position, rather than in the regulation. To provide a degree of consistency between Class A wastes and the Class B and C wastes, the limitations on liquids in Class A wastes have been modified. Liquid Class A waste must be packaged at a minimum with sufficient absorbent material to absorb twice the volume of the liquid. Solid Class A wastes with incidental liquids must meet the 1% free standing liquid requirement.

5.3.3 Institutional Controls

Since the use of institutional controls to control site access and to monitor and care for the site over the long term is current practice, NRC included the costs for 100 years of active institutional control in the costs for the base case (reference) disposal facility. As such, this requirement reflects current practice and does not represent an increased cost over that today. The potential costs for maintenance of the site during this period can, however, vary depending upon the degree of site stability. As discussed above, the requirements in Part 61 directed at site stability should reduce the need and costs to actively maintain a site during this period.

Institutional controls (physical activities of man such as site surveillance or inspection) should only be relied upon for 100 years following site closure to keep people from inadvertently intruding into the site and to carry out an environmental monitoring program and minor custodial care.

It may be noted that no commenters to the draft EIS questioned NRC's numerical analysis in determining the 100-year limit, other than remarking that since there was no compelling analytical reason for one number over another, the limit should be the last criterion chosen. There were, however, a number of comments on the institutional control period in connection with the Part 61 rule. All commenters expressed support in one way or another for defining a time frame for institutional control related either to the hazard duration of the waste or assurance of continued government stability or concern. It was generally agreed that waste that was potentially hazardous after the end of the assured institutional controls should be disposed of by methods providing greater controls and assurances against potential exposure. These comments are judged to support the provisions of Part 61 that combine institutional controls with waste

form, site characteristics, and site design and operations to provide assurances that potential exposures will be within acceptable limits. Class A waste that is potentially accessible and unrecognizable is no longer hazardous after 100 years. Special provisions for waste being in a stable form and in some cases buried deep assure against potentially unacceptable exposures or releases for up to 500 years.

There were a number of suggestions that the period of institutional control should be raised from 100 to 300 years. There appear to be two basic reasons for these suggestions. One reason is that institutions such as a state or the Federal government can reasonably be expected to survive for much longer than 100 years. A second reason is that the 100 year restriction on institutional control affects the waste concentrations acceptable for disposal as Class A waste with resultant higher costs to the waste generator. With respect to the first reason, NRC staff believes that it is not a question of how long the government can survive, but how long should they be expected to provide custodial care. In addition, initiation of the intrusion scenario is not linked to the survivability of the government structure but is rather linked to the possibility of bureaucratic error. Based on work done by EPA, public comments on a preliminary draft of Part 61 and an advanced notice of proposed rulemaking, and four regional workshops, a clear consensus was developed which supported the 100-year limit. In addition, a stable waste form is needed for other reasons than intruder protection--particularly in regard to minimizing migration and enhancing site stability. Use of the 100-year institutional control period results in limits on waste stability similar to those already in effect at existing disposal facilities. NRC staff has not seen any compelling reasons to change its view on the 100-year limit.

Some commenters expressed the view that the government landowner should have flexibility in controlling site access during the institutional control period and that productive uses of the land which would not affect site integrity should be permitted. NRC staff agrees; this point was addressed in the draft EIS.

5.3.4 Safety During Operations

An applicant's or licensee's operational procedures and programs for compliance with the operational safety performance objective would be evaluated on a case-by-case basis. NRC staff believes that this approach would be preferable to setting out a number of prescriptive requirements for safe facility operation. Measures which could be used to minimize potential operational releases and exposures will be influenced by site-specific conditions at the particular disposal facility considered. Detailed prescriptive requirements would also inhibit incorporation of potential improvements in site safety. Some of the procedures and programs which would be analyzed as part of a specific application would include the following:

- The applicant's radiation safety program for control and monitoring radioactive effluents, occupational and public radiation exposure to demonstrate compliance with the Part 20 and 61 requirements and to control contamination of disposal facility personnel, vehicles, equipment, buildings, and grounds. Both routine operations and accidents would be addressed, and the program description would include procedures, instrumentation, facilities, and equipment.

- The applicant's quality assurance program for siting, design, construction, and operation of the disposal facility, and the receipt, handling, and emplacement of waste. Audits and managerial controls would be included as part of this program.

- The applicant's procedures and plans for construction and operation of the disposal facility. These would include methods of construction; waste emplacement; procedures for and areas of waste segregation; types of intruder barriers; onsite traffic and drainage systems; methods and areas of waste storage; and methods to control surface water and ground-water access to the wastes.

- The applicant's environmental monitoring program to provide data to evaluate potential health and environmental impacts, as well as plans for taking corrective measures if migration of radionuclides is indicated.

- The applicant's administration procedures to control activities.

- The applicant's physical security measures.

- If the application includes the proposed receipt, possession, and disposal of special nuclear material, the procedures and provisions for criticality control.

Despite this, however, NRC analyzed some potential impacts associated with facility operation and concluded that many of the same requirements that would reduce long-term environmental impacts and impacts to a potential intruder would also help reduce operational impacts. For example, segregated disposal of low activity compressible wastes from stabilized high activity waste--which reduces exposures to an inadvertent intruder, reduces ground-water migration and reduces long-term maintenance of the disposal facility--would also tend to reduce the impacts of a potential accidental fire in a disposal cell. Stabilizing high activity waste streams reduces the impacts of a waste container potentially dropped accidentally from a height and releasing part of the container's contents.

Finally, NRC identified some specific general waste form and packaging requirements that have been developed and applied in the past at disposal facilities. These requirements provide protection of the health and safety of site workers, facilitate handling of waste, and minimize the potential for releases to offsite areas. These requirements have been condensed from consideration of current practices at existing disposal facilities and are presented in the final rule as minimum waste form and packaging requirements.

These requirements are also summarized below:

1. Wastes must not be packaged for disposal in cardboard or fiberboard boxes.

2. Waste containing liquids must be packaged in sufficient absorbent material to absorb twice the volume of the liquid. Solid wastes containing liquid shall contain as little free standing or non-corrosive liquid as is reasonably achievable but in no case shall the liquid exceed 1% of the volume.

3. Waste must not be readily capable of detonation or of explosive decomposition or reaction at normal pressures and temperatures, or of explosive reaction with water.

4. Waste must not contain, or be capable of generating, quantities of toxic gases, vapors, or fumes harmful to persons transporting, handling, or disposing of the waste. This would not apply to radioactive gaseous waste covered by number 6 below.

5. Wastes must not be pyrophoric. Pyrophoric materials contained in wastes shall be treated, prepared, and packaged to be nonflammable.

6. Wastes in a gaseous form must be packaged at a pressure that does not exceed 1.5 atmospheres at 20°C. Total activity must not exceed 100 curies per container.

7. Wastes containing hazardous, biological, pathogenic, or infectious material must be treated to reduce to the maximum extent practicable the potential hazard from the nonradiological materials.

A large number of comments were received addressing the minimum requirements for waste form characteristics. The following summarizes the comments on the minimum requirements.

Several commenters stated that the requirement (proposed in Table 1, §61.55) to obtain specific approval to dispose of wastes containing greater than 0.1 percent chelating agents was too restrictive, and stated that utilities might decide against performing decontamination operations which could reduce occupational exposures. Several commenters requested the basis for the 0.1% limit. One commenter recommended that no chelating agents be permitted.

Since chelating agents have been shown to increase the migration of certain radionuclides at certain sites, NRC staff desired to evaluate the disposal of large quantities of wastes containing high concentrations of chelating agents on a case-by-case basis. This approach was used when the Commission staff reviewed the disposal of wastes that would be generated in the decontamination operations at the Dresden Unit 1 Station. Because the disposal of wastes containing chelating agents is dependent on the characteristics of the disposal facility and on the properties of the waste form, the Commission staff has modified the chelating agent disposal requirements to reflect this. The Commission staff has placed on the disposal site license applicant the responsibility for describing the conditions for disposal of waste containing chelating agents. If approved by the Commission, site-specific requirements will be placed on the disposal facility licensee. At this time the waste generator will be required only to identify such wastes in the information contained on the shipping manifest.

At the request of comments, definitions have been added to the Part 61 rule for the terms, "hazardous," "pyrophoric," and "explosive."

Of five comments received on the prohibition against packaging waste in cardboard or fiberboard boxes, four felt the prohibition is unnecessary. The Department of Energy, for example, stated that they had successfully used cardboard containers for disposal of waste generated at their facilities for a

number of years. One commenter supported the provision. After reviewing the comments, including the reasons presented, NRC staff still believes that such a prohibition is needed. The experience cited by the Department of Energy of successfully using cardboard containers for waste packages at their sites does not include extensive handling and transportation that commercially generated wastes would encounter. The existing prohibition against cardboard and fiberboard containers at existing disposal facilities came about as a result of unfavorable experience in receiving, handling, and disposing of wastes in such containers. No change has been made in this requirement.

Ten commenters addressed the requirements relating to waste packaged in a gaseous form. Several noted an inconsistency between the provisions in proposed Section 61.56(a)(5) that prohibits wastes capable of generating toxic gases, and 61.56(a)(7) that permits up to 100 curies of activity in waste in a gaseous form. Several requested the basis for the 100 curie limit. A recommendation was made that gases should be processed into liquid or solid forms, and another felt that gases should be limited to several microcuries. The Department of Energy recommended that krypton-85 immobilized by zeolite encapsulation or ion implantation into metal be permitted with concentrations up to five million curies per cubic meter.

The intent of proposed §61.56(a)(5) was to prohibit the disposal of wastes that are chemically reactive under ambient conditions and produce toxic gaseous reaction products. This section is not intended to prohibit the disposal of properly packaged gases such as H-3 or Kr-85 which occasionally require disposal. This section has been reworded to clarify the intent. The 100 curie limit derives from the existing limits at commercial disposal facilities. The Commission has studies underway to determine whether higher limits would be appropriate. Such limits, if justified, would be proposed in a future rulemaking. In lieu of a requirement that gases be converted to a liquid or a solid, the Commission staff is evaluating the significant generators of tritium wastes and investigating improved package designs for tritium wastes which would be capable of retaining the contents until they had decayed to innocuous levels. The requirements of Part 61 do not contemplate the disposal of millions of curies of Kr-85 as suggested by the Department of Energy. The Commission is not prepared to set disposal requirements for this waste at this time, and since this waste is not liable to be generated by Commission licensees in the near future, the Commission staff believes there is ample time to assess the still emerging technology for krypton fixation and establish suitable disposal requirements through future technical guidance or rulemaking action.

Some commenters felt that the requirement in proposed §61.56(a)(1) that waste packages presented for disposal must comply with NRC and DOT transportation regulations implied that the packaging must also be disposed. This was not the Commission's intent. Since proper packaging for transportation purposes is specified in regulations elsewhere, the Commission feels that it is not necessary to restate them in Part 61, particularly in view of the confusion created. This requirement has been deleted.

As discussed earlier, the Commission is concerned with the possible hazards presented by non-radiological components of the radioactive waste. This was recognized in the requirement proposed that wastes containing biological, pathogenic, or infectious material must be treated to reduce the potential hazard to the maximum extent practicable. The Commission believes it is prudent to add hazardous properties to this requirement and has done so.

5.3.5 Waste Classification

Of the 107 commenters responding to the proposed Part 61 regulation, over half of the commenters offered comments on one aspect or another of the waste classification provisions. Many of these comments had to with clarification of statements or other procedural items which did not involve reconsideration of the technical bases for the requirements. Given this interest, it was deemed useful to reconsider in the final EIS a number of major issues raised in the comments on the regulation.

These are discussed below. First, a background is provided which sums up the overall basis for the waste classification provisions. Next, the following issues are discussed in order:

- o Calculated waste classification limits.
- o Isotopes considered for waste classification purposes.
- o Volume reduction.
- o Compliance with waste classification.
- o Manifest Tracking System.
- o Classification by Total Hazard.
- o "De minimis" levels for waste.

Background

In developing the Part 61 regulation, NRC staff followed an approach of tiering technical requirements from the more general to the more specific. NRC staff first developed four overall performance objectives for land disposal of low-level waste. Based upon the analyses for the performance objectives, a number of technical requirements were developed to help ensure that the performance objectives would be met. Given the performance objectives and technical requirements, it is necessary to combine and unify them so that they may be uniformly implemented. In so doing, one of the factors that must be considered is that disposal facility operators must accept waste as delivered to them. Thus, to ensure that the performance objectives and technical criteria are achieved, it is necessary to set requirements on waste characteristics that must be met by waste generators. Particular waste characteristics important to the performance objectives and technical criteria must be identified and relevant information provided to disposal facility operators so that waste may be properly disposed. All of the above considerations may be accomplished through the concept of waste classification.

The waste classification system (and waste classes) developed for the Part 61 regulation follow directly from the Part 61 performance objectives and technical criteria. The classification system is intended to ensure as far as possible on a non-site-specific basis that the Part 61 requirements are met. This does not mean that site-specific analyses would not be required, however, merely that the classification system goes as far as judged generically possible on a cost basis to ensure that the requirements are achieved.

Three classes of waste are determined by the Part 61 requirements:

1. Wastes for which there are no stability requirements but which must be disposed of in a segregated manner from other wastes. These wastes, termed Class A wastes, are defined in terms of maximum allowable concen-

trations of certain isotopes and certain minimum requirements on waste form and packaging that are necessary for safe handling.

2. Wastes which need to be placed in a stable form and disposed in a segregated manner from unstable waste forms. These wastes, termed Class B wastes are also defined in terms of allowable concentrations of isotopes and requirements for a stable waste form as well as minimum handling requirements.

3. Wastes which need to be placed into a stable form, disposed in a segregated manner from nonstable waste forms, and disposed so that a barrier is provided against potential inadvertent intrusion after institutional controls have lapsed. These wastes are termed Class C wastes and are also defined in terms of allowable concentrations of isotopes and requirements for disposal by deeper burial or some other barrier.

It can be seen that the three waste classes address all four of the performance objectives and technical requirements developed from the performance objectives. Minimum requirements on waste form and packaging are established which apply to all waste classes. They are intended to help achieve operational safety. Probably one of the more important requirements is that of stability for Class B and C wastes. Waste stability helps to achieve all four of the performance objectives. For example, waste stability helps to:

- o Reduce long-term potential environmental releases through such possible processes as groundwater migration, wind or water erosion, or intrusion by deep-rooted plant roots and burrowing animals;
- o Reduce short-term potential environmental releases through such possible processes as operational accidents (e.g., a fire or a dropped container) or waste decomposition gases;
- o Reduce institutional control costs to a site owner;
- o Provide insurance against possible contingencies (e.g., early site closure) which could involve increased costs to a site owner over those originally projected;
- o Reduce concern over uncertainties in site environmental, geological and hydrological properties; and
- o Reduce impacts to a potential inadvertent intruder.

As discussed in Chapter 2, a lack of waste and disposal site stability has been a fundamental cause of most of the past problems that have been identified at existing disposal facilities.

The draft EIS concluded that it would be preferable if all waste was placed into a stable form. However, it was also judged that to implement such a requirement on a generic basis would impose a hardship on many licensees. Low-level waste may contain a wide variety of radionuclides which may range in concentrations from extremely low to moderately high levels. It is difficult to justify at this time expensive additional waste form and packaging requirements for radioactive wastes which are not particularly hazardous. This is

particularly true since many of the licensees who generate such wastes are small entities.

As a compromise, NRC staff adopted the approach of establishing a category of low activity waste (Class A waste) for which no waste stability requirements are implemented. This waste class is to be disposed in a segregated manner from higher activity wastes which must be in a stable form. The limits for this class may be reevaluated after consideration of de minimis levels. (See discussion below.) To determine the concentration limits for Class A waste, an analysis was made based upon limiting exposure to a potential inadvertent intruder. The results of the analysis showed that using the derived limits for intrusion protection resulted in about the same volume of waste requiring stabilization as that according to existing license conditions at existing disposal facilities. Thus the only real change in existing disposal requirements involves the requirement for segregation of low activity waste. NRC staff analyzed the potential groundwater impacts associated with this decision and determined that given reasonable disposal facility siting, design, operation, and closure, the performance objective for long-term environmental releases would be achieved. However, four isotopes were identified--^{3}H, ^{14}C, ^{99}Tc, and ^{129}I--which would require close examination on a site-specific basis for groundwater migration considerations.

Wastes that require stabilization are further separated into two additional classes: Class B and Class C. Class C wastes are required to be disposed with a barrier of at least 5 meters thick between the top of the waste and the surface of the earth. This barrier may be composed of earth, lower activity waste (Class B waste and/or Class A waste which meets the stability requirements), or other similar material. This requirement serves two principal purposes. First, it provides protection to a potential inadvertent intruder. Second, since most Class C wastes are also expected to have high levels of gamma radiation at the package surface, disposal according to this requirement will help to reduce personnel exposures at the disposal facility. In fact, special procedures (such as deeper disposal) for disposal of wastes having high surface radiation levels has been common practice for several years at all operating waste disposal facilities. It is believed, then, that in a large part requiring special disposal procedures for Class C waste conforms to existing disposal practice. Finally, establishing the Class C wastes helps to reduce potential long-term environmental releases from such possible occurrences as intrusion by deep-rooted plants and burrowing animals or wind or water erosion.

Finally, a "fourth" class of waste is established which is generally considered unacceptable for near-surface disposal. The acceptability for disposal of such waste at near-suface disposal facilities will require case-by-case determinations.

Calculated Waste Classification Limits

The numerical basis for the limits calculated for the three waste classes is presented in Chapter 7, Volume 2 of the draft EIS. The principal basis used for setting the classification limits was limiting exposures to a potential inadvertent intruder, although as discussed earlier a number of other considerations went into setting the values--principally long-term environmental impacts, disposal facility stability, institutional control costs, and financial impacts to small entities.

Briefly, the radionuclide limits for Class A waste disposal were calculated based upon an assumed limit of institutional control of 100 years. This does not mean that institutional controls may not last longer than 100 years. Nor does it mean that assuming a limit to institutional controls requires assuming a large social disruption. Rather, the 100-year institutional control limit: (1) recognizes that it is possible that at some time in the future a disposal site may be mistakenly temporarily released for inappropriate use, and (2) is intended to help provide a boundary on long-term costs and social commitment. Given the combination of 100 years of institutional control, an acceptable site, and disposal of waste without any regard to its waste form, NRC staff calculated what the upper concentrations of certain isotopes would be such that if, at the end of the 100-year institutional period, an intruder came onto the site and engaged in typical near-surface activities (lives on the site), he would not receive more than a 500 millirem (whole-body) exposure.

It was assumed that the waste by then is indistinguishable from surrounding material (soil) and that the intruder does not recognize it as low-level waste. From this analysis NRC staff derived the values listed in Column A of Table 1 of the proposed Part 61 rule. These limits are the maximum concentrations for isotopes that are acceptable under that combination of conditions. Wastes containing higher concentrations would exceed the 500-millirem limit, and at that point become Class B waste.

Class B waste must be in a stable waste form. That is, the waste form must last a long time and not change its size and shape significantly during that period of time. The analysis at the end of the 100-year period assumes that upon intruding on the site, and attempting to carry out typical construction activities during which the waste is contacted, the waste does not look resemble soil or other natural material. Rather it still looks like waste--i.e., chunks of concrete, vinyl ester styrene, or other such material. Carrying out construction and agriculture activities given this condition is difficult, and it is assumed the intruder leaves upon discovery of the waste. Thus, this is termed the intruder-discovery scenario.

There comes a point, however, for higher activity wastes at which even the intruder's discovery of the waste would cause him to exceed the 500-millirem (whole-body) limit. One way to prevent that from happening is to take the waste that has higher activity and dispose of it at greater depths (put it down at the bottom of the trench), covering it up with stable lower activity waste or using some other barrier to intrusion. This waste is called Class C waste. In the draft EIS, 500 years was the limiting time period for allowing credit for an intruder barrier. The values in Column C represent the maximum values that are acceptable for disposal under these conditions.

Waste classification thus represents a combination of waste form, radioisotope characteristics, radioisotope concentrations, the method of emplacement, and to some extent site characteristics.

Based on comments received on the proposed Part 61 rule, two items were reevaluated in the final EIS: (1) the limits for Class A waste disposal and (2) the limits for Class C waste disposal.

Limits for Class A Waste Disposal. As discussed earlier, there were a number of suggestions by commenters on the draft rule that the period of institutional

control should be raised from 100 to 300 years. There appear to be two basic reasons for these suggestions. One reason is that institutions such as a state or the Federal government can reasonably be expected to survive for much longer than 100 years. A second reason is that the 100-year restriction on institutional control affects the waste concentrations acceptable for disposal as Class A waste. If the institutional control limit were raised to 300 years, then the Class A waste concentrations would be higher and less waste would be required to be stabilized, and overall costs would be reduced. With respect to the first reason, the Commission believes that it is not a question of how long the government can survive, but how long should they be expected to provide custodial care. In addition, initiation of the intrusion scenario is not linked to the survivability of the governmental structure, but is rather linked to the possibility of bureaucratic error. Based on work done by EPA, public comments on a preliminary draft of Part 61 and an advanced notice of proposed rulemaking, and four regional workshops, a consensus was developed which supported the 100-year limit. NRC staff has not seen any compelling reasons to change its views on the consensus achieved.

Moreover, there are other technical reasons for the Class A waste limits than those related to the institutional control period and protection of a potential inadvertent intruder. Among other things, a stable waste form is desirable for limiting long-term environmental releases and institutional control costs. If one wished to base Class A waste limits on environmental releases and institutional control costs, one place to start would be current license conditions at the disposal facilities located near Richland, Washington and Barnwell, South Carolina. License conditions at these sites, which affect over 90% of the waste disposed in the country, require that ion exchange resins, filter media and other LWR process waste streams having concentrations over 1 μCi/cc of any radionuclide having a half-life exceeding 5 years be either solidified or disposed within a high integrity container. At the Barnwell site, this requirement has been extended to waste from medical isotope production facilities. If one compares the costs and environmental impacts of a limit based on the existing license conditions with the limit based on consideration of intrusion, one sees several similarities. This is illustrated in Table 5.1 below.

Table 5.1 Comparison of Impacts of Class A Limits Based Upon the Final Part 61 Rule and Existing License Conditions

	Part 61 Conditions	Existing License Conditions
I. <u>Long-Term Individual Exposures (mrem/yr)</u>:		
<u>Intruder - construction</u>		
o 100 yrs - Body	1.84E+2*	2.04E+2
Bone	1.87E+2	2.07E+2
Thyroid	1.84E+2	2.04E+2

See footnote(s), last page of table.

Table 5.1 (Continued)

	Part 61 Conditions	Existing License Conditions
o 500 yrs - Body	3.02E+0	3.12E+0
Bone	1.63E+1	1.65E+1
Thyroid	2.42E+0	2.55E+0
Intruder - agriculture		
o 100 yrs - Body	2.02E+2	2.22E+2
Bone	2.08E+2	2.31E+2
Thyroid	2.01E+2	2.21E+2
o 500 yrs - Body	3.04E+0	3.15E+0
Bone	9.17E+0	9.33E+0
Thyroid	9.02E+0	1.01E+1
Boundary well		
o Body	1.11E-1	1.11E-1
o Bone	3.70E-2	3.88E-2
o Thyroid	4.16E+0	5.22E+0
Population well		
o Body	3.33E-3	3.85E-3
o Bone	8.24E-3	8.69E-3
o Thyroid	1.32E+0	1.65E+0
Surface water		
o Body	1.44E-4	1.67E-4
o Bone	3.37E-4	3.55E-4
o Thyroid	5.99E-2	7.52E-2
II. Other Long-Term Exposures:		
Offsite releases from intrusion		
o Waterborne (mrem/yr)		
Body	1.16E-2	1.33E-2
Bone	2.42E-2	5.21E-2
Thyroid	4.78E-4	5.07E-4
o Airborne (man-mrem/yr)		
Body	2.39E-1	2.36E-1
Bone	2.25E+0	2.44E+0
Thyroid	8.62E-2	9.35E-2
III. Short-Term Whole Body Exposures (total man-mrem over 20 yrs):		
Occupational		
o Process by waste** generator	+4.50E+5	+2.70E+5
o Process by regional process center	1.25E+5	1.25E+5
o Waste transport	4.97E+6	5.15E+6
o Waste disposal	2.14E+6	2.22E+6

Table 5.1 (Continued)

	Part 61 Conditions	Existing License Conditions
To population		
o Process by waste** generator	+1.26E+2	+4.39E+1
o Process by regional process center	0.	0.
o Waste transport	4.76E+5	4.91E+5
IV. Costs (total $ over 20 yrs):		
Waste generation and transport		
o Process by waste** generator	+8.20E+7	+6.10E+7
o Process by regional process center	3.63E+7	3.63E+7
o Waste transport	1.72E+8	1.76E+8
Waste disposal		
o Design & op.	3.50E+8	3.50E+8
o Postoperational		
Closure	3.87E+6	3.87E+6
Obs. & maint.	1.13E+6	1.15E+6
Inst. control	1.57E+7	1.59E+7
Total post op.	2.07E+7	2.09E+7
o Total disp. cost	3.71E+8	3.71E+8
o Unit cost ($/m³)	5.73E+2	5.69E+2
V. Energy Use (equivalent gallons of fuel oil)**:	-1.42E+6	-2.32E+6
VI. Land Use (m²):	2.25E+5	2.27E+5
VII. Waste Volume (m³):		
Volume acceptable		
o Class A unstable	4.23E+5	4.43E+5
o Class A stable	1.61E+5	1.98E+5
o Class B	5.95E+4	8.89E+3
o Class C	3.47E+3	3.06E+3
o Total volume acceptable	6.48E+5	6.52E+5
Volume not acceptable	2.20E+4	2.14E+4

*The notation 1.84E+2 means 1.84×10^2.

**In this table, population exposures due to waste processing by waste generators, occupational exposures due to waste processing by waste generators, and energy use are presented as impacts and costs in addition to those associated with the base case as set forth in Chapter 4.

Table 5.1 compares the costs and impacts of waste Class A limits based upon consideration of potential inadvertent intrusion with waste Class A limits based upon existing disposal facility license conditions. In both cases, unstable low activity (Class A wastes) are disposed in a segregated manner from Class B and C wastes. Emplaced wastes are backfilled with a sand/gravel backfill, compacted with improved compaction techniques, and covered with improved disposal cell covers. Maximum limits for near-surface disposal are the same for both cases.

As shown, differences are relatively small, and are principally due to small differences in the two cases regarding methods used to achieve stability. This influences the volumes of waste determined to be stable Class A, Class B, Class C, and unacceptable. These small volume differences in turn influence the calculated impact measures such as, individual intruder exposures, occupational exposures or waste transportation impacts. In general, however, basing Class A limits on existing license conditions would appear to involve somewhat higher long-term environmental impacts than the Part 61 case in which Class A limits are based upon potential inadvertent intrusion. These additional environmental impacts are seen for both the intruder and ground water migration impacts, and are calculated for a case in which a moderate amount of percolation into the segregated unstable waste disposal cells is assumed. If under a worst case situation, the improved cell covers placed over the unstable waste disposal cells are assumed to have reduced effectiveness, then additional percolation into the unstable waste disposal cells would occur. In this situation, the difference in ground water impacts between the two cases presented in Table 5.1 would be larger.

Conversely, waste processing costs for the Part 61 case are higher than similar costs for the case in which Class A limits are based upon existing license conditions. These additional costs are calculated to be about $21 million over 20 years, or about an additional $1.05 million per year. One reason for these additional costs is that the Part 61 case is more general than the case based upon existing disposal facility license conditions. That is, in the Part 61 case, the Class A waste limits are applied to all waste streams while in the existing license condition case, the Class A waste limits are applied to LWR process waste streams as well as waste from isotope production facilities. If the Class A limits based upon existing license conditions were applied to all waste streams, then the calculated cost differential between the two cases would be reduced. As a matter of fact, a trend at existing operating disposal facilities to extend the requirements for waste stabilization to additional waste streams has been observed.

Otherwise, postoperational costs are seen to be somewhat reduced for the Part 61 case relative to the case representing existing license conditions. This is because a lower percentage of the waste in the Part 61 case is in an unstable form. Under a worst case situation, in which a high level of maintenance is assumed for the unstable waste disposal cells, then the difference in post-operational costs would be about four times larger. This is given higher importance than the small difference in costs would otherwise indicate, since post-operational costs are difficult to predict over the long term. Based upon past bad experiences, minimizing post-operational costs to the site owner has been given high priority in this EIS.

<u>Limits for Class C Waste Disposal</u>. The second item concerns the limits for Class C waste disposal. A number of comments were received on the calculated limits, including the following:

- o Rather than setting restrictive limits based on protection of a potential inadvertent intruder, NRC should consider requiring warning devices which would warn an intruder against excavating into the disposal facility.
- o NRC should consider and incorporate a probability that intrusion will occur.
- o NRC should consider that at the end of 500 years, Class C waste disposed under 5 meters of cover would still be difficult to contact; and that if someone did contact the waste, it would be considerably diluted by lower activity waste.
- o NRC should consider that actual waste concentrations will typically exhibit an activity distribution with average concentrations well below the maximum permissible concentration.
- o The fact that Class C waste will be in an improved waste form will help to lessen the likelihood that extensive intrusion activities will occur; and if they do occur, will lessen the potential for airborne dispersion or uptake by plant roots.
- o Since Class C limits have been raised by a factor of 10 for Cs-137, why not do the same for other radionuclides?

NRC staff has evaluated these comments and has concluded that an increase in the Class C limits by a factor of 10 is warranted for all radionuclides except for Cs-137.

It is very difficult to set a numerical value on the probability that an intrusion event will occur, and on the probability of the event's extensiveness. One can say, however, that the probability will probably increase with the passage of time. Given the uncertainty, some judgment is required as to the likelihood and extensiveness of intrusion. Based upon much consideration, the best approach was judged by NRC staff to first conservatively assume that an intrusion event occurs, and after that, to try and assume a range of reasonable activities on the part of the intruder. As commenters have observed, one way to further reduce the possibility for intrusion is to establish long lasting warning markers on the disposal site. The staff feels that this is a reasonable suggestion that can be implemented inexpensively and it has been incorporated into the final Part 61 rule.

It is also believed to be true that waste which has been disposed beneath a cover at least 5 meters thick would be difficult to contact extensively even after 500 years. In the calculations for the draft EIS, it was assumed that at the end of 500 years the 5-meter intruder barrier was no longer effective. The scenario was taken to be the same as that which was used to determine the Class A waste limits. The only difference was that a 500-year radioactivity decay period was used instead of a 100-year decay period. This is believed to

be very conservative since if Class C waste was brought to the surface it would probably be considerably diluted with soil and lower activity waste. The degree of dilution is difficult to estimate but is believed to be at least an order of magnitude.

It is also true that past data on waste streams indicates that the average radioactivity concentration within waste would be expected to be well below peak concentrations. For example, the authors of one reference (Ref. 4) refer to survey of five major Department of Energy disposal sites in which it was estimated that greater than 97% of the material disposed at these sites is either only very slightly radioactive or is suspected of being radioactive (due to the place where the waste is generated). The five DOE sites surveyed cover 86% of the total DOE waste volume and 99+% of the activity. The authors state that if it was assumed that the 3% of the waste that is contaminated is at a maximum level and 97% of the low activity or suspect waste was clean, then a dilution factor on the order of 30 would occur (Ref. 4). The authors (Ref. 4) also cite data obtained from room trash generated at a plutonium facility at Los Alamos National Laboratory.

The authors suggest caution in interpreting the data, however. They note that the data is limited and that wastes such as sludges or oils would probably be more uniform than waste such as trash (Ref. 4). "The use of incineration will tend to increase the uniformity of the transuranium content of individual packages, and the sludges from treatment of wastes have a similar characteristic of relatively constant concentrations." In conclusion, the authors suggest that two dilution factors be considered for DOE waste. A dilution factor of about 20 is suggested for routine trash and decommissioning types of waste, while a dilution factor of 1 (no dilution) is suggested for ash from oxidized combustibles, sludges from water treatment, and artifacts (either solid items with surface contamination or trash types of waste contained in nondegradable plastic containers).

Data more directly applicable to waste disposed in commercial disposal facilities has been obtained and is presented in Appendix C of this final EIS. Table C.35 lists for wet wastes generated by light water power reactor plants, the volume-percent distribution of gross concentration (Ci/ft^3) as determined from two years (1978 and 1979) of shipment records to disposal facilities. Six different waste streams are shown: PWR resins, PWR filter sludge, PWR concentrated liquids, BWR resins, BWR filter sludge, and BWR concentrated liquids. The data from which Table C.35 was prepared covers 79% and 77%, respectively, of the total volume of waste disposed in the country during the two years (Ref. 5).

The data illustrates that most of the LWR waste process waste activity is well below the maximum observed. For example, less than 0.1% of the BWR resin volume would exceed 10 Ci/ft^3 (353 Ci/m^3), while almost 70% of the volume is in a range of .01 to 0.5 Ci/ft^3 (.35 Ci/m^3 to 17.7 Ci/m^3). The average activity across this distribution is in fact about 0.16 Ci/ft^3 (5.6 Ci/m^3).

It is apparent that the above considerations would tend to reduce potential inadvertent intruder impacts and therefore increase the allowable concentrations. However, there are other considerations which could also tend to increase potential inadvertent intruder impacts. Some of these include differences in waste

form characteristics such as waste density or the size and solubility class of dispersed respirable particles. Another factor is the observation that the average activity across most commercial waste streams has been rising over the past several years. This is due to the reduced availability of waste disposal space in conjunction with rising disposal costs, resulting in much increased use of volume reduction techniques. This phenomenon is expected to be even more pronounced in the future, since regional disposal facilities (or disposal facilities serving a compact) are likely to be small operations disposing of relatively small volumes of waste. These small operations will likely need to charge higher disposal fees than larger operations. The result will be an incentive for licensees to drive concentrations in waste to the allowable limits.

Another factor is the accelerated NRC program for identifying low activity waste streams which may disposed by less restrictive means. Such disposal will tend to reduce dilution of higher activity waste streams by lower activity waste streams.

Other considerations include the potential for future changes or improvements in health physics methodologies and consideration of site-specific environmental conditions. For example, dispersion of contaminated dust into the air where it may be inhaled by humans may be expected to be greater at arid sites than at humid sites. This will probably be counter balanced to some extent by an expected reduced rate of waste degredation at arid sites in comparison with humid sites. In addition, wastes can be generally disposed at greater depths at arid sites than at humid sites, thus reducing the potential for human contact.

Finally, there is the potential for localized areas of higher activity ("hot spots") within waste containers. However, this would tend to be mitigated through averaging areas of higher concentration over areas of lower concentration. When concentration limits are calculated using the waste classification methodology, what is really being established is the average concentration across the volume of waste contacted. This could be several hundred cubic meters of soil and waste material.

In conclusion, the Class C limits have been raised by a factor of 10. This is due to consideration of (1) the reduced likelihood of significant intruder exposures with incorporation of passive warning devices at the disposal facility, and (2) the difficulty of contacting waste disposed at greater depths. Another consideration is that the average concentrations in waste would be expected to be less than the peak concentrations, although it is difficult to totally account for this given the other factors discussed above. The effect of the change in the Class C concentrations is illustrated in Table 5.2.

Two cases are considered in Table 5.2. In the first case, Class C limits are assumed which correspond to those established for the final Part 61 rule. For example, the limit for disposal of alpha-emitting (except Cm-242) transuranic radionuclides are set at 100 nCi/gm. The results of this case are in fact obtained from the "preferred case" analysis performed in Chapter 4. The second case corresponds to Class C limits which were proposed for the proposed Part 61 rule. In both cases, a low level of postoperational costs is projected for the stable waste streams while a moderate level of postoperational costs is projected for the unstable waste streams.

As can be seen in Table 5.2, only slight differences are observed between the two cases. Most of the differences in the calculated impact measures appear to be directly derived from the slightly reduced volume of waste delivered to the disposal facility for the case corresponding to the limits proposed in the proposed Part 61 rule. For example, groundwater impacts are slightly lower, as are impacts to a potential inadvertent intruder and population exposures due to waste transportation.

Table 5.2 Comparison of Impacts and Costs of the Proposed and Final Part 61 Waste Classification Requirements

	Final Part 61	Proposed Part 61
I. Long-Term Individual Exposures (mrem/yr):		
Intruder - construction		
o 100 yrs - Body	1.84E+2*	1.84E+2
Bone	1.87E+2	1.87E+2
Thyroid	1.84E+2	1.84E+2
o 500 yrs - Body	3.02E+0	2.31E+0
Bone	1.63E+1	1.03E+1
Thyroid	2.42E+0	2.01E+0
Intruder - agriculture		
o 100 yrs - Body	2.02E+2	2.02E+2
Bone	2.08E+2	2.08E+2
Thyroid	2.01E+2	2.01E+2
o 500 yrs - Body	3.04E+0	2.47E+0
Bone	9.17E+0	6.46E+0
Thyroid	9.02E+0	7.65E+0
Boundary well		
o Body	1.11E-1	1.11E-1
o Bone	3.70E-2	8.23E-3
o Thyroid	4.16E+0	4.14E+0
Population well		
o Body	3.33E-3	3.32E-3
o Bone	8.24E-3	8.23E-3
o Thyroid	1.32E+0	1.31E+0
Surface water		
o Body	1.44E-4	1.43E-4
o Bone	3.37E-4	3.36E-4
o Thyroid	5.99E-2	5.96E-2

See footnote(s), last page of table.

Table 5.2 (Continued)

	Final Part 61	Proposed Part 61
II. Other Long-Term Exposures:		
Offsite releases from intrusion		
o Waterborne (mrem/yr)		
Body	1.16E-2	1.17E-2
Bone	2.42E-2	2.43E-2
Thyroid	4.78E-4	4.78E-4
o Airborne (man-mrem/yr)		
Body	2.39E-1	2.39E-1
Bone	2.25E+0	2.25E+0
Thyroid	8.62E-2	8.62E-2
III. Short-Term Whole Body Exposures (total man-mrem over 20 yrs):		
Occupational		
o Process by waste** generator	+4.50E+5	+4.60E+5
o Process by regional process center	1.25E+5	1.25E+5
o Waste transport	4.97E+6	4.92E+6
o Waste disposal	2.14E+6	2.11E+6
To population		
o Process by waste** generator	+1.26E+2	+0.
o Process by regional process center	0.	0.
o Waste transport	4.76E+5	4.72E+5
IV. Costs (total $ over 20 yrs):		
Waste generation and transport		
o Process by waste** generator	+8.20E+7	+7.70E+7
o Process by regional process center	3.63E+7	3.63E+7
o Waste transport	1.72E+8	1.71E+8
Waste disposal		
o Design & op.	3.50E+8	3.50E+8
o Postoperational		
Closure	3.87E+6	3.87E+6
Obs. & maint.	1.13E+6	1.13E+6
Inst. control	1.57E+7	1.57E+7
Total post op.	2.07E+7	2.07E+7
o Total disp. cost	3.71E+8	3.71E+8
o Unit cost ($/$m^3$)	5.73E+2	5.76E+2

Table 5.2 (Continued)

		Final Part 61	Proposed Part 61
V.	Energy Use (equivalent gallons of fuel oil)**:	-1.42E+6	-1.97E+6
VI.	Land Use (m^2):	2.25E+5	2.24E+5
VII.	Waste Volume (m^3):		
	Volume acceptable		
	o Class A unstable	4.23E+5	4.23E+5
	o Class A stable	1.61E+5	1.61E+5
	o Class B	5.95E+4	5.95E+4
	o Class C	3.47E+3	0.
	o HWF	0.	0.
	o Total volume acceptable	6.48E+5	6.44E+5
	Volume not acceptable	2.20E+4	2.74E+4

*The notation 1.84E+2 means 1.84×10^2.

**In this table, population exposures due to waste processing by waste generators, occupational exposures due to waste processing by waste generators, and energy use are presented as impacts and costs in addition to those associated with the base case as set forth in Chapter 4.

As discussed earlier, the calculated increase in intruder exposures at 500 years for the final rule case is probably an overestimate, since no credit is taken for an intruder barrier after 500 years. If a factor of 10 credit at 500 years is assumed for layered waste, then individual intruder impacts associated with the final rule case would be the following:

	Body	Bone	Thyroid
Intruder-construction scenario (mrem/yr)	2.37E+0	1.09E+1	2.04E+0
Intruder-agriculture scenario (mrem/yr)	2.52E+0	6.70E+0	7.75E+0

As shown, if such credit is taken, the difference in potential inadvertent intruder impacts between the final and proposed rule cases is significantly reduced.

A reduced amount of waste processing is also projected for the proposed rule case relative to the final rule case. This results in somewhat lower population exposures due to waste incineration for the proposed rule case as well as lower total waste processing costs and occupational exposures. Most of these differences are due to the increased use of volume reduction technology for the final rule case. Unit disposal costs are slightly raised for the proposed rule case, however, which is due to the reduced volume of waste delivered to the disposal facility.

Overall costs to disposal facility customers, however, would be reduced. Under the Final Part 61 rule, waste streams having a transuranic content between 10 and 100 nCi/gm must be stabilized and disposed as Class C waste. Approximately 3500 m^3 of waste (after processing) is estimated to fall within this class. If the limit were 10 nCi/gm, then this waste would be projected to be unacceptable for near-surface disposal. (The difference between the non-acceptable volumes for the two cases is about 5400 m^3, which is about 1900 m^3 higher than the Class C waste volume. This increase in volume is due to increased waste processing by volume reduction assumed for the final rule case. If waste processing were to result in the waste stream being unacceptable for near-surface disposal, then the processing would not be performed.) Costs for the additional processing run at an average of about \$1428 per m^3 of packaged waste, much of which is due to increased use of volume reduction technology for the final rule case. If the waste streams in question were merely stabilized, then stabilization costs could be as low as \$450/m^3, although disposal costs (due to the increased volume) would be somewhat raised. This may be contrasted by estimated costs for disposal into a geologic repository. Based upon an estimated \$5200 per m^3 of waste, which includes costs for retrievable storage, retrieval, processing, transportation, and disposal, costs for geologic disposal of 3500-5400 m^3 of waste would run at about \$18.2 million to \$28.1 million over 20 years.

Isotopes Considered for Waste Classification Purposes

In the draft EIS, a total of 23 different radionuclides were considered in the numerical analysis. These nuclides were nearly all moderate- or long-lived radionuclides. Based upon these 23 radionuclides, concentration limits were proposed in the proposed Part 61 rule for 11 individual radionuclides plus alpha-emitting transuranics, enriched uranium, and depleted uranium. The individual isotopes included ^{3}H, ^{14}C, ^{59}Ni, ^{63}Ni, ^{60}Co, ^{94}Nb, ^{99}Tc, ^{129}I, ^{135}Cs, ^{137}Cs, and ^{241}Pu (a beta emitter). For the final rule, limits for ^{135}Cs, enriched uranium, and depleted uranium are eliminated, as are limits for ^{59}Ni and ^{94}Nb except as contained in activated metal. A separate limit for ^{242}Cm, a transuranic nuclide with a 162.9 day half-life, is provided.

The isotope deletions came about principally in response to commenters on the proposed Part 61 who were concerned regarding the costs and impacts of compliance with the waste classification requirements. In particular, many commenters were concerned that they would have to directly measure every isotope in every waste package. This would be difficult since measurement of many of the listed isotopes--which would usually be present only in trace quantities--could not be performed except by complex radiochemical separation techniques by laboratories. (Isotopes which are pure beta emitters, for example.) Commenters were concerned that costs and personnel radiation exposures would be significantly increased.

Development of a workable approach to compliance with the waste classification requirement received much attention between the time of preparation of the draft EIS and preparation of the final EIS. A preliminary draft of a technical position paper on compliance was prepared and forwarded to a number of interested parties. (Ref. 6) This technical position is discussed further below. To further ease the burden of compliance, the number of isotopes listed in the waste classification table were reduced to those judged to be needed on a generic basis for waste classification purposes, as well as those judged to be most needed for assessment of potential impacts from groundwater migration. Other isotopes may be added later either generically or in specific waste streams.

Cesium-135 was removed because it is present in wastes in very small concentrations, and because Cs-135 is a pure beta emitter which is very difficult to measure. Waste classification for waste containing Cs-135 will be determined by the presence of other isotopes such as Cs-137. Similarly, the radionuclides Ni-59 and Nb-94 have been removed except as they may be contained in activated metals. Based upon examination of the waste source data used for the EIS, these nuclides are, at this time, believed to be present in reactor wastes (other than activated metals) in such small concentrations as to be insignificant. Again, other than the possible case of activated metals, waste classification of waste containing Ni-59 and Nb-94 will be determined by other isotopes.

Uranium has also been removed as a limiting element for waste classification. Analysis of the data base for the Part 61 EIS indicates that the types of uranium-bearing wastes being typically disposed of by NRC licensees do not present a sufficient hazard to warrant limitation on the concentration of this naturally occurring material. Both depleted and enriched uranium typically do not contain daughter products in any quantity because of the relatively short time since the uranium was refined from ore, compared to the half-lives of the uranium isotopes. The daughter products are disposed of primarily as uranium mill tailings.

However, NRC is aware of some uranium-daughter-contaminated material which is typically being stored today and which may in the future be disposed as low-level waste. In addition, there are quantities of low activity waste material which also may be sent to disposal sites and which are not covered under the Atomic Energy Act and are not subject to NRC license. Such material may be generated by rare earth processing facilities, for example. This material, which is primarily contaminated soil, has characteristics sufficiently different from other low-level waste streams that separate treatment is warranted. NRC staff intends to examine specific disposal guidance for such material in the near future.

The remaining isotopes in the waste classification table are included due to (1) their presence in a wide variety of waste types, (2) concern due to their radiotoxicity, or (3) their importance in the groundwater migration pathway.

The radionuclide curium-242 was deleted from the overall combined transuranic limit and is considered separately for waste classification purposes. While Cm-242 is a relatively short-lived nuclide (163 days), it decays to plutonium-238, an alpha emitting transuranic nuclide with a half-life of nearly 90 years. A concentration of 20,000 nanocuries per gram for Cm-242 will result in a concentration of 100 nanocuries per gram of Pu-238.

Several commenters on the proposed rule inquired about the disposal of waste containing radium-226, a radioisotope which is not currently listed. It appears that there are two types of radium wastes to be considered: (1) small concentrated sources of radium such as radiation sources or luminescent dials; and (2) wastes which contain small amounts of radium incidental to other radioisotopes, such as radium contained in wastes from uranium separation processes.

The former is not subject to regulation by the Commission, since radium is a naturally-occurring isotope and is not included in the provisions of the Atomic Energy Act of 1954, as amended. The Environmental Protection Agency has a program for collection of radium sources. This program may be phased out in the next few years. Such sources are expected to be transferred to the Department of Energy for storage and disposal.

As for radium incidental to other types of waste, the Commission has made provisions for disposal of small quantities of uranium tailings as Class A waste. For purposes of this provision, a small quantity is defined as 10,000 kilograms containing not more than 5 millicuries of radium-226. This concentration is typical of uranium mill tailings (0.5 nanocuries per gram). The quantity of radium-226 is that contained in 150 pounds of natural uranium at equilibrium with its daughter products. 10 CFR Part 40 permits some persons to possess and use under general license 150 pounds of source material per year. Permitting the disposal of such a quantity in a near-surface disposal facility is judged to be acceptable. For large quantities, an additional evaluation would be appropriate. As discussed above, NRC staff plans to further examine guidance for disposal of such waste material in the future.

For the final Part 61 rule, limits for alpha-emitting transuranic radionuclides are given not in terms of individual radionuclides, but in terms of combined concentration limits for all alpha-emitting radionuclides having half lives greater than five years. This approach is believed to be the easiest to comply with by most licensees, although NRC recognizes that there may be exceptions to this based upon the particular distribution of transuranic isotopes within a particular licensee's waste. A discussion of the process by which NRC converted from individual transuranic radionuclide limits to a single combined limit is included in Appendix C.

Volume Reduction

Some commenters were concerned that the waste classification requirement would discourage volume reduction. This concern is believed to be alleviated by the increase in the Class C waste disposal limits. As an illustration, the volumes of waste determined to be unacceptable for near-surface disposal under extreme volume reduction conditions (waste spectrum 4) may be compared against the proposed and final Part 61 limits.

These comparative volumes are as follows:

	Unacceptable Volumes (m^3)	Percent of Total Generated
Proposed Part 61 Limits	9.42 E+3	4
Final Part 61 Limits	1.93 E+3	1

Compliance with Waste Classification

As discussed above, many commenters on the draft Part 61 rule were concerned regarding acceptable procedures for determining compliance with the waste classification requirements. The concern focused on how one estimates and

reports radionuclide concentrations and quantities in waste streams, particularly when some radionuclides may be difficult to measure and/or in existence in only trace quantities. It was recognized in the draft EIS that developing a reasonable approach to compliance would be an important consideration. A balance needed to be achieved between the need for knowledge of waste contents and practical limitations in measurement.

It should be realized, however, that such considerations are independent of the waste classification requirement, and would be a proper issue for consideration even without the waste classification requirement. That is, acceptable means of estimating and reporting radionuclide concentrations and quantities within waste streams are important for compliance with existing NRC regulations. For example, existing NRC regulations incorporate DOT transportation regulations. These DOT regulations require that shipments of radioactive material be classified according to waste transport types. Manifests accompanying the shipment must describe the contents of the shipments. In addition, existing Commission regulations state that radioactive material may only be transferred to persons authorized to receive it. Implicit in these requirements is a requirement for knowledge of the radionuclide content of the material transferred.

Based upon discussions with licensees and other interested parties, comments on the proposed Part 61 rule, and comments on the draft EIS, a preliminary draft technical position paper was prepared (Ref. 6). This draft paper was made available to interested persons, and comments on the draft position paper were requested. The essential features of this preliminary draft position paper are presented below.

The staff's position is that all licensees must carry out a compliance program to assure proper classification of waste. Licensee programs to determine radionuclide concentrations and waste classes may, depending upon the particular operations at the licensee's facility, range from simple programs to very complex ones. In general, more sophisticated programs would be required for licensees generating Class B or Class C waste, for licensees generating waste for which minor process variations may cause a change in classification, or for licensees generating waste for which there is a reasonable possibility of the waste containing concentrations of radionuclides which exceed limiting concentration limits for near-surface disposal. Some licensees, such as nuclear power facilities, are expected to employ a combination of methods.

There are four basic programs, however, which may be potentially used either individually or in combination by licensees:

- materials accountability;
- classification by source;
- gross radioactivity measurements; or
- direct measurement of individual radionuclides.

One method which the staff would find acceptable to determine radionuclide concentrations and demonstrate compliance with the waste classification requirement is through a program of materials accountability. That is, a given quantity (and resulting concentration) of radioactive material may be known to be contained within a given waste or may be inferred through determining the difference between the quantity of radioactive material entering and exiting a given process. This procedure is expected to be most useful for licensees who

receive and possess only a limited number of different radioisotopes in known concentrations and activities (e.g., holders of source material, special nuclear material, or byproduct material licenses). An example would be a biomedical research facility at which known amounts of a radioisotope are injected into research animals, the carcasses of which are ultimately disposed as radioactive waste. Another example would be a research or test facility performing activation analysis experiments. In this case, the quantity of radioactive material within a given waste stream may be inferred through calculation. A third example would involve a process such as treatment of contaminated water by ion exchange. If the radionuclide concentrations into and out of the process container are known, as well as the total flow through the process container, then the radionuclide content of the process container may be readily determined.

This method may also be used to determine the absence of particular radionuclides. That is, for most licensees, the absence of particular radionuclides may be determined through a knowledge of the types of radioisotopes received and possessed, as well as the process producing the waste. For example, if a licensee receives, possesses and uses only tritium, there is no need to measure the waste stream for other isotopes such as iodine-129 or cesium-137.

Classification by source is similar to the above method of materials accountability and involves determining the radionuclide content and classification of waste through knowledge and control of the source of the waste. This method is expected to be useful for occasions when the radionuclide concentrations within waste generated by a particular process are relatively constant and unaffected by minor variations in the process.

This method is also expected to be frequently useful for determining the absence of particular radionuclides from a given waste stream. For example, within a given licensed facility there may be a number of separate controlled areas within which only a limited number of radioisotopes are possessed and used (e.g., Cs-137 may be used on one area and tritium in another). As long as facility operations are conducted so that transfer of radioactive material from one controlled area to another cannot occur, waste generated from a particular area may be readily classified by source. An example of a licensee for which this method is expected to be useful is a large university which holds a broad license for byproduct material.

There may be some Class B or Class C waste streams having odd geometries or physical characteristics which make collection of samples and/or data difficult. In such cases, gross measurements may be the only practicable means of determining radionuclide concentrations. In addition, there may be some Class B and Class C waste streams for which the distribution of radionuclides within the waste streams is essentially fixed (e.g., a waste stream whose radionuclide distribution is known and either the distribution is relatively insensitive to process changes or the process generating the waste streams is relatively nonvariable) and minor process changes are not likely to result in a significant change in this distribution. Gross radioactivity measurements may also be acceptable in this case provided that radionuclide distributions are initially determined and periodically verified by direct measurement techniques which correlate measured radioactivity levels with radionuclide concentrations in wastes. The accuracy of the correlation would be periodically checked through detailed sample analysis involving measurement of specific radionuclides. The accuracy of the correlation would also be checked whenever there was reason to

believe that process changes may have significantly altered previously determined correlations.

Another method acceptable to the staff for determining radionuclide concentrations in waste is direct measurements for individual radionuclides. Finally, it is recognized that some radionuclides are amenable to routine quantification by direct measurement techniques (e.g., gamma-spectral analysis of isotopes such as Co-60 or Cs-137), while other radionuclides require more costly and time consuming analysis frequently removed from the waste generator's facility. For these latter radionuclides, determinations of concentrations through use of scaling factors whereby concentrations of radioisotopes which cannot be readily measured (through techniques such as gamma-spectral analysis) are projected through ratioing to concentrations of radioisotopes which can be readily measured may be applied. An example would be the practice of scaling transuranic concentrations to concentrations of the isotope Ce-144. Scaling factors would generally be developed on a facility and waste stream specific basis, and would be initially determined through direct measurement techniques. The representativeness of the scaling factors would be periodically confirmed through direct measurements on at least a semiannual basis.

As discussed above, a compliance program for a particular licensee could involve a combination of the above methods and would be implemented on a facility-specific basis. For nuclear power facilities, NRC staff included in the preliminary draft branch technical position a general waste classification implementation program consisting of a three-tiered approach. (Ref. 6) This three-tiered approach includes:

(1) Periodic analysis for all nuclides considered for waste classification purposes,

(2) Gamma spectroscopy of certain nuclides from which waste classification nuclides are correlated, and

(3) Dose-rate measurements which correlate activity levels of wastes from similar batches to the gamma-spectroscopy measurements.

The NRC staff believes that the above approach presents a workable and enforceable program for implementing the waste classification system. This approach should minimize the administrative and operational burdens on plant personnel, but still provide reasonably accurate data for use in quantifying disposal site nuclide concentrations and inventories.

Manifest Tracking System

The proposed section 20.311 of 10 Part 20 established requirements for a manifest tracking system for waste transported to disposal sites. The system addressed the need for more complete information on the classification and characteristics of disposed waste, for improved accountability of wastes, and for a better data base. The General Accounting Office (GAO) noted the need for improvements in these areas in its report entitled "The Problem of Disposing of Nuclear Low-Level Waste: Where Do We Go from Here?" (Ref. 7). The GAO recommended that the Commission "determine who the generators of low-level waste are in both the Agreement and non-Agreement States and how much waste each licensee is generating" and "establish a method to track waste from the point of generation

to the point of disposal." Improving the data base on waste characteristics will improve the credibility of decision-makers, enable better planning for inspections and emergencies, enhance projections of future waste generation, and help in site-specific analyses and planning. The information on waste classification and characteristics is necessary for proper handling and disposal at the land disposal facility.

Based upon the above considerations as discussed in more detail in the draft EIS, the section 20.311 requirements were drafted. Additional input on these requirements, however, was desired by NRC staff. Because any NRC licensee might make a waste shipment and thus be subject to the manifest system requirements, NRC staff mailed copies of the proposed Part 61 rule to each of the Commission's approximately 9,000 licensees. In addition, some 12,000 copies were furnished to the 26 Agreement States for distribution to their licensees. Out of this large group came a total of 29 letters commenting on the manifest system. These comments were wide ranging, with the majority of the questions or suggestions being raised by only one commenter. Only a handful of issues drew more than one comment, with four being the largest number of comments on any issue. As a result of these comments, as well as other comments on NRC's proposed waste classification system, several clarifying changes were made to the proposed requirements.

Licensees who ship under existing regulations are required to prepare and forward shipping manifests that comply with DOT regulations. The proposed manifest content requirements in Section 20.311 are somewhat more comprehensive but are compatible with DOT requirements. The waste generator must be specifically identified. The information requirements concerning the waste itself are somewhat more extensive and geared to information needed for disposal, not just transportation and handling. That is, more explicit information on chemical content, waste composition, and solidification agents is required. For example, the presence of chelating agents in quantities greater than 0.1% by volume must be recorded. This requirement is intended to enable waste disposal facility operators to to identify waste containing large quantities of chelating agents. Special disposal measures (to be implemented on a site-specific basis) for such waste would be carried out at the disposal facility. Licensees would be required to comply with and certify compliance with waste form requirements of Part 61. This latter requirement stems solely from the technical requirements for disposal. The land disposal facility licensee must record data on the condition of the waste itself and document and certify receipt, handling, repackaging, storage, and disposal.

Questions were raised whether the manifest reporting requirement applied to radionuclides having half-lives less than 5 years, since there is a waste stability provision in the Part 61 rule for waste having radionuclides with half-lives less than 5 years and in concentrations exceeding 700 $\mu Ci/cm^3$. Although NRC staff believe that the principal radionuclides contained in waste should be identified for purposes of transportation and disposal facility operational safety, there is no need to list short half-lived nuclides contained in trace quantities. The total quantity of the four radionuclides believed to be especially important to safety from ground-water migration--i.e., H-3, C-14, Tc-99, and I-129--will continue to be required on the manifest.

The use of the manifests provides a tracking system that is inspectable. Section 20.311 requires that the shipper precede and accompany shipments with copies

of the manifest and investigate if notification of receipt or disposal is not received. The responsibility for tracking shipments is with the shipper who may also be the waste generator, a service company who collects, stores and delivers the waste, or an intermediate processor. A crosscheck is provided to ensure that delayed or missing shipments are investigated by requiring land disposal facility operators to periodically match advance copies of manifests to those for shipments actually received.

The manifest being required by this rulemaking is consistent with DOT shipping paper requirements, and the same document may be used by licensees to meet requirements of both agencies. Neither NRC nor DOT require a specific form and both allow such dual use. The waste form and packaging requirements are in addition to and compatible with DOT rules. In addition, the manifest terminology and requirements were compared to those in the proposed Uniform Hazardous Waste Manifest, the joint EPA/DOT proposed form published March 4, 1982 (Ref. 8). A few minor procedural and terminology changes were made to conform to this proposed form. Licensees may use the Uniform Hazardous Waste Manifest as a DOT shipping paper or NRC manifest for radioactive wastes (once it is implemented as a final rule) by using additional spaces to describe wastes or by adding infomation to the back. These changes were made based on consultation with EPA and DOT staff and help to reduce the burden on all licensees.

Classification by Total Hazard

Several commenters were concerned with materials potentially present in low-level radioactive waste which may be chemically toxic or hazardous. Some suggested that the Commission's waste classification system incorporate a "total hazard" approach that would consider both the radiological and chemical hazard of wastes. At least one comment did not favor the total hazard approach because of the very complex classification system that the commenter perceived would result.

The Commission has stated publicly on several occasions that if it were technically feasible to classify waste by total hazard, then it would make eminently good sense to do so. The staff does not now know of any scheme for such classification. The Commission will study the chemical toxicity of low-level waste, with special emphasis on identifying any licensees who generate hazardous wastes subject to requirements of the Environmental Protection Agency. NRC will then examine methods (e.g., perhaps through processing), by which the hazard may be minimized.

Furthermore, the Commission believes that the technical provisions of Part 61 generally meet or exceed those expected in the Environmental Protection Agency's rules for the disposal of hazardous wastes. Although it is not the Commission's intent to allow disposal of hazardous wastes in a radioactive waste disposal facility, as is noted in the regulation, the Commission recognizes that certain chemicals or other materials which are defined by EPA as being toxic or hazardous may be present in some low-level radioactive wastes. It is the Commission's view that disposal of such wastes in accordance with the requirements of Part 61 will adequately protect the public health and safety. Such hazardous chemicals or other materials are expected to be such a small percentage of the total waste volume that dilution by other wastes would greatly minimize any risks. The Commission intends to work closely with the Environmental Protection Agency

to assure continued compatibility. Further, EPA in its response to a resolution of the Conference of Radiation Control Program Directors indicated their willingness to work with other Federal agencies to address this problem.

"De minimis" Levels of Radioactive Waste

Over one-fourth of all commenters on the draft EIS and Part 61 rule endorsed the concept of setting levels for wastes below which there is no regulatory concern, the so-called "de minimis" level. Some of the commenters supporting the de minimis concept made direct reference to the NRC staff's position that exempting particular waste streams from compliance with the Part 61 regulations was preferable to setting generic levels for all isotopes. Several disagreed with this position, although at least one of these commenters remarked that as there is not yet a consensus on a generic de minimis level, any level chosen would be premature. A number of other commenters suggested that a de minimis classification be added to the Part 61 regulations, perhaps as an additional column in Table 1 of the proposed Section 61.55.

Several commenters suggested that NRC permit case-by-case review of requests for specific application of the de minimis concept during the period criteria are being developed. Others suggested specific values for specific waste streams or radioisotopes.

The fundamental concern of practically all commenters appeared to be not whether a generic or a case-by-case approach should be taken, but rather that action to develop de minimis standards should be taken as soon as possible.

NRC staff agrees with the importance of setting timely standards for disposal of certain wastes by less restrictive means. NRC staff agrees with the commenters that establishment of such de minimis levels would reduce costs of disposal for many licensees and would also conserve space in disposal facilities which are otherwise designed for wastes having much higher activities. It is also believed that establishment of de minimis levels is important in enhancing overall stability of a disposal facility, and therefore in reducing potential long-term site maintenance and corresponding costs, since de minimis levels would reduce the volume of Class A unstable waste. This would also tend to reduce groundwater migration impacts, since subsidence and water infiltration would be reduced.

Regarding the issue of setting de minimis levels on a generic or on a case-by-case basis, NRC staff still believes that the current policy of examining waste streams on a case-by-case basis will result in the quickest and best results. It is recognized that setting generic limits may be a desirable goal, and the NRC plans to work toward this goal over the next few years. Meanwhile, NRC staff believes that the process of examining a few specific waste streams will facilitate the development of generic requirements and is accelerating its efforts on setting standards for disposal of wastes by less restrictive means. In this regard, NRC staff is willing to accept petitions for rulemaking from licensees for declaring certain waste streams to be of no regulatory concern. In making such petitions, licensees should provide at least the following information:

- a description of the process by which the waste is generated;

- a description of the waste generated, including chemical characteristics;
- the radionuclide content of the waste, including principal as well as trace contaminants;
- a description of the potential change in the radionuclide content as a function of process variations;
- a description of the process control and quality control programs by which the licensee would ensure compliance.

Waste streams in which the radionuclide content is well known and relatively nonvariant are generally preferred.

5.4 ADMINISTRATIVE, PROCEDURAL, AND FINANCIAL ASSURANCE REQUIREMENTS

This section summarizes the principal administrative, procedural, and financial requirements to be set forth in the final Part 61 rule. The principal administrative and procedural requirements on disposal facility operators are presented first, and are discussed in the context of the expected life cycle of a typical LLW disposal facility. The financial requirements are then presented.

5.4.1 Procedural and Administrative Requirements on Disposal Facility Operators

The life cycle of a disposal facility can be divided into five phases: (1) preoperational phase, (2) operational phase, (3) closure phase, (4) observation and maintenance phase, and (5) institutional control phase. These five phases are summarized in Figure 5.1 and discussed in more detail below.

Preoperational Phase

The preoperational phase consists of disposal site selection, characterization, and licensing. Disposal site selection and characterization is a period of data gathering and planning. As visualized by NRC staff, the applicant selects a region of interest and searches for a number of possible disposal sites (a slate of candidate disposal sites) using reconnaissance-level information. The applicant then narrows the possible sites down to one. After a proposed disposal site has been selected, the applicant begins a detailed investigation (geology, depth to ground-water table, amount of rainfall, etc.) of the proposed disposal site. The applicant also initiates a preoperational monitoring program.

The applicant prepares an application for the land disposal facility following Subpart B of the Part 61 rule. The applicant also prepares an environmental report. Of particular importance to this application are the methods by which the applicant will comply with the Part 61 performance objectives and technical requirements, the preliminary site closure plan, arrangements concerning land ownership and associated responsibilities, and financial assurance.

Licensing activities begin when the applicant files the application. Prior to docketing, the application is reviewed for completeness and acceptability in accordance with ¶2.101(b)(2) of 10 CFR Part 2. A notice of receipt of the

Figure 5.1 Life Cycle and Financial Assurances for a Disposal Facility Following the Final 10 CFR Part 61

Time in years	Activity	Form of financial assurance
1-2 yrs	Site Selection and Characterization	Licensee responsible for costs incurred
1-2 yrs	Licensing Activities	Licensee responsible for costs incurred including license fee
		Site closure plan including cost estimates for closure is submitted as part of license application
		Lease arrangement with long-term care arrangements for financial responsibility between licensee and state submitted for review to NRC for adequacy
		Licensee obtains adequate short-term sureties to provide for closure
20-40 yrs	License Issued; Site is in Active Operation; Waste Received	Short-term sureties in place for closure: NRC periodically reviews and requires updating to account for changes in inflation, site conditions, etc.
		NRC periodically reviews revisions to lease arrangements to ensure that arrangements for financial responsibilities for long-term care are adequate
1-2 yrs	Site Closure and Stabilization	Costs covered from short-term sureties, if necessary; otherwise, licensee performs activities
		Lease arrangement between site owner and operator for long-term care is still in effect
5-15 yrs	Observation and Maintenance	Licensee still responsible for all further costs during this period, with short-term assurances still in place
100 yrs	License Transferred to Site Owner; "Active Institutional Control Period"	Terms and conditions of lease are met, and either state or licensee provides funds to pay for all required and necessary activities of this period

tendered application is published in the Federal Register. The Commission notifies state, local, and tribal officials and begins to coordinate with these officials. Once docketed, the application is again noticed in the Federal Register and the application and accompanying environmental report widely distributed. An opportunity for interested parties to request a hearing is provided pursuant to 10 CFR 2.105. Application fees are paid in accordance with 10 CFR Part 170.

The regulatory review period follows. The applicant continues any disposal site studies and the preoperational observation and monitoring program. The applicant also responds to informational requests from NRC. Section 61.3 will require that construction not begin until a decision is made to issue the license. The application and environmental report are updated if necessary.

Based upon the application, environmental report, and any additional information, the Commission prepares a draft environmental impact statement (DEIS) and publishes it for public comment. Based upon public comments on the DEIS and any additional information, the staff prepares and publishes a final environmental impact statement (FEIS). If hearings are requested, an Atomic Safety and Licensing Board (ASLB) is appointed. Hearings, if any, would be held in accordance with existing rules in 10 CFR Part 2. An Atomic Safety and Licensing Appeal Board and/or the Commission may review the findings of the ASLB, or the ASLB findings may be appealed to these next levels and to the courts. Upon resolution of the hearings, reviews, and appeals, the Director* takes final action to issue or deny the application in accordance with the criteria in Section 61.23, plus any conditions rendered by the Licensing or Appeals Boards or the Commission. A notice is published in the Federal Register in accordance with Section 2.106. If the ownership of the land has not been transferred to the state or federal government, transfer would now take place. If the license is issued, it is subject to the general license condition in Section 61.24 and to any specific conditions as required.

States and Indian tribes may participate in the Commission's license review process. Subpart F of the final Part 61 rule addresses such participation, which is in addition to participation as already provided in Parts 2 and 51. Examples of the forms that state and tribal participation may take include:

1. Development of technical data, including but not limited to, socioeconomic, hydrological, geological, environmental, or land use data for incorporation into the Commission's environmental impact statement on the application or other analyses.

2. Development of public participation mechanisms to be included in the licensing process.

3. Provision of a technical data base to provide verification to the Commission for materials presented in the license application.

4. Exchange of state and Commission staff for cooperative review.

*The "Director" means the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission.

It should be noted that participation by States and Indian tribes pursuant to Subpart F of Part 61 is not through an adjudicatory hearing. If an adjudicatory hearing is requested, then 10 CFR Part 2 rules apply.

Many commenters to the draft rule and EIS were concerned regarding the length of the licensing process. One way in which the licensing process can be shortened in time is to conduct activities in parallel where possible, rather than sequentially. One such area is in the submittal and evaluation of proposals by States and Indian tribes for participation in the NRC license review. As proposed in the draft Part 61 rule, a State or tribe would have up to 120 days after an application was docketed to submit a proposal for participation. The time from initial submittal of the application until it has been docketed is estimated to be 60 days or more. Thus, there is a potential delay of 180 days between the time NRC would receive a proposal and could begin the serious consideration of the proposal. Until resolution were reached on the role a state or tribe would play in the review, the NRC's review of the application would be significantly hampered.

The Low Level Radioactive Waste Policy Act of 1980 clearly states that it is a State responsibility to provide for the disposal of low-level waste. The Act also provides for the formation of interstate compacts for this purpose, subject to Congressional approval. Thus, any application for a disposal facility license will have had State or compact participation and backing for a significant period of time before submittal. During this time, the Commission believes that the State will have had ample opportunity to determine what role it wants to play in the review of the application. This also holds true for other states that are parties to an interstate compact. Therefore, the final Part 61 rule will require that a proposal from the state in which the facility is proposed, or from any state involved in a compact with the state must be submitted within 15 days after the application has been tendered.

Although it is to be hoped that the States will inform Indian tribes of plans for disposal facilities and provide them with sufficient information to permit them to make a proposal at an early time, there is no way of ensuring this. Therefore, Indian tribes and states not covered above will be given 120 days from the tendering of an application to submit their proposal. It is anticipated that the participation of Indian tribes and non-compact states will not impact the schedule of the licensing process as much and this additional time can be accommodated.

The Commission believes that there should be sufficient information in the tendered application on which to base a proposal and that it is not necessary to wait until the acceptance review is completed and the docketing procedure carried out. Review of proposals can be carried out earlier and in parallel with the other reviews.

A provision has been added to §61.25 to ensure that State, local, and Indian officials are notified of the opportunity for a hearing for certain types of amendments to the disposal facility license.

In response to public comments on the draft rule, the requirements in the final Subpart F have been specifically worded to ensure that Commission staff will be available for discussion with a State or tribal governing body. A provision

has also been included in §2.102 to indicate that NRC will inform the U.S. Bureau of Indian Affairs when tribes have been notified of the filing of an application.

Operational Phase

After issuance of a license by the Commission, the land disposal facility is constructed and waste receipt and disposal operations start. At intervals specified in the license (the normal term for materials licenses is currently 5 years), the licensee would be required to submit a license renewal application (Section 61.27). At this time, the disposal site closure plan and funding requirements would be updated and financial arrangements for assurance of adequate funding reviewed. The licensee may also apply for amendments to the license at any time during the operational phase (Section 61.26).

Section 61.25 of the Part 61 will set forth a tiered approach for NRC review of changes in the disposal facility or operating procedures described in the license application. Changes important to public health and safety are subject to Commission review and approval. Changes not important to public health and safety do not have to have Commission review and approval, but must be provided to NRC staff for their information.

Disposal Site Closure Phase

As the disposal site becomes filled, the time for disposal site closure approaches. Prior to closure, the licensee would submit a final closure plan for review and approval (Section 61.28). A public hearing would be offered. Upon approval, the licensee implements the plan. This would consist of decontamination and dismantlement, as appropriate, of buildings or other site facilities. Final disposal site contouring and preparation is performed. The licensee would work toward closure during the entire operational phase so that disposal site closure would not involve a major task.

Post-closure Observation and Maintenance

Implementation of the closure plan would be followed by a period of post-closure observation and maintenance on the part of the licensee, in which the licensee's monitoring and maintenance programs would continue.

This period will normally last 5 years and will help assure that the disposal site is in a stable condition so that only minor care, surveillance, and monitoring by the custodial agency are required. Shorter or longer time periods may be approved by the Commission in connection with the approval of the site closure plan for a specific site. When the disposal site has reached a stable condition, the licensee may prepare and submit an application for transfer of the license to the site owner. A public hearing would be offered. Among other things, the licensee must provide reasonable assurance that the site meets all performance objectives under Subpart C of the Part 61 rule, and the Commission must find that the state or federal agency responsible for post-closure care of the site is prepared to assume these responsibilities. As a condition for assuming these responsibilities, a state may require the licensee to comply with requirements of its own, as long as the state's requirements are not inconsistent with the requirements of the Commission. Upon a satisfactory finding, the license will be transferred to the appropriate federal or state custodial agency to cover their activities during the active institutional control period (Section 61.30).

One of the technical requirements for transfer of the disposal facility title to the site owner is that the radiation levels at the surfaces of the disposal unit covers be controlled to minimize potential exposures to the site owner's maintenance personnel. The proposed Part 61 rule stated that the radiation levels be limited to "a few percent of background." Commenters on the draft rule questioned the ambiguity of the requirement, and some suggested values from as low as 1% of background to as high as 1 mrem/hour (about 5000% of background).

The rules in section 20.105 of 10 CFR Part 20 contain provisions for permissible levels of radiation in unrestricted areas. NRC staff considers these to be appropriate for application at the time that the disposal site is transferred to the site owner for the period of institutional control. Although access to the site will be controlled to prevent inadvertent intrusion and the site could be viewed as a restricted area, NRC staff believes that it is not proper to consider those who do have access to the site, such as caretakers and site maintenance personnel, as radiation workers who could receive much higher occupational exposures. Therefore, the Part 20 unrestricted limits will be used for limits to radiation levels at the surfaces of disposal units. In practice NRC staff would expect that radiation levels may easily be limited to levels significantly less than the Part 20 limits.

Institutional Control Period

During the institutional control period, which for purposes of the Part 61 rule the Commission assumes to be not more than 100 years, the custodial agency carries out a program of monitoring and physical surveillance to assure continued satisfactory site performance, as well as other minor custodial activities. During this period, productive uses of the land might be permitted if those uses do not affect the stability of the site and its ability to meet the performance objectives. As a part of the license termination requirements, the licensee is required to place records of the disposal facility with local, state, and federal agencies. These records, along with restrictions on the property deed and trench markers, should help minimize disturbance of the disposal site. These latter mechanisms are those that would continue after the active institutional control period. At the end of the necessary institutional control period, the custodial agency license may be terminated (Section 61.31).

5.4.2 Financial Assurance Requirements

Financial assurance requirements for low-level waste disposal facilities are needed to help ensure the long-term protection of public health and safety and the environment. Financial assurance requirements are set forth in Subpart E of the final Part 61 rule.

A review by the staff of the operating experiences at both hazardous waste and LLW disposal sites reveals that operators of both types of sites did not adequately plan for closure and long-term care activities. With respect to LLW sites, the state and federal governments recognized the need to care for the sites over the long term. The sites had to be located on land owned by the federal or state government and funds were collected for long-term care activities. In most cases, however, the funds collected for long-term care activities (e.g., the Maxey Flats, Kentucky site) were not adequate and there was need to pump trenches and treat trench leachate. In addition, until recently

little planning or financial assurance was provided for funding final closure and stabilization of the existing sites. This has led to a situation where financial responsibility for the continued assurance of protection of the public health and safety at several of the existing closed sites already has or could become a responsibility of the state or federal government. Closure, post-closure, and active institutional control costs are generally incurred after the site operator is no longer receiving revenues from waste generators. Thus, proper planning during the operating phase when revenues can be accrued is essential.

Based on these considerations, there is a strong need for regulatory requirements to ensure that: (1) the licensee has sufficient financial resources to construct and operate the facility and to provide for final closure and post-closure care of the site and (2) the licensee provides financial assurance for the active institutional control period after the site is closed and stabilized. The staff believes these closure and active institutional control costs should be identified early and should be provided for as part of the necessary costs of operating a site. Financial assurance mechanisms to provide for these costs should be established during the active operating period of the site, when revenues are still being received by the licensee and he has access to financial resources. The need for stringent financial requirements to ensure that the licensee is financially responsible has been voiced by a number of sources, including the U.S. General Accounting Office and the National Conference of Radiation Control Program Directors. The costs for short- and long-term financial assurances have been included as part of the cost for the reference facility.

Requirements for Short-Term Financial Assurances for Operations, Closure, and Post-closure Observation and Maintenance

Given the past history at some of the existing disposal sites, one of the requirements in the Part 61 rule is assurance of adequate financial qualification on the part of the applicant to construct and operate the disposal facility and to provide adequate financial provisions for disposal site closure and post-operational activities.

Short-term financial assurance mechanisms refer to arrangements intended to ensure that the licensee is financially responsible for undertaking required closure, stabilization, and post-closure activities at a low-level waste site, and would be particularly based on a specific site closure and stabilization plan. The amount of financial assurance required would be based on cost estimates submitted by the licensee in an approved plan for disposal site closure and stabilization. The applicant must submit a cost estimate for disposal site closure that includes consideration of inflation, increases in the amount of disturbed land, and the closure and stabilization activities that have already occurred at the disposal site. As used in the Part 61 rule, the concept of financial assurances does not include any requirements for third party liability coverage for damages to people or property resulting from operation of the facilities.

The rule requires applicants to provide proof of financial qualifications prior to the commencement of construction of the disposal facility. Proof of the

financial qualifications of applicants is not currently required by Parts 30 and 40. Requiring such financial qualification in the Part 61 rule will help assure that resources are not expended on projects without adequate backing and should minimize the potential for early default or the abandonment of the site by the operator.

The NRC has received strong public interest concerning the issue of financial responsibility for closure of a disposal site. Numerous written comments were made on this portion of the preliminary draft regulation, and the issue was also raised at all four workshops held to review this regulation. Many commenters felt that the licensee should be held responsible for the full costs of closure of a disposal site, and that the license should not be terminated and the land returned to custodial government authority until the licensee has completed satisfactory closure.

Comments on the proposed Part 61 regulation and draft EIS also indicated considerable public concern regarding financing for closure (and for long-term care). Commenters mentioned that the existing history of LLW disposal sites revealed a strong need to require licensees to demonstrate evidence of financial responsibility so that the public health and safety were protected and also so that potential liabilities do not rest with state taxpayers.

There are a variety of short-term financial assurance mechanisms that could be used by a low-level waste disposal facility operator to assure that sufficient funds are available for closure and post-closure care. Short-term financial assurance mechanisms considered by the staff included the following:

1. Surety bonds, obtained from a surety company;
2. Escrow arrangements between a bank, the government, and the licensee;
3. Trust funds, arranged between the government, a financial institution, and the licensee;
4. Certificates of deposit to a state or federal agency;
5. Cash deposits to a state or federal agency;
6. Deposits of securities to a state or federal agency;
7. Secured interests in the disposal operator's assets;
8. Letters of Credit from a financial institution;
9. Self-insurance by the low-level waste disposal facility operator;
10. Financial tests of the operator or his holding company;
11. Development of a sinking fund based on receipts from surcharges on received wastes; and
12. Development of a closure assurance pool.

These types of financial assurances are standard commercial law arrangements currently being used by state and federal government agencies for the chemical waste disposal, uranium milling, low-level waste disposal, and surface coal mining industries. The staff considers these to be reasonable alternatives.

The primary criterion considered by the staff in evaluating these alternative financial mechanisms was the degree of assurance provided by each method to ensure that funds are available to close the disposal site and to provide for all necessary activities to protect the public's health and safety. Other criteria considered by the staff included the following:

- The degree of security (or level of difficulty) in obtaining funds in case of default.

- The administrative time and expense required by the regulatory agency to implement and monitor the financial assurance mechanisms.

- The cost to the licensee of utilizing the financial assurance mechanism.

Conclusions

Based on the review of the alternative financial assurance mechanisms, the staff concluded that a number of mechanisms exist that will provide adequate assurance of funds for closure and post-closure in the event that the site operator defaults or unforeseen site conditions require early closure of the site. These requirements are set forth in section 61.62 of the final Part 61 rule. The alternatives that the staff finds generically acceptable for a disposal facility licensee are:

- surety bonds
- trust funds
- escrow arrangements
- cash deposits
- certificates of deposit
- deposits of government securities
- irrevocable letters of credit
- combinations of the above

These alternatives were all found to be acceptable because they did not impose a significant economic burden on the license, they did not impose an administrative burden on the staff, and yet they each could be structured to ensure a high degree of confidence that funds would be available to ensure proper closure. The staff has also concluded that approving a range of satisfactory financial assurance alternatives allows the operator flexibility in selecting the mechanism that best suits his needs.

Some commenters on the proposed Part 61 regulation and draft EIS observed that at present no commercial market exists to provide surety bonds of the type required in the Part 61 rule. In drafting the EIS and developing the rule, NRC staff were well aware that surety bonds of the type required in the rule may be currently unavailable. The staff included this alternative in the rule and EIS, however, since it does provide the necessary assurances and may become available in the insurance market at a later date.

While the other financial assurance mechanisms discussed earlier may be acceptable in certain isolated cases, they are not acceptable to the staff on a generic basis. Plans for alternative financial assurance mechanisms not discussed here would be evaluated and approved by the staff on a case-by-case basis. Comments on the proposed rule and draft EIS revealed strong interest in other financial mechanisms--particularly in regard to self insurance. Several commenters felt that self-insurance would not satisfy the surety requirements, and they recommended that licensees should be required to place specific funds in escrow to cover costs of decontamination, closure and stabilization. Another commenter suggested that self-insurance be based on an annual submittal of financial reports, i.e., a financial test.

The Commission rejected the use of stand alone "self-insurance" as a result of discussions with state officials with prior experience with LLW disposal sites. They expressed the need to have tangible funds available from the licensee for site closure, so the State as landowner would not be left financially responsible. While not specifically allowing its use on a generic basis in the rule, the Commission will evaluate the use of financial tests proposed by licensees on a case-by-case basis.

Additional information regarding criteria by which acceptable short-term financial assurances will be judged by NRC is provided in a draft Branch Technical Position on Funding Arrangements for Closure and for Long-term Care of a LLW Disposal Site. (Ref. 9)

Requirements for Long-Term Financial Assurances for Institutional Control

Based on a review of the operating history at existing LLW disposal sites, the staff finds that financial responsibility for active institutional control should be established prior to issuance of the disposal facility license. A review of the history of commercial low-level waste sites in this country indicates that there has been continuing concern by the public and by regulatory authorities over long-term financial responsibility for low-level waste disposal sites. In addition to questions over the equity issues of who pays for active institutional control over the site, the government and the public are concerned that funds be readily available for postoperational activities to ensure that the public's health and safety are continually protected.

Financial assurances for active institutional control involve the financing of any required activities at a low-level waste site after transfer of the disposal facility license to the site owner. These funding assurances would cover surveillance, monitoring, and any necessary maintenance to ensure that the stability and integrity of the site are maintained and that there are no disruptive human activities at the site for up to 100 years. The requirements do not cover unanticipated contingencies that may occur at the site. Based on these considerations, the Commission staff concluded that requirements for financial guarantees for active institutional control should be included in the final Part 61 regulation.

A review of the various financial assurance mechanisms commonly used in the commercial law area (see Section 9.3.3 of Volume 2 of the draft EIS) revealed that few, if any, of these mechanisms are suitable for the long-term nature of a long-term financial assurance mechanism. The extended time period (100 years) means that few financial institutions are willing or able to handle that type

of long-term financial assurance. There are, however, several other alternative long-term financial assurance mechanisms that can be used for active institutional control at a disposal site. Several criteria were applied in reviewing the adequacy of alternative financial assurance mechanisms for active institutional control. The staff considered that the most important consideration for long-term financial assurances was the extent to which they were able to provide a guarantee that the necessary funds would be produced by the responsible parties. Another necessary consideration was the extent to which enabling authority existed to allow the Commission staff to require a specific financial assurance mechanism. Several of the financial assurance mechanisms proposed by various parties would require enabling legislation that is currently lacking at the federal level. Financial assurance mechanisms reviewed by the staff included a sinking fund funded by a surcharge recovered from disposal facility customers, an LLW disposal "superfund," and a lease or a legally binding arrangement.

Conclusions

The staff has determined that all low-level waste disposal site operators must establish evidence of financial responsibility to provide for long-term care of the site during the active institutional control period. Financial responsibility for long-term care must be demonstrated prior to the issuance of the facility license, including costs for all required and necessary activities at the site, including surveillance, monitoring, and required maintenance. States regulating existing commercial low-level waste disposal sites have traditionally required licensees to establish sinking funds based on surcharges collected from the disposal facility customers, along with leases between themselves and the operator specifying financial responsibility for long-term care of the site. The staff is aware of the benefits of requiring disposal operators to require a surcharge on waste generators which is consequently deposited into a sinking fund and then invested. Such a cost recovery mechanism directly charges the benefiting parties (i.e., the waste generators) with the costs of long-term care. However, this approach cannot be required by the Commission, since the Commission lacks the legal authority to: (a) require that a long-term care fund be established, and (b) require that the operator impose a surcharge on waste generators. This lack of authority has been raised before Congress several times.

Since the Commission lacks the authority to explicitly require that a surcharge be imposed and a sinking fund be established, the staff considers that the next best regulatory alternative is to require that the operator be party to a binding arrangement such as a lease between himself and the site's landowner which establishes evidence of financial responsibility. (Current Commission regulations require the state or federal government to be the site landowner.) The staff is aware of the shortcomings of such an approach, but considers this the most viable regulatory alternative based on the current statutory authority of the Commission. Such regulatory requirements will help to ensure that the licensee or the site owner is responsible for performing all required long-term care activities that are necessary to protect the public health and safety and the environment. These requirements are set out in Section 61.63 of the final Part 61 rule.

The staff has included the costs for 100 years of active institutional control into the cost of the reference facility as well as the alternatives considered in the EIS. The actual costs of long-term care, however, will vary depending upon the level of active maintenance required under varying disposal facility conditions. Long-term site stability will significantly reduce and possibly eliminate the need for any major maintenance and cost over the long term.

Additional information regarding the types of long-term financial assurances that NRC staff would find acceptable is provided in a draft Branch Technical Position on Funding Arrangements for Closure and for Long-Term Care of a LLW Disposal Site. (Ref. 9)

Contingencies

One of the points raised by commenters on both the proposed Part 61 rule and the draft EIS was that the proposed regulation failed to address financial responsibility for unanticipated contingencies at a LLW disposal site. One group expressed concern that the regulations set the stage for a "tax-payer funded bail-out" of poorly-run disposal sites. They felt the industry should bear these costs, and that the regulations should be written to make this explicit. Another commenter noted that the experience of the State of Kentucky with Maxey Flats emphasized the importance of making contingency funds available in the event that serious problems occur. They felt this issue should be addressed in the rulemaking. One State further noted that the rule failed to mention who would be financially responsible if problems occur at the site that cost more than were budgeted on an assumption of normal operation. These questions cover such a variety of different scenarios (i.e., Acts of God, licensee negligence, etc.), that it is not possible to specifically respond to all of the potential contingencies. However, a general response to the overall issue of responsibility for contingencies at a low-level waste disposal site is possible. These comments cover two different time periods: the post-closure period, when the original licensee is still responsible at the site, and the institutional control period, when the license has been transferred to the landowner of the site for a period of up to one hundred years. In the case of the post-closure care period, the licensee would be responsible for all activities at the site found necessary by the Commission to protect the public health and safety. Financial responsibility for activities during the institutional control period are a matter to be worked out between the site owner (i.e., the State or Federal Government) and the licensee in their lease or other legally binding arrangement, and it is possible that if the site owner were a state, they would work out an arrangement whereby the site operator would collect a surcharge from waste generators for the institutional control period. The rights and responsibilities of the state and the licensee would be determined at such a time.

One issue is the question of who would assume responsibility for a disposal site and its accompanying waste if it were to be closed prematurely by NRC due to rule violation. In such a situation it is possible that insufficient funds will have been collected for care of the site during the institutional control period. Responsibility for a site closed prematurely by the NRC would depend on the situation. Additionally, closure would be a last resort of the Commission, since the agency has other authorities besides closure, such as civil penalties, to require licensee compliance. In the event it would become necessary to close the site for health and safety reasons, the final rule provides

that the licensee continues to be responsible until the license is terminated. In the event that the licensee's financial condition deteriorated so that he was unable to maintain the site to protect the health and safety, then the Commission would probably require the site owner (either the State or Federal government) to assume responsibility at the site.

Regardless of who assumed responsibility of a prematurely closed site, the Part 61 rule requires that a licensee have available at all times during the site life, sufficient financial guarantees to ensure that sufficient funds are available for site closure and decommissioning. These funds would be available for properly closing the site if the original licensee were unable to do so. In addition, it is apparent that any technical steps taken (such as a stable waste form or package) to enhance long-term site stability that will reduce long-term institutional costs, and therefore reduce the amount of funds that would have to be collected.

Several commenters on the proposed rule and draft EIS believed that the rule should resolve the issue of financial responsibility for contingencies by requiring liability insurance or specific language that licensees would be required to indemnify property owners in case of off-site migration. Although not proposed in the original rule, the staff evaluation of these public comments indicates there is a need for licensees to demonstrate evidence of financial responsibility for liability coverage for off-site bodily injury and property damage. The Commission thinks the public health and safety and the environment will be protected from unanticipated contingencies by such a requirement, as well as assisting the States in establishing disposal sites. Four existing LLW disposal facilities currently carry this type of liability coverage, and several other State and Federal agencies, including EPA have imposed similar requirements for hazardous and radioactive waste disposal facilities in order to protect the public health and safety and the environment. However, at the present time, the Commission's only statutory framework for establishing such a requirement is Section 170 of the Atomic Energy Act, also known as the "Price-Anderson" Act. This type of coverage is designed to cover "catastrophic events" primarily for nuclear reactor licensees, and the Commission feels this coverage would be in excess of the risk at a low-level waste facility. Therefore, the Commission has not established a third party liability requirement in this regulation. The Commission will strongly encourage licensees to continue to carry third party liability insurance coverage through the conventional insurance market.

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Chapter 6

UNMITIGATED IMPACTS OF FINAL PART 61 RULE

6.1 INTRODUCTION

The purpose of this chapter is to identify, evaluate, and quantify the effects of the final rulemaking action: NRC's promulgation of a comprehensive regulation governing the management of low-level radioactive waste disposal (10 CFR Part 61). The environmental consequences or impacts discussed are based on the final rule as developed in previous chapters and do not include consideration of impacts of alternative versions of the rule. The consequences discussed are incremental, in some cases, with respect to the current regulatory framework.

Both direct and indirect environmental impacts will occur as a result of the final Part 61 rule. Direct impacts are discussed first in this chapter (Section 6.2) and, although such impacts are readily identified and evaluated, they are significantly different than the impacts typically considered in an EIS for a physical project such as a nuclear power plant or a fuel fabrication facility. Because this final EIS is being prepared for a rulemaking action, the direct effects of the action do not fall upon the physical and natural environments, but rather upon those segments of the human environment whose conduct of affairs will be affected by the change in regulatory requirements. Among the directly affected groups considered in Section 6.2 are:

- o Waste generators and processors;
- o Waste transporters;
- o Waste disposal facility operators;
- o Federal agencies and the states; and
- o The public.

Section 6.3 discusses the indirect impacts of the final Part 61 rule. In this section the performance objectives and minimum technical requirements of the rule are applied to four hypothetical disposal facility sites located on a regional basis. Through this analysis, the residual or unmitigated impacts are identified which will occur even with the application of the final Part 61 requirements. By applying these requirements to a reference facility design and analyzing the benefits and residual impacts, the reader is provided with an estimate of the "real world" effects of the rule in terms that are more reflective of a typical project-specific EIS.

6.2 ENVIRONMENTAL CONSEQUENCES OCCURRING DIRECTLY AS A RESULT OF THE FINAL PART 61 RULE

6.2.1 Impacts on Federal Agencies

A number of federal agencies have responsibilities relative to low-level waste management. These agencies are: NRC, the Environmental Protection Agency

(EPA), the Department of Energy (DOE), the Department of Transportation (DOT) and the U.S. Geological Survey (USGS). The effects of the final Part 61 rule on these agencies are discussed in the following subsections.

6.2.1.1 Impacts on NRC

In general terms, the chief impact of the adoption of 10 CFR Part 61 on NRC would be to more clearly define to the staff the established policies, licensing procedures, and performance objectives governing LLW disposal. It would also help ensure that LLW disposal facilities are treated uniformly in terms of complying with the above regulations and procedures.

Adoption of the final Part 61 rule is not expected to significantly increase NRC's regulatory expenditures. Although the new requirements should result in some increased costs and effort, these probable increases in regulatory costs will be offset by gains in NRC's administrative efficiency. The application of a comprehensive set of regulations governing LLW will aid both potential licensees, the states, the public, and NRC by more clearly defining respective responsibilities, requirements, analyses, and determinations. In particular, NRC would have a uniform set of administrative procedures and performance requirements to apply in each instance. NRC would also have a set of clearly enunciated technical performance requirements that would permit more effective control of the performance and operating procedures of commercial LLW disposal facilities.

6.2.1.2 Impacts on EPA

The Environmental Protection Agency (EPA) is charged with the responsibility of protection and enhancement of environmental quality and it carries out its mission through research, monitoring, regulatory, and enforcement functions. An important EPA role with regard to low-level radioactive waste management is in the establishment of generally applicable environmental standards for waste disposal. The Agency does not license radioactive waste disposal facilities.

At the present time, the overall environmental standards for waste disposal are in the development process. The fact that EPA's standards in this field are not currently established required NRC to make a choice with regard to development of the Part 61 rule: proceed with rulemaking based on interim standards developed by NRC and coordinated with EPA, or suspend rulemaking until the EPA standards are formulated. NRC chose the former course of action.

In proceeding, NRC consulted with EPA on the performance objectives, minimum technical criteria, and other aspects of the rule. EPA comments on the draft Part 61 rule were considered and for the most part, incorporated into the final Part 61 rule. In addition, through their comments on the draft Part 61 rule EPA indicated that NRC's selection for the performance objective for long-term environmental releases was within the range of values that EPA expects to consider as part of their work to establish overall environmental standards for waste disposal.. As a result of this coordinated effort, the technical criteria established in this statement and the rule itself will not impact the ongoing program of that agency for establishing overall environment standards for waste disposal. Rather, the NRC rulemaking effort may in fact advance EPA's efforts in this regard.

6.2.1.3 Impacts on DOE

The Department of Energy (DOE) is responsible for managing disposal of low-level radioactive waste generated by government operations and for conducting research into various aspects of radioactive waste disposal. Disposal of LLW by DOE is exempted from NRC licensing authority and would remain so under the final Part 61 rule. Therefore, DOE's LLW disposal operations would be unaffected by the rule and could not come under its purview without an amendment to the Energy Reorganization Act of 1974.

One impact of the Part 61 rule on DOE would occur if DOE resumed using commercial disposal facilities for disposal of DOE LLW. Under this situation DOE would have to ensure that its waste conformed to applicable parts of the new rule. In addition, the Part 61 rule will help to provide additional specific guidance to DOE's programs of technology development and assistance to states in establishing new sites.

6.2.1.4 Impacts on DOT

Transportation of radioactive materials in the United States is jointly regulated by the Department of Transportation (DOT) and NRC. DOT regulates all radioactive materials in interstate commerce while NRC regulates the transportation of byproduct, source, and special nuclear material. The agencies continue to work closely in establishing standards and regulating packaging and other aspects of radioactive material transport. NRC's existing regulations for transport reflect the requirements of DOT and the situation will remain the same under the final Part 61 rule. The minimum requirements for waste form and packaging under the proposed rule are in compliance with existing DOT and NRC regulations and thus will not impact the regulatory program of DOT. The stability waste form requirements for higher activity wastes will help improve transportation safety as a byproduct, as will the minimum waste form requirements intended to improve operational safety at the disposal facility. Finally, the requirements for the manifesting system established in the final paragraph 20.311 are compatible with the common manifest system for hazardous wastes currently being developed by EPA and DOT.

6.2.2 Impacts on the States

Promulgation by NRC of the final Part 61 regulation will have impacts on the states in addition to these realized by industry and federal agencies. These impacts will primarily affect those states which have entered into agreements with NRC for regulation of certain radioactive materials--i.e., the Agreement States.

Under provisions of the Atomic Energy Act, the states and NRC maintain compatible programs, which include specific rules and regulations. The promulgation of 10 CFR Part 61 would mean that the Agreement States would have to modify their regulations to include provisions compatible with the new NRC regulation. This process of modification would involve, at a minimum, the following steps:

- o Preparation of draft regulations to reflect the requirements of the Part 61 rule;

- Review and approval of proposed regulations by NRC; and
- Public review and formal incorporation into state code.

In preparation of this final EIS, NRC has not attempted to quantify the actual costs which would be incurred by the Agreement States in modification of their programs. In part, this is because the periodic updating and modification of Agreement State rules and regulations to maintain a program compatible with NRC regulations is part of the normal functioning of the Agreement State program. Moreover, the Agreement State programs vary from state to state and the costs to one state to assure compatibility may not necessarily reflect the costs to another state.

Another possible source of costs to the states is the additional requirements set out by Part 61 which will need to be enforced. However, many of these additional requirements will help ensure that future costs over the long term due to maintenance of a disposal facility are minimized.

6.2.3 Impacts on the Public

Promulgation of the final Part 61 rule by NRC will impact the public most significantly. The purpose of the rule is to provide improved safeguards for protection of public health and safety and the environment, but despite these improvements, the technology of waste disposal is not risk-free. Whatever risks remain in the presence of the operative rule will be borne by the public, as will the ultimate costs of implementing the rule. In the following paragraphs, the beneficial as well as the adverse impacts of implementing the Part 61 rule are considered.

6.2.3.1 Beneficial Impacts

The requirements of the Part 61 regulation are expected to result in beneficial impacts to the public in three major areas. First, the implementation and enforcement of performance objectives and uniform minimum technical requirements will improve the performance of future LLW disposal facilities and thereby reduce the hazards of LLW disposal to public health and safety and environmental quality. Although the benefits of the rule's requirements may not be immediately apparent, the staff believes that in the long term these requirements will improve the stability of both the waste form and the disposal facility and will lessen the potential for radionuclide migration into the environment and the need for active long-term maintenance of the facility.

Second, the requirements of the Part 61 rule should assure that near-surface disposal remains a safe viable option for the disposal of LLW. Therefore, the public can be assured of the continued availability of goods and services whose provision results in generation of LLW. Among these goods and services are electricity from nuclear power plants, medical diagnostic aids based on nuclear technology, research into causes and cures of debilitating diseases such as cancer, and research research into new applications of nuclear technology.

Finally, the Part 61 rule provides public benefits in the form of more explicit provisions for participation in the licensing process for future LLW disposal

facilities. Licensing requirements and procedures have heretofore been fragmented and somewhat difficult for interested citizens to fathom. These procedures are consolidated in rule, and expanded provisions for participation by state and tribal governments are set out under Subpart F of the rule.

6.2.3.2 Adverse Impacts

The final Part 61 rule will result in benefits to the public. However, the staff does not expect that implementation of the rule will be without adverse public impacts. Three primary impacts are expected to occur.

The first of these impacts will be residual environmental and human health hazards resulting from LLW disposal. Despite the provisions of the Part 61 rule, the variables and processes involved in LLW disposal are sufficiently complex that unmitigated impacts cannot be avoided. These may include occupational exposures, migration of radionuclides, and subsequent offsite exposures. (Section 6.3 discusses these unmitigated impacts in more detail.) It should be noted, however, that these impacts are not impacts caused by the rule, but rather impacts which are considered beyond the capability of the rule to eliminate entirely.

Achieving reductions in impacts from LLW disposal will not be without costs in an economic sense. Implementing the requirements of the Part 61 rule will involve costs to the disposal facility operators, waste transporters, and waste generators. These costs, of course, will be passed on to the public in the form of increased prices for goods and services whose provision involves the generation of LLW. It is not expected that the passing on of these costs will create an incremental change to the consumer, but rather will appear along with many other costs of doing business in aggregate price increases. These anticipated increased costs can also be balanced against the likely costs, which would be significantly higher, that could result without the promulgation of a uniform series of criteria for waste disposal. The current lack of such a uniform series of criteria for waste disposal is believed by many to significantly contribute to the current shortage of disposal capacity.

Finally, implementation and enforcement of the provisions of the Part 61 rule will require the allocation of federal and state resources during the operational and postoperational periods of a LLW disposal facility. To the extent that these public resources are allocated to regulation of LLW disposal, they are unavailable for other purposes. Conversely, to the extent that the public incurs this cost, it reduces (within limits) the costs of LLW disposal in terms of human health hazards and environmental impacts.

6.3 ENVIRONMENTAL CONSEQUENCES OCCURRING INDIRECTLY AS A RESULT OF THE FINAL PART 61 RULE

This section discusses the indirect impacts of the final Part 61 regulation. To estimate these impacts, the performance objectives and minimal technical criteria established in the final rule are applied to four reference disposal facilities assumed to be constructed on four hypothetical regional sites. Through this analysis, the residual or unmitigated impacts that could occur even with the application of the Part 61 requirements are addressed.

This section is divided into four subsections as follows. Section 6.3.1 provides a very brief summary of the assumed regional sites, while a description of the disposal facilities assumed to be constructed at each regional site is provided in Section 6.3.2. The waste form and packaging options assumed for the regional case study analysis are also summarized in Section 6.3.2. Section 6.3.3 presents the results of the analysis in terms of radiological impacts and costs. Section 6.3.4 presents a discussion of other impact measures such as air quality, land use, and incremental energy use.

6.3.1 Hypothetical Regional Sites

This section presents a very brief review of the four hypothetical regional sites assumed in this EIS. For the purposes of this final EIS, the conterminous U.S. has been divided into four regions having boundaries based upon the existing five NRC regions (see Figure 4.1). These are referred to in this EIS as the northeast region (NRC Region I), the southeast region (NRC Region II), the midwest region (NRC Region III), and the western region (a combination of NRC Regions IV and V). Each region is projected to generate from 600,000 to 1,000,000 m^3 of LLW between the years 1980 and 2000. (These volumes are given prior to further waste processing such as compaction.) A disposal facility is assumed to be located at a hypothetical site within each region. The western regional site is meant to be representative of the southwestern portion of the region, and is usually termed the southwest site in this EIS.

Each site has been developed from a number of sources and is meant to be consistent with: (a) the basic disposal facility siting considerations set forth in the final Part 61 rule, (b) the generic environmental characteristics within that region. The regional sites are intended to be representative of reasonable realistic sites--i.e., sites that could be licensed under the Part 61 rule--but are not intended to represent the "best" sites that could be located within the regions. Although the regional sites are meant to be typical of the environmental characteristics within the regions, the sites are not meant to describe any existing or potentially planned disposal facility, or any specific location within a particular region.

A detailed description of the regional sites is provided in Appendices E and J of the draft EIS. Briefly, however, the northeast, southeast, and midwest sites are located in humid environments. The soils of the northeast site are quite impermeable while the soils of the southeast and midwest sites are moderately permeable. The southwest site is located in a semi-arid environment and has permeable soils.

A short summary of most of the principal site environmental properties used in the analyses is included as Table 6.1. Table 6.2 contains a summary of the (dimensionless) retardation coefficients assumed for the soils in the vicinity of the regional sites, while Table 6.3 contains a summary of the assumed population distributions.

6.3.2 Assumed Regional Disposal Facility Designs and Waste Source Term

This section provides a description of the disposal facilities assumed to be situated at the four regional sites, as well as the wastes which are assumed to be disposed in the facilities. The disposal facilities and waste forms

Table 6.1 Summary of Regional Disposal Facility Site Environmental Properties

Environmental property	Regional Sites NE	SE	MW	SW
Mean average temperature °C (°F)	8°C (46°F)	17°C (63°F)	11°C (51°F)	14°C (57°F)
Average wind speed km/hr	16.6	13	17	25
Average annual precipitation mm (in)	1,034 (41)	1,168 (46)	777 (30.5)	485 (19)
Average annual natural percolation (PERC) into groundwater system mm (in)	74 (2.9)	180 (7.1)	50 (2.0)	1 (.04)
Precipitation-evaporation (PE) index of site vicinity	136	91	93	21
Average silt context of site soils (%)	65	50	85	65
Average cation exchange capacity (meq/100g)	15	10	12	5
Groundwater travel time (yrs)				
Waste to:				
o Water table	50	10	23	277
o Site boundary	200	32	130	280
o Population well	2,500	400	2,100	580
o Surface water body	5,000	800	3,800	880
Distance (m)				
Waste to:				
o Water table	4	5	4	84
o Site boundary	30	30	30	30
o Population well	500	500	1,250	3,000
o Surface water body	1,000	1,000	2,500	6,000
Average transportation distance to regional facility (miles)	300	400	600	1,000

Table 6.2 Retardation Coefficients Assumed for Regional Disposal Facility Sites

Isotope	Regional Site NE	SE	MW	SW
H-3	1	1	1	1
C-14	10	10	10	10
Fe-55	5,400	2,640	2,640	1,290
Ni-59	3,600	1,750	1,790	860
Ni-63	3,600	1,750	1,750	860
Co-60	3,600	1,750	1,750	860
Sr-90	73	36	36	18
Nb-94	10,000	4,640	4,640	2,150
Tc-99	5	4	4	3
I-129	5	4	4	3
Cs-135	720	350	350	173
Cs-137	7,200	350	350	173
U-235	7,200	3,520	3,520	1,720
U-238	7,200	3,520	3,520	1,720
Np-237	2,500	1,200	1,200	600
Pu-238	7,200	3,520	3,520	1,720
Pu-239/240	7,200	3,520	3,520	1,720
Pu-241	7,200	3,520	3,520	1,720
Pu-242	7,200	3,520	3,520	1,720
Am-241	2,500	1,200	1,200	600
Am-243	2,500	1,200	1,200	600
Cm-243	2,500	1,200	1,200	600
Cm-244	2,500	1,200	1,200	600

Table 6.3 Population Distributions for the Regional Disposal Facility Sites

Distance From Facility	Northeast	Southeast	Midwest	Southwest
0-5 miles	3,400	2,000	3,100	60
5-10 miles	20,500	8,100	5,000	180
10-20 miles	73,600	36,000	27,900	3,500
20-30 miles	121,600	125,000	104,200	9,100
30-40 miles	556,600	203,400	121,900	4,900
40-50 miles	1,012,800	104,900	359,100	27,200

described are intended to provide an example of potential impacts associated with disposal of waste according to the minimum requirements of the final Part 61 regulation. These should not be interpreted as representing the best or the only designs or waste forms which could be implemented in compliance with the rule. There may be a number of ways in which the Part 61 requirements may be met for a specific disposal facility, and compliance with the Part 61 rule, as well as measures which may be implemented to reduce potential impacts to levels as low as reasonably achievable, would be evaluated on a case-by-case basis. The examples, rather, are intended to illustrate an upper bound range of impacts from implementation of the rule, with the expectation that actual impacts from implementation of the rule at existing or future disposal facilities would be less.

Assumed Facility Designs

The design assumptions for the four regional disposal facilities are summarized in Table 6.4. As shown, the assumed design cases all involve disposal in "regular" shallow land burial disposal cells. All disposal cells for the four regional sites are assumed to be constructed to depths of 8 meters below the earth's surface. This introduces an additional conservatism regarding intruder and erosional impacts calculated for the southwest site, since the great depth to the water table at this site would allow construction to much greater depth than at the other three sites. All cases assume segregated disposal of waste streams containing organic chemicals as well as unstable Class A waste streams. Layering is used for Class C waste.

The principal differences among the four cases lies in the methods to limit contact of water with disposed waste and to minimize long-term maintenance requirements. For the three humid sites (northeast, southeast, and midwest), a moisture barrier in the form of a thick clay cap is installed and compacted using standard construction techniques. Variations in the effectiveness of the clay caps placed over the disposal cells containing unstable waste streams are considered for the northeast, southeast, and midwest regional disposal facilities.

In the southwest site, there is assumed to be considerably less concern regarding ground-water migration due to the extreme depth of the water table and the semiarid climate. In this case, the standard "thin" cap is assumed to be installed. Similar to the humid sites, however, the disposed waste, backfill, and cap are assumed to be compacted using improved methods (e.g., a vibratory compactor). This helps to reduce voids within the disposal cell and therefore reduces the potential for settling and further reduces potential long-term maintenance costs.

At the three humid disposal facility sites, an imported permeable (sand or gravel) backfill is assumed to be used to reduce the contact time of percolating water. At the southwest site, the originally excavated material from the site is used as backfill.

All regional facilities are assumed to be operated for 20 years, followed by a two-year closure period and a five-year observation period prior to license termination and transfer of site control to the site owner.

Table 6.4 Design Assumptions for Regional Disposal Facilities

Northeast

- Regular SLB trench
- Use of a thick clay cap
- Compaction using improved methods
- Segregation of wastes containing organic chemicals
- Segregation of unstable Class A waste
- Random disposal of waste
- Use of a permeable backfill
- Layering used for disposal of Class C waste
- Humid site having low permeable soils

Southeast

- Regular SLB trench
- Use of a thick clay cap
- Compaction using improved methods
- Segregation of wastes containing organic chemicals
- Segregation of unstable Class A waste
- Random disposal of waste
- Use of a permeable backfill
- Layering used for disposal of Class C waste
- Humid site having moderately permeable soils

Midwest

- Regular SLB trench
- Use of a thick clay cap
- Compaction using improved methods
- Segregation of wastes containing organic chemicals
- Segregation of unstable Class A
- Random disposal of waste
- Use of a sand backfill
- Layering used for disposal of Class C waste
- Humid site having moderately permeable soils

Southwest

- Regular SLB trench
- Use of a "standard" cap
- Compaction using improved methods
- Segregation of wastes containing organic chemicals
- Segregation of unstable Class A waste
- Random disposal of waste
- Backfill with originally excavated soils
- Layering used for disposal of Class C waste
- Semiarid site having permeable soils

Assumed Waste Forms

In the analysis, all Class B and C waste streams are assumed to be stabilized. A number of techniques may be potentially used to achieve waste stability, ranging from solidification to improved waste packaging. NRC staff expects that less expensive techniques will be generally preferred by most licensees. For this analysis, waste stabilization is assumed to be for the most part carried out through use of high integrity containers, and relatively smaller volumes are assumed to be solidified using a binder such as cement or vinyl ester styrene. In making this assumption, it should be emphasized that NRC staff is in no way attempting to judge the relative merits or de merits of a particular waste stabilization technique. Rather, an attempt is made to represent one method by which licensees generating Class B and C wastes could use to comply with the stabilization requirement.

In the analysis, all waste streams are tested for acceptability into the three disposal classes, and those waste streams (other than concentrated liquids which are solidifed) which must be stabilized are assumed to be stabilized using high integrity containers. Some waste streams or portions of waste streams (e.g., portions of light water reactor process waste streams) may exceed the Part 61 concentration limits for near surface disposal. These waste streams are then assumed to be stabilized through solidification and the resulting concentrations again tested against the Part 61 concentration limits. Since solidification results, compared to internment in high integrity containers, in a net waste volume increase, additional portions of waste streams may be determined to be acceptable. This results in nearly 90% of the Class B and C waste streams being stabilized through use of high integrity containers. The remaining 10% are either already stable due to waste form or are solidified.

These potential waste stabilization techniques are assumed to be applied in the analysis to all four regional disposal facilities generally without consideration of possible additional waste form requirements that could be implemented at a particular site. An example requirement would be the prohibition of certain types of organic chemicals at a particular humid site. These and other potential additional requirements are conservatively (in terms of groundwater impacts) ignored in the analysis. (An exception to this, discussed below, concerns some variations on the northeast site case.)

In the analysis, the volumes of waste projected to be generated in each region over a 20-year period are processed and delivered to the disposal facility. Compressible waste streams are compacted prior to disposal. This results in a range in projected waste volumes (in m^3) for each region as follows:

	Northeast	Southeast	Midwest	Southwest
Prior to Waste Processing	1.01E+6	1.10E+6	7.74E+5	7.48E+5
After Waste Processing	6.68E+5	7.45E+5	5.13E+5	5.05E+5

In the forthcoming analysis, some small volumes of wastes from each region will be classified as being unacceptable for near surface disposal.

6.3.3 Results of the Regional Analysis

This section presents a discussion of the indirect unmitigated impacts of implementation of the Part 61 rule based on analysis of the above regional cases. The section is divided into subsections as follows: 6.3.3.1, long-term radiological impacts; 6.3.3.2, short-term radiological impacts; 6.3.3.3, costs; 6.3.3.4, additional considerations; and 6.3.3.5, other impacts (including nonquantifiable impacts such as impacts to biota and cultural resources). Quantifiable impact measures are summarized on Table 6.5.

6.3.3.1 Long-Term Radiological Impacts

Long-term radiological impacts for the regional case study as summarized in Table 6.5 include potential individual and population intruder impacts, erosional impacts, and groundwater impacts. Individual inadvertent intruder impacts are calculated for two scenarios for two time periods (100 and 500 years) following transfer of the disposal facility to the site owner, and for three organs: whole body, bone, and thyroid. The intruder-construction scenario consists of a scenario in which persons are assumed to construct a house on the disposal facility. The intruder-agriculture scenario assumes that an individual or group of individuals live in the house thus constructed and consume vegetables grown in a small onsite garden.

As shown, the limiting individual inadvertent intruder impacts appear to be to the bone. In the analysis, volume-weighted intruder impacts for the northeast, southeast, and midwest sites run at a few hundred millirem/yr at 100 years and from 10 to 20 millirem at 500 years. These impacts calculated at 500 years would be further reduced if credit were taken at 500 years for the protection provided by the layered stable waste streams.

The highest individual intruder exposures are estimated to occur at the southwest site. These potential exposures are on the order of 170 mrem to the bone at 500 years, although such exposures are still about a third of the 500 millirem limit used to formulate the waste classification tables. This increased exposure is due to the increased silt content of the site soils as well as the increased wind speed relative to the other three sites. The indicated impacts are believed to be conservative, however, and possibly overconservative, since the great depth to the water table allows disposal at much greater depths than the other three sites. This means that there is even less chance for Class C and other wastes to be contacted after 500 years. In addition, no credit is taken in the calculations for improved waste forms to reduce airborne dispersion or plant root uptake, or for waste to be in a recognizable form (as something other than dirt) after 500 years. This is very conservative for the southwest site since the semiarid nature of the environment would tend to reduce the rate of decomposition relative to the other three buried sites.

The population intruder impacts are given as impacts to offsite individuals and populations that could result from intrusion at the disposal facility. Two such radiological impacts are calculated: waterborne and airborne. Both waterborne and airborne impacts are calculated at 100 years following transfer of the site license to the site owner. One involves potential exposures to an

Table 6.5 Summary of Quantifiable Impact Measures for Regional Analysis

	NE Site		SE Site		MW Site		
	low perc.	high perc.	low perc.	high perc.	low perc.	high perc.	SW site
I. Long-Term Individual Exposures (mrem/yr):							
Intruder-construction							
° 100 yrs - Body	1.82E+2*		1.97E+2		2.24E+2		1.27E+2
Bone	1.83E+2		2.01E+2		2.28E+2		1.67E+2
Thyroid	1.82E+2		1.97E+2		2.24E+2		1.24E+2
° 500 yrs - Body	2.39E+0		3.36E+0		3.68E+0		1.45E+1
Bone	7.92E+0		1.85E+1		2.16E+1		1.71E+2
Thyroid	2.15E+0		2.66E+0		2.91E+0		6.76E+0
Intruder-agriculture							
° 100 yrs - Body	1.95E+2		2.18E+2		2.49E+2		1.38E+2
Bone	2.01E+2		2.23E+2		2.56E+2		1.46E+2
Thyroid	1.94E+2		2.17E+2		2.47E+2		1.37E+2
° 500 yrs - Body	2.87E+0		3.32E+0		3.53E+0		6.03E+0
Bone	8.19E+0		1.01E+1		1.04E+1		2.07E+1
Thyroid	8.58E+0		9.87E+0		1.09E+1		9.96E+0
Intruder well							
° Body	7.58E-3 -	9.69E-3	1.27E-2 -	3.28E-2	7.93E-3 -	1.04E-2	3.06E-1
° Bone	7.63E-3 -	1.33E-2	3.15E-2 -	1.04E-1	9.83E-3 -	1.79E-3	2.03E-2
° Thyroid	4.73E+0 -	5.49E+0	5.02E+0 -	9.38E+0	4.66E+0 -	5.37E+0	7.83E-1
Boundary well							
° Body	6.78E-3 -	8.57E-3	2.61E-2 -	5.59E-2	7.90E-3 -	1.04E-2	3.84E-3
° Bone	6.44E-3 -	1.25E-2	3.13E-2 -	1.04E-1	9.65E-3 -	1.75E-2	1.42E-2
° Thyroid	4.29E+0 -	4.97E+0	5.02E+0 -	9.38E+0	4.66E+0 -	5.33E+0	7.82E-1

Table 6.5 Summary of Quantifiable Impact Measures for Regional Analysis (Continued)

	NE Site	SE Site	MW Site	
	low perc. - high perc.	low perc. - high perc.	low perc. - high perc.	SW site
Population well				
° Body	**	3.44E-3 - 8.40E-3	**	1.48E-4
° Bone	**	7.06E-3 - 2.31E-2	**	5.46E-4
° Thyroid	**	1.59E+0 - 2.96E+0	**	3.01E-2
Surface water				
° Body	**	1.50E-4 - 3.76E-4	**	***
° Bone	**	2.90E-4 - 1.02E-3	**	***
° Thyroid	**	7.23E-2 - 1.35E-1	**	***
II. Other Long-Term Exposures:				
Erosion impacts				
° Waterborne releases (mrem/yr)				
Body	8.77E-2	9.94E-2	8.01E-2	#
Bone	7.30E-1	8.82E-1	6.64E-1	#
Thyroid	8.43E-1	1.05E+0	8.17E-1	#
° Airborne releases (man-mrem/yr)				
Body	1.97E+1	9.92E+0	7.05E+0	5.81E-1
Bone	3.88E+2	1.96E+2	1.38E+2	9.88E+0
Thyroid	1.56E+2	6.82E+1	5.81E+1	2.19E+0
Offsite releases from intrusion				
° Waterborne (mrem/yr)				
Body	1.28E-2	1.14E-2	2.73E-2	#
Bone	2.80E-2	2.25E-2	2.73E-2	#
Thyroid	4.83E-4	4.68E-4	6.11E-4	#
° Airborne (man-mrem/yr)				
Body	7.32E-1	2.40E-1	2.85E-1	1.57E-2
Bone	5.92E+0	2.49E+0	2.52E+0	1.72E-1
Thyroid	2.30E-1	9.32E-2	1.20E-1	4.40E-3

Table 6.5 Summary of Quantifiable Impact Measures for Regional Analysis (Continued)

	NE Site		SE Site		MW Site		
	low perc.	high perc.	low perc.	high perc.	low perc.	high perc.	SW site
III. Short-Term Whole Body Exposures (man-mrem over 20 yrs):							
Occupational							
° Process by waste generator##	+1.70E+5		+2.40E+5		+1.70E+5		+1.50E+5
° Process by regional process center	1.81E+5		7.25E+4		1.08E+5		9.13E+4
° Waste transport	4.70E+6		5.91E+6		4.26E+6		4.48E+6
° Waste disposal	2.06E+6		2.58E+6		1.73E+6		1.66E+6
To population							
° Process by waste generator##	+1.26E+2		+1.51E+2		+1.23E+2		+5.83E+1
° Process by regional process center	0.		0.		0.		0.
° Waste transport	3.79E+5		5.86E+5		6.07E+5		1.07E+6
IV. Costs (total $ over 20 yrs):							
Waste generation and transport							
° Process by waste generator##	+2.20E+7		+2.90E+7		+2.10E+7		+1.60E+7
° Process by regional process center	5.29E+7		2.10E+7		3.14E+7		2.66E+7
° Waste transport	1.22E+8		2.04E+8		2.01E+8		3.05E+8
Waste disposal							
° Design & op.	3.51E+8		3.54E+8		3.42E+8		3.29E+8
° Postoperational							
Closure	3.87E+6		3.87E+6		3.87E+6		3.87E+6
Obs. & maint.	1.13E+6 -	1.42E+6	1.14E+6 -	1.43E+6	1.11E+6 -	1.39E+6	5.86E+5
Inst. Control	1.57E+7 -	3.86E+7	1.57E+7 -	3.06E+7	1.54E+7 -	2.96E+7	9.32E+6
Total post op.	2.07E+7 -	4.38E+7	2.07E+7 -	3.59E+7	2.04E+7 -	3.49E+7	1.38E+7
° Total disp. cost	3.72E+8 -	3.95E+8	3.75E+8 -	3.90E+8	3.62E+8 -	3.77E+8	3.43E+8
° Unit cost ($/m^3)	5.70E+2 -	6.06E+2	5.03E+2 -	5.24E+2	7.06E+2 -	7.34E+2	6.79E+2

Table 6.5 Summary of Quantifiable Impact Measures for Regional Analysis (Continued)

	NE Site		SE Site		MW Site		
	low perc.	high perc.	low perc.	high perc.	low perc.	high perc.	SW site
V. Waste Volume (m^3):							
Volume acceptable							
° Class A unstable	4.25E+5		4.72E+5		3.12E+5		3.25E+5
° Class A stable	1.56E+5		1.73E+5		1.27E+5		1.28E+5
° Class B	6.76E+4		6.70E+4		5.33E+4		3.26E+4
° Class C	3.26E+3		4.34E+3		2.97E+3		2.18E+3
° Total volume acceptable	6.52E+5		7.17E+5		4.95E+5		4.88E+5
Volume not acceptable	1.69E+4		2.80E+4		1.82E+4		1.67E+4

*The notation 1.82E+2 means 1.82×10^2.

**Less than $1. \times 10^{-6}$ millirem/year.

***Impacts at the surface water body are not given for the southwest site due to the intermittent nature of the nearest stream to the site and the extreme depth to groundwater at the site.

#Impacts due to waterborne releases from human intrusion and erosion are not given for the southwest site due to the semiarid environmental conditions and the intermittent nature of the nearest stream to the site.

##In this EIS, population exposures due to waste processing by waste generators, occupational exposures due to waste processing by waste generators, and costs due to waste processing by waste generators are presented as impacts and costs in addition to those associated with a no action case (i.e., continuance of current disposal practices).

individual resulting from precipitating water washing exposed contaminated soil down to a nearby surface stream. Contaminated water is then assumed to be used by an individual (i.e., comsuption, watering crops and livestock, and so forth). As shown, such offsite waterborne impacts for the three humid sites are very low; the highest calculated impacts are on the order of 0.03 mrem/yr to the bone. Such waterborne impacts are not given for the southwest site. This is due to the semiarid nature of the site and also because the nearest "stream" to the site is ephemeral, and only contains water during periods of precipitation.

The other radiological impact calculated results from airborne dispersion of the exposed waste/soil mixture to the surrounding environment. Impacts are calculated as total impacts (in man-millrem) to the projected population out to a 50-mile radius.

Opposite to the impacts calculated to the potential inadvertent individual intruder, the intruder airborne population impacts at the southwest site run at better than an order of magnitude less than those calculated for the other three sites. This is principally due to the low population density in the environs of the southwest site.

In the same manner, potential erosional impacts are calculated as impacts to the surrounding population for airborne releases and as impacts to an individual for waterborne releases. These are calculated at a time period equal to 2,000 years following facility closure for the 3 humid sites and at 1,000 years following facility closure for the southwest site. In addition, the entire disposal facility is assumed to be affected. (All of the disposal cell covers are assumed to be removed by the erosional forces.) It is worth emphasizing that disposal facilities would be sited, designed, and operated under the Part 61 regulation so that erosional problems would be avoided. Thus, the calculated erosional impacts represent a rather improbable upper bound of potential impacts.

At any rate, compared to the offsite exposures calculated from intrusion, erosion impacts exhibit a reversal. Waterborne impacts are much greater than those calculated from intrusion while airborne impacts are significantly less. Apparently, the long lived nuclides remaining in the disposal facility are more of an ingestion hazard (e.g., C-14, I-129) than an inhalation hazard (e.g., Pu-239).

Potential impacts from groundwater migration are listed for three different organs (whole body, bone, and thyroid) for four different biota access locations (see Table 6.1). These include:

1. A well (intruder well) located on the disposal facility and potentially used by an inadvertent intruder following the end of the 100-year institutional control period;

2. A well (boundary well) located at the site boundary which is assumed to be used by a few individuals;

3. A well (population well) assumed to be located down-gradient from the disposal facility and used by a small population of about 100 persons; and

4. A small stream (surface water access) located down-gradient of the disposal facility and assumed to be used by a small population of about 300 persons.

The analysis also considers the effect of varying the percolation rate into the disposed unstable waste streams. This is accomplished by assuming (for purposes of groundwater impacts) that for the low percolation case the improved disposal cell covers over the unstable waste disposal cells are reasonably effective. For the high percolation case, the disposal cell covers over the unstable waste disposal cells are assumed to function no better than a standard "thin" disposal cell cover composed of locally available soil.

The southwest site is somewhat of a different case. A water balance calculation for the site indicated that due to the low rainfall and high evapotranspiration, essentially no precipitation falling upon the site reaches the underlying aquifer. For completeness in this analysis, however, a percolation coefficient of 1 mm is conservatively assumed for the site. Given the arid nature of the site, there is assumed to be no attempt to emplace improved disposal cell covers at the site. This results in maximum impacts for this case. In addition, exposures at the surface water body access location are not calculated. The closest water body downgradient of the site is an intermittent stream, and in any case, the water table is located on the order of 80 meters below ground surface.

As shown in Table 6.5, the highest exposures due to ground-water migration are to the thyroid, although in all cases the performance objectives as set out in Chapter 5 for inadvertent intrusion and ground-water migration are met. The estimated impacts reflect the differing volumes of waste streams and corresponding radionuclide inventories within each regional facility, as well as the differing environmental characteristics of each regional site. Of the three humid regional disposal facilities considered (northeast, southeast, and midwest), reasonably comparable impacts are estimated at the intruder well and the boundary well. For the intruder well, the highest exposures to whole body and bone occur at the southeast site. Intruder well exposures to thyroid are similar among the three humid sites, with the highest exposures occurring at the southeast site. For the boundary well, the highest exposures are again estimated for the southeast site.

Of the three humid regional sites, the southeast is assumed to experience the largest percolation component (PERC) as well as the quickest ground-water travel times to biota access locations. In addition, the midwest and southeast site soils are assumed to have moderate retardation capabilities (NRET=3) while the retardation capability of the northeast site soil is higher (NRET=4). The influence of these factors is clearly seen in calculated exposures for the population well and the surface water body. The highest estimated population well and surface water body exposures occur at the southeast site. Population well and surface water exposures for the northeast and midwest sites are less than 10^{-6} millirem/yr over 10,000 years following disposal facility closure.

Also of interest is the relatively small range of calculated impacts for the two percolation cases calculated for the southeast and midwest sites. This confirms that most of the activity that could contribute to groundwater migration is contained in the stabilized waste streams. The effect of increased

percolation into the unstable waste streams has a relatively minor effect on the overall impacts.

Additional care needs to be taken in interpreting the results for the northeast case. The groundwater impacts for the low percolation case are believed to be reasonable, since for this case, all waste streams have been placed into a stable form prior to disposal. For the high percolation case, reduced effectiveness is assumed for disposal cell covers over the unstable waste disposal cells. Due to the impermeable nature of the northeast site soils, it is possible that percolation into the disposal cells might exceed the rate of transfer out of the bottom of the disposal cells. In such a case, it is possible that the disposal cells containing unstable waste could accumulate water and fill up like a bathtub. This could lead further to overflow of the disposal cells.

Leachate accumulation impacts are, therefore, approximated for the northeast site in the following manner. First, waterborne impacts are calculated assuming that 425,000 gallons of leachate annually overflow the unstable waste disposal cells. This overflow is assumed to be carried to a nearby stream where contaminated water is consumed by an individual. The impacts to the surrounding population from processing the leachate through an evaporator are also calculated. The results of this calculation are as follows:

	Body	Bone	Thyroid
Individual dose from disposal cell overflow (mrem/yr)	6.64E+1	1.14E+2	4.37E+1
Population dose from leachate treatment (man-millirem/yr)	1.98E+2	7.40E-1	1.98E+2

6.3.3.2 Short-Term Radiological Impacts

Short-term radiological impacts are summarized in Table 6.5. Included in this table are (1) potential impacts to populations (in man-mrem) from transporting waste to the regional facilities, (2) potential occupational impacts (in man-mrem) associated with processing, transporting, and disposing of waste within the region, and (3) potential impacts from incinerating small volumes of waste at the waste generator's facilities.

As shown, transportation impacts over 20 years range from about 380 to 1,070 man-rems, or about 19 to 54 man-rems per year. Of interest is the narrow range of impacts for the three humid sites compared to the higher (about double) impacts calculated for the southwest. The higher estimated impacts are due to the greater transportation distance for the western region as compared to the other three regions (1,000 miles vs. 300 to 600 miles).

Occupational impacts are listed as total impacts over 20 years for waste processing, transportation to the disposal facility, and waste disposal. Waste processing occupational exposures are presented as additional exposures to those associated with a "no action" situation. That is, these exposures are presented

as incremental exposures to those that would be received if existing disposal practices and disposal facility license conditions were continued.

Also included are the occupational exposures that are estimated to be associated with operation of regional processing centers. This waste processing is assumed to consist of compaction of compressible waste streams by large compactor/shredders. This is possibly not a cost effective operation at this time but may possibly be so in the future.

Some small levels of population impacts from incineration of waste is included in the regional analysis.

6.3.3.3 Costs

Costs, including waste processing, transport, and disposal costs are listed in Table 6.5. Similarly to occupational exposures, costs due to processing the waste by the waste generator are presented as additional costs to those associated with a continuation of existing disposal facility disposal practices and license conditions. These costs consist of costs for additional waste stabilization.

Waste transportation costs range from about $120 to $300 million, depending upon the waste spectra and the region considered. The largest costs are for the southwest region, for which the reduced volume of waste relative to the other three regions is counterbalanced by the longer transportation distances. The effects of the Part 61 regulation on transportation costs is expected to be low.

Waste disposal costs are set out into design and operational costs and post-operational costs, where postoperational costs include costs to waste customers (over 20 years of operation) for providing for: (1) facility closure, (2) a 5-year observation and maintenance period, and (3) 100 years of institutional control. Also shown are total disposal costs as well as unit ($\$/m^3$) costs.

As shown, the largest total design and operational costs are for the northeast and southeast sites, due to the larger volumes of waste delivered to these two sites. The southwest site is projected to experience a low level of postoperational costs, due to the semiarid nature of the site.

Postoperational costs for the northeast, southeast, and midwest sites are presented in Table 6.5 as a range from a reasonable to a worst case, corresponding to the variation in percolation into the disposed unstable waste streams. A low level of postoperational costs is projected for the stable waste streams. A moderate (reasonable case) to high (worst case) level of postoperational costs, however, is assumed for the unstable waste streams.

The presentation of the worst case here is believed to be conservative, since it discounts the improvements in disposal facility operations implemented which would help to reduce water percolation into contact with the unstable waste streams. It also discounts the increased use of compaction for the compressible waste streams. Such compaction would tend to retard the rate of subsidence and slumping associated with the unstable waste disposal cells.

Unit costs are seen to vary widely depending upon the assumed design and operating practices carried out at the particular disposal facility as well as the volumes of waste delivered to the facility. For example, the design and operation of the southeast site is essentially the same as the midwest facility. However, the volume of waste delivered to the midwest facility is much less than the southeast facility, while the design and operational costs are only slightly less. This is because capital costs to construct the disposal facility are much less dependent upon the volumes of waste delivered to the facility than the operating costs. Many of the same expenses to design, build, and operate the facility would be incurred whether a high or a low volume of waste was received.

6.3.3.4 Additional Considerations

Given the possibility for leachate accumulation at the northeast site, it is well to consider if there are additional options which may be implemented at the site to eliminate the possibility of leachate accumulation by increasing the stability of the unstable waste streams. One option could be to stabilize all of the now unstable waste streams prior to disposal. For example, compressible waste streams could be incinerated and the ashes solidified prior to disposal. Costs for this option, however, would run on the order of $927/m^3$ ($26.25/ft^3$). Another option may be to emplace all unstable waste streams within a container providing structural support. The only such containers currently available and marketed are high integrity containers which are estimated in this EIS to cost on the order of $450/m^3$. At the time the above high integrity container unit cost estimates were developed, however, there was only one company marketing high integrity containers. Since that time, additional companies are marketing high integrity containers. It may very well be that given business competition and future manufacturing savings, future costs for high integrity containers (or some equivalent container providing structural support) may be significantly reduced.

Another option might be to provide stability through variations in disposal facility design and operation--e.g., through such possible techniques as grouted disposal, disposal into grouted concrete-walled trenches, or extreme compaction. Such possible techniques would have to be developed and tested for a specific disposal facility, since past experience regarding these techniques at low level waste disposal facilities has ranged from occasional to none.

One example, however, might be to stack waste packages containing unstable waste into disposal cells and then grout the intersticial spaces between waste packages. This is projected to raise total disposal facility design and operating costs to $385 million over 20 years, or about $34 million higher than the cases presented for the northeast site in Table 6.5. Assuming that these additional costs are only applied to the unstable waste streams, unit design and operating costs for unstable waste disposal would run at about $616 per m^3 of unstable waste disposed. This is $81/m^3$ higher than similar costs for unstable waste disposal for the case presented in Table 6.5. Total postoperational costs (to be collected from disposal facility customers) would be expected to be reduced, however, to levels on the order of $13.8 million.

Occupational exposures at the disposal facility would be increased. The additional steps of stacking and grouting unstable waste packages are projected to

result in additional occupational exposures (compared to the case listed in Table 6.5) of 1.18E+6 man-millirem over 20 years, or about 59 man-rems per year.

6.3.3.5 Other Impacts

This section discusses indirect impacts associated with the proposed Part 61 regulation other than radiological impacts or costs. The impacts are broken down into the following subsections: air quality (nonradiological), biota (ecology), land use, energy use, and social impacts.

Air Quality

Nonradiological impacts to air quality due to LLW management and disposal would principally arise from two sources: combustion of fossil fuels during processing, transporting, and disposing of waste and (2) particulate matter (dust) released into the air due to earth moving activities at the disposal facility. Typical combustion products would include suspended particulates, sulphur dioxide, CO_2, CO, various hydrocarbons, and various nitrogen oxides.

It is believed that implementation of the Part 61 regulation would have a relatively slight effect upon overall air quality. For example, increased waste processing such as compaction and solidification would probably result in increased combustion of fossil fuels, with correspondingly increased release of combustion products into the air. However, many waste generators are already performing such waste processing activities to reduce transportation costs or to comply with existing license conditions at disposal facilities. Moreover, waste processing activities that reduce waste volumes would tend to reduce releases of fossil fuel combustion products during transportation.

At the disposal facility, local impacts to air quality result from combustion of fossil fuels by vehicles delivering waste to the facility, by vehicles owned by facility personnel, and by heavy equipment operated at the facility. Dust could be raised by excavating, backfilling, and grading activities. However, combustion of fossil fuels and earth-moving activities are not unique to the fact that it is a disposal facility. Similar types of impacts can and would be raised by many other types of small industrial concerns.

Since the Part 61 regulation emphasizes increased disposal facility stability, somewhat additional air quality impacts could result during the operating life of the disposal facility. That is, additional personnel may be needed as well as additional equipment to segregate waste, carry out improved compaction techniques, install improved disposal cell covers, and so forth. However, such additional impacts would be felt only during the time the facility was operating. In addition, if the facility was left in an unstable condition after operation, increased longer-term air quality impacts could result due to operating machinery to repair holes in disposal cell covers, potential operation of a leachate evaporator, and so forth. Placing the facility in a more stable condition during site operations reduces the maintenance that would be required after closure and during the institutional control period. Since less maintenance would be required, lower longer term nonradiological air quality impacts would result.

Biota

The operation of a disposal facility would involve acquiring and fencing in up to a few hundred acres of land. Existing vegetation would be mostly cleared, and after waste disposal, the disposal cells would be regraded, recontoured, and probably reseeded with short-rooted local vegetation. During this process, impacts to biota could result from destruction of habitat. Such impacts would again not be caused by the fact that the facility is used for waste disposal, but arise from the decision to change the land from one use to another. Similar types of impacts would result from other uses of the land which involve heavy construction. These could include, for example, clearing the land for a small industrial concern, a school, a farm, and so forth.

Implementation of the Part 61 rule is expected to have little effect on the potential for impacts to biota. There are already existing federal and state laws and regulations governing protection of endangered or unique flora and fauna. These regulations and laws would be considered during licensing of a disposal facility whether or not the Part 61 regulation is implemented.

Land Use

In most cases, the operation of a licensed nuclear facility by a licensee does not result in the land being permanently committed to that activity. That is, at the end of operation of the facility it may be decontaminated, if necessary, and used for another purpose. At an LLW disposal facility, however, possible future use of the facility after it has closed is greatly influenced and somewhat circumscribed by the presence of the disposed waste. This does not mean that land used for LLW disposal is permanently excluded from productive use. Rather, as long as care was taken to restrict activities to those which would not involve excavating into the disposed waste or bringing contamination to the surface, there may be a number of useful purposes the facility surface may be put to. These could possibly include use of the facility for grazing, golf courses, recreational areas, or light industry.

Notwithstanding this, however, it is useful to consider the amount of land that would be committed to LLW disposal over the next 20 years. It is difficult to assess the influence of the Part 61 regulation on this land use. Depending upon the design and operation of the disposal facility and the manner in which higher activity wastes are stabilized, land use could be lower or potentially higher than without the regulation. A range in land use may be estimated, however, using the regional analysis as a guide. Land use for each of the regions is shown below:

	$m^2 \times 10^5$ (acres)			
Land Use	Northeast	Southeast	Midwest	Southwest
	2.26 (56.0)	2.49 (61.5)	1.72 (42.5)	1.69 (41.8)

Energy Use

One way in which the effects of a proposed action can be quantified is to estimate the total energy requirements associated with that action. In terms of LLW management and disposal, this would be a difficult project given the large number of waste generators, the many different types and forms of LLW, and the many possible processing techniques that could be used. As a simplification, then, an effort has been made to estimate the increase in energy use due to the promulgation of the final Part 61 rule. This is still realized as a difficult task given the recent increase in the level of waste processing activities carried out by waste generators. In addition, there may be a number of ways in which the Part 61 requirements may be met and there are considerable uncertainties regarding the energy use associated with various technologies, etc.

In any case, approximate estimates can be made using the regional analysis as a guide. The estimated increase in energy use due to the Part 61 regulation (over that associated with a no action case) is listed below in gallons of equivalent fuel for each region for the range of postoperational activities projected:

	(gal x 10^6)		
Northeast	Southeast	Midwest	Southwest
+0.83-+0.96	+1.11-+1.31	+0.90-+1.00	+0.66

Social Impacts

In general, social impacts due to promulgation of the final Part 61 regulation are difficult to address. These impacts are very site-specific and would include such aspects as the effect of bringing a labor force into an area on local utilities, schools, and other services. These types of impacts are typically of most concern during the siting, construction, and operation of large facilities such as a large nuclear power plant. A low-level waste disposal facility is by comparison a very small operation, and the final Part 61 regulation is not expected to result in any significant incremental changes in social impacts associated with operation of LLW disposal facilities.

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16. ABSTRACT (200 words or less)

The three-volume final environmental impact statement (FEIS) is prepared to guide and support publication of a final regulation, 10 CFR Part 61, for the land disposal of low-level radioactive waste. The FEIS is prepared in response to public comments received on the draft environmental impact statement (DEIS) on the proposed Part 61 regulation. The DEIS was published in September 1981 as NUREG-0782. Public comments received on the proposed Part 61 regulation separate from the DEIS are also considered in the FEIS. The FEIS is not a rewritten version of the DEIS, which contains an exhaustive and detailed analysis of alternatives, but rather references the DEIS and presents the final decision bases and conclusions (costs and impacts) which are reflected in the Part 61 requirements. Four cases are specifically considered in the FEIS representing the following: past disposal practice, existing disposal practice, Part 61 requirements, and an upper bound example.

17. KEY WORDS AND DOCUMENT ANALYSIS

17a. DESCRIPTORS

low-level waste
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social commitment
groundwater migration
inadvertent intrusion
10 CFR Part 61
waste form
financial assurances
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radioactive waste
disposal technologies
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