

## **RULEMAKING ISSUE NOTATION VOTE**

March 31, 2005

SECY-05-0054

FOR: The Commissioners

FROM: Luis A. Reyes  
Executive Director for Operations

SUBJECT: PROPOSED RULE: RADIOLOGICAL CRITERIA FOR  
CONTROLLING THE DISPOSITION OF SOLID MATERIALS  
(RIN 3150-AH18)

PURPOSE:

To request Commission approval for publication of a proposed rule in the *Federal Register* to amend 10 CFR Part 20, "Standards for Protection Against Radiation," to include radiological criteria for controlling the disposition of solid materials that have no, or very small amounts of, residual radioactivity resulting from licensed operations, and which originate in restricted or impacted areas of Nuclear Regulatory Commission (NRC)-licensed facilities.

SUMMARY:

In response to the Commission's October 25, 2002, Staff Requirements Memorandum (Attachment 1), the staff has conducted an enhanced participatory rulemaking on controlling the disposition of solid materials and is requesting Commission approval of publication of a proposed rule. This paper provides the Commission with the draft *Federal Register* notice (FRN) (Attachment 2) containing the "Statement of Considerations" for the rulemaking and the proposed rule text. This paper also provides the Commission with the draft Generic Environmental Impact Statement (DGEIS) (NUREG-1812) (Attachment 3) and the draft regulatory impact analysis (Attachment 4).

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**BACKGROUND:**

NRC's existing regulations contain a framework of radiation standards to ensure protection of public health and safety from the routine use of materials at licensed facilities. These standards include a public dose limit in 10 CFR Part 20 and dose criteria for certain types of media released from licensed facilities, such as airborne and liquid effluents. However, Part 20 does not contain a specific dose criterion to be used to verify that solid materials being considered for release have no, or very small amounts of, residual radioactivity. Instead, NRC's current approach is to make decisions on disposition of solid materials by using a set of existing guidelines, primarily based on survey instrument capabilities. In a report reviewing NRC's current approach, the National Academies indicates that the current approach is "sufficiently protective of public health and safety that it does not need immediate revamping." However, because the current approach does not derive from a specific regulation, NRC's decisions in this area are inefficient in that they lack an overall risk basis, consistency, and regulatory finality. Therefore, the proposed rule is intended to improve NRC's regulatory process by incorporating risk-informed criteria into the Commission's regulations for disposition of solid material.

The staff has engaged in several information gathering-activities as part of its decision-making for this rulemaking and has actively sought stakeholder participation and input on alternate disposition approaches. Activities to solicit stakeholder input have included requesting public comment in the *Federal Register* in June 1999 and February 2003 on issues associated with rulemaking in this area. In response, the staff has received nearly 3500 letters and e-mails, from a range of different stakeholder groups, that present a diverse set of views. The staff held nine public meetings to solicit stakeholder views between September 1999 and February 2005. In addition, at the Commission's request, the staff supported a study by the National Academies to obtain an independent review of the issues and alternatives. In preparing its report, provided to the Commission in March 2002, the National Academies held three meetings with stakeholders between January and June 2001.

As part of its information gathering, the staff reviewed various related reports prepared by recognized national and international organizations such as the National Academies; the National Council on Radiation Protection and Measurements (NCRP); the American National Standards Institute (ANSI); and the International Atomic Energy Agency (IAEA). These organizations have issued findings about possible criteria for controlling the disposition of solid materials. In addition, the staff considered reports suggested by stakeholders. The staff also considered other relevant Federal and international standards in this area. Finally, as part of its information gathering, NRC completed several technical studies to evaluate alternatives for controlling the disposition of solid materials. The results of these studies have been incorporated into the DGEIS.

As part of this rulemaking effort, the staff is maintaining a website on NRC's activities regarding the disposition of solid materials at [www.nrc.gov/materials.html](http://www.nrc.gov/materials.html). The website has information about current activities, relevant documents, opportunities for public comment, and summaries of public comments received to date.

DISCUSSION:

As noted, the principal reason for this rulemaking is to improve the efficiency and effectiveness of the NRC regulatory process by establishing criteria for the disposition of solid materials in the regulations. In conducting this rulemaking, the staff has been guided by the goals in the NRC Strategic Plan of which the primary goal is ensuring the protection of public health and safety and the environment. In addition, as described in the Strategic Plan, the staff is conducting the rulemaking process in an open manner so that stakeholders are informed and involved in the process as appropriate.

The staff is proposing to amend NRC's regulations to establish requirements having the following elements:

- (1) Limited allowed disposition paths: Solid material, meeting the dose criterion of #2, below, may be released from licensed control if sent to: (a) disposal in Environmental Protection Agency (EPA)/State-regulated landfills; (b) re-use in a pre-defined set of uses (specifically concrete in road bed construction and re-use of tools and equipment); or (c) other disposition paths, if supported by a case-specific analysis and approval of proposed procedures.
- (2) A dose criterion set at 1 millirem per year (mrem/yr) [0.01 milliSievert per year (mSv/yr)]: This dose criterion is based on scientific analysis and regulatory considerations and is a generic constraint set well below levels established to ensure adequate protection of public health and safety.
- (3) Tables of volumetric and surface nuclide concentration levels associated with the dose criterion of 1 mrem/yr [0.01 mSv/yr]: Solid material would be considered acceptable for release if its nuclide concentrations did not exceed the levels in the tables.
- (4) A recordkeeping system: Maintenance of records provides reasonable assurance that disposition of the solid material has been conducted in accordance with the provisions of the proposed amendment.

The staff discussed with stakeholders and gathered information about a range of alternate approaches for disposition of solid material. These alternates included a rule allowing unrestricted release of solid material (i.e., the clearance approach); an approach in which all solid material goes to a licensed low-level waste (LLW) disposal facility (i.e., the prohibition approach); and a limited disposition approach.

The staff has decided to propose a limited disposition approach that it believes is a balanced consideration of technical issues and overall stakeholder concerns. The proposed approach would limit release of solid material, meeting a 1 mrem/yr [0.01 mSv/yr] dose criterion, from licensed control to the set of limited disposition paths, noted above. This approach is consistent with NCRP Report No. 141, which suggests an approach that would initially prohibit recycling into certain consumer products and which notes that it is possible to designate certain acceptable restricted industrial uses where direct contact of solid material with the general public can be minimized and avoided. Similarly, the National Academies' report also notes the merits of an approach focusing on restricted uses and/or landfill disposal. This approach is also consistent with the diverse range of stakeholder comments that sought uniform standards for

release, but which were either concerned about unrestricted releases or did not specifically support an unrestricted release approach.

Some stakeholders saw the limited disposition path approach as a means to provide additional protection of public health and safety, whereas others expressed concern about the feasibility and potential regulatory burden of limited disposition paths and about their ability to limit where material goes and protect public health and safety. As discussed in detail in Sections III.B.1.1 and III.B.1.2 of the attached FRN, the staff believes that the provisions in the proposed amendment provide reasonable assurance that doses will be maintained well below levels established to protect public health and safety and that unnecessary burden will be minimized. These provisions include: direct material to allowed destinations, including facilities under the regulatory structure of the Resource Conservation and Recovery Act (RCRA); establish a dose criterion that is a small fraction of the public dose limit in 10 CFR Part 20; place bounds on nuclide concentrations; and require maintenance of records. The staff does indicate in the FRN that it is interested in stakeholder input as to practices at various types of EPA/State-regulated RCRA landfills and specifically requests comment regarding this matter in the FRN.

Although the proposed rule would authorize disposal of solid material from NRC-licensed facilities to an EPA/State-regulated RCRA landfill facility or to a specific end user, it is the operator (or regulator) of each landfill facility and/or other recipient who will determine if a transfer to a specific facility will be allowed. Licensees will have to be aware of monitoring practices for incoming shipments to landfills or other destinations as part of their business practices, in addition to complying with the requirements of this proposed amendment for releasing solid material from further licensed control.

If a licensee chooses not to use one of the disposition paths allowed in the proposed amendment, it may request case-specific approval of another disposition path. Disposition paths considered as part of a case-specific request would include, in particular, metal recycle and soil disposition. Developing scenarios for use in the DGEIS for disposition of metals and soil is difficult, and neither stakeholders nor our technical analyses have provided a clear process as to how these materials could be generically directed for recycle or re-use into non-licensed industrial or construction related end uses. Thus, the proposed amendment indicates that any consideration of disposition of metal or soil should be proposed by a licensee as a case-specific request.

A 1 mrem/yr [0.01 mSv/yr] dose criterion is a small fraction (1/100) of NRC's public dose limit in 10 CFR Part 20 established to provide adequate protection of public health and safety. It is also in the range of Federal agency standards and allowable risk ranges for other similar media, like air and liquid effluent requirements in 10 CFR Part 50, Appendix I, and EPA drinking water standards in 40 CFR Part 141. A 1 mrem/yr [0.01 mSv/yr] dose criterion also comports with technical findings in reports prepared by various recognized scientific organizations. In particular, NCRP Report No. 141 notes that a dose below 1 mrem/yr [0.01 mSv/yr] can be defined as a "negligible individual dose," and that doses that fall into this range have an associated average annual excess risk below which "...efforts to reduce radiation exposure to the individual is unwarranted." NCRP Report No. 141 also cites several health effects studies and notes that this dose is in a risk range ( $10^{-7}$  to  $10^{-6}$  per year) that is generally regarded as "trivial." A dose criterion of 1 mrem/yr [0.01 mSv/yr] represents a minute fraction (1/300) of natural background and also is a small fraction of the variability in natural background across the U.S. that members of the public are exposed to without health impact. The staff is cognizant of reports on low doses of radiation cited by citizen groups that are different from the current

scientific consensus views. However, the staff is confident in the information it does have to determine that a proposed standard of 1 mrem/yr [0.01 mSv/yr] is an appropriate dose criterion for this proposed rule. More detail on the 1 mrem/yr [0.01 mSv/yr] dose criterion is provided in the attached FRN, Section III.B.2, including a discussion of consistency with other NRC and EPA standards, relationship of the dose criterion to recommendations from national and international scientific bodies, comparability to background radiation, and effect of exposures from multiple sources.

The staff plans to supplement the proposed rule's dose criterion of 1 mrem/yr [0.01 mSv/yr] with tables of measurable nuclide concentration levels to facilitate confirmation that the dose criterion has been met. Several organizations have developed reports (including the NRC in NUREG-1640; IAEA in RS-G-1.7; and ANSI in N13.12-1999) that relate measurable nuclide concentrations to a dose of 1 mrem/yr [0.01 mSv/yr]. Each of these reports evaluates various exposure scenarios and pathways by which potential population groups might be exposed, based on release of a range of materials and nuclide concentrations. The appropriateness of the models in NUREG-1640 to evaluate the relationship between material released and a dose criterion of 1 mrem/yr [0.01 mSv/yr] was reviewed by the National Academies and peer-reviewed as part of the report's preparation. The National Academies report noted the technical soundness of NUREG-1640 and recommended that for any dose-based approach for disposition of solid materials, the NRC should use the conceptual framework of NUREG-1640 to assess dose implications. Table 2 of IAEA's RS-G-1.7 contains volumetric concentrations for nuclides of artificial origin, developed independently from NUREG-1640. The staff has reviewed Table 2 and found its concentrations reasonably consistent with NUREG-1640. An advantage of using the internationally accepted nuclide concentrations in RS-G-1.7 in this proposed NRC amendment is that it would promote consistency among nations in setting numeric standards for release of solid material from regulatory control.

Thus, the staff has decided to use Table 2 of RS-G-1.7 in this proposed amendment because it would make NRC's release concentrations consistent with international numeric standards. In addition, our review of RS-G-1.7 and NUREG-1640 indicates that the use of either document can provide reasonable assurance that the dose criterion in this proposed amendment is met. More detail on the bases for the nuclide concentrations is provided in the attached FRN, Section III.B.3.

The staff had to make decisions on two specific issues with regard to nuclide concentration tables. First, for nuclides not included in Table 2 of RS-G-1.7, the staff is using nuclide levels taken from NUREG-1640 normalized to the 1 mrem/yr [0.01 mSv/yr] dose criterion of this proposed amendment. Primarily, this includes licensees authorized to possess source material under 10 CFR Part 40 and special nuclear material under 10 CFR Parts 50, 70, and 72. Second, RS-G-1.7 does not yet contain limiting values for surface nuclide concentrations. Therefore, the staff has developed a table of acceptable surface concentration levels. In developing this table, the staff noted that solid materials released from further license control by the NRC under this proposed amendment would likely be transported in a variety of manners and that consistency between NRC requirements and Department of Transportation (DOT) regulations in 49 CFR Part 173 for transport of material is important. The staff decided to use surface concentrations based on the definition in 49 CFR 173.403 for surface concentrations not requiring DOT regulation to provide consistency between these two Federal agencies regarding material needing no further regulation. Although the DOT values are not a direct derivation from a 1 mrem/yr [0.01 mSv/yr] dose level, they result in doses of less than 1 mrem/yr [0.01 mSv/yr] and are also reasonably consistent with existing values in Regulatory

Guide 1.86. In considering how to proceed in this area, the staff also derived estimates of surface concentrations directly from the volume concentrations in RS-G-1.7 using information in the DGEIS for ratios of the mass of various solid materials to their surface areas. The DOT values are reasonably consistent with these derived surface concentrations for certain nuclides (such as Co-60 and Cs-137) and for typical mixes of nuclides, although for some nuclides the DOT values may introduce additional conservatism resulting in more restrictive concentration levels. The staff is particularly interested in stakeholder views on the approach it has taken, and in the FRN specifically requests input from stakeholders on this item.

The volumetric and surface nuclide concentration tables are contained in a new Appendix E to 10 CFR Part 20. These tables provide an acceptable means to comply with the 1 mrem/yr [0.01 mSv/yr] dose criterion in an effective and efficient manner. Licensees may elect to calculate case-specific nuclide concentrations under the case-specific element of this proposed amendment.

The proposed amendment would require licensees to maintain records of material released (e.g., type and quantity of solid material, and nuclides present and their concentrations) and, as appropriate, its destination (e.g., the landfill or specific end use shipped to, etc.). The records required by this proposed amendment will provide for verification during routine inspections that the dose criterion has been met and provide reasonable assurance that the material was dispositioned in accordance with this proposed amendment. More detail on recordkeeping requirements is provided in the attached FRN, Section III.B.4.

Section III.C of the FRN discusses the scope of this proposed amendment and interfaces with other NRC requirements. One of the specific areas noted is that all materials in restricted or impacted areas would be subject to the provisions of the proposed amendment. However, it is also noted that making decisions on disposition of solid material based on its location in a "restricted area" may not be appropriate because the definition of restricted area in 10 CFR Part 20 may relate more to exposure to ambient external radiation fields than to residual radioactivity on solid material. Thus, it is noted that a more appropriate scope may be only material in "impacted areas" which is currently defined in 10 CFR Part 50 as "areas with some reasonable potential for residual radioactivity in excess of natural background." In the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (NUREG-1575) this term, "impacted area" is used to signify the extent of surveys needed to release areas from licensed control. It would seem reasonable that this proposed amendment should have a similar requirement to allow for better focus by the NRC and licensees on disposition of solid materials from those areas where a reasonable potential for the presence of residual radioactivity exists. In the FRN, the staff specifically requests input from stakeholders on this item.

An interface with other NRC requirements is the relation to 10 CFR 20.2002. Currently, under the provisions of 10 CFR 20.2002, licensees can apply to the Commission for approval of proposed procedures, not otherwise authorized in the regulations, to dispose of licensed material. The proposed amendment would not change that provision. A licensee can continue to use the existing provisions of 10 CFR 20.2002 to request disposal of materials not within the scope of this proposed amendment and also request consideration of alternate dose levels for materials covered by this proposed amendment (for example, if a specific landfill is permitted by EPA or State regulator to receive material with a potential dose greater than that in this proposed amendment).

#### Discussion of the Rulemaking Process

The staff has participated in 12 meetings (from September 1999 to February 2005) with a range of stakeholder groups, and received over 3500 separate comment letters and e-mails (in response to June 1999 and February 2003 FRNs) representing viewpoints from a wide range of stakeholders. Information gathered in this effort has included: identification of economic concerns by the metals and cement industries; citizens groups concerns over the potential presence of radioactivity in solid materials, even in very small amounts, in consumer products and general commerce; reference to various studies regarding low doses of radioactivity; identification of practical issues of how solid materials are handled at the range of facilities that NRC licenses; issues of feasibility related to limiting solid materials to only a set of defined uses; and various viewpoints associated with disposal of solid materials in RCRA landfills. The staff believes that this proposed rule represents a reasonable position based on the information-gathering process it has conducted. The evolution of alternatives, from the range of alternatives initially discussed with stakeholders to the present content of the proposed rule (i.e., the limited disposition approach), clearly indicates that the NRC carefully considered stakeholder views, as well as various technical reports and related health standards and development of technical bases and the DGEIS analyses on disposition of solid materials, in formulating this proposed rule. The staff is issuing this proposed rule and DGEIS for public comment and also is considering discussing this issue further with stakeholders in two public meetings to solicit additional input on these documents.

#### Comments from Cooperating Agencies

The EPA, the Department of Energy (DOE), and the State of Massachusetts, identified as a State representative by the Conference of Radiation Control Program Directors and the Organization of Agreement States, have participated as cooperating agencies in the development of the DGEIS and submitted written comments on the DGEIS. The Naval Nuclear Propulsion Program (NNPP), a joint DOE/Navy program, also participated in the cooperating agency reviews at the request of DOE. In their comments on the DGEIS (Attachment 5), the agencies indicated that, in general, they found little difference in the environmental impacts between the current approach, the unrestricted release alternate, and limited disposition alternate; thus, they concluded the DGEIS analysis does not provide a compelling basis for selecting the limited disposition alternative. The NNPP indicated that it disagrees with the proposed limited disposition alternative, preferring instead the unrestricted release alternate. The cooperating agencies also recommend there should be an unrestricted release process for clearing material with no residual radioactivity from a restricted area. In addition, the agencies commented that there could be confusion regarding imports from other countries to the U.S. if those countries follow the IAEA safety guide which recommends unrestricted release for solid material meeting a 1 mrem/yr [0.01 mSv/yr] dose criterion, whereas the DGEIS recommends limited disposition. The cooperating agencies also made specific comments on the technical analyses in the DGEIS.

#### AGREEMENT STATE ISSUES:

A copy of the draft FRN for the proposed rule was posted on NRC's Technical Conference Forum for review by Agreement States. Input was received from the States of Massachusetts, Texas, and Washington (Attachment 5). In general, it was stated that there may not be a technical reason for this rule (with reference to the National Academies finding that the current approach is "sufficiently protective"), that there should be provisions for unrestricted use, and

that the dose criterion is well below that needed to protect public health and safety and below constraints for other media such as liquid and gaseous effluents. Input was also received indicating the need for a provision for unrestricted release of material that was clean and/or had non-detectable activity. There also were questions regarding oversight of this material once it is released from the NRC license and how handling, inspections, or enforcement in the public domain would take place to ensure that the material stayed at the destinations allowed in the proposed amendment. There was also concern that the landfills may not take material released and that the case-specific approach may not be feasible for the metals and for soils. There also was some question about interface between this proposed amendment and the provisions of 10 CFR Part 20, Subpart E, on license termination of sites and provisions for on-site dispositions of solid materials. The staff believes that these comments have been considered in preparation of the draft FRN.

Based on the Management Directive 5.9 process, the staff has assigned compatibility categories to the sections of the proposed rule. Some Part 20 sections remain the same, in particular the Category C designation of 10 CFR 20.2001 and the Category A designations in 10 CFR 20.1003. Proposed 10 CFR 20.2008 and 20.2009 and proposed Appendix E to 10 CFR Part 20 have been designated Category B because there could be transboundary impacts with respect to transporting or distributing material released in accordance with both proposed sections and the appendix. The recordkeeping requirements in 10 CFR 20.2108(a) are categorized as Category C to ensure that licensees in Agreement States keep a minimum set of records important to keeping track of where the material goes.

#### RECOMMENDATIONS:

That the Commission:

1. Approve, for publication in the *Federal Register*, the attached notice of proposed rulemaking (Attachment 2).
2. Note:
  - a. A DGEIS has been prepared for this rulemaking (Attachment 3).
  - b. A draft Regulatory Analysis has been prepared for this rulemaking (Attachment 4).
  - c. An initial regulatory analysis of the impact of this proposed rule on small entities has been prepared as part of the draft Regulatory Analysis. Based on that analysis, the staff believes that this proposed rule would not have a significant impact on small entities. However, because it would be useful to have additional information on small entities as part of its analysis, the staff has specifically requested public comment on the potential impact of the proposed rule on small entities.
  - d. The appropriate Congressional committees will be informed.
  - e. A press release will be issued by the Office of Public Affairs when the proposed rulemaking is filed with the Office of the *Federal Register*.
  - f. The proposed rule would amend information collection requirements that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501, et seq.). These requirements

must be submitted to the Office of Management and Budget for review no later than the date the proposed rule is forwarded to the *Federal Register* for publication.

RESOURCES:

It is anticipated that 3.5 NRC FTE will be needed to complete this rulemaking action (2.5 FTE NMSS and 1.0 FTE all other). These resources are within the approved budget for FY 2005 and FY 2006.

COORDINATION:

The Office of the General Counsel has no legal objection to the proposed rulemaking. Resources needed to complete this rulemaking action are within existing budget allocation. The Office of the Chief Financial Officer has reviewed this Commission Paper for resource implications and has no objections. The Office of Information Services has reviewed this Commission Paper for recordkeeping implications and has no objections.

A copy of the draft FRN for the proposed rule was posted on NRC's Technical Conference Forum so the Agreement States could review it.

**/RA/**

Luis A. Reyes  
Executive Director  
for Operations

Attachments:

1. SRM Dated October 25, 2002
2. *Federal Register* Notice
3. Draft Generic Environmental Impact Statement
4. Draft Regulatory Analysis
5. Letters from Cooperating Agencies and Agreement States

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A copy of the draft FRN for the final rule was posted on the NRC's Technical Conference Forum so the Agreement States could review it.

**/RA/**

Luis A. Reyes  
Executive Director  
for Operations

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1. SRM Dated October 25, 2002
2. *Federal Register* Notice
3. Draft Generic Environmental Impact Statement
4. Draft Regulatory Analysis
5. Letters from Cooperating Agencies and Agreement States

**ML041550790**

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October 25, 2002

MEMORANDUM TO: William D. Travers  
Executive Director for Operations

FROM: Annette L. Vietti-Cook, Secretary **/RA/**

SUBJECT: STAFF REQUIREMENTS - SECY-02-0133 - CONTROL OF  
SOLID MATERIALS: OPTIONS AND RECOMMENDATIONS  
FOR PROCEEDING

The Commission has approved the staff's recommendation to proceed with an enhanced participatory rulemaking (Option 3b), subject to the comments provided below.

Considerable information collection efforts and numerous public workshops have been conducted on the control of solid materials issues and the staff should not duplicate these efforts but should utilize this information as a starting point to focus on potential solutions. Information and data from related national (e.g., ANSI and DOE) and international (e.g., IAEA and EC) efforts also should be used in this effort. Additional workshops should be limited to areas where substantial new input is needed. For issues which may not warrant a workshop, the staff should explore increased use of web-based methods for interacting with stakeholders.

The staff should give fair consideration to all alternatives in developing a proposed rule so that a broad range of alternatives is identified and can be weighed by the Commission. The staff should encourage stakeholder participation and involvement in consideration of alternative approaches (including the current case-by-case approach, clearance, a conditional clearance approach, and a policy of no-release). But, in approaching stakeholders on this issue, the staff should reiterate the Commission's continuing support for the release of solid material when there are no significant health consequences.

The staff should specifically explore and document the feasibility of conditional or restricted clearance. The staff should assume sufficient latitude to address multiple scenarios in discussions with stakeholders in order to determine the feasibility of options for conditional or restricted clearance that (1) are effective, (2) are reasonably possible to implement, and (3) would increase public confidence in the process.

As required by Public Law 104-113, the staff should weigh the pros and cons of either implementing or endorsing the ANSI N13.12 standard (10  $\mu$ Sv/yr (1 mrem/yr)) as the primary dose standard for clearance.

The staff should bypass the proposed Advance Notice of Proposed Rulemaking (ANPR) and move directly to development of a rulemaking plan and proposed rule. The staff should submit for Commissioner approval a proposed schedule for the rulemaking effort within 90 days of this SRM. This schedule should reflect the Commission's desire to complete this rulemaking within 3 years.

(EDO)

(SECY Suspense:

1/21/03)

cc: Chairman Meserve  
Commissioner Dicus  
Commissioner Diaz  
Commissioner McGaffigan  
Commissioner Merrifield  
OGC  
CFO  
OCA  
OIG  
OPA  
Office Directors, Regions, ACRS, ACNW, ASLBP (via E-Mail)  
PDR

[7590-01-P]

NUCLEAR REGULATORY COMMISSION

10 CFR Part 20

RIN 3150-AH18

Radiological Criteria for Controlling the Disposition of Solid Materials

AGENCY: Nuclear Regulatory Commission.

ACTION: Proposed rule.

SUMMARY: The Nuclear Regulatory Commission (NRC) is proposing to amend its regulations to provide radiological criteria for controlling the disposition of solid materials that originate in restricted or impacted areas of NRC-licensed facilities but which have no, or very small amounts of, residual radioactivity resulting from licensed operations. The proposed amendment would result in more efficient and consistent licensing actions related to the routine handling of solid materials at licensed facilities by providing a clear and consistent regulatory framework for their disposition. The proposed requirements for the disposition of solid materials include a set of allowed limited paths for disposition, a dose criterion, tables of radionuclide concentrations for implementing the dose criterion, and recordkeeping provisions. The NRC has also prepared a Draft Generic Environmental Impact Statement (DGEIS) for the proposed rule.

DATE: Submit comments on the rule by (insert date 75 days after publication in the Federal Register). Submit comments specific to the information collection aspects of this rule by (insert date 30 days after publication in the Federal Register). Comments received after the above

dates will be considered if it is practicable to do so, but assurance of consideration cannot be given to comments received after these dates.

ADDRESSES: You may submit comments by any one of the following methods. Please include the number RIN 3150-AH18 in the subject line of your comments. Comments on rulemakings submitted in writing or in electronic form will be made available for public inspection. Because your comments will not be edited to removed any identifying or contact information, the NRC cautions you against including personal information such as social security numbers and birth dates in your submission.

Mail comments to: Secretary, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, ATTN: Rulemakings and Adjudications Staff.

E-mail comments to: [SECY@nrc.gov](mailto:SECY@nrc.gov). If you do not receive a reply e-mail confirming that we have received your comments, contact us directly at (301) 415-1966. You may also submit comments via the NRC's rulemaking website at <http://ruleforum.llnl.gov>. Address questions about our rulemaking website to Carol Gallagher at (301) 415-5905; email [cag@nrc.gov](mailto:cag@nrc.gov). Comments can also be submitted via the Federal eRulemaking Portal at <http://www.regulations.gov>.

Hand deliver comments to: 11555 Rockville Pike, Rockville, Maryland 20852, between 7:30 am and 4:15 pm Federal workdays. (Telephone (301) 415-1966).

Fax comments to: Secretary, U.S. Nuclear Regulatory Commission at (301) 415-1101.

Publicly available documents related to this rulemaking may be viewed electronically on the public computers located at the NRC's Public Document Room (PDR), Room O1 F21, One White Flint North, 11555 Rockville Pike, Rockville, Maryland. The PDR reproduction contractor will copy documents for a fee. Selected documents, including comments, may be viewed and downloaded electronically via the NRC rulemaking website at <http://ruleforum.llnl.gov>.

Publicly available documents created or received at the NRC after November 1, 1999, are available electronically at the NRC's Electronic Reading Room at <http://www.nrc.gov/reading-rm/adams.html>. From this site, the public can gain entry into the NRC's Agencywide Document Access and Management System (ADAMS), which provides text and image files of the NRC's public documents. If you do not have access to ADAMS or if there are problems in accessing the documents located in ADAMS, contact the NRC Public Document Room (PDR) Reference staff at 1-800-397-4209, 301-415-4737 or by email to [pdrr@nrc.gov](mailto:pdrr@nrc.gov).

Note: Public access to documents, including access via ADAMS and the PDR, has been temporarily suspended so that security reviews of publicly available documents may be performed and potentially sensitive information removed. However, access to the documents identified in this rule continue to be available through the rulemaking web site at <http://ruleforum.llnl.gov>, which was not affected by the ADAMS shutdown. Please check with the listed NRC contact concerning any issues related to document availability.

FOR FURTHER INFORMATION CONTACT: Frank Cardile, telephone: (301) 415-6185; e-mail: [fpc@nrc.gov](mailto:fpc@nrc.gov); USNRC, Office of Nuclear Material Safety and Safeguards, Mail Stop T8F3, Washington, DC 20555-0001. For information on the DGEIS, you can contact Phyllis Sobel; telephone: (301) 415-6714; e-mail [pas@nrc.gov](mailto:pas@nrc.gov); USNRC, Office of Nuclear Material Safety and Safeguards, Mail Stop T7J8, Washington, DC 20555-0001.

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## I. Introduction

The Nuclear Regulatory Commission (NRC) is proposing to amend its regulations to provide criteria for controlling the disposition of solid materials that have no, or very small amounts of, residual radioactivity resulting from licensed operations and which originate in restricted or impacted areas<sup>1</sup> of NRC-licensed facilities. Background information regarding this

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<sup>1</sup> A "restricted area" is defined in the NRC's regulations in 10 CFR 20.1003. An "impacted area" is defined in the NRC regulations in 10 CFR 50.2 (that definition is being added in these amendments to 10 CFR 20.1003).

effort (including why the NRC is conducting a rulemaking; the scope of the rulemaking; and the process for decision-making, including alternatives considered) is contained in Section II.

A discussion of the NRC's decision regarding its proposed approach, including the rationale for the decision, is contained in Section III. A request for specific comments on certain topics is contained in Section IV. Additional matters regarding this effort are discussed in Section V.

A section-by-section analysis of the rule text implementing the proposed approach is contained in Section VI.

As part of this rulemaking effort, the NRC is maintaining a website on its activities regarding the disposition of solid materials at [www.nrc.gov/materials.html](http://www.nrc.gov/materials.html). The website has information about current activities, relevant documents, opportunities for public comment, and summaries of public comments received to date.

## **II. Background**

### **A. Why the NRC is Conducting Rulemaking on Disposition of Solid Materials**

Currently, the NRC's existing regulations contain a framework of radiation standards to ensure protection of public health and safety from the routine use of materials at licensed facilities. These standards include a public dose limit in 10 CFR Part 20 and criteria on certain types of media released from licensed facilities, such as airborne and liquid effluent releases.

The NRC's existing regulations also permit the release of solid material from licensed facilities. Radiation surveys are conducted on solid material before it leaves restricted or impacted areas of a site. However, 10 CFR Part 20 does not contain a specific dose criterion to be used to verify that the solid material has no or very small amounts of residual radioactivity. Instead, the NRC's current approach is to make decisions on the disposition of solid material on a case-by-case basis by using a set of existing guidelines that are based primarily on survey instrument capabilities. These existing guidelines are summarized in Appendix B of the DGEIS, NUREG-1812, prepared as part of this rulemaking. These guidelines include NRC Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors," (January 1974) and other NRC documents.

A report by the National Academies ("The Disposition Dilemma; Controlling the Release of Solid Materials from Nuclear Regulatory Commission-Licensed Facilities," 2002) notes that the current NRC approach for the disposition of solid materials "is sufficiently protective of public health that it does not need immediate revamping." However, because NRC decisions on disposition of solid materials do not derive from a specific regulation, they are inefficient in that they lack an overall risk basis, consistency, and regulatory finality. Therefore, the NRC is conducting this rulemaking to improve the regulatory process by incorporating risk-informed criteria for disposition of solid materials in the regulations.

#### B. The NRC's Main Focus in this Rulemaking

As noted, the principal reason for this rulemaking is to improve the efficiency and effectiveness of the NRC regulatory process by establishing criteria for the disposition of solid

materials in the regulations. In conducting this rulemaking, the NRC is guided by the goals in its Strategic Plan<sup>2</sup> of which the primary goal is ensuring the protection of public health and safety and the environment. In addition, as described in the Strategic Plan, the NRC is conducting the rulemaking process in an open manner that informs stakeholders about the process and provides them with a reasonable opportunity to participate meaningfully in the NRC's regulatory process.

### C. Solid Materials Considered in this Rulemaking

Various solid materials originating from restricted or impacted areas of NRC-licensed facilities are no longer needed or useful at the facilities, or otherwise need to be taken out of the restricted or impacted areas. Much of this material has no residual radioactivity resulting from licensed operations; some of these materials may have very small amounts of radioactivity but at levels so low that potential radiation exposure from them to the public would be a very small fraction of natural background radiation levels and of negligible health impact. These solid materials can include office furniture; metal components; equipment and tools; pipes; ventilation ducts; laboratory materials (gloves, beakers, etc.); routine trash (plastics, paper, glass); and concrete. Soil, soil-like materials and other similar process materials can also be present in restricted or impacted areas and need disposition.

This rulemaking covers all NRC licensees, including: (a) academic -- university laboratories and small reactors that use or produce radioactive materials for research and

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<sup>2</sup> NUREG-1614, Volume 3, "Strategic Plan, FY2004-2009," (August 2004)

teaching purposes; (b) medical -- hospitals and clinics that use radioactive materials for diagnostic and therapeutic medical purposes; (c) manufacturing -- facilities and laboratories that manufacture products that contain and/or incorporate radioactive materials as part of their functional design (e.g., smoke detectors, certain types of gauges); and (d) power production -- reactor and fuel cycle facilities that produce and handle radioactive fuel and materials as part of the generation of electricity.

There are other solid materials at licensed facilities that contain larger amounts of radioactivity. These materials are kept separate from the solid materials with no or very small amounts of radioactivity and requirements already exist in the NRC's regulations at 10 CFR Part 61 for their disposal at licensed low-level waste (LLW) disposal facilities. Solid materials that contain larger amounts of radioactivity are not the subject of this rulemaking. Examples of such material not considered in this rulemaking are components of the reactor system and sealed sources.

Additional discussion about the scope of the rulemaking is contained in Section III.C of this document.

#### D. Information Gathering as Part of the Decision-Making Process for this Rulemaking

The NRC has been engaged in several information gathering activities as part of its decision-making for this rulemaking, particularly with regard to alternate approaches for

disposition of solid materials. Three broad alternate approaches for disposition of solid materials that the NRC has sought information about have included:

(1) Unrestricted release: In this approach, if a radiation survey of the material confirms that a release criterion<sup>3</sup> has been met, solid material is allowed to be released and go to any or all of the non-licensed paths shown in Figure 1 (Paths G, S, and/or L). This approach has been referred to as “clearance”;

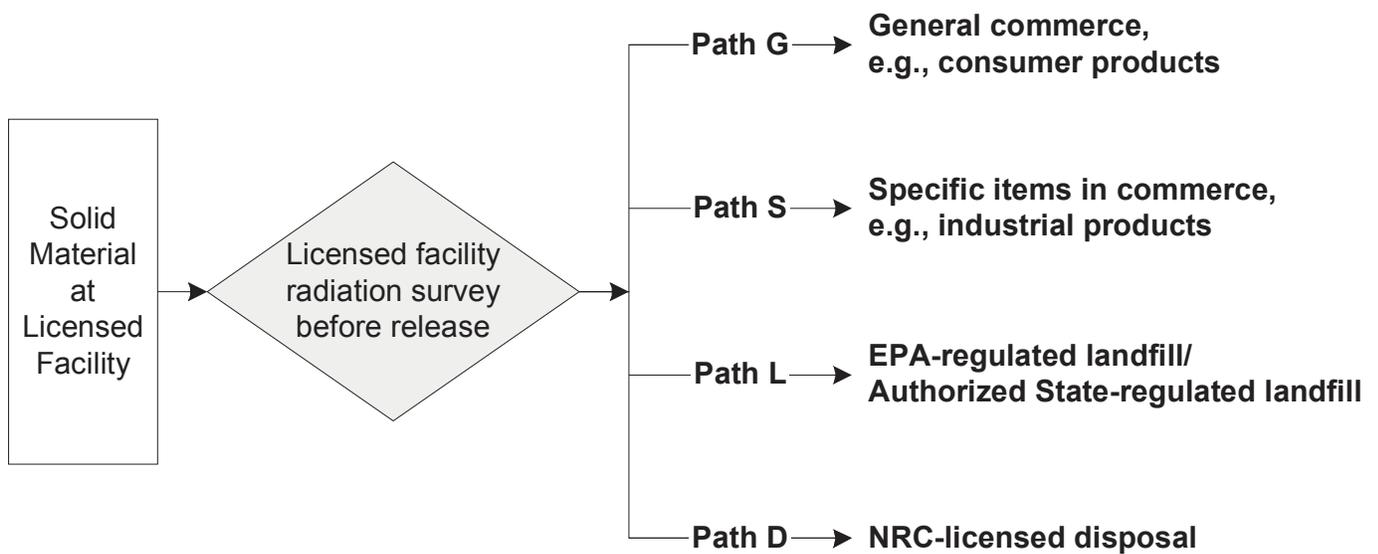
(2) Limited disposition: In this approach, disposition of solid material is limited to one or more of the non-licensed paths shown in Figure 1 (e.g., Paths S and/or L) if it meets a dose-based release criterion<sup>4</sup>. This approach has been referred to as “conditional release” or “restricted release.” Under this limited disposition path approach, the release of material from licensed facilities would not be allowed into the general stream of consumer goods (Path G); and

(3) LLW disposal only: In this approach, all solid material from restricted or impacted areas would be required to be disposed of in a licensed LLW disposal site (Path D of Figure 1).<sup>4</sup> This has been referred to as “prohibition”.

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<sup>3</sup> Under approach 1, a criterion could either continue to be based on the current approach which uses instrument detection capability as its basis, or it could be dose-based which would require amending the NRC’s regulations to include a dose-based criterion.

<sup>4</sup> Both approaches 2 and 3 would require amending the NRC’s regulations because they would involve changes to the current approach .



**Figure I**

The NRC has actively sought stakeholder participation and input on these alternate disposition approaches. This effort has included conducting a scoping process related to the alternate approaches and their associated environmental impacts. Activities to solicit stakeholder input have included requesting public comment on alternate approaches for disposition of solid materials in the Federal Register on June 30, 1999 (64 FR 35090) (hereafter referred to as the “June 1999 Issues Paper”) and on February 28, 2003 (68 FR 9595). In response, the NRC received nearly 3,500 letters and e-mails from a range of different stakeholder groups that presented a diverse set of views. In addition, the NRC held nine public meetings to solicit stakeholder views between September 1999 and February 2005. The NRC also supported a study by the National Academies to obtain an independent review of the issues and alternatives. The National Academies held three meetings with stakeholder groups between January and June 2001; in March 2002, the National Academies provided a report

(hereafter referred to as the “National Academies Report”), referred to in Section II.A of this document, containing nine recommendations to the Commission.

Input from stakeholders was considered in NRC decision-making on the disposition of solid materials and is discussed further in Section III in the context of the discussion of this proposed amendment, and also in Section V. Generally, stakeholder views to date are centered on potential health impacts of the alternates and issues with implementing the alternates, including potential economic impacts on stakeholders. A detailed summary of stakeholder input on the alternates can be found in Appendix A of the DGEIS. A summary of stakeholder input can also be found in NUREG/CR-6682 and NUREG/CR-6682, Supplement 1.

The NRC also has considered other relevant Federal and international standards in this area. There is a range of Federal health protection standards covering both radiation and chemical materials. The NRC has responsibility, under the Atomic Energy Act of 1954, as amended, for setting standards to ensure that the nation’s civilian use of radioactive material is carried out in a manner which protects public health and safety and the environment. The Environmental Protection Agency (EPA) sets chemical standards, standards for radiation protection in the general environment, and standards for managing material at landfills under the Resource Conservation and Recovery Act (RCRA) which is one of the alternate approaches being considered by this rulemaking. International agencies (such as the International Atomic Energy Agency (IAEA) and the European Commission (EC)) as well as individual nations, are developing standards for controlling the disposition of solid materials.

In addition, the NRC conducted reviews of various related reports prepared by recognized national and international standards organizations, including the National Academies, the National Council on Radiation Protection and Measurements (NCRP), the American National Standards Institute (ANSI), and the IAEA. Each of these organizations has issued findings about possible criteria for controlling the disposition of solid materials. The NRC also has considered other reports suggested by stakeholders.

Finally, the NRC has completed several technical studies to evaluate alternatives for controlling the disposition of solid materials. The results of these studies have been incorporated into the DGEIS<sup>5</sup>. The DGEIS provides a detailed analysis of each of the alternate approaches, including their potential impacts on human health and the environment. The NRC also has conducted studies on the ability of radiation survey methods and instrumentation to verify radioactivity levels on solid materials so that a licensee can verify compliance with an alternate approach. The DGEIS and the technical studies which form its basis are available on the NRC's website at [www.nrc.gov/materials.html](http://www.nrc.gov/materials.html).

### **III. Proposed Approach: Revisions to NRC Regulations in 10 CFR Part 20 on Disposition of Solid Materials**

The NRC's proposed approach for disposition of solid materials is described in Section III.A of this document. Section III.B discusses the rationale and technical basis supporting the

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<sup>5</sup> Comments on the DGEIS may be submitted as specified in the ADDRESSES section of this document.

proposed approach. Section III.C provides additional information on the scope of this proposed approach. Section III.D provides consideration of other alternate approaches for disposition of solid materials.

#### A. The NRC's Proposed Approach

The NRC has decided upon a proposed approach that is a balanced consideration of technical issues and overall stakeholder concerns and needs. Specifically, the NRC is proposing to amend its regulations for the disposition of solid materials to establish requirements that have the following elements.

- (1) Limited allowed disposition paths: Solid material may be released from licensed control if it meets the dose criterion indicated in #2, below, and follows one of these limited disposition paths: (a) disposal in EPA/State-regulated landfills; (b) re-use in a pre-defined set of uses specified in the regulations; and (c) case-specific analysis and approval of proposed procedures for other disposition paths. The rationale for this element is described in Section III.B.1;
  
- (2) A dose criterion set at 1 mrem/yr (0.01 mSv/yr)<sup>6</sup>: This dose criterion is based on scientific analysis and regulatory considerations and is a generic dose constraint set well

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<sup>6</sup> Other documents, including various international documents, use the convention of 10 uSv/yr when converting from English to SI units. This document uses the convention of 0.01 mSv/yr to be consistent with the units in other parts of the NRC's regulations in 10 CFR Part 20.

below levels established to ensure adequate protection of public health and safety.

Solid material can be released from licensed control if it meets this dose criterion and if it goes to one of the limited disposition paths discussed in detail in Section III.B.1. The rationale for this element is described in Section III.B.2;

- (3) Tables of volumetric and surface radionuclide concentration levels associated with the 1 mrem/yr (0.01 mSv/yr) dose criterion: Solid material would be considered acceptable for release if its volumetric and surface radionuclide concentration levels did not exceed the levels in Table 1 and Table 2, as applicable, of Appendix E of 10 CFR Part 20. The rationale for this element is described in Section III.B.3;

- (4) A recordkeeping system. Maintenance of records provides reasonable assurance that the dose criterion has been met and that disposition of the solid material has been conducted in accordance with provisions of this amendment. The rationale for this element is described in Section III.B.4.

A section-by-section analysis of amended rule text implementing the proposed approach is provided in Section VI.

## B. Rationale Supporting the NRC's Proposed Approach

### B.1 The Set of Allowed Limited Disposition Paths

A discussion of the NRC's basis for choosing the limited disposition path approach is contained in Section III.B.1.1. A discussion of specific details related to the limited disposition path approach is contained in Section III.B.1.2.

#### B.1.1 Basis for Selecting Limited Disposition Path Approach

The NRC discussed with stakeholders and gathered information about a range of alternate approaches for the disposition of solid material, discussed in Section II.D, i.e., unrestricted release of solid material (either by continuing the current approach or issuing a proposed rule), limited disposition paths, and disposal of all material at licensed LLW disposal facilities.

The NRC believes that establishing requirements for unrestricted release of solid material at a 1 mrem/yr (0.01 mSv/yr) dose criterion would satisfy the NRC's strategic goal of ensuring protection of public health and safety. Material released at this level would be a very small fraction of the NRC's public dose limit in 10 CFR Part 20 and reports prepared by the NCRP and other scientific organizations indicate that 1 mrem/yr (0.01 mSv/yr) represents a negligible individual dose (See Section III.B.2). A number of stakeholders supported use of this alternative. In addition, the IAEA recently issued guidelines in RS-G-1.7 ("Application of the

Concepts of Exclusion, Exemption, and Clearance”) to assist countries in setting standards for disposition of solid material that would include unrestricted release (clearance) at a dose level of 1 mrem/yr (0.01 mSv/yr).

However, there have been concerns expressed by metals and concrete industry stakeholders about the unrestricted release alternative because they believe their businesses would be negatively impacted by public reaction to the introduction of solid material from licensed facilities in their products. In addition, citizen and environmental groups expressed concerns about unrestricted release of solid material from licensed facilities into general commerce. In reflecting on these same issues, the NCRP, in Report No. 141, notes that, despite the relative safety of a 1 mrem/yr (0.01 mSv/yr) clearance level, “there are significant concerns from the recycling industry and the public over unrestricted release of scrap metal into the public domain,” and that rulemaking in this area should consider avoiding placing material in consumer products. In addition, our review of stakeholder comments indicates that there is little stakeholder support for proceeding with the unrestricted release alternative, even among nuclear industry representatives.

At the same time, the NRC does not believe that a complete prohibition on all releases of material with very low amounts of, or no, residual radioactivity from restricted or impacted areas is appropriate. First, as noted above, the potential risks associated with allowing release of material meeting a 1 mrem/yr (0.01 mSv/yr) dose criterion are negligible. Secondly, as discussed below, results from the DGEIS indicate that a prohibition alternative is much more expensive than the other alternates. This is in concert with findings in NCRP Report No. 141 which states that an approach for disposition of solid material (having no or very small amounts

of residual radioactivity) that allows some form of release from licensed control (either for unrestricted release or in a limited manner) should be a priority. NCRP Report No. 141 notes that this is because the potential radiological hazards of these materials are so low that their exemption from continued regulation is deemed warranted and because funds unnecessarily spent on controlling trivial risks in one sector are not available for application to the control of “real” risks elsewhere. NCRP Report No. 141 states that disposal of these materials as LLW is an alternative that should be exercised only as a last resort. The National Academies Report noted that certain risks, e.g., those associated with transportation of solid materials, could be lower for other alternatives, like the landfill alternative, than the prohibition alternative.

To provide further consideration of the alternatives discussed in Section II.D, the NRC completed a cost-benefit analysis in the DGEIS based on potential environmental and public health impacts and economic considerations. The analysis includes impacts and costs of: radiation surveys of solid materials before they are released to ensure that the levels are below release criteria; transport of solid materials to EPA-regulated landfills, for use in a road-bed, or to NRC-licensed LLW facilities; and disposal of solid materials in EPA-regulated landfills or NRC-licensed LLW facilities. The DGEIS indicates that, compared to a No-Action alternative of retaining the current approach, the costs and benefits of the alternatives for disposition of solid materials are: the unrestricted release alternative has a net positive incremental cost-benefit at a 1 mrem/yr (0.01 mSv/yr) dose criterion; an alternative of limited disposition also has net positive incremental cost-benefit at a 1 mrem/yr (0.01 mSv/yr) dose criterion, although slightly larger than the unrestricted release alternative; and the prohibition alternative has a substantial net negative cost-benefit.

The difference in the DGEIS analysis of costs and benefits between the unrestricted release and limited disposition alternatives is not considered significant for regulatory decision-making. However, the prohibition alternative is significantly less cost-effective. This analysis is in line with the National Academies Report which concluded that the landfill disposal alternative could be significantly less costly than prohibition, and with the NCRP Report No. 141 which indicated that the “prohibition” approach is a costly alternative due to the high prevailing costs of disposal at licensed LLW disposal facilities, the costs of transportation to LLW disposal facilities, and issues of access to the limited number of LLW disposal facilities.

With regard to issues of disposal capacity, the DGEIS indicates that for the prohibition alternative the amount of solid material under the scope of this rulemaking needing disposition would exceed the available disposal capacity at LLW disposal facilities. With regard to the limited path alternative (which includes disposal at landfills as an allowed path), the DGEIS found that, given the current and projected disposal capacity at EPA/State-regulated landfills, there is sufficient capacity to accommodate even an alternative in which all solid material is sent to landfills.

Based on the above, the NRC is proposing an approach that it believes is a balanced consideration of technical issues and overall stakeholder concerns and needs. The proposed approach would limit the release of solid material, meeting a 1 mrem/yr (0.01 mSv/yr) dose criterion, from licensed control to the following disposition paths: disposal in EPA/State-regulated landfills; re-use in a limited pre-defined set of uses (specifically concrete in road bed construction and re-use of tools and equipment); and case-specific analysis and approval of proposed procedures for other disposition paths and approaches. The disposition paths

considered in this proposed approach are consistent with NCRP Report No. 141, which suggests an approach that would initially prohibit recycling into certain consumer products, including products used by children, in food preparation, personal items, or household items. NCRP Report No. 141 also notes that it is possible to designate certain acceptable restricted industrial uses where direct contact of solid material with the general public can be minimized and/or avoided. Similarly, the National Academies Report notes the merits of an approach focusing on restricted uses and/or landfill disposal. This approach is consistent with the diverse range of stakeholder comments which sought uniform standards for release, but which were either concerned about unrestricted release or did not specifically support an unrestricted release approach.

The NRC's proposed approach represents an improvement over its current approach because it provides a clear, risk-informed dose criterion and associated radionuclide concentrations for the disposition of solid materials. Even for the case-specific element, a risk-informed dose criterion is proposed to form the basis for decisions rather than the measurement-based guidelines used now. Thus, the proposed amendment enhances consistency and regulatory finality in decisions made regarding the disposition of solid materials. With regard to the disposition paths, as noted in Section III.C, for much of the materials covered by this amendment (e.g., trash, equipment and tools, concrete), the allowed disposition paths are fairly broad and similar to what licensees currently do with the materials. For some materials (e.g., bulk metals), the paths are more limited, however the case-specific provision is available for requesting alternate disposition.

### B.1.2 Specific Details on Limited Disposition Approach

Some stakeholders saw the limited disposition path approach, particularly with regard to landfills, as a means to provide additional protection of public health and safety citing EPA requirements on storage, treatment, and other controls at landfills. Others expressed concern about the feasibility and potential regulatory burdens of the proposed disposition paths and the ability of the proposed disposition paths to limit where material goes and protect public health and safety. These areas are discussed in Sections III.B.1.2.1 and III.1.2.2.

Although the proposed amendment would authorize disposal of solid material from NRC-licensed facilities in an appropriate EPA/State-regulated landfill facility, it is the operator and/or regulator of each landfill facility who will determine if a transfer to a specific facility will be allowed. Similarly, for intended end uses, a particular recipient is not required to take the material and can decide whether or not to accept the material. Thus, in addition to complying with the requirements of this proposed amendment, licensees will have to be aware of monitoring practices for incoming shipments to landfills or other destinations as part of their business practices.

#### B.1.2.1 Feasibility of Limited Disposition Paths

With regard to disposition of solid materials in EPA/State-regulated landfills, a number of stakeholders stated that it is not clear if the landfills would accept material from licensed facilities released under the dose criterion of this proposed amendment. These stakeholders

noted that many States have bans against release of radioactivity into landfills. Also, some stakeholders noted that difficulties in siting landfills could be more acute if concerns over radioactivity increased, even if the radioactivity was present at very low levels.

The NRC considered the provisions of the RCRA in making a decision on an approach in this area. RCRA was enacted by Congress in 1976 to ensure that solid wastes from human activities are managed and disposed of in a manner that assures protection of public health and safety and the environment. One of the principal programs for managing solid wastes under RCRA is Subtitle D which includes minimum federal standards, as well as guidelines for State plans, for non-chemically-hazardous solid wastes. Specifically, Subtitle D sets criteria for disposal facilities for these solid wastes, encourages States to develop plans to manage these solid wastes, and prohibits open dumping of solid waste. Under Subtitle D, the EPA provides information, guidance, policy, and regulations to deal with solid waste issues. States and local governments are the primary planning, regulating, and implementing agencies for the management of solid wastes under Subtitle D. Three broad types of landfills covered under RCRA Subtitle D are municipal solid waste landfills (MSWLF), construction and demolition landfills, and industrial landfills. MSWLFs typically receive household wastes (e.g., appliances, newspapers, containers, food wastes, and miscellaneous organic waste). MSWLFs also may receive commercial and industrial solid wastes, although they are less likely to take large bulk industrial items like water tanks, large concrete slabs, etc. Construction and demolition landfills typically take road material, excavated material, and demolition/construction/renovation wastes. Industrial wastes are non-hazardous solid wastes from manufacturing or industrial processes. Industrial landfills can be located on industrial/manufacturing facility sites and receive wastes only from those facilities.

The NRC believes that disposal in a landfill regulated under Subtitle D of RCRA is a feasible option for the disposition of solid material. The 1 mrem/yr (0.01 mSv/yr) dose criterion of this proposed amendment is a constraint set at a very small fraction (1/100) of the NRC's public dose limit established to ensure adequate protection of public health and safety and represents a negligible individual dose level (see Section III.B.2). Material below this level would not require any further regulatory control by the NRC. This material could then be kept out of general commerce if disposed of under the regulatory scheme of the RCRA.

The NRC's decision to authorize disposition of solid material in RCRA Subtitle D landfills is similar to a suggested approach in a June 26, 2003, comment letter from the Association of State and Territorial Solid Waste Management Officials (ASTSWMO). In its letter, ASTSWMO suggested an approach which uses a 1 mrem/yr (0.01 mSv/yr) clearance-type level and which would not result in a change to landfill operations or need for any additional engineered features, nor subject an EPA/State-regulated landfill to any extra controls, or special monitoring or treatment of leachate, groundwater, or landfill gases. The levels in the solid material released under this proposed amendment would be at levels noted in the ASTSWMO letter, and no change in landfill operations should be needed. In addition, the EPA has noted (68 FR 65120; November 18, 2003) that some States have determined that RCRA Subtitle D facilities may offer sufficient protection for certain types of radioactive material. For example, the State of Michigan, in conjunction with the NRC, concluded in 2001 that certain very low-activity wastes (such as concrete rubble) from the decommissioning of the Big Rock Point nuclear facility could be sent to a RCRA Subtitle D landfill (66 FR 63567; December 7, 2001).

Based on the above (as well as the discussions in Section III.B.1.2.2), the NRC is including disposal in a RCRA Subtitle D landfill as one of the acceptable disposition paths under this proposed rule. The NRC does not want to prejudge eventual EPA decisions regarding RCRA Subtitle C<sup>7</sup> landfills; a licensee request to dispose of solid material in a RCRA Subtitle C landfill could be addressed under existing provisions in 10 CFR 20.2002 (see Section III.C.2(5) of this document).

Finally, as noted above, there is no requirement that a landfill operator take the material. Factors such as market forces, agreements between generator and operator, and landfill monitor setpoints will determine if material released under the NRC's standards are accepted at the landfill.

With regard to the limited disposition alternative that would restrict material to certain end uses, a fairly uniform concern expressed by a range of stakeholders (including the metals industry, licensees, and States) was whether it is feasible or practical to establish a generic

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<sup>7</sup> The EPA has initiated an effort to consider modifying its Subtitle C regulations and published an Advanced Notice of Proposed Rulemaking (68 FR 65119; November 18, 2003) soliciting stakeholder input on a potential regulatory framework for disposal of low-activity waste in RCRA Subtitle C facilities. Subtitle C establishes a system for controlling chemically-hazardous solid waste from the time it is generated until its ultimate disposal. There are RCRA Subtitle C regulations (40 CFR Parts 260-264) for the generation, transport, treatment, storage, and disposal of chemically-hazardous wastes. EPA's ANPR indicated that it is considering a range of allowable dose limits for disposal in Subtitle C facilities different from the criteria being considered in this NRC proposed rulemaking. In a January 14, 2004, letter, the Commission stated that it believed that the approach described in the ANPR has the potential to provide a safe and economical alternative for the disposition of low activity radioactive waste. The EPA is coordinating with the NRC on the ANPR effort. If the EPA decides to move forward with a rulemaking for Subtitle C facilities, the NRC would need to take conforming regulatory action in a separate rulemaking. As discussed above, this NRC rulemaking effort is proposing requirements for disposition of materials below a dose criterion of 1 mrem/yr (0.01 mSv/yr) which is a risk level well below the chemical hazard considered at Subtitle C facilities.

approach for restricted use. These stakeholders noted that developing a rule with generic standards for defined restricted uses would be difficult because of regulatory burden and other problems in enforcing controls to limit disposition paths for entities not covered by NRC regulations and because it is not likely to be economically practical for a steel mill to routinely process the limited quantities of material from licensed facilities for a specific set of limited end uses.

Some stakeholders suggested that the NRC should proceed with a rulemaking that would not include a generic approach for limited disposition, but instead provide a regulatory framework and process, similar to the current 10 CFR 20.2002 disposal approval process, so that licensee plans involving limited disposition could be characterized and dealt with on a case-specific basis rather than in a generic standard. This would allow the NRC and the public to review specific details of a particular limited disposition. The NRC agrees in part with these comments; therefore, the case-specific approach is one of the elements of its limited disposition approach. Examples of materials that would be considered as part of a case-specific approach are:

(1) Metal recycle. Developing scenarios for recycling of metals is difficult and stakeholders have not provided any clear process as to how metal could be generically directed for recycle into a non-licensed industrial or construction related end uses (e.g., bridges, etc.). Thus, the NRC has decided that any consideration of restricted recycling of metal could only be proposed by a licensee under the case-specific element of this proposed rule;

(2) Soil and soil-like materials. Results of the DGEIS analyses considering potential uses of released soil under varying scenarios indicate that under some conditions, soils initially intended for burial in a landfill could be diverted, at a point beyond the licensee's control, and used in other purposes given that there is a demand for "clean fill" for use as backfill. Discussion in the DGEIS indicates that, at this time, there is not enough information to characterize how soils might be used locally and that the engineering properties of soils are expected to dictate where and under what conditions soils might be reused. These considerations could not be fully addressed in the DGEIS because of the lack of supporting information. Thus, the NRC decided to address the disposition of soils on a case-specific basis. As discussed in Section III.B.1.1 of this document, this case-specific approach represents an improvement over NRC's current approach, in particular because the risk-informed dose criterion in the proposed amendment would be used in making decisions regarding a specific request. This case-specific approach is not anticipated to result in significant additional burden for licensees or regulators because information referenced in the DGEIS on experience with soil disposition over the past 20 years indicates that licensee requests for offsite disposal have been infrequent. To aid in minimizing burden, the NRC is including in draft NUREG-1813, information that can be used by licensees in providing case-specific requests for off-site disposition of soil (e.g., potentially acceptable radionuclide concentrations). Similarly, information, e.g., model elements and model assumptions, contained in NUREG-1640 may be used in preparing case-specific requests.

However, the NRC's review of its technical information bases has indicated that it is also feasible for this proposed amendment to contain a generic approach for certain materials and end uses. Therefore, the NRC is including in this proposed amendment a set of pre-defined

limited end uses (Section III.B.1.2.2 discusses the ability of these end uses to limit where solid materials would go):

(1) Concrete in road-bed construction. NUREG-1640 (see Section III.B.3.1 of this document) reviewed various concrete re-use scenarios and notes that recycle and re-use of reclaimed concrete from licensed facilities in uses such as road-bed construction is its most likely destination because of the physical nature of reclaimed concrete. Other uses of reclaimed concrete are less likely and result in much lower exposure compared to use in road beds made with reclaimed concrete;

(2) Re-use of solid materials, equipment, and tools in their original form, in industrial or construction settings, for their original intended purpose and function. For most large and/or stationary components at a licensed facility (e.g., scaffolds, cranes, trucks, office furniture, etc.), the NRC considers this a feasible approach for limiting where these items go and restricting them from general consumer use. Discussion of how this approach would work to limit where solid materials go is discussed in Sections III.B.1.2.2 and III.B.4, including maintenance of records of the type and amount of material released, the destination of the material, and indication that the radionuclides released were in compliance with the proposed amendment.

There is a class of smaller pieces of equipment and tools used by workers which may be transported by an individual in and out of restricted/impacted areas as part of the routine conduct of work in those areas (e.g., hand tools, testing equipment). The NRC considered

restricting further use of these items to only industrial/construction settings and requiring records of the end destination of these items. However, given the very low dose criterion and low allowable radionuclide concentrations in these proposed amendments, the NRC has determined that trying to direct each small tool to an industrial/construction use, and maintaining records of such transfers, would be unduly burdensome, given the very low risk involved. Instead, the NRC has decided that the proposed amendments should direct that these items be limited to re-use in their original form for their original intended purpose and function, and that required records can be limited to specifying the specific tool or equipment removed from the restricted/impacted area and indication that the radionuclides released were in compliance with the proposed amendment (See Section III.B.4). This approach is similar to the method for handling such items under the NRC's current approach which the National Academies Report found to be protective of public health. However, the proposed approach represents an improvement because it enhances the current approach for these materials by placing them under the proposed requirement of the 1 mrem/yr (0.01 mSv/yr) dose criterion (including its associated radionuclide concentrations) and the limited disposition paths and recordkeeping requirements of this proposed amendment.

#### B.1.2.2 Ability of Disposition Paths to Limit Where Solid Materials Go and Maintain Exposures Below the Dose Criterion

The limited disposition approach is intended to restrict disposition of material to certain authorized uses and/or to landfills to minimize the likelihood of release of material from licensed facilities into the general stream of commerce, in particular consumer goods, and to maintain doses below the 1 mrem/yr (0.01 mSv/yr) dose criterion discussed in Section III.B.2. An issue

raised by stakeholders regarding limited disposition is how it will be assured that restrictions function to limit where material can go and to limit the dose, while not being a burden on regulators and the public. The NRC believes that the provisions in the proposed amendment, discussed in this section and in Section III.B.2 (regarding the dose criterion) and Section III.B.4 (regarding recordkeeping), provide reasonable assurance that doses will be maintained well below levels established to adequately protect public health and safety while minimizing unnecessary burden.

(1) Considerations related to directing and limiting material to landfills or to the defined end use. The proposed amendment contains specific requirements which direct licensees as to allowed destinations for solid material. Therefore, licensees would have to provide reasonable assurance under the proposed amendments in 10 CFR 20.2008, 20.2009, and 20.2108 that solid material is being disposed of under the regulatory scheme of RCRA, specifically 40 CFR Parts 257 and 258, and/or actually placed into an approved use.

As discussed above, the NRC believes that RCRA controls associated with landfill operations and closure provide for a reasonable level of isolation from the public, especially given that the dose criterion of 1 mrem/yr (0.01 mSv/yr) being proposed in this amendment is well below levels established to ensure adequate protection of public health and safety. Under RCRA, the EPA has developed Federal criteria in 40 CFR Part 257, for proper design and operation applicable to all RCRA Subtitle D landfills, and in 40 CFR Part 258 specifically for MSWLFs. Provisions to ensure that wastes in solid waste disposal units do not threaten surface water, ground water, biota, and flood plains, and precautions to restrict public access to the facility are contained in 40 CFR Part 257. The criteria in 40 CFR Part 258 address location,

operation, design, ground water monitoring, corrective action, closure and post-closure care, and financial responsibility for MSWLFs. The EPA has noted (68 FR 65120; November 18, 2003) that recent standards for RCRA Subtitle D facilities in 40 CFR Part 258 require them to have engineered features that are similar to RCRA Subtitle C facilities. Many States have adopted the criteria in 40 CFR Parts 257 and 258 into their solid waste programs although the extent of adoption varies; thus, there can be a range in standards for landfill operation and design among the fifty States for RCRA Subtitle D landfills within the requirements of 40 CFR Parts 257 and 258. A review of certain State standards indicates that some impose engineered features beyond those required by 40 CFR Part 257. A dose criterion of 1 mrem/yr (0.01 mSv/yr) would limit potential doses to levels substantially lower than, and well within the variation in, background radiation levels received from the surrounding geologic material and other materials present in the landfills.

The NRC believes that the approach outlined in this section will result in doses well below that established to provide adequate protection of public health and safety. For much of the solid materials considered here (e.g., routine trash) there is little recycle value and thus it is likely that the material will be disposed of by burial at the landfill. However, for certain materials such as bulk metals, the NRC is aware that there may be some economic impetus for a landfill to recycle the material. The provisions of the proposed amendment requiring disposal by burial under the regulatory scheme of RCRA attempt to minimize the potential for this to occur. In addition, most major bulk shipments of metal would be made at the time of decommissioning or other large facility outage and/or could be to industrial or construction and demolition landfills (rather than MSWLFs), both of which lend themselves to better direction by the licensee regarding the need for disposal (and not recycle) of the metal by the landfill. Nevertheless, the

NRC is specifically interested in stakeholder input as to practices at the various types of RCRA Subtitle D landfills with regard to recycle of material sent for disposal and how the potential for recycle of solid materials from those facilities can be minimized. A specific question regarding this matter is contained in Section IV.A of this document.

Similarly, it is likely that solid materials, such as rubble concrete or specific components, will remain in their pre-defined allowed end uses (e.g., road bed construction or re-use of a scaffold). The NRC believes that establishing the 1 mrem/yr (0.01 mSv/yr) dose criterion as part of this proposed amendment would make it unlikely that any future uses of the material would result in reconcentrating residual levels of radioactivity to levels that could impact public health and safety.

(2) Placing bounds on radionuclide concentrations that can be released so as to limit potential exposures. The NRC recognizes that it is difficult to provide absolute assurance that solid material goes to and remains at a landfill, despite the relative protectiveness of the RCRA regulatory structure, or to another designated end use. Some stakeholders expressed concern that there would be a significant regulatory burden in dealing with this material after it reached potential recipients.

Because of the very low level of risk posed by the material released, a reasonable approach that both provides assurance of adequate protection and should not be burdensome, is to use unrestricted release path radionuclide concentration tables (see Section III.B.3.1) for material released to the limited disposition paths of this proposed rule. This is a reasonably

conservative approach because, for the same 1 mrem/yr (0.01 mSv/yr) dose criterion, an unrestricted release is generally associated with lower (more restrictive) radionuclide concentrations than a limited path release, for which persons are exposed in a more limited manner. Thus, there is reasonable assurance that even if all materials released in a year from a licensee were inadvertently diverted for unrestricted release, a 1 mrem/yr (0.01 mSv/yr) dose would not be exceeded. It could also be assured that an isolated unrestricted release would result in doses well below 1 mrem/yr (0.01 mSv/yr). Because the 1 mrem/yr (0.01 mSv/yr) dose criterion is well below the NRC's public dose limit established to ensure adequate protection of public health and safety and is also considered a negligible individual dose by national and international scientific organizations, this approach and this level of assurance is considered appropriate.

This proposed approach of requiring use of the unrestricted release radionuclide concentrations would allow the use of limited disposition paths without imposing the regulatory burden of trying to enforce additional controls on released materials in the public sector. Use of the unrestricted release concentrations is not expected to result in significant additional burden because the NRC's review of the various dose modeling analyses and results (see Section III.B.3.1) indicates that the limiting radionuclide concentrations for both unrestricted and limited path scenarios are within a reasonable range of each other. Also, the lower unrestricted release radionuclide concentrations are not dissimilar from levels which licensees currently measure when using the NRC's current approach.

(3) Inspections. Periodic inspections can provide continuing confirmation or verification that the regulations are being followed. The inspections would look at how licensees identify

and survey materials for release and address the end use of such materials by checking shipment records to recipients.

## B.2 The 1 mrem/yr (0.01 mSv/yr) Dose Criterion

A discussion of the NRC's basis for choosing the 1 mem/yr (0.01 mSv/yr) dose criterion is contained in this section. Specific discussion of the relationship of the dose criterion to other NRC/EPA standards, to recommendations from national and international scientific bodies, to background radiation, and to considerations of effects of exposures from multiple sources, are contained in Sections III.B.2.1 to III.B.2.4. Those sections are briefly summarized here.

A 1 mrem/yr (0.01 mSv/yr) dose criterion is a generic dose constraint set at a small fraction (1/100) of the public dose limit of 100 mrem/yr (1 mSv/yr) in 10 CFR Part 20. Both the NCRP and the International Commission on Radiation Protection (ICRP) have indicated that the public dose limit provides adequate protection of public health and safety, although they also indicate that the amount a person would receive from a single source should be a fraction of the limit. The proposed 1 mrem/yr (0.01 mSv/yr) criterion is also in the range of, but less than, other Federal agency standards and allowable risk ranges for other media such as gaseous and liquid effluents. A 1 mrem/yr (0.01 mSv/yr) dose criterion also comports with technical findings in reports prepared by various recognized scientific organizations with regard to its very small potential risk. In particular, NCRP Report No. 141, "Managing Potentially Radioactive Scrap Metal," notes that a dose below 1 mrem/yr (0.01 mSv/yr) can be defined as a "negligible individual dose" and that doses that fall into this range have an associated average annual

excess risk below which “efforts to reduce radiation exposure to the individual is unwarranted.” NCRP Report No. 141 also cites several health effects studies and notes that this dose is in a risk range ( $10^{-7}$  to  $10^{-6}$  per year) that is generally regarded as “trivial.” A dose criterion of 1 mrem/yr (0.01 mSv/yr) represents a minute fraction (1/300) of natural background and is also a small fraction of the variability in natural background across the U.S. that members of the public are exposed to without health impact. The NRC is cognizant of studies and reports on radiation health effects cited by citizen and environmental groups that are different from the current scientific consensus views, however, the NRC is confident in the information it does have to determine that the proposed standard of 1 mrem/yr (0.01 mSv/yr) is well below levels established to ensure adequate protection of public health and safety for disposition of solid material from any further licensed control.

The 1 mrem/yr (0.01 mSv/yr) dose criterion is expressed here in terms of effective doses because the basis of RS-G-1.7 is the ICRP 60 dose concept and methodology. In 10 CFR Part 20, dose limits are based on ICRP 26 methodology with dose concepts referring to “deep dose equivalent” doses for external exposures and “effective dose equivalent” doses for internal exposures, expressed as “TEDE” in dose summations. For the purpose of this amendment, equivalence is assumed between effective dose and total effective dose equivalent. Accordingly, the 1 mrem/yr (0.01 mSv/yr) dose criterion is considered to be an “total effective dose equivalent (TEDE)” dose in the proposed amendment.

In addition to the discussions in Sections III.B.2.1 to III.B.2.4, considerations of how the dose criterion would be implemented through use of measurable radionuclide concentrations and appropriate recordkeeping are discussed in Sections III.B.3 and III.B.4, respectively.

### B.2.1 Consistency with other NRC/EPA Standards

The NRC utilizes recommendations of other scientific organizations in setting radiation protection standards. For example, the NCRP in its publication No. 116 (Chapter 15) recommends that, for continuous exposure, the effective dose to members of the public not exceed 100 mrem/yr (1 mSv/yr) from all man-made sources, excluding medical and natural background sources. Similarly, the ICRP, in Table 6 of Publication 60, recommends a limit of 100 mrem/yr (1 mSv/yr) as the dose limit for the public. Consistent with these bodies, the NRC's regulations in 10 CFR Part 20, Subpart D, establish a public dose limit of 100 mrem/yr (1 mSv/yr). The NCRP and ICRP also agree that, although the limit for the public dose should be 100 mrem/yr (1 mSv/yr) from all man-made sources combined, the amount that a person would receive from a single source should be further reduced to a fraction of the limit. This would account for the possibility that an individual may be exposed to more than one source of man-made radioactivity and limit the potential that an individual would receive a dose at the public dose limit.

The proposed 1 mrem/yr (0.01 mSv/yr) dose criterion for solid material is well below and a very small fraction (1/100) of the public dose limit of 100 mrem/yr (1 mSv/yr) in 10 CFR Part 20, Subpart D; it is also well below the dose criterion in 10 CFR Part 20, Subpart E for license termination of facilities at 25 mrem/yr (0.25 mSv/yr) which is a "sufficient and ample" margin below the public dose limit for that application (62 FR 39058; July 21, 1997).

The 1 mrem/yr (0.01 mSv/yr) dose criterion for solid materials is comparable to, and smaller than, standards and design objectives set by both the NRC and EPA for other specific media being released from licensed facilities. The NRC sets design objectives in 10 CFR 50, Appendix I, limiting gaseous and liquid effluents from power reactors to less than 5 mrem/yr (0.05 mSv/yr) and 3 mrem/yr (0.03 mSv/yr). The EPA has responsibility for setting generally applicable radiation protection standards in the environment. Currently, the EPA has a drinking water standard of 4 mrem/yr (0.04 mSv/yr), which has been implemented under the Safe Drinking Water Act (1974) in 40 CFR Part 141 and a national emissions standard for air pollutants at 10 mrem/yr (0.1 mSv/yr), which has been implemented under the Clean Air Act, in 40 CFR Part 61. Finally, as noted in the National Academies Report, the risk associated with the 1 mrem/yr (0.01 mSv/yr) dose criterion is below the range of acceptable lifetime risks of  $10^{-6}$  to  $10^{-4}$  that the EPA has used in developing health-based dose standards for exposure to radiation.

#### B.2.2 Relationship of Dose Criterion to Recommendations from National and International Scientific Bodies Regarding Health Impacts

There are differing views from stakeholders on studies that have been conducted on health impacts. Some commenters cited studies by various national and international scientific organizations that state that there are negligible health impacts from radioactivity at levels near 1 mrem/yr (0.01 mSv/yr). Other stakeholders stated that health effects of low dose radiation are greater than predicted for current radiation limits and cited other studies indicating concerns about impacts at low radiation doses.

In considering these comments, the NRC notes that in developing its overall radiation protection standards, a number of reports and studies by recognized scientific organizations are reviewed. For this proposed amendment, the NRC considered how these organizations address this specific issue, particularly the use of a dose criterion of 1 mrem/yr (0.01 mSv/yr). The organizations include the NCRP, ICRP, National Academies, IAEA, and ANSI. To supplement this review, the NRC also reviewed information from other studies cited by commenters.

In establishing its basic protection standards, the NRC relies on national and international scientific authorities. The NRC believes that reports by the NCRP and ICRP provide a widely held consensus view by national and international scientific authorities on radiation dose responses and accepts their principal conclusions and recommendations on the matter of health impacts.

The NCRP is a nonprofit corporation chartered by Congress to develop and disseminate information and recommendations about protection against radiation, and to cooperate with the ICRP and other national and international organizations with regard to these recommendations. NCRP publications are developed by recognized experts in the fields of radiation protection and health effects. In NCRP Report No. 116, "Limitation of Exposure to Ionizing Radiation", 1 mrem/yr (0.01 mSv/yr) is referred to as a "Negligible Individual Risk Level" which is defined as a level of average annual excess risk below which "efforts to reduce radiation exposure to the individual is unwarranted." NCRP Report No. 141, "Managing Potentially Radioactive Scrap Metal", notes the growing consensus among national and international communities to choose a criterion of 1 mrem/yr (0.01 mSv/yr), in part, because a dose at this level can be considered

“trivial.” The NCRP notes the ICRP’s recommendation that 1 mrem/yr (0.01 mSv/yr) is appropriate for cessation of regulatory control and that the risk associated with 1 mrem/yr (0.01 mSv/yr) is within a range that is almost universally regarded as trivial. NCRP No. 141 further notes that, in NCRP No. 95, “Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources”, levels near or above 1 mrem/yr (0.01 mSv/yr) in consumer products and other miscellaneous sources have not resulted in actions to avoid or mitigate potential exposures. For these reasons, NCRP Report No. 141 states that it is the NCRP’s position that a “few” mrem/yr (hundredths of mSv/yr) would be an appropriate dose criterion for a clearance standard.

The ICRP was established in 1928 as a Commission linked to the International Congresses of Radiology and is supported by a number of international organizations and by many governments. The ICRP issues recommendations on the fundamental principles and quantitative bases upon which appropriate radiation protection measures can be established. The ICRP’s “Recommendations of the International Commission on Radiological Protection” (ICRP 60, 1990) recommends that the grounds for exempting material from regulation are that a source gives rise to small individual doses, of the order of 1 mrem/yr (0.01 mSv/yr) or less, and the protection is optimized.

During 2002, the National Academies/National Research Council prepared the National Academies Report for the NRC on disposition alternatives for solid material. The National Academies is a society of scientists and engineers, operating under the authority of a charter granted by Congress in 1863, that provides advice to the Federal government on scientific and technical matters. The National Research Council is the principal operating agency of the

National Academies in providing services to the government, the public, and the scientific and engineering communities. As noted in the National Academies Report, the members of the committee responsible for the 2002 National Academies Report were chosen by the National Academies for their special competencies and with regard for appropriate balance.

One of the findings of the National Academies Report was that the NRC's current approach for disposition of solid materials is sufficiently protective of public health that it does not need immediate revamping. However, the report also noted that, for the sake of efficiency of regulation, the NRC should move ahead with a process for evaluating alternatives.

In discussing a 1 mrem/yr (0.01 mSv/yr) dose criterion, Recommendation #5 of the National Academies Report noted that 1 mrem/yr (0.01 mSv/yr) is: a small fraction of the dose received per year from natural background sources; significantly less than the dose we receive from our own bodies due to radioactive potassium and other elements, and due to routine medical procedures; within the range of acceptable lifetime risks of  $10^{-4}$  to  $10^{-6}$  used by the EPA in developing health-based standards for exposure to radiation; able to be measured with radiation measurement technologies available at reasonable cost; and widely accepted by recognized national and international organizations.

The IAEA operates as an organization within the United Nations and works with member nations worldwide with a mission of safety and security; science and technology; and safeguards and verification. The IAEA's standards reflect the recommendations of the ICRP and have been adopted by many of its member nations. IAEA's "Safety Series No. 89, Principles for the Exemption of Radiation Sources and Practices from Regulatory Control",

recognized that there was “no internationally unified policy for excluding or exempting (e.g., clearing) sources from regulatory control.” The first criterion of dealing with this issue was setting a level of trivial dose. The publication noted that most authors proposing values of trivial individual dose have set the level of annual risk which is held to be of no concern to the individual at  $10^{-7}$  to  $10^{-6}$ . Based on this risk, the IAEA concluded that the level of trivial individual effective dose equivalent would be in the range of 1 to 10 mrem/yr (0.01 to 0.1 mSv/yr). Because an individual could be exposed to radiation doses from multiple cleared sources or practices, the IAEA concluded that doses on the order of 1 mrem/yr (0.01 mSv/yr) per practice would be reasonable.

In addition, the NRC reviewed the ANSI national standard (ANSI/HPS N13.12-1999) which contains criteria for unrestricted release of solid materials and includes a dose limit of 1 mrem/yr (0.01 mSv/yr). This standard, which was jointly issued by the ANSI and the Health Physics Society (HPS), contains guidance on the clearance of solid materials based on 1 mrem/yr (0.01 mSv/yr), or higher dose levels when justified on a case-by-case basis, taking into account exposures to multiple sources. The standard recommends maintaining the as low as reasonably achievable (ALARA) principle because it provides an adequate margin of safety below the public dose limit of 100 mrem/yr (1 mSv/yr).

Some stakeholders agreed with the recommendations of the organizations noted above. For example, in an August 2004 position statement, the HPS noted that risks of health effects from exposures below 5000 to 10,000 mrem/yr (50 to 100 mSv/yr) are either too small to be observed or are nonexistent; the 1 mrem/yr (0.01 mSv/yr) dose criterion in this proposed amendment is 5000 to 10,000 times lower than the health effect levels cited by the HPS in their position statement.

Other stakeholders cited studies and reports on radiation health effects that are different from the current scientific consensus views. The NRC collected and reviewed a number of the reports, books, and studies that were cited in the public comment letters (and noted in the DGEIS, Appendix A). One of the publications cited by stakeholders was prepared by Green Audit, an environmental consultancy, who published, on behalf of the European Committee on Radiation Risk (ECRR), a review and analysis entitled, *Health Effects of Ionizing Radiation Exposure at Low Doses for Radiation Protection Purposes* (2003). The authors of the report believe that the health risks associated with inhalation or ingestion of radioactive material are grossly underestimated by the ICRP. A new methodology for estimating radiation exposure was proposed in the ECRR document. Specifically, the new methodology retains the ICRP's system of radiation weighting factors and tissue weighting factors, but includes two additional factors: a biophysical factor and a biochemical enhancement factor, for enhanced hazard weighting for certain kinds of internal exposure to radioactive material. The result of this alternate methodology would be a very substantial increase in effective dose.

The ECRR report was reviewed in detail by the National Radiological Protection Board (NRPB) in the United Kingdom. NRPB staff observed that the methodology proposed by Green Audit for estimating radiation risk from internal emitters did not have a sound scientific basis and that weighting factors proposed by Green Audit appear to have little or no supporting scientific evidence. Similarly, Green Audit criticized the ICRP's value of a risk factor used to convert radiation dose to health risk and proposed its own value, but also failed to provide a scientific basis for its own selection. The NRPB report, in noting that ICRP radiation protection recommendations and radiation dosimetry methodologies are based on extensive knowledge of health effects of ionizing radiation, concluded that the "recommendations of the ICRP provide a

sound technical basis for radiological protection standards. In particular, risks from internal emitters are acceptably well understood and may, in some cases, be overestimated by ICRP.”

### B.2.3 Comparability to Background Radiation

In considering health impacts of very low doses of radiation, it is noted that humans have evolved in a world constantly exposed to low doses from everyday sources of radiation (such as solar and cosmic radiation, radon, certain foods, etc.) which expose people to background radiation and to wide variations in background each day from place to place with no discernible effect on health (see [www.nrc.gov/reading-rm/doc-collections/fact-sheets/bio-effects-radiation.html](http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/bio-effects-radiation.html)). The average radiation exposure in the U.S. from all such natural sources is approximately 300 mrem/yr (3 mSv/yr). The proposed dose criterion of 1 mrem/yr (0.01 mSv/yr) is a minute fraction (less than 1/300) of these background levels of radiation received in routine activities and is also a small fraction of background variations which are, themselves, well below the levels where health effects are expected to occur, as discussed in Section III.B.2.2. In addition, man-made sources of radiation from medical, commercial, and industrial activities contribute another 60 mrem/yr (0.6 mSv/yr) to our radiation exposure. Of this, diagnostic medical procedures account for about 40 mrem/yr (0.4 mSv/yr) and can range up to between 500 to 1,000 mrem (5 to 10 mSv) without any documented adverse effects. In addition, some consumer products such as tobacco, fertilizer, welding rods, gas mantles, luminous watch dials, and smoke detectors can contribute another 10 mrem (0.1 mSv) to our annual radiation exposure.

#### B.2.4 Effect of Exposures from Multiple Sources of Cleared Materials Meeting the Dose

##### Criterion

Concerns were raised by stakeholders that there could be exposures to multiple products or scenarios as a result of solid material released from licensed facilities, even if individual releases met the NRC's dose criterion.

This issue of "multiple exposures" is discussed in detail in Appendix E of the DGEIS. The DGEIS notes that the possibility of multiple exposures concurrently applying to an individual implies that the individual would be exposed to very low amounts of radioactivity as a result of more than one potential situation due to material released from licensed facilities (e.g., from products made from solid materials, disposal in landfills, material present in a road bed, etc.). In considering this, the DGEIS notes that the potential for the same individual to be involved in concurrent scenarios is physically constrained by the relatively limited amount of materials that could be released from licensed facilities, geographical distances between licensees, and the different locations where scenarios could occur. In addition, the limited disposition paths required by this proposed amendment minimizes the number of potential exposure scenarios to the public, in particular with regard to recycle into general commerce. Furthermore, realistically conservative models are used to estimate potential dose to a "critical group" which are likely to overestimate the dose to any specific individual. Based on these varied considerations, and the 1 mrem/yr (0.01 mSv/yr) individual dose criterion, the DGEIS notes that the likelihood of multiple exposure scenarios gets small as the number of potential concurrent scenarios increases and that any combined exposures from multiple exposures would still be a very small fraction of the NRC's public dose limit of 100 mrem/yr (1 mSv/yr).

## B.3 Tables of Radionuclide Concentrations Associated with the Dose Criterion

### B.3.1 Tables of Radionuclide Concentrations

The proposed amendment is supplementing the dose criterion of 1 mrem/yr (0.01 mSv/yr) with tables of measurable radionuclide concentrations to facilitate confirmation that the dose criterion has been met (i.e., if a licensee can demonstrate for a solid material being considered for release that the radionuclide concentrations are less than levels in the tables, this will provide assurance that the 1 mrem/yr (0.01 mSv/yr) dose criterion has been met). Based on the studies and activities noted in Sections III.B.3.1.1 and III.B.3.2, the NRC has concluded that the dose criterion of 1 mrem/yr (0.01 mSv/yr) can be effectively modeled, measured, and monitored for compliance so that there is reasonable assurance that the dose criterion will not be exceeded.

#### B.3.1.1 Basis for Radionuclide Concentrations

Because doses in the environment cannot be easily measured, “dose models” are used to model the behavior of nuclides in the environment to translate the residual radionuclide concentrations on, or in, a solid material to a potential dose to an individual. There were comments received from some stakeholders about the ability of dose models to accurately model potential doses. A discussion of technical studies performed to provide reasonable models for estimating potential doses and efforts to establish the accuracy of these models follows.

Several organizations, including the NRC, IAEA, EC, and ANSI have developed reports containing tables that relate measurable radionuclide concentrations to a dose of 1 mrem/yr (0.01 mSv/yr). Each of these reports evaluate various exposure scenarios and pathways by which potential population groups might be exposed, based on the potential release of a range of materials with various radionuclide concentrations. These reports also provide a method for converting the actual measured concentrations when the materials are released to the potential dose received by the various receptors.

The NRC's report (NUREG-1640, "Radiological Assessments for Clearance of Materials from Nuclear Facilities") contains analyses of various potential uses of materials (steel, aluminum, copper, concrete, and reused tools and equipment) and resultant potential exposures as a result of different dispositions of solid materials. The appropriateness of the models in NUREG-1640 to evaluate the relationship between material released and a dose criterion of 1 mrem/yr (0.01 mSv/yr) was reviewed by the National Academies and peer reviewed as part of NUREG-1640's preparation. In particular, the National Academies Report noted the technical soundness of NUREG-1640 and recommended that for any dose-based approach for disposition of solid materials, the NRC should use the conceptual framework of NUREG-1640 to assess dose implications.

The IAEA developed RS-G-1.7 to assist countries in setting standards for exemption, exclusion, and clearance from regulatory control. Radionuclide concentration tables in RS-G-1.7 are based on a consideration of various exposure pathways, scenarios, and potential receptors of released materials developed to encompass typical exposure situations for all material types. The NRC has reviewed the tables of radionuclide concentrations in RS-G-1.7 and, as discussed in the DGEIS, found these concentrations reasonably consistent with

NUREG-1640. An advantage in the use of a table of internationally-accepted radionuclide concentrations in RS-G-1.7 is that their use in this proposed amendment would promote consistency among nations in setting numeric standards for release of solid materials from regulatory control.

The NRC has decided to use the radionuclide concentrations in RS-G-1.7 in this proposed regulation (specifically in a proposed Appendix E to Part 20) because of consistency in international numeric standards, and because the NRC's review of RS-G-1.7 and NUREG-1640 indicates that the use of either document can provide reasonable assurance that the radionuclide concentrations used result in potential doses that meet the 1 mrem/yr (0.01 mSv/yr) dose criterion in this proposed amendment. As discussed below, for certain situations, the NRC is supplementing the radionuclide concentration information from RS-G-1.7 with data from NUREG-1640.

As noted above, the radionuclide concentration tables in RS-G-1.7 and NUREG-1640 have been developed for a range of scenarios and pathways. As discussed in Section III.B.1.2.2, the radionuclide tables taken from these documents, and proposed as an element of this proposed amendment, are based on the limiting scenario of unrestricted release even though the proposed amendment would only authorize limited disposition pathways. Section III.B.1.2.2, further discusses the rationale for this approach.

### B.3.1.2 Specific Considerations in Use of the Radionuclide Tables

Table 2 of RS-G-1.7 contains a list of concentrations of radionuclides of artificial origin derived independently from this NRC rulemaking. These concentrations are based on the concepts of exempting and/or clearing these radionuclides from regulation. Because the concentrations in Table 2 of RS-G-1.7 are based on the same 1 mrem/yr (0.01 mSv/yr) value as the dose criterion contained in this proposed amendment, the concentration levels in Table 2 of RS-G-1.7 have been directly transferred into this proposed amendment as Table 1 of Appendix E of 10 CFR Part 20. For radionuclides not included in Table 2 of RS-G-1.7, the NRC has decided to use radionuclide levels taken from NUREG-1640 normalized to the same 1 mrem/yr (0.01 mSv/yr) dose criterion as other facilities covered by this proposed amendment. Primarily, this includes licensees authorized to possess source material (e.g., depleted-U, U-238 and Th-232, and their decay products) for facilities licensed under Part 40, and special nuclear material (e.g., U-238, U-234, and U-235) for facilities licensed under Parts 50, 70, and 72.

Another consideration is that the radionuclide tables in RS-G-1.7 are expressed in terms of the quantity of the radionuclides contained within the volume of the solid material. However, in many situations, surface concentrations will be more readily measurable (indeed, the NRC's current approach for considering release of solid materials in Regulatory Guide 1.86 includes a table of acceptable surface concentration levels). Therefore, there should continue to be guidelines based on surface concentration levels.

Because the IAEA has not yet developed such information on surface concentrations, the NRC has had to develop a table of acceptable surface concentrations as part of this rulemaking. The NRC notes that solid materials released from further license control by the NRC under this proposed amendment would likely be transported in a variety of manners and that consistency between NRC requirements and Department of Transportation (DOT) regulations in 49 CFR Part 173 for transport of material is important. The NRC decided to base its surface concentrations on the definition in 49 CFR 173.403 for surface concentrations not requiring DOT regulation to provide consistency between these two Federal agencies regarding material needing no further regulation. Although the DOT values are not a direct derivation from a 1 mrem/yr (0.01 mSv/yr) dose level (and instead reflect historical practices), they result in doses of less than 1 mrem/yr (0.01 mSv/yr) and are reasonably consistent with the existing values in Regulatory Guide 1.86. In considering how to proceed in this area, the NRC also derived estimates of surface concentrations directly from the volume concentrations of RS-G-1.7 using information in Appendix D of the DGEIS for ratios of the mass of various solid materials to their surface areas (i.e., “mass-to-surface” ratios). The DOT values are reasonably consistent with these derived surface concentrations for certain radionuclides, such as Co-60 and Cs-137, and for multiple radionuclides taking into account their relative mix for specific types of materials, although for some radionuclides the DOT values may introduce additional conservatism, i.e., resulting in more restrictive concentration levels.

Based on the considerations of the previous paragraph, the NRC has included a set of surface concentrations in Table 2 of Appendix E of 10 CFR Part 20. Table 2 groups nuclides in a manner similar to the existing table in Regulatory Guide 1.86 which has been in use for several years. Licensees would have the option of applying to the Commission for case-specific approval to release material at radionuclide concentration levels higher than those in

Table 2 of the proposed amendments; however licensees would have to comply with DOT regulations regarding shipment of material for those cases.

The NRC is specifically interested in stakeholder input on the proposed approach of using DOT values from 49 CFR 173.403 for the surface concentrations in Table 2 of Appendix E of this proposed amendment as opposed to developing concentration levels that take into account representative mass-to-surface ratios. Specific questions regarding this matter are contained in Section IV.B of this document.

As noted in Section III.A, this proposed amendment contains a dose criterion of 1 mrem/yr (0.01 mSv/yr). The radionuclide concentrations developed based on dose modeling and other regulatory considerations, noted above, provide an acceptable means to comply with this dose criterion in an effective and efficient manner by eliminating the need to calculate a set of radionuclide concentrations for each case. If a licensee decides to use radionuclide concentrations other than those in the proposed Appendix E of 10 CFR Part 20 for meeting the dose criterion, it will have to provide a case-specific analysis with the basis for the radionuclide concentrations used under the case-specific element of this proposed amendment.

### B.3.2 Ability to Accurately Measure the Radionuclide Concentrations

After a set of radionuclide concentrations corresponding to a dose criterion is established, there must be reasonable assurance that these radionuclide concentrations can be accurately measured. Some stakeholders expressed concerns about the ability to measure the radionuclide releases accurately. An approach to demonstrate that radionuclides at these low

levels can be accurately measured is discussed in draft NUREG-1761, "Radiological Surveys for Controlling Release of Solid Materials," June 2004. This report was submitted for public comment and modified in response to the comments. NUREG-1761 indicates that radionuclide concentrations at levels corresponding to 1 mrem/yr (0.01 mSv/yr) for any of the alternate disposition paths can be measured accurately with existing survey and detection instruments.

In addition, an interagency working group from the EPA, DOD, DOE, and NRC has incorporated a series of planning steps for survey design (Data Quality Objectives developed by the EPA) and QA/QC principles into a Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), NUREG-1575, for surveying lands and structures. The MARSSIM methodology was adopted by the NRC in NUREG-1757. A follow-on interagency working group is developing methods for improving the conduct of radiation surveys for solid materials at very low radiation levels. This group intends to issue guidance as a supplement to MARSSIM in a document entitled "Multi-Agency Radiation Survey and Assessment of Materials and Equipment" (MARSAME).

To assure that the actual measurements are made and documented accurately, the NRC is issuing a draft regulatory guidance document (draft NUREG-1813) for licensees to follow in implementing the requirements of this proposed rule. NUREG-1813 provides information on procedures for designing a survey and for the quality assurance (QA) and quality control (QC) of the measurement process. NUREG-1813 is based on the concepts of NUREG-1761 and MARSSIM and provides specific information on implementing the requirements of the proposed amendment, including information about design, performance, and documentation of radiological surveys of materials to ensure radionuclide concentrations are accurately measured.

#### B.4 Recordkeeping

The NRC is proposing to require licensees to maintain records in 10 CFR 20.2108 indicating the nature of the material released (e.g., type and quantity of solid material, and radionuclides present and information on their concentrations) and its destination (e.g., the landfill or specific end use). An exception, as noted in Section III.B.1.2.1, is for tools and equipment carried from restricted/impacted areas by an individual as part of routine conduct of business; for these materials, licensees would only be required to maintain records regarding the specific tool or equipment removed from the restricted/impacted area and an indication that radionuclides released were in compliance with the proposed amendment. The records required by the proposed amendment will provide verification that the dose criterion has been met and provide reasonable assurance that the material was delivered to an authorized destination. The records required are considered an appropriate level of control for a material that the NRC considers to be of negligible health consequence.

Some commenters expressed concern that they would not know what doses would result from products made from recycled materials and that materials should be tagged before release. Because the limited disposition path approach in this proposed amendment would limit the potential for exposure to products made from recycled materials and because the dose criterion would be set at a negligible individual dose level of 1 mrem/yr (0.01 mSv/yr), there are no requirements included in the proposed amendment for tagging or marking released materials because this would add regulatory burden without a commensurate health and safety benefit. Also, in conjunction with a dose criterion of 1 mrem/yr (0.01 mSv/yr), it is unlikely that any future uses would reconcentrate residual radioactivity to levels that could impact public health and safety.

## C. Other Considerations, Including Scope and Interfaces

To provide additional clarification in considering the implementation of this proposed amendment, this section discusses the scope of this proposed amendment and interfaces with other NRC requirements.

### C.1 Materials within the scope of this rule

As noted in Section II.C, materials present in restricted or impacted areas that need disposition would be subject to the provisions of proposed 10 CFR 20.2008, 20.2009, and 20.2108. The materials include metals (tanks, pipes, ventilation ducts, etc); equipment and tools; routine trash (plastics, paper, glass); office furniture, laboratory materials (gloves, beakers, etc.); concrete; and soil, soil-like materials, and other process materials. This material would need to be evaluated and surveyed for radioactivity (either by use of process knowledge or direct measurement) and sent to one of the disposition paths required by 10 CFR 20.2008 or 20.2009. For much of the material covered by the proposed amendment (equipment and tools, routine trash, concrete, etc), the allowed disposition paths are fairly broad and similar to how licensees currently disposition such materials. If a licensee wishes to use a disposition path not listed in 10 CFR 20.2008 for these materials, or for other types of material like metal components, the licensee can apply to the NRC for case-specific approval of disposition procedures under 10 CFR 20.2009.

As noted above, materials within restricted and impacted areas would be subject to the requirements of proposed 10 CFR 20.2008, 20.2009, and 20.2108. However, basing decisions

on disposition of solid materials from a “restricted area” may not be appropriate because the definition of restricted area in 10 CFR Part 20 is based on limiting access for the purpose of protecting an individual against undue risks from exposure to radiation. Some licensees create restricted areas to protect individuals from exposure to ambient external radiation fields, and not necessarily based on the residual radioactivity in or on solid material. Thus, a more appropriate scope to define what material is covered by this amendment may be the term “impacted area” which is currently defined in 10 CFR Part 50 as “areas with some reasonable potential for residual radioactivity in excess of natural background.” (The term “non-impacted area” is also defined in 10 CFR Part 50 as an area with “no reasonable potential for residual radioactivity in excess of natural background”). This same definition of impacted area is included in § 20.1003 of this proposed amendment.

In MARSSIM (NUREG-1575) these same terms, “impacted areas” and “non-impacted areas”, are used to signify the extent of surveys needed to release the areas from licensed control. NUREG-1575, in Figure 2.4, states that for non-impacted areas no survey is required to release the area from licensed control. For impacted areas, NUREG-1575 indicates a range of survey requirements, even for those areas that are not expected to contain any residual radioactivity or expected to contain very small amounts of radioactivity. Because a similar logic can be drawn for those solid materials present in impacted versus non-impacted areas, it would seem reasonable that this proposed amendment on disposition of solid materials should only apply to materials from impacted areas. Thus, it may be appropriate to use only the term “solid materials originating in impacted areas” when indicating the scope of materials covered by this rule. This would mean that for licensees like medical facilities or research laboratories, who may define restricted areas broadly based on facility design, the NRC could better focus its disposition and recordkeeping requirements on solid materials from those areas where a

reasonable potential for the presence of residual radioactivity exists. Licensees could either designate the entire restricted area as an impacted area or could focus more on those areas they were designating as impacted areas, whichever was more cost-effective.

The NRC is interested in stakeholder input with regard to considering material in restricted and/or impacted areas within the scope of this proposed amendment and specifically requests comment on this matter (see Section IV.C).

## C.2 Materials not within the scope of this rule

(1) Materials outside the restricted or impacted areas. Solid materials not located in or originating in restricted or impacted areas and considered to be free of radioactivity resulting from licensed operations, are not currently required to be part of a disposition radiological survey program (e.g., material from administrative buildings or office areas). This amendment would not alter this approach; therefore, materials in these areas are not covered by the provisions of this proposed amendment.

(2) Materials with larger amounts of radioactivity. There are other solid materials at licensed facilities that contain larger amounts of radioactivity (e.g., reactor system components, sealed sources, etc.) that are routinely kept separate from solid materials with no, or very small amounts of, radioactivity. Because requirements in 10 CFR Part 61 already cover the disposal of materials with larger amounts of radioactivity at licensed low-level waste (LLW) disposal sites, these materials are outside the scope of this rulemaking.

(3) Treated process materials. Treated process materials (materials whose properties have been modified or are unique to the process from which they originate), such as spent ion-exchange resins; sludge from spent ion-exchange process systems; microspheres; oily sludge and sediments; spent filters and filter sludge; spent charcoal beds; incinerator ashes; and materials that have been solidified or stabilized, contain chelating agents, pathogenic or infectious biotic agents, and pyrophoric or explosive chemicals, are not within the scope of this rulemaking. These materials are not part of the scope of this rulemaking and were not analyzed in the supporting technical basis or in the DGEIS. As noted in item 5, below, licensees may continue to apply to the NRC under the provisions of 10 CFR 20.2002 for their disposal on a case-by-case basis.

(4) Liquids and gases. These materials currently have requirements related to their release in 10 CFR Parts 20 and 50 and are outside the scope of this rulemaking.

(5) Materials covered under existing 10 CFR 20.2002. Currently, licensees can apply to the Commission for approval of proposed procedures, not otherwise authorized in the regulations, to dispose of licensed material under the provisions of existing 10 CFR 20.2002. A licensee can continue to request disposal of treated process materials (discussed in #3, above) under the provisions of 10 CFR 20.2002. Licensees also can continue to use the existing provisions of 10 CFR 20.2002 to request consideration of alternate dose criteria for solid materials, soils, soil-like materials, and process materials covered by this proposed amendment.

(6) Materials associated with persons leaving restricted or impacted areas. Licensees are required to monitor workers for radiation dose as they come and go from restricted areas. It is

industry practice for workers to pass through a personnel frisker before they leave the restricted area under the existing requirements of 10 CFR Part 20. This proposed amendment would not apply to those persons or their personal items such as jewelry, watches, etc.

(7) Material intentionally made radioactive as part of manufacturing or research process at a licensed facility. Some facilities are licensed by the NRC to introduce radioactive material into products or to conduct research using radioactive materials. Handling of these materials is subject to other NRC regulatory requirements and would not be subject to the provisions of this proposed rule.

(8) Materials associated with Radiological Dispersion Device (RDDs) incidents. The scope of this proposed amendment would only include release of solid materials from licensed control at facilities licensed by the NRC and/or Agreement States. The proposed amendment would not be applicable to emergency provisions associated with handling or setting criteria for cleanup of RDD events.

### C.3 Other transfers of solid material

#### C.3.1 Transfers from one licensee to another for use in a restricted or impacted area

Nothing in this proposed amendment would preclude a licensee from transferring material and equipment to another NRC or Agreement State licensee for re-use in a regulated environment because other requirements already exist for such transfers and this proposed amendment does not alter that.

### C.3.2 Transfers of unimportant quantities of source material exempt under 10 CFR 40.13(a)

As indicated in the June 1999 Issues Paper, 10 CFR 40.13 and 40.51, which contain unimportant quantities or transfer provisions, respectively, are the subject of a separate Commission initiative and are outside the scope of this rulemaking. Hence, nothing in this proposed amendment would affect the definition of unimportant quantities in 10 CFR 40.13(a) nor their transfer under 10 CFR 40.51.

### C.4 Relationship to the Requirements of 10 CFR Part 20, Subpart E

Subpart E to 10 CFR Part 20 contains radiological criteria for license termination. Section 20.1402 of Subpart E contains radiological criteria for unrestricted use of a site based on a dose criterion of 25 mrem/yr (0.25 mSv/yr) and, in addition, provisions that the residual radioactivity has been reduced to levels that are ALARA. These criteria for license termination were based on considerations (62 FR 39058; July 21, 1997) related to providing a sufficient and ample margin of safety below the NRC's public dose limit of 100 mrem/yr (1 mSv/yr) and cost-benefit considerations of further reducing the dose below 25 mrem/yr (0.25 mSv/yr) for lands and structures.

The June 1999 Issues Paper, released to solicit early comment on this rulemaking on disposition of solid materials, addressed the different circumstances and issues between Subpart E and the disposition of solid material. Specifically, it was noted that the Subpart E dose limit of 25 mrem/yr (0.25 mSv/yr) is intended to apply to termination of a license, at a specific point in time, and disposition of structures and land whereas, in contrast, release of

solid materials could involve periodic releases over the lifetime of the facility. In developing the dose criterion for this rulemaking, as discussed in Section III.B.2, the NRC considered factors such as: more limiting fractions of the public dose limit to account for the potential for multiple releases and exposures; similarity to the range of requirements in 10 CFR Part 50, Appendix I, for other media such as air and liquid effluents; and consideration of NCRP Report Nos. 116 and 141 regarding the negligible risk associated with a 1 mrem/yr (0.01 mSv/yr) standard.

Solid material released from the site during facility operations and during the active decommissioning period would be covered by the provisions of this amendment. As indicated in 10 CFR 20.1401 and 20.1402, facilities and sites released from a license are covered by the provisions of 10 CFR Part 20, Subpart E and their disposition after license termination would not be subject to the elements of this proposed amendment (i.e., the dose criterion, allowed disposition path, radionuclide concentration, or recordkeeping provisions) because the site would no longer be licensed.

#### D. Implementation Schedules

Licensees will need adequate time to implement changes in their radiation protection programs as a result of this proposed amendment when it becomes final. Such changes would include changes in survey methodology, including the setpoint for radionuclide concentrations allowed for release, and recordkeeping provisions. Additionally, some licensees (primarily those holding Part 30 licenses) may have existing license conditions that specify radionuclide concentration release levels based on the existing guidelines noted in Section II.A of this document. If the existing license conditions are less restrictive than the Commission

regulations, then licensees will be required to comply with the proposed provisions of this rulemaking when they become final by seeking amendments to their licenses. At this time, the NRC is not proposing an implementation schedule for when licensee would need to comply with the rule when it becomes final. However, as noted in Section IV.D of this document, the NRC is inviting comments on the time period for implementing these changes, including specific information on timing and economic considerations.

#### E. Consideration of Other Alternate Approaches for Disposition of Solid Materials

The National Technology Transfer and Advancement Act of 1995 (NTTAA), Pub. L. 104-113, requires all Federal agencies and departments, in carrying out policy objectives or activities, to use technical standards developed or adopted by voluntary consensus standards bodies, except when utilization of such standards “is inconsistent with applicable law or otherwise impractical.” Therefore, the NRC considered the use of ANSI N13.12 which is a technical standard, issued by the ANSI, presenting screening clearance criteria for unrestricted release of solid materials based on an annual dose limit of 1 mrem (0.01 mSv/yr). However, for the reasons discussed in Sections III.A and III.B of this document, the NRC is proposing an amendment to limit disposition of solid materials, based on a 1 mrem/yr (0.01 mSv/yr) dose criterion (similar to ANSI N13.12) and an associated set of radionuclide concentrations based on RS-G-1.7. The NRC’s approach incorporates elements of ANSI N13.12, but does not use it in its entirety. The NRC regards this approach as appropriate given the range of considerations discussed above. Other reasons for why the ANSI N13.12 was not used in its entirety are discussed in the DGEIS; the NRC believes that use of this ANSI standard is impractical for the reasons noted in the DGEIS.

Another alternate discussed by some stakeholders, and referred to in the National Academies Report, was recapture of solid material already released from licensed facilities. As noted in Section I, The NRC's current approach allows release of solid material if it is below a measurement-based guideline. Some stakeholders requested that the NRC include, as one of its alternatives, review of previous releases and their recapture. However, the NRC is not proceeding with this approach as part of this rulemaking for two reasons. First, as noted in the National Academies Report, the NRC's current practice protects public health; therefore, attempting to find and retrieve materials released under the current approach would be unduly burdensome given the National Academies' finding. Second, because this proposed amendment would specify criteria for disposition of material currently at licensed facilities and available for release, the recapture approach is not within the scope of this rulemaking.

#### **IV. Request for Specific Comments**

The NRC is requesting comment on all issues related to this proposed rulemaking and comments can be sent to the ADDRESSES section of this document. In addition, the NRC is specifically requesting comments on the following items.

##### A. Landfill Disposal

As noted in Section III.B.1.2.2, the NRC is interested in stakeholder input regarding landfill disposal practices. Input on the following questions related to this issue is requested.

1) What are practices at the various types of RCRA Subtitle D landfills (MSWLFs, industrial, construction and demolition) with regard to recycle of material sent for burial at the landfill, i.e., is it likely that material sent to the different types of RCRA Subtitle D landfills for burial would be removed from the landfill and sold or sent for other uses or recycle?

2) How can the potential for recycle of solid materials from the RCRA Subtitle D landfills be minimized?

#### B. Surface Radionuclide Concentration Levels

Section III.B.3.1.2 indicates that the NRC has based the surface radionuclide concentration levels in Table 2 of proposed Appendix E to 10 CFR Part 20 on the definition in DOT's 49 CFR 173.403 for surface concentrations not requiring DOT regulation. Using the DOT values provides consistency between these two Federal agencies regarding material needing no further regulation, although it is noted there that this approach may introduce additional conservatism for certain radionuclides. Input on the following questions related to this issue is requested:

1) Should the NRC, instead of using the DOT values, base its surface concentrations on levels derived directly from the volume concentrations in IAEA's RS-G-1.7 using mass-to-surface-ratios? If so, and given the wide range of components and materials, as well as the diverse range of NRC licensees, covered by this rule, what would be a reasonable approach for deriving surface concentrations, keeping in mind the need for a relatively simple screening table of release values to be used in Appendix E to 10 CFR Part 20?

2) NRC's preliminary estimates for surface concentrations, derived directly from the RS-G-1.7 volume concentrations, indicates that the surface concentration for some radionuclides corresponding to 1 mrem/yr (0.01 mSv/yr) may be in excess of the DOT definition for material requiring regulation in transport. Releases of such material may require placarding, labeling, or recordkeeping under the DOT regulations. What would be the implications to stakeholders in releasing materials if the NRC's table of surface release concentrations contained levels in excess of the DOT values?

### C. Scope of the rule.

Section III.C.1 indicates that the scope of the proposed amendment includes materials in restricted and impacted areas of a licensed facility. Section III.C.1 also indicates that the NRC is considering whether it is more appropriate for the scope to include only impacted areas. Input on the following questions related to this issue is requested:

1) How does the burden on licensees, for an amendment requiring both restricted and impacted areas be part of its scope, compare to an amendment requiring just impacted areas? Provide specific information on how an amendment that limited its scope to material in impacted areas would be beneficial in licensed operations.

2) How would a licensee provide assurance that material from non-impacted areas did not have residual radioactivity resulting from licensed operations? How would a licensee provide assurance that non-impacted areas did not become impacted?

#### D. Implementation schedules

As noted in Section III.D, the NRC is interested in stakeholder input regarding the schedule for implementation of the requirements of this proposed amendment at such time as it becomes final. Input on the following questions related to this issue is requested.

1) What would be an appropriate time period for the effective date of implementation of this proposed amendment at such time as it becomes final? In your response provide specific rationale related to time and economic considerations.

2) What would be an appropriate time period for amending license conditions containing requirements for release of solid materials to make them comply with the provisions of this proposed amendment at such time as it becomes final? In your response provide specific rationale related to time and economic considerations.

#### **V. Discussion of Stakeholder Input on Other Issues**

In addition to the discussion of alternatives for disposition of solid materials, stakeholders also provided comments on other issues associated with this rulemaking, including: stakeholder involvement in the rulemaking process, development of NRC's technical basis, the relationship to the Below Regulatory Concern (BRC) Policy, and State, other Federal agency, and international related issues. Stakeholder comments are summarized in the DGEIS, Appendix A; a discussion of considerations related to those concerns follows.

## **A. Stakeholder Involvement in the Rulemaking Process:**

As discussed briefly in Section II.D, the NRC has had a continuing effort, both early in the process and during its decision-making, to seek stakeholder input on major issues associated with this effort. This has included release of several documents, including an NRC Issues Paper issued in June 1999, a scoping Federal Register document (68 FR 9595; February 28, 2003), and a web-based Information Packet issued in February 2003. These documents invited written and/or electronic comment from stakeholders on the issues. Also, 12 public meetings were conducted between September 1999 and February 2005 with stakeholders, including three meetings convened by the National Academies as part of their study on this subject. The NRC has considered a range of viewpoints presented at the meetings from a diversity of stakeholders on alternatives and possible impacts. Stakeholders included representatives from metals and cement industries; citizen and environmental groups; licensees and licensee organizations; State and Federal agencies; Tribal organizations; and organizations such as the HPS. Summaries of stakeholder input received through these forums are presented in various documents, including Appendix A of the DGEIS, in the background section of the NRC's website at [www.nrc.gov/materials.html](http://www.nrc.gov/materials.html), and in NUREG/CR-6682.

The NRC Issues Paper stated that the NRC was seeking public comment and participation at a series of meetings before the start of any formal rulemaking to solicit early and active public participation on major issues associated with disposition of solid materials. The objectives of these meetings were to identify relevant issues, exchange information on these issues, and identify concerns and areas of disagreement and approaches for resolution.

Despite a boycott by citizens groups of the first two meetings in Fall 1999, the NRC held two additional meetings that were attended by several citizens groups. In addition, the meetings during 1999 were attended by representatives of metals industries and cement industries, both of whom expressed concern about aspects of certain alternatives. The meetings were also attended by State and landfill groups who provided information on issues related to landfill disposal. Also, various licensee groups (including representatives from university laboratories and hospitals) provided input on unique issues associated with disposition of solid material at their facilities. In addition to the four public meetings held in 1999, the NRC also received over 900 written comment letters and emails on the June 1999 Issues Paper from a range of stakeholder groups, including citizens groups and individuals. The NRC held follow-up meetings in January 2000 to specifically hear from representatives of the metals industry about their concerns related to clearance and in May 2000, at which time the NRC invited 14 different stakeholder groups (including several citizens groups, the metals industry, States, and licensees) to a Commission meeting to provide representatives of those groups the opportunity to present their views directly to the Commissioners.

The Commission sought further information on this subject in May 2000 by requesting the National Academies to provide an independent analysis of alternatives for disposition of solid materials. As discussed in Section II.D of this document, the National Academies held three meetings with a range of stakeholder groups in 2001 and provided the Commission with a report on its findings, including nine recommendations, in March 2002. Subsequently, the NRC sought additional public comment on alternatives for disposition of solid materials in a FRN issued February 28, 2003 (68 FR 9595). Stakeholders also were invited to comment via an "Information Packet" placed on the NRC's website in February 2003. The NRC held a workshop in May 2003 at which 30 invited stakeholder groups provided their additional views on

alternatives. Also, the NRC held an additional meeting open to the public, at which the Nuclear Energy Institute, representing utility licensees, at their request, was afforded the opportunity to provide additional information about their views on disposition of solid materials. The NRC also received over 2600 written comment letters and e-mails in response to the February 28, 2003, FRN from a range of stakeholder groups.

Thus, the NRC has participated in 11 meetings with a range of stakeholder groups and has received over 3500 comment letters and emails representing viewpoints from a wide range of stakeholders. Information gathered in this effort has included: identification of economic concerns by the metals and cement industries; public concern over the potential presence of radioactivity in solid materials, even in very low amounts, from licensed facilities in general commerce and consumer products; reference to various health studies regarding low doses of radioactivity; identification of practical issues of how solid materials are handled at the range of facilities that the NRC licenses, including small licensees like university laboratories and hospitals and larger ones like manufacturers and power reactors; issues of feasibility related to limiting solid materials to only a selected set of defined uses; and viewpoints on both sides of the issue associated with disposal of solid materials in RCRA landfills at radioactivity levels near 1 mrem/yr (0.01 mSv/yr). The NRC has benefitted from this process in the knowledge that it has now regarding issues and stakeholder viewpoints related to disposition of solid materials and appreciates greatly those who took the time to participate in this process.

The NRC is now issuing this proposed amendment which it believes represents a reasonable position based on the information gathering process it has conducted. The information used in the NRC's decision-making has included input from stakeholders, review of reports by other organizations in this area, review and comparison with other related health

standards, development of technical bases (including dose analysis and survey procedures), and NEPA analysis on disposition of solid materials. The NRC is issuing this proposed amendment and the DGEIS for public comment and also plans to discuss this issue further with stakeholders to solicit additional input on these documents.

## **B. Development of Technical Basis and DGEIS.**

The NRC has expended substantial effort to review and develop technical information to be able to provide a complete analysis of all reasonable alternatives for disposition of solid materials. Principal factors affecting decisions on alternatives could include impacts on human health and the environment, cost-benefit considerations, impacts on other industries, and the capability to survey the material for the various alternatives. To support decision-making on all alternatives, technical information has been developed which includes inventories of solid material potentially available for release; assessment of individual and collective radiation doses which could occur depending on the alternative selected, including the potential for exposure to multiple sources; and costs associated with handling, surveying, transport, disposal, and possible uses of these materials. The NRC also developed information on methods that could be used for performing radiation surveys of solid material available for release. Solid materials analyzed as part of this effort have included metals, concrete, soil, and ordinary trash.

A principal support document prepared by the NRC as part of the technical basis for the proposed amendment is NUREG-1640 (Volumes 1 and 3, published September 2003; Volume 2, published October 2004; Volume 4, published May 2004). NUREG-1640 includes an assessment of inventory of solid materials at licensed facilities covered by this rulemaking and

those solid materials potentially available to be released or sent to a LLW disposal site under a prohibition alternative. NUREG-1640 also assesses pathways by which an individual could be exposed as a result of release of solid materials, either for general or limited recycle, reuse, or disposal in a landfill. As discussed in Section III.B.3.1, in an effort separate from the development of NUREG-1640, the IAEA developed RS-G-1.7 to assist countries in setting standards for exemption, exclusion, and clearance from regulatory control. RS-G-1.7 is based on a consideration of various exposure pathways, scenarios, and potential receptors of released materials developed to encompass typical exposure situations for all material types. The NRC has reviewed IAEA's RS-G-1.7 concentrations and, as discussed in the DGEIS, found these concentrations reasonably consistent with NUREG-1640. Dose pathways from released material for individuals for the prohibition alternative are not explicitly analyzed in NUREG-1640 or RS-G-1.7 because there would not be release pathways; pathways related to prohibition were analyzed in the Final Environmental Impact Statement on 10 CFR Part 61 "Licensing Requirements for Land Disposal of Radioactive Waste" (NUREG-0945, November 1982).

Draft report NUREG-1640, Supplement 1, extends the information already contained in NUREG-1640 to include other materials (trash and soil) and dispositions (re-use of materials). Additionally, draft report NUREG-1761 provides technical information on survey approaches for the control of solid material, including considerations for different types of material and the presence of multiple radionuclides. NUREG-1761 supplements the information presented in NUREG-1813. Comments on both of these draft reports may be submitted as specified in the ADDRESSES section of this document.

The DGEIS being issued with this proposed rule, includes an analysis of the impacts (including collective doses) and costs associated with all of the alternatives for disposition of

solid materials. The analyses and results are available for public review and comment. Also, based on the analyses conducted, the NRC has issued a regulatory guidance document (NUREG-1813) for assuring that radiation surveys are conducted in a manner that will confirm that the licensee has met the criteria of this proposed amendment. NUREG-1813 is also available for public review and comment. With the issuance of these documents for review and comment, the NRC believes that an appropriate basis exists to make a decision regarding criteria for disposition of solid materials and can proceed with this proposed rule.

NUREG-1640 and NUREG-1761, and the DGEIS (NUREG-1812) and regulatory guidance (NUREG-1813), are available on the NRC website at [www.nrc.gov/materials.html](http://www.nrc.gov/materials.html).

Some stakeholders stated that NUREG-1640 should not be used in any further analysis or decision-making because the initial contractor in its preparation, SAIC, was found to have an organizational conflict of interest (COI). However, the NRC has peer reviewed and verified the scientific accuracy of NUREG-1640. Based on this review, the NRC believes that the final NUREG-1640 provides an appropriate basis for analysis of potential exposures and for decision-making on alternatives. The NRC's peer review included an independent technical review of draft NUREG-1640 by the Center for Nuclear Waste Regulatory Analyses (CNWRA) which found that SAIC performed a quality analysis in draft NUREG-1640. In addition, the National Academies reviewed NUREG-1640 along with other technical documents and stated in its report that draft NUREG-1640 provides a "conceptual framework that best represents the current state of the art in risk assessment, particularly with regard to its incorporation of formal uncertainty," as judged by recommendations of the National Academies study committee and other committees of the National Research Council. The National Academies Report also noted the questions of contractor organizational COI associated with development of the draft

NUREG-1640; however, the report also noted that the mathematics and completeness of scenarios considered in draft NUREG-1640 had been verified through an audit carried out by another NRC contractor. The National Academies also conducted its own review that confirmed the reasonableness of several dose factor analyses although its report did note certain improvements that were needed to the draft NUREG-1640, including a thorough review of certain parameters, scenarios, and assumptions to complete the reassessment of draft NUREG-1640. Partly in response to the CNWRA and National Academies reviews, the NRC had its new contractor, SC&A, review and revise various parameters, scenarios, and assumptions, and following an additional peer review the final NUREG-1640 was issued, in four volumes from June 2003 to October 2004. Based on these various independent reviews, the NRC considers NUREG-1640 appropriate for use in its further analyses and rulemaking. As discussed in Section III.B.3.1 of this document, the NRC has used NUREG-1640 both to review the content of IAEA's RS-G-1.7 and to supplement its radionuclide concentration tables. The methods of NUREG-1640 could also be used as part of a licensee's submittal under the case-specific provisions of this proposed rule.

### **C. Relationship of This Rulemaking to the NRC's Below Regulatory Concern (BRC) Policy**

Some stakeholders stated that this effort is similar to the NRC's previous efforts to establish a BRC policy<sup>8</sup> in the early 1990s. These stakeholders also stated that the public had

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<sup>8</sup> The BRC policy was an effort by the NRC to develop a general statement of policy (55 FR 27522; July 3, 1990) that would provide a broad framework for making decisions on exempting certain practices involving small quantities of radioactive material from regulatory control, including recycle of solid materials. There was extensive public comment from licensees, the States, and citizens groups when the BRC policy was issued. The Commission decided that a more extensive public involvement process in establishing such a decision framework would be beneficial and instituted a moratorium on the BRC Policy in July 1991. In October 1992, Congress enacted the Energy Policy Act of 1992 which revoked the BRC Policy Statement.

opposed the BRC policy, which helped result in promulgation of the Energy Policy Act in 1992 that revoked the BRC policy.

Although the general subject matter of this rulemaking is similar to that of the BRC policy (e.g., to provide a clear, consistent, regulatory framework for regulating the disposition of solid materials in a manner that ensures protection of public health and safety), the NRC's current use of a rulemaking process to establish a regulatory basis is unlike the broad policy-setting approach of the BRC policy, which initially sought to establish a policy on releases prior to a full Administrative Procedure Act (APA) process. The NRC's current rulemaking process (as discussed in Section VI.A of this document) has had, and continues to include, stakeholder participation in consideration of alternatives under the APA and under NEPA. This rulemaking also has included enhanced public participation in the form of several public meetings and review by the National Academies.

#### **D. Other Federal Agency, State, and International Interfaces**

As a means of including views from other agencies in this process, DOE, EPA, and State agencies have been represented at the stakeholder meetings. The DOE has a separate effort to disposition scrap metal from DOE facilities. The NRC's effort is for solid materials being considered for disposition from NRC/Agreement State licensed facilities. Materials from DOE facilities that are also NRC licensees were included in the NRC's analysis in the DGEIS. The

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Subsequently, the NRC envisioned conducting rulemakings to implement some of the approaches of the BRC policy through the Administrative Procedure Act process. The license termination rulemaking completed in 1997 was an example of such a rulemaking (62 FR 39058; July 21, 1997).

NRC has worked with the EPA to develop technical bases on estimating exposures from various scenarios and pathways that could result from release of solid materials. In addition, the NRC has reviewed various EPA and State regulations and documents regarding landfill requirements, and has met with the EPA to discuss requirements in this area,

Input from these agencies have been used in the development of various parts of this rulemaking including the proposed amendment and draft NUREG-1813. In addition, DOE, EPA, and the State of Massachusetts (identified as a State representative by the Conference of Radiation Control Program Directors and the Organization of Agreement States) have been cooperating agencies in the development of the DGEIS.

The NRC has included volumetric radionuclide concentrations taken from IAEA's RS-G-1.7 in this proposed amendment to provide for levels that result in doses that meet the 1 mrem/yr (0.01 mSv/yr) dose criterion. There also could be potential issues relating to export-import of materials; however, the NRC's regulations in 10 CFR Part 110 already contain requirements for export and import of material. Today's proposed amendments do not change those requirements or the procedures associated with them.

An additional area where the NRC considered Federal agency interface is related to potential issues with transport regulations issued by the DOT. Solid materials released from further licensed control by the NRC under this proposed amendment will likely be transported in a variety of manners, and there needs to be consistency between NRC's requirements and the DOT's requirements in 49 CFR Part 173 for transport of material. Section III.B.3.1.2 of this document provides further discussion of these interfaces.

## VI Section-by-Section Analysis of Proposed Rule

### Section 20.1003 Definitions.

This section would be amended to add definitions of the terms “impacted area,” “process materials,” “reuse,” “soil,” “soil-like materials,” and “solid materials.”

The term “impacted area” would be added to 10 CFR Part 20 to reflect the origin of the solid materials that are the subject of this rule. This definition is consistent with the definition of “impacted area” in 10 CFR Part 50.

The term “reuse” would be added to reflect the NRC proposed disposition path of limited disposition alternative. Certain solid materials may be released in their original form for their original intended purpose as indicated in the proposed amendment (*e.g.*, scaffolds, cranes, forklifts, hand tools, testing equipment, etc.).

The terms “soils,” “soil-like materials,” and “process materials” would be added to describe the types of materials that would be dispositioned under proposed 10 CFR 20.2009. Proposed § 20.2009 would ensure that these materials could be dispositioned on a case-by-case basis with the same dose limit as solid material. Even though these types of materials are considered solid in form, they were not analyzed in the DGEIS and would not be considered as material that can be dispositioned under 10 CFR 20.2008.

The term “solid materials” would be added to distinguish such solid material that would be regulated under this action based on the analysis made in the DGEIS and supporting technical basis.

#### Section 20.2001 General requirements.

This section would be amended to reflect additional disposition options under § 20.2008 for solid material, § 20.2009 for soils, soil-like materials, and process materials, and for case-specific review requirements for disposition of these various materials. Sections 20.2008 and 20.2009 would be included in the list of referenced sections in § 20.2001(a)(4).

#### Section 20.2008 Limited disposition of solid material.

Section 20.2008 includes requirements for the limited disposition of solid material. The effect of this requirement is to exempt material released under § 20.2008 from further NRC licensing and regulatory requirements. Licensees meeting the requirements set forth in §§ 20.2008(b) and 20.2008(c) can release solid material without further Commission approval.

#### Section 20.2008(a).

This paragraph would be added to indicate a dose criterion of 1 mrem/yr (0.01 mSv/yr), total effective dose equivalent, for limited disposition that is well below levels established in 10 CFR Part 20 to ensure adequate protection of public health and safety for disposition of solid

material. This dose is consistent with other radiation and chemical protection standards and can be modeled and verified by measurement. The discussion regarding the proposed dose criterion can be found in Section III.B.2.

#### Section 20.2008(b).

This paragraph introduces the various solid material disposition paths permitted under the proposed rule. New §§ 20.2008(b)(1), 20.2008(b)(2), 20.2008(b)(3), and 20.2008(b)(4) provide the acceptable disposition paths for release of solid materials. Section 20.2008(b)(1) would allow for disposition of solid materials by burial in an EPA or State authorized RCRA landfill. Proposed §§ 20.2008(b)(2), 20.2008(b)(3), and 20.2008(b)(4) allow for disposition in a set of defined non-licensed end uses. Section 20.2008(b)(2) would allow the release of concrete for use in road bed construction. Section 20.2008(b)(3) would allow the reuse of solid materials, equipment, and tools in their original form in industrial or construction settings for their original intended design purpose and function. It is intended that these particular materials would only be reused in industrial and construction settings.

Section 20.2008(b)(4) would be added to the regulations to differentiate between the larger, more stationary pieces of material that would be reused in § 20.2008(b)(3) and the equipment and tools that would be removed from the restricted and/or impacted areas by an individual as part of the routine conduct of work. It is intended that these materials would be reused in their original form for their original intended design purpose and function. These equipment and tools that would be the subject of § 20.2008(b)(4) would not be required to have as detailed recordkeeping requirements as the material described in § 20.2008(b)(3). This

difference in requirements accounts for the difficulty in trying to direct the equipment and tools under § 20.2008(b)(4) to an industrial/construction use; further, maintaining records of such transfers would be unduly burdensome due to the very low risk involved.

#### Section 20.2008(c).

New § 20.2008(c) would reference tables of volumetric and surface radionuclide concentration levels for solid materials. Solid material would be considered acceptable for release if its radionuclide concentrations do not exceed the levels in Table 1 or Table 2 of Appendix E to 10 CFR Part 20, as applicable. Discussion regarding the use of the radionuclide concentrations can be found in Section III.B.3. The volumetric concentration level in Table 1 were taken from IAEA's RS-G-1.7. The surface concentration level in Table 2 are consistent with DOT regulations. When using Table 1, if more than one radionuclide is released, the licensee shall determine the fraction of the limit in Table 1 represented by the concentration of each radionuclide; the sum of the fractions for each radionuclide must not exceed unity.

#### Section 20.2009.

This new section would be added to 10 CFR Part 20 to include provisions how a licensee would apply to the NRC for a case-specific approval for disposition of solid materials, soil, soil-like materials, and process materials, and would outline the requirements for a case-specific analysis. The effect of this requirement is to exempt material released under § 20.2009 from further NRC licensing and regulatory requirements.

Section 20.2009(a).

This paragraph would stipulate how and at what dose level soils, soil-like material, and process material could be dispositioned. Because an analysis of this type of material was not included in the DGEIS, a case-specific review and approval would be required. Each application for case-specific approval must include the information in § 20.2009(d).

Section 20.2009(a)(1).

New § 20.2009(a)(1) would include a dose criterion of 1 mrem/yr (0.01 mSv/yr), total effective dose equivalent, for disposition of soils, soil-like material, and process material, consistent with other radiation and chemical protection standards, and can be modeled and readily verified by measurement. Discussion regarding the proposed dose criteria can be found in Section III.B.2.

Section 20.2009(a)(2).

This paragraph would allow for disposition of soils, soil-like material, and process material only in an EPA or State authorized RCRA landfill. Licensees that want to disposition soils, soil-like material, and process material under this provision would have to meet the requirement in § 20.2009(d).

#### Section 20.2009(b).

This paragraph would stipulate that licensees who disposition soils, soil-like material, and process material into disposition paths other than the path indicated in § 20.2009(a)(2) (i.e., to landfills) would need a case-specific review because analysis of other pathways for these types of material were not included in the DGEIS. The dose criterion of 1 mrem/yr (0.01 mSv/yr) would have to be met to disposition soil, soil-like materials, and process materials under provisions of § 20.2009(b). Licensees who disposition these materials must also meet the requirements of § 20.2009(d).

#### Section 20.2009(c).

This paragraph would address case-specific approval for procedures not otherwise authorized in §§ 20.2008(b) or §§ 20.2008(c). A licensee may propose an alternative disposition path than in § 20.2008(b) for solid materials and/or a different radionuclide concentration level from that listed in Table 1 or Table 2 of Appendix E to 10 CFR Part 20, as applicable, as long as the 1 mrem/yr (0.01 mSv/yr) dose criterion is met. Licensees who use an alternative path would also have to meet the requirements of § 20.2009(d).

#### Section 20.2009(d).

This new paragraph would describe the requirements needed for a case-specific application for proposals made under §§ 20.2009(a), 20.2009(b), and 20.2009(c). These requirements are modeled after existing language in § 20.2002.

Section 20.2009(d)(1).

This new paragraph would ensure that a description of the material (including physical, chemical, and radiological properties), the way the material would be dispositioned, and a description of the nature of controls or restrictions to prevent the material from an unrestricted release would be included in an application. Similar text is found in § 20.2002(a).

Section 20.2009(d)(2).

This paragraph would require an analysis and evaluation of pertinent information on the nature of the environment. Similar text is found in § 20.2002(b).

Section 20.2009(d)(3).

This paragraph would be added to ensure that the nature and location of other potentially affected licensed and unlicensed facilities would be described in the application. Similar text is found in the current disposal requirements in § 20.2002(c).

Section 20.2009(d)(4).

This paragraph would be added to require doses to be maintained within the dose limit in § 20.2008(a) for solid materials or in § 20.2009(a)(1) for soils, soil-like material, and process

material. The regulation would restrict licensees to the 1 mrem/yr (0.01 mSv/yr) dose/yr criteria for limited disposition of these materials.

Section 20.2108(a) Records of waste disposal and material disposition.

The title of this section would be revised to indicate that records need to be maintained for material that is dispositioned as well as disposed. This section would be revised to include §§ 20.2108(a)(1), (2), and (3). Section 20.2108(a)(1) would include the requirements that were in the previous § 20.2108(a), which requires licensees to maintain records of disposal of licensed materials made under §§ 20.2002, 20.2003, 20.2004, 20.2005, 10 CFR Part 61 and disposal by burial in soil, including burials authorized before January 28, 1981.<sup>6</sup>

A new § 20.2108(a)(2) would include recordkeeping requirements for materials dispositioned under §§ 20.2008(b)(1), 20.2008(b)(2), 20.2008(b)(3), and 20.2009. Licensees would be required to maintain records of the types and amounts of material shipped, the destination of the material, the date it was delivered to its destination, and the radionuclides in the material released, in a format indicating that the released residual radioactivity was in compliance with the volumetric concentration levels specified in Table 1 of Appendix E to Part 20 or the surface concentration levels specified in Table 2 of Appendix E to Part 20, as applicable. These records would aid in providing reasonable assurance that the material would be delivered to one of the authorized destinations noted in §§ 20.2008(b)(1), 20.2008(b)(2), 20.2008(b)(3), and 20.2009.

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<sup>6</sup>A previous § 20.304 permitted burial of small quantities of licensed materials in soil before January 28, 1981, without specific Commission authorization.

A new § 20.2108(a)(3) would add recordkeeping requirements for materials regulated under § 20.2008(b)(4). Licensees would be required to maintain records of tools and equipment that are removed on a routine basis by an individual from the restricted and/or impacted areas. Those records would include a listing of the radionuclides released in a format indicating that residual radioactivity was in compliance with the volumetric or surface concentration levels specified in Tables 1 or 2, as applicable, of Appendix E to Part 20. These records are deemed appropriate for these equipment and tools given the very low risk involved, as noted in Section III.B.1.2.1.

Section 20.2108(b) would be revised to require licensees to retain records for the materials regulated under §§ 20.2108(a)(1) and 20.2108(a)(2) until the Commission terminates the license. Requirements for disposition of these records prior to license termination remain unchanged. A new sentence would be added to indicate that the retention for records material regulated under § 20.2108(a)(3) would only be for three years after the record is made. This retention period was determined to be adequate because it is similar to the timeframe set for retaining records of surveys under § 20.2103(a).

#### APPENDIX E TO PART 20 - SOLID MATERIAL RELEASE CONCENTRATION LEVELS

A new appendix, Appendix E, would be added to 10 CFR Part 20 to include concentration levels for solid material release. Appendix E would contain Table 1 and Table 2 which are tables of volumetric and surface concentration levels, respectively.

## TABLE 1 “VOLUMETRIC CONCENTRATION LEVELS”

A new section would be added to introduce Table 1 which includes measurable volumetric radionuclide concentration release levels for solid material applicable to the limited disposition of solid materials under § 20.2008. Solid material would be considered acceptable for release if its radionuclide concentrations do not exceed the levels in Table 1. The levels in Table 1 for man-made radionuclides are taken from the International Atomic Energy Agency’s report RS-G-1.7, “Application of the Concepts of Exclusion, Exemption, and Clearance.” The levels in Table 1 for source material and special nuclear material are based on NUREG-1640, “Radiological Assessments for Clearance of Materials from Nuclear Facilities.”

## TABLE 2 “SURFACE CONCENTRATION LEVELS”

A new section would be added to introduce Table 2 which includes measurable surface radionuclide concentration release levels for solid material applicable to the limited disposition of solid materials under § 20.2008. Solid material would be considered acceptable for release if its radionuclide concentrations do not exceed the levels in Table 2. The levels in Table 2 are based on the definition in 49 CFR 173.403 for surface concentrations not requiring DOT regulation to provide consistency between these two Federal agencies regarding material needing no further regulation.

## NOTATION

This section would be added to state that the levels in Tables 1 and 2 are presented in the computer “E” notation. This is the same notation as used for Tables 1, 2, and 3 in Appendix B to 10 CFR Part 20.

## **VII. Plain Language**

The Presidential memorandum entitled "Plain Language in Government Writing" (63 FR 31883; June 10, 1998), directed that the Government's writing be in plain language. The NRC requests comments on the proposed rule specifically with respect to the clarity and effectiveness of the language used. Comments should be sent using one of the methods detailed under the ADDRESSES heading of the preamble to this proposed rule.

## **VIII. Availability of Documents**

The NRC is making the documents identified below available to interested persons through one or more of the following:

Public Document Room (PDR). The NRC's Public Document Room is located at 11555 Rockville Pike, Public File Area O-1 F21, Rockville, MD 20082. Copies of publicly available documents related to this rulemaking can be viewed electronically on public computers in the PDR. The PDR reproduction contractor will make copies of documents for a fee.

Rulemaking Website (Web). The NRC's interactive rulemaking Website is located at <http://ruleforum.llnl.gov>. Selected documents may be viewed and downloaded electronically via this Website.

Public Electronic Reading Room (ADAMS). The NRC's public Electronic Reading Room is located at <http://www.nrc.gov/reading-rm/adams.html>. Through this site, the public can gain access to ADAMS, which provides text and image files of the NRC's public documents.

<b>Document</b>	<b>PDR</b>	<b>Web</b>	<b>ADAMS</b>
Proposed Rule <sup>7</sup>	x	x	ML # - TBD
Draft GEIS, NUREG-1812 <sup>8</sup>	x	x	ML# - TBD
Draft Regulatory Guidance, NUREG-1813 <sup>8</sup>	x	x	ML# - TBD
Draft Regulatory Analysis <sup>8</sup>	x	x	ML# - TBD
NUREG-1640, Volumes 1-4	x	x	ML# - TBD
Draft NUREG-1640, Supplement 1 <sup>8</sup>	x	x	ML# - TBD
Draft NUREG-1761 <sup>8</sup>	x	x	ML# - TBD
IAEA RS-G-1.7	x	x	ML# - TBD

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<sup>7</sup> Comments on this proposed rule may be submitted as specified in the ADDRESSES section of this document.

<sup>8</sup> Comments on this draft report may be submitted as specified in the ADDRESSES section of this document.

## **IX. Agreement State Compatibility**

Under the “Policy Statement on Adequacy and Compatibility of Agreement State Programs” which became effective on September 3, 1997 (62 FR 46517), NRC program elements (including regulations) are placed into four compatibility categories. In addition, NRC program elements also are identified as having particular health and safety significance or as being reserved solely to the NRC. Compatibility Category A are those program elements that are basic radiation protection standards and scientific terms and definitions that are necessary to understand radiation protection concepts. An Agreement State should adopt Category A program elements in an essentially identical manner to provide uniformity in the regulation of solid material on a nationwide basis. Compatibility Category B are those program elements that apply to activities that have direct and significant effects in multiple jurisdictions. An Agreement State should adopt Category B program elements in an essentially identical manner. Compatibility Category C are those program elements that do not meet the criteria of Category A or B, but the essential objectives of which an Agreement State should adopt to avoid conflict, duplication, gaps, or other conditions that would jeopardize an orderly pattern in the regulation of solid material on a nationwide basis. An Agreement State should adopt the essential objectives of the Category C program elements. Compatibility Category D are those program elements that do not meet any of the criteria of Category A, B, or C, and thus, do not need to be adopted by Agreement States for purpose of compatibility.

The compatibility characterization of the existing sections in Part 20 that were proposed to be amended based on the implementation of this rule, remain the same. Section 20.2001, General Requirements, was categorized as a Category C prior to the proposed amendments and

remains a Category C based on the result from implementation of the procedure in Management Directive 5.9, “Adequacy and Compatibility of Agreement States”. A Category C compatibility ensures that Agreement States adopt the essential objectives of the provision in order to eliminate confusion regarding the disposition of solid material on a nationwide basis. All of the new definitions included in 10 CFR 20.1003, Definitions, have been designated as Category A compatibilities. According to Management Directive 5.9, these are scientific definitions that are necessary to understand radiation protection concepts and are needed to ensure uniformity in the implementation and understanding of these key concepts on a nationwide basis.

The new sections that have been added to 10 CFR 20.2008, Dose Limits and Compliance for Release of Solid Materials, and 10 CFR 20.2009, Case-specific Review Requirements for Disposition, have been designated Category B based on the results from following the procedure in Management Directive 5.9. These new sections, 10 CFR 20.2008 and 20.2009, could have transboundary impacts with respect to transporting or distributing of such material, if not designated as Category B. Similarly, the new Appendix E, referred to by 10 CFR 20.2008, has been designated as Category B; 10 CFR 20.2008 indicates that solid material would be considered acceptable for release if its volumetric and surface radionuclide concentrations do not exceed the levels in Tables 1 and Table 2, as applicable, of Appendix E. The recordkeeping requirements in 10 CFR 20.2108(a) are categorized as Category C to ensure that licensees in Agreement States keep a minimum set of records important to keeping track of where the material goes.

## **X. Draft Generic Environmental Impact Statement: Availability**

As required by the National Environmental Policy Act of 1969, as amended, and the NRC's regulations in 10 CFR 51.20, the NRC has prepared a DGEIS (NUREG-1812) for this proposed rule. The DGEIS is available for inspection in the NRC Public Document Room at NRC headquarters in Rockville, Maryland. Single copies of the DGEIS may be obtained by written request or telefax (301-415-2289) from: Office of Information Services, Attention: Reproduction Distribution Services Section, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by e-mail at [distribution@nrc.gov](mailto:distribution@nrc.gov). The DGEIS is also available on the NRC website at [www.nrc.gov/materials.html](http://www.nrc.gov/materials.html). The NRC requests public comment on the DGEIS.

## **XI. Paperwork Reduction Act Statement**

This proposed rule contains amended information collection requirements that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq). This rule has been submitted to the Office of Management and Budget for review and approval of the information collection requirements.

Type of Submission: Revised

Title: 10 CFR Part 20, Radiological Criteria for Controlling the Disposition of Solid Materials, Proposed Rule

Form Number: N/A

How often the information is required: On occasion

Who will be required or asked to report: NRC-licensed Facilities

An estimate of the number of annual responses: 240

The estimated number of annual respondents: 240

An estimate of the total number of hours needed annually to complete the requirement or request: 46,280 (192.8 hours per respondent)

Abstract: The NRC is proposing to amend its standards for protection against radiation in 10 CFR Part 20 to establish criteria for determining if solid materials, soils, soil-like material, and process materials originating in restricted and/or impacted areas of a facility will be considered acceptable for release. The proposed rule would establish requirements for records of disposition of solid materials and soils, soil-like materials, and process materials, to be prepared and retained by licensees, and would establish retention periods for such records.

The U.S. Nuclear Regulatory Commission is seeking public comment on the potential impact of the information collections contained in this proposed rule and on the following issues:

1. Is the proposed information collection necessary for the proper performance of the functions of the NRC, including whether the information will have practical utility?
2. Is the estimate of burden accurate?
3. Is there a way to enhance the quality, utility, and clarity of the information to be collected?
4. How can the burden of the information collection be minimized, including the use of automated collection techniques?

A copy of the OMB clearance package may be viewed free of charge at the NRC Public Document Room, One White Flint North, 11555 Rockville Pike, Room O-1 F21, Rockville, MD 20852. The OMB clearance package and rule are available at the NRC worldwide Web site: <http://www.nrc.gov/public-involve/doc-comment/omb/index.html> for 60 days after the signature date of this notice and are also available at the rule forum site, <http://ruleforum.llnl.gov>.

Send comments on any aspect of these proposed information collections, including suggestions for reducing the burden and on the above issues, by (INSERT DATE 30 DAYS AFTER PUBLICATION IN THE FEDERAL REGISTER) to the Records and FOIA/Privacy Services Branch (T-5 F53), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by Internet electronic mail to [INFOCOLLECTS@NRC.GOV](mailto:INFOCOLLECTS@NRC.GOV) and to the Desk Officer, John A. Asalone, Office of Information and Regulatory Affairs, NEOB-10202, (3150-0014), Office of

Management and Budget, Washington, DC 20503. Comments received after this date will be considered if it is practical to do so, but assurance of consideration cannot be given to comments received after this date. You may also e-mail comments to [John\\_A.\\_Asalone@omb.eop.gov](mailto:John_A._Asalone@omb.eop.gov) or comment by telephone at (202) 395-4650.

#### Public Protection Notification

The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.

### **XII. Regulatory Analysis**

The Commission has prepared a regulatory analysis on this proposed amendment. The analysis examines the costs and benefits of the alternatives considered by the Commission. The analysis is available for inspection in the NRC Public Document Room at NRC headquarters in Rockville, Maryland. Single copies of the regulatory analysis may be obtained by written request from the Regulations and Guidance Branch, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, DC 20555. The regulatory analysis can also be viewed at the NRC's website at [www.nrc.gov/materials.html](http://www.nrc.gov/materials.html). Comments on the draft regulatory analysis may be submitted as specified in the ADDRESSES section of this document.

### **XIII. Regulatory Flexibility Analysis**

The NRC has prepared an initial regulatory analysis of the impact of this proposed rule on small entities (see Section XII of this document). As discussed in Section V of this document, the NRC has had a continuing effort to obtain stakeholder input on major issues associated with this rulemaking and has interacted with a diversity of stakeholders (including representatives from university laboratories, hospitals, manufacturers, etc.) on alternatives and possible impacts. Based on this input, the NRC has developed this proposed rule which would establish requirements that to a large extent formalize existing practices regarding decisions on disposition of solid material. As part of the rulemaking, the NRC is considering ways to minimize unnecessary impacts; for example, Section IV.B of this document specifically requests comment on the scope of material that should be covered by this proposed rule. In addition, because many small entities would have only sealed sources or devices containing sealed sources, there would not be significant effort involved in disposition of solid materials. Therefore, the NRC believes that this proposed rule would not have a significant impact on small entities.

However, most of the data available for the regulatory analysis of this proposed rule is for large entities, which account for the vast majority of materials covered by the proposed rule. Limited data has been available for analysis of small entities. Therefore, the NRC is seeking public comment on the potential impact of the proposed rule on small entities. The NRC particularly desires comment from small entities (small businesses, small organizations, and small jurisdictions under the Regulatory Flexibility Act) as to how the regulations will affect them. In addition to providing comment in response to the request in Section IV.B, these small entities

should specifically discuss information regarding how they currently release materials under NRC's existing guidelines, including—

- (a) The NRC license classification of such entities;
- (b) The types of materials released under existing NRC guidelines and license conditions;
- (c) The frequency and amounts of such releases;
- (d) The radionuclides and range of concentration levels; and
- (e) The destination, end-use, or disposition of the materials.

Comments may be submitted as specified in the ADDRESSES section of this document.

#### **XIV. Backfit Analysis**

The NRC has determined that the backfit rule does not apply to this proposed rule; therefore, a backfit analysis is not required for this proposed amendment because it does not involve any provisions that would impose backfits as defined in 10 CFR 50.109, 70.76, 72.62, and 76.76. The existing regulations in 10 CFR Part 20 provide a framework of radiation standards to ensure the protection of public health and safety from the routine use of materials at

licensed facilities. These standards include a public dose limit and specific dose criteria on certain types of media released from licensed facilities such as liquid effluent releases. Under current regulations, every disposition of solid material requires NRC review and approval. This proposed amendment would establish specific criteria for controlling the disposition of solid materials including a dose limit and radionuclide concentration levels. Solid materials meeting the requirements of the proposed amendment could be dispositioned under the amendment without seeking prior NRC approval. Licensees seeking to disposition solid material not meeting the criteria of the amendment would continue to be required to seek case-specific approval from the NRC. The proposed amendment also includes changes to the information collection and reporting requirements in 10 CFR 20.2108 which are not subject to the provisions of the backfit rule. Accordingly, the proposed rule's provisions do not constitute a backfit and a backfit analysis need not be performed.

## List of Subjects

### 10 CFR Part 20

Byproduct material, Criminal penalties, Licensed material, Nuclear materials, Nuclear power plants and reactors, Occupational safety and health, Packaging and containers, Radiation protection, Reporting and recordkeeping requirements, Source material, Special nuclear material, Waste treatment and disposal.

For the reasons set out in the preamble and under the authority of the Atomic Energy Act of 1954, as amended; the Energy Reorganization Act of 1974, as amended; and 5 U.S.C. 553; the NRC is proposing to adopt the following amendment to 10 CFR Part 20.

## PART 20 - STANDARDS FOR PROTECTION AGAINST RADIATION

1. The authority citation for Part 20 continues to read as follows:

AUTHORITY: Secs. 53, 63, 65, 81, 103, 104, 161, 182, 186, 68 stat. 930, 933, 935, 936, 937, 948, 953, 955, as amended (2 U.S.C. 2073, 2093, 2095, 2111, 2133, 2134, 2201, 2232, 2236), secs. 201, as amended, 202, 206, 88 stat. 1242, as amended, 1244, 1246, (42 U.S.C. 5841, 5842, 5846); Sec. 1704, 112 Stat.2750 (44 U.S.C. 3504 note).

2. In § 20.1003, new definitions Impacted area, Process materials, Reuse, Soil, Soil-like materials, and Solid materials and are added in alphabetical order to read as follows:

### § 20.1003 Definitions.

\* \* \* \* \*

Impacted area means an area with some reasonable potential for residual radioactivity in excess of natural background or fallout levels.

\* \* \* \* \*

Process materials means material such as material with soil-like or cementitious properties, including sediments, sands, filter cake, sludge, and crushed slag, among others.

\* \* \* \* \*

Reuse means to release solid material in its original form for its intended original use.

\* \* \* \* \*

Soil means unconsolidated earthy material with no specific distinction as to its composition, nor its initial origin from either onsite or offsite locations.

\* \* \* \* \*

Soil-like materials means material such as backfill consisting of a mixture of soil with rocks, gravel, or sand, with no distinctions made as to the material's initial origins or proportions of constituents.

\* \* \* \* \*

Solid materials means material such as concrete, asphalt, metal, trash, equipment, supplies, and tools used by licensees in restricted and/or impacted areas of a facility. Soils, soil-like materials, process materials, and treated process materials are excluded from this definition.

\* \* \* \* \*

3. In § 20.1009, paragraph (b) is revised to read as follows:

§ 20.1009 Information collection requirements: OMB approval.

\* \* \* \* \*

(b) The approved information collection requirements contained in this part appear in §§ 20.1003, 20.1101, 20.1202, 20.1203, 20.1204, 20.1206, 20.1208, 20.1301, 20.1302, 20.1403, 20.1404, 20.1406, 20.1501, 20.1601, 20.1703, 20.1901, 20.1902, 20.1904, 20.1905, 20.1906, 20.2002, 20.2004, 20.2006, 20.2102, 20.2103, 20.2104, 20.2105, 20.2106, 20.2107, 20.2108, 20.2110, 20.2201, 20.2202, 20.2203, 20.2204, 20.2205, 20.2206, 20.2301, and Appendices F and G to 10 CFR Part 20.

\* \* \* \* \*

4. In § 20.2001, paragraph (a)(4) is revised to read as follows:

§ 20.2001 General requirements.

(a) \* \* \*

(4) As authorized under §§ 20.2002, 20.2003, 20.2004, 20.2005, 20.2008, or 20.2009.

\* \* \* \* \*

5. Section 20.2008 is added under Subpart K to read as follows:

§ 20.2008 Limited disposition of solid material.

Solid materials, originating in restricted and/or impacted areas of a facility will be considered acceptable for release if:

(a) The residual radioactivity that is distinguishable from background radiation results in a total effective dose equivalent to an average member of the critical group, that does not exceed 1 mrem (0.01 mSv) per year ;

(b) The solid material is released for only certain limited disposition paths, as follows:

(1) Disposal of solid material by burial in an EPA RCRA landfill regulated under 40 CFR Parts 257 and 258, or in a State landfill as authorized by the EPA under 40 CFR Part 271;

(2) Use of concrete in road bed construction;

(3) Reuse of solid materials, equipment, and tools in their original form, in industrial or construction settings for their original intended design purpose and function (e.g., scaffolds, cranes, forklifts);

(4) Reuse of equipment and tools in their original form for their original intended design purpose and function, that are removed by an individual from the restricted and/or impacted areas on a routine basis (e.g., hand tools, testing equipment); and

(c) The radionuclide volumetric concentrations do not exceed the levels specified in Table 1 of Appendix E to 10 CFR Part 20 or the radionuclide surface concentrations do not exceed the levels specified in Table 2 of Appendix E to 10 CFR Part 20. For Table 1, if more than one radionuclide is released, the licensee shall determine the fraction of the limit in Table 1 of Appendix E to Part 20 represented by the concentration of each radionuclide; the sum of the fractions for each radionuclide must not exceed unity.

6. Section 20.2009 is added under Subpart K to read as follows:

§ 20.2009 Case-specific review requirements for disposition.

(a) A licensee may apply to the Commission for approval of proposed procedures to disposition soils, soil-like material, and process material, originating in restricted and/or impacted areas of a facility. Each application shall include the information described in paragraph (d) of this section and demonstrate that:

(1) The residual radioactivity that is distinguishable from background radiation results in a total effective dose equivalent, to an average member of the critical group, that does not exceed 1 mrem (0.01 mSv) per year; and

(2) The material is disposed by burial in an EPA RCRA landfill regulated under 40 CFR Parts 257 and 258, or in a State landfill as authorized by the EPA under 40 CFR Part 271.

(b) For soils, soil-like material, and process material, a licensee may apply to the Commission for case-specific approval of proposed procedures, not otherwise authorized in § 20.2009(a)(2), if a case-specific analysis is submitted under paragraph (d) of this section.

(c) For solid material, a licensee may apply to the Commission for case-specific approval of proposed procedures, not otherwise authorized in § 20.2008(b) or § 20.2008(c), if a case-specific analysis is submitted under paragraph (d) of this section.

(d) Each application for case specific approval of proposed procedures under paragraphs (a), (b), and (c) of this section must include:

(1) A description of the material to be released, including the physical, chemical, and radiological properties important to risk evaluation, and the proposed manner and conditions of the disposition of this material, including a description of the nature of the controls or restrictions that would keep the material from going to an unrestricted use; and

(2) An analysis and evaluation of pertinent information on the nature of the environment;  
and

(3) The nature and location of other potentially affected licensed and unlicensed facilities;  
and

(4) Analyses and procedures to ensure that doses are maintained within the dose limit in § 20.2008(a) for solid materials or within the dose limit in paragraph (a)(1) of this section for soils, soil-like material, and process material.

7. § 20.2108, should be revised to read as follows:

§ 20.2108 Records of waste disposal and material disposition.

(a) Each licensee shall maintain the following:

(1) Records of disposal of licensed materials made under §§ 20.2002, 20.2003, 20.2004, 20.2005, 10 CFR Part 61 and disposal by burial in soil, including burials authorized before January 28, 1981.<sup>6</sup>

(2) Records of disposition of solid materials, equipment, and tools and soils, soil-like materials, and process materials made under §§ 20.2008(b)(1), 20.2008(b)(2), 20.2008(b)(3), and 20.2009 including - -

(i) The types and amounts of material shipped;

(ii) The destination of the material;

(iii) The date it was delivered to its destination; and

(iv) The radionuclides released in a format indicating that the residual radioactivity levels were in compliance with the volumetric concentration levels specified in Table 1 of Appendix E to Part 20 or the surface concentration levels specified in Table 2 of Appendix E to Part 20, as applicable.

(3) Records of disposition of solid materials made under § 20.2008(b)(4), including - -

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<sup>6</sup>A previous § 20.304 permitted burial of small quantities of licensed materials in soil before January 28, 1981, without specific Commission authorization.

(i) The tools and equipment that are removed from the restricted and/or impacted areas on a routine basis; and

(ii) the radionuclides released in a format indicating that the residual radioactivity levels were in compliance with the volumetric concentration levels specified in Table 1 of Appendix E to Part 20 or the surface concentration levels specified in Table 2 of Appendix E to Part 20, as applicable

(b) The licensee shall retain the records required by paragraph (a)(1) and (a)(2) of this section until the Commission terminates each pertinent license requiring the record. Requirements for disposition of these records, prior to license termination, are located in §§ 30.51, 40.61, 70.51, and 72.80 for activities licensed under these parts. The licensee shall retain the records required by paragraph (a)(3) of this section for 3 years after the record is made.

\* \* \* \* \*

8. Appendix E to 10 CFR Part 20 is added to read as follows:

APPENDIX E TO PART 20 - SOLID MATERIAL RELEASE CONCENTRATION LEVELS

TABLE 1 "VOLUMETRIC CONCENTRATION LEVELS"

Table 1 contains measurable volumetric radionuclide concentrations applicable to the limited disposition of solid materials under § 20.2008. Solid material would be considered acceptable for release if its radionuclide concentrations do not exceed the levels in Table 1. The levels in Table 1 for man-made radionuclides are taken from the International Atomic Energy Agency's report RS-G-1.7, "Application of the Concepts of Exclusion, Exemption, and Clearance." The levels in Table 1 for source material and special nuclear material are based on NUREG-1640, "Radiological Assessments for Clearance of Materials from Nuclear Facilities."

TABLE 2 "SURFACE CONCENTRATION LEVELS"

Table 2 contains measurable surface radionuclide concentrations applicable to the limited disposition of solid materials under § 20.2008. Solid material would be considered acceptable for release if its radionuclide concentrations do not exceed the levels in Table 2. The levels in Table 2 are based on the definition in 49 CFR 173.403 for surface concentrations not requiring DOT regulation to provide consistency between these two Federal agencies regarding material needing no further regulation.

## NOTATION

The levels in Tables 1 and 2 are presented in the computer “E” notation. For example, in this notation, a value of 2.7E+01 represents a value of  $2.7 \times 10^{+1}$  or 27.

Table 1

Volumetric Concentration Levels		
Atomic No.	Nuclide	Volume pCi/g
1	Hydrogen-3	2.7E+03
4	Beryllium-7	2.7E+02
6	Carbon-14	2.7E+01
9	Fluorine-18*	2.7E+02
11	Sodium-22	2.7E+00
11	Sodium-24*	2.7E+01
14	Silicon-31*	2.7E+04
15	Phosphorus-32	2.7E+04
15	Phosphorus-33	2.7E+04
16	Sulfur-35	2.7E+03
17	Chlorine-36	2.7E+01
17	Chlorine-38*	2.7E+02
19	Potassium-40**	2.7E+01
19	Potassium-42	2.7E+03
19	Potassium-43*	2.7E+02
20	Calcium-45	2.7E+03
20	Calcium-47	2.7E+02
21	Scandium-46	2.7E+00
21	Scandium-47	2.7E+03
21	Scandium-48	2.7E+01
23	Vanadium-48	2.7E+01
24	Chromium-51	2.7E+03
25	Manganese-51*	2.7E+02
25	Manganese-52	2.7E+01
25	Manganese-52m*	2.7E+02
25	Manganese-53	2.7E+03
25	Manganese-54	2.7E+00
25	Manganese-56*	2.7E+02

Table 1

Volumetric Concentration Levels		
Atomic No.	Nuclide	Volume pCi/g
26	Iron-52	2.7E+02
26	Iron-55	2.7E+04
26	Iron-59	2.7E+01
27	Cobalt-55*	2.7E+02
27	Cobalt-56	2.7E+00
27	Cobalt-57	2.7E+01
27	Cobalt-58	2.7E+01
27	Cobalt-58m*	2.7E+05
27	Cobalt-60	2.7E+00
27	Cobalt-60m*	2.7E+04
27	Cobalt-61*	2.7E+03
27	Cobalt-62m*	2.7E+02
28	Nickel-59	2.7E+03
28	Nickel-63	2.7E+03
28	Nickel-65*	2.7E+02
29	Copper-64*	2.7E+03
30	Zinc-65	2.7E+00
30	Zinc-69*	2.7E+04
30	Zinc-69m*	2.7E+02
31	Gallium-72*	2.7E+02
32	Germanium-71	2.7E+05
33	Arsenic-73	2.7E+04
33	Arsenic-74*	2.7E+02
33	Arsenic-76*	2.7E+02
33	Arsenic-77	2.7E+04
34	Selenium-75	2.7E+01
35	Bromine-82	2.7E+01
37	Rubidium-86	2.7E+03

Table 1

Volumetric Concentration Levels		
Atomic No.	Nuclide	Volume pCi/g
38	Strontium-85	2.7E+01
38	Strontium-85m*	2.7E+03
38	Strontium-87m*	2.7E+03
38	Strontium-89	2.7E+04
38	Strontium-90	2.7E+01
38	Strontium-91*	2.7E+02
38	Strontium-92*	2.7E+02
39	Yttrium-90	2.7E+04
39	Yttrium-91	2.7E+03
39	Yttrium-91m*	2.7E+03
39	Yttrium-92*	2.7E+03
39	Yttrium-93*	2.7E+03
40	Zirconium-93*	2.7E+02
40	Zirconium-95	2.7E+01
40	Zirconium-97*	2.7E+02
41	Niobium-93m	2.7E+02
41	Niobium-94	2.7E+00
41	Niobium-95	2.7E+01
41	Niobium-97*	2.7E+02
41	Niobium-98*	2.7E+02
42	Molybdenum-90*	2.7E+02
42	Molybdenum-93	2.7E+02
42	Molybdenum-99	2.7E+02
42	Molybdenum-101*	2.7E+02
43	Technetium-96	2.7E+01
43	Technetium-96m*	2.7E+04
43	Technetium-97	2.7E+02
43	Technetium-97m	2.7E+03

Table 1

Volumetric Concentration Levels		
Atomic No.	Nuclide	Volume pCi/g
43	Technetium-99	2.7E+01
43	Technetium-99m*	2.7E+03
44	Ruthenium-97	2.7E+02
44	Ruthenium-103	2.7E+01
44	Ruthenium-105*	2.7E+02
44	Ruthenium-106	2.7E+00
45	Rhodium-103m*	2.7E+05
45	Rhodium-105	2.7E+03
46	Palladium-103	2.7E+04
46	Palladium-109	2.7E+03
47	Silver-105	2.7E+01
47	Silver-110m	2.7E+00
47	Silver-111	2.7E+03
48	Cadmium-109	2.7E+01
48	Cadmium-115	2.7E+02
48	Cadmium-115m	2.7E+03
49	Indium-111	2.7E+02
49	Indium-113m*	2.7E+03
49	Indium-114m	2.7E+02
49	Indium-115m*	2.7E+03
50	Tin-113	2.7E+01
50	Tin-125	2.7E+02
51	Antimony-122	2.7E+02
51	Antimony-124	2.7E+01
51	Antimony-125	2.7E+00
52	Tellurium-123m	2.7E+01
52	Tellurium-125m	2.7E+04
52	Tellurium-127	2.7E+04

Table 1

Volumetric Concentration Levels		
Atomic No.	Nuclide	Volume pCi/g
52	Tellurium-127m	2.7E+02
52	Tellurium-129*	2.7E+03
52	Tellurium-129m	2.7E+02
52	Tellurium-131*	2.7E+03
52	Tellurium-131m	2.7E+02
52	Tellurium-132	2.7E+01
52	Tellurium-133*	2.7E+02
52	Tellurium-133m*	2.7E+02
52	Tellurium-134*	2.7E+02
53	Iodine-123	2.7E+03
53	Iodine-125	2.7E+03
53	Iodine-126	2.7E+02
53	Iodine-129	2.7E-01
53	Iodine-130*	2.7E+02
53	Iodine-131	2.7E+02
53	Iodine-132*	2.7E+02
53	Iodine-133*	2.7E+02
53	Iodine-134*	2.7E+02
53	Iodine-135*	2.7E+02
55	Cesium-129	2.7E+02
55	Cesium-131	2.7E+04
55	Cesium-132	2.7E+02
55	Cesium-134	2.7E+00
55	Cesium-134m*	2.7E+04
55	Cesium-135	2.7E+03
55	Cesium-136	2.7E+01
55	Cesium-137	2.7E+00
55	Cesium-138*	2.7E+02

Table 1

Volumetric Concentration Levels		
Atomic No.	Nuclide	Volume pCi/g
56	Barium-131	2.7E+02
56	Barium-140	2.7E+01
57	Lanthanum-140	2.7E+01
58	Cerium-139	2.7E+01
58	Cerium-141	2.7E+03
58	Cerium-143	2.7E+02
58	Cerium-144	2.7E+02
59	Praseodymium-142*	2.7E+03
59	Praseodymium-143	2.7E+04
60	Neodymium-147	2.7E+03
60	Neodymium-149*	2.7E+03
61	Promethium-147	2.7E+03
61	Promethium-149	2.7E+04
62	Samarium-151	2.7E+04
62	Samarium-153	2.7E+03
63	Europium-152	2.7E+00
63	Europium-152m*	2.7E+03
63	Europium-154	2.7E+00
63	Europium-155	2.7E+01
64	Gadolinium-153	2.7E+02
64	Gadolinium-159*	2.7E+03
65	Terbium-160	2.7E+01
66	Dysprosium-165*	2.7E+04
66	Dysprosium-166	2.7E+03
67	Holmium-166	2.7E+03
68	Erbium-169	2.7E+04
68	Erbium-171*	2.7E+03
69	Thulium-170	2.7E+03

Table 1

Volumetric Concentration Levels		
Atomic No.	Nuclide	Volume pCi/g
69	Thulium-171	2.7E+04
70	Ytterbium-175	2.7E+03
71	Lutetium-177	2.7E+03
72	Hafnium-181	2.7E+01
73	Tantalum-182	2.7E+00
74	Tungsten-181	2.7E+02
74	Tungsten-185	2.7E+04
74	Tungsten-187	2.7E+02
75	Rhenium-186	2.7E+04
75	Rhenium-188*	2.7E+03
76	Osmium-185	2.7E+01
76	Osmium-191	2.7E+03
76	Osmium-191m*	2.7E+04
76	Osmium-193	2.7E+03
77	Iridium-190	2.7E+01
77	Iridium-192	2.7E+01
77	Iridium-194*	2.7E+03
78	Platinum-191	2.7E+02
78	Platinum-193m	2.7E+04
78	Platinum-197*	2.7E+04
78	Platinum-197m*	2.7E+03
79	Gold-198	2.7E+02
79	Gold-199	2.7E+03
80	Mercury-197	2.7E+03
80	Mercury-197m	2.7E+03
80	Mercury-203	2.7E+02
81	Thallium-200	2.7E+02
81	Thallium-201	2.7E+03

Table 1

Volumetric Concentration Levels		
Atomic No.	Nuclide	Volume pCi/g
81	Thallium-202	2.7E+02
81	Thallium-204	2.7E+01
82	Lead-203	2.7E+02
82	Lead-210**	2.7E+01
83	Bismuth-206	2.7E+01
83	Bismuth-207	2.7E+00
84	Polonium-203*	2.7E+02
84	Polonium-205*	2.7E+02
84	Polonium-207*	2.7E+02
84	Polonium-210**	2.7E+01
85	Astatine-211	2.7E+04
88	Radium-225	2.7E+02
88	Radium-226**	2.7E+00
88	Radium-227	2.7E+03
88	Radium-228**	2.7E+00
89	Actinium-227**	2.7E+00
90	Thorium-226	2.7E+04
90	Thorium-228**	2.7E+00
90	Thorium-229	2.7E+00
90	Thorium-230**	2.7E+01
90	Thorium-232**	2.7E+00
91	Protactinium-230	2.7E+02
91	Protactinium-231**	2.7E+00
91	Protactinium-233	2.7E+02
92	Uranium-230	2.7E+02
92	Uranium-231	2.7E+03
92	Uranium-232	2.7E+00
92	Uranium-233	2.7E+01

Table 1

Volumetric Concentration Levels		
Atomic No.	Nuclide	Volume pCi/g
92	Uranium-234**	2.7E+01
92	Uranium-235**	2.7E+00
92	Uranium-236	2.7E+02
92	Uranium-237	2.7E+03
92	Uranium-238**	2.7E+01
92	Uranium-239*	2.7E+03
92	Uranium-240*	2.7E+03
93	Neptunium-237	2.7E+01
93	Neptunium-239	2.7E+03
93	Neptunium-240*	2.7E+02
94	Plutonium-234*	2.7E+03
94	Plutonium-235*	2.7E+03
94	Plutonium-236	2.7E+01
94	Plutonium-237	2.7E+03
94	Plutonium-238	2.7E+00
94	Plutonium-239	2.7E+00
94	Plutonium-240	2.7E+00
94	Plutonium-241	2.7E+02
94	Plutonium-242	2.7E+00
94	Plutonium-243*	2.7E+04
94	Plutonium-244	2.7E+00
95	Americium-241	2.7E+00
95	Americium-242*	2.7E+04
95	Americium-242m	2.7E+00
95	Americium-243	2.7E+00
96	Curium-242	2.7E+02
96	Curium-243	2.7E+01
96	Curium-244	2.7E+01

Table 1

Volumetric Concentration Levels		
Atomic No.	Nuclide	Volume pCi/g
96	Curium-245	2.7E+00
96	Curium-246	2.7E+00
96	Curium-247	2.7E+00
96	Curium-248	2.7E+00
97	Berkelium-249	2.7E+03
98	Californium-246	2.7E+04
98	Californium-248	2.7E+01
98	Californium-249	2.7E+00
98	Californium-250	2.7E+01
98	Californium-251	2.7E+00
98	Californium-252	2.7E+01
98	Californium-253	2.7E+03
98	Californium-254	2.7E+01
99	Einsteinium-253	2.7E+03
99	Einsteinium-254	2.7E+00
99	Einsteinium-254m	2.7E+02
100	Fermium-254*	2.7E+05
100	Fermium-255*	2.7E+03

\*\* = naturally occurring

\* = half life less than 1 day

Atomic No.	Nuclide Category	Volume (pCi/g)
---	Any nuclides not listed above with beta-gamma decay modes other than alpha emissions and without regard to half-lives	2.7E+00
---	Any nuclides not listed above with alpha or spontaneous fission decay modes and with half-lives less than 10 days	2.7E+00
---	Any nuclides not listed above with alpha or spontaneous fission decay modes and with half-lives equal to or greater than 10 days	2.7E-01

Table 2 Surface Concentration Levels

Radionuclide Groupings	Release Level – Total Surface Activity	
	pCi/cm <sup>2</sup>	dpm/100 cm <sup>2</sup>
Beta-gamma emitters (nuclides with decay modes other than alpha emission and without regard to half-lives)	11	2400
U-natural, Th-natural, U-235, U-238, Th-232, Th-228, Th-230, U-depleted, and associated decay products; and alpha emitters with half-lives of less than 10 days	11	2400
Radionuclides with alpha or spontaneous fission decay modes and with half-lives equal to or greater than 10 days	1.1	240

Dated at Rockville, Maryland, this \_\_\_\_ day of \_\_\_\_\_ 2005.

For the Nuclear Regulatory Commission

---

Annette Vietti-Cook,  
Secretary of the Commission.

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**Generic Environmental Impact Statement**  
**Controlling the Disposition of Solid Materials**

**Draft Report for Comment**

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**U.S. Nuclear Regulatory Commission**  
**Office of Nuclear Materials Safety and Safeguards**  
**Washington, DC 20555-0001**

**State of Massachusetts**  
**U.S. Department of Energy**  
**U.S. Environmental Protection Agency**

March 2005



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Date Published:

**U.S. Nuclear Regulatory Commission  
Office of Nuclear Materials Safety and Safeguards  
Washington, DC 20555-0001**

**State of Massachusetts  
U.S. Department of Energy  
U.S. Environmental Protection Agency**



1 **COMMENTS ON DRAFT REPORT**

2  
3 Any interested party may submit comments on this report for consideration by the NRC staff.  
4 Comments may be accompanied by additional relevant information or supporting data. Please  
5 specify the report number, NUREG-1812 draft in your comments, and send them by \_\_\_\_\_  
6 2005 to the following address.

7  
8 Chief, Rules Review and Directives Branch  
9 U.S. Nuclear Regulatory Commission  
10 Mail Stop T6-D59  
11 Washington, DC 20555-0001

12  
13 Electronic comments may be submitted to the NRC by the internet at [nrcprep@nrc.gov](mailto:nrcprep@nrc.gov).

14  
15 For any questions about the material in this report, please contact:

16  
17 Phyllis Sobel  
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23

**ABSTRACT**

1  
2  
3 The Nuclear Regulatory Commission (NRC) is considering amending its regulations in 10 CFR  
4 Part 20 to include radiological criteria for controlling the disposition of solid materials at nuclear  
5 facilities. This Draft Generic Environmental Impact Statement (Draft GEIS) was prepared in  
6 compliance with the National Environmental Policy Act (NEPA) and the NRC regulations for  
7 implementing NEPA. This Draft GEIS evaluates the potential environmental impacts of the  
8 proposed action and its reasonable alternatives. This document also compares the potential  
9 environmental impacts resulting from the proposed rulemaking and its alternatives and the costs  
10 and benefits associated with those alternatives.  
11



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**EXECUTIVE SUMMARY**

**BACKGROUND**

The U.S. Nuclear Regulatory Commission (NRC) is considering whether to promulgate a regulation to control the disposition of solid materials that originate in restricted or impacted areas of NRC/Agreement-State licensed facilities, and have no, or very small amounts of, radioactivity resulting from licensed operations. These solid materials are referred to as “potentially clearable” solid materials. Materials considered by this rulemaking are concrete, metals (including steel, copper and aluminum), trash, soils, and tools and equipment. To support its rulemaking decision, NRC determined that a generic environmental impact statement (GEIS) is required by the NRC National Environmental Policy Act (NEPA)-implementing regulations in 10 CFR Part 51.

Nuclear facilities routinely use different types of solid materials in support of various activities, including operations, production, research and development, maintenance, facility refurbishment, and ultimately decommissioning. In support of operations, materials and items are introduced into areas that contain radioactivity. Once no longer needed, a licensee must decide how to disposition this material. Materials and equipment are surveyed before being taken out of restricted areas. The results of the surveys are used to determine the final disposition of materials or items. Based on the survey results, licensees determine whether it is worthwhile to decontaminate the materials or items or simply dispose of them as low-level waste (LLW).

At present, NRC generally addresses the release of solid material on a case-by-case basis using license conditions and existing regulatory guidance. In each case, material may be released from a licensed operation if the existing guidelines are met. Under the current approach, licensees survey materials to detect the presence of Atomic Energy Act (IAEA) materials above natural background levels. Solid materials with radioactivity below detection limits or below guideline values may be released from control with NRC approval. The process used to identify, survey and disposition solid materials is found in guidance, not regulations. Solid materials with higher levels of radioactivity are required to be disposed of at licensed LLW disposal facilities under NRC’s existing regulations in 10 CFR Part 61.

NRC initially considered a proposed rulemaking in 1999. As part of the scoping process, NRC published an issues paper on the release of solid materials. Public comments were received on the preliminary alternatives at public workshops and in written comments. The Commission decided to defer a final decision on whether to proceed with a rulemaking and directed the staff to request that the National Academies conduct a study of alternatives for controlling the disposition of solid materials.

In March 2002, a report issued by the National Academy of Sciences discussed the advantages and disadvantages of various alternatives. The report found that NRC’s current approach for controlling the disposition of solid materials “is sufficiently protective of public health that it does not need immediate revamping.” However, the National Academies report also stated that NRC’s current approach is incomplete and inconsistent and concluded that NRC should therefore undertake a process to evaluate a broad range of alternatives to provide clear risk-informed

1 direction on controlling the disposition of solid materials. The report also recommended that an  
2 individual dose standard of 1 mrem/yr provides a reasonable starting point for the process of  
3 considering alternatives for a dose-based standard.  
4

5 Based on these efforts, the Commission decided to proceed with a rulemaking for controlling the  
6 disposition of solid materials. In February 2003, the NRC resumed the scoping process by  
7 publishing a request for comments on the scope of the proposed rulemaking. The NRC also held  
8 a public workshop in May 2003 to solicit additional input on the alternatives being considered.  
9

## 10 **PROPOSED ACTION**

11  
12 The Proposed Action being considered in this Draft GEIS is to promulgate an NRC regulation  
13 that would establish criteria for the disposition of solid materials from NRC-licensed facilities.  
14 The Proposed Action would improve the efficiency and effectiveness of the NRC regulatory  
15 process for disposing of solid materials. The NRC is guided by the goals of the NRC Strategic  
16 Plan (NRC, 2004d) of which the primary goal is ensuring protection of public health and safety  
17 and the environment. The proposed rulemaking would result in related rulemakings in the  
18 Agreement States.  
19

## 20 **PURPOSE AND NEED FOR THE PROPOSED ACTION**

21  
22 The NRC agrees with the findings in the National Academies report regarding the need to  
23 consider modifying its current approach to provide risk-informed direction on controlling the  
24 disposition of solid materials. The purpose of the Proposed Action is to develop an efficient and  
25 effective regulatory process that ensures the disposition of these solid materials is controlled in a  
26 manner that ensures that NRC's strategic goal of ensuring protection of public health and safety  
27 and the environment is met. The Proposed Action should provide a consistent criterion for  
28 controlling solid materials, guidance for surficially and volumetrically contaminated materials,  
29 and a reduction in the time and resources required to evaluate case-specific applications.  
30

## 31 **ALTERNATIVES**

32  
33 This Draft GEIS considers alternative amendments to NRC's regulations that would include a  
34 criterion for controlling the disposition of solid materials. Based on the input from the scoping  
35 process, the following alternatives are studied in detail in this Draft GEIS.  
36

- 37 • No Action
- 38 • Unrestricted Release
- 39 • U.S. Environmental Protection Agency (EPA)/State-Regulated Disposal
- 40 • Low-Level Waste (LLW) Disposal/Prohibition
- 41 • Limited Dispositions

### 42 No Action

43  
44  
45 This Draft GEIS includes an analysis of the No Action Alternative to provide the decisionmaker  
46 with a basis for comparison to the reasonable alternatives. In this case, under the No Action

1 Alternative, NRC would continue to apply its current approach to determining the eligibility of  
2 solid material for unrestricted release in general commerce or disposal. The NRC's current  
3 approach is one that employs measurement-based guidelines to determine if solid materials can  
4 be released for any use or disposal. In implementation, license conditions and facility-specific  
5 procedures require that solid materials that have been used in restricted or impacted areas are  
6 surveyed for the presence of radioactivity before being taken out of radiologically controlled  
7 areas. Solid materials can currently be released for any unrestricted use or disposal if the survey  
8 indicates that the existing guidelines are met. However, 10 CFR Part 20 does not currently  
9 specify a numerical level (e.g., dose or radionuclide concentration limits below which the  
10 material can be released). Decisions on disposition of solid materials are currently made using  
11 levels contained in a set of existing guidelines that are based primarily on the ability of survey  
12 techniques to measure the radioactivity level on, or in, the solid material. Under the No Action  
13 Alternative, solid material released (at or below guideline levels) for unrestricted release may be  
14 recycled and reused in a variety of end products, or it may be sent for disposal. Disposal may  
15 take place in an EPA/State-regulated landfill or LLW disposal facility.

### 16 Unrestricted Release

17  
18  
19 The Unrestricted Release Alternative would allow solid materials to be released for any use in  
20 general commerce (recycling and/or reuse into consumer products and industrial and  
21 construction uses) or for disposal, if they are below a dose-based criterion. All materials to be  
22 released would undergo a radiation survey and the measured levels of radiation would be  
23 compared against the criterion for unrestricted release. Solid materials with measured radiation  
24 levels below the established criterion would be released from licensed control, while solid  
25 materials with radiation levels above the criterion would be sent to a LLW disposal site. The  
26 proposed rulemaking would include a table of radionuclide concentrations or clearance levels  
27 corresponding to the selected dose-based criterion. Solid material released for unrestricted use  
28 may follow any disposition path – it may be recycled and reused in a variety of end products, or  
29 it may be sent for disposal. Disposal may take place in an EPA/State-regulated landfill or LLW  
30 disposal facility. This Draft GEIS considers a range of dose options for allowing the release of  
31 solid materials. The allowable dose level that NRC selects would directly impact the amount of  
32 solid material released for use in general commerce, with the amount of material released  
33 decreasing as the allowable dose criterion decreases. These dose options vary from 0.03 to 10  
34 mrem/yr and include the International Atomic Energy Agency (IAEA) Safety Guide No. RS-G-  
35 1.7 dose limit of 1 mrem/yr.

### 36 EPA/State-Regulated Disposal

37  
38  
39 Under the EPA/State-Regulated Disposal Alternative, all potentially clearable solid material  
40 below a dose-based criterion would be released to EPA/State regulated landfills and would be  
41 prohibited from general commerce (recycling into consumer products and industrial and  
42 construction uses). Solid materials above the dose-based criterion would be sent to a LLW  
43 disposal site. In the base case, all released solid materials (including tools and equipment) would  
44 be disposed of in EPA/State-regulated Resource Conservation and Recovery Act (RCRA)  
45 Subtitle D landfills. The Draft GEIS also considers one variation in which all the potentially  
46 clearable trash would be incinerated at EPA/State-regulated landfills and the ash disposed of in

1 those landfills. This Draft GEIS considers a range of dose options varying from 0.03 to  
2 10 mrem/yr. Under this alternative, the radionuclide concentrations are higher so a greater  
3 amount of activity could be released to landfills than the amount that could be released to general  
4 commerce under the Unrestricted Release Alternative. (This is because the public exposure  
5 scenarios for landfills differ from those for unrestricted release.)  
6

### 7 LLW Disposal

8

9 Under the LLW Disposal Alternative, also known as Prohibition, all potentially clearable solid  
10 material (including tools and equipment) would be prohibited from general commerce and  
11 EPA/State-regulated landfill disposal. All solid material in restricted or impacted areas would be  
12 classified as LLW and required to be disposed of under NRC's existing regulations (10 CFR  
13 Part 61).  
14

### 15 Limited Dispositions

16

17 In the Limited Dispositions Alternative, solid material would be released, but NRC would allow  
18 only certain authorized dispositions to limit the potential for public exposure. The radionuclide  
19 criterion was chosen to be a dose limit of 1 mrem/yr using the IAEA Safety Guide No. RS-G-  
20 1.7. The NRC chose to consider a table of radionuclide concentrations accompanying the IAEA  
21 Safety Guide that is based on unrestricted release. Use of these concentration levels limits any  
22 potential impacts in the unlikely event that these materials were to end up in different  
23 dispositions, including reuse and recycling into other products. Solid materials above the  
24 radionuclide concentrations associated with the 1 mrem/yr criterion would be sent to a LLW  
25 disposal facility.  
26

27 Based on public comments during the scoping period and on the analyses for the Unrestricted  
28 Release and EPA/State-Regulated Disposal Alternatives, the only limited dispositions considered  
29 under this alternative are disposal in a RCRA Subtitle D landfill, concrete use in road fill, and  
30 reuse of tools and equipment for its original purpose. Licensees would need to demonstrate that  
31 the material proposed for release is less than the radionuclide concentrations in the proposed rule.  
32

33 The following are the components of this alternative.

- 34 • For landfill disposal under this alternative, the released solid materials (concrete, metal or  
35 trash) at or below the 1 mrem/yr criterion could be disposed of in RCRA Subtitle D landfills.  
36
- 37 • Released concrete at or below the 1 mrem/yr criterion could be recycled into roadbed  
38 material.  
39
- 40 • Tools and equipment that meet the 1 mrem/yr criterion could be reused or disposed of in  
41 RCRA Subtitle D landfills.  
42
- 43 • Any request to release solid material other than to these limited dispositions or releases at  
44 higher radionuclide concentration levels would require case-specific approval from NRC.  
45 Disposition of soils would be case-specific.  
46

- To ensure that the material releases are occurring to the pre-approved dispositions, licensees will be required to keep records and these activities would be evaluated periodically during NRC staff inspections at licensed facilities.

#### Alternatives Eliminated from Detailed Study

One alternative (Conditional Use) and two dose options (both clearance standards) were considered by NRC and eliminated from detailed study. These options are therefore not analyzed in detail in this Draft GEIS.

In the Conditional Use Alternative, solid material would be released, but its further use would be restricted to only certain authorized uses with limited potential for public exposure, such as use in controlled environments. Examples might include industrial uses such as metals in bridges, sewer lines, or industrial components, or concrete use in road fill. Material from these authorized uses may ultimately be reused or recycled into products not authorized under the Conditional Use Alternative. Further, the Conditional Use Alternative would allow a greater amount of activity than the amount released under the Limited Dispositions Alternative. This is because the Limited Dispositions Alternative uses lower, and therefore more restrictive, radionuclide concentrations based on the Unrestricted Use Alternative to establish the 1 mrem/yr dose limit. For this reason, the Conditional Use Alternative was replaced with the more restrictive Limited Dispositions Alternative, which uses radionuclide concentrations based on unrestricted release.

In addition to the dose options being analyzed under the Unrestricted Release Alternative, the 1999 American National Standards Institute (ANSI)/Health Physics Society (HPS) Standard N13.12 was also considered. The ANSI standard presents a screening clearance criterion for unrestricted release of solid materials based on an annual dose limit of 1 mrem. However, the bases for the screening clearance levels in the standard have not been fully documented and the use of the ANSI standard was thus difficult to justify. The standard is due for its first 5-year review cycle in 2004 and may be revised.

An additional international standard considered by NRC as an option under the Unrestricted Release Alternative was the European Commission's (EC's) clearance levels. The EC's standard was rejected because using the more recently adopted IAEA safety guide would provide more consistency in international standards.

### **COMPARISON OF PREDICTED ENVIRONMENTAL IMPACTS OF ALTERNATIVES**

NEPA regulations require a comparison of the environmental impacts of the alternatives, in order to define the issues and provide a clear basis for choice among the alternatives. This section presents a comparison of the environmental impacts of the alternatives. Table 2-1 provides a summary of the impacts.

Some environmental issues are not analyzed in detail in this Draft GEIS because NRC does not anticipate activities that could have the potential to impact these environmental resources. These environmental resources and issues include soils, noise, ecological resources, socioeconomic, historic and cultural resources, environmental justice, visual and scenic resources, and land use.

1 In the event that there are site-specific construction activities associated with the disposition of  
2 solid materials, any such activities would be subject to a site-specific NEPA analysis conducted  
3 on a case-by-case basis.  
4

5 The time period over which impacts are considered includes (1) the operational phase of  
6 reactors, during which some materials are expected to be released, (2) the post-shutdown and  
7 decommissioning phase of reactors, during which materials will be released as well, (3) and the  
8 post-decommissioning time period after which materials that have been released are presumed to  
9 have some long-term impacts on the public. The operational phase of reactors takes into account  
10 the currently operating and shutdown reactors over the next 50 years. The post-  
11 decommissioning phase considers impacts over the next 200 years, while the analysis notes that  
12 doses beyond 200 years and out to 1000 years become vanishingly small and contribute very  
13 little to the total of collective doses.  
14

### 15 **Public and Worker Health and Safety**

16  
17 The radiological effects to the General Public, Non-Licensed Facility Workers, and Licensed  
18 Facility Workers are assessed in this Draft GEIS in terms of collective dose, in units of person-  
19 rem. Even at the highest dose option (10 mrem/year), the effects of exposure on all three  
20 categories of exposed groups would be small when compared with background exposure coming  
21 from natural, medical, and other sources. However, there is a variation between alternatives.  
22

23 Table ES-1 presents a summary of the collective dose results discussed in Section 3.2. For the  
24 Unrestricted Release Alternative, the dose option chosen for the comparison is the IAEA Safety  
25 Guide RS-G-1.7, which is also part of the Limited Dispositions Alternative. The dose option  
26 chosen for the EPA/State-Regulated Disposal was 1 mrem/yr. For Licensed Facility Workers,  
27 the collective doses associated with all of the alternatives are similar, except that for the LLW  
28 Disposal Alternative, the collective dose is lower because there is no decontamination of the  
29 solid materials.  
30

31 For Non-Licensed Facility Workers and the General Public, the highest collective doses are for  
32 the No Action and Unrestricted Release Alternatives because for these alternatives the collective  
33 dose is dominated by exposure of the General Public to products made from recycled ferrous  
34 metal. The lowest collective dose to Non-Licensed Facility Workers and the General Public is  
35 for the EPA/State-Regulated Disposal Alternative without trash incineration. Collective dose  
36 was not calculated for the LLW Disposal Alternative for Non-Licensed Facility Workers and the  
37 General Public, but is assumed to be low, similar to the collective dose for the EPA/State-  
38 Regulated Disposal Alternative without trash incineration. The collective dose for the Limited  
39 Dispositions Alternative is smaller than the No Action and Unrestricted Release Alternatives.  
40

41 The collective dose analysis indicates that for all the Alternatives, the exposures to all categories  
42 of exposed groups would be small when compared with background exposure coming from other  
43 sources. The annual background collective dose to the U.S. population due to natural sources of  
44 radiation and radioactivity is estimated to be about 84 million person-rem (Appendix E).  
45

**Table ES-1 Summary of Collective Dose Results  
(person-rem)**

Alternative	Collective Dose	
	Licensed Workers	Non-Licensed Facility Workers and General Public
No Action	631	3,996
Unrestricted Release	631	3,429
EPA/State-Regulated Disposal without Trash Incineration	631	2
EPA/State-Regulated Disposal with Trash Incineration	631	1,011
LLW Disposal	323	-
Limited Dispositions	631	112

**Transportation**

Transportation effects are measured in this Draft GEIS in terms of fatal vehicle accidents and railcar incidents (e.g., derailments) (Table ES-2). These effects are based on statistical information on non-radiological accidents. The effects are highest for the LLW Disposal Alternative, with an estimated 32 fatal accidents over the time period of the analysis (about 50 years) if the material is transported by truck, or approximately 7 accidents if it is transported by rail. This results from the fact that the analysis for the LLW Disposal Alternative assumes that all materials must be transported to a single LLW disposal site in Utah, which is an average trip of 1,544 miles. Transport distances associated with all the other alternatives are significantly shorter, resulting in lower transportation effects. The number of fatal accidents under the No Action Alternative is estimated at 10, which is about double the effect associated with the Unrestricted Release Alternative at 1 mrem/yr. For the EPA/State-Regulated Disposal Alternative, the effect would be even lower due to the large number of Subtitle D landfills located throughout the country resulting in short transportation distances, typically less than 100 miles. The number of fatal accidents under the Limited Dispositions Alternative is estimated at 9.

**Water Quality**

Impacts to water quality are expected to be small because compliance with EPA and State permits would preclude significant impacts. Water quality effects are primarily associated with point source and area source water discharges from the storage, handling, and processing of solid materials. For the No Action and Unrestricted Use Alternatives, the effects are generated mostly by runoff discharges from rubblization of concrete and runoff and process wastewater discharges from recycling of steel. The incremental quantity of these discharges generated would be small as compared to the overall amount of discharges generated from the total amount of concrete and steel being recycled annually in the U.S., and the impact on water quality would be equally small. Similarly, the quantity of additional leachate and potential effects on ground water associated with disposal of solid materials under the EPA/State-Regulated Disposal Alternative and the LLW Disposal Alternative would be small compared with the overall amount of leachate being

generated annually by these facilities. Therefore the overall effects on water quality associated with all of the alternatives would be small.

**Table ES-2 Summary of Transportation Impacts  
(Accident Fatalities)**

Alternative	Dose Option (mrem/year)	Vehicle Miles Traveled (millions)	Fatalities	Impact
No Action	not applicable	423	10	small
Unrestricted Release	1	230	5	small
EPA/State-Regulated Disposal	1	88	2	small
LLW Disposal	not applicable	1,402 (truck)	32	moderate
		319 (rail)	7	small
Limited Dispositions	1	405	9	small

**Air Quality**

Air quality effects are primarily associated with mobile source emissions from transportation of solid materials to recycling and disposal facilities, fugitive dust emissions from rubblization of concrete, process emissions from recycling of steel, and emissions from the incineration of trash. The effects on air quality would be greatest for the EPA/State-Regulated Disposal Alternative trash incineration variation. The air quality effects associated with all other alternatives would be negligible. However, the overall effects on air quality associated with all of the alternatives are small when compared with other sources of emissions.

**Waste Management**

The resource being evaluated for waste management is disposal capacity. The EPA/State-regulated disposal facilities considered were RCRA Subtitle D landfills. The analysis in Section 3.7 demonstrates that the existing capacity of Subtitle D landfills would be adequate for the disposal of all of the potentially clearable materials that could be released under any of the alternatives.

NRC analyzed disposal capacity at LLW disposal sites for all the alternatives. A summary of the LLW disposal capacity analysis is shown in Table ES-3. A small impact indicates there is currently sufficient LLW disposal capacity and the need to expand existing LLW storage is small. Moderate impact indicates there is currently insufficient LLW disposal capacity and expansion of existing LLW storage capacity would be needed. A large impact indicates the amount of additional low-level waste disposal capacity needed is of such a magnitude that this impact should be avoided.

Under the No Action Alternative, the amount of solid material that would be sent to the Envirocare LLW disposal site (the only site considered in this analysis) is approximately 84 percent of the existing capacity of the site; this is considered a moderate impact. For the Unrestricted Release and EPA/State Regulated Disposal Alternatives, the dose option chosen for

the comparison is IAEA Safety Guide RS-G-1.7, which is also part of the Limited Dispositions Alternative. Under the Unrestricted Release, EPA/State-Regulated Disposal, and Limited Dispositions Alternatives, the amount of potentially clearable solid material that would not be released for unrestricted use, but that would be disposed of at the Envirocare LLW disposal site, would total approximately 11 to 15 percent of the existing LLW disposal capacity of the Envirocare facility; these are considered small impacts. The effects associated with the LLW Disposal Alternative are considered large. Under this alternative, the amount of solid material projected to be disposed of in the Envirocare LLW disposal facility totals more than four times the existing capacity of the facility under its current State licenses and permits.

**Table ES-3 Summary of LLW Disposal Capacity Analysis**

Alternative	Percent of Estimated Remaining LLW Disposal Capacity That Would Be Filled		Impact
	Hanford, Barnwell and Envirocare	Envirocare Only	
No Action	22	84	moderate
Unrestricted Release	4	15	small
EPA/State-Regulated Disposal	3	11	small
LLW Disposal	112	426	large
Limited Dispositions	4	15	small

**Cost/Benefit**

The cost/benefit analysis is discussed in Chapter 4 and summarized in Table ES-4 for the dose limit of 1 mrem/yr. The No Action Alternative is the baseline and by definition there are no incremental costs or benefits associated with this alternative. Incremental costs for the other alternatives are those costs above the No Action Alternative costs. In Table ES-4, only the most significant attributes are shown. Public and Occupational Health (Routine) includes collective doses to the public and licensed workers and represents less than 0.5 percent of the total incremental benefit or cost of each alternative. Public and Occupational Health (Accident) includes traffic accidents and represents about 1 percent of the total. Industry Operations includes the cost of surveys, disposal fees, and transportation costs and represents about 99 percent of the total benefits or costs. Environmental considerations include air emissions and reductions in the use of virgin materials due to recycling and represent less than 1 percent of the total. Transportation and disposal costs are the most significant sub-attributes when considering costs and benefits.

The incremental costs and benefits associated with the various alternatives vary greatly. The highest incremental costs are associated with the LLW Disposal Alternative and are estimated to exceed \$1.4 billion, primarily from transportation and disposal costs. For the Unrestricted Use and EPA/State-Regulated Disposal Alternatives, the incremental costs and benefits are highly dependent on the dose option selected. For both, benefits are associated with the 1 mrem/yr and 10 mrem/yr dose options, but costs are associated with the 0.03 mrem/yr and 0.1 mrem/yr dose options due to the fact that under the smaller dose options, smaller amounts of solid material are cleared, and larger amounts must be transported and disposed of in LLW disposal sites. For the

1 comparison of alternatives in Table ES-4, IAEA Safety Guide RS-G-1.7 for the Limited  
 2 Dispositions Alternative. For the Unrestricted Release, EPA/State Regulated Disposal, and  
 3 Limited Dispositions Alternatives, the total benefits are similar.  
 4

5 **Table ES-4 Summary of Net Incremental Benefit (Cost)**  
 6 **Associated with Major Attributes by Alternative**

Alternative	Benefit (Cost) in Millions of Dollars (2003\$)				Total
	Public and Occupational Health (Routine)	Public and Occupational Health (Accident)	Industry Operations	Environmental Considerations	
No Action	-	-	-	-	-
Unrestricted Release	<1	0	246	1	247
EPA/State-Regulated Disposal	1	0	181	(1)	181
LLW Disposal	1	(13)	(1,378)	(13)	(1,404)
Limited Dispositions	1	0	258	(2)	257

13  
 14 The net benefits of the Unrestricted Release, EPA Disposal and Limited Dispositions  
 15 Alternatives are largely the result of less LLW transportation and disposal costs for concrete  
 16 compared to the No Action Alternative. This is because there are many more tons of potentially  
 17 clearable concrete than steel or trash. Also, there are less benefits for steel recycling because  
 18 recycling revenue for steel is offset by the fact that the average distance to the steel recycling  
 19 facilities is greater than the average distance to the EPA/State-regulated landfills.  
 20

21 **Summary**

22  
 23 As discussed above, the impacts on public and worker health and safety, transportation, water  
 24 quality, air quality, and waste management were studied in detail. The impacts on public and  
 25 worker health and safety, water quality, and air quality are predicted to be small for all the  
 26 alternatives. The transportation effects are highest for the LLW Disposal Alternative, because  
 27 transport distances associated with this alternative are significantly higher for truck transport,  
 28 resulting in higher estimated fatal traffic accidents. The effects on waste management associated  
 29 with the LLW Disposal Alternative are considered large (more than four times the existing LLW  
 30 capacity at the Envirocare site under its current State licenses and permits). Under the other  
 31 alternatives, the amount of solid material that would be sent to a LLW facility is less than the  
 32 existing LLW disposal capacity.  
 33

34 In analyzing the costs and benefits associated with the alternatives, the No Action Alternative is  
 35 the baseline against which the other alternatives are compared. The highest incremental costs  
 36 are associated with the LLW Disposal Alternative and are estimated to exceed \$1.4 billion,  
 37 primarily from transportation and disposal operations. For the Limited Dispositions Alternative,  
 38 with a criterion based on the IAEA standard, the incremental benefit would be \$257 million.  
 39

1  
2 **CUMULATIVE IMPACTS**  
3

4 Cumulative impacts are those impacts on the environment which result from the incremental  
5 impacts of an action (in this case, a rulemaking for disposition of solid materials) when added to  
6 the impact of other past, present and reasonably foreseeable future actions (40 CFR 1508.7).  
7 The following cumulative impacts were considered: (1) exposure of individuals to multiple  
8 sources, (2) disposition of DOE scrap metals with small amounts of radioactivity, (3) industries  
9 not licensed by NRC that use or process materials that contain naturally-occurring radioactive  
10 materials (NORM), which because of their operations create higher concentrations of  
11 radioactivity than that associated with an undisturbed natural setting, and (4) two proposed new  
12 uranium enrichment plants which would generate large quantities of LLW. Cumulative impacts  
13 to doses to the public are expected to be small due to the low doses considered in the NRC  
14 rulemaking.  
15

16 **UNAVOIDABLE ADVERSE ENVIRONMENTAL IMPACTS, SHORT-TERM USES OF**  
17 **THE ENVIRONMENT, AND LONG-TERM PRODUCTIVITY**  
18

19 The radiation doses that would occur as a result of the proposed action are well below NRC  
20 regulatory limits and represent a small fraction of the existing background levels of radiation.  
21 Unavoidable adverse environmental impacts, short-term uses of the environment, and long-term  
22 productivity were previously considered under the activities expected during operation and  
23 decommissioning of licensed facilities.  
24

25 **IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES**  
26

27 For all but the LLW Disposal Alternative, no resources would be lost because the Proposed  
28 Action falls within the activities expected during operation and decommissioning of licensed  
29 facilities. For the LLW Disposal Alternative, the amount of LLW would exceed the available  
30 LLW disposal capacity, and thus this alternative would result in the commitment of land for  
31 additional LLW facilities or the expansion of current facilities. This alternative also represents  
32 approximately a 350 percent increase in energy expended for transportation as compared to the  
33 No Action Alternative.  
34

35 The No Action and Unrestricted Release Alternatives would result in recycling of concrete, steel,  
36 aluminum and copper. The Limited Dispositions Alternative would result in recycling of  
37 concrete but not metals, except by case-by-case determination by NRC. The recycled steel would  
38 displace the need for production of new steel, and the production of recycled steel requires less  
39 energy and materials than production of new steel. Thus the No Action and Unrestricted Release  
40 Alternatives, under which steel would be recycled, would commit fewer resources towards  
41 steelmaking than would the EPA/State-Regulated Disposal Alternative or LLW Disposal  
42 Alternative, under which no recycling would be conducted. The amount of steel that would be  
43 recycled under the Limited Dispositions Alternative cannot be estimated, but would likely be  
44 much lower than the amount for the No Action Alternative or Unrestricted Release Alternative.  
45

1  
2 **MONITORING AND MITIGATION MEASURES**  
3

4 All radioactive materials used, possessed, or stored onsite are required to be periodically  
5 monitored and inventoried. The monitoring includes the conduct of external radiation and  
6 surface contamination surveys. The inventory addresses quantities of radioactive materials as to  
7 their physical and chemical forms, uses, and dispositions, including radioactive decay. These  
8 requirements are stated in 10 CFR Part 20 and as license conditions stipulated in each license.  
9 Accordingly, the radiological status and locations of materials, before being designated for  
10 release, fall under the full control of the radiation safety program of each licensee. As a result no  
11 additional mitigation measures are anticipated as a result of implementing any of the alternatives.  
12 The implementation of the rule will be monitored through inspections, similar to those for  
13 releases to sewers.  
14

15 **STAFF ASSESSMENT AND PRELIMINARY RECOMMENDATION**  
16

17 After weighing the costs and benefits of the alternatives and comparing the impacts of the  
18 alternatives, the NRC staff, in accordance with 10 CFR 51.71(e), sets forth their preliminary  
19 NEPA recommendation regarding the proposed action. The NRC staff recommends that the staff  
20 promulgate a regulation for limited dispositions.  
21

22 The National Academies report indicated that NRC's current approach for controlling the  
23 disposition of solid materials (the No Action Alternative) is sufficiently protective of public  
24 health; however, the report also indicated that the current approach is incomplete and  
25 inconsistent and that NRC's approach should be risk-informed.  
26

27 Some commenters were in favor of the Unrestricted Release Alternative because disposal of all  
28 potentially clearable solid material in a licensed LLW disposal facility is costly to licensees  
29 without an accompanying health and safety benefit and would cause a severe economic impact  
30 for small licensees (e.g., medical facilities, universities). However, most of the public  
31 commenters were concerned that risks associated with unrestricted release of these solid  
32 materials are avoidable and involuntary, radiation risks are underestimated, there is a potential  
33 for exposures to multiple products, and releases would not be accurately measured and tracked.  
34 Also commenters from the steel and concrete industries, who would receive the cleared material,  
35 indicated that their potential costs could be very large because consumers could choose not to  
36 purchase items made from material recycled from licensed facilities.  
37

38 We also examined the EPA/State-Regulated Landfill Disposal Alternative. This approach would  
39 prevent solid material from licensed facilities from entering general commerce, thus limiting the  
40 potential for radiation exposure to the general public. Also, limiting disposal of released solid  
41 materials to an EPA/State-Regulated landfill would place a smaller economic burden on  
42 licensees than disposal of all potentially clearable solid materials at a licensed LLW disposal  
43 site. (Some potentially clearable solid material would still go to a LLW facility if it was above the  
44 dose limit.) However, because this alternative would allow higher radionuclide concentrations, a  
45 greater amount of activity could be released to landfills than the amount that would be released to  
46 general commerce under the Unrestricted Release Alternative.

1 The next alternative considered was the Low Level Waste Disposal Alternative, also referred to  
2 as Prohibition. In this alternative, all potentially clearable solid material would be prohibited  
3 from general commerce and would be disposed of in a LLW disposal site. This approach would  
4 prevent solid material from licensed facilities from entering general commerce, thus limiting the  
5 potential for radiation dose to the general public. However, if all potentially clearable material  
6 (which has no, or very small amounts of, radioactivity and which has some economic value) is  
7 sent to LLW disposal sites, this would be costly to licensees. Furthermore, there is a large  
8 impact on LLW disposal capacity - the solid materials to be generated from the existing  
9 commercial nuclear reactors would represent more than the existing LLW disposal capacity.

10  
11 After assessing the above alternatives, NRC considered the Limited Dispositions Alternative.  
12 Under this alternative, potentially clearable solid material (concrete, steel and trash) could be  
13 released, if it were below radionuclide concentrations associated with a dose criterion of 1  
14 mrem/yr, but with only certain authorized dispositions to limit the potential for public exposures.  
15 Three pre-authorized dispositions are considered in this alternative - RCRA Subtitle D landfill  
16 disposal, concrete use in road beds, and the reuse of tools and equipment. Any requests to  
17 release material other than the three pre-approved dispositions (for example, soils or industrial  
18 uses such as metals in bridges, sewer lines, or industrial components in a factory) or at higher  
19 radionuclide concentrations would require case-specific approval.

20  
21 To limit potential impacts in the unlikely event that released solid materials are recycled into  
22 other products, the radionuclide concentrations considered in the Limited Dispositions  
23 Alternative are based on the Unrestricted Release Alternative. The IAEA radionuclide  
24 concentrations were chosen to be consistent with national and international numeric guidelines.  
25 Another economic benefit is that potentially clearable solid materials could be used under certain  
26 authorized conditions, rather than using the more costly licensed LLW disposal facilities. As  
27 shown in Table ES-1, the collective dose for this alternative is lower than for the No Action  
28 Alternative because exposures to the public are more limited. To ensure that the material  
29 releases are occurring to the pre-approved dispositions, there would be licensee recordkeeping  
30 and these activities would be evaluated periodically during routine staff inspections at licensed  
31 facilities. Also enforcement action would be taken if necessary.

32  
33 Municipal solid waste operators, EPA and the State agencies have the discretion of allowing or  
34 refusing disposals in Subtitle D facilities. Even if allowed, EPA and the State agencies might  
35 impose additional constraints on such disposals. Accordingly, the implementation of the rule  
36 would have to consider EPA and State agency requirements as well as the concerns of the  
37 landfill operators. It is envisioned that some landfill operators might not want to receive such  
38 materials, but others would, considering economic factors. At this time, however, it is not  
39 possible to determine readily which landfill operators and State agencies might find the NRC  
40 rule as an effective option.

41  
42 After considering the costs, benefits and impacts of the alternatives, the staff has concluded that  
43 the Limited Dispositions Alternative is NRC's preliminary recommendation. The NRC staff  
44 concluded the overall benefits of the proposed rulemaking outweigh the disadvantages based on  
45 consideration of the following. The proposed rulemaking would  
46

- 1 • provide a risk-informed consistent criterion for controlling the disposition of solid materials,
- 2 • allow for a predictable regulatory process that is efficient and effective,
- 3 • set a dose criterion well below levels established to ensure adequate protection of public
- 4 health and safety and the environment,
- 5 • be consistent with international numeric guidelines,
- 6 • provide limited potential for public exposure,
- 7 • address public concerns with unrestricted release of solid materials into general commerce,
- 8 • address concerns from the steel and concrete industries that consumers could choose not to
- 9 purchase items made from materials recycled from licensed facilities,
- 10 • provide guidance on materials with surficial and volumetric residual radioactivity, and
- 11 • ensure less time and resources would be expended on case-specific applications.

12  
13 The cooperating agencies (State of Massachusetts, EPA and DOE) are currently reviewing the  
14 Draft GEIS and have not expressed a preference regarding the alternatives discussed in the  
15 GEIS. The agencies found little difference in the environmental impacts among the No Action,  
16 Unrestricted Release, EPA/State-Regulated Disposal, and Limited Dispositions Alternatives.  
17 Thus they have concluded the Draft GEIS analysis does not provide a compelling basis for  
18 selecting the Limited Dispositions Alternative. Also, the cooperating agencies recommend there  
19 should be a process for clearing material without residual radioactivity in a restricted area for  
20 unrestricted release. The agencies have commented that there could be confusion regarding  
21 other nations' imports into the U.S. because the IAEA safety guide recommends unrestricted  
22 release, but the Draft GEIS recommends limited disposition.  
23

**ACRONYMS AND ABBREVIATIONS**

1		
2		
3	ACBFS	Air-cooled blast furnace slag
4		
5	AEC	Atomic Energy Commission
6		
7	AGN	Aerjet General Nucleonics
8		
9	AISI	American Iron and Steel Institute
10		
11	ALARA	As Low As Reasonably Achievable
12		
13	ANSI	American National Standards Institute
14		
15	APA	Administrative Procedure Act
16		
17	AS	Agreement State
18		
19	ATSDR	Agency for Toxic Substances and Disease Registry
20		
21	BCGs	Biota Concentration Guides
22		
23	BOF	Blast Oxygen Furnace
24		
25	BRC	Below regulatory concern
26		
27	BWR	Boiling water reactor
28		
29	CAA	Clean Air Act
30		
31	C&D	Construction & Demolition
32		
33	CDA	Copper Development Association
34		
35	CEQ	Council on Environmental Quality
36		
37	CFR	Code of Federal Regulations
38		
39	CH <sub>4</sub>	Methane
40		
41	CO <sub>2</sub>	Carbon dioxide
42		
43	COI	Conflict of interest
44		
45	cosmic	Outer space
46		

1	CRCPD	Conference of Radiation Control Program Directors
2		
3	CWM	Chemical Waste Management
4		
5	D&D	Decontamination and Decommissioning
6		
7	DCF	Dose conversion factor
8		
9	DF	Dose factor
10		
11	DGEIS	Draft Generic Environmental Impact Statement
12		
13	DNAPL	Dense non-aqueous phase liquids
14		
15	DOD	Department of Defense
16		
17	DOE	Department of Energy
18		
19	DOS	Department of State
20		
21	DOT	Department of Transportation
22		
23	DUF <sub>6</sub>	Depleted uranium hexafluoride
24		
25	EAF	Electric Arc Furnace
26		
27	EC	European Commission
28		
29	EDE	Effective dose equivalent
30		
31	EFIG	Emission Factors and Inventories Group
32		
33	EPA	Environmental Protection Agency
34		
35	FGR	Federal Guidance Report
36		
37	FMCSA	Federal Motor Carrier Safety Administration
38		
39	GEIS	Generic Environmental Impact Statement
40		
41	GGBFS	Ground granulated blast-furnace slag
42		
43	GHG	Greenhouse gas
44		
45	GP	General Public
46		

1	HAP	Hazardous air pollutant
2		
3	HLW	High-level waste
4		
5	HPS	Health Physics Society
6		
7	HSM	Horizontal Storage Modules
8		
9	IAEA	International Atomic Energy Agency
10		
11	ICRP	International Commission on Radiological Protection
12		
13	ISFSI	Independent spent fuel storage installation
14		
15	LES	Louisiana Energy Services
16		
17	LLRW	Low Level Radioactive Waste
18		
19	LLRWDF	Low-Level Radioactive Waste Disposal Facility
20		
21	LLW	Low-Level Waste
22		
23	LNAPL	Light non-aqueous phase liquids
24		
25	LWR	Light water reactor
26		
27	MACT	Maximum Achievable Control Technology
28		
29	MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
30		
31	MCL	Maximum Contaminant Level
32		
33	MOX	Mixed oxide
34		
35	mrem/yr per pCi/g	Millirem per year of radiation exposure per picocurie per gram of material
36		
37		
38	mrem/yr per pCi/cm <sup>2</sup>	Millirem per year of radiation exposure per picocurie per square centimeter of material
39		
40		
41	MSW	Municipal Solid Waste
42		
43	MSWLF	Municipal Solid Waste Landfill
44		
45	MVDS	Modular Vault Dry Storage
46		

1	NAAQS	National Ambient Air Quality Standards
2		
3	NCRP	National Council on Radiation Protection and Measurements
4		
5	NEI	National Emissions Inventory
6		
7	NEPA	National Environmental Policy Act
8		
9	NESHAP	National Emissions Standards for Hazardous Air Pollutants
10		
11	NKBA	National Kitchen and Bath Association
12		
13	NLFW	Non-Licensed Facility Workers
14		
15	NPDES	National Pollutant Discharge Elimination System
16		
17	NPR	Non-power reactor
18		
19	NPTS	Nationwide Personal Transportation Survey
20		
21	NRC	Nuclear Regulatory Commission
22		
23	NTTAA	National Technology Transfer and Advancement Act of 1995
24		
25	N <sub>2</sub> O	Nitrous oxide
26		
27	OAQPS	Office of Air Quality Planning and Standards
28		
29	OAS	Organization of Agreement States
30		
31	OTAQ	Office of Transportation and Air Quality
32		
33	P&O	Public and occupational health and safety
34		
35	PM <sub>10</sub>	Particulate matter
36		
37	PM <sub>2.5</sub>	Fine particulate matter
38		
39	POTW	Publicly Owned Treatment Facility
40		
41	ppm	Parts per million
42		
43	PWR	Pressurized water reactor
44		
45	R&D	Research and development
46		

1	RCRA	Resource Conservation and Recovery Act
2		
3	RDF	Refuse-derived fuel
4		
5	Rebars	Reinforcement bars
6		
7	SDMP	Site Decommissioning Management Plan
8		
9	SIP	State implementation plan
10		
11	Smelters	NRC-Licensed Recycling Facilities
12		
13	SRM	Staff Requirements Memorandum
14		
15	TEDE	Total Effective Dose Equivalent
16		
17	TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
18		
19	terrestrial	The ground
20		
21	TRIGA	Training, Research, Isotopes, General Atomics
22		
23	U <sub>3</sub> O <sub>8</sub>	Uranium oxide
24		
25	UF <sub>6</sub>	Uranium hexafluoride
26		
27	UO <sub>2</sub>	Uranium dioxide
28		
29	USC	United States Code
30		
31	USEC	U.S. Enrichment Corporation
32		
33	VOC	Volatile organic compounds
34		
35	WWW	World Wide Web
36		
37		

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1 **FOREWORD**

2  
3 This Draft GEIS is organized consistent with the National Environmental Policy Act (NEPA)  
4 and the President’s Council on Environmental Quality (CEQ) regulations at 40 CFR 1502.10. It  
5 is intended to provide clear and concise information on the Proposed Action and Alternatives to  
6 agency decision-makers and the public. This Draft GEIS describes the Proposed Action and  
7 Alternatives, the affected environment, and potential impacts associated with the Proposed  
8 Action and Alternatives. The following is a brief description of the contents of this Draft GEIS.  
9

10 **Chapter 1 - Purpose and Need**

11 Chapter 1 introduces the Proposed Action, describes the background and history of NRC’s  
12 efforts for controlling the disposition of solid materials, describes the purpose and need for  
13 action, and introduces the cooperating agencies. This chapter also describes the scope of the  
14 analysis.  
15

16 **Chapter 2 - Proposed Action and Alternatives**

17 Chapter 2 describes the Proposed Action and Alternatives, including the No Action Alternative,  
18 that are studied in detail in the Draft GEIS. It also describes the Alternatives that were  
19 considered, but eliminated from detailed analysis. Chapter 2 concludes with a summary  
20 comparison of the predicted environmental impacts that would result from implementation of the  
21 Proposed Action or Alternatives, based on the information and analysis presented in Chapter 3.  
22

23 **Chapter 3 - Description of the Affected Environment and Environmental Consequences**

24 Chapter 3 describes the existing natural and human resources that could be affected by the  
25 Proposed Action and Alternatives. It also contains the methodology and results of the analysis  
26 of potential environmental impacts associated with the Proposed Action and Alternatives,  
27 including the No Action Alternative. The results address direct, indirect, cumulative, short-term,  
28 and long-term impacts.  
29

30 **Chapter 4 - Cost-Benefit Analysis**

31 Chapter 4 summarizes the results of the cost-benefit analysis, which is provided in full, including  
32 a discussion of methodology, in Appendix K. This chapter presents the costs and benefits  
33 associated with the Proposed Action and each of the Alternatives.  
34

35 **Chapter 5 - Staff Assessment**

36 Chapter 5 presents the staff’s assessment of the proposed action and other alternatives  
37 considering their costs, benefits, and impacts to the public and the environment.  
38

39 **Chapter 6 - List of Preparers**

40 Chapter 6 provides a list of the names and qualifications of the preparers of the Draft GEIS.  
41

42 **Chapter 7 - References**

43 Chapter 7 includes citations of all the published sources of information used in the preparation of  
44 the Draft GEIS.  
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## CHAPTER 1 PURPOSE AND NEED

### 1.0 THE PROPOSED ACTION

The Nuclear Regulatory Commission (NRC) is considering whether to promulgate a regulation to control the disposition of solid materials that originate in restricted or impacted areas<sup>1</sup> of NRC/Agreement State-licensed facilities, and have no, or very small amounts of, radioactivity resulting from licensed operations. These solid materials, which are referred to as “potentially clearable” materials, can include furniture and ventilation ducts in buildings; metal equipment; steel and copper pipes; wood, paper, and glass; laboratory materials (gloves, beakers, etc); routine trash; site fences; concrete; soil; or other similar materials. Under the current approach, licensees survey materials to detect the presence of radioactivity from Atomic Energy Act materials above natural background levels. Solid materials can currently be released for any unrestricted use if the survey indicates that existing guidelines are met. The process used to identify, survey and disposition solid materials is found in guidance, not regulations.

Other solid materials in these restricted or impacted areas can contain more appreciable levels of radioactivity. However, these materials are required to be disposed of at licensed low-level waste (LLW) disposal sites under NRC’s existing regulations in 10 CFR Part 61. Solid materials containing appreciable levels of radioactivity are not the subject of this NRC rulemaking. Also, solid materials not located in restricted or impacted areas, and considered to be free of radioactivity resulting from licensed operations, are not the subject of this NRC effort.

The Proposed Action is to promulgate a regulation to control the disposition of solid materials (metals, concrete, trash, and soil) from NRC-licensed facilities. In the Proposed Action, all materials to be released would undergo a radiation survey and the measured level of radiation (i.e., concentration) would be compared against radionuclide concentration levels for release of solid materials. Solid materials with measured radiation levels below these radiation levels would be released from licensed control. Solid materials with measured radiation levels above the standard would be sent to a LLW disposal facility. NRC regulations in 10 CFR Part 20 would be amended to add a new solid material release standard. A new regulation would provide a clear and consistent regulatory basis for determining the disposition of solid materials. In developing the new regulations, the NRC is guided by the goals of its Strategic Plan (NRC, 2004d) of which the primary goal is protection of public health and safety and the environment. The proposed rulemaking could result in related rulemakings in the Agreement States. (Agreement States are States that signed an agreement with NRC under which the State regulates the use of by-product, source and small quantities of special nuclear material within that State.)

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<sup>1</sup> A restricted area is defined in the NRC regulations at 10 CFR 20.1003 as an area to which access is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. An impacted area is defined in 10 CFR 50.2 as an area with some reasonable potential for residual radioactivity in excess of natural background or fallout levels.

1 To support its decision on the proposed rulemaking, the NRC staff determined that a generic  
2 environmental impact statement (GEIS) is required by the NRC National Environmental Policy  
3 Act (NEPA)-implementing regulations in 10 CFR Part 51. The Draft GEIS is part of the draft  
4 rulemaking package on which the public is asked to comment. This Draft GEIS describes the  
5 environment potentially affected by the proposal and evaluates the potential environmental  
6 impacts of the Proposed Action, including its reasonable alternatives.

## 7 8 **1.1 BACKGROUND**

9  
10 NRC initially considered a proposed rulemaking in 1999. As part of the scoping process, NRC  
11 published an Issues Paper on the release of solid materials from licensed facilities in June 1999  
12 in the Federal Register (64 FR 35090) (NRC 1999a) and requested public comments. NRC  
13 indicated that it was examining alternatives for controlling the disposition of solid materials.  
14 NRC held four public meetings during the fall of 1999 as part of the scoping process to receive  
15 comments. Over 800 public comment letters were received during the public comment period in  
16 1999. Comments were diverse in the views expressed, and provided a number of alternatives for  
17 controlling the disposition of solid materials.

18  
19 On March 23, 2000, the NRC staff provided the Commission with a paper (SECY-00-0070) on  
20 the diversity of views expressed in public comments received on the Issues Paper. Attachment 2  
21 of SECY-00-0070 (NRC 2000a) provides a summary of views and comments received;  
22 summaries of the comments can also be viewed in NUREG/CR-6682, “Summary and  
23 Categorization of Public Comments on the Control of Solid Materials” (September 2000) (NRC  
24 2000b). To solicit additional input, the Commission held a public meeting on May 9, 2000, at  
25 which stakeholder groups presented their views and discussed alternatives for controlling the  
26 disposition of solid materials.

27  
28 On August 18, 2000, the Commission decided to defer a final decision on whether to proceed  
29 with a rulemaking and directed the staff to request that the National Academies conduct a study  
30 of alternatives for controlling the disposition of solid materials. The Commission also directed  
31 the staff to continue to develop technical information and to stay informed of international and  
32 U.S. agency activities in this area.

33  
34 The National Academies study of alternatives for controlling the disposition of solid materials  
35 was initiated in August 2000. As part of the study, the National Academies held three  
36 information gathering meetings in January, March, and June of 2001, at which it obtained input  
37 from various stakeholder groups. The input received was similar to that presented to the NRC  
38 earlier. Based on these meetings, and on its deliberations on this topic, the National Academies  
39 submitted a report to the NRC in March 2002 titled *The Disposition Dilemma - Controlling the*  
40 *Release of Solid Materials from Nuclear Regulatory Commission-Licensed Facilities* (National  
41 Research Council 2002). The report contains findings and nine recommendations related to the  
42 decision-making process, potential approaches for controlling the disposition of solid materials,  
43 and additional technical information needs. An important finding in the National Academies  
44 report was that NRC’s current approach for controlling the disposition of solid materials “is  
45 sufficiently protective of public health that it does not need immediate revamping.” However,  
46 the National Academies report also states that NRC’s current approach is incomplete and

1 inconsistent and concludes that NRC should therefore undertake a process to evaluate a broad  
2 range of alternatives to provide clear risk-informed direction on controlling the disposition of  
3 solid materials. The report notes that broad stakeholder involvement and participation in the  
4 NRC’s decision-making process on the alternatives is critical as the process moves forward. The  
5 report also recommends that an individual dose standard of 1 mrem/yr provides a reasonable  
6 starting point for the process of considering alternatives for a dose-based standard. A link to the  
7 National Academies report is contained in the Background section of the NRC’s web page on  
8 controlling the disposition of solid materials.<sup>2</sup>  
9

10 Following completion of the National Academies report, the NRC staff submitted a paper to the  
11 Commission on July 15, 2002 (SECY-02-0133) (NRC 2002a) which contained a set of options  
12 for proceeding with a regulatory process for examining alternatives for controlling the  
13 disposition of solid materials. Based on its review of the National Academies report and of  
14 SECY-02-0133, the Commission, in a Staff Requirements Memorandum dated October 25,  
15 2002, directed the staff to proceed with an enhanced participatory rulemaking to develop specific  
16 requirements for controlling the disposition of solid materials.  
17

18 On February 28, 2003, NRC published a notice in the Federal Register (68 FR 9595) (NRC  
19 2003a) requesting comments on the scope of the proposed rulemaking and announcing its  
20 intention to prepare a GEIS to analyze alternatives for establishing requirements for controlling  
21 the disposition of solid materials. On April 18, 2003 NRC published another notice in the  
22 Federal Register (68 FR 19232) (NRC 2003b) announcing the dates and location of a public  
23 workshop to discuss the proposed rulemaking and the scoping process.  
24

## 25 **1.2 PURPOSE AND NEED FOR AGENCY ACTION**

26  
27 Just as is the case for many industrial operations, there are “solid materials” that are no longer  
28 needed or useful at facilities licensed by NRC or otherwise need to be removed from restricted or  
29 impacted areas. This can occur, for example, during normal facility operations when: (a) metal  
30 equipment and tools become surplus, obsolete or worn; (b) glass, plastic, paper, or other trash-  
31 like materials are no longer useful; (c) concrete is removed from a building being renovated; or  
32 (d) soil is being excavated from a site and is no longer needed. This can also occur at the end of  
33 facility operations when a licensee seeks to terminate its NRC license.  
34

35 Solid materials can currently be released for any unrestricted use if a survey indicates that  
36 existing guidelines are met. Appendix B discusses current guidelines used regarding the release  
37 of solid materials from sites for unrestricted use. However, these levels are in NRC guidance and  
38 10 CFR Part 20 does not currently specify the dose or concentration limits below which the  
39 material can be released. The disadvantages of the current case-by-case approach are (1) the lack  
40 of a consistent criterion for controlling solid materials can result in inconsistent release levels,  
41 (2) there is no guidance for volumetrically contaminated materials, (3) there have been some  
42 inconsistencies when other types of detectors with different sensitivities are used and still lower

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<sup>2</sup> <http://www.nrc.gov/materials.html>. Click on “Controlling the Disposition of Solid Materials”  
under “Key Issues.”

1 levels of radioactivity are detected in previously released materials, and (4) additional time and  
2 resources are required to evaluate and implement an approach that can vary with each case.  
3

4 The purpose and need of the Proposed Action is to develop an efficient and effective regulatory  
5 process that ensures the disposition of solid materials are controlled in a manner that ensures  
6 protection of public health and safety and the environment. The Proposed Action should provide  
7 a consistent criterion for controlling solid materials, guidance for surficially and volumetrically  
8 contaminated materials, and a reduction in the time and resources required to evaluate case-  
9 specific applications.  
10

11 NRC agrees with the findings in the National Academies report (National Research Council,  
12 2002) regarding the need to consider modifying its current approach to provide specific direction  
13 on controlling the disposition of solid materials. The National Academies report indicates that  
14 NRC's current approach for controlling the disposition of solid materials (the No Action  
15 Alternative) "is sufficiently protective of public health." However, the National Academies  
16 report also indicates that the current approach is incomplete and inconsistent and that NRC's  
17 approach should be risk-informed. As a result, the National Academies study states that NRC  
18 should conduct a process to evaluate alternatives to provide clear risk-informed direction on  
19 controlling the disposition of solid materials. This Draft GEIS is part of that process and  
20 considers several alternatives for rulemakings.  
21

### 22 **1.3 SCOPE OF ENVIRONMENTAL ANALYSIS**

#### 23 Scoping Process

24  
25  
26 The NRC is conducting an enhanced participatory process to evaluate alternative courses of  
27 action at NRC-licensed facilities for controlling the disposition of solid materials that have no or  
28 very small amounts of radioactivity. As part of NRC's examination of its approach for control of  
29 solid materials, including the scope of an environmental impact statement, NRC sought early  
30 stakeholder input on the major issues associated with this effort, as described in Section 1.1.  
31

32 As an additional part of its continuing efforts to solicit stakeholder involvement, NRC published,  
33 on February 28, 2003, a Request for Comments on the scope of a proposed rulemaking and  
34 notice of a workshop in the Federal Register (68 FR 9595) (NRC 2003a). In this Federal  
35 Register Notice, NRC sought stakeholder participation and involvement in identifying  
36 alternatives and their environmental impacts that should be considered as part of a rulemaking  
37 and analyzed in a GEIS. The NRC also announced in this Federal Register Notice its intent to  
38 conduct a workshop to solicit new input with a focus on the feasibility of alternatives that would  
39 limit where solid materials could go. The workshop was held at NRC Headquarters in Rockville,  
40 MD May 21-22, 2003. A summary of the results of this workshop is available on NRC's website  
41 (see footnote 2 on page 1-3).  
42

43 Over 2,600 written comments were received in addition to the discussion at the workshop.  
44 NUREG/CR-6682 Supplement 1 (*Summary and Categorization of Public Comments on*  
45 *Controlling the Disposition of Solid Materials, February 2004*) (NRC 2004a) summarizes the  
46 comments received as a result of NRC's request for comments and the workshop discussion.

1 Comments were received from various stakeholder groups, including environmental and  
2 citizen's groups, members of the general public, scrap and recycling companies, steel and  
3 cement manufacturers, hazardous and solid waste management facilities, the U.S. Environmental  
4 Protection Agency (EPA), U.S. Department of Energy (DOE), State agencies, Tribal  
5 Governments, scientific organizations, international organizations, and NRC licensees and  
6 licensee organizations.

7  
8 The scoping process (as described in Appendix A) helped to determine the scope of this Draft  
9 GEIS, including significant issues to be analyzed in depth. For example, in response to  
10 comments received during the scoping process, the Draft GEIS includes an alternative where the  
11 potentially clearable solid material can only be disposed of in a LLW facility (i.e., Prohibition).

### 12 Scope of the GEIS

13  
14  
15 The issues analyzed in depth in the Draft GEIS include the impacts and costs associated with  
16 rule alternatives for controlling the disposition of solid materials at licensed facilities.  
17 Information was developed on (a) types and contamination levels of solid materials potentially  
18 available for release at licensed facilities; (b) pathways of exposure from, and environmental  
19 impacts of, solid materials released from licensed facilities; and (c) regulatory alternatives and  
20 methods of approach for analysis of the alternatives.

21  
22 The Draft GEIS recognizes previous and ongoing reports and analyses related to the control of  
23 solid materials, including the National Academies report completed in March 2002. In addition,  
24 other scientific organizations are engaged in similar processes. Recognized radiation protection  
25 organizations like the National Council on Radiation Protection and Measurements (NCRP),  
26 International Commission on Radiological Protection (ICRP), and American National Standards  
27 Institute (ANSI) have issued findings about possible criteria for controlling the disposition of  
28 solid materials. DOE is preparing a Programmatic Environmental Impact Statement on  
29 alternatives for disposition of DOE scrap metals. EPA sets radiation protection standards in the  
30 general environment, although it does not currently have a program on controlling the  
31 disposition of solid materials from licensed facilities. International agencies (such as the  
32 International Atomic Energy Agency (IAEA) and the European Commission (EC)) as well as  
33 other individual nations, are in the process of establishing standards or have standards for  
34 clearance of solid materials.

35  
36 NRC's goal in preparing this Draft GEIS is to set forth the impact analyses in a manner which is  
37 readily understandable to the public. Decisions and the rationale for those decisions are  
38 described and significant impacts discussed in this Draft GEIS. Topical areas whose impacts are  
39 less significant are discussed in less detail, with an explanation of why they were found to be less  
40 significant. This should allow the readers to focus on issues that were important in reaching the  
41 conclusions of the Draft GEIS. The following topical areas and issues are analyzed in the Draft  
42 GEIS.

- 43  
44 • **Human Health and Safety.** The potential human health impacts of the Alternatives on the  
45 workers and the general public are evaluated for normal licensee operations and  
46 decommissioning of licensee facilities. Potential exposures to radioactive materials and to

1 chemicals are considered. Models, assumptions, and supporting data used to analyze the  
2 impacts from these potential exposures are described.  
3

- 4 • **Transportation.** The transportation impacts of shipping released materials under each  
5 alternative are discussed. The Draft GEIS contains an analysis of potential impacts resulting  
6 from the transportation of each material type by various types of transport, including truck.  
7 The Draft GEIS discusses the quantities of material to be shipped and the vehicle miles  
8 traveled for each alternative. The impacts of transportation are evaluated in terms of risk to  
9 the population during normal transportation (including truck emissions) and under credible  
10 accident scenarios.  
11
- 12 • **Water Resources.** The Draft GEIS assesses the potential impacts of the alternatives on  
13 surface water, groundwater, and drinking water resources.  
14
- 15 • **Air Quality.** Potential air quality impacts of each alternative are evaluated in the Draft GEIS.  
16 The evaluation includes potential impacts resulting from operational activities for both  
17 radiological constituents and other priority air pollutants and compares the anticipated air  
18 quality impacts with relevant standards.  
19
- 20 • **Ecological Impacts.** Potential impacts of alternatives on ecological receptors (plants and  
21 animals) are considered.  
22
- 23 • **Waste Management.** The Draft GEIS documents the quantities and types of the various  
24 released materials to be disposed for each alternative. The Draft GEIS also considers the  
25 disposal capacity impacts associated with the release of these materials for both LLW  
26 disposal facilities and EPA/State-regulated landfills.  
27
- 28 • **Cumulative Impacts.** The Draft GEIS analyzes the potential cumulative impacts of the  
29 alternatives when added to other past, present, and reasonably foreseeable future actions.  
30 Both DOE and technologically enhanced naturally occurring radioactive material  
31 (TENORM) facilities are considered in this analysis.  
32
- 33 • **Unavoidable Adverse Impacts.** A discussion is included on the potential environmental  
34 impacts that could not be avoided if any of the alternatives were implemented.  
35
- 36 • **Short-Term Use Versus Long-Term Productivity of the Environment.** The Draft GEIS  
37 compares the potential adverse impacts on the environment associated with short-term use  
38 for the alternatives to the potential adverse impacts on the long-term productivity of the  
39 environment.  
40
- 41 • **Irreversible and Irrecoverable Commitment of Resources.** The irreversible and irretrievable  
42 commitment of resources, including land use, materials, and energy are discussed.  
43
- 44 • **Mitigation and Monitoring.** The Draft GEIS assesses whether any monitoring or mitigation  
45 measures are anticipated as a result of implementing any of the alternatives.  
46

- 1 • **Cost-Benefit Analysis.** The Draft GEIS includes a cost-benefit analysis that summarizes the  
2 environmental and other costs and benefits of each of the alternatives compared to the No  
3 Action Alternative.  
4

5 Issues raised during the scoping period for the Draft GEIS are summarized in Section 2 of  
6 Appendix A. Section 3 of Appendix A discusses the subjects and issues that are addressed in  
7 depth in the Draft GEIS. Issues raised during the scoping period have been considered in the  
8 preparation of the scoping report. As discussed in Section 4 of Appendix A, certain issues are  
9 not addressed in depth in the Draft GEIS. NRC has made a determination that some issues are  
10 associated with small or no impacts. The following topical areas and issues are not addressed in  
11 the Draft GEIS because no impacts are anticipated for these site-specific issues:  
12

- 13 • Soils;  
14 • Socioeconomics;  
15 • Environmental justice;  
16 • Land use;  
17 • Visual/scenic resources;  
18 • Noise; and  
19 • Historical, archaeological, and cultural resources.  
20

21 Further, the scope of the Proposed Action does not include any activities related to construction  
22 of facilities. The scope of the Proposed Action is limited to impacts associated with the release,  
23 transportation, recycling, and disposal of solid materials. The potential impacts of any  
24 construction of facilities that is proposed would be assessed on a site-specific basis.  
25

26 The scope of the Proposed Action does not include any solid materials left on site at licensee  
27 facilities after license termination. The scope of the Proposed Action is limited to transfer of  
28 solid materials off site for either recycling, reuse, or disposal. Solid materials remaining on site  
29 at facilities after license termination are subject to existing NRC regulations that would not be  
30 changed by the Proposed Action. When an NRC-licensed facility is decommissioned, the  
31 licensee must decontaminate the facility site to at least the minimum prescribed criterion prior to  
32 the NRC terminating the license (10 CFR 20 Subpart E). This limit pertains to both the  
33 facilities' remaining intrinsic structure (e.g., buildings) and site (e.g., soil). The potential  
34 impacts to the General Public, Non Licensed-Facility Workers, and Licensed-Facility Workers of  
35 the existing NRC regulations applicable to material left on site have already been analyzed  
36 through the NRC rulemaking for these regulations. Therefore, solid materials left on site are not  
37 included within the scope of the Draft GEIS.  
38

39 Some commenters asked NRC to collect materials that have been previously released. NRC has  
40 no plans to collect these materials because once released, there is no tracking of these materials.  
41

42 The U.S. imports and exports material that may contain residual radioactivity. The analysis of  
43 these imports and exports is outside the scope of the GEIS because this rulemaking only applies  
44 to control of the disposition of solid materials from NRC and Agreement State licensed facilities.  
45 NRC's requirements in 10 CFR Part 110 already contain requirements for export and import of  
46 material that assures that these actions are done in a safe, regulated manner. The proposed

1 rulemaking does not propose to change those requirements or the procedures associated with  
2 them. However, this Draft GEIS does consider the use of an international standard (IAEA Safety  
3 Guide RS-G-1.7) (IAEA 2004), which would provide more consistency with international  
4 numeric guidelines.

#### 6 **1.4 APPLICABLE REGULATORY REQUIREMENTS**

7  
8 The NRC's primary mission is to help ensure that public health and safety and the environment  
9 are protected in the many different peaceful uses of nuclear materials. The NRC is responsible  
10 for regulating various commercial, industrial, academic, and medical uses of nuclear materials.  
11 For example, NRC regulates commercial nuclear power plants, fuel cycle and nuclear waste  
12 facilities and nuclear materials used in the diagnosis and treatment of cancer and in smoke  
13 detectors. Information about NRC is available at NRC's World Wide Web (WWW) site  
14 <http://www.nrc.gov>. One way the NRC accomplishes its mission is by issuing regulations. The  
15 process of developing regulations is called rulemaking. The NRC's regulations are found in  
16 Chapter I of Title 10, "Energy," of the Code of Federal Regulations (CFR). These regulations  
17 are binding on all persons and organizations who receive a license from NRC to use nuclear  
18 materials or operate nuclear facilities.

19  
20 NRC currently addresses the release of solid materials on a case-by-case basis using license  
21 conditions and existing regulatory guidance. Appendix B contains details of the current  
22 approach. Solid materials can be released for any unrestricted use if a survey indicates that  
23 existing guidelines are met.

24  
25 Under current NRC regulations, licensees also have the option of proposing disposal methods  
26 and procedures that are not otherwise authorized in the regulations. These NRC provisions are  
27 contained in 10 CFR Part 20.2002<sup>3</sup>. Under these provisions, a licensee's application must  
28 provide a description of the waste, including the physical, chemical, and radiological properties,  
29 for the purpose of assessing potential doses; methods and manner of disposal of such wastes;  
30 location and nature of the environment where such wastes will be disposed of; analyses showing  
31 projected doses for the proposed disposal methods, and procedures that will be used to maintain  
32 doses ALARA for workers and members of the public. NRC policy and guidance for these  
33 dispositions uses a dose criterion of "a few millirem" per year. Agreement States have similar  
34 provisions in their regulations. Licensees have used the specific process set out in 10 CFR  
35 20.2002 to seek approval for the unrestricted release of material for disposal.

36  
37 Regulatory Guide 1.86 titled *Termination of Operating Licenses for Nuclear Reactors* (USACE  
38 1974) is used to evaluate solid materials before they are released. A similar guidance document  
39 is Fuel Cycle Policy and Guidance Directive FC 83-23, titled *Guidelines for Decontamination of*  
40 *Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Byproduct,*  
41 *Source or Special Nuclear Materials Licenses* (NRC 1983a). Both documents contain a table of  
42 surface contamination criteria which may be applied by licensees for use in demonstrating that

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<sup>3</sup> Part 20.2002 - Method for Obtaining Approval of Proposed Disposal Procedures. Before the revision of Part 20 (January 1, 1994), these provisions were contained in Part 20.302 under the same title.

1 solid material with surface contamination can be safely released with no further regulatory  
 2 control.

3  
 4 The Agreement States use a variety of practices and criteria for the release of solid materials on a  
 5 case-by-case basis, including the use of radiation levels that are indistinguishable from  
 6 background, use of guidelines similar or equivalent to Regulatory Guide 1.86, and the use of dose  
 7 based analyses.

8  
 9 NRC shares responsibility for radioactive material transport with the U.S. Department of  
 10 Transportation (DOT). DOT is responsible for regulating safety in transportation of all  
 11 hazardous materials, including radioactive materials, whereas NRC is responsible for regulating  
 12 safety in receipt, possession, use, and transfer of byproduct, source, and special nuclear materials.  
 13 NRC recently amended 10 CFR Part 71 - *Packaging and Transportation of Radioactive Material*  
 14 to make it compatible with DOT's regulations at 49 CFR and with the latest version of the  
 15 International Atomic Energy Agency standards in TS-R-1 (*Regulations for the Safe Transport of*  
 16 *Radioactive Materials*) (NRC 2004b) and to address the Commission's goals for risk-informed  
 17 regulations and eliminating inconsistencies with other regulatory approaches. The 10 CFR Part  
 18 71 Final Rule was published in the Federal Register (69 FR 3698) (NRC 2004b) on January 26,  
 19 2004. DOT published a parallel rule in the Federal Register (69 FR 3632) (DOT 2004) on the  
 20 same date. Table 1-1 lists the major agencies, acts and activities evaluated in this Draft GEIS.

21  
 22 **Table 1-1 Federal Regulations**

23  
 24

Agency	Authority	Activity Covered
Nuclear Regulatory Commission	Atomic Energy Act	Licensing Decommissioning Release of Solid Materials
Nuclear Regulatory Commission	National Environmental Policy Act (10 CFR Part 51)	Environmental Impact Statement
U.S. Environmental Protection Agency	Resource Conservation and Recovery Act (RCRA)	Landfill disposal
U.S. Environmental Protection Agency	Clean Air Act	Air Quality Permits
U.S. Environmental Protection Agency	Clean Water Act	National Pollutant Discharge Elimination System Permits
U.S. Environmental Protection Agency	Clean Water Act	National Primary Drinking Water Regulations
U.S. Department of Transportation	49 CFR Parts 171 - 180	Transportation Regulations

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2 **1.5 COOPERATING AGENCIES**  
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4 EPA, DOE, and the State of Massachusetts are cooperating agencies in the preparation of this  
5 Draft GEIS, pursuant to the President’s Council on Environmental Quality (CEQ) regulations  
6 (40 CFR 1501.6).  
7

8 EPA has an interest in the proposed rulemaking because EPA sets radiation protection standards  
9 in the general environment. EPA previously had related rulemaking activities, coordinated with  
10 NRC on the development of the technical information bases on controlling the disposition of  
11 solid materials, and currently is engaged in rulemaking activities on Resource Conservation and  
12 Recovery Act (RCRA) landfill disposal. Cooperating agency status will assist EPA in its own  
13 rulemaking process, focused on landfill disposal of materials containing residual radioactivity.  
14 EPA’s Office of Radiation and Indoor Air serves as the principal point of coordination for the  
15 Draft GEIS (Appendix C).  
16

17 NRC invited DOE to be a cooperating agency in the development of the Draft GEIS because of  
18 DOE’s experience and efforts in the control and release of property containing residual  
19 radioactivity. Participating as a cooperating agency will help DOE stay apprised of the relevant  
20 issues and will provide a mechanism for DOE to contribute its expertise to the review process,  
21 while ensuring effective communication between NRC and DOE. Cooperating agency status  
22 will also assist DOE in its own EIS process involving DOE scrap metal, which is a separate,  
23 ongoing effort. The Office of Air, Water and Radiation Protection Policy and Guidance is  
24 serving as DOE’s principal point of coordination for DOE participation in the Draft GEIS  
25 (Appendix C).  
26

27 NRC asked the Conference of Radiation Control Program Directors (CRCPD) and the  
28 Organization of Agreement States (OAS) to assist in the development of the Draft GEIS because  
29 the proposed NRC rulemaking would result in related rulemakings in the Agreement States. In a  
30 joint decision, CRCPD and OAS appointed the State of Massachusetts to act as a cooperating  
31 agency on their behalf. Massachusetts’ participation as a cooperating agency in the preparation  
32 of the Draft GEIS will keep the Agreement States apprised of the issues associated with  
33 controlling the disposition of solid material and provide a mechanism for the States to contribute  
34 their expertise to the review process, as well as ensure effective communication between NRC  
35 and the States.  
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## CHAPTER 2 PROPOSED ACTION AND ALTERNATIVES

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This chapter describes the alternatives for amending NRC’s regulations to include criteria for controlling the disposition of solid materials that originate in restricted or impacted areas of NRC/Agreement State licensed facilities. These materials have no, or very small amounts of, radioactivity resulting from licensed operations and are referred to in this Draft Generic Environmental Impact Statement (Draft GEIS) as “solid materials.” The alternatives studied in detail are No Action, Unrestricted Release, Environmental Protection Agency (EPA)/State-Regulated Disposal, Low-Level Waste (LLW) Disposal (Prohibition), and Limited Dispositions. In addition, one alternative and two options are presented which were considered but not studied in detail.

### 2.1 PROPOSED ACTION

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The Proposed Action being considered in this Draft GEIS is to promulgate an NRC regulation that would include criteria for disposition of solid materials from NRC licensed facilities. The Proposed Action would improve the efficiency and effectiveness of the NRC regulatory process for disposing of solid materials. The NRC is guided by the goals of the NRC Strategic Plan (NRC, 2004d), of which the primary goal is ensuring protection of public health and safety. The proposed rulemaking would result in related rulemakings in the Agreement States.

### 2.2 SOLID MATERIALS CONSIDERED UNDER THIS RULEMAKING

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Nuclear facilities routinely use different types of materials in support of various activities, including operations, production, research and development, maintenance, facility refurbishment, and ultimately decommissioning. In support of these activities, materials and items are introduced in areas that contain radioactivity. Areas that contain radioactivity include systems that process radioactive process fluid or gas streams, and waste storage and processing areas. Areas where radioactive materials are present are collectively referred to as “radiologically controlled” or “radiologically restricted” areas. Once materials or items are no longer needed or otherwise need to be removed, a licensee must decide how to disposition this material. For equipment and items such as tools, vehicles, and test equipment, the items could be considered for recycle or reuse rather than disposed of in LLW facilities because of their usefulness and value. Materials and equipment are surveyed before being taken out of restricted areas. The results of the surveys are used to determine the final disposition of materials or items. Based on the survey results, licensees determine whether it is worthwhile to decontaminate the materials or items or simply dispose of them as LLW. Materials considered by this rulemaking are described below. Descriptions of licensees and inventories of materials are discussed in Appendix F.

Concrete - Concrete is expected to be generated mostly during the decommissioning phase of facilities, although smaller amounts of concrete could be generated during facility or system modifications or refurbishment while still in operation. Larger amounts of concrete are expected to come from structural concrete, with and without steel reinforcement bars (rebars). Other origins of concrete may vary, ranging from sidewalks or equipment pedestals to building foundations.

1 Metals - For ferrous metals, this grouping includes carbon steel, stainless steel, forged steel,  
2 galvanized steel, cast iron, etc. with no specific distinctions being made as to their relative  
3 amounts. For the sake of inclusiveness, copper and aluminum were added to this category. In  
4 origin, ferrous metal and aluminum are expected to come from process system components,  
5 structural support, system piping and tanks, pumps, heat exchangers, valves, pipe hangers,  
6 motors, ventilation ductwork, etc. Copper is expected to come from cabling and wiring, electric  
7 motors, power distribution panels, etc.  
8

9 Trash - The composition of trash is expected to vary widely depending on the type of facility and  
10 operations. Generally, trash consists of plastics, paper, cloth, rubber, absorbent materials, wood,  
11 glass, filters, and metals (such as cans, wiring, etc.), and non-compactible waste (such as rubble,  
12 bricks, etc.).  
13

14 Soils - Soils are generated during facility operations and remediation activities. Most of the soil  
15 volumes are expected to be associated with decommissioning activities at the time of license  
16 termination. In broad terms, soils include natural soils, engineered backfill, and process related  
17 materials that may be present by themselves or commingled with natural soils. Backfills may  
18 consist of a mixture of rocks, gravel, and sand, with some being native to the site or imported  
19 from offsite locations. Some process materials that are soil-like materials include sediments,  
20 sands, filter cake, sludge, and crushed slag, with all excess water drained. These materials are  
21 characterized by a water content and other physical properties that are similar to that of natural  
22 soils (NRC 2005b). Soils are not within the scope of this Draft GEIS because they were not  
23 analyzed as part of this effort (see Section 2.4.5).  
24

25 Tools and Equipment - Tools and equipment include a variety of items used during facility  
26 operations, maintenance, and routine support activities. Tools may include hand tools and power  
27 tools. Equipment may include electronic test equipment, welding equipment and test  
28 instrumentation. Similarly, heavy equipment may include forklifts, trucks, backhoes, and cranes.  
29 Equipment also includes items used in offices, such as desks, file cabinets, chairs, computers,  
30 printers, phones, and copy and fax machines.  
31

32 Treated process materials, which are materials whose properties have been modified or are  
33 unique to the process from which they originate, include spent ion-exchange resins, sludge from  
34 spent ion-exchange process systems, microspheres, oily sludge and sediments, spent filters and  
35 filter sludge, spent charcoal beds, and incinerator ashes. They also include materials that have  
36 been solidified or stabilized, contain chelating agents, pathogenic or infectious biotic agents, and  
37 pyrophoric or explosive chemicals. These materials are not within the scope of this Draft GEIS  
38 and they were not analyzed as part of this effort. Moreover, radioactive materials present as  
39 sealed sources, as sources within devices and equipment, and bulk or discrete amounts of  
40 radioactive materials (in any form) are excluded from the provisions of this rule.  
41

### 42 **2.3 PROCESS USED TO FORMULATE ALTERNATIVES**

43

44 A set of preliminary alternatives for controlling the disposition of solid materials was first  
45 described in an NRC Issues Paper published for public comment in the Federal Register on June  
46 30, 1999 (64 FR 35090) (NRC 1999a). Public comments were received on the alternatives at

1 public workshops and in written comments during the comment period (NUREG/CR-6682  
2 (NRC, 2000b) and SECY-00-0070 (NRC 2000a)).  
3

4 In March 2002, a report issued by the National Academies (National Research Council 2002)  
5 provided additional discussion concerning the advantages and disadvantages of various  
6 alternatives. The report found that NRC's current approach for controlling the disposition of  
7 solid materials "is sufficiently protective of public health that it does not need immediate  
8 revamping." However, the National Academies report also states that NRC's current approach is  
9 incomplete and inconsistent and concludes that NRC should therefore undertake a process to  
10 evaluate a broad range of alternatives to provide clear risk-informed direction on controlling the  
11 disposition of solid materials.  
12

13 Based on these efforts, the Commission decided in October 2002 to proceed with a rulemaking  
14 for controlling the disposition of solid material. The Commission published a request for  
15 comments on the scope of the proposed rulemaking and notice of a workshop in the Federal  
16 Register on February 28, 2003 (68 FR 9595) (NRC 2003a). NRC held a public workshop on  
17 May 21-22, 2003 to solicit additional input on the alternatives being considered. This workshop  
18 was attended by a range of stakeholder groups who provided a diverse set of comments on the  
19 alternatives. In addition, more than 2,600 letters and e-mails were submitted to the NRC in  
20 response to the February 28, 2003 Federal Register notice, also from various stakeholders. A  
21 more complete description of the details of the entire scoping process for this Draft GEIS  
22 (including a summary of the public comments) is provided in Section 1.3 and the Scoping  
23 Summary Report in Appendix A.  
24

25 NRC has explored the range of all reasonable alternatives suggested during the scoping process  
26 and by the National Academies. After considering input from this scoping process, NRC  
27 determined the following reasonable range of alternatives for detailed study in this Draft GEIS.  
28 The order of the alternatives follows the order in which the alternatives were formulated and  
29 analyzed.  
30

- 31 • No Action
- 32 • Unrestricted Release
- 33 • EPA/State-Regulated Disposal
- 34 • LLW Disposal (Prohibition) (hereinafter referred to as LLW Disposal)
- 35 • Limited Dispositions  
36

37 Two dose-based standards were considered and then eliminated from detailed study. These  
38 standards, which are described in Section 2.5, are the American National Standards Institute  
39 (ANSI)/Health Physics Society (HPS) Standard ANSI/HPS N13.12-1999 and the European  
40 Commission (EC) Radiation Protection Reports Nos. 89 and 122 (European Commission 2000a;  
41 European Commission 2000b).  
42

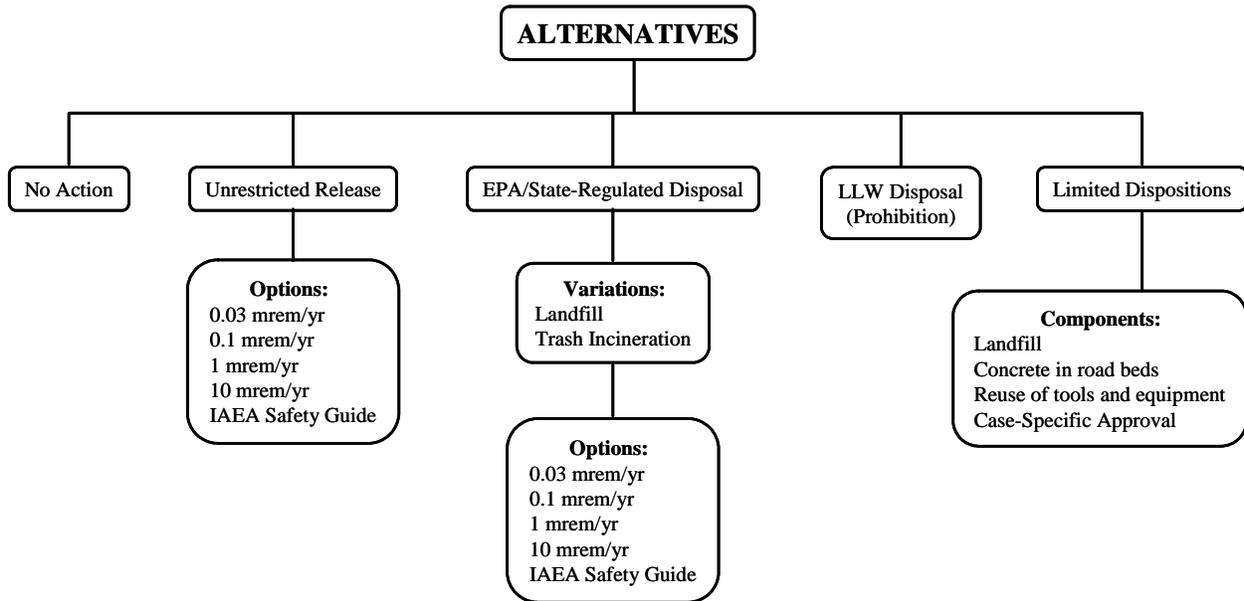
## 43 **2.4 ALTERNATIVES STUDIED IN DETAIL**

44

45 Regulatory alternatives for controlling the disposition of solid material analyzed in this Draft  
46 GEIS are shown in Figure 2-1 and described in detail in this section. The Unrestricted Release

and EPA/State-Regulated Disposal Alternatives have dose options, which are sensitivity studies for those alternatives. The order of the description of the alternatives in this section follows the order in which the alternatives were analyzed. The Limited Dispositions Alternative evolved from the study of the other alternatives.

**Figure 2-1 Alternatives**



**2.4.1 No Action**

National Environmental Policy Act (NEPA) regulations (40 CFR 1502.14) require the analysis of a No Action Alternative to provide the decisionmaker with a basis for comparison to reasonable alternatives. In this case, under the No Action Alternative, NRC would continue to apply its current approach to determining the eligibility of solid material for unrestricted release in general commerce or disposal. The NRC’s current approach is one that employs measurement-based guidelines to determine if solid materials can be released for any use or disposal. License conditions and facility-specific procedures require that solid materials that have been used in controlled or restricted areas are surveyed for the presence of radioactivity before being taken out of radiologically controlled areas. Solid materials can currently be released for any unrestricted use or disposal if the survey indicates that existing guidelines are met. Although NRC does not track release quantities if the materials meet the criteria, NRC inspectors routinely inspect a licensee’s radiation protection programs and implementing procedures, which includes the survey records for compliance with Part 20 and license conditions.

However, 10 CFR Part 20 does not currently specify a numerical level (e.g., dose or concentration limits) below which the material can be released. Decisions on disposition of solid materials are currently made using levels contained in a set of existing guidelines that are based primarily on the ability of survey techniques to measure the radioactivity level on, or in, the solid material. Solid material releases have been evaluated at many sites during decommissioning.

1 Under the current case-by-case approach, NRC considers the volumes of material, exposure  
2 pathways, doses to individuals, environmental impacts, stakeholder concerns, and ALARA  
3 issues in evaluating licensee requests. Additional details on NRC's current approach to  
4 determining the eligibility of solid material for unrestricted release in general commerce can be  
5 found in Appendix B.

6  
7 Under the No Action Alternative, solid material released (at or below guideline levels) for  
8 unrestricted release may be recycled and reused in a variety of end products, or it may be sent for  
9 disposal. Disposal may take place in an EPA/State-regulated landfill or LLW disposal facility.  
10 The potential exposures and the groups of individuals subject to exposures from released  
11 materials are dependent on their final dispositions.

12  
13 Disadvantages of the current case-by-case approach are (1) the lack of a consistent criterion for  
14 controlling solid materials can result in inconsistent release levels, (2) there is no guidance for  
15 volumetrically contaminated materials, (3) there have been some inconsistencies when other  
16 types of detectors with different sensitivities are used and still lower levels of radioactivity are  
17 detected in previously released materials, and (4) additional time and resources are required to  
18 evaluate and implement an approach that can vary with each case.

#### 20 **2.4.2 Unrestricted Release**

21  
22 The Unrestricted Release Alternative would allow solid materials to be released for any use in  
23 general commerce (recycling and/or reuse into consumer products and industrial and  
24 construction uses) or for disposal, if they are below a dose-based criterion. Under the  
25 Unrestricted Release Alternative, all materials to be released would undergo a radiation survey  
26 and the measured level of radiation would be compared against the criterion for release for  
27 unrestricted release.<sup>1</sup> Solid materials with measured radiation levels below the established  
28 criterion would be released from licensed control, while solid materials with radiation levels  
29 above the criterion would be sent to a LLW disposal site. The proposed rulemaking would  
30 include a table of radionuclide concentrations (or clearance levels) corresponding to the selected  
31 dose-based criterion. In implementation, survey results would be compared to the clearance  
32 level of each radionuclide or mixture of radionuclides in demonstrating compliance with the rule.  
33 Compliance would be demonstrated when the survey results are less than the applicable  
34 clearance levels.

35  
36 Under the Unrestricted Release Alternative, solid material released for unrestricted use may  
37 follow any disposition path – it may be recycled and reused in a variety of end products, or it  
38 may be sent for disposal. Disposal may take place in an EPA/State-regulated landfill or LLW  
39 disposal facility. The potential radionuclide exposures and the groups of individuals subject to  
40 exposures from released materials are dependent on their final dispositions.

41  
42 This Draft GEIS considers a range of dose level options for the release of solid materials. The  
43 dose level that NRC selects would directly impact the amount of solid material released for use

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<sup>1</sup> The term “clearance” is also used by various organizations and in various documents to mean removal from licensed control of material that meets certain release criteria.

1 in general commerce, with the amount of material released decreasing as the allowable dose  
2 criterion decreases. These dose options are:

- 3  
4 • 0.03 mrem/yr<sup>2</sup>  
5 • 0.1 mrem/yr  
6 • 1 mrem/yr  
7 • 10 mrem/yr  
8 • International Atomic Energy Agency (IAEA) Safety Guide No. RS-G-1.7 (1 mrem/yr)  
9 (IAEA 2004)

10  
11 For the first four dose options, NRC has independently assessed potential doses to individuals  
12 that could result from release of solid materials (NUREG-1640 (NRC 2003c)). This independent  
13 analysis is discussed in Chapter 3 of this Draft GEIS.

14  
15 For the fifth dose option, IAEA Safety Guide No. RS-G-1.7 (IAEA 2004) was assessed.  
16 Appendix E compares RS-G-1.7, which is based on 1 mrem/yr, with a 1 mrem/yr dose criterion  
17 based on NUREG-1640 (NRC 2003c). The IAEA safety guide was considered because its use  
18 would provide more consistency with international numeric standards. Although both dose  
19 options (RS-G-1.7 and NUREG-1640) are based on a dose limit of 1 mrem/yr, their associated  
20 radionuclide concentration levels differ due to differences in dose modeling assumptions.

21  
22 Under each of the dose options, solid materials to be released would have their level of  
23 radioactivity measured on-site by licensed facility workers (survey workers) prior to release.  
24 Those materials whose level of activity are found to be below the applicable clearance levels  
25 would be cleared for unrestricted release, including disposal in a landfill. Materials that do not  
26 meet clearance levels would be disposed of in a licensed LLW facility.

### 27 28 **2.4.3 EPA/State-Regulated Disposal**

29  
30 Under this alternative, all potentially clearable solid material below a dose-based criterion would  
31 be released to EPA/State-regulated landfills and would be prohibited from general commerce  
32 (recycling into consumer products and industrial and construction uses). A base case and one  
33 variation of this alternative are being considered, specifically:

- 34  
35 • EPA/State-Regulated Landfill (base case) – All released solid materials (including tools and  
36 equipment) would be disposed of in EPA/State-regulated Resource Conservation and  
37 Recovery Act (RCRA) Subtitle D landfills. Solid materials above the dose-based criterion  
38 would be sent to a LLW disposal facility.  
39  
40 • EPA/State-Regulated Trash Incineration (variation) – Trash would be incinerated at  
41 EPA/State-regulated incinerators and the ash disposed of in EPA/State-Regulated landfills.  
42 All non-trash solid materials (concrete, ferrous metal, etc.) would not be incinerated, but

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<sup>2</sup> A realistic lower-bound dose limit of 0.03 mrem/yr was chosen because it is a small value at, or marginally above, detectable levels.

1 would be disposed of in EPA/State-regulated landfills. Solid materials above the dose-based  
2 criterion would be sent to a LLW disposal facility.

3  
4 Under both the base case and the incinerator variations of this alternative, the following four  
5 dose options are being considered.

- 6  
7 • 0.03 mrem/yr  
8 • 0.1 mrem/yr  
9 • 1 mrem/yr  
10 • 10 mrem/yr

11  
12 The four dose options are based on NRC's independent analysis in NUREG-1640 (NRC 2003c).  
13 Because allowing only landfill disposal would limit the public's exposure to potentially clearable  
14 material, this alternative results in higher radionuclide concentration limits. Thus a greater  
15 amount of activity could be released to landfills than the amount that could be released to general  
16 commerce under the Unrestricted Release Alternative because persons are exposed in a more  
17 limited manner.

18  
19 EPA regulates municipal and industrial solid waste under RCRA. Under RCRA Subtitle D, the  
20 solid waste program encourages States to develop comprehensive plans for managing non-  
21 hazardous industrial solid waste and municipal solid waste and also sets criteria for municipal  
22 solid waste landfills and other solid waste disposal facilities. Further discussion of RCRA  
23 facilities is contained in Appendix J.

24  
25 Under RCRA Subtitle C, the hazardous waste program establishes a system for controlling  
26 hazardous waste from the time it is generated until its disposal. Because hazardous materials are  
27 typically disposed of in Subtitle C facilities, this alternative considers only RCRA D facilities.  
28 However, it is useful to discuss the status of EPA efforts on RCRA Subtitle C facilities. EPA is  
29 considering a rulemaking that could permit disposal of certain NRC-regulated material in a  
30 RCRA Subtitle C facility subject to, if necessary, an appropriate NRC approval process (e.g., a  
31 site-specific or general license, or exemption). EPA published an Advanced Notice of Proposed  
32 Rulemaking (ANPR) in the Federal Register (68 FR 65119, November 18, 2003) (EPA 2003a) to  
33 solicit stakeholder input on a potential regulatory framework to permit disposal of low-activity  
34 radioactive waste, including mixed waste and other low-level waste, in RCRA Subtitle C  
35 disposal facilities. EPA is considering a wide range of allowable dose limits for materials being  
36 disposed, most of which are higher than the 1 mrem/yr dose limit. EPA is coordinating with  
37 NRC on the ANPR. If EPA decides to move forward with a rulemaking for RCRA Subtitle C  
38 facilities, NRC would need to take conforming regulatory action in a separate rulemaking. That  
39 effort would be different from the proposed action discussed in this GEIS and would take place  
40 at a later time once EPA decides if it is moving forward with a rulemaking.

#### 41 42 **2.4.4 LLW Disposal (Prohibition)**

43  
44 Under the other alternatives, solid materials in excess of the release criteria would be sent to  
45 licensed LLW disposal facilities. However, under this alternative, also known as Prohibition, all  
46 potentially clearable solid material would be prohibited from general commerce and EPA/State-

1 regulated landfill disposal. All solid material in restricted or impacted areas (including tools and  
2 equipment) would be classified as LLW and required to be disposed of under NRC's existing  
3 regulations. The requirements of 10 CFR Part 61 address the siting, operation, and closure of  
4 LLW disposal facilities. Requirements in Appendix G to 10 CFR Part 20 focus on licensees (as  
5 waste generators) and provide procedures to ship LLW to such disposal sites.

6  
7 There are currently three LLW disposal sites operating in the country that could accept solid  
8 material under this alternative. These facilities are:

- 9  
10 • Envirocare - Clive, UT  
11 • Barnwell Disposal Facility - Barnwell, SC  
12 • Hanford Off-Site LLW Disposal Facility - Hanford, WA

13  
14 The Barnwell Disposal Facility will only accept non-regional waste until 2008, at which time it  
15 will accept waste only from the Atlantic Compact States of South Carolina, New Jersey, and  
16 Connecticut, which is a relatively small subset of the total population of licensed facilities. The  
17 Hanford Off-Site LLW Disposal Facility accepts waste only from the Northwest and Rocky  
18 Mountain Compact States, which are: Washington, Oregon, Idaho, Montana, Utah, Wyoming,  
19 Nevada, Colorado, New Mexico, Alaska, and Hawaii. Because it is assumed that very little of  
20 the solid material would be eligible for disposal at the Barnwell and Hanford facilities, this  
21 alternative assumes that in the future all solid material would be sent to the Envirocare site for  
22 disposal. Information on the remaining available capacity of the existing LLW disposal facilities  
23 is presented in Section 3.7.

#### 24 25 **2.4.5 Limited Dispositions**

26  
27 In this alternative, solid material would be released, but NRC would allow only certain  
28 authorized dispositions to limit the potential for public exposure. All materials to be released  
29 would undergo a radiation survey and the measured level of radiation would be compared  
30 against the criterion for release for limited dispositions. Solid materials with measured radiation  
31 levels below the established criterion would be released for pre-approved limited dispositions,  
32 while solid materials with radiation levels above those radionuclide concentrations would be sent  
33 to a LLW disposal facility. Any requests to release material other than to these limited end uses  
34 or at higher radionuclide concentrations would require case-specific approval from NRC. NRC  
35 regulations in 10 CFR Part 20 would be amended to add a dose-based regulation for limited  
36 dispositions.

37  
38 For the pre-approved dispositions, the radionuclide concentrations were chosen based on a dose  
39 limit of 1 mrem/yr using the IAEA Safety Guide No. RS-G-1.7 (IAEA 2004). A dose limit of 1  
40 mrem/yr was chosen because it is a small fraction of the public dose limit and it is based on the  
41 NCRP and the National Academies recommendations. The table of radionuclide concentrations  
42 accompanying the IAEA Safety Guide is based on unrestricted release. This is a reasonably  
43 conservative approach because, for the same 1 mrem/yr dose criterion, an unrestricted release is  
44 generally associated with lower (more restrictive) nuclide concentrations than a limited path  
45 release, for which persons are exposed in a more limited manner. Thus, it can be assured that  
46 even in the unlikely event that all materials released in a year from a licensee were inadvertently

1 diverted for unrestricted release (despite the requirements of the proposed rule directing it to a  
2 limited use or disposal), a 1 mrem/yr dose would not be exceeded, and it could also be assured  
3 that an isolated unrestricted release would result in doses well below 1 mrem/yr. The materials  
4 that could be released under the Limited Dispositions Alternative are concrete, metals, and trash.  
5 The disposition of soils is excluded from this Alternative based on the analyses considering  
6 potential uses of released soil under varying scenarios. The results indicate that under some  
7 conditions, soils initially intended for burial in landfills could be diverted, at a point beyond the  
8 licensee's control, and used in other purposes given that there is a demand for "clean fill" that  
9 can be used as backfill. The staff analysis revealed that there is not enough information to  
10 characterize how soils might be used locally. Thus, the disposition of soils would be considered  
11 under the case-specific component of the rule, as is done under current practices. This aspect is  
12 discussed in more detail in the section addressing "case-specific approvals."  
13

14 The radionuclide tables in RS-G-1.7 are expressed in terms of the quantity of the nuclides  
15 contained within the volume of the solid material. However, in many situations, surface  
16 concentrations will need to be measured or be more readily measurable. In fact, NRC's current  
17 approach in Regulatory Guide 1.86 includes a table of acceptable surface concentration levels.  
18 Since IAEA has not developed such information on surface concentrations at this time, NRC  
19 developed a table of surface concentrations by converting the volume concentrations of RS-G-  
20 1.7 to surface concentrations using information in NUREG-1640 (NRC 2003c) and by  
21 considering the values in the Department of Transportation transport requirements in 49 CFR  
22 Part 173. These surface concentrations are described in the NRC guidance document (NRC  
23 2005a) that is being issued with this rule.  
24

25 NRC considered whether solid material could be released if its further use would be restricted to  
26 only certain uses with limited potential for public exposure, such as use in a controlled  
27 environment. Examples include industrial uses such as metals in bridges or sewer lines, concrete  
28 use in road fill, and reuse of tools and equipment for their original purposes. Based on public  
29 comments during the scoping period, some of the possible recycling uses were not considered as  
30 pre-approved dispositions. Also, the marketplace is likely to limit the range of end-uses for the  
31 disposition of solid materials. For example, the recycling industry indicated it would be difficult  
32 to find scrap metal brokers and steels mills willing to accept and process the released materials.  
33 Although recycling of scrap metal was not considered as a pre-approved disposition, metal  
34 recycling could be considered as a case-specific application.  
35

36 Based on public comments during the scoping period and on the analyses for the Unrestricted  
37 Release and EPA/State-Regulated Disposal Alternatives in Chapter 3, the only limited  
38 dispositions considered under this alternative are disposal in a RCRA Subtitle D landfill,  
39 concrete use in roadbeds, and reuse of tools and equipment for their original purpose. Licensees  
40 would need to demonstrate that material proposed for release is less than the radionuclide  
41 concentrations in the proposed rule. Any requests to release material other than these limited  
42 end uses would require case-specific approval (including the disposition of soils).  
43

44 To ensure that the material releases are occurring to the pre-approved dispositions, there will be  
45 licensee recordkeeping and these activities would be evaluated periodically during routine staff

1 inspections at licensed facilities. Also, enforcement action would be taken if necessary,  
2 according to NRC regulations in 10 CFR Part 2.

3  
4 The following are the components of this alternative.

5  
6 **Landfills.** For landfill disposal under this alternative, the released solid materials (concrete,  
7 metal or trash) at or below the 1 mrem/yr criterion using the RS-G-1.7 standard could be  
8 disposed of in RCRA Subtitle D landfills. At this risk level, the controls associated with disposal  
9 of solid materials at RCRA Subtitle D landfills are sufficient to provide reasonable assurance  
10 that doses are maintained well below levels established to ensure adequate protection of public  
11 health and safety and the environment. Solid materials above the 1 mrem/yr criterion would be  
12 sent to a LLW disposal facility. As explained in Section 2.4.3 (EPA/State-Regulated Disposal  
13 Alternative), this proposed rulemaking considers only RCRA Subtitle D facilities because EPA  
14 is currently evaluating the possibility of higher dose limits at RCRA Subtitle C facilities. At this  
15 time, because NRC does not want to prejudge eventual EPA decisions regarding RCRA Subtitle  
16 C landfills, a licensee request to dispose of solid material in a RCRA Subtitle C landfill could be  
17 addressed under existing provisions in 10 CFR 20.2002.

18  
19 Although NRC would authorize, by rule, disposal in a RCRA Subtitle D facility, the municipal  
20 solid waste operators and the regulator of each RCRA facility (EPA and the States) have the  
21 discretion of allowing or refusing disposals in Subtitle D facilities. Even if allowed, EPA and  
22 the State agencies might impose additional constraints on such disposal. Accordingly, the  
23 implementation of the rule would have to consider EPA and State agency requirements. It is  
24 envisioned that some landfill operators and EPA and State agencies might not want to receive  
25 such materials, but others would, considering economic factors. At this time, however, it is not  
26 possible to determine readily which landfill operators and State agencies might find the NRC  
27 rule an effective option.

28  
29 **Concrete in Roadbeds.** Released concrete at or below the 1 mrem/yr criterion using the RS-G-  
30 1.7 standard could be recycled into roadbed material. Licensees who could demonstrate that  
31 concrete would be recycled into roadbed material could proceed with that release of material  
32 without NRC approval, but subject to NRC inspections in demonstrating compliance with the  
33 provisions of the rule.

34  
35 **Reuse of Tools and Equipment for their Original Purpose.** A separate provision of the rule  
36 would address the reuse of equipment, such as tools and vehicles, for their original purposes.  
37 Tools and equipment that meet the 1 mrem/yr dose criterion could be reused. Equipment at a  
38 licensed facility includes scaffolds, cranes, trucks and office furniture. Smaller pieces of  
39 equipment and tools are used by workers and may be transported in and out of  
40 restricted/impacted areas as part of the routine conduct of work in those areas.

41  
42 **Case-specific approvals.** Any request to release solid material other than to these limited  
43 dispositions or releases at higher radionuclide concentration levels would require case-specific  
44 approval from NRC. For these requests, NRC would codify the process and the criteria for  
45 licensees to seek case-specific approvals under a license amendment request. The licensee would  
46 also be required to submit an environmental report on the proposed action. The proposed rule

1 would identify the requirements that licensees need to observe in preparing and submitting such  
2 requests. It is expected that such applications would address end-uses for limited types and  
3 amounts of materials. For example, some types of structural steel could be reused for the  
4 construction of a framework for warehouses. For soils, materials may be used as backfill or as  
5 bedding in pipe trenches. For soil-like materials with cementitious properties, materials may be  
6 used as an additive to concrete in industrial settings, such as building footings and foundations or  
7 equipment pedestals. A licensee seeking a limited release for some restricted end use of material  
8 would be required to request an exemption based on pathways, worker protection, future uses,  
9 etc. A licensee could have to provide reasonable assurance that such materials are kept out of  
10 disposition paths that are not allowed and could have to submit a dose assessment to NRC for a  
11 case-specific disposition application.

12  
13 The decision to include the disposal of soil under the case-specific component of the Alternative  
14 reflects the results of analyses considering potential uses of released soil under varying  
15 scenarios. The results indicate that under some conditions, soils initially intended for burial in a  
16 RCRA D landfill could be diverted, at a point beyond the licensee's control, and used in other  
17 purposes given that there is a demand for "clean fill" for use as backfill. The staff analysis  
18 revealed that, at this time, there is not enough information to characterize how soils might be  
19 used locally. For example, the analysis presented in NUREG-1725 (Human Interaction with  
20 Reused Soil: An Information Search) and evaluation conducted in support of this GEIS, indicates  
21 that there is much uncertainty in the potential volumes and types of soils that might be released  
22 and how soils might be used once released. For instance, is the amount of soil a decisive factor  
23 in dictating whether it would be used or disposed of locally? do USDA and State regulations  
24 and restrictions impose limitations on the movement and use of soils? are there shipping cost  
25 constraints that would favor disposal over use? are there factors that would lead licensees to  
26 leave soil onsite instead of shipping it for disposal? Moreover, the engineering properties of  
27 soils are expected to dictate where and under what conditions soils might be reused. For  
28 example, the relative proportions of soil, gravel, sand, and other materials (e.g., concrete and  
29 asphalt rubble) might restrict the use to very limited applications or dictate disposal. These  
30 considerations could not be fully addressed in the staff analysis because of the lack of supporting  
31 information. Given these uncertainties, the staff deemed it prudent to address the disposition of  
32 soils on a case-specific basis, as is done under current practices.

33  
34 **Recordkeeping.** As part of its proposed rule, the NRC would include a requirement for records  
35 maintenance. These records would aid in allowing verification that the criterion has been met  
36 and provide reasonable assurance that the material was delivered to one of the allowed  
37 destinations. This recordkeeping could also provide the means to assess the effectiveness of this  
38 rule by confirming material released and estimated doses that have occurred as a result.  
39 Licensees would be required to maintain records indicating the nature of the material released  
40 (i.e., type and quantity of solid material, and nuclides present and their concentrations) and its  
41 destination (i.e., the landfill or specific end use shipped to, etc.).

42  
43 **Monitoring.** All radioactive materials used, possessed, or stored onsite are required to be  
44 periodically monitored and inventoried. The monitoring includes the conduct of external  
45 radiation and surface contamination surveys. The inventory addresses quantities of radioactive  
46 materials as to their physical and chemical forms, uses, and dispositions, including radioactive

1 decay. These requirements are stated in 10 CFR Part 20 and as license conditions stipulated in  
2 each license. Accordingly, the radiological status and locations of materials, before being  
3 designated for release, fall under the full control of the radiation safety program of each licensee.  
4 As a result no additional mitigation measures are anticipated as a result of implementing any of  
5 the alternatives. The implementation of the rule will be monitored through inspections, similar to  
6 those for releases to sewers.

7  
8 In summary, the limited dispositions for each material are as follows:

- 9  
10 • Concrete could be disposed in a RCRA Subtitle D landfill or recycled into roadbed material.  
11 • Metals could be disposed in a RCRA Subtitle D landfill.  
12 • Tools and equipment could be reused or disposed in a RCRA Subtitle D landfill.  
13 • Trash could be disposed in a RCRA Subtitle D landfill.  
14 • Disposition of soils, soil-like materials, or process materials would be case-specific.  
15 • Any other disposition of these materials or disposition at higher radionuclide concentrations  
16 would require case-specific approval by NRC.

17  
18 **2.5 ALTERNATIVES AND OPTIONS CONSIDERED BUT ELIMINATED FROM**  
19 **DETAILED STUDY**

20  
21 One alternative (conditional use) and two dose options (both clearance standards) were  
22 considered by NRC and eliminated from detailed study. These options are therefore not  
23 analyzed in detail in this Draft GEIS. The following sections describe the reasons why they have  
24 been eliminated from consideration.

25  
26 **2.5.1 Conditional Use**

27  
28 In this alternative, solid material would be released, but its further use would be restricted to  
29 only certain authorized uses with limited potential for public exposure, such as use in controlled  
30 environments. Examples might include industrial uses such as metals in bridges, sewer lines, or  
31 industrial components, or concrete use in road fill. NRC regulations in 10 CFR Part 20 would be  
32 amended to add a dose-based regulation for conditional use. The Conditional Use Alternative  
33 would allow a greater amount of activity to be released than the amount that would be released  
34 under the Limited Dispositions Alternative because the latter uses unrestricted release  
35 radionuclide concentrations to establish the 1 mrem/yr dose limit and these are more  
36 conservative.

37  
38 Material from these authorized uses may ultimately be reused or recycled into products not  
39 authorized under the Conditional Use Alternative. For this reason, the Conditional Use  
40 Alternative was replaced with the more restrictive Limited Dispositions Alternative, which uses  
41 radionuclide concentrations based on unrestricted release.  
42

1 **2.5.2 American National Standards Institute/Health Physics Society Standard N13.12-**  
2 **1999**

3  
4 In addition to the dose options being analyzed under the Unrestricted Release Alternative, the  
5 1999 American National Standards Institute (ANSI)/Health Physics Society (HPS) Standard  
6 N13.12 was also considered. The National Technology Transfer and Advancement Act of 1995  
7 (NTTAA), Public Law 104-113, requires all Federal agencies and departments to use technical  
8 standards developed or adopted by voluntary consensus standards bodies as a means to carry out  
9 policy objectives or activities determined by the agencies and departments, except when  
10 utilization of such standards “is inconsistent with applicable law or otherwise impractical.”

11  
12 The ANSI standard presents screening clearance criteria for unrestricted release (clearance) of  
13 solid materials based on an annual dose limit of 1 mrem. When justified on a case-by-case basis,  
14 clearance could be permitted at higher dose levels when it can be assured that exposures to  
15 multiple sources (including those that are beyond the scope of this standard) will be maintained  
16 ALARA (as low as reasonably achievable) and will provide an adequate margin of safety below  
17 the public dose limit of 1 mSv/yr (100 mrem/yr) TEDE. The standard excludes the release of  
18 land and soils intended for agricultural purposes.

19  
20 As identified by the National Academies, one problem with the standard is that the bases for the  
21 screening clearance levels have not been fully documented. Moreover, the National Academies  
22 note that the approach used in deriving the volumetric screening levels is based on a room  
23 modeling scenario involving exposures only to external radiation, inhalation, and incidental  
24 ingestion of dust containing radioactivity. The total duration of the exposures is assumed to be  
25 only 500 hours, occurring over a brief time period. In evaluating case-specific applications, the  
26 NRC would consider exposure scenarios and pathways that were not addressed by the standard.  
27 Such differences make the use of the ANSI standard difficult to justify. Finally, the standard is  
28 due for its first 5-year review cycle in 2004 and ANSI may decide to revise it in accommodating  
29 comments from the National Academies and others. For these reasons, NRC believes that use of  
30 the ANSI standard is impractical, and the ANSI standard was not included in the detailed  
31 analysis.

32  
33 **2.5.3 European Commission Standard - Reports Nos. 89 and 122**

34  
35 An additional international standard considered by NRC as an option under the Unrestricted  
36 Release Alternative was the European Commission’s (EC’s) clearance levels as described in  
37 Radiation Protection Reports Nos. 89 and 122 (EC 2000a and 2000b). In these documents, there  
38 are a range of assumptions used for converting the actual measured concentrations at the release  
39 point to the dose received by various receptors. Appendix E provides a comparison between  
40 NRC’s independent dose analysis (NUREG-1640), IAEA Safety Guide RS-G-1.7, and the EC  
41 clearance levels. Using the more recently adopted IAEA safety guide instead of the EC  
42 clearance levels would provide more consistency in international standards.

1  
2 **2.6 SUMMARY COMPARISON OF PREDICTED ENVIRONMENTAL IMPACTS**  
3

4 NEPA regulations require a comparison of the environmental impacts of all of the alternatives, in  
5 order to define the issues and provide a clear basis for choice among the various options. This  
6 section presents a brief comparison of the environmental impacts of the alternatives, which are  
7 compared in greater detail in Section 3.12. Table 2-1 provides a summary of the impacts.  
8

9 Nuclear power plants would be disposing of material over the next 50 years. However, the time  
10 period over which impacts are considered includes (1) the operational phase of reactors during  
11 which some materials are expected to be released, (2) the post-shutdown and decommissioning  
12 phase of reactors during which materials will be released as well, (3) and the post-  
13 decommissioning time period after which materials that have been released are presumed to have  
14 some long-term impacts on the public. The operational phase of reactors takes into account the  
15 currently operating and shutdown reactors over the next 50 years. The post-decommissioning  
16 phase considers impacts over the next 200 years, while the analysis notes that doses beyond 200  
17 years and out to 1,000 years become vanishingly small and contribute very little to the total of  
18 collective doses.  
19

20 As discussed in Section 1.3, some environmental issues are not analyzed in detail in this Draft  
21 GEIS because NRC does not anticipate impacts to these environmental resources. These  
22 environmental resources and issues include soils, noise, ecological resources, socioeconomics,  
23 historic and cultural resources, environmental justice, visual and scenic resources, and land use  
24 (Table 2-1).  
25

26 The impacts shown in Table 2-1 are defined in 10 CFR Part 51, Appendix B.  
27

- 28 • “Small Impact” is defined as: “For the issue, environmental effects are not detectable or are  
29 so minor that they will neither destabilize nor noticeably alter any important attribute of the  
30 resource. For the purposes of assessing radiological impacts, the Commission has concluded  
31 that those impacts that do not exceed permissible levels in the Commission's regulations are  
32 considered small as the term is used in this table.” In addition, those environmental  
33 resources or issues where there is no potential to cause impact are included under the term  
34 “small impact.”  
35
- 36 • “Moderate Impact” is defined as: “For the issue, environmental effects are sufficient to alter  
37 noticeably, but not to destabilize, important attributes of the resource.”  
38
- 39 • “Large Impact” is defined as: “For the issue, environmental effects are clearly noticeable and  
40 are sufficient to destabilize important attributes of the resource.”  
41

42 As described in Chapter 3, the following impacts were studied in detail: water quality,  
43 transportation, air quality, waste management, and public and worker health and safety. The  
44 impacts on water quality, air quality and public and worker health and safety would be small for  
45 all alternatives. The transportation effects (which are based on statistical information on non-  
46 radiological fatal traffic accidents) are highest for the LLW Disposal Alternative, because

transport distances associated with this alternative are significantly higher for truck transport, resulting in higher estimated fatal traffic accidents. The effects on waste management associated with the LLW Disposal Alternative are considered large (more than four times the existing LLW capacity at the Envirocare site under its current State licenses and permits). Under the other alternatives, the amount of solid material that would be sent to a LLW facility is less than the existing LLW disposal capacity.

**Table 2-1 Comparison of Alternatives and Associated Impacts<sup>3</sup>**

	Alternatives				
	No Action	Unrestricted Release	EPA/State-Regulated Disposal	LLW Disposal (Prohibition)	Limited Dispositions
Soils	○	○	○	○	○
Noise	○	○	○	○	○
Ecological Resources	○	○	○	○	○
Socioeconomics	○	○	○	○	○
Historic and Cultural Resources	○	○	○	○	○
Environmental Justice	○	○	○	○	○
Visual and Scenic Resources	○	○	○	○	○
Land Use	○	○	○	○	○
Water Quality	○	○	○	○	○
Transportation	○	○	○	○ to ◐	○
Air Quality	○	○	○	○	○
Waste Management	◐	○	○	●	○
Public and Worker Health and Safety	○	○	○	○	○
Benefit or (Cost)	0	247	181	(1,404)	257

○ Small Impact      ◐ Moderate Impact      ● Large Impact

In analyzing the monetary costs and benefits associated with the alternatives, the No Action Alternative is the baseline against which the other alternatives are compared. There are no incremental costs or benefits for the No Action Alternative. For the Unrestricted Release and EPA/State-Regulated Disposal Alternatives, the incremental costs and benefits are dependent on the dose option selected. For both alternatives, benefits are associated with the 1 mrem/yr and 10 mrem/yr dose options, but costs are associated with the 0.03 mrem/yr and 0.1 mrem/yr dose options. These costs are due to the fact that under these lower dose options, smaller amounts of solid material are released, and larger amounts must be transported and disposed of in LLW disposal sites. In Table 2-1, the benefit shown for these alternatives is for a dose limit of 1 mrem/yr. The highest incremental costs are associated with the LLW Disposal Alternative and

<sup>3</sup> The terms “small,” “moderate” and “large” impacts are discussed in Section 2.6.

1 are estimated to exceed \$1.4 billion, primarily from transportation and disposal operations. For  
2 Limited Dispositions, with a dose criterion of 1 mrem/yr based on the IAEA standard, the benefit  
3 would be \$257 million.  
4

## 5 **2.7 PRELIMINARY RECOMMENDATIONS REGARDING THE PROPOSED** 6 **ACTION**

7  
8 The comparison of the alternatives is presented briefly in Section 2.6 and in detail in Section  
9 3.12. After weighing the costs and benefits and comparing the impacts of the alternatives, the  
10 NRC staff, in accordance with 10 CFR 51.71(e), sets forth their preliminary National  
11 Environmental Policy Act (NEPA) recommendation regarding the proposed action. The NRC  
12 staff recommends that the staff promulgate a regulation for limited dispositions. As discussed in  
13 Section 2.4.5, solid material would be released, but NRC would allow only certain authorized  
14 dispositions to limit the potential for public exposure. The only pre-authorized limited  
15 dispositions considered under this alternative would be disposal of concrete, metal or trash in a  
16 RCRA Subtitle D landfill, concrete use in road fill, and reuse of tools and equipment for its  
17 original purpose. Licensees would need to demonstrate that releases would be below Part 20  
18 radionuclide concentrations derived for a dose limit of 1 mrem/yr using the IAEA Safety Guide  
19 RS-G-1.7 for unrestricted release. Any requests to release material other than to these limited  
20 end uses or disposition at higher radionuclide concentrations would require case-specific  
21 approval from NRC.  
22

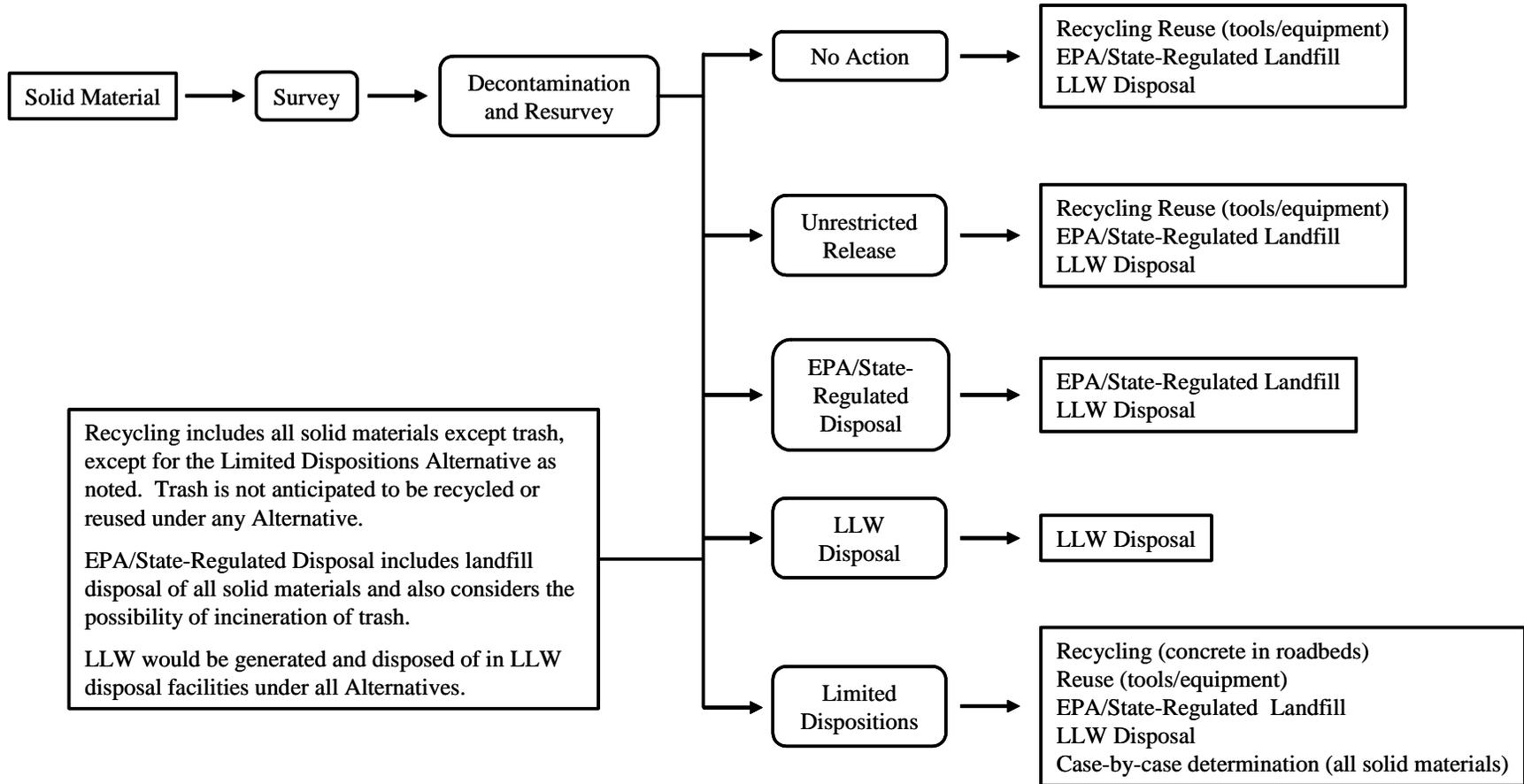
23 The NRC staff preliminarily concluded the overall benefits of the proposed rulemaking outweigh  
24 the disadvantages based on consideration of the following:  
25

- 26 • provide a risk-informed consistent criterion for controlling the disposition of solid materials,
- 27 • allow for a predictable regulatory process that is efficient and effective,
- 28 • set a dose criterion well below levels established to ensure adequate protection of public and  
29 safety and the environment,
- 30 • be consistent with international numeric guidelines,
- 31 • provide limited potential for public exposure,
- 32 • address public concerns with unrestricted release of solid materials into general commerce,
- 33 • address concerns from the steel and concrete industries that consumers could choose not to  
34 purchase items made from materials recycled from licensed facilities,
- 35 • provide guidance on materials with surficial and volumetric residual radioactivity, and
- 36 • ensure less time and resources would be expended on case-specific applications.  
37



1  
2  
3

**Figure 3-1 Disposition Pathways**



1 **3.2 HUMAN HEALTH AND SAFETY**

2  
3 The Affected Environment is defined for the purposes of the Human Health and Safety Impact  
4 assessment as workers and the public potentially exposed to radiation dose from activities  
5 associated with generation, handling, processing, disposition, transportation, and disposal of the  
6 materials generated from licensed facilities under the Alternatives. Appendix G describes the  
7 affected General Public groups and the affected Non-Licensed Facility Worker groups and the  
8 radiological impact assessment methodology used for the collective dose assessment for the No  
9 Action, Unrestricted Use, EPA/State-Regulated Disposal, and Limited Disposition Alternatives  
10 for each solid material. This includes a description of the characteristics of each affected group  
11 and the assumed dispositions of each solid material under each Alternative upon which the  
12 collective dose assessment for each Alternative and solid material is based.

13  
14 Occupational workers are defined in 10 CFR 20.1003 as only radiation workers, i.e., workers  
15 that work at LLW disposal facilities. Non-radiation workers are defined in 10 CFR 20.1003 as  
16 part of the public. For the purposes of the Draft GEIS, NRC has categorized potentially exposed  
17 individuals as (1) “Workers at Licensed Facilities,” (2) “Workers at Non-licensed Facilities,” and  
18 (3) “General Public,” as defined below. Affects on radiation workers (Workers at Licensed  
19 Facilities), non-radiation workers (Workers at Non-licensed Facilities), and the General Public  
20 are discussed in Section 3.2.3, 3.2.4, and 3.2.5 of the Draft GEIS.

21  
22 Workers at Licensed Facilities - These workers are employed at NRC- or Agreement  
23 State-licensed sites, including licensee facilities and LLW disposal facilities. Their duties may  
24 involve exposure to radiation or to radioactive material which is potentially clearable. Doses to  
25 these workers could occur from surveying and decontaminating potentially clearable materials at  
26 licensed facilities or disposing of solid materials at licensed facilities.

27  
28 Workers at Non-Licensed Facilities - These workers are members of the public who may  
29 experience work-related exposure while handling or otherwise encountering released material at  
30 their place of employment. Examples of these individuals include workers in scrap yards, iron  
31 and steel mills, EPA/State-regulated landfills, and EPA/State-regulated incinerators; truck  
32 drivers transporting released material; and building and road construction workers utilizing  
33 released material or byproducts of processing released material. Truck drivers transporting LLW  
34 to LLW disposal facilities are not workers situated at licensed facilities and are therefore  
35 categorized for the purposes of the Draft GEIS as Non-Licensed Facility Workers.

36  
37 General Public - These individuals are members of the public who may experience non-work  
38 related exposures, i.e., exposures that occur outside their place of employment. For example, the  
39 General Public could be exposed to released materials utilized in automobiles, roadbeds, and  
40 buildings. Note that Workers are also members of the General Public when they are not working  
41 at their place of employment.

42  
43 This section assesses the potential radiation exposures of workers at licensed facilities and non-  
44 licensed facilities, and the general public for each alternative. Detailed dose analyses were  
45 performed for concrete, ferrous metal, and trash generated from licensee facilities. Non-radiation

1 impacts are discussed in Sections 3.3 (Transportation), 3.4 (Water Resources), 3.5 (Air Quality),  
2 and 3.6 (Ecological Impacts).

### 3.2.1 Background Radiation

6 Radiation is all around us, and it is naturally present in our environment. Consequently, life has  
7 evolved in an environment which has significant levels of ionizing radiation. It comes from  
8 outer space (cosmic), the ground (terrestrial), and even from within our own bodies. It is present  
9 in the air we breathe, the food we eat, the water we drink, and in the construction materials used  
10 to build our homes. Certain foods such as bananas and brazil nuts contain higher levels of  
11 naturally-occurring radiation than other foods. Brick and stone homes have higher natural  
12 radiation levels than homes made of other building materials such as wood. Furthermore, a lot  
13 of our natural exposure is due to radon, a gas from the Earth's crust, that is present in the air we  
14 breathe.

16 Background radiation is defined as radiation that comes from cosmic sources, naturally  
17 occurring radioactive materials, including radon (except as a decay product of source or special  
18 nuclear material) and global fallout as it exists in the environment from the testing of nuclear  
19 explosive devices. Background radiation does not include radiation from source, byproduct, or  
20 special nuclear materials regulated by the NRC. The typically quoted average individual  
21 exposure from background (natural and artificial) radiation is 360 millirem (3.6 mSv) per year  
22 (Table 3-1) (NCRP 1987a). Appendix E provides additional discussion of background radiation  
23 data.

25 Levels of natural or background radiation can vary greatly from one location to the next. For  
26 example, people residing in Colorado are exposed to more natural radiation than residents of the  
27 east or west coasts because Colorado has more cosmic radiation at a higher altitude and more  
28 terrestrial radiation from soils enriched in naturally occurring uranium. The average annual  
29 radiation exposure from natural sources that every individual in the United States receives is  
30 about 300 millirem (3 mSv) (Table 3-1). Radon gas accounts for two-thirds of this exposure,  
31 while cosmic, terrestrial, and internal radiation account for the remainder. No adverse health  
32 effects have been discerned from doses arising from these levels of natural radiation exposure  
33 (NCRP 1987a).

35 Man-made sources of radiation from medical, commercial, and industrial activities contribute  
36 another 60 mrem (0.6 mSv) to our annual radiation exposure. One of the largest of these sources  
37 of exposure is medical x-rays. Diagnostic medical procedures account for about 40 mrem (0.4  
38 mSv) each year. In addition, some consumer products such as tobacco, fertilizer, welding rods,  
39 gas mantles, luminous watch dials, and smoke detectors contribute another 10 mrem (0.1 mSv)  
40 to our annual radiation exposure (NCRP 1987b).

42 A typical breakdown between natural background radiation and artificial sources of radiation is  
43 shown in Table 3-1. Natural radiation contributes about 82 percent of the annual dose to the  
44 population while medical procedures contribute most of the remaining 18 percent. Both natural  
45 radiation and artificial radiation affect people in the same way.

**Table 3-1 Average Annual Effective Dose Equivalent of Ionizing Radiations to a Member of the U.S. Population**

Source of Radiation	Effective dose equivalent	
	mSv (mrem)	Percent
<i>Natural</i>		
Radon <sup>a</sup>	2 (200)	55
Cosmic	0.27 (27)	8
Terrestrial	0.28 (28)	8
Internal	0.39 (39)	11
<b>Total natural<sup>b</sup></b>	<b>3 (300)</b>	<b>82</b>
<i>Artificial</i>		
Medical		
X-Ray Diagnosis	0.39 (39)	11
Nuclear Medicine	0.14 (14)	4
Consumer Products	0.1 (10)	3
Other		
Occupational	less than 0.01 (less than 1)	less than 0.03
Nuclear Fuel Cycle	less than 0.01 (less than 1)	less than 0.03
Fallout	less than 0.01 (less than 1)	less than 0.03
Miscellaneous <sup>c</sup>	less than 0.01 (less than 1)	less than 0.03
<b>Total artificial<sup>b</sup></b>	<b>0.63 (63)</b>	<b>18</b>
<b>Total natural and artificial<sup>b</sup></b>	<b>3.6 (360)</b>	<b>100</b>

<sup>a</sup> Dose equivalent to bronchi from radon daughter products.

<sup>b</sup> Totals have been rounded and may not be numerically identical to the sum of the dose values shown.

<sup>c</sup> From Department of Energy facilities, smelters, transportation, etc.

Source: NCRP, 1987a.

### 3.2.2 Dose Assessment

The dose-based standards considered in this Draft GEIS express doses to an individual on a yearly basis, such as 1 mrem (0.01 mSv) per year. The dose modeling developed under NUREG-1640 is discussed in Appendix E. The IAEA RS-G-1.7 (IAEA 2004) radionuclide concentration levels are based on a dose of 1 mrem (0.01 mSv) per year. The differences between the radionuclide concentration levels in RS-G-1.7 and the levels derived for a dose of 1 mrem/yr from the modeling studies in NUREG-1640 are generally considered to be minor by modelers because of the uncertainties in making such estimates and taking into account, to the extent practicable, variations in modeling complex industrial processes. In part, the uncertainty and variability are attributed to differences in code models; scenarios and exposure pathways describing industrial practices; model assumptions and parameters; differences in dose coefficients between ICRP 26 and 60 (ICRP 1991) recommendations given their respective use by the NRC and IAEA; methods in incorporating radon and its decay products; adjustments of

1 IAEA clearance values with that of other exemptions to ensure compatibility; and the process  
2 used in rounding off IAEA values to the nearest power of ten. For each given disposition of  
3 released materials, this means that a dose of one mrem would be incurred annually by an  
4 individual, ignoring radioactive decay, if the material continued to be released year after year.  
5

6 The sum of all individual doses for a group of individuals or a population is called the collective  
7 dose, which is expressed in person-rem or person-Sv. As a measure, collective dose provides a  
8 way of comparing the impacts to population groups against various activities. The annual  
9 background collective dose to the U.S. population due to natural sources of radiation and  
10 radioactivity is estimated to be about 84 million person-rem (840,000 person-Sv), assuming an  
11 annual average effective dose equivalent of 300 mrem (3 mSv). Appendix E presents a more  
12 detailed discussion of the concept and its application, including the limitations in the application  
13 of collective dose (Section E-III). For example, at low individual doses, the uncertainty in  
14 potential health risk includes the possibility of zero risk. Thus for populations where all  
15 members receive low doses, collective dose provides a very uncertain measure of risk, and there  
16 may be no significant impacts or risks to the population. However, NRC's regulatory analysis  
17 uses collective dose to a population because it enables a more direct comparison of the relative  
18 impacts of the different alternatives.  
19

20 The collective dose results are inclusive of all exposure pathways. (See the analytical methods  
21 using the Monte Carlo technique and pathways described in Appendix D.) The collective dose  
22 results are inclusive of the sum of all doses over all exposure pathways and times specified for  
23 the analysis. Exposure pathways, dose receptors, and dose contributions are dynamic in that the  
24 dominance of each varies as a function of time. At first, facility workers and truck drivers are the  
25 first group to incur doses and later the dose contribution shifts to members of the general public.  
26 The pathways include doses associated with external radiation, ingestion, and inhalation  
27 exposures. The pathways can be further defined as whether they are workers or members of the  
28 public. For workers and truck drivers, doses are associated, in decreasing order of contribution,  
29 with the following exposure pathways: external radiation, inhalation, and incidental ingestion of  
30 dust containing residual levels of radioactivity. The exposures and doses occurring early in the  
31 front end of the process involve the release of materials (i.e., while materials are being generated  
32 by licensed facilities, during transportation, and during end-use or disposal in landfills). During  
33 transportation, members of the public are exposed to external radiation while vehicles are  
34 traveling on roads. Once materials are no longer generated, there are no additional doses to  
35 workers and dose contributions shift to the members of the public over a more protracted time.  
36 At this point, doses to the public are associated with the movement of radioactive materials  
37 through ground and surface water. The predominant exposure pathways, in decreasing order, are  
38 the consumption of water and food crops irrigated with surface or ground water. In terms of  
39 radionuclides contributing to doses, the following, in decreasing order of relative presence in the  
40 mix, contribute to external radiation: Co-60, Cs-137, Co-58, and Cs-134. For worker exposures  
41 associated with inhalation and incidental ingestion, the following radionuclides, in decreasing  
42 order of the mix, contribute to internal doses: Co-60, Fe-55, Cs-137, Ni-63, Co-58, and Cs-134.  
43 For members of the public where doses are associated with slow environmental transport,  
44 radionuclides with long half-lives dominate - in decreasing order of the mix, they include Cs-  
45 137, Ni-63, Sr-90, C-14, Pu-238, Pu-239, and I-129.  
46

1 Although collective doses are used to compare the alternatives, the rule will be based on  
2 individual risk. The individual would not receive a dose of more than a specified dose limit (e.g.  
3 1 mrem/yr (0.01 mSv/yr)). If the individual dose limit is low, then the population is protected as  
4 well since it is virtually impossible for everyone in any population group to receive the  
5 maximum dose. In fact, the great majority of individuals in the population group considered in  
6 the analysis are expected to receive doses that are a small fraction of the dose limit considered in  
7 this Draft GEIS (1 mrem/yr). The collective dose analysis is summarized in Appendix D.

8  
9 The majority of the mass, activity and collective dose associated with licensed facilities is  
10 associated with solid materials released from commercial nuclear reactor licenses. For nuclear  
11 power plants, the radionuclide profile and relative fraction of each are based on site  
12 characterization results and selected low-level waste data. A single inventory was derived for all  
13 reactors, both operating and shutdown. The radioactivity profile assumed the presence of 17  
14 radionuclides, as beta and gamma emitters, and transuranics. The most predominant  
15 radionuclides, comprising about 96% of expected residual radioactivity levels, are Mn-54, Co-58,  
16 Co-60, Ni-63, Fe-55, Cs-134, and Cs-137. For these radionuclides, the radioactive half-lives  
17 range from about 71 days to 100 years. The collective doses are based on the time period up to  
18 the point when the currently operating reactors will be decommissioned. The collective dose  
19 analysis considers the time period (50 years) during which solid materials will be generated and  
20 200 years beyond in assessing long-term impacts. The analysis assumes that the decontamination  
21 and decommissioning and remediation work of all commercial nuclear power reactors effectively  
22 will be completed by 2050. The time period of this analysis is 250 years, which is the time when  
23 potentially clearable materials from existing licensees would result in significant contribution to  
24 collective dose. It should be noted that because most of the radioactivity is due to radionuclides  
25 with half-lives measured in years (a fraction of a year to about 30 years) rather than in thousands  
26 of years, the collective doses and impacts beyond 250 years become vanishingly small.

27  
28 However, for the impacts associated with landfill disposals, the analysis was carried out to 1,000  
29 years. In both cases, no specific distinction is made between the results associated with the 250  
30 or 1,000-year analysis given that beyond 250 years, collective doses become negligible.

31  
32 The collective dose analysis (SC&A 2003) considered Licensed Facility Workers involved in  
33 surveying and decontamination at licensed facilities generating solid material and at LLW  
34 disposal facility sites. The analysis considered the following scenarios for exposures to Non-  
35 Licensed Facility Workers and the General Public (Figure 3-1):

- 36  
37
- 38 • The collective dose from recycled concrete analyzed in this Draft GEIS results only from its  
39 use for road bed construction. The selection of road bed construction as the single end use is  
40 based on the fact that approximately 85 percent of road construction is recycled concrete  
41 (Appendix G).
  - 42 • The collective dose from ferrous metals is dominated by five scenarios depicting population  
43 exposures to finished ferrous metal products. These five end use products are office  
44 buildings, beds, automobiles, office furniture and home appliances.
- 45

- The end use for trash was disposal at EPA/State-regulated disposal facilities. Most of the trash from licensed facilities consists of items not likely to be reused (e.g., rubber gloves). Even if there were some recycling of this trash, its amount, compared to the much larger volumes of other materials intended for recycle would be insignificant in terms of collective dose. Also, current practice for trash from restricted/impacted areas at licensed facilities is that various trash items are mixed together and sent for disposal, not reuse or recycle.
- Inventory information on other metals, besides ferrous metal, indicated these were primarily copper or aluminum, and there is a small amount of these materials generated as compared to ferrous metal. The results of a screening analysis indicated that collective doses for copper and aluminum are about one to two orders of magnitude lower than that of ferrous metals.
- The disposition for all materials could be LLW disposal.
- Collective doses were calculated for reuse of small and large pieces of equipment.

### 3.2.3 Licensed Facility Workers

This section describes the affected environment and environmental consequences associated with the Alternatives for Licensed Facility Workers.

#### 3.2.3.1 Affected Environment

The affected environment with respect to Licensed Facility Worker collective dose includes survey workers and decontamination workers at licensed facilities generating solid material, and LLW disposal facility workers. Licensed Facility Worker activities contributing to collective dose include activities associated with surveying and decontaminating solid materials at licensed facilities and disposing of LLW at LLW disposal facility sites. Other solid material handling activities conducted at licensee facility sites, including management of solid material storage piles and loading of solid materials for transport to recycling or disposal facilities are assumed to be conducted by Licensed Facility Workers. Truck drivers within the impacted area during handling and loading operations would be considered Non-Licensed Facility Workers.

Activities conducted by Licensed Facility Workers in surveying and decontaminating the solid materials generated at licensed facilities are anticipated to be similar for all Alternatives. Licensed Facility Workers at LLW disposal facilities disposing of solid material as LLW are anticipated to be similar for all Alternatives. Therefore the affected environment for Licensed Facility Workers is similar for all Alternatives. These activities are described in this section and discussed in more detail in Appendix D.

#### Survey Workers

Survey workers are workers at licensed facilities who conduct radiation surveys of solid materials to assess their radiological characteristics. It is assumed for the purposes of the Draft GEIS that survey workers would conduct surveys specifically to characterize the solid materials in support of implementation of the proposed rule for the release of solid materials. Surveys of material

1 expected to result in doses to members of the public ranging from 10 mrem/yr (0.1 mSv/yr) to 25  
2 mrem/yr (0.25 mSv/yr) would be addressed as part of decommissioning activities under an NRC-  
3 approved license termination plan. Surveys conducted by survey workers in support of the  
4 decommissioning activities of licensed facilities for LLW disposal and to demonstrate  
5 compliance with the License Termination Rule, and that are not directly related to the release of  
6 solid materials, are not within the scope of the Proposed Action.

#### 7 8 Decontamination Workers

9  
10 Decontamination workers are workers at licensed facilities who decontaminate solid materials,  
11 mostly ferrous metal, to reduce the level of radioactivity of the solid materials. It is assumed for  
12 the purposes of the Draft GEIS that decontamination workers would conduct such activities  
13 specifically to decontaminate the solid materials in support of implementation of the proposed  
14 rule for release of solid materials. Decontamination activities conducted by workers in support  
15 of the decommissioning of licensed facilities and that are not related to the release of solid  
16 materials are not within the scope of the Proposed Action.

17  
18 It is assumed that the Proposed Action would only apply to materials considered to be relatively  
19 free of both internal and external surface or volumetric contamination and with residual  
20 radioactivity levels close to or below the release criteria. In other words, the provisions of a  
21 proposed rule are not expected to change licensee practices in identifying and segregating  
22 materials with contamination levels that may warrant decontamination or disposal as LLW.  
23 Moreover, it is assumed that if decontamination were considered as a precursor to compliance  
24 with a proposed rule, the initial contamination levels would need to be such that release criteria  
25 could be readily achieved given the selection of an appropriate decontamination method. This  
26 recognizes that if contamination levels were too high and the decontamination factor were too  
27 low, it would be a futile exercise to spend time and resources on decontamination. In such a  
28 situation, disposal as LLW would be the most cost-effective course of action. The proposed  
29 action is not expected to impact this decision process, nor affect the related economic factors.

#### 30 31 LLW Disposal Facility Workers

32  
33 Under each alternative, different amounts of solid material would be disposed of as LLW at a  
34 LLW disposal facility. The quantity of solid material that would be disposed as LLW depends  
35 upon the Alternative and dose option selected and affects the collective dose to workers at these  
36 facilities.

37  
38 The decision to dispose of useful material and equipment as LLW is driven by operational and  
39 economic considerations, taking into account replacement costs versus cost of repairs, lead time  
40 in procuring new equipment, amortization, and cost of money. These factors are expected to be  
41 different among facilities. The proposed action is not expected to impact this decision process,  
42 nor affect such economic factors.

1 **3.2.3.2 Environmental Consequences**

2  
3 This section describes the environmental consequences associated with the Alternatives for  
4 Licensed Facility Workers. Environmental consequences are presented in terms of collective  
5 dose, in units of person-rem, for each alternative.  
6

7 The collective doses to survey workers and decontamination workers at licensed facilities are  
8 assumed not to vary among the Alternatives and their associated dose options since all solid  
9 materials would be surveyed under each Alternative. However, it may be the case that for the  
10 0.03 mrem/yr dose option for some of the Alternatives that the number of labor hours required to  
11 survey the material would be higher because the survey would be more difficult for the workers  
12 to conduct. Note that surveying materials at an actual “zero above background” dose option  
13 would not be feasible, because radiation survey equipment would be incapable of distinguishing  
14 the radiation content of the materials generated from ambient “background” radiation. Only  
15 sample collection followed by laboratory analysis are feasible, but at a much greater cost.  
16

17 This analysis assumes that decontamination workers would decontaminate some of the ferrous  
18 metal generated from commercial nuclear reactor facilities in order to reduce the radionuclide  
19 concentration of the ferrous metal to below the dose option for the No Action, Unrestricted  
20 Release, EPA/State-Regulated Disposal and Limited Dispositions Alternatives. The analysis  
21 also assumed that some metals generated by commercial nuclear reactors would be  
22 decontaminated under all of the alternatives and over all dose options. The analysis assumed a  
23 representative decontamination factor of 15, with a range of 10 to 100 based on industry data.  
24 The resulting amount of steel is estimated to be about 40 tons per year per reactor and a total of  
25 4,200 tons as additional material available for release. NRC has assumed that trash and concrete  
26 would not be decontaminated because it is not economical to do so.  
27

28 Because the estimate of collective dose to decontamination workers is based on the  
29 decontamination of a fixed percentage of the ferrous metal generated, the collective dose to  
30 decontamination workers is assumed not to vary by Alternative. However, it may be the case for  
31 the 0.03 mrem/yr and 0.1 mrem/yr dose options for the Unrestricted Release Alternative and  
32 EPA/State-Regulated Disposal Alternative that decontamination of ferrous metals may not be  
33 feasible, based on economic considerations alone.  
34

35 The collective doses are estimated to be about 290 person-rem (2.99 person-sievert) for survey  
36 workers and 308 person-rem (3.08 person-sievert) for decontamination workers for all dose  
37 options (Appendix D).  
38

39 Under all the alternatives, solid material generated from licensed facilities that is within the  
40 scope of the alternatives but that does not meet the radiological criteria for release would be  
41 transported to a LLW disposal facility. Truck drivers transporting the solid material to the LLW  
42 disposal facility are classified as Non-Licensed Facility Workers. LLW disposal facility workers  
43 are classified as Licensed Facility Workers. The collective dose to workers at LLW disposal  
44 facilities does not vary significantly among the Alternatives and their associated dose options.  
45 The collective dose to LLW disposal facility workers for the Unrestricted Release Alternative  
46 and EPA/State-Regulated Disposal Alternative is 28 person-rem (0.28 person-sievert) for the 10

1 mrem/yr dose option and 35 person-rem (0.35 person-sievert) for the 0.03 mrem/yr dose option.  
 2 The collective dose to LLW disposal facility workers is 34 person-rem (0.34 person-sievert) for  
 3 the No Action Alternative and LLW Disposal Alternative (SC&A 2003).  
 4

5 **3.2.3.2.1 No Action Alternative**

6  
 7 Survey Workers

8  
 9 The estimate of collective dose to survey workers for the No Action Alternative is based on  
 10 surveying all of the potentially clearable solid material. The collective dose to Licensed Facility  
 11 Workers for surveying the entire inventory of ferrous metal, trash, and concrete generated from  
 12 commercial nuclear reactor facilities would be about 290 person-rem (2.9 person-sievert), as  
 13 shown in Table 3-2. The collective dose is dominated by the surveying of trash. This is because  
 14 of the relatively low mass to surface area ratio of trash as compared to concrete and ferrous  
 15 metal, which results in relatively large surface areas of trash to be surveyed compared to concrete  
 16 and ferrous metal, and this increases the number of labor hours needed to conduct the surveys.  
 17

18 **Table 3-2 No Action Alternative - Licensed Facility Worker Collective Dose from**  
 19 **Surveying Materials Generated from Commercial Nuclear Reactor Facilities**

Material	Exposure Rate (rem/hr)	Total Labor Hours	Collective Dose (person-rem) <sup>1</sup>
Trash	1.0E-04	27,400,000	274
Concrete and Ferrous Metal	5.0E-06	3,000,000	15
Total		31,400,000	289

20  
 21  
 22  
 23  
 24 <sup>1</sup> Source: SC&A 2003, Table 7.3.

25  
 26 Decontamination Workers

27  
 28 The collective dose to decontamination workers is estimated to be approximately 308 person-  
 29 rem (3.08 person-sievert), as shown in Table 3-3.  
 30

31 **Table 3-3 No Action Alternative - Licensed Facility Worker Collective**  
 32 **Dose from Decontaminating Materials Generated**  
 33 **from Commercial Nuclear Reactor Facilities**  
 34 **(person-rem)**

	Operating Ferrous metal	D&D Ferrous metal	Concrete	Trash	Total
Collective Dose	77	231	not applicable	not applicable	308

35  
 36  
 37 Source: SC&A 2003, Table 7.4.

38  
 39 LLW Disposal Facility Workers

40  
 41 Table 3-4 summarizes the collective dose to LLW disposal facility workers that would result  
 42 from disposal of solid materials in LLW disposal facilities under the No Action Alternative.

**Table 3-4 No Action Alternative - Licensed Facility Worker Collective Dose at LLW Disposal Facilities from Materials Generated from Commercial Nuclear Reactor Facilities**

Total Radioactivity Generated (Ci)	Radioactivity in LLW (Ci)	Radioactivity Released (Ci)	Collective Dose (person-rem)
2,951	2,947	4	34

Source: SC&A 2003, Tables 8.6 and 8.7.

**3.2.3.2.2 Unrestricted Release Alternative**

The collective dose to survey workers and decontamination workers, for the Unrestricted Release Alternative is estimated to be 289 person-rem (2.89 person-sievert) for survey workers and 308 person-rem (3.08 person-sievert) for decontamination workers.

The collective dose to workers at LLW disposal facilities does not vary significantly among the dose options for the Unrestricted Release Alternative, as shown in Table 3-5. The total radioactivity generated is 2,951 Ci, as shown in Table 3-4. The collective dose to LLW disposal facility workers for the Unrestricted Release Alternative ranges from 28 person-rem (0.28 person-sievert) for the 10 mrem/yr dose option to 34 person-rem (0.34 person-sievert) for the other dose options.

**Table 3-5 Unrestricted Release Alternative - Licensed Facility Worker Collective Dose at LLW Disposal Facilities from Materials Generated from Commercial Nuclear Reactor Facilities**

Dose Option	Radioactivity in LLW (Ci)	Radioactivity Released (Ci)	Collective Dose (person-rem)
10 mrem/yr	2,413	538	28
1 mrem/yr	2,910	41	34
0.1 mrem/yr	2,948	3	34
0.03 mrem/yr	2,950	1	34

Source: SC&A 2003, Table 8.7.

**3.2.3.2.3 EPA/State-Regulated Disposal Alternative**

The collective dose to survey workers and decontamination workers for the EPA/State-Regulated Disposal alternative is estimated to be 289 person-rem (2.89 person-sievert) for survey workers and 308 person-rem (3.08 person-sievert) for decontamination workers.

The collective dose to workers at LLW disposal facilities does not vary significantly among the dose options for the EPA/State-Regulated Disposal Alternative, as shown in Table 3-6. The collective dose to LLW disposal facility workers for the EPA/State-Regulated Disposal Alternative ranges from 28 person-rem (0.28 person-sievert) for the 10 mrem/yr dose option to 34 person-rem (0.34 person-sievert) for the other dose options.

**Table 3-6 EPA/State-Regulated Disposal Alternative - Licensed Facility Worker Collective Dose at LLW Disposal Facilities from Materials Generated from Commercial Nuclear Reactor Facilities**

Dose Option	Radioactivity in LLW (Ci)	Radioactivity Released (Ci) to Landfills	Collective Dose (person-rem)
10 mrem/yr	2,402	549	28
1 mrem/yr	2,906	45	34
0.1 mrem/yr	2,946	5	34
0.03 mrem/yr	2,950	1	34

Source: SC&A 2003, Table 8.7.

#### 3.2.3.2.4 Low-Level Waste Disposal Alternative

Under this Alternative, all the potentially clearable solid material would be disposed in LLW facilities. The collective dose to survey workers is estimated to be 289 person-rem (2.89 person-sievert). No decontamination is assumed for this Alternative. The collective dose to LLW disposal facility workers, as shown in Table 3-7, is 34 person-rem (0.34 person-sievert).

**Table 3-7 Low-Level Waste Disposal Alternative - Licensed Facility Worker Collective Dose at LLW Disposal Facilities from Materials Generated from Commercial Nuclear Power Reactors**

Total Radioactivity Generated (Ci)	Radioactivity in LLW (Ci)	Radioactivity Released (Ci)	Collective Dose (person-rem)
2,951	2,951	None	34

Source: SC&A 2003, Table 8.7.

#### 3.2.3.2.5 Limited Dispositions Alternative

The environmental consequences for Workers at Licensed Facilities would be the same for the Limited Dispositions Alternative as for the No Action, Unrestricted Release and EPA/State-Regulated Disposal Alternatives described above. Solid material generated from licensed facilities under the Limited Dispositions Alternative would be subject to similar activities conducted by survey workers and decontamination workers as under the other Alternatives, resulting in similar collective doses to survey workers and decontamination workers. Solid materials not meeting the requirements under the Limited Dispositions Alternative would be

disposed of in LLW disposal facilities, resulting in collective dose to LLW disposal facility workers. As shown above, the collective dose to LLW disposal facility workers does not vary significantly by Alternative, ranging from approximately 28 person-rem (0.28 person-sievert) to 34 person-rem (0.34 person-sievert). The collective dose to LLW disposal facility workers associated with the Limited Dispositions Alternative would be within the range of that for the other Alternatives.

### 3.2.3.2.6 Summary

Table 3-8 summarizes the collective dose for Licensed Facility workers for each of the alternatives. This table is derived from Tables 3-2 to 3-7 of this report. The total collective dose ranges from 323 person-rem (3.23 person-sievert) to 665 person-rem (6.65 person-sievert).

**Table 3-8 Summary of Licensed Facility Worker  
Collective Dose Results (person-rem)**

Alternative	Collective Dose			
	Survey Workers	Decontamination Workers	Workers at LLW Disposal Facilities	TOTAL
No Action	289	308	34	631
Unrestricted Release	289	308	28 - 34	625 - 631
EPA/State-Regulated Disposal	289	308	28 - 34	625 - 631
LLW Disposal	289	0	34	323
Limited Dispositions	289	308	34	631

### 3.2.4 Non-Licensed Facility Workers and the General Public

This section describes the affected environment and environmental consequences associated with the Alternatives for Non-Licensed Facility Workers and the General Public.

#### 3.2.4.1 Affected Environment

This section describes the affected environment associated with the Alternatives for Non-Licensed Facility Workers and the General Public.

##### Non-Licensed Facility Workers

The affected environment for Non-Licensed Facility Workers for the No Action and Unrestricted Release Alternatives includes truck drivers transporting solid materials to recycling facilities and transporting products and byproducts from recycling facilities, and also includes workers at the recycling facilities. The categories of activities for affected Non-Licensed Facility Workers are:

- Material processing, including processes for recycling of materials into finished commodities and end use products;

- 1 • Materials disposition, including the installation of finished commodities (e.g., recycled  
2 concrete road building material) and end use products (e.g., metal products made from  
3 recycled ferrous metal);  
4
- 5 • Byproducts disposition, including the application of products (e.g., furnace slag concrete)  
6 produced from byproducts of materials recycling processes;  
7
- 8 • Waste disposal, including disposal of wastes (e.g., foundry dust) produced by materials  
9 recycling processes;  
10
- 11 • Transportation, including transportation of generated materials, finished commodities and  
12 end use products made from recycled materials, and byproducts and wastes generated from  
13 materials processing activities.  
14

15 The affected environment for all the Alternatives except the LLW Disposal Alternative includes  
16 truck drivers transporting solid material from licensed facilities to EPA/State-Regulated disposal  
17 facilities and workers at the EPA/State-Regulated disposal facilities, including EPA/State-  
18 Regulated landfills and incinerators.  
19

20 The only Non Licensed-Facility Workers involved in the LLW Disposal Alternative are truck  
21 drivers or railroad workers transporting the LLW to the licensed disposal facility. The workers  
22 involved in surveying the LLW at the licensee facilities are categorized as Licensed-Facility  
23 Workers, and the workers involved in disposing of the LLW at licensed disposal facilities are  
24 also categorized as Licensed-Facility Workers.  
25

26 Under the Limited Dispositions Alternative, the affected environment for concrete would be  
27 similar to that for the Unrestricted Release Alternative, which assumes recycling of concrete into  
28 road bed material. The affected environment for solid materials that would be disposed of in  
29 EPA/State-Regulated disposal facilities would be similar to that for the EPA/State-Regulated  
30 Disposal Alternative. The affected environment for reuse of equipment would be similar to that  
31 for the No Action and Unrestricted Release Alternatives for the reuse of furniture in office  
32 buildings and reuse of tools and other equipment in other workplace settings. The affected  
33 environment for equipment reuse would also include truck drivers driving trucks formerly used  
34 at licensed facilities.  
35

### 36 General Public 37

38 The affected environment for the General Public for the No Action and Unrestricted Release  
39 Alternatives includes those individuals located in the vicinity of recycling facilities and along  
40 material transportation routes, and in locations where products produced from recycled materials  
41 are used. Products produced from recycled materials could be transported and utilized anywhere  
42 in the United States, and therefore the affected environment for the General Public for the No  
43 Action and Unrestricted Release Alternatives may encompass locations throughout the country.  
44

45 Activities potentially contributing to General Public collective dose for the No Action  
46 Alternative and Unrestricted Release Alternatives are:

- 1 • Materials disposition, including direct radiation exposure from use of finished commodities  
2 (e.g., recycled concrete as road building material) and end use products (e.g., metal products  
3 made from recycled ferrous metal);  
4
- 5 • Residuals disposition, including direct radiation exposure from the disposition of products  
6 (e.g., furnace slag concrete) produced from byproducts of materials recycling processes;  
7
- 8 • Waste disposal, including ground-water discharges from disposal of wastes (e.g., concrete  
9 dust) produced by materials recycling processes; and  
10
- 11 • Transportation of solid materials to recycling facilities and transportation of commodities  
12 from recycling facilities, including direct radiation exposure to finished commodities and end  
13 use products made of recycled solid materials, and byproducts and wastes generated from  
14 materials processing activities.  
15

16 Under the No Action and Unrestricted Release Alternatives some material generated from  
17 licensed facilities would be disposed of as LLW, and byproducts from recycling activities would  
18 be disposed of in EPA/State-Regulated disposal facilities. Therefore the affected environment  
19 for the No Action and Unrestricted Release Alternatives also includes the General Public located  
20 in the vicinity of LLW disposal facilities and EPA/State-Regulated disposal facilities.  
21

22 Under the EPA/State-Regulated Disposal Alternative some material generated from licensed  
23 facilities and covered under the Proposed Action would be disposed of as LLW. Therefore the  
24 affected environment for the EPA/State-Regulated Disposal Alternative also includes individuals  
25 located in the vicinity of LLW disposal facilities and along transportation routes.  
26

27 Activities potentially contributing to radiation exposure to the General Public for the EPA/State-  
28 Regulated Disposal Alternative are:  
29

- 30 • Transportation of solid materials for EPA/State-regulated disposal;
- 31 • Material disposal in EPA/State-regulated Subtitle D landfills;
- 32 • Trash disposal in EPA/State-regulated incinerators; and
- 33 • Landfill disposal of ash generated from trash incineration.  
34

35 The affected environment for the General Public under the Limited Dispositions Alternative  
36 would be similar to that for the No Action, Unrestricted Release, EPA/State-Regulated Disposal,  
37 and LLW Disposal alternatives.  
38

### 39 **3.2.4.2 Environmental Consequences**

40  
41 This section describes the environmental consequences for Non-Licensed Facility Workers and  
42 the General Public associated with each Alternative. Environmental consequences are presented  
43 in terms of collective dose, in units of person-rem, for each Alternative.  
44

1 **3.2.4.2.1 No Action Alternative**

2  
3 This section summarizes the collective dose to Non-Licensed Facility Workers and the General  
4 Public for the No Action Alternative. A screening analysis conducted for the No Action  
5 Alternative and Unrestricted Release Alternatives indicates that the collective dose to Non-  
6 Licensed Facility Workers is negligible as compared to the collective dose to the General Public  
7 for the No Action Alternative. Therefore, quantitative collective dose results presented in this  
8 section for the No Action Alternative are primarily collective dose to the General Public.

9  
10 Non-Licensed Facility Workers Collective Dose

11  
12 A screening analysis was conducted (SC&A 2003) to illustrate the relative collective dose  
13 associated with the various activities conducted by Non-Licensed Facility Workers and the  
14 General Public for recycling of ferrous metal and concrete. The screening analysis is based on an  
15 evaluation of the collective dose experienced in the first year the solid material is released. The  
16 analysis indicates that the collective dose from recycling ferrous metal is dominated by five end  
17 use products manufactured from recycled ferrous metal: office buildings (i.e., structural ferrous  
18 metal); beds; automobiles; office furniture; and home appliances, all of which contribute to  
19 collective dose to the General Public. These five end use products manufactured from recycled  
20 ferrous metal and their associated collective dose to the General Public represent 99.8 percent of  
21 the total combined collective dose to the General Public and Non-Licensed Facility Workers.  
22 The collective dose to Non-Licensed Facility Workers involved in activities for recycling ferrous  
23 metal under the No Action and Unrestricted Release Alternatives represents less than 0.2 percent  
24 of the total collective dose. Thus the collective dose for ferrous metal for the No Action and  
25 Unrestricted Release Alternatives is dominated by the collective dose to the General Public.

26  
27 The only end use of recycled concrete analyzed in the Draft GEIS is its use for roadbed  
28 construction (Appendix G). The amount of concrete dust that can become airborne depends  
29 mainly on its moisture content, physical properties, and engineered measures used to minimize  
30 such releases. The analysis assumed that the amounts of materials released via fugitive  
31 emissions are small, such releases are short-lived in duration, and long-term exposures associated  
32 with end uses are dominant in terms of collective doses. The collective dose from recycling of  
33 concrete is dominated by the collective dose to the General Public associated with this single  
34 disposition of recycled concrete: driving on roads built using recycled concrete. The collective  
35 dose to Non-Licensed Facility Workers involved in recycling concrete under the No Action  
36 Alternative represents less than 10 percent of the total first year collective dose. These Non-  
37 Licensed Facility Worker activities include transporting the concrete rubble, processing concrete  
38 rubble into road bed material, and building the road. More than 90 percent of the collective dose  
39 for concrete for the No Action and Unrestricted Release Alternatives is represented by collective  
40 dose to the General Public.

41  
42 The use of concrete rubble is limited because reclaimed concrete is not pure Portland concrete,  
43 but rather a mixture of concrete, soil, some amounts of bituminous concrete, and other small size  
44 debris generated during demolition. The use of concrete with more than 15 percent reclaimed  
45 concrete has lead to problems in meeting material quality specifications, resulting in its difficult  
46 use and workability. Besides road construction, reclaimed concrete is being used in bulk fill

1 applications on land and water, as riprap for shoreline protection, as trench backfill, as a mix in  
 2 asphaltic concrete, and in revetments for fieldwork and mining. It is expected that such uses  
 3 would result in much lower exposures and collective doses as compared to the construction and  
 4 use of road bed made with reclaimed concrete.

5  
 6 General Public Collective Dose

7  
 8 Table 3-9 shows the collective dose to the General Public for the No Action Alternative. The  
 9 total collective dose for the No Action Alternative is 3,996 person-rem (39.9 person-sievert). The  
 10 collective dose is dominated by exposure of the General Public to products made from recycled  
 11 ferrous metal. The primary exposure pathway for ferrous metal is external exposure (direct  
 12 radiation) to products made from recycled ferrous metal, such as automobiles and appliances.  
 13 Because Co-60 (with a 5-year half-life) is the primary radionuclide from the ferrous metal that  
 14 partitions to the recycled metal (as opposed to partitioning to the furnace dust), the radiation  
 15 exposure to the General Public rapidly decreases after the end of the period when there would be  
 16 no additional nuclear reactors being decommissioned and when there would be no additional  
 17 ferrous metal being generated from reactor decommissioning to be made into products. The  
 18 other primary radionuclide considered in the collective dose assessment for the No Action  
 19 Alternative, Cs-137, partitions primarily to the furnace dust at the mill. For the purposes of the  
 20 collective dose assessment, the furnace dust is assumed to be disposed of in an EPA/State-  
 21 Regulated landfill. Exposure pathways associated with landfill disposal of furnace dust include  
 22 ground water and surface water discharges from the landfill and subsequent exposure of the  
 23 General Public through drinking water and food ingestion, and direct radiation exposure of Non-  
 24 Licensed Facility Workers (e.g., landfill workers, truck drivers) encountering the furnace dust.  
 25 However, as discussed above, the collective dose to Non-Licensed Facility Workers from ferrous  
 26 metal recycling is negligible as compared to the collective dose to the General Public.

27  
 28 **Table 3-9 No Action Alternative - General Public Collective Dose for Materials**  
 29 **Released from Commercial Nuclear Reactor Facilities**  
 30 **(person-rem)<sup>1</sup>**

Ferrous Metal	Concrete	Trash	Equipment Reuse	All Materials
3,920	3.91	0.006	72	3,996

31  
 32  
 33  
 34 <sup>1</sup> Source: SC&A 2003, Table 10.8.

35  
 36 Equipment Reuse

37  
 38 Table 3-10 describes the mean collective dose values to the General Public associated with the  
 39 reuse of both large and small pieces of equipment for the Alternatives. The collective dose  
 40 associated with equipment reuse for the No Action Alternative is 72 person-rem (0.72 person-  
 41 sievert). The analysis of collective dose for equipment reuse is described in Section 12 of  
 42 Appendix D.  
 43  
 44

**Table 3-10 General Public Collective Doses Associated with Reuse of Large and Small Equipment from Commercial Nuclear Power Reactors**

Dose Option	Collective Dose (person-rem) Small Equipment	Collective Dose (person-rem) Large Equipment	Total Collective Dose (person-rem) for Equipment Reuse
Unrestricted Release Alternative			
RS-G-1.7	5	56	61
10 mrem/yr	160	150	310
1 mrem/yr	16	15	31
0.1 mrem/yr	2	2	4
0.03 mrem/yr	<1	<1	<1
No Action Alternative			
	6	66	72

**Note:** Mean profile taken from Appendix D, Section 12 of this GEIS.  
The IAEA volumetric criteria were converted to surficial limits using a mass-to-surface ratio of 5 g/cm<sup>2</sup>, assuming that equipment consist of ferrous metals.

Collective doses to the General Public associated with the reuse of equipment were evaluated for two categories of equipment, large and small. The approach used in estimating collective doses relies on a scoping analysis because practices associated with the reuse of equipment are known to be highly variable. For example, it is known that different types of equipment and tools are used in radiologically controlled areas and later taken out of those areas. The type of equipment that could be potentially cleared from licensed facilities for reuse in an environment free of radiological controls ranges from small items, such as hand tools, to very large ones, such as mechanized equipment and industrial vehicles. The following are examples of potentially reusable equipment, tools, and miscellaneous items:

- small hand tools (wrenches, screw drivers, etc.) and power tools (drills, saws, etc.)
- electrical equipment, such as control panels, motors, pumps, and generators
- office furniture (desks, chairs, filing cabinets, etc.) and office equipment (copiers, computers, printers, fax machines, etc.)
- construction equipment, such as scaffolding, noise or dust-control barriers, wheelbarrows, etc.
- mechanized equipment, such as trucks, backhoes, bulldozers, and other vehicles
- materials and supplies for use in their original forms, but taken out as excess, such as piping, tubing, electrical wiring, floor covering, ductwork, sheet metal, pipe hangers, light fixtures, wall board, and sheet glass.

Table 3-10 describes the mean collective dose values to the General Public associated with the reuse of both large and small pieces of equipment.

1 **3.2.4.2.2 Unrestricted Release Alternative**

2  
3 Non-Licensed Facility Workers and General Public

4  
5 The screening analysis conducted for the collective dose to Non-Licensed Facility Workers for  
6 the No Action Alternative also applies to the Unrestricted Release Alternative as the same  
7 disposition of solid materials is assumed for both Alternatives in the screening analysis. The  
8 analysis indicates that the collective dose to Non-Licensed Facility Workers is negligible as  
9 compared to the collective dose to the General Public. Therefore, quantitative collective dose  
10 results are not presented separately for Non-Licensed Facility Workers for the Unrestricted  
11 Release Alternative.

12  
13 Material-Specific and Material-Independent Collective Doses

14  
15 Material-specific dose factors are developed for each radionuclide and each type of material.  
16 For example, the analysis for Co-60 in ferrous metal uses the dose factor for the scrap yard  
17 worker since it is the most limiting of all ferrous metal related scenarios that were evaluated  
18 (these scenarios include handling and processing, transportation, and product use). On the other  
19 hand, the material-independent dose factors consider the most conservative dose factor for each  
20 radionuclide, regardless of the type of material. For example, the presence of Co-60 in concrete  
21 (used in road building) results in the most limiting dose factor as compared to the presence of  
22 Co-60 in ferrous metal. More details can be found in Appendix D of the Draft GEIS for both  
23 cases - material-specific results (Case A) and material-independent results (Case B) (see Tables  
24 D-1 to D-3).

25  
26 General Public Collective Dose

27  
28 Table 3-11 shows the collective dose for the Unrestricted Release Alternative for concrete,  
29 ferrous metal, and trash for material specific and material independent dose factors. The  
30 collective dose is dominated by the exposure of the General Public to end-use products made  
31 from recycled ferrous metal. The primary exposure pathway for ferrous metal is external  
32 exposure (direct radiation) to products made from recycled ferrous metal. The total collective  
33 dose for concrete, ferrous metal, and trash ranges from 208 person-rem (2.08 person-sievert) for  
34 the 0.03 mrem/year dose option to 28,430 person-rem (284 person-sievert) for the 10 mrem/year  
35 dose option. Note that Table 3-11 presents collective dose results for material independent and  
36 material-specific cases, whereas Table 3-10 does not.

37  
38 The collective dose for the RS-G-1.7 dose option is twice that of the 1 mrem/year dose option  
39 because the amount of activity anticipated to be released for this dose option is approximately  
40 twice that of the 1 mrem/year dose option, as shown in Table 3-11 (see Appendix D, Section 11).

**Table 3-11 Unrestricted Release Alternative - General Public  
Mean Collective Dose Results (person-rem)<sup>1</sup>**

Solid Material	Dose Option				
	0.03 mrem/yr	0.1 mrem/yr	1 mrem/yr	10 mrem/yr	RS-G-1.7
Unrestricted Release/ Material Specific					
Ferrous Metal	205	881	6,380	28,400	NA
Concrete	3	7	24	28	NA
Trash	<1	<1	<1	2	NA
TOTAL	208	887	6,404	28,430	NA
Unrestricted Release/Material Independent <sup>2</sup>					
Ferrous Metal	19	107	1,660	9,650	3,320
Concrete	3	7	24	28	48
Trash	<1	<1	<1	<1	<1
TOTAL	22	114	1,684	9,680	3,370

<sup>1</sup> Source: SC&A 2003, Table 10.8.

<sup>2</sup> For RS-G-1.7 results, see Appendix D, Section 11 of this report.

Inventory information on other metals, besides ferrous metal, indicated these were primarily copper or aluminum, and present in insignificant amounts as compared to ferrous metals. NUREG-1640 considers dose factors for both copper and aluminum for individual dose estimating purposes. However, regarding collective dose, the results were developed for ferrous metal and the small amounts of copper and aluminum inventory were evaluated using a screening analysis for the collective dose associated with the unrestricted release (recycling) of aluminum and copper generated from licensed facilities. A detailed collective dose assessment was not performed for aluminum and copper because of the small amount of these materials generated as compared to ferrous metal. The results indicate that collective doses for copper and aluminum are about one to two orders of magnitude lower than that of ferrous metal for all alternatives.

Table 3-10 describes the mean collective dose values to the General Public associated with the reuse of both large and small pieces of equipment for the Alternatives. The collective dose associated with equipment reuse for the Unrestricted Use Alternative is 61 person-rem.

### 3.2.4.2.3 EPA/State-Regulated Disposal Alternative

The collective dose to the Non-Licensed Facility Workers and the General Public for the EPA/State-Regulated Disposal Alternative is estimated for two scenarios, one assuming that the trash generated from licensed facilities is disposed of in EPA/State-Regulated landfills and one assuming that the trash generated from licensed facilities is disposed of in an EPA/State-Regulated incinerator, with subsequent disposal of the incinerator ash in an EPA/State-Regulated landfill. Concrete and metal solid materials are assumed not to be incinerated. Table 3-12 provides a summary of collective dose to Non-Licensed Facility Workers and the General Public for the EPA/State-Regulated Disposal Alternative for the trash landfill disposal and trash incineration disposal scenarios. The total collective dose for the EPA/State-Regulated Disposal Alternative without trash incineration ranges from 0.11 person-rem (0.0011 person-sievert) for

**Table 3-12 EPA/State Regulated Disposal Alternative - General Public Mean Collective Dose Results (person-rem)**

Solid Material	Dose Option				
	0.03 mrem/yr	0.1 mrem/yr	1 mrem/yr	10 mrem/yr	RS-G-1.7
EPA/State-Regulated Landfill					
Ferrous Metal	<1	<1	1	5	NA
Concrete	<1	<1	<1	<1	NA
Trash	0	<1	<1	2	NA
TOTAL	<1	<1	2	6	NA
EPA/State-Regulated Landfill with Trash Incineration					
Ferrous Metal	<1	<1	1	5	3
Concrete	<1	<1	<1	<1	<1
Trash	16	70	1,010	14,400	2,020
TOTAL	16	70	1,011	14,405	2,023

Source: SC&A 2003, Table 10.8.

the 0.03 mrem/year dose option to 6 person-rem (0.06 person-sievert) for the 10 mrem/year dose option. For the EPA/State-Regulated Disposal Alternative with trash incineration the total collective dose ranges from 16 person-rem (0.16 person-sievert) for the 0.03 mrem/year dose option to 14,400 person-rem (144 person-sievert) for the 10 mrem/year dose option. The collective dose assessment for trash for Non-Licensed Facility Workers and the General Public accounts for work activities involving truck drivers hauling trash, trash disposal in a landfill, trash incineration and ash disposal in a landfill, and a crane operator loading trash into an incinerator. Doses to offsite receptors consider the impacts associated with effluent discharges from landfill and incinerator operations. The collective dose associated with trash incineration is dominated by exposure of the General Public to airborne effluents.

The collective dose results in Table 3-12 are material specific. SC&A 2003 does not provide dose results for landfills evaluated for the material-independent case. It should be noted that such doses will be lower still than that shown for the material-specific case. This is because the material-independent case is based on the most limiting dose factors and corresponding lower release levels. Lower release levels yield lower collective doses.

The use of incineration at solid waste landfills has declined over the past decade (EPA, personal communication). In 2001, about 15 percent of all solid waste was incinerated, about 30 percent was recycled or composted, and the rest is sent to landfills. In the past, there was more emphasis on incineration when it was thought that landfill capacity would become scarce and expensive, but those concerns have not been borne out. In the near term, it seems likely that the percentage of waste incinerated will decline further. (See [www.epa.gov/epaoswer/non-hw/muncpl/facts.htm](http://www.epa.gov/epaoswer/non-hw/muncpl/facts.htm) for some basic information on solid waste.) However, even if all the trash is assumed to be incinerated, at the 1 mrem/yr dose option the collective dose is still less than for the No Action Alternative.

1 It is common practice for landfills to monitor incoming waste shipments for the presence of  
2 radioactivity. The radiation monitoring systems typically are installed at the scales where trucks  
3 are weighed before being sent to specific waste processing areas. The alarm set-points are set at  
4 varying levels, typically set at a multiple of ambient background levels. If a waste shipment  
5 were to set off an alarm, the shipment is set aside and the originator of the shipment is informed  
6 of the situation. Depending on operational procedures, landfill operators call the State agency  
7 responsible for radiation protection for guidance on how to proceed. In both cases, the  
8 originator of the shipment, at a minimum, is called upon to identify the type and quantities of  
9 radioactive materials present in the waste shipment, and demonstrate that the shipment complies  
10 with existing NRC or Agreement State regulations. In other instances, landfill operators do not  
11 accept any type of radioactive materials and the shipments are refused and returned to the  
12 originator.

13  
14 Appendix J contains a discussion of RCRA facilities, including regulatory requirements, siting  
15 criteria, engineering design features, monitoring requirements, and exposure pathways. The  
16 evaluation of different RCRA Subtitle D landfills and their ability to affect environmental  
17 impacts supports the collective dose analysis. For municipal solid waste landfills the most  
18 important landfill parameters that affect the amount of radioactivity released are infiltration,  
19 waste thickness, and distribution coefficients ( $K_d$ ).

#### 20 21 **3.2.4.2.4 Low-Level Waste Disposal Alternative**

22  
23 The only Non-Licensed Facility Workers that are associated with the LLW Disposal Alternative  
24 are truck drivers transporting the material to LLW disposal facilities. For the purposes of this  
25 analysis NRC has assumed that all of the potentially clearable material released from licensed  
26 facilities and transported to LLW disposal facilities under the LLW Disposal Alternative would  
27 be transported to the Envirocare facility in Utah. This is a reasonable assumption because little  
28 of the solid material would be eligible for disposal at the Barnwell and Hanford sites (Section  
29 2.4.4). Also, this assumption would bound the analysis. Exposure time to truck drivers  
30 transporting the materials to the Envirocare facility under the LLW Disposal Alternative would  
31 be approximately a factor of eight higher than the exposure time for transport under the No  
32 Action and Unrestricted Release Alternatives, as calculated based on the vehicle miles traveled  
33 shown in Table 3-15. However, exposure time to truck drivers transporting the materials to the  
34 Envirocare facility would also depend on the curies transported to LLW disposal facilities.  
35 Under the No Action Alternative, 2,947 of a possible 2,951 curies of activity would be  
36 transported to LLW disposal facilities (Table 3-4). As shown in Tables 3-4 and 3-5, the  
37 collective dose to workers at LLW disposal facilities does not vary significantly among the  
38 alternatives and dose options.

39  
40 Potential exposures for the General Public (which includes Non-Licensed Facility Workers) from  
41 the operation of LLW disposal facilities has been analyzed in the Final Environmental Impact  
42 Statement for 10 CFR Part 61 and in environmental reviews for licensing of existing LLW  
43 disposal facilities. The potential types of exposure mechanisms associated with the disposal of  
44 solid materials in LLW disposal facilities are similar to those for disposal in EPA/State-regulated  
45 landfills. Since materials that have been released have properties that are more like those found  
46 in the lower-most range of Class A wastes, it follows that potentially clearable materials can be

1 safely disposed of in LLW sites without any further impacts to the public and environment. This  
2 aspect was addressed by comparing typical radioactive inventories of waste accepted by LLW  
3 disposal sites against that associated with releases (SC&A 2003, Section 8.1). A review of the  
4 data indicates that total receipts of radioactivity sent for disposal from 1986 to 2002 are about  
5 9,300 curies, and 2 and 6.2 million curies at the Envirocare, Richland, and Barnwell disposal  
6 sites, respectively. These activity levels represent total curies without the contribution from H-3  
7 and C-14, since these radionuclides contribute only minimally to exposures and doses. A review  
8 of the results presented earlier indicates that such inventories of radioactivity are lower by orders  
9 of magnitude. This comparison indicates that if LLW sites are authorized to receive several  
10 hundred thousands curies and be in compliance with Part 61 regulations, the small incremental  
11 amounts of radioactivity associated with potentially clearable materials will not adversely impact  
12 the site, nor compromise the health and safety of the public and workers. Therefore, no  
13 assessment of General Public or Non-Licensed Facility Worker collective dose is included in this  
14 Draft GEIS for the LLW Disposal Alternative.  
15

#### 16 **3.2.4.2.5 Limited Dispositions Alternative**

17  
18 The Limited Dispositions Alternative involves different disposition pathways for different solid  
19 materials generated from licensed facilities. Tools and equipment released from licensed  
20 facilities could be reused in other locations. Recycling of concrete released from licensed  
21 facilities would be limited to recycling as road bed. Ferrous metals and trash released from  
22 licensed facilities would be limited to EPA/State-regulated disposal. Other dispositions could be  
23 approved on a case-by-case determination by NRC. The collective dose to Non-Licensed  
24 Facility Workers and the General Public resulting from the Limited Dispositions Alternative is  
25 anticipated to be similar to that for the Unrestricted Release Alternative for concrete and similar  
26 to that for the EPA/State-Regulated Disposal Alternative for other materials for ferrous metals  
27 and trash.  
28

29 The collective dose for concrete under the Limited Dispositions Alternative would be similar to  
30 the Unrestricted Release Alternative, for which the collective dose assessment is based on  
31 concrete reuse as road bed (see Table 3-11). The collective dose for ferrous metals and trash  
32 would be similar to the EPA/State-Regulated Disposal Alternative (Table 3-12). The collective  
33 dose for reuse of tools and equipment would be similar to the Unrestricted Release Alternative.  
34

35 The collective dose to the General Public associated with the Limited Dispositions Alternative is  
36 the sum of the following collective doses using the IAEA Safety Guide:  
37

- 38 • concrete use in roadbeds (48 person-rem (0.48 person-sievert)) (Table 3-11);
  - 39 • disposal of ferrous metal and trash in EPA/State-regulated disposal facilities (3 person-rem  
40 (0.03 person-sievert)) (Table 3-12); and
  - 41 • reuse of tools and equipment (61 person-rem (0.61 person-sievert)) (Table 3-10).
- 42

### 3.2.4.2.6 Summary of Collective Doses for Non-Licensed Facility Workers and the General Public

Table 3-13 presents a summary of the collective doses to the General Public and Non-Licensed Facility Workers for the No Action, Unrestricted Use, EPA/State-Regulated Disposal, and Limited Dispositions Alternatives. This table is based on Tables 3-9 to 3-12 of this report. Results for the LLW Disposal Alternative are expected to be small (Section 3.2.4.2.4). For comparison purposes, the collective doses for the Unrestricted Release Alternative are material-independent and presented for the 1 mrem/yr dose option using the IAEA Safety Guide to be comparable to the Limited Dispositions Alternative. These collective dose results are for potentially clearable solid materials released from commercial nuclear reactor facilities.

**Table 3-13 Summary of Non-Licensed Facility Workers and General Public Collective Dose Results (person-rem)**

Alternative	Collective Dose				
	Concrete	Ferrous metal	Trash	Equipment Reuse	Total
No Action	4	3,920	<1	72	3,996
Unrestricted Use	48	3,320	<1	61	3,429
EPA/State-Regulated Disposal without Trash Incineration	<1	1	<1	0	2
EPA/State-Regulated Disposal with Trash Incineration	<1	1	1,010	0	1,011
Limited Dispositions	48	3	<1	61	112

### 3.2.5 Collective Dose from Materials Generated from Licensed Facilities Other Than Reactors

The collective dose values reported above include only solid materials generated from commercial nuclear reactor licensees. These materials constitute the majority of the mass, activity, and collective dose associated with material generated from licensed facilities. The other licensed facilities (which are described in Appendix F) include:

- Large medical centers: includes regional and university medical centers administering nuclear medicine.
- Fuel fabrication facilities: includes wastes generated from decontamination and decommissioning of licensed facilities that fabricate nuclear reactor fuel and daily operations (e.g., trash).
- Conversion plant: includes wastes generated from decontamination and decommissioning of licensed facilities that manufacture uranium hexafluoride.
- Non-power reactor: includes wastes generated from decontamination and decommissioning of research reactors and reactors other than commercial power reactors.

- Independent Spent Fuel Storage Installations (ISFSI): includes wastes generated from decontamination and decommissioning of ISFSI and daily operations (e.g., trash).

Other licensed facilities also generate trash from within radiation control areas during operations.

A screening analysis was conducted for materials generated from NRC-licensed facilities other than commercial reactors for the No Action and Unrestricted Release Alternatives. A screening analysis was used because the mass and activity of the reactor-generated solid materials is much greater than that of other licensed facilities. A screening analysis was not necessary for the other alternatives because the No Action and Unrestricted Release Alternatives would result in the greatest quantities of materials released. Table 3-14 summarizes the collective doses associated with solid materials released from NRC licensees other than commercial nuclear reactor facilities for the No Action and Unrestricted Release Alternatives.

**Table 3-14 Summary of Collective Dose Scoping Calculations for Solid Materials Generated from Licensees other than Commercial Nuclear Reactors (person-rem)**

Alternative	Large Medical Centers (person-rem)	Fuel Fab.	Conv. Plant	Non-power Reactor	ISFSI	Total Non- Reactor	Trash Generated from Other Licensees
<b>No Action</b>	6	<1	<1	<1	<1	6	<1
<b>Unrestricted Release</b>							
10 mrem/yr	1,020	4	1	2	38	1,066	<1
1 mrem/yr	71	<1	<1	<1	4	76	<1
0.1 mrem/yr	4	<1	<1	<1	<1	5	<1
0.03 mrem/yr	1	<1	<1	<1	<1	1	<1

Source: SC&A 2003, Table 5.31, and Tables 3-9 and 3-11 of this report.

The collective dose associated with release of materials from large medical centers was estimated for the No Action Alternative and for all the dose options under the Unrestricted Release Alternative. The dose is attributed to tritium and carbon-14, which are the major long-lived radionuclides contributing to the collective dose. Short-lived radionuclides used in routine nuclear diagnostic tests (Tc-99m) and therapy (I-131) are not considered since current practices manage these radionuclides using radioactive decay. The material associated with routine releases are assumed to consist of miscellaneous glass and plastic wares, absorbent pads, protective clothing, trays and racks, disposable equipment, and some parts of experimental apparatus, such as sampling and dispensing devices, fluid path tubing, pumps, filters, etc. It should be noted that waste volumes could be higher in a few instances, such as when gutting a room during facility refurbishment or after spills. However, in such instances, all materials would be disposed as LLW. Collective doses vary from about 1 to 1,000 person-rem (0.011 to 10 person-sievert) over all dose options and for the duration of the Proposed Action (46 years).

1 For the No Action Alternative, the collective dose is estimated to be nearly 6 person-rem (0.06  
2 person-sievert). At 1 mrem/yr the collective dose for materials generated from licensees other  
3 than commercial reactor facilities is less than 5 percent of the collective dose associated with  
4 materials generated from commercial reactors for the Unrestricted Release Alternative.

5  
6 The collective dose associated with materials generated from commercial reactor facilities,  
7 including concrete, ferrous metal, and trash for the Unrestricted Release Alternative is  
8 approximately 3,400 person-rem (34 person-sievert) for the 1 mrem/year dose option using the  
9 IAEA standard (IAEA 2004) (Table 3-11).

10  
11 Unlike the detailed inventory information available for power reactors, and their very detailed  
12 analysis, the other licensed facilities inventory information was much more limited. Because the  
13 preponderance of contribution to the collective dose comes from the power reactor industry, and  
14 only a small percentage comes from the rest of the licensees, a screening analysis for bounding  
15 the collective dose contribution associated with these other facilities was considered appropriate.  
16 Consequently, the level of detail presented for collective dose breakouts in terms of contributions  
17 from concrete, ferrous metal, trash, etc. was not developed to the same degree as for the more  
18 detailed analysis of commercial nuclear power reactors. However, more details about inventory  
19 (type of material, amount, and curie content) for these licensed facilities is available from  
20 Appendix F. The trash volume is based on a total from all different categories of facilities, and  
21 its method of estimation is presented in Chapter 4 of the collective dose report (SC&A 2003),  
22 which is summarized in Appendix D.

### 23 24 **3.2.6 Summary of Collective Doses**

25  
26 The human health and safety impacts are measured in this Draft GEIS in terms of collective dose.  
27 Table 3-8 summarizes the predicted collective doses for Licensed Facility Workers and Table 3-  
28 13 for Non-Licensed Facility Workers and the General Public. All of these doses are small when  
29 compared to the background collective dose to the U.S. population due to natural sources of  
30 radiation and radioactivity (Appendix E).

## 31 32 **3.3 TRANSPORTATION**

33  
34 The affected environment and environmental consequences related to transportation of solid  
35 materials released from licensed facilities are related to:

- 36  
37 • Radiation doses to Workers at Non-Licensed Facilities and to the General Public, as  
38 associated with the routine transportation of solid materials by truck; and
- 39  
40 • Potential non-radiological consequences to Workers at Non-Licensed Facilities and to the  
41 General Public, as related to truck and rail transportation accidents as obtained from  
42 statistical highway and rail data.

43  
44 Truck drivers transporting materials generated from licensed facilities are categorized as Workers  
45 at Non-licensed Facilities for the purposes of the Draft GEIS. Radiation dose to truck drivers is  
46 included in the collective dose assessment for Non Licensed-Facility Workers and the General

1 Public, as discussed in Section 3.2, and is not further discussed in this section. In addition, the  
2 radiological impacts from the transport of all licensed radioactive material has been generically  
3 evaluated in NUREG-0170, "Final Environmental Statement on the Transportation of  
4 Radioactive Material by Air and Other Modes" (NRC 1977). This analysis considered radiation  
5 exposure of transport workers and members of the General Public along transportation routes  
6 from both normal transportation and accidents. Based on this analysis, radiological  
7 transportation impacts are expected to be small for all alternatives. As a result, only non-  
8 radiological impacts from transportation accidents are discussed below.

### 9 **3.3.1 Affected Environment**

11  
12 The affected environment associated with non routine occurrences (transportation accidents)  
13 involving truck and rail transportation of solid materials are Workers at Non-Licensed Facilities  
14 (truck drivers and railroad workers) and the General Public (persons along a route) potentially  
15 affected by injuries or fatalities resulting from transportation accidents involving trucks or  
16 railcars. Such injuries or fatalities would be the result of accidents during transport (e.g., truck  
17 collisions, railcar derailments). The affected environment with respect to the General Public  
18 includes transportation routes throughout the United States. The locations of the licensed  
19 facilities that would generate solid materials affected by the Proposed Action are known;  
20 however, the specific transportation routes that would be used in transporting solid materials  
21 from licensed facilities to recycling facilities and disposal facilities cannot be fully determined.  
22 The affected environment therefore cannot be associated with specific transportation routes.

23  
24 The affected environment for transportation is generally similar for all Alternatives except  
25 workers at Non-Licensed Facilities for the LLW Disposal Alternative would include both truck  
26 drivers and railroad workers. Transportation routes in the vicinity of recycling facilities would  
27 be primarily affected under the No Action and Unrestricted Release Alternatives.  
28 Transportation routes in the vicinity of EPA/State-regulated disposal facilities would be  
29 primarily affected under the EPA/State-Regulated Disposal Alternative. Transportation routes in  
30 the vicinity of LLW disposal facilities would be affected under the LLW Disposal Alternative.  
31 The Limited Dispositions Alternative would involve both recycling concrete and EPA/State-  
32 regulated disposal of solid material and would therefore affect transportation routes in the  
33 vicinity of both recycling and EPA/State-regulated disposal facilities.

### 34 **3.3.2 Transportation Requirements**

35  
36  
37 Transportation safety addresses the performance of rail or motor carriers, trucks or rail cars, and  
38 drivers or crews, and is often measured through accident rates. The Federal Motor Carrier Safety  
39 Administration and Federal Railroad Administration each enforce comprehensive safety  
40 standards and monitor carrier operations. Rail shipments involve compliance with regulations  
41 for track quality and condition, signal and control systems, freight car standards, operating  
42 practices, inspections, crew qualifications, etc.

43  
44 Intrastate, interstate, and international shipments of hazardous materials (including hazardous  
45 wastes) by any mode of transport are covered by federal and international laws. These laws  
46 cover:

1 Proper identification and classification of hazardous materials;

- 2 • Required hazard communications, such as shipping papers, markings, labels, and placards;
- 3 and
- 4 • Material-specific packaging requirements.

5  
6 Transport of LLW is subject to all of the hazardous materials requirements above, and the U.S.  
7 Department of Transportation (DOT) (in consultation with NRC) establishes the applicable  
8 packaging standards. The disposal of LLW is conducted in accordance with the specific waste  
9 acceptance criteria of the recipient disposal site and Federal regulations. These requirements are  
10 addressed in NRC regulations in 10 CFR Part 61. The requirements of 10 CFR Part 61 are  
11 complemented with Subpart K (waste disposal) and Appendix G (shipping) to 10 CFR Part 20  
12 and DOT regulations for radioactive materials in Subpart I to 49 CFR Part 173. Among others,  
13 the criteria address radiological and non-radiological profiles of waste, containerization and  
14 package labeling, shipping requirements, and use of shipping manifests. There are also RCRA  
15 exclusions that are applicable to the transportation of recycled scrap metal, which can relieve  
16 some of the requirements for packaging, shipping papers, marking, labeling, placarding, etc. for  
17 such materials. However, since the proposed release levels for the Limited Dispositions  
18 Alternative are less than or equal to the DOT activity concentrations for exempt material under  
19 49 CFR Part 173.436, the solid materials are not regulated as radioactive material while in  
20 transport.

### 21 **3.3.3 Environmental Consequences**

22  
23  
24 This section describes the potential non-radiological environmental consequences to Workers at  
25 Non-Licensed Facilities and the General Public from potential transportation accidents  
26 associated with solid materials released from licensed facilities. In the transportation accident  
27 analysis in this section, for transportation by truck, the analysis is based on the total vehicle  
28 miles traveled for each Alternative. For transportation by rail, in the main analysis, railcar miles  
29 are assumed only for the LLW Disposal Alternative; however, a sensitivity study assumed that  
30 for all the alternatives the material would be shipped to LLW facilities by rail (Section 4.6).  
31 National accident rates for truck and rail transportation are applied to the total miles traveled.  
32 The national accident rates are independent of the material being transported. That is, the railcar  
33 accident rate, in units of the number of accidents per billion railcar miles traveled, applies  
34 equally to railcars containing solid materials released from licensed facilities and railcars  
35 containing salt, grain, or other materials.

36  
37 The environmental consequences associated with non-routine occurrences (i.e., transportation  
38 accidents) do not include collective dose to Non-Licensed Facility Workers and the General  
39 Public. As discussed in Section 3.2, the collective dose to truck drivers for routine transportation  
40 of solid materials is included as part of the collective dose assessment. It is anticipated that any  
41 individual truck driver would experience no more than a single transportation accident and would  
42 therefore be exposed to no more than one incident of exposure. In addition, it should be pointed  
43 out that the occurrence of an accident does not necessarily result in an additional exposure. Any  
44 additional incremental exposure that did occur would not significantly increase the collective  
45 dose to Non Licensed Facility Workers and the General Public. Therefore, no collective dose

assessment for potential radiation exposures related to transportation accidents is included in the Draft GEIS.

Table 3-15 summarizes the transportation characteristics for the No Action, Unrestricted Release, EPA/State-Regulated Disposal, and LLW Disposal Alternatives under the bounding dose options. The table shows the total amount of material that would be transported under each Alternative (SC&A 2003, Tables 10.3 and 10.7) as well as the total truck or rail car miles traveled. These distances are based on the distances between current nuclear power plants and recycling and disposal facilities (SC&A 2003, Table 9-62 and page K-25 of this report). The distances for non-reactors are assumed to be the same. Based on the assumed capacity of the trucks (25 tons), the number of miles trucks would needed to transport material to recycling or disposal facilities was calculated (Appendix K).

**Table 3-15 Solid Materials Transported Under Alternatives**

Solid Material	No Action		Unrestricted Release 10 mrem/yr dose option		Unrestricted Release 0.03 mrem/yr dose option	
	Tons	Vehicle Miles Traveled	Tons	Vehicle Miles Traveled	Tons	Vehicle Miles Traveled
Ferrous metal	2,059,800	22,163,448	2,450,961	26,372,340	970,286	10,440,278
Concrete	16,213,364	128,409,843	19,772,249	156,596,212	15,038,234	119,102,813
Trash	20,408	326,528	66,102	1,057,632	13,643	218,288
Aluminum	173	1,861	211	2,270	192	2,066
Copper	5,362	57,695	6,539	70,360	4,255	45,784
Total Released	18,299,107	150,959,375	22,296,062	184,098,814	16,026,610	129,809,228
Total to LLW Disposal	4,406,964	272,174,097	410,009	25,322,156	6,679,461	412,523,511
<b>TOTAL</b>	<b>22,706,071</b>	<b>423,133,472</b>	<b>22,706,071</b>	<b>209,420,970</b>	<b>22,706,071</b>	<b>542,332,740</b>

Solid Material	EPA/State-Regulated Disposal 10 mrem/yr dose option		EPA/State-Regulated Disposal 0.03 mrem/yr dose option		LLW Disposal	
	Tons	Vehicle Miles Traveled	Tons	Vehicle Miles Traveled	Tons	Miles Traveled
Ferrous metal	2,480,000	5,753,600	1,570,000	3,642,400	2,498,911	19,791,375
Concrete	19,800,000	45,936,000	15,600,000	36,192,000	19,877,341	157,428,541
Trash	66,000	1,056,000	14,000	224,000	323,023	2,558,342
Aluminum	211	490	192	445	212	1,679
Copper	6,369	14,776	4,255	9,872	6,584	52,145
Total Released	22,352,580	52,760,866	17,188,447	40,068,717	22,706,071	-
Total to LLW Disposal	353,491	21,831,604	5,517,624	340,768,458	22,706,071	318,710,669 by rail
<b>TOTAL</b>	<b>22,706,071</b>	<b>74,592,470</b>	<b>22,706,071</b>	<b>380,837,175</b>	<b>22,706,071</b>	<b>1,402,326,945 by truck</b>

Source: Materials tonnage based on SC&A 2003, Tables 4.7, 10.2 and 10.3.

The amount of potentially clearable solid material varies among the Alternatives, depending on (1) dose limits and (2) whether the material is transported to recycling facilities, EPA/State-

1 regulated disposal facilities, or LLW disposal facilities. Separate quantitative analyses are  
2 provided for the 10 mrem/year dose option and the 0.03 mrem/year dose option for the  
3 Unrestricted Release and the EPA/State-Regulated Disposal Alternatives as lower and upper  
4 bounds for all the dose options. Note that some solid material is transported to LLW disposal  
5 facilities under each of the Alternatives. Only a single analysis is provided for the No Action  
6 Alternative and the LLW Disposal Alternative because there are no dose options for these  
7 Alternatives.

8  
9 The fatal accident rate for large truck transportation is 3.2E-09 fatalities per vehicle mile traveled  
10 for truck occupants (Non-Licensed Facility Workers), and 2.0E-08 fatalities per vehicle mile for  
11 the occupants of other vehicles involved in an accident or for pedestrians (the General Public) as  
12 obtained from statistical highway data (FMCSA 2004). The accident rate for rail transportation is  
13 generally presented as an accident rate per train mile, or a combination of accident rates based on  
14 both train miles and rail car miles depending on the accident cause. In this instance an overall  
15 rate per rail car mile is desired as it is not known how many rail cars might be shipped per train.

16  
17 Based on Federal Railroad Administration (FRA 2004) statistics, the accident rate for the crew  
18 (Non-Licensed Facility Workers) is 7.6E-10 fatalities per rail car mile traveled, and the rate for  
19 occupants of other vehicles and pedestrians (the General Public) is 2.0E-08 fatalities per rail car  
20 mile traveled.

21  
22 Table 3-16 provides a summary of predicted transportation fatalities for each of the Alternatives  
23 over the period of the impacts (about 50 years). As shown, the fewest number of transportation  
24 accident fatalities, roughly 2 total fatalities for Non-Licensed Facility Workers and the General  
25 Public, is associated with the 1 mrem/year dose option under the EPA/State-Regulated Disposal  
26 Alternative. This result is because the largest amount of solid materials are transported the  
27 shortest distance under this Alternative and dose option. The highest number of transportation  
28 accident fatalities, approximately 32 fatalities, is associated with the LLW Disposal Alternative  
29 assuming truck transportation. This Alternative involves the highest vehicle miles traveled. For  
30 the LLW Disposal Alternative assuming rail transportation the number of transportation  
31 accidents is approximately 7. By comparison, there are approximately 10 fatalities from  
32 transportation accidents estimated for the No Action Alternative. For the Limited Dispositions  
33 Alternative, there are approximately 9 transportation fatalities.

### 34 35 **3.3.3.1 No Action Alternative**

36  
37 The No Action Alternative is predicted to result in 1.4 fatalities for truck drivers (Non-Licensed  
38 Facility Workers) and 8.5 fatalities for the General Public over the time period of the Proposed  
39 Action.

40

**Table 3-16 Summary of Transportation Impacts (Accident Fatalities)  
for Alternatives  
(Vehicle Miles are for Trucks, unless indicated)**

Alternative	Dose Option (mrem/year)	Vehicle Miles Traveled	Fatalities		Total
			NLFW <sup>a</sup>	GP <sup>b</sup>	
No Action	not applicable	423,133,472	1.4	8.5	9.9
Unrestricted Release	10	209,420,970	0.7	4.2	4.9
	1	230,120,298	0.8	4.6	5.3
	0.03	542,332,740	1.7	10.9	12.6
EPA/State-Regulated Disposal	10	74,592,470	0.2	1.5	1.7
	1	87,624,470	0.3	1.8	2.1
	0.03	380,837,175	1.2	7.6	8.8
LLW Disposal	not applicable	1,402,326,945 (truck)	4.5	28	32.5
		318,710,669 (rail)	0.2	6.4	6.6
Limited Dispositions	RS-G-1.7	405,493,883	1.3	8.1	9.4

a - NLFW = Non-Licensed Facility Workers      b - General Public

### 3.3.3.2 Unrestricted Release Alternative

The 10 mrem/yr and the 0.03 mrem/yr dose options provide a lower bound and upper bound for the vehicle miles traveled and number of transportation fatalities for the 1 mrem/year, 0.1 mrem/year, and RS-G-1.7 dose options. The fatalities to Non-Licensed Facility Workers are predicted to fall between 1 and 2 over the period of the Proposed Action, while for the General Public the range is 4 to 11 over the same period.

### 3.3.3.3 EPA/State-Regulated Disposal Alternative

The 10 mrem/year and the 0.03 mrem/yr dose options provide a lower bound and upper bound for the vehicle miles traveled and number of transportation fatalities for the 1 mrem/year, 0.1 mrem/year, and RS-G-1.7 dose options. The fatalities to Non-Licensed Facility Workers are predicted to fall between 0 and 1 over the period of the Proposed Action, while for the General Public the range is 2 to 8 over the same period.

### 3.3.3.4 Low-Level Waste Disposal Alternative

Transportation of solid material under the LLW Disposal Alternative could be conducted by truck, rail, or a combination of the two. The analyses in Table 3-16 are based on all of the solid material being transported either by rail or all of the solid material being transported by truck. Depending on the actual mix of rail and truck, the fatalities predicted would be expected to fall between 0 and 5 for Non-Licensed Facility Workers and between 6 and 28 for the General Public over the period of the Proposed Action.

1 **3.3.3.5 Limited Dispositions Alternative**

2  
3 It is assumed that transportation impacts associated with reuse of tools and equipment are  
4 negligible. The fatalities are predicted to be 1 for Non-Licensed Facility Workers and 8 for the  
5 General Public over the period of the Proposed Action (about 50 years). NRC could allow solid  
6 material (e.g., metal) generated by a particular licensed facility to be recycled as a case-specific  
7 approval. Trash is not anticipated to be recycled. For these specific cases, the total amount of  
8 material that would be transported to recycling facilities and transported to disposal facilities  
9 under the Limited Dispositions Alternative and the associated vehicle miles traveled cannot be  
10 estimated. However, the case-by-case approval of a licensee’s application would include an  
11 environmental review.  
12

13 **3.3.4 Summary of Transportation Impacts**

14  
15 Transportation impacts are measured in this Draft GEIS in terms of fatal vehicle accidents and  
16 railcar incidents (e.g., derailments). Table 3-16 summarizes the predicted transportation  
17 fatalities for each of the alternatives. The Unrestricted Release, EPA/State-Regulated Disposal  
18 and Limited Dispositions alternatives have similar impacts compared to the No Action  
19 Alternative, and the transportation impacts associated with these Alternatives are small.  
20 However, the LLW Disposal Alternative assuming truck transportation has a higher number of  
21 transportation accident fatalities because this alternative involves the highest vehicle miles  
22 traveled. Thus, the transportation impacts associated with the LLW Disposal Alternative are  
23 small to moderate, depending on whether transportation is by rail or truck.  
24

25 **3.4 WATER RESOURCES**

26  
27 This section discusses the potential incremental exposures associated with non-radionuclide  
28 releases to surface water, ground water, and drinking water. Supplemental detailed information  
29 is in Appendix H. The potential radiological impacts in terms of collective dose associated with  
30 discharges to surface water, ground water, and drinking water are addressed in Section 3.2.  
31

32 The significance of any exposure consequences depends on the presence, identity, and level of  
33 contaminants in the materials released from licensed facilities, and the ability of those  
34 contaminants to migrate to the waters which contact those materials. This section limits the  
35 discussion of the affected environment to populations potentially exposed to waterborne  
36 constituents, and does not address secondary paths involving waterborne constituents which  
37 transfer to other media, such as by adsorption onto soil particles, dispersion as airborne  
38 particulate matter, or conversion to a gaseous state. These secondary pathways are considered to  
39 have negligible exposure consequences. Inhalation pathways are specifically excluded from this  
40 section and covered in Section 3.5. Impacts from stormwater runoff along transportation routes  
41 are considered to be insignificant for all the Alternatives, and therefore are excluded from this  
42 discussion. The analysis begins at the point following release of the material, and does not  
43 address wastewater from decontamination activities. Potential exposure of decontamination  
44 workers to nonradiological constituents of wastewater is considered to be a negligible exposure  
45 pathway.  
46

1 The incremental quantities of secondary aluminum and secondary copper under all the  
2 Alternatives will have negligible non-radiological impacts on water resources, and are excluded  
3 from further discussion in this section. The quantity of aluminum generated from commercial  
4 nuclear reactor facilities under the Proposed Action is less than 212 tons. The incremental  
5 impacts of this amount of aluminum, compared to the 1.1 million metric tons (USGS 2004) of  
6 secondary aluminum produced from old scrap in 2003, are negligible. The quantity of copper  
7 generated from commercial nuclear reactor facilities under the Proposed Action is less than 6,600  
8 tons over the period of the Proposed Action. The annual release would be less than 700 tons per  
9 year. The incremental impacts of this amount of copper, compared to the 210,000 metric tons  
10 (USGS, 2004b) of secondary copper produced from old scrap in 2003, are negligible.

### 11 12 **3.4.1 Regulatory Framework**

13  
14 The NRC recognizes, in 10 CFR 51.10(c), “ ... that responsibility for Federal regulation of  
15 nonradiological pollutant discharges into receiving waters [from Licensed Facilities] rests by  
16 statute with the Environmental Protection Agency.”

#### 17 18 Surface Water

19  
20 The National Pollutant Discharge Elimination System (NPDES) (40 CFR Part 122) requires  
21 permits for the discharge of pollutants from any point source into waters of the United States  
22 under authority of the Clean Water Act. The requirements for discharge permits cover, among  
23 other activities, process wastewater discharges and industrial stormwater discharges (including  
24 construction activities). Ground water generally does not meet the definition of a water of the  
25 United States and is not subject to NPDES requirements.

26  
27 NPDES sets two types of discharge criteria: technology-based limits (based on the ability of  
28 dischargers in the same industrial category to treat wastewater) and water quality-based limits (if  
29 technology-based limits are not sufficient to provide protection of the water body). The effluent  
30 limits and conditions in an individual NPDES permit are unique to the permittee.

31  
32 NPDES regulations apply to the discharge of industrial process water, wastewater and  
33 stormwater. The stormwater regulations define 11 industrial categories. For all the Alternatives,  
34 applicable industrial categories and the relevant covered industries or activities appear in  
35 Table 3-17.

36  
37 Subtitle D of the Resource Conservation and Recovery Act (RCRA) of 1976 (42 USC 82,  
38 Subchapter IV) authorized regulation of State or regional solid waste plans. RCRA Subtitle D  
39 covers solid wastes, including hazardous wastes specifically excluded from RCRA Subtitle C.  
40 The promulgated solid waste regulations appear in 40 CFR Part 239 to 282, with Part 257  
41 (Criteria For Classification Of Solid Waste Disposal Facilities And Practices) and Part 258  
42 (Criteria For Municipal Solid Waste Landfills) specifying the siting, design, operational,

**Table 3-17 NPDES Storm Water Discharges Associated with Relevant Industrial Activities**

NPDES Industrial Category	Relevant Covered Industries or Activities
Category (I), 40 CFR Subchapter N	40 CFR 411 Cement manufacturing 40 CFR 420 Iron and steel manufacturing 40 CFR 421 Nonferrous metal manufacturing 40 CFR 433 Metal finishing 40 CFR 443 Paving and roofing materials 40 CFR 464 Metal molding and casting 40 CFR 467 Aluminum forming 40 CFR 468 Copper forming
Category (ii)	SIC Code 33 Primary metal industry SIC Code 3441 Fabricated structural steel SIC Code 373 Ship and boat building and repair
Category (iv) Hazardous waste	Subtitle C Hazardous waste disposal facilities
Category (v) Landfills	Industrial waste landfills Subtitle D landfills receiving industrial waste
Category (vi) Recycling Facilities	Metal scrap yards Salvage yards
Category (ix) Treatment Works	Domestic or municipal sewage treatment works or wastewater treatment system
Category (x) Construction	Clearing, grading, and excavation
Category (xi) Light Industry	SIC Code 34 Fabricated metal products SIC Code 35 Industrial machinery and equipment SIC Code 36 Electronic and other electric equipment SIC Code 37 Transportation equipment (except 373) SIC Code 38 Instruments and related products SIC Code 39 Miscellaneous manufacturing

Source: 40 CFR Part 122.

monitoring, and closure requirements. Subtitle D landfills that receive or have received any industrial waste from facilities requiring an NPDES discharge permit are themselves required to have an NPDES discharge permit. Subtitle D landfills have additional restrictions on run-on and run-off control, discharges to surface water bodies, and contamination of ground water.

The EPA regulations pertaining to incineration, 40 CFR Part 60 (Standards of Performance for New Stationary Sources), deal primarily with air emissions. 40 CFR Part 240 (Guidelines for the Thermal Processing of Solid Wastes), Section 240.204-1 additionally requires that all waters discharged by a solid waste thermal processing facility "shall be sufficiently treated to meet the most stringent of applicable water quality standards, established in accordance with or effective under the provisions of the Federal Water Pollution Control Act, as amended."

Ground Water

Federal laws provide for ground-water protection primarily by regulating potential sources of ground-water contamination. EPA oversees ground-water protection activities authorized by the laws listed in Table 3-18, but actual implementation and enforcement normally resides with individual States. All 50 States have some form of ground-water protection program.

**Table 3-18 Federal Ground-water Protection Laws**

Federal Laws	Summary Description
Safe Drinking Water Act	authorizes maximum contaminant levels in drinking water, regulates deep well disposal of wastes, designates single aquifer water supply areas, and encourages development of State wellhead protection programs
Resource Conservation and Recovery Act	regulates the storage, transportation, treatment, and disposal of solid and hazardous wastes to prevent contaminants from leaching into ground water from municipal landfills, underground storage tanks, surface impoundments, and hazardous waste disposal facilities
Comprehensive Environmental Response, Compensation, and Liability Act (Superfund)	authorizes government clean up of contamination caused by chemical spills or hazardous waste sites that do or could pose threats to the environment
Federal Insecticide, Fungicide, and Rodenticide Act	controls the availability of pesticides that can leach into ground water
Toxic Substances Control Act	controls the manufacture, use, storage, distribution, or disposal of toxic chemicals that can leach into ground water
Clean Water Act	helps States develop ground-water protection strategies

NRC regulations for disposal facility performance objectives (10 CFR 61.41) address only radiological discharge restrictions. However, 10 CFR 51.10(c) states "In accordance with section 511(c)(2) of the Federal Water Pollution Control Act (86 Stat. 893, 33 U.S.C 1371(c)(2)) the NRC recognizes that responsibility for Federal regulation of nonradiological pollutant discharges into receiving waters rests by statute with the Environmental Protection Agency."

Drinking Water

The Safe Drinking Water Act regulates all public water supplies, defined as water systems with at least 15 service connections or regularly serving at least 25 persons. Under the National Primary Drinking Water regulations, 40 CFR Part 141, the EPA has set Maximum Contaminant Levels (MCLs) applicable to public water systems for organic chemicals, inorganic chemicals, radioactivity, turbidity, microbiological contaminants, and disinfection byproducts. EPA has also developed non-enforceable National Secondary Drinking Water Standards to regulate contaminants that may cause cosmetic or aesthetic effects in drinking water.

**3.4.2 Affected Environment**

Many of the activities associated with the generation, handling, processing, end use, and disposal of solid materials are common to two or more of the Alternatives. Under every Alternative, material handling, stockpiling and loading is expected to occur at the Licensed Facility; transportation of the material will occur; and some fraction of the material streams may be sent for direct disposal in LLW Disposal Facilities. Other activities only occur under some Alternatives. Table 3-19 indicates which activities occur under each Alternative.

**Table 3-19 Water Resources Affected Environment for Alternatives**

Activity	Alternatives Under Which Activity Occurs				
	No Action	Unrestricted Release	EPA/State-Regulated Disposal	Low-Level Waste Disposal	Limited Dispositions
Material handling, stockpiling, and loading at Licensee Facility	X	X	X	X	X
Material unloading, handling, stockpiling, and loading at recycling facility	X	X			X
Transportation	X	X	X	X	X
Recycling processing	X	X			X
Disposition to End Use for recycled material	X	X			X
Disposal in EPA/State-Regulated Landfill	X	X	X		X
Disposal in EPA/State-Regulated Incinerator	X	X	X		X
Disposal in LLW Disposal Facility	X	X	X	X	X

The affected environment for surface water is the surface water in the U.S. Workers at Licensed Facilities and Workers at Non-Licensed Facilities may potentially be exposed to wastewater, runoff, or collected leachate either created by direct contact with the materials released from a licensed site during the generation, handling, processing, usage, or disposal of the released materials; or created by direct contact with any byproducts, end use products, or waste products derived from the released materials. The General Public and Ecological Receptors may also potentially be exposed to surface water bodies into which wastewater, runoff, or collected leachate flows or is discharged, either directly or through a ground-water pathway.

The affected environment for ground water is all ground waters in the U.S. Workers at Licensed Facilities, Workers at Non-Licensed Facilities, the General Public, and Ecological Receptors may potentially be exposed to ground water compromised by process wastewater, surface runoff, or leachate which is not retained by or escapes barrier systems and subsequently seeps into the soil. The General Public faces potential non-drinking water exposures to affected ground water

1 through dermal contact only. Ground water has little to no ecological influence until it is  
2 extracted from a well. Ground water extracted from a well and used for agricultural or residential  
3 irrigation is not considered a significant pathway for ecological impacts.

4  
5 Ground water or surface water bodies may be used as sources for drinking water. Standard  
6 monitoring and treatment of public drinking water supplies, including wells on industrial  
7 properties serving more than 25 persons, limit the risk of exposure of Workers at Licensed  
8 Facilities and Workers at Non-Licensed Facilities to elevated levels of contaminants from the  
9 Proposed Action. Ingestion of drinking water by the General Public from private ground-water  
10 wells or private surface water supplies may lead to potential exposures.

### 11 12 **3.4.3 Environmental Consequences**

13  
14 Environmental consequences for Workers at Licensed Facilities and Workers at Non Licensed  
15 Facilities are limited to dermal exposure to surface water in the form of process wastewater,  
16 runoff, and collected leachate. There are not anticipated to be any significant ground-water or  
17 drinking water impacts to workers.

18  
19 The General Public does not face any significant environmental consequences from any of the  
20 Alternatives related to surface water. The General Public may experience impacts from dermal  
21 exposure to ground water extracted from a private well, or ingestion of drinking water from a  
22 private ground-water well or private ground-water fed surface water body. However, such  
23 exposure is expected to be minimal due to the low probability of the simultaneous occurrence of  
24 the combination of factors required.

25  
26 Ecological receptors only face potential environmental consequences from surface water in  
27 ground-water fed surface water bodies. Ground water extracted from a well and used for  
28 agricultural or residential irrigation is not considered a significant pathway for ecological  
29 impacts.

30  
31 Water quality effects are primarily associated with point source and area source water discharges  
32 from the storage, handling, and processing of solid materials. For the No Action and  
33 Unrestricted Release Alternatives, the effects are generated mostly by runoff discharges from  
34 rubblization of concrete and runoff and process wastewater discharges from recycling of ferrous  
35 metal. The incremental quantity of these discharges would be small as compared to the overall  
36 amount of discharges generated from the total amount of concrete and ferrous metal being  
37 recycled annually in the U.S. The impact on water quality would be proportionally small.  
38 Similarly, the quantity of additional leachate and potential effects on ground water associated  
39 with disposal of solid materials under the EPA/State-Regulated Disposal Alternative and the  
40 LLW Disposal Alternative would be small compared with the overall amount of leachate being  
41 generated annually by these facilities. Therefore, the overall effects on water quality associated  
42 with all of the alternatives would be small when compared with other sources of discharges. The  
43 quantities of materials released and therefore the volumes of surface water potentially impacted  
44 will differ among the alternatives. The contaminant concentrations in impacted waters may also  
45 be higher in scenarios in which greater volumes of material are released. Table 3-20 presents a  
46 summary of the potential environmental consequences to water resources.

**Table 3-20 Summary of Potential Water Resources Environmental Consequences**

	<b>Workers</b>	<b>General Public</b>	<b>Ecological Receptors</b>
<b>Surface Water</b>	Dermal exposure to process water, runoff, and leachate.  Mitigated by avoidance of contact and use of personal protective equipment.	Direct discharge precluded by NPDES requirements.  Low probability of indirect impacts from ground-water fed surface water bodies.	Direct discharge precluded by NPDES requirements.  Low probability of indirect impacts from ground-water fed surface water bodies.
<b>Ground Water</b>	Limited potential for contact.  Mitigated by avoidance of contact and use of personal protective equipment.	Low probability of dermal impacts from private wells.	None
<b>Drinking Water</b>	Limited by testing of onsite drinking water wells.	Low probability of ingestion impacts from private wells or ground-water fed surface water bodies.	N/A

**3.4.4 Summary of Water Resources Impacts**

This section assesses non-radiological impacts to surface water, ground water and drinking water. Radiological impacts are included in the dose assessments in Section 3.2.

The impacts to surface water described in Sections 3.4.2 and 3.4.3 are expected to be small because compliance with EPA and State permits (discussed in Section 3.4.1) would preclude significant impacts from direct discharges, the low probability of the simultaneous occurrence of the combination of factors required to affect surface water chemistry through ground-water flow limits the potential for impacts from indirect discharges, and the mild acidity of the majority of lakes and ponds provides natural protection against the most likely impact, an increase in pH level.

Ground water impacts are anticipated to be small due to limited opportunities for worker exposure to ground water and the use of personal protective equipment, and due to the low probability of the simultaneous occurrence of conditions required to cause dermal impacts to the General Public from the use of water from private wells.

The General Public may experience impacts from ingestion of drinking water from a private ground-water well or private ground-water fed surface water body. However such exposure is expected to be minimal due to the low probability of the simultaneous occurrence of the combination of factors required.

Furthermore, the incremental quantity of predicted discharges would be small as compared to the overall amount of discharges generated from the total amount of concrete and ferrous metal being recycled annually in the U.S. Similarly, the quantity of additional leachate and potential effects on ground water associated with disposal of solid materials under the EPA/State-Regulated Disposal Alternative and the LLW Disposal Alternative would be small compared with the overall amount of leachate being generated annually by these facilities. Therefore, the overall

1 effects on water quality associated with all of the alternatives would be small when compared  
2 with other sources of discharges.

### 3 4 **3.5 AIR QUALITY**

5  
6 The affected environment and potential environmental consequences discussed in this section  
7 address non radiological air pollutants emitted from activities associated with the release,  
8 handling, processing, transportation, and disposal of potentially clearable solid materials.  
9 Supplemental detailed information is in Appendix I. The affected environment and potential  
10 impacts associated with radionuclide air emissions are included in the collective dose analysis  
11 discussed in Section 3.2.

12  
13 Activities associated with the Alternatives would occur at licensed facilities, along transportation  
14 routes, and at recycling facilities, EPA/State-regulated disposal facilities and LLW disposal  
15 facilities. The specific locations of recycling facilities, EPA/State-regulated disposal facilities,  
16 and transportation routes where activities would occur cannot be identified. Therefore the  
17 discussion of the affected environment in Section 3.5.2 is not site specific.

18  
19 Air quality impacts are assessed in Section 3.5.3 through comparison of the air emissions  
20 associated with each Alternative with national air emissions trends. The emissions estimates are  
21 compared to the national emissions estimates for the processes that are involved on an average  
22 annual basis. In the analysis it is assumed that materials generated at the licensed facilities are  
23 released at a uniform rate over a 47 year period. Site-specific air quality impacts are not  
24 addressed, because the locations of activities emitting air pollutants cannot be identified.

#### 25 26 **3.5.1 Regulatory Framework**

27  
28 There are four broad categories of air pollutants associated with the processes and activities  
29 under the Alternatives. These include:

- 30
- 31 • Pollutants regulated as National Ambient Air Quality Standards (NAAQS) under Title 1 of  
32 the Clean Air Act (CAA) (EPA 2003b);
  - 33
  - 34 • Pollutants regulated by National Emissions Standards for Hazardous Air Pollutants  
35 (NESHAP) under Title 3 of the CAA (EPA 2003c);
  - 36
  - 37 • Pollutants regulated for the purposes of public welfare (e.g., acid rain, visibility); and
  - 38
  - 39 • Pollutants considered to be greenhouse gases (e.g., carbon dioxide, methane, nitrous oxide).
  - 40

41 NAAQS are pollutants that are emitted by or caused by emissions from a wide variety of air  
42 emissions sources and have been identified as contributing to human health effects. All States  
43 are required under the CAA to monitor these pollutants and develop State implementation plans  
44 (SIPs) to control the emissions of these pollutants to achieve and then maintain the concentration  
45 levels stipulated by the NAAQS. Table 3-21 lists the National Ambient Air Quality Standards.  
46

**Table 3-21 National Ambient Air Quality Standards**

Parameter	Standard	National Standard	Average Period
Ozone*	Primary and Secondary	0.12 ppm (235 µg/m <sup>3</sup> )	1-hour average
		0.08 ppm (150 µg/m <sup>3</sup> )	8-hour average
Particulate matter (PM <sub>10</sub> )	Primary	150 µg/m <sup>3</sup>	24-hour average
		50* µg/m <sup>3</sup>	Annual average
Fine particulate matter (PM <sub>2.5</sub> )*	Primary	65 µg/m <sup>3</sup>	24-hour average
	Primary and Secondary	15 µg/m <sup>3</sup>	Annual average
Nitrogen dioxide	Primary and Secondary	0.053 ppm (100 µg/m <sup>3</sup> )	Annual average
	Secondary	0.50 ppm (1,300 µg/m <sup>3</sup> )	3-hour average
Sulfur dioxide	Primary	0.14 ppm (365 µg/m <sup>3</sup> )	24-hour average
		0.03 ppm (80 µg/m <sup>3</sup> )	Annual average
Carbon monoxide	Primary	35 ppm (40 mg/m <sup>3</sup> )	1-hour average
		9 ppm (10 mg/m <sup>3</sup> )	8-hour average
Lead	Primary and Secondary	1.5 µg/m <sup>3</sup>	3-month average

ppm Parts per million

µg/m<sup>3</sup> Micrograms per cubic meter.

\* The revised ozone standard of 0.08 parts per million (ppm) for an 8-hour averaging period, and the standards for particulate matter of 2.5 microns in diameter (PM<sub>2.5</sub>) became effective in September 1997. However, due to legal challenges EPA has just recently completed designating attainment or nonattainment areas; and SIP plans to achieve these standards are currently in development.

Source: 40 CFR Part 50.

Hazardous air pollutants (HAPs), frequently referred to as air toxics, have been linked to human health effects. These pollutants are generally associated with specific types of air emissions sources and activities and, therefore, affect primarily specific local areas. Since these pollutants are emitted by specific types of air emissions sources, they are not regulated under the NAAQS provisions of the CAA, but are regulated under the source-specific National Emissions Standards for Hazardous Air Pollutants (NESHAP). Sources of these pollutants are required to apply Maximum Achievable Control Technology (MACT) to control releases of the HAP pollutants. A list of NESHAP regulations applicable to source categories related to the Alternatives is provided in Table 3-22.

Pollutants identified in the CAA associated with public welfare effects include precursors of acid rain and regional haze. Acid rain is produced by sulfur and nitrogen-containing air pollutants that react in the atmosphere to create acidic compounds that are then deposited through precipitation or dry deposition processes onto the surface of the Earth. The accumulation of these acid compounds over time can damage sensitive aquatic, agricultural, and forest ecosystems resulting in reduced productivity and reduced biodiversity. Regional haze results from the same precursors of acid rain, plus organic compounds, and soils that are suspended in the atmosphere by mechanical processes. The largest stationary sources of sulfur compounds and a major source of nitrogen compounds are coal-fired power plants. The precursor pollutants of acid rain and regional haze are also emitted by highway and off road mobile sources, ferrous metal mills, other secondary metals processes, incinerators, and the processes used to reduce concrete into smaller pieces that can be hauled away and used as road bed aggregate. These sources, however,

**Table 3-22 Potential Relevant Source Categories Covered by NESHAP MACT Regulations**

Source Category	Federal Register Citation	Pollutants Regulated	Date of Implementation
Hazardous Waste Combustion	64 FR 52827	dioxins, furans, mercury, cadmium, lead, antimony, arsenic, beryllium, chromium, acid gases and chlorine gas	9/20/01
Ferroalloys Production	64 FR 27450	particulate matter	5/20/01
Secondary Aluminum Production	65 FR 15689	metals, dioxins, furans, polycyclic organic matter, HCl, and chlorine gas	3/24/03
Integrated Iron and Steel Production	68 FR 27645	particulate matter	5/20/06
Iron and Steel Foundries	signed 8/29/03	HAP Metals and HAP Organics	
Subtitle D Landfills	68 FR 2227	Represented as total PM and Total Organics	11/16/03
Offsite Waste Recovery Operations <sup>1</sup>	61 FR 34140	Removal of HAP Materials Before Treatment	7/10/06

<sup>1</sup> Includes non RCRA exempt hazardous waste landfills and incinerators (EPA 2003c).

represent only a small fraction of the emissions resulting from power plants, existing mobile sources and existing activities of the type related to the Alternatives. Acid rain is regulated largely by the emissions trading program implemented under Title 4 of the CAA which restricts the collective emissions of sulfur dioxide and oxides of nitrogen from the largest coal-fired power plants. Regional haze precursor pollutants are regulated in conjunction with PM<sub>2.5</sub> programs and most States are just beginning to implement plans to achieve the visibility objectives.

Sources associated with the Alternatives emit long lasting air contaminants that absorb heat energy and are thought to be capable of causing changes in the Earth's climate. These compounds act like the panes of glass in a greenhouse to trap heat and, therefore, have become known as greenhouse gases (GHGs). The primary GHGs are carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O). Carbon dioxide is the dominant gaseous byproduct of fossil and biomass fuel combustion, and any such combustion source (e.g., industrial furnaces, solid waste incinerators, gasoline engines, diesel engines) releases CO<sub>2</sub>. Methane and N<sub>2</sub>O are also released by fuel combustion sources, although at very small levels, and also by other industrial processes. EPA prepares an annual assessment of emissions of GHGs in the U.S.<sup>1</sup> (EPA 2003d): Greenhouse gases are not currently regulated under the CAA, although there are many voluntary programs that are being implemented to reduce the amount of these gases that are released in the

<sup>1</sup> <http://yosemite.epa.gov.oar/globalwarming.nsf/ResourceCenterPublicationsGHGEmissions.html>.

U.S. The contribution of the activities associated with the Alternatives to total GHG loading is negligible in comparison to power generation and total mobile source activities.

### 3.5.2 Affected Environment

The affected environment, as defined for the purposes of the air quality impact assessment, includes the ambient air affected by non radiological air pollutants emitted from activities associated with the release, handling, processing, transportation, and disposal of solid materials generated from licensed facilities under the Alternatives, and the General Public potentially exposed to such non radiological air pollutants. The affected environment also includes environmental receptors potentially affected by air emissions from activities associated with the Alternatives.

### 3.5.3 Environmental Consequences

Total national air emissions (in units of tons per year) from processes and activities associated with the Alternatives are estimated using emission factors. For example, the total amount of particulate matter (PM) associated with the recycling of ferrous metal under the Unrestricted Release Alternative is estimated by multiplying the total amount of ferrous metal generated from licensed facilities that is recycled in ferrous metal mills (in units of tons per year) by a factor for the amount of particulate matter emitted per ton of ferrous metal recycled (in units of mass PM per ton ferrous metal processed). Emission factors (EPA 2004a) are applied to appropriate estimates of the material flow through each process to estimate the incremental effects on air quality associated with each Alternative. A summary of the total air emissions expected to result from each of the Alternatives is provided in Table 3-23.

**Table 3-23 Summary Table – Total Air Emissions from Alternatives (metric tons)**

<i>No Action and Unrestricted Release Alternatives</i>	<b>PM<sub>10</sub></b>	<b>SO<sub>2</sub></b>	<b>NO<sub>x</sub></b>	<b>VOC</b>	<b>CO</b>
Concrete	1,219	Neg.	4,654	1,132	910
Ferrous Metal	8,362	2,905	7,248	4,614	--
Trash (landfill disposal)	67	Neg.	186	94	94
<b>TOTAL</b>	<b>9,648</b>	<b>2,905</b>	<b>12,124</b>	<b>5,839</b>	<b>1,004</b>
<i>EPA/State-Regulated Disposal Alternative</i>	<b>PM<sub>10</sub></b>	<b>SO<sub>2</sub></b>	<b>NO<sub>x</sub></b>	<b>VOC</b>	<b>CO</b>
Concrete (landfill disposal)	1,210	Neg.	3	1,132	910
Ferrous metal (landfill disposal)	36	Neg.	772	60	326
Trash (landfill disposal)	10	Neg.	186	94	94
Trash (incineration)	171	117	337	94	157
<b>TOTAL</b>	<b>1,417</b>	<b>117</b>	<b>5,696</b>	<b>1,285</b>	<b>1,393</b>
<i>LLW Disposal Alternative</i>	<b>PM<sub>10</sub></b>	<b>SO<sub>2</sub></b>	<b>NO<sub>x</sub></b>	<b>VOC</b>	<b>CO</b>
All Materials total	93	7	889	94	94
<i>Limited Dispositions Alternative</i>	<b>PM<sub>10</sub></b>	<b>SO<sub>2</sub></b>	<b>NO<sub>x</sub></b>	<b>VOC</b>	<b>CO</b>
All Materials	205	62	258	123	21

Note: Neg. means negligible.

1 Approximately 19.8 million metric tons of concrete and 2.4 million tons of ferrous metal would  
2 be released from licensed commercial nuclear reactor facilities under any of the Alternatives  
3 (SC&A 2003, Table 10.3). This amount of ferrous metal is compared to approximately  
4 82 million metric tons per year in the United States. Conversely, approximately 6,600 metric  
5 tons of copper and 200 metric tons of aluminum are anticipated to be released from commercial  
6 nuclear reactor facilities. Due to the relatively small quantities, air quality impacts associated  
7 with recycling and disposal of aluminum and copper are not discussed quantitatively in the Draft  
8 GEIS. Approximately 0.066 million metric tons of trash would be released from licensed nuclear  
9 reactor facilities, with an additional 0.886 million tons of trash released from licensed facilities  
10 other than commercial nuclear reactors. This compares with estimates of approximately 209  
11 million metric tons per year of municipal solid waste. The air quality impact analysis for trash is  
12 based on the disposal of trash in either EPA/State-regulated landfills, EPA/State-regulated  
13 incinerators, or LLW disposal facilities. Trash is not assumed to be recycled or reused under any  
14 of the Alternatives.

15  
16 Sources and activities associated with the Alternatives to which NESHAP standards apply are  
17 described in Appendix I. Process emissions of hazardous air pollutants (HAPs) would be  
18 generated from the recycling of ferrous metal under the No Action and Unrestricted Release  
19 Alternatives. The emission factors for HAPs for ferrous metal recycling are small compared to  
20 the emission factors for the criteria (NAAQS) air pollutants for ferrous metal recycling, in terms  
21 of emissions per ton of ferrous metal recycled. Therefore, the HAP emissions from ferrous metal  
22 recycling would be small as compared to the total inventory of HAPs emitted on a national basis.  
23 Similarly, the HAP emissions associated with disposal of licensee-generated material in Subtitle  
24 D landfills or EPA/State-regulated incinerators would also be small as compared to the total  
25 inventory of HAPs emitted from landfill disposal and incineration of solid waste. In addition,  
26 the facilities where these materials would be processed are already subject to HAP emissions  
27 limitation standards whether or not the materials from licensed facilities are processed.  
28 Therefore, HAP emissions from ferrous metal recycling and landfill disposal and incineration of  
29 solid waste are not discussed quantitatively in the Draft GEIS.

30  
31 The preceding analysis has been completed based on material quantity estimates for commercial  
32 reactor licensees. There are a variety of other types of activities that release materials that could  
33 be included in the various alternatives. With the exception of trash, the total quantities of the  
34 other materials from these non reactor facilities are extremely low and will not add to the air  
35 quality impacts. The quantity of trash generated from these other licensed facilities is estimated  
36 to be 883,000 tons (SC&A 2003, Tale 5.6). The emissions totals for trash incineration assume  
37 incineration of only the 66,000 tons (SC&A 2003, Table 10.7) generated from commercial  
38 nuclear reactor facilities. These totals remain in the range of less than one percent of existing  
39 emissions represented in the annual national emissions inventory.

#### 40 **3.5.4 Summary of Air Quality Impacts**

41  
42 This section assesses non-radiological impacts to air quality. Radiological impacts are included  
43 in the dose assessments in Section 3.2.  
44  
45

1 Non-radiological air emissions associated with processes and activities associated with the  
2 Alternatives are summarized in Table 3-23. These emissions will take place over a large  
3 geographical area, and at various times depending on when individual sites are decommissioned  
4 and the materials are released. Some of these emissions will also occur over the operating life of  
5 the facility. The potential impacts on any individual community will be intermittent and short  
6 lived. Therefore, it is concluded that incremental impacts on ambient air quality and human  
7 exposure to non-radiological air pollutants in individual communities will be inconsequential for  
8 all of the alternatives.

9  
10 Furthermore, the incremental quantity of predicted air emissions would be small as compared to  
11 the overall amount of air emissions generated from the total amount of concrete and ferrous  
12 metal, being recycled annually in the U.S. The overall effects on air quality associated with all of  
13 the alternatives would be small when compared with other sources of emissions.

### 14 **3.6 ECOLOGICAL IMPACTS**

15  
16 Section 3.4 concludes the potential non-radiological impacts to surface water, ground water and  
17 drinking water are expected to be small because compliance with EPA and State permits would  
18 preclude significant impacts. Furthermore, ecological receptors only face potential  
19 environmental consequences from surface water in ground-water fed surface water bodies.  
20 Leachate or runoff that seeps into ground water and ultimately reaches a surface water body,  
21 especially a small pond, could alter the pH of or introduce organic and inorganic compounds into  
22 the surface water body. Since the non-radiological impacts to surface water, ground water and  
23 drinking water described in Section 3.4 are expected to be small, then non-radiological impacts  
24 to ecological receptors are also expected to be small.

25  
26 Radiological impacts to environmental receptors are considered to be insignificant. The current  
27 position of the International Commission on Radiological Protection (ICRP 1991) is that "the  
28 standard of environmental control needed to protect man to the degree currently thought  
29 desirable will ensure that other species are not put at risk." Recently, ICRP has stated that the  
30 ICRP "system for protection of human beings has indirectly provided a fairly good level of  
31 protection of the human habitat." (ICRP 2003, page 201) However, the ICRP has decided to  
32 develop a framework for the assessment of radiation effects in non-human species. "The primary  
33 purpose of developing such a framework is to fill a conceptual gap in radiological protection; it  
34 does not reflect any particular concern over environmental radiation hazards." (ICRP 2003, page  
35 207) Since a dose rate of 1 mrem/yr is a small fraction of background radiation, there would be  
36 no significant radiological impact to ecological resources associated with the Alternatives.

37  
38  
39 The DOE standard *A Graded Approach for Evaluating Radiation Doses to Aquatic and*  
40 *Terrestrial Biota* (DOE-STD-1153-2002, July 2002, p. xxi) (DOE 2002a) states:

41  
42 "The technical standard assumes a threshold of protection for plants and animals  
43 at the following doses: for aquatic animals, 1 rad/d (10 mGy/d); for terrestrial  
44 plants, 1 rad/d (10 mGy/d); and for terrestrial animals, 0.1 rad/d (1 mGy/d).  
45 Available data indicate that dose rates below these limits cause no measurable  
46 adverse effects to populations of plants and animals."

1 These exposure thresholds are consistent with the values in the Report of the United Nations  
2 Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) to the General Assembly  
3 - "Effects of Radiation on the Environment" (UNSCEAR 1996). The units associated with  
4 exposure and dose to non-human species, and value of the relative biological effectiveness is  
5 currently the subject of international debate. It should be noted that the annual dose rate  
6 thresholds identified by these agencies are orders of magnitude above any of the dose limits  
7 being considered under the alternatives. As a result, it is impossible under the provisions of the  
8 proposed rule to attain such high dose rates. Consequently, the rule provides ample protection to  
9 biota.

### 10 **3.7 WASTE MANAGEMENT**

11  
12  
13 Under the five proposed Alternatives, materials generated from licensee facilities can be released  
14 to one or more of the following dispositions: use in general commerce (including recycling into  
15 consumer products or industrial and construction uses); reuse; disposal in EPA/State-regulated  
16 facilities<sup>2</sup>; or disposal at Low-Level Radioactive Waste (LLW) disposal facilities. The waste  
17 management discussion below describes the affected environment and analyzes potential  
18 environmental consequences of the Alternatives with respect to disposal of materials in  
19 EPA/State-regulated landfills and LLW disposal facilities. Section 3.7.1 provides a discussion  
20 of the affected environment with respect to waste management, and Section 3.7.2 provides a  
21 discussion of the potential environmental consequences with respect to waste management.  
22

#### 23 **3.7.1 Affected Environment**

24  
25 The affected environment for the Proposed Action includes EPA/State-regulated disposal  
26 facilities (landfills and incinerators) and LLW disposal facilities where licensees would dispose  
27 released solid material. Under each of the Alternatives some amount of potentially clearable  
28 material would be disposed of at LLW disposal facilities; the amount of material disposed of as  
29 LLW varies by Alternative. For the LLW Disposal Alternative all of the potentially clearable  
30 material released would be disposed of as LLW. For the other Alternatives a smaller amount of  
31 the material which is below the release criteria would be disposed of as LLW. Under the  
32 EPA/State-Regulated Disposal Alternative almost all of the potentially clearable solid material  
33 would be disposed of in EPA/State-regulated disposal facilities, with the remainder disposed of  
34 in LLW disposal facilities.<sup>3</sup> Under the No Action and Unrestricted Release Alternatives  
35 licensees could dispose of solid materials in EPA/State-regulated disposal facilities or recycle the  
36 materials. Under the Limited Dispositions Alternative, ferrous metals and trash could be

---

<sup>2</sup> Disposal in EPA/State-regulated Subtitle C disposal facilities is not being considered as an Alternative in the Draft GEIS. Please see the discussion on Subtitle C disposal facilities in Chapter 2, Section 2.4.3.

<sup>3</sup> Note that under the No Action, Unrestricted Release, and Limited Dispositions Alternatives byproducts of solid material recycling processes (e.g., furnace slag) are anticipated to be disposed of in EPA/State-regulated landfills. Such disposal is not quantitatively evaluated in the waste management consequences analysis in Section 3.7.2., because these quantities are much lower quantities than the quantities of solid materials that would be disposed of under the Alternatives.

1 disposed of in EPA/State-regulated disposal facilities, while concrete could either be recycled  
2 into roadbed material or disposed of in EPA/State-regulated landfills.

3  
4 The environment in the vicinity of the EPA/State-regulated disposal facilities and LLW disposal  
5 facilities may be affected by disposal in terms of consumption of the existing disposal capacity of  
6 these facilities and associated consumption of available land area. The environmental  
7 consequences analysis for disposal of solid materials in EPA/State-regulated disposal facilities or  
8 in LLW disposal facilities evaluates the effects of such disposal on the existing disposal  
9 capacities of these waste disposal facilities and the potential need for additional facility capacity  
10 and the associated utilization of land. There are three licensed LLW disposal facilities -  
11 Barnwell, South Carolina, Hanford, Washington, and Clive, Utah. These three facilities and their  
12 environs represent the affected environment with respect to LLW disposal conducted under any  
13 of the Alternatives. Under the EPA/State-Regulated Disposal Alternative, NRC would authorize  
14 the disposal of solid materials at any EPA/State-regulated landfill or incinerator (for trash only)  
15 in the United States. The affected environment with respect to EPA/State-regulated disposal  
16 potentially includes any RCRA Subtitle D landfill or incinerator facility in the United States and  
17 the environs of such facilities. However, no site-specific analyses are conducted for EPA/State-  
18 regulated disposal because the specific facilities that may accept solid materials for disposal  
19 cannot be identified, and therefore no site-specific discussion of the affected environment is  
20 provided in this section.

### 21 22 **3.7.1.1 EPA/State-Regulated Disposal Facilities**

23  
24 As discussed in Section 2.4.3, the EPA/State-regulated facilities are RCRA Subtitle D landfills.

25  
26 Capacity data for Subtitle D landfills was obtained from “The State of Garbage in America”, a  
27 report on municipal solid waste published annually in *BioCycle* (BioCycle 2002). The  
28 methodology and a full discussion of these data can be found in Attachment 2 of Appendix J.  
29 The remaining Subtitle D landfill capacity reported in 2001 is 6,584,885,975 tons. Although  
30 capacity expanded between 1998 and 2000 as a result of the addition of new landfills or  
31 expansion of existing landfills, NRC assumes that the amount of remaining capacity would  
32 remain equal to the 2001 value for the purposes of this environmental consequences analysis.

33  
34 The actual cubic yards of disposal capacity remaining in the Subtitle D landfills depends on what  
35 assumption is made concerning how tightly the waste is compacted. Using low, middle, and high  
36 end conversion factors (see Table 3-24) gives the following range of the remaining volume of  
37 disposal capacity.

38  
39 Regional disposal capacity, regional waste generation, and remaining years of capacity have been  
40 calculated as part of Appendix J. In general, the Mountain region of the U.S. has much more  
41 disposal capacity than it needs to dispose of the solid waste generated in that region, while the  
42 New England and the Mid Atlantic regions have the lowest amount of disposal capacity (out of  
43 seven regions) as compared to the amount of solid waste generated in those regions. However,  
44 exporting solid waste to different regions alleviates some of the disparity in capacity. For the  
45 assessment of environmental consequences with respect to Subtitle D landfills in Section 3.7.2,  
46 the national low and high capacity estimates from 2001 in Table 3-24 were used.

Table 3-24 Remaining Disposal Capacity for Subtitle D Landfills, 2001

Remaining Capacity in 2001 (million tons)	Cubic Yards per Ton	Cubic Yards of Remaining Capacity (million cubic yards)
6,584	1.66 (low)	10,970
6,584	4.33 (medium)	28,513
6,584	7 (high)	46,094

Source: Online searches and interviews with randomly chosen landfill operators were used to find standard “tons to cubic yards” conversions. Conversions ranged from 1.66 cubic yards per ton to 7 cubic yards per ton, depending on the compaction rate and density of waste.

### Solid Waste Incinerator Capacity

The existing solid waste incinerator capacity was evaluated with respect to disposal of trash for the EPA/State-Regulated Disposal Alternative. Solid materials other than trash (concrete and metal) are assumed not to be incinerated. The incinerator capacity data were derived from *BioCycle's* (BioCycle 2002) annual report. The methodology is described in Appendix J. The existing solid waste incinerator capacity for the 2001 study year is 33,791,899 tons/year. For the purposes of the capacity analysis, the analysis assumed that the incineration capacity would remain equal to the capacity reported in 2001.

#### **3.7.1.2 LLW Disposal Facilities**

Three facilities in the country currently accept LLW for disposal. Their total remaining capacity is roughly 10.4 million cubic yards, as summarized in Table 3-25.

The Hanford LLW disposal facility accepts waste from the Northwest and Rocky Mountain compacts. Hanford is licensed by the State of Washington to receive wastes in Classes A-C. The "compact States" include Washington, Oregon, Idaho, Montana, Utah, Wyoming, Nevada, Colorado, New Mexico, Alaska, and Hawaii. The only power reactors in these compact States are the four "Energy Northwest" units at Hanford. The Barnwell LLW disposal facility currently accepts waste from all U.S. generators except those in Rocky Mountain and Northwest compacts. Beginning in 2008, Barnwell will only accept waste from the Atlantic Compact States (Connecticut, New Jersey, and South Carolina). The Barnwell facility is licensed by the State of South Carolina to receive wastes in Classes A-C. Therefore, the existing LLW disposal capacity is reported in the following section with and without consideration of the capacity at the Barnwell and Hanford facilities, as most commercial nuclear reactor facilities would be precluded from disposing of LLW at the Hanford and Barnwell facilities during the period of the Proposed Action.

**Table 3-25 NRC-Licensed LLW Disposal Facility Capacity, 2002**

Facility	Remaining Volume (million cubic yards)	Notes
Envirocare - Clive, UT	2.7	Remaining capacity as of 12/02
Barnwell Disposal Facility - Barnwell, SC	0.008	Reported as 230,000 cubic feet. This only accounts for non-regional* waste. Barnwell will stop accepting non-regional waste in 2008.
Hanford Off-Site LLW Disposal Facility - Hanford, WA	7.7	Excluding facilities for wastes generated at the Hanford Site.
<b>Total</b>	<b>10.4</b>	<b>Not including Barnwell.</b>

\* Non-regional waste is anything generated outside the Atlantic Compact, which includes South Carolina, New Jersey, and Connecticut.

### 3.7.2 Environmental Consequences

Environmental consequences could affect EPA/State-regulated disposal facilities and LLW disposal facilities. Potential environmental consequences to RCRA Subtitle D facilities under each Alternative are discussed in Section 3.7.2.1. Potential environmental consequences to LLW disposal facilities under each Alternative are discussed in Section 3.7.2.2.

#### 3.7.2.1 EPA/State-Regulated Disposal Facilities

Under four of the five Alternatives, some amount of solid material released from licensed facilities could be disposed of in EPA/State-regulated licensed landfills. For the Unrestricted Release Alternative and the EPA/State-Regulated Disposal Alternative, the amount of material that could be disposed of at EPA/State-regulated landfills would depend upon the specific dose option for the Alternative. For the No Action and the Limited Dispositions Alternatives the amount of material that could be disposed of in EPA/State-regulated landfills would be determined by case-by-case assessment by NRC, and therefore the amount of material that would be disposed of cannot be estimated. However, the No Action and Limited Dispositions Alternatives would be bounded by the Unrestricted Release and EPA/State-Regulated Disposal Alternatives.

The environmental consequences of disposal of solid materials in EPA/State-regulated landfills relates to the consumption of disposal capacity of the existing population of landfills, displacement of materials from other sources that would normally have been disposed of in EPA/State-regulated landfills, and potential exceedance of available disposal capacity. If only a small percentage of the overall existing landfill disposal capacity would be utilized under a

1 particular Alternative, then neither exceedance of capacity nor displacement of materials would  
2 occur. The following evaluation of environmental consequences is based on the projected  
3 amount of material released for disposal and the remaining capacity of EPA/State-regulated  
4 landfills. The analysis demonstrates that the existing capacity of Subtitle D landfills is adequate  
5 for disposal of all potentially clearable solid materials that could be released under any of the  
6 alternatives.

### 7 8 **3.7.2.1.1 No Action Alternative**

9  
10 Solid materials can currently be released for unrestricted use or disposal. Any future changes in  
11 the proportion of those dispositions would be covered by the impacts of the Unrestricted Release  
12 and EPA/State Regulated Disposal Alternatives. The EPA/State-regulated landfill capacity  
13 discussed in Section 3.7.1 would be adequate to accommodate the disposal of solid material in  
14 RCRA Subtitle D landfills under the No Action Alternative.

### 15 16 **3.7.2.1.2 Unrestricted Release Alternative**

17  
18 Under the Unrestricted Release Alternative five dose options are considered for the release of  
19 solid materials. For purposes of this analysis, it is assumed that all of the ferrous metal, concrete,  
20 and trash<sup>4</sup> released for each dose option would be disposed of in EPA/State-regulated landfills.  
21 This assumption would represent the maximum amount of material that would be disposed of in  
22 Subtitle D landfills under any of the Alternatives and would include solid material that could  
23 otherwise be recycled under the Unrestricted Release Alternative. Under this assumption, the  
24 amount of material that would be disposed of in EPA/State-regulated landfills under the  
25 Unrestricted Release Alternative is approximately the same as the amount that would be disposed  
26 of in EPA/State-regulated landfills under the EPA/State-Regulated Disposal Alternative. This  
27 also bounds the amount from the Limited Dispositions Alternative.

28  
29 Figure 3-2 shows the amount of total material released and the amounts of ferrous metal,  
30 concrete, and trash under each dose option. The amount of material released under each dose  
31 option is: 8.4 million cubic yards for the 0.03 mrem/yr dose option; 9.9 million cubic yards for  
32 the 0.1 mrem/yr dose option; 11.1 million cubic yards for the 1 mrem/yr dose option, and  
33 11.3 million cubic yards for the 10 mrem/yr dose option. The amount of material that would be  
34 released under the Unrestricted Release Alternative RS-G-1.7 dose option would be  
35 approximately the same as the 1 mrem/yr dose option.

36  
37 Table 3-26 provides a comparison of the estimated remaining Subtitle D landfill capacity and the  
38 maximum estimated amount of material anticipated to be released under the Unrestricted Release  
39 Alternative that could be disposed of in EPA/State-regulated landfills.

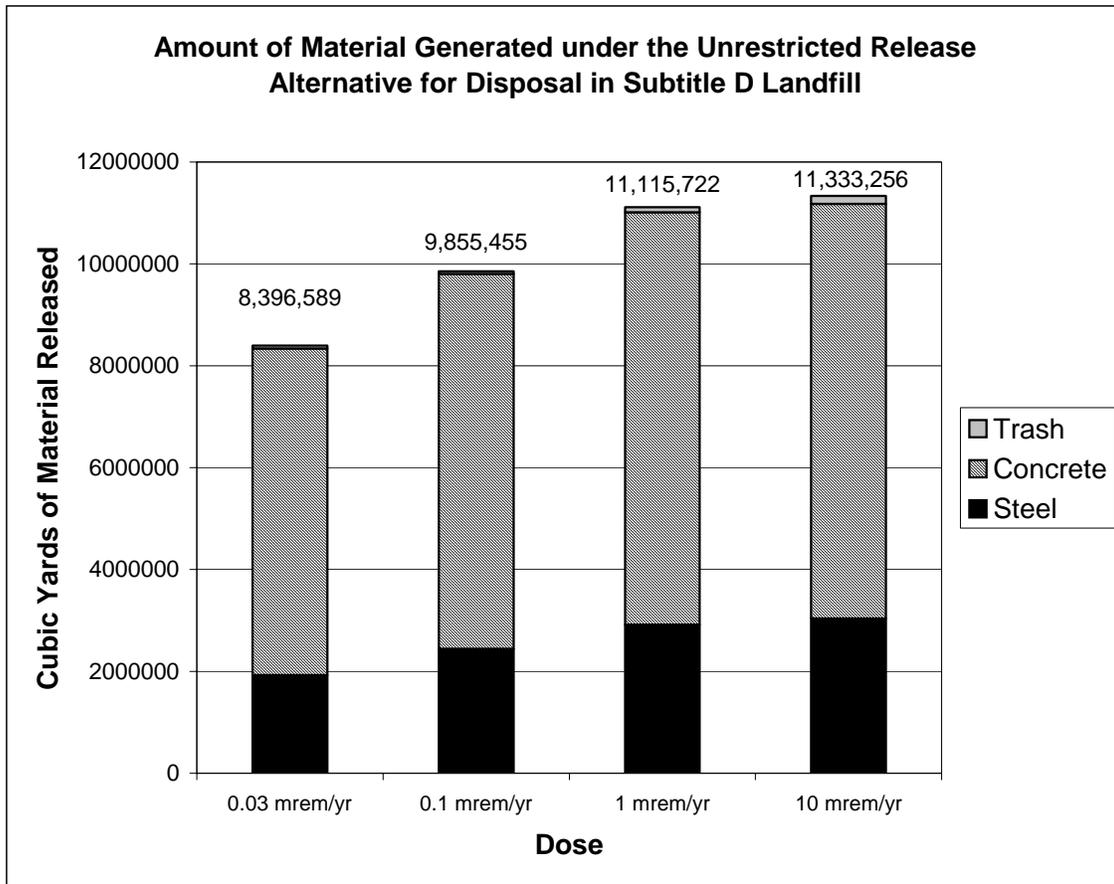
40  
41 By 2049 an estimated 6.4 million cubic yards of concrete and 1.9 million cubic yards of ferrous  
42 metal is anticipated to be released under the 0.03 mrem/yr dose option for the Unrestricted  
43 Release Alternative. This 8.3 million cubic yards of material represents 0.08 percent of the

---

<sup>4</sup> These figures represent the total amount of concrete, ferrous metal, and trash. Note that aluminum, and copper are not included in this capacity analysis.

1 remaining capacity of Subtitle D landfills in the United States. For the 10 mrem/yr dose option  
 2 an estimated 11.3 million cubic yards of concrete, ferrous metal, and trash would be released.  
 3 This represents 0.10 percent of the remaining Subtitle D landfill capacity. Thus, the existing  
 4 capacity of Subtitle D landfills would be adequate for the disposal of all of the potentially  
 5 clearable materials that would be released under the Unrestricted Release Alternative under all  
 6 dose options. There will therefore be no additional environmental consequences from the release  
 7 of materials for disposal in Subtitle D landfills under the Unrestricted Release Alternative.  
 8

Figure 3-2



9 Note: Volumes of materials for the 1 mrem/yr and RS-G-1.7 dose options are the same.  
 10  
 11

**Table 3-26 Estimated Remaining Subtitle D Disposal Capacity and Projected Materials Released under the Unrestricted Release Alternative**

Subtitle D Landfill	Estimated Remaining Disposal Capacity (million cubic yards)	Projected Material Released (million cubic yards and percent of remaining capacity)*							
		.03 mrem/yr		.1 mrem/yr		1 mrem/yr		10 mrem/yr	
Low Capacity Estimate	10,970	8.4	0.08%	9.9	0.09%	11.1	0.10%	11.3	0.10%
High Capacity Estimate	46,094	8.4	0.02%	9.9	0.02%	11.1	0.02%	11.3	0.02%

\* Figures for “projected material released” apply to the period of 2003 to 2049.

**3.7.2.1.3 EPA/State-Regulated Disposal Alternative**

The EPA/State-Regulated Disposal Alternative would require that all potentially clearable materials released from licensed facilities be disposed of in EPA/State-regulated landfills or incinerators (for trash only). The same five dose options evaluated under the Unrestricted Release Alternative apply to the release of materials for disposal in EPA/State-regulated landfills under this Alternative. Each dose option represents a different amount of material released, as shown in Figure 3-2. Under the EPA/State-Regulated Disposal Alternative, all solid material would be prohibited from general commerce (recycling into consumer products and industrial and construction uses). The maximum amounts of materials assumed to be disposed of in EPA/State-regulated landfills under the EPA/State-Regulated Disposal Alternative under each dose option are the same as for the Unrestricted Release Alternative in Section 3.7.2.1.2.

The estimated remaining Subtitle D landfill disposal capacity under the EPA/State-Regulated Disposal Alternative is the same as shown in Table 3-26. The maximum amount of remaining Subtitle D landfill capacity that would be utilized under the EPA/State-Regulated Disposal Alternative is approximately 0.10 percent. There will therefore be no additional environmental waste management impacts from the release of materials for disposal in Subtitle D landfills under the EPA/State-Regulated Disposal Alternative.

**3.7.2.1.4 Low-Level Waste Disposal Alternative**

No solid material would be disposed of in Subtitle D disposal facilities under the LLW Disposal Alternative.

**3.7.2.1.5 Limited Dispositions Alternative**

Under the Limited Dispositions Alternative concrete could be recycled only into roadbed material. Other materials would be required to be disposed of in EPA/State-regulated disposal facilities, except for those materials released in a case-by-case assessment by NRC. Tools and other equipment could be reused under this Alternative. Therefore the amount of solid material anticipated to be disposed of in EPA/State-regulated landfills under this Alternative would be less than that anticipated to be disposed under the EPA/State-Regulated Disposal Alternative described in Section 3.7.2.1.3 above.

**3.7.2.2 LLW Disposal Facilities**

Similar to the discussions above for environmental consequences to EPA/State-regulated disposal facilities, environmental consequences associated with waste management at LLW facilities can be categorized in two main groups: potential exceedance of capacity of the current population of LLW facilities or displacement of materials from other sources that would normally have been disposed of in a LLW facility. Exceedance of capacity or displacement of materials would most likely precipitate construction of new LLW facilities or expansion of existing facilities. The impacts associated with construction of new facilities or expansion of existing facilities are outside of the scope of the Proposed Action, but are discussed qualitatively in Section 3.7.3 below.

The total amount of potentially clearable solid material anticipated to be released from commercial nuclear reactor facilities is summarized in Table 3-27. Under the LLW Disposal Alternative all of this material would be disposed of in LLW disposal facilities. The amount of solid material that would be disposed of as LLW under the other four Alternatives will be less. Table 3-28 lists the estimated amount of material to be disposed of as LLW under each of the Alternatives.

**Table 3-27 Mass of Potentially Clearable Materials from Commercial Nuclear Reactor Facilities**

<b>Material</b>	<b>Total Mass (tons)</b>
Ferrous Metal	2,498,911
Concrete	19,877,341
Trash	323,023
Aluminum	212
Copper	6,584
<b>Total</b>	<b>22,706,071</b>
<b>Total Cubic Yards</b>	<b>11.5 Million Cubic Yards</b>

Source: SC&A 2003, Table 10.3.

**Table 3-28 Projected Material Released to LLW Disposal\* and Estimated Remaining Disposal Capacity Under Each Alternative**

Alternative	Projected Material Released (million cubic yards)	Percent of Estimated Remaining LLW Disposal Capacity		
		Hanford, Barnwell and Envirocare (10.4 Mil cubic yards)	Envirocare Only (2.7 Mil cubic yards)	
No Action	2.27	21.9	84.5	
Unrestricted Release	0.03 mrem/yr	3.4	125	
	1.0 mrem/yr	0.41	15.2	
	10 mrem/yr	0.21	7.9	
EPA/State-Regulated Disposal	0.03 mrem/yr	2.8	103	
	1.0 mrem/yr	0.29	10.9	
	10 mrem/yr	0.18	6.6	
LLW Disposal	11.5	111.6	425.9	
Limited Dispositions	RS-G-1.7	0.41	15.2	

\* Figures for “projected material released” apply to the period 2003 to 2049.

Source: Volume of materials based on Table 10.3 SC&A 2003 and Tables 3-15 and 3-27 of this report. Tonnage to cubic yard conversions assume a density of 0.51 cubic yard per ton.

The estimated remaining LLW disposal capacity for each alternative is shown in Table 3-28. It is anticipated that because of waste acceptance restrictions on the Hanford and Barnwell facilities the only licensed facility that would be available to accept LLW generated under the Proposed Action would be the Envirocare facility in Utah. As shown above, several of the “projected material released” scenarios exceed the current capacity of the Envirocare LLW facility. Under the No Action Alternative the amount of solid material anticipated to be disposed as LLW would utilize 84 percent of the available Envirocare facility disposal capacity or 22 percent of the available capacity of all three of the currently licensed LLW disposal facilities. The amount of solid material anticipated to be disposed of as LLW under the LLW Disposal Alternative is equivalent to 426 percent of the LLW disposal capacity of the Envirocare facility, or 112 percent of the disposal capacity of all three of the currently licensed LLW disposal facilities.

Note that these disposal capacity utilization estimates include only the solid materials that would be generated from commercial nuclear reactors under the Proposed Action. Given the anticipated rate of generation of LLW from all facilities under the Proposed Action, the existing LLW disposal capacity at the Envirocare disposal facility may be either completely utilized or come close to capacity for at least one dose option under each of the Alternatives. This is even without considering the fact that facilities that are not reactors would also continue to generate LLW during the time frame of the Proposed Action. The 1 mrem/yr dose option under the Unrestricted Release and EPA/State-Regulated Disposal Alternatives, however, would not exceed the current

1 LLW disposal capacity, but would utilize only 11 to 15 percent of Envirocare’s total available  
2 disposal capacity.

3  
4 If the existing LLW disposal capacity is completely utilized within the time frame of the  
5 Proposed Action, then either other material will need to be displaced from LLW disposal, waste  
6 acceptance restrictions on the Hanford and Barnwell facilities will need to be lifted, or LLW  
7 facilities will need to be constructed or expanded to accommodate the LLW disposal. Note  
8 however that under the LLW Disposal Alternative, even if all the waste acceptance restrictions  
9 were lifted from the Hanford and Barnwell facilities, the total capacity of the three licensed LLW  
10 disposal facilities would not be sufficient to accommodate all of the LLW that would be  
11 generated. Potential construction of new LLW disposal facilities or expansion of LLW disposal  
12 facilities is discussed in Section 3.7.3, however quantitative evaluation of construction impacts is  
13 not within the scope of the Draft GEIS.

### 14 **3.7.3 Potential Impacts from Construction of Additional Facilities**

15  
16  
17 There will be no need for construction of additional RCRA Subtitle D disposal facilities as a  
18 direct result of any of the Alternatives described in Section 3.7.1 above. The existing Subtitle D  
19 landfill capacity will not be adversely affected under any of the Alternatives and associated dose  
20 options and therefore no land-take for future construction would occur related to these  
21 Alternatives in the time period analyzed. Because there will be no new construction, there are no  
22 associated waste management consequences from disposal in current landfills. If in the future, a  
23 need for constructing new Subtitle D landfills arises in response to any site-specific conditions,  
24 then a site-specific environmental review would be conducted for that Proposed Action as it falls  
25 outside of the scope of this analysis.

26  
27 The need for construction of additional LLW disposal facilities or expansion of existing facility  
28 capacity may result from any of the Alternatives described in Section 3.7.2. This would depend  
29 upon the specific dose option. The LLW Disposal Alternative would result in utilization of more  
30 than 100 percent of the available LLW disposal capacity. The availability of LLW disposal  
31 facility capacity could potentially be adversely affected by several of the proposed Alternatives,  
32 and therefore land-take for future construction of new facilities or expansion of existing facilities  
33 may be necessary. Potential environmental consequences related to new construction or  
34 expansion of LLW facilities are outside of the scope of this Draft GEIS, however. If, in the  
35 future, new LLW disposal facilities are proposed to be constructed or existing facilities  
36 expanded, then site-specific environmental reviews would be conducted that would evaluate all  
37 related environmental consequences.

## 38 **3.8 CUMULATIVE IMPACTS**

39  
40  
41 Cumulative impact is defined in 40 CFR 1508.7 as “the impact on the environment which results  
42 from the incremental impact of the action when added to other past, present, and reasonably  
43 foreseeable future actions regardless of what agency (Federal or non-Federal) or person  
44 undertakes such other actions. Cumulative impacts can result from individually minor but  
45 collectively significant actions taking place over a period of time.” CEQ guidelines (CEQ 1997)

1 describe those attributes that should be considered when analyzing cumulative impacts of a  
2 proposed action (such as this rulemaking), including:

- 3
- 4 • Determining which resources are affected by the proposed action;
- 5
- 6 • Identifying other past, present, and reasonably foreseeable future actions that either have or  
7 might affect those resources;
- 8
- 9 • Identifying and evaluating potential impacts, but focusing on the most important cumulative  
10 impact issues; and
- 11
- 12 • Determining the magnitude and significance of the proposed action in the context of the  
13 cumulative impacts of other past, present and future actions.
- 14

15 The environmental consequences we considered were doses to the public and LLW disposal  
16 capacity. The cumulative impacts considered in this section are (1) exposure of individuals to  
17 multiple sources, (2) disposition of DOE scrap metals, (3) industrial activities involving  
18 naturally-occurring radioactive materials (NORM), and (4) the proposed NRC licensing of  
19 facilities with significant quantities of LLW.

20

21 Individuals could be exposed to very low levels of radioactivity from more than one source, for  
22 example from a vehicle's engine block and recycled concrete in a roadbed. Appendix E  
23 considers the possible frequency of multiple scenarios affecting the same individual. There could  
24 be multiple radionuclides involved, or multiple kinds of materials released, or multiple  
25 concurrent scenarios (such as multiple facilities releasing materials, or processing released  
26 materials while using consumer products made from released materials). Appendix E concludes  
27 the likelihood of such multiple concurrent exposures becomes vanishingly small as the number  
28 of potential concurrent scenarios increases. While it is difficult to estimate the actual probability  
29 of a particular scenario, with each additional scenario, the potential for all the scenarios occurring  
30 together becomes smaller. Even with only a few scenarios, this potential is very small.

31

32 Another source of potentially clearable solid materials is the decommissioning of DOE facilities.  
33 DOE is developing an environmental impact statement (EIS) related to the disposition of DOE  
34 scrap metals with small amounts of radioactivity. At this time, because DOE has not yet  
35 published its EIS, NRC has found insufficient information in the published literature to  
36 quantitatively characterize DOE facilities. Although the relative contribution of DOE materials  
37 to public doses cannot be estimated, the release of DOE scrap metal could contribute to  
38 cumulative impacts if the material leaves DOE sites.

39

40 Most Department of Defense facilities using potentially clearable materials are licensed by the  
41 NRC and are thus captured by the licensed facilities analyzed in this GEIS.

42

43 Other sources of potentially clearable solid materials are commercial industries not licensed by  
44 NRC that use or process materials that contain NORM, which because of their operations create  
45 higher concentrations of radioactivity than that associated with an undisturbed natural setting.  
46 This material is defined as technologically enhanced NORM (TENORM). The following

1 industries generate TENORM - petroleum production, uranium mining, phosphate and  
2 phosphate fertilizer production, fossil fuel combustion, drinking water treatment, metal mining  
3 and processing, and geothermal energy production. Radioactive species associated with  
4 TENORM are typically uranium, thorium and their decay products. Contaminated equipment  
5 could be decontaminated and reused, disposed of, or sold as scrap. Limited information was  
6 uncovered in the published literature to quantitatively characterize potential cumulative impacts  
7 (DOE 1996).

8  
9 Investigation of the recycle of scrap metal contaminated with NORM has found that the NORM  
10 goes into the slag rather than the metal products. Because the same NORM species present as  
11 contamination are present in the ore or raw materials that initially contain the metals, and these  
12 species go to the slag during processing, recycle of metals from these industries has been  
13 performed for decades and gives no cause for concern. Although NORM use is not federally  
14 regulated, many States have promulgated regulations to control exposure from TENORM. In  
15 2004, the States published model State regulations and Implementation Guidance for TENORM  
16 (Part N of the Suggested State Regulations for Control of Radiation), which were developed  
17 working through the Conference of Radiation Control Program Directors, Inc. Adoption of State  
18 regulations equivalent to Part N provide basic radiation protection standards for TENORM that  
19 are the same as the basic standards for radiation protection in NRC's 10 CFR Part 20. Although  
20 the industries mentioned above are not licensed by NRC, some States may amend their  
21 TENORM regulations in response to an NRC rulemaking on controlling the disposition of solids.

22  
23 When considering cumulative impacts related to LLW disposal capacity, the analysis considered  
24 proposed NRC-licensed facilities that would generate large quantities of solid materials that  
25 would be classified as LLW. There are two proposed new uranium enrichment plants, one  
26 proposed by the USEC, Inc. for construction in Portsmouth, Ohio and one proposed by Louisiana  
27 Energy Services (LES) for construction in Lea County, New Mexico, that would generate LLW.  
28 In the event that NRC does not license a new enrichment plant, the existing USEC enrichment  
29 plant in Paducah, Kentucky is anticipated to remain in operation. (The Paducah plant is  
30 anticipated to cease operations if a new USEC plant is licensed.) Each proposed enrichment  
31 plant and also the existing USEC Paducah plant, if it continues to operate, would generate  
32 depleted uranium hexafluoride ( $DUF_6$ ) that under current DOE requirements would be converted  
33 to uranium oxide ( $DU_3O_8$ ) in a  $DUF_6$  conversion plant. DOE is proposing to construct and  
34 operate two conversion facilities for converting  $DUF_6$  at Portsmouth, OH and Paducah, KY.  
35 These facilities would convert DOE's inventory of  $DUF_6$  to a more stable chemical form suitable  
36 for beneficial use or disposal. For the proposed USEC enrichment plant, LLW would be  
37 generated from site preparation activities including D&D of existing USEC-controlled buildings  
38 and structures at the USEC Portsmouth and Paducah plants. For the proposed USEC and LES  
39 enrichment plants, additional LLW would be generated from D&D of the enrichment plants at  
40 the end of their operating life. The amount of such D&D waste that would be classified as LLW  
41 would depend upon what Alternative NRC selects for the Proposed Action.

42  
43 The license application processes for the proposed USEC and LES enrichment facilities are in  
44 their early stages and quantitative estimates of the amount of LLW that would be generated from  
45 these proposed facilities are not available. In the event that no new commercial LLW disposal  
46 capacity is constructed in the U.S. during the time frame of the Proposed Action, the Proposed

1 Action itself would have a small to large (significant) impact on existing LLW disposal capacity.  
2 The combined amount of LLW generated from the Proposed Action and the two proposed  
3 uranium enrichment plants would have a greater impact on existing LLW disposal capacity than  
4 the Proposed Action alone.  
5

6 When considering past, present, and foreseeable future actions and the impacts from the  
7 proposed rulemaking, cumulative impacts to doses to the public are expected to be small due to  
8 the low doses considered in the NRC rulemaking. In considering cumulative impacts on LLW  
9 disposal capacity, NRC will continue to follow DOE's environmental review of the recycling of  
10 DOE scrap metals and the licensing of the USEC and LES enrichment facilities. NRC considers  
11 the cumulative impacts on LLW disposal capacity to be potentially small to large (significant),  
12 depending on the Alternative considered under this Proposed Action.  
13

### 14 **3.9 UNAVOIDABLE ADVERSE ENVIRONMENTAL IMPACTS, SHORT-TERM** 15 **USES OF THE ENVIRONMENT, AND LONG-TERM PRODUCTIVITY**

16  
17 The radiation doses that would occur as a result of the proposed action are well below NRC  
18 regulatory limits and represent a small fraction of the existing background levels of radiation.  
19 Unavoidable adverse environmental impacts, short-term uses of the environment, and long-term  
20 productivity were previously considered under the activities expected during operation and  
21 decommissioning of licensed facilities.  
22

### 23 **3.10 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES**

24  
25 For all but the LLW Disposal Alternative, no resources would be lost because the Proposed  
26 Action falls within the activities expected during operation and decommissioning of licensed  
27 facilities. For the LLW Disposal Alternative, no solid material would be released and all the  
28 potentially clearable material would be disposed of in LLW disposal facilities. This amount of  
29 LLW would be more than four times the available LLW disposal capacity at Envirocare and  
30 more than the disposal capacity at Hanford, Barnwell and Envirocare combined (Table 3-28).  
31 The LLW Disposal Alternative would result in the commitment of land for additional LLW  
32 facilities or the expansion of current LLW facilities.  
33

34 The Proposed Action would also commit energy resources related to transportation of the solid  
35 material to either recycling or disposal facilities. For the No Action Alternative, approximately  
36 475 million vehicle miles would be traveled transporting the solid materials to recycling facilities  
37 and licensed LLW disposal facilities (Table 3-15). By comparison, under the LLW Disposal  
38 Alternative, approximately 1.4 billion vehicle miles would be traveled transporting by truck all of  
39 the solid materials released to licensed LLW disposal facilities. The LLW Disposal Alternative  
40 represents approximately a 350 percent increase in energy expended for transportation as  
41 compared to the No Action Alternative.  
42

43 The No Action and Unrestricted Release Alternatives would result in recycling of concrete,  
44 ferrous metal, aluminum and copper. The Limited Dispositions Alternative would result in  
45 recycling of concrete but not metals, except by case-by-case determination by NRC. For the No  
46 Action Alternative 18.3 million tons of solid material, including 16.2 million tons of concrete

1 and 2.06 million tons of ferrous metal, would be recycled (Table 3-15). The recycled ferrous  
2 metal could displace the need for production of more than 2 million tons of new ferrous metal.  
3 Production of one ton of recycled ferrous metal requires less energy and materials than  
4 production of one ton of new ferrous metal using virgin materials. Therefore the No Action  
5 Alternative and Unrestricted Release Alternative, under which ferrous metal would be recycled,  
6 would commit fewer resources towards steelmaking than would the EPA/State-Regulated  
7 Disposal Alternative or LLW Disposal Alternative, under which no recycling would be  
8 conducted. The amount of ferrous metal that would be recycled under the Limited Dispositions  
9 Alternative cannot be estimated but would likely be much lower than the amount for the No  
10 Action or Unrestricted Release Alternatives.

### 11 **3.11 MITIGATION MEASURES AND MONITORING**

12 All radioactive materials used, possessed, or stored onsite are required to be periodically  
13 monitored and inventoried. The monitoring includes the conduct of external radiation and  
14 surface contamination surveys. The inventory addresses quantities of radioactive materials as to  
15 their physical and chemical forms, uses, and dispositions, including radioactive decay. These  
16 requirements are stated in 10 CFR Part 20 and as license conditions stipulated in each license.  
17 Accordingly, the radiological status and locations of materials, before being designated for  
18 release, fall under the full control of the radiation safety program of each licensee. As a result, no  
19 additional mitigation measures are anticipated as a result of implementing any of the alternatives.  
20 The implementation of the rule will be monitored through inspections, similar to those for  
21 releases to sewers.

### 22 **3.12 COMPARISON OF PREDICTED ENVIRONMENTAL IMPACTS**

23 NEPA regulations require a comparison of the environmental impacts of the alternatives, in order  
24 to define the issues and provide a clear basis for choice among the alternatives. This section  
25 presents a comparison of the environmental impacts of the alternatives described in Section 2.4  
26 of this Draft GEIS, based on information and analysis presented in Chapter 3, Affected  
27 Environment and Environmental Consequences. Table 2-1 provides a summary of the impacts.

28 Some environmental issues are not analyzed in detail in this Draft GEIS because NRC does not  
29 anticipate activities that could have the potential to impact these environmental resources. These  
30 environmental resources and issues include soils, noise, ecological resources, socioeconomics,  
31 historic and cultural resources, environmental justice, visual and scenic resources, and land use.  
32 In the event that there are site-specific construction activities associated with the disposition of  
33 solid material, any such activities would be subject to site-specific NEPA analysis conducted on  
34 a case-by-case basis.

#### 35 **3.12.1 Human Health and Safety**

36 The radiological effects to the General Public, Non-Licensed Facility Workers, and Licensed  
37 Facility Workers are assessed in this Draft GEIS in terms of collective dose, in units of person-  
38 rem. Even using the highest dose option (10 mrem/year), the effects of exposure on all three  
39  
40

categories of exposed groups would be small when compared with background exposure coming from other sources (Appendix E). However, there is a variation between alternatives.

Table 3-29 presents a summary of the collective dose results discussed in Section 3.2. For the Unrestricted Release Alternative, the dose option chosen for the comparison is the IAEA Safety Guide RS-G-1.7, which is also part of the Limited Dispositions Alternative. For Licensed Facility Workers, the collective doses associated with all of the alternatives are similar, except that for the LLW Disposal Alternative the collective dose is lower because there is no decontamination of the solid materials.

**Table 3-29 Summary of Collective Dose Results (person-rem)**

Alternative	Collective Dose	
	Licensed Workers	Non-Licensed Facility Workers and General Public
No Action	631	3,996
Unrestricted Release	631	3,429
EPA/State-Regulated Disposal without Trash Incineration	631	2
EPA/State-Regulated Disposal with Trash Incineration	631	1,011
LLW Disposal	323	-
Limited Dispositions	631	112

For Non-Licensed Facility Workers and the General Public, the highest collective doses are for the No Action and Unrestricted Release Alternatives because for these alternatives the collective dose is dominated by exposure of the General Public to products made from recycled ferrous metal. The lowest collective dose to Non-Licensed Facility Workers and the General Public is for the EPA/State-Regulated Disposal Alternative without incineration. Collective dose was not calculated for the LLW Disposal Alternative for Non-Licensed Facility Workers and the General Public, but is assumed to be low, similar to the collective dose for the EPA/State-Regulated Disposal Alternative. The collective dose for the Limited Dispositions Alternative is smaller than for the No Action and Unrestricted Release Alternatives.

**3.12.2 Transportation**

Transportation effects are measured in this Draft GEIS in terms of fatal vehicle accidents and railcar incidents (e.g., derailments). These effects are based on statistical information on non-radiological accidents. The effects are highest for the LLW Disposal Alternative, with an estimated 32 fatal accidents over the 250 year period of the analysis if the material is transported by truck, or approximately 7 accidents if it is transported by rail (Table 3-16). This results from the fact that the analysis for the LLW Disposal Alternative assumes that all materials must be transported to a single LLW disposal site in Utah, which is an average trip of 1,544 miles. Transport distances associated with all the other alternatives are significantly shorter, resulting in

1 significantly lower transportation effects. The number of fatal accidents under the No Action  
2 Alternative is estimated at 11, which is about double the effect associated with the Unrestricted  
3 Release Alternative at 1 mrem/yr. For the EPA/State-Regulated Disposal Alternative, the effect  
4 would be even lower due to the large number of Subtitle D landfills located throughout the  
5 country resulting in short transportation distances, typically less than 100 miles. For the Limited  
6 Dispositions Alternative, there are approximately 9 fatalities.

### 7 8 **3.12.3 Water Quality**

9  
10 As discussed in Section 3.4, impacts to water quality are expected to be small because  
11 compliance with EPA and State permits would preclude significant impacts. Water quality  
12 effects are primarily associated with point source and area source water discharges from the  
13 storage, handling, and processing of solid materials. For the No Action and Unrestricted Release  
14 Alternatives, the effects are generated mostly by runoff discharges from rubblization of concrete  
15 and runoff and process wastewater discharges from recycling of ferrous metal. The incremental  
16 quantity of these discharges generated would be small as compared to the overall amount of  
17 discharges generated from the total amount of concrete and ferrous metal being recycled annually  
18 in the U.S., and the impact on water quality would be equally small. Similarly, the quantity of  
19 additional leachate and potential effects on ground water associated with disposal of solid  
20 materials under the EPA/State-Regulated Disposal Alternative and the LLW Disposal Alternative  
21 would be small compared with the overall amount of leachate being generated annually by these  
22 facilities. Therefore the overall effects on water quality associated with all of the alternatives  
23 would be small when compared with other sources of discharges.

### 24 25 **3.12.4 Air Quality**

26  
27 Air quality effects are primarily associated with mobile source emissions from transportation of  
28 solid materials to recycling and disposal facilities, fugitive dust emissions from rubblization of  
29 concrete, process emissions from recycling of ferrous metal, and emissions from the incineration  
30 of trash (Section 3.5). The effects on air quality would be greatest for the EPA/State-Regulated  
31 Disposal Alternative trash incineration variation. The air quality effects associated with all other  
32 alternatives would be negligible. However, the overall effects on air quality associated with all  
33 of the alternatives are small when compared with other sources of emissions (Table 3-23).

### 34 35 **3.12.5 Waste Management**

36  
37 The resource being evaluated for waste management is disposal capacity. The EPA/State-  
38 regulated disposal facilities considered were RCRA Subtitle D landfills. The analysis in Section  
39 3.7 demonstrates that the existing capacity of Subtitle D landfills would be adequate for the  
40 disposal of all of the potentially clearable materials that could be released under any of the  
41 alternatives.

42  
43 Section 3.7 also discusses the analysis of disposal capacity at LLW disposal sites for all the  
44 alternatives. A summary of the LLW disposal capacity analysis is shown in Table 3-30. For the  
45 Unrestricted Release and EPA/State Regulated Disposal Alternatives, the dose option chosen for  
46 the comparison is IAEA Safety Guide RS-G-1.7, which is also part of the Limited Dispositions

Alternative. For small impacts, there is currently sufficient LLW disposal capacity and the need to expand existing LLW storage is small. For moderate impacts, there is currently insufficient LLW disposal capacity and expansion of existing LLW storage capacity would be needed. For large impacts, the amount of additional LLW disposal capacity needed is of such a magnitude that this impact should be avoided.

**Table 3-30 Summary of LLW Disposal Capacity Analysis**

Alternative	Percent of Estimated Remaining LLW Disposal Capacity	
	Hanford, Barnwell and Envirocare	Envirocare Only
No Action	22	84
Unrestricted Release	4 <sup>1</sup>	15
EPA/State-Regulated Disposal	3 <sup>1</sup>	11
LLW Disposal	112	426
Limited Dispositions	4	15

<sup>1</sup> Percentage presented is based on the 1 mrem/yr dose option. See Table 3-28.

The effects associated with the LLW Disposal Alternative are considered large. Under this alternative, the amount of solid material projected to be disposed of in the Envirocare LLW facility totals more than four times the existing capacity of the facility under its current State licenses and permits. Under the No Action Alternative, the amount of solid material that would be sent to the Envirocare LLW disposal site is approximately 84 percent of the existing capacity of the site; this is considered a moderate impact. For the other Alternatives, the impacts are small. Under the Unrestricted Release and Limited Dispositions Alternatives the amount of potentially clearable solid material that would be disposed of at the Envirocare LLW disposal site, would total approximately 15 percent of the existing LLW disposal capacity of the Envirocare facility for the 1 mrem/year dose option. Similarly, for the EPA/State-Regulated Disposal Alternative, the amount of potentially clearable solid material that would not be disposed in an EPA/State-regulated landfill, but would be disposed at the Envirocare LLW disposal site, would correspond to approximately 11 percent of the existing LLW disposal capacity of the Envirocare facility.

### 3.12.6 Cost/Benefit

The cost/benefit analysis is discussed in Chapter 4 and summarized in Table 3-31 for the dose limit of 1 mrem/yr. The No Action Alternative is the baseline and by definition there are no incremental costs or benefits associated with this alternative. Incremental costs for the other alternatives are those costs above the No Action Alternative costs. In Table 3-31 only the most significant attributes are shown. Public and Occupational Health (Routine) includes collective doses to the public and licensed workers and represents less than 0.5 percent of the total incremental benefit or cost of each alternative. Public and Occupational Health (Accident) includes traffic accidents and represents about 1 percent of the total. Industry Operations

1 includes the cost of surveys, disposal fees, and transportation costs and represents about  
 2 99 percent of the total. Environmental considerations include air emissions and reductions in the  
 3 use of virgin materials due to recycling and represent less than 1 percent of the total.  
 4 Transportation and disposal costs are the most significant sub-attributes when considering costs  
 5 and benefits.

6  
 7 **Table 3-31 Summary of Net Incremental Benefit (Cost)**  
 8 **Associated with Major Attributes by Alternative**

Alternative	Benefit (Cost) in Millions of Dollars				Total
	Public and Occupational Health (Routine)	Public and Occupational Health (Accident)	Industry Operations	Environmental Considerations	
No Action	-	-	-	-	-
Unrestricted Release	<1	0	246	1	247
EPA/State-Regulated Disposal	1	0	181	(1)	181
LLW Disposal	1	(13)	(1,378)	(13)	(1,404)
Limited Dispositions	1	0	258	(2)	257

16  
 17 The incremental costs and benefits associated with the various alternatives vary greatly. The  
 18 highest incremental costs are associated with the LLW Disposal Alternative and are estimated to  
 19 exceed \$1.4 billion, primarily from transportation and disposal costs. For the Unrestricted Use  
 20 and EPA/State-Regulated Disposal Alternatives, the incremental costs and benefits are highly  
 21 dependent on the dose option selected. For both, benefits are associated with the 1 mrem/yr and  
 22 10 mrem/yr dose options, but costs are associated with the 0.03 mrem/yr and 0.1 mrem/yr dose  
 23 options due to the fact that under these smaller dose options, smaller amounts of solid material  
 24 are cleared, and larger amounts must be transported and disposed of in LLW disposal sites. For  
 25 the comparison of the Unrestricted Release, EPA/State-Regulated Disposal and Limited  
 26 Disposition Alternatives in Table 3-31, the 1 mrem/yr dose option was chosen. For these three  
 27 alternatives, the total benefits are similar.

1

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## CHAPTER 4 COST-BENEFIT ANALYSIS

### 4.1 INTRODUCTION

This chapter describes the costs and benefits of the alternatives described in Chapter 2. Although a cost-benefit analysis is not a specific NEPA or CEQ requirement, NRC regulations in 10 CFR 51.71(d) specify that “draft environmental impact statements should also include consideration of the economic, technical, and other benefits and costs of the proposed action and alternatives.”

The cost-benefit analysis sets forth the various economic benefits and costs of the alternatives under consideration, including environmental benefits. Benefits and costs are assessed at the national level. The benefits and costs are with respect to the No Action Alternative, which is the baseline. Table 4-3 summarizes the net incremental benefits for each alternative by dose option. Table 4-4 presents a summary of the net incremental benefits for each “attribute” by alternative and dose-option. (Attributes are defined in Section 4.3) Some costs and benefits may be significant but not quantifiable in terms of dollars, as discussed in Section 4.5, and these are not reflected in Tables 4-3 and 4-4. Further details on the cost-benefit analysis are provided in Appendix K.

Based on the currently available data:

- The Limited Dispositions Alternative is expected to result in a net incremental benefit of about \$257 million (present value, 2003\$) (compared to the No Action Alternative).
- The Unrestricted Release Alternative is projected to result in a net incremental *benefit* under the 1 mrem/yr, 10 mrem/yr and IAEA RS-G-1.7 dose options, but to result in a net *cost* at the lower dose option levels.
- The Unrestricted Release Alternative results in a benefits of \$247 million, which is approximately the same as, but slightly lower than the benefit of \$257 million associated with the Limited Dispositions Alternative for the IAEA RS-G-1.7 dose option. This may appear counter intuitive because in the Limited Dispositions Alternative ferrous metals cannot be recycled, resulting in the loss of a revenue stream and the addition of a disposal fee. However, a larger quantity of material can be released in the Limited Dispositions Alternative than in the Unrestricted Release Alternative, resulting in a benefit that offsets those costs.
- The EPA/State-Regulated Disposal Alternative, while less beneficial than the Unrestricted Release Alternative, also would result in a substantial net incremental benefit at the 1 mrem/yr, 10 mrem/yr and IAEA RS-G-1.7 dose options, but would result in a net cost under the lower dose levels. This net benefit arises because under this Alternative a larger quantity of material can be released than in the No Action Alternative. Thus the avoided transport and disposal costs for LLW create a benefit relative to the No Action Alternative, which is offset slightly by the loss of recycling revenues and the cost of EPA/State-regulated disposal.

- The LLW Disposal Alternative would result in a substantial net cost of about \$1.4 billion.

## 4.2 SCOPE OF COST-BENEFIT ANALYSIS

Ideally, the cost-benefit analysis should analyze each of the following five rule alternatives under consideration:

1. No Action
2. Unrestricted Release
  - ▶ Material-specific limits
  - ▶ Material-independent limits
3. EPA/State-Regulated Disposal
  - ▶ RCRA Subtitle D Landfill Disposal without Incineration
  - ▶ Disposal with Trash Incineration
4. LLW Disposal
5. Limited Dispositions

The five dose options (for the dose-specific alternatives):

- 0.03 mrem/yr;
- 0.1 mrem/yr;
- 1.0 mrem/yr;
- 10.0 mrem/yr; and
- IAEA Safety Guide No. RS-G-1.7.

All facility types:

- Light water reactors (LWRs);
- Independent spent fuel storage installations (ISFSIs);
- Research reactors;
- Facilities included in the site decommissioning management plan (SDMP);
- Fuel cycle facilities; and
- Other materials licensees including, but not limited to medical, academic, industrial, source, and special nuclear licensees.

All affected materials:

- Ferrous Metal;
- Concrete;
- Copper;
- Aluminum;
- Equipment, and
- Trash.

Due to the broad scope of this Draft GEIS and limited data availability, not all facility types and materials could be evaluated for all rule alternatives. Nevertheless, the analysis captures a

1 substantial majority of material and activity (i.e., radioactivity) that could be released, as well as  
2 the resulting dose.

3  
4 **Alternatives/Dose Options Considered**

5  
6 The cost-benefit analysis addresses all of the alternatives under consideration. For the dose-  
7 specific alternatives (Unrestricted Release and EPA/State-Regulated Disposal), all five dose  
8 options are evaluated.

9  
10 **Materials/Facilities Covered**

11  
12 This analysis quantitatively addresses LWRs for ferrous metal, concrete, and trash. LWR copper,  
13 aluminum, and equipment suitable for reuse were analyzed qualitatively, because distributions of  
14 these materials were not available over time for the alternatives analyzed. The analysis focuses  
15 on LWRs because the collective dose for materials generated from licensees other than  
16 commercial reactor facilities is approximately 5 percent or less of the collective dose associated  
17 with materials generated from commercial reactors for both the No Action and Unrestricted  
18 Release Alternatives.

19  
20 **4.3 IDENTIFICATION OF AFFECTED ATTRIBUTES**

21  
22 This section identifies the factors within the public and private sectors that the alternatives are  
23 expected to affect. These factors are classified as "attributes" using the list of potential attributes  
24 provided in Chapter 5 of the *Regulatory Analysis Technical Evaluation Handbook* (NRC 1997b).

- 25  
26 • **Environmental Considerations.** For each alternative, air emissions could be affected by the  
27 number of vehicle miles traveled and/or the relative production of new versus recycled  
28 materials (i.e., ferrous metal, copper, aluminum).  
29
- 30 • **Industry Operation.** Industry may incur operational costs or savings related to surveys,  
31 transportation of either LLW or released material, disposal as either LLW or released  
32 material, and recycling fees or revenues for released material.  
33
- 34 • **Public Health (Routine).** The dose to the public associated with release levels or released  
35 materials may increase or decrease as a result of the alternatives. The dose is monetized  
36 using a value of \$2,000 per person rem.  
37
- 38 • **Occupational Health (Routine).** The dose to workers associated with release levels or  
39 released materials may increase or decrease as a result of the alternatives. The dose is  
40 monetized using a value of \$2,000 per person rem.  
41
- 42 • **Public Health (Accidental).** The number of driver deaths associated with accidents may be  
43 affected by changes in the number of vehicle miles traveled. Deaths are monetized using a  
44 value of \$3 million per death.  
45

- 1 • **Industry Implementation.** One-time costs or savings may result from incremental activities  
2 such as reading the regulations and guidance documents; training employees on new  
3 procedures; capital outlays for equipment; increased recordkeeping if required; and  
4 researching markets and vendors for released material.  
5
- 6 • **NRC Implementation.** The NRC may incur an incremental staff burden to conduct the  
7 following implementation tasks: develop guidance, procedures, and aids for use by NRC;  
8 develop enforcement procedures; and develop guidance, procedures, and aids for use by  
9 licensees.  
10
- 11 • **NRC Operation.** The NRC may incur an annual incremental staff burden to conduct  
12 inspections, evaluate licensee compliance, and conduct enforcement activities.  
13
- 14 • **Other Government.** Other government costs could include costs related to rulemakings in  
15 Agreement States. (This excludes facilities that are assumed to be covered under the  
16 industry operation and industry implementation attributes, such as DOE and DoD facilities.)  
17

18 In addition to the above, two attributes are evaluated on an entirely qualitative basis:

- 19
- 20 • **Regulatory Efficiency.** The alternatives will result in benefits associated with the  
21 streamlining of procedures compared with baseline (current) procedures.  
22
- 23 • **Other Considerations.** Public confidence in NRC may be affected by the outcome of this  
24 action.  
25

26 The following attributes are not expected to be affected:

- 27
- 28 • Occupational Health (Accidental),
- 29 • Offsite Property,
- 30 • Onsite Property,
- 31 • Other Costs to General Public,
- 32 • Improvements in Knowledge,
- 33 • Antitrust Considerations, and
- 34 • Safeguards and Security Considerations.  
35

#### 36 **4.4 ANALYTICAL METHODOLOGY**

37  
38 This section describes the process used to evaluate benefits and costs associated with the  
39 alternatives. The benefits include any desirable changes in affected attributes (e.g., improved  
40 safety, monetary savings) while the costs include any undesirable changes in affected attributes  
41 (e.g., increased radiological exposure, monetary costs).  
42

1 With the two exceptions noted above, the analysis evaluates all attributes quantitatively.<sup>1</sup>  
2 Quantitative analysis requires a baseline characterization of factors such as the number of  
3 affected facilities, the quantities of materials generated, the rate and time over which the  
4 materials are generated, cost information, and a range of other factors. Additional details  
5 regarding the calculations used in the analysis are presented in Appendix K. The appendix also  
6 presents equations for the analysis and input data, including data on unit costs, hourly wage rates,  
7 number of affected facilities, and other information.  
8

#### 9 **4.4.1 Baseline for Analysis**

10  
11 The analysis measures the incremental impacts of each alternative relative to a baseline, which is  
12 how things would be if the alternative were not imposed (i.e., the No Action Alternative). The  
13 baseline used in this analysis assumes full licensee compliance with existing NRC requirements,  
14 including current regulations. This is consistent with the *Regulatory Analysis Guidelines of the*  
15 *U.S. Nuclear Regulatory Commission* which states that, "...in evaluating a new requirement for  
16 existing plants, the staff should assume that all existing NRC and Agreement State requirements  
17 have been implemented" (NRC 2000c). The incremental costs and savings relative to this  
18 baseline are presented in Section 4.5.  
19

#### 20 **4.4.2 Data and Assumptions**

21  
22 As discussed in more detail in Appendix K, this analysis draws on data regarding material  
23 quantities, doses, and survey costs that were developed in the SC&A 2003 and NRC 2004a  
24 reports, prepared under technical basis contracts for NRC. Some additional information was  
25 collected as part of the Draft GEIS and regulatory analysis.  
26

27 The collective dose is based on the time period when each reactor will be decommissioned. For  
28 metals, the modeling is a cumulative total of all source terms and pathways having significance.  
29 Since all of the expected amounts of materials are expected to be generated during the  
30 remediation of power reactors, the analysis considers the time period (47 years) during which  
31 such materials will be generated and 200 years beyond in assessing long-term impacts. The  
32 analysis assumes that the remediation work of all power reactors effectively will be completed by  
33 2050. The time period of the analysis in SC&A 2003 is 250 years, which is the time during  
34 which potentially clearable materials from existing licensees would be released. It should be  
35 noted that because most of the radioactivity is due to radionuclides with half-lives measured in  
36 years (fraction of a year to about 30 years) rather than in thousands of year, the doses and impacts  
37 beyond 250 years become vanishingly small. For the impacts associated with landfill disposals,  
38 the analysis was carried out to 1,000 years. However, in both cases, no specific distinction is  
39 made between the results associated with the 250 or 1000-year analysis given that beyond 250  
40 years collective doses become negligible.  
41

---

<sup>1</sup> A third attribute, environmental considerations, is evaluated partly quantitatively and partly qualitatively. In addition, the analysis addresses certain subsets of material on a qualitative basis (copper and aluminum from LWRs and all materials from research reactors).

The analysis estimates costs based on the actual remaining operating lives of the LWRs. For the analysis as a whole, however, costs and savings are estimated for 47 years, with each year's costs and savings discounted back to the present at a 7 percent discount rate, in accordance with NUREG/BR-0184 (NRC 1997b). The 47 year period encompasses the planned shutdown dates and subsequent decommissioning of all LWRs. Dose is estimated for 100 years, because the dose will not cease at the end of 47 years (SC&A 2003). In fact, dose will continue after 100 years, however, after that point, dose becomes negligible in the cost-benefit analysis. As a sensitivity analysis, the analysis also presents results calculated using a 3 percent discount rate, as called for by NUREG/BR-0184 and the Office of Management and Budget (OMB) Circular A-4 (OMB 2003). Section 4.6 presents the results of this sensitivity analysis.

SC&A 2003 estimates differing quantities of materials that could be released under each dose option and each alternative. In many combinations of alternative and dose option, more material could be released than in the No Action Alternative. Consequently, this shift in the amount of material released has a great impact on the calculated costs, often eclipsing the impacts on costs associated with the shifts in management of the material. Tables K-10 and K-11 in Appendix K show the quantities of materials assumed to be released under each alternative and dose option. By far, the attribute that has the biggest effect on the overall benefits and costs of the rule is industry operation, which includes paperwork costs, survey costs, transportation costs and disposal costs. Section 2.2 of Appendix K describes the major assumptions and unit costs associated with this attribute.

The analysis assumes economic rationality (i.e., least cost behavior) on the part of all entities affected by the rule. For example, under the Unrestricted Release Alternative, in which ferrous metal could be recycled, this analysis assumes that ferrous metal will only be recycled if it is more profitable (or less costly) to recycle steel than to dispose of it. Similarly, the costs associated with a municipal solid waste (MSW) incinerator are greater than those associated with an MSW landfill due to transport and disposal costs. Therefore, this analysis assumes that facilities will not choose to send their trash to an MSW incinerator, even if allowed to do so, and instead will dispose of their trash in a MSW landfill. Consequently, the costs and benefits of EPA/State-regulated trash incineration are the same as the RCRA Subtitle D Landfill Alternative. Table 4-1 summarizes the assumptions made about how materials are managed in the baseline and in each alternative under consideration.

**Table 4-1 Disposition of Released Material under Baseline and Alternatives**

<b>Alternative</b>	<b>Concrete<sup>1</sup></b>	<b>Ferrous Metal</b>	<b>Trash</b>
<b>Baseline/No Action</b>	Recycled	Recycled	MSW Landfill
<b>Unrestricted Release</b>	Recycled	Recycled	MSW Landfill
<b>EPA/State-Regulated Landfill Disposal</b>	MSW Landfill	MSW Landfill	MSW Landfill
<b>LLW Disposal</b>	LLW	LLW	LLW
<b>Limited Dispositions</b>	Recycled	MSW Landfill	MSW Landfill

<sup>1</sup> Concrete would be released at or below the 1 mrem/yr criterion and could be recycled into roadbed material.

MSW = municipal solid waste; LLW = low-level waste.

The analysis also assumes it will not be cost effective to decontaminate and resurvey any material that is not releasable based on the initial survey. Such material is assumed to be sent for disposal at a LLW facility. Additionally, recycling fees and/or revenues from recycling are calculated only for the first recipient of the material (e.g., a scrap yard) because after that point, the material has been released.<sup>2</sup>

Finally, the analysis assumes that future disposal costs will not change. It is possible that new disposal capacity will be required, or required earlier, as a result of some alternatives of this rule. Appendix J presents a capacity analysis addressing this subject. As available disposal capacity is used, or if new disposal facilities are constructed, it is possible that disposal costs will change as a result. To address the uncertainty of LLW disposal cost, which is a major cost driver, this analysis conducts a sensitivity analysis that considers the effect of a 15 percent increase in disposal costs effective in the year 2020 (see Section 4.6).

Inventory information on other metals, besides ferrous metal, indicated these were primarily copper or aluminum, and there is a small amount of these materials generated as compared to ferrous metal. The results of a screening analysis indicated that collective doses for copper and aluminum are about one to two orders of magnitude lower than that of ferrous metals (Section 3.2.4.2.2 and Appendix F, Table F-1). Consequently, these materials were not included in the cost-benefit analysis. Since data on the type and quantity of tools and equipment available for reuse and the frequency at which they are being released were not available, equipment reuse was not included in the cost-benefit analysis, but a scoping assessment of collective doses is presented in Appendix D, Section 12.

#### 4.5 RESULTS

The quantifiable net benefits associated with each of the various alternatives are presented in Table 4-2. Negative benefits (shown in parentheses) reflect net costs, rather than benefits. These

**Table 4-2 Net Incremental Benefit (Cost) Associated with Rule Alternatives by Dose Level (\$2003)**

Dose	No Action	Unrestricted Release Material Specific Limits	Unrestricted Release Material Independent Limits	EPA Landfill	LLW Disposal/ Prohibition	Limited Dispositions
0.03 mrem/yr		(\$1,402,791,183)	(\$1,404,275,647)	(\$1,402,724,765)		
0.1 mrem/yr		(\$226,445,926)	(\$293,721,822)	(\$282,786,154)		
1 mrem/yr		\$294,339,854	\$247,048,219	\$180,994,024		
10 mrem/yr		\$323,222,558	\$306,761,633	\$193,277,348		
IAEA RS-G-1.7			\$246,520,945	\$180,993,217		\$257,201,896
No Action	-					
LLW Disposal					(\$1,404,070,173)	

Notes: Results are calculated as the present value of all quantitatively analyzed attributes calculated over 50 years and discounted at 7 percent. This excludes attributes described qualitatively in Section 4.5 (regulatory efficiency and other considerations).

<sup>2</sup> In contrast, dose is calculated through end users.

1 benefits are broken out by attribute in Table 4-3. Appendix K presents year-by-year  
2 undiscounted costs for each alternative, by dose option and attribute, in Tables K-15 through  
3 K-28. Qualitative results are discussed below.

- 4
- 5 • By definition, there are no benefits or costs associated with the No Action Alternative.
- 6
- 7 • The Unrestricted Release Alternative is expected to result in net incremental benefits under  
8 the 1 mrem/yr, 10 mrem/yr, and IAEA RS-G-1.7 dose options. As shown in Table 4-4, most  
9 of the benefits result from changes in industry operations (i.e., costs and benefits associated  
10 with survey, transportation, and recycling or disposal of material). Public health benefits  
11 arise as there are fewer vehicular accidents. Environmental benefits arise as there are fewer  
12 air emissions due to a decrease in vehicle miles traveled and as a result of favorable  
13 manufacturing tradeoffs as recycled steel replaces virgin steel. (The changes in ferrous metal  
14 scrap due to this rule would be approximately a tenth of a percent of the total U.S. market  
15 and therefore not expected to have any significant disruptions.) Sometimes these benefits are  
16 slightly offset by a cost resulting from a slight increase in dose to the public.
- 17
- 18 • Conversely, under the Unrestricted Release Alternative, at the 0.1 mrem/yr and 0.03 mrem/yr  
19 dose option levels, the analysis projects net costs, because more material fails to clear and,  
20 therefore, must be transported across the country for disposal as low-level waste.
- 21
- 22 • The EPA/State-Regulated Disposal Alternative, while less beneficial than the Unrestricted  
23 Release Alternative also is expected to result in substantial net incremental benefits at the 1  
24 mrem/yr, 10 mrem/yr, and IAEA RS-G-1.7 dose options. In this alternative, benefits result  
25 from changes in industry operation. A small additional benefit results from changes in public  
26 health (routine) because the dose to the public is less than in the baseline. However, some  
27 benefit is offset by environmental costs related to a decrease in recycling.
- 28
- 29 • The LLW Disposal Alternative is projected to result in a net cost of approximately  
30 \$1.4 billion. Most of this cost results from changes in industry operation, including  
31 transportation and disposal of materials as LLW. Other substantial costs result from change  
32 in public health - accidental, as a result of more deaths from the increased transportation  
33 distances. A lower collective dose to the public is the only benefit of this alternative. All of  
34 the other quantifiable attributes contribute to a net cost.
- 35
- 36 • The Limited Dispositions Alternative is expected to result in a net incremental benefit of  
37 about \$260 million. Most of the benefits result from changes in industry operations (i.e.,  
38 benefits associated with survey, transportation, and recycling or disposal of material). Public  
39 health benefits arise from both lower radiological doses and fewer vehicular accidents. There  
40 is a slight environmental cost associated with the loss of otherwise recyclable ferrous metals  
41 being disposed in landfills. Because this material is not recycled, recycled ferrous metal  
42 cannot replace virgin ferrous metal production.
- 43

**Table 4-3 Net Incremental Benefit (Cost) Associated with Attributes by Alternative and Dose Level (\$2003)**

Alternative	Dose option	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations	Total
No Action	NA	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Unrestricted Release Material	0.03	\$1,174,216	(\$13,514,350)	(\$219,720)	(\$1,376,897,891)	(\$3,395)	\$0	(\$451,377)	(\$12,878,667)	(\$1,402,791,183)
Specific Limits	0.1	\$960,746	\$0	(\$219,720)	(\$226,113,873)	(\$3,395)	\$0	(\$451,377)	(\$618,308)	(\$226,445,926)
	1	(\$787,022)	\$0	(\$219,720)	\$293,675,372	(\$3,395)	\$0	(\$451,377)	\$2,125,995	\$294,339,854
	10	(\$8,167,397)	\$0	(\$219,720)	\$329,263,365	(\$3,395)	\$0	(\$451,377)	\$2,801,081	\$323,222,558
Unrestricted Release Material	0.03	\$1,233,593	(\$13,514,350)	(\$219,720)	(\$1,378,418,237)	(\$3,395)	\$0	(\$451,377)	(\$12,902,162)	(\$1,404,275,647)
Independent Limits	0.1	\$1,205,052	\$0	(\$219,720)	(\$291,974,108)	(\$3,395)	\$0	(\$451,377)	(\$2,278,274)	(\$293,721,822)
	1	\$713,415	\$0	(\$219,720)	\$246,021,542	(\$3,395)	\$0	(\$451,377)	\$987,754	\$247,048,219
	10	(\$1,851,424)	\$0	(\$219,720)	\$306,935,439	(\$3,395)	\$0	(\$451,377)	\$2,352,109	\$306,761,633
	RS-G-1.7	\$186,142	\$0	(\$219,720)	\$246,021,542	(\$3,395)	\$0	(\$451,377)	\$987,754	\$246,520,945
EPA/State-Regulated Disposal (Landfill)	0.03	\$1,240,634	(\$13,514,350)	(\$219,720)	(\$1,376,897,891)	(\$3,395)	\$0	(\$451,377)	(\$12,878,667)	(\$1,402,724,765)
	0.1	\$1,240,530	\$0	(\$219,720)	(\$281,093,000)	(\$3,395)	\$0	(\$451,377)	(\$2,259,193)	(\$282,786,154)
	1	\$1,239,881	\$0	(\$219,720)	\$181,462,308	(\$3,395)	\$0	(\$451,377)	(\$1,033,674)	\$180,994,024
	10	\$1,237,267	\$0	(\$219,720)	\$193,637,557	(\$3,395)	\$0	(\$451,377)	(\$922,985)	\$193,277,348
	RS-G-1.7	\$1,239,074	\$0	(\$219,720)	\$181,462,308	(\$3,395)	\$0	(\$451,377)	(\$1,033,674)	\$180,993,217
LLW Disposal/Prohibition	NA	\$1,240,689	(\$13,514,350)	\$0	(\$1,378,439,254)	(\$3,395)	\$0	(\$451,377)	(\$12,902,486)	(\$1,404,070,173)
Limited Dispositions	RS-G-1.7	\$1,227,219	\$0	(\$219,720)	\$258,149,485	(\$3,395)	\$0	(\$451,377)	(\$1,500,316)	\$257,201,896

Notes: Results are calculated as the present value of all quantitatively analyzed attributes calculated over 50 years and discounted at 7 percent. This excludes attributes described qualitatively in Section 4.5 (regulatory efficiency and other considerations).

**Table 4-4 Sensitivity Analysis in Net Incremental Benefit  
Using a 3 Percent Discount Rate (\$2003)**

Dose	No Action	Unrestricted Release Material Specific Limits	Unrestricted Release Material Independent Limits	EPA Landfill	LLW Disposal/ Prohibition	Limited Dispositions
0.03 mrem/yr		(\$3,096,851,438)	(\$3,098,955,560)	(\$3,096,677,677)		
0.1 mrem/yr		(\$503,025,207)	(\$648,746,117)	(\$625,205,528)		
1 mrem/yr		\$646,271,345	\$546,801,706	\$398,563,623		
10 mrem/yr		\$704,293,966	\$677,063,566	\$422,314,544		
IAEA RS-G-1.7			\$545,402,481	\$398,561,911		\$567,379,193
No Action	-					
LLW Disposal					(\$3,098,503,318)	

Notes: Results are calculated as the present value of all quantitatively analyzed attributes calculated over 50 years and discounted at 3 percent. This excludes attributes described qualitatively in Section 4.5 (regulatory efficiency and other considerations).

- For the 0.03 mrem/yr dose options (regardless of the Alternative) it is economically infeasible to survey concrete and ferrous metal. Consequently, these materials are sent to LLW disposal, resulting in costs similar to the LLW Disposal Alternative. Because trash can still be surveyed at this dose level, some trash is sent to EPA landfills, resulting in a slightly lower cost than the LLW disposal alternative.
- Note that OMB considers a rule “economically significant” under Executive Order 12866 if annual effects are greater than \$100 million. The \$1.4 billion cost associated with the LLW Disposal Alternative and the 0.03 dose options of the Unrestricted Release and EPA/State-Regulated Disposal Alternatives are discounted. When these costs are spread over the 47 year time frame of the analysis using a 7 percent discount rate, the annual cost exceeds the \$100 million threshold and thus would qualify as “economically significant.”

**Qualitative Results**

- Regulatory Efficiency - By developing standardized procedures to clear material, there will be increased regulatory efficiency for both NRC and for facilities that are undergoing decommissioning (except under the No Action Alternative). By having clearly defined procedures for clearing materials, facilities will be more certain of the options open to them at decommissioning. At the same time, NRC will have guidance in place that address how material can be released.
- Other Considerations - Public confidence in NRC likely will be affected by this action, regardless of which one of the alternatives NRC adopts. Early public comment indicated that the public is concerned about the safety issues related to radioactive materials. NRC will need to consider public confidence as it proceeds in the decision making process.

**4.6 DISCUSSION OF SENSITIVITY RESULTS**

This analysis utilizes many assumptions to estimate the net costs and benefits of the alternatives. This section presents several sensitivity analyses to determine the impact of several key assumptions.

Table 4-4 presents a sensitivity analysis using a three percent discount rate. Compared to the seven percent discount rate used in the main analysis, all net benefits and costs are roughly twice as high using the three percent discount rate. This reflects the relatively long timeframe (i.e., almost 50 years) in which materials will be affected.

As described in Section 4.4.2, there is uncertainty about future LLW disposal costs. Table 4-5 presents the results of a sensitivity analysis in which LLW disposal costs increase by 15 percent in 2020 to address increases in cost associated with the need for additional LLW disposal capacity. These results are not significantly different from the results of the main analysis. For example, for the Limited Dispositions Alternative, the change in disposal costs results in about a five percent *increase* in the overall benefit. The benefits increase because more material is sent to LLW Disposal in the baseline than in the alternative. In the LLW Disposal alternative, the change results in about a four percent *decrease* in overall benefit. The benefits decrease because more material is sent to LLW disposal in this alternative than in the baseline, resulting in a higher cost.

**Table 4-5 Sensitivity Analysis in Net Incremental Benefit Assuming a 15 Percent Increase in LLW Disposal Costs in 2020**

Dose	No Action	Unrestricted Release Material Specific Limits	Unrestricted Release Material Independent Limits	EPA Landfill	LLW Disposal/ Prohibition	Limited Dispositions
0.03 mrem/yr		(\$1,467,655,460)	(\$1,469,165,029)	(\$1,467,589,042)		
0.1 mrem/yr		(\$223,501,643)	(\$293,222,556)	(\$276,935,787)		
1 mrem/yr		\$307,248,543	\$258,283,611	\$194,858,206		
10 mrem/yr		\$337,467,478	\$320,393,318	\$207,587,058		
IAEA RS-G-1.7			\$257,756,338	\$194,857,399		\$270,719,576
No Action	-					
LLW Disposal					(\$1,468,959,903)	

Notes: Results are calculated as the present value of all quantitatively analyzed attributes calculated over 50 years and discounted at 3 percent. This excludes attributes described qualitatively in Section 4.5 (regulatory efficiency and other considerations).

A third sensitivity analysis was performed to assess the impact of transportation costs on the overall benefits and costs of the alternatives. In the main analysis all material was assumed to be shipped by truck. However, given the long distances that are involved in transporting material to LLW disposal facilities (1,544 miles on average), a sensitivity analysis was run in which all material being shipped to LLW facilities was shipped by rail. Table 4-6 presents the results of this analysis. Use of rail lowers the cost of this rule by about 40 percent for the LLW Disposal

**Table 4-6 Sensitivity Analysis in Net Incremental Benefit (Cost) Assuming Transport of Material Destined for LLW Disposal by Rail (\$2003)**

Dose	No Action	Unrestricted Release Material Specific Limits	Unrestricted Release Material Independent Limits	EPA Landfill	LLW Disposal/ Prohibition	Limited Dispositions
0.03 mrem/yr		(\$883,613,800)	(\$884,334,260)	(\$883,547,382)		
0.1 mrem/yr		(\$242,967,381)	(\$284,430,964)	(\$325,705,793)		
1 mrem/yr		\$195,798,319	\$166,990,577	\$73,595,507		
10 mrem/yr		\$211,169,015	\$203,341,050	\$80,396,722		
IAEA RS-G-1.7			\$166,463,304	\$73,594,700		\$152,405,179
No Action	-					
LLW Disposal					(\$884,118,225)	

Notes: Results are calculated as the present value of all quantitatively analyzed attributes calculated over 50 years and discounted at 3 percent. This excludes attributes described qualitatively in Section 4.5 (regulatory efficiency and other considerations).

Alternative as well as the 0.03 mrem/yr dose option in the Unrestricted Release and EPA/State-Regulated Disposal Alternatives. The benefit of this rule for the Limited Dispositions Alternative, and the 1 mrem/yr and 10 mrem/yr dose options for the Unrestricted Release and EPA/State-Regulated Disposal Alternatives is reduced, because the more expensive truck transport of material to LLW disposal is avoided, reducing overall baseline costs.

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## CHAPTER 5 STAFF ASSESSMENT

Based on the analyses presented in this document, it can be concluded that for all the alternatives there are no significant impacts, except for the LLW Disposal Alternative. For this alternative, there are higher estimated transportation accidents, a large impact on LLW disposal capacity, and a large cost. A summary of the environmental impacts of the alternatives is presented in Section 2.6.

The No Action Alternative (NRC’s current approach) is workable and familiar to licensees. However, there is a lack of an overall risk basis or consistent approach, the measurement bases are outdated, there is no regulation associated with the current approach, licensees have problems using the current approach when dealing with materials day-to-day, and there are expenditures of NRC staff resources on case-specific reviews.

The National Academies report indicates that NRC’s current approach for controlling the disposition of solid materials (the No Action Alternative) is “sufficiently protective of public health that it does not need immediate revamping.” However, the National Academies report also indicates that the current approach is incomplete and inconsistent and that NRC’s approach should be risk-informed. As a result, the National Academies study states that NRC should conduct a process to evaluate alternatives to provide clear risk-informed direction on controlling the disposition of solid materials. This Draft GEIS is part of that process and considers several alternatives which are risk-based rulemakings.

One of the rulemakings considered is the Unrestricted Release Alternative. This alternative would allow solid materials to be released for use in general commerce if a radiation survey verifies that radionuclide concentrations in a dose-based regulation have been met. This alternative satisfies the NRC strategic goal of ensuring protection of public health and safety and the environment. A dose limit of 1 mrem/yr was analyzed for this alternative because it is a small fraction of the public dose limit, the National Academies recommended it in their study, and it is consistent with national and international clearance guidelines. Other dose limits (0.03, 0.1 and 10 mrem/yr) were also considered as options. The lower dose limits were rejected because there are difficulties in surveying at these dose limits (Appendix K) and disposal costs would be higher. Larger amounts of material were released for the 10 mrem/yr dose limit.

Some commenters viewed the Unrestricted Release Alternative as the least expensive option, while still providing adequate protection. They found disposal of all potentially clearable solid materials in a licensed LLW disposal facility is costly to licensees without an accompanying health and safety benefit and would cause a severe economic impact for small licensees (e.g., medical facilities, universities). However, most of the public commenters were concerned that risks associated with unrestricted use of these solid materials are avoidable and involuntary, the risks of radiation are underestimated, there is a potential for exposures to multiple products, and releases would not be accurately measured and tracked. Also commenters from the steel and concrete industries, who would receive the cleared material, indicated that their potential costs could be very large because consumers could choose not to purchase items made from material recycled from licensed facilities.

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2 To answer some of the public's concerns with unrestricted use, we also examined the EPA/State-  
3 Regulated Landfill Disposal Alternative. This alternative considers release of solid materials  
4 only to EPA/State-Regulated RCRA Subtitle D facilities. This approach would prevent solid  
5 material from licensed facilities from entering general commerce, thus limiting the potential for  
6 radiation dose to the general public. Also, limiting disposal of released solid materials to an  
7 EPA/State-Regulated landfill would place a smaller economic burden on licensees than disposal  
8 of all potentially clearable solid materials at a licensed LLW disposal site. (Some potentially  
9 clearable solid material would still go to a LLW facility if it was above the dose limit.)  
10 However, this alternative would allow higher radionuclide concentrations because a greater  
11 amount of activity could be released to landfills than the amount that would be released to  
12 general commerce under the Unrestricted Release Alternative.  
13

14 The next alternative considered was the LLW Disposal Alternative, also referred to as  
15 Prohibition. In this alternative, all potentially clearable solid material would be prohibited from  
16 general commerce. The solid material would be required to be disposed of in a LLW disposal  
17 site. This approach would prevent potentially clearable solid material from licensed facilities  
18 from entering general commerce, thus limiting the potential for public exposure to radiation.  
19 However, if all potentially clearable material (which has no, or very small amounts of,  
20 radioactivity and which has some economic value) is sent to LLW disposal sites, this would be  
21 costly to licensees. Furthermore, there is a large impact on LLW disposal capacity - the solid  
22 materials to be generated from the existing commercial nuclear reactors would represent more  
23 than the existing LLW disposal capacity.  
24

25 After assessing the above alternatives, NRC considered the Limited Dispositions Alternative.  
26 Under this alternative, potentially clearable solid material (concrete, steel and trash) could be  
27 released, if it were below radionuclide concentrations associated with a dose criterion of 1  
28 mrem/yr, but with only certain authorized dispositions to limit the potential for public exposures.  
29 Three pre-authorized dispositions are considered in this alternative - RCRA Subtitle D landfill  
30 disposal, concrete use in road beds, and the reuse of tools and equipment. Any requests to  
31 release material other than the three pre-approved dispositions (for example, soils or industrial  
32 uses such as metals in bridges, sewer lines, or industrial components in a factory) or at higher  
33 radionuclide concentrations would require case-specific approval.  
34

35 To minimize the potential impacts of the unlikely release of solid material into other products,  
36 the radionuclide concentrations considered in this alternative are based on unrestricted release.  
37 The IAEA radionuclide concentrations were chosen to be consistent with national and  
38 international numeric guidelines. Another economic benefit is that potentially clearable solid  
39 materials could be used under certain authorized conditions, rather than using the more costly  
40 licensed LLW disposal facilities. As shown in Table 3-29, the collective dose for this alternative  
41 is lower than for the No Action Alternative because exposures to the public are more limited. To  
42 ensure that the material releases are occurring to the pre-approved dispositions, there would be  
43 licensee recordkeeping and these activities would be evaluated periodically during routine staff  
44 inspections at licensed facilities. Also enforcement action would be taken if necessary.  
45

1 Municipal solid waste operators, EPA and the State agencies have the discretion of allowing or  
2 refusing disposals in Subtitle D facilities. Even if allowed, EPA and the State agencies might  
3 impose additional constraints on such disposals. Accordingly, the implementation of the rule  
4 would have to consider EPA and State agency requirements as well as the concerns of the  
5 landfill operators. It is envisioned that some landfill operators might not want to receive such  
6 materials, but others would, considering economic factors. At this time, however, it is not  
7 possible to determine readily which landfill operators and State agencies might find the NRC  
8 rule an effective option.  
9

10 Most landfills routinely monitor incoming waste shipments for the presence of radioactivity.  
11 The radiation monitoring systems typically are installed at the scales where trucks are weighed  
12 before being sent to specific waste processing areas. The alarm set-points are set at varying  
13 levels, typically at a multiple of ambient background levels. If a waste shipment were to set off  
14 an alarm, the shipment is typically set aside and the originator of the shipment is informed of the  
15 situation. Also, landfill operators may call the State agency responsible for radiation protection  
16 for guidance on how to proceed. Licensees will have to be aware of monitoring practices for  
17 incoming shipments to landfills or other destinations as part of their business practices, in  
18 addition to complying with the nuclide concentrations in this regulation for release of solid  
19 materials from licensed control.  
20

#### 21 Recommendation 22

23 After considering the costs, benefits, and impacts of all the alternatives, the staff has  
24 preliminarily concluded that the Limited Dispositions Alternative would ensure that doses are  
25 maintained well below levels established to ensure protection of public health and safety and the  
26 environment, has among the lowest costs, and its dose criterion is consistent with international  
27 guidelines. The No Action Alternative (NRC's current approach) sufficiently protects public  
28 health, but there is a need for a risk-informed regulation. Most public commenters were  
29 concerned about the Unrestricted Release Alternative because of the increased potential for  
30 exposures to consumer products. The EPA/State-Regulated Disposal Alternative would limit the  
31 potential for radiation dose to the general public, but the radionuclide concentration limits for  
32 only landfill disposal are higher than for unrestricted release. For the LLW Disposal Alternative,  
33 there are higher estimated transportation accidents, a large impact on LLW disposal capacity,  
34 and a large cost. Thus the Limited Dispositions Alternative is the staff's preliminary  
35 recommendation.  
36



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**APPENDIX A  
SCOPING SUMMARY REPORT**

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# **SCOPING SUMMARY REPORT**

**Controlling the Disposition of Solid Materials**

**March 2004**



U.S. Nuclear Regulatory Commission  
Rockville, MD

## 1. INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) staff is preparing a generic environmental impact statement (GEIS) on the proposed rulemaking on controlling the disposition of solid materials. This rulemaking concerns materials at NRC-licensed facilities that have very low amounts of, or no, radioactivity. The purpose of the rulemaking is to continue to assure the control of the disposition of solid materials in a manner that protects public health and safety and the environment while improving efficiency in regulation. This GEIS is part of the NRC staff's decision-making process.

The NRC, the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE) and the States have an interest in the proposed rulemaking and have agreed to participate as cooperating agencies. EPA sets radiation protection standards in the general environment. DOE is preparing a Programmatic EIS on alternatives for disposition of DOE scrap metals at their facilities. Also, the proposed NRC rulemaking could result in related rulemakings in the Agreement States and Suggested State Regulations; the Conference of Radiation Control Program Directors (CRCPD) and the Organization of Agreement States (OAS) have identified the State of Massachusetts as the State representative in the preparation of the GEIS.

The NRC's regulations in 10 CFR Part 51 contain requirements for conducting a scoping process prior to preparation of an EIS. As part of the NRC staff's examination of its approach for control of solid materials, including the scope of an environmental impact statement, the NRC staff sought early input on the major issues associated with this effort. In June 1999, the NRC staff published an Issues Paper (64 FR 35090) for public comment that described issues and alternatives related to the release of solid materials. To provide further opportunity for public input, the NRC staff held a series of four public meetings during the fall of 1999. The NRC staff received over 800 public comment letters and emails from stakeholders representing the metals, metal scrap, and concrete industries; citizens groups; licensees and licensee organizations; landfill operators; Federal and State agencies; and Tribal governments. Comments were also received from stakeholders at the four public meetings. Comments were sharply diverse in the views expressed, and there was support and rationale provided by commenters for a range of alternatives for controlling the disposition of solid materials. On March 23, 2000, the NRC staff provided the Commission with a paper (SECY-00-0070) on the diversity of views expressed in public comments received on the Issues Paper. Attachment 2 of SECY-00-0070 provides a summary of views and comments received; summaries of the comments can also be viewed in NUREG/CR-6682, "Summary and Categorization of Public Comments on the Control of Solid Materials" (September 2000). SECY-00-0070 also provided the status of the staff's technical analyses being developed as support for making decisions in this area and noted the related actions of international and national organizations and agencies that could be factors in the NRC staff's decision-making.

To solicit additional input, the Commission held a public meeting on May 9, 2000, at which stakeholder groups presented their views and discussed alternatives for controlling the disposition of solid materials. On August 18, 2000, the Commission decided to defer a final decision on whether to proceed with rulemaking and directed the staff to request that the National Academies conduct a study of alternatives for controlling the disposition of solid

materials. The Commission also directed the staff to continue to develop technical information and to stay informed of international and U.S. agency activities in this area. The National Academies study of alternatives for controlling the disposition of solid materials was initiated in August 2000. As part of the study, the National Academies held three information gathering meetings in January, March, and June of 2001, at which it obtained input from various stakeholder groups similar to those that presented information to the NRC staff earlier. Based on these meetings, and on its deliberations on this topic, the National Academies submitted a report to the NRC in March 2002 ("The Disposition Dilemma - Controlling the Release of Solid Materials from Nuclear Regulatory Commission-licensed Facilities"). The report contains nine recommendations on the decision-making process, potential approaches for controlling the disposition of solid materials, and additional technical information needed. One finding of particular note in the National Academies report was that NRC's current approach for controlling the disposition of solid materials protects public health and does not need immediate revamping. However, the National Academies report also states that NRC's current approach is incomplete and inconsistent and concludes that the NRC staff should therefore conduct a process to evaluate a broad range of alternatives to provide clear risk-informed direction on controlling the disposition of solid materials. The report notes that broad stakeholder involvement and participation in the NRC staff's decision-making process on the alternatives is critical as the process moves forward. A summary of the National Academies report can be found in an NRC staff paper, SECY-02-0133, and a link to the National Academies report, itself, is contained in the Background section of the NRC's web page on Controlling the Disposition of Solid Materials (<http://www.nrc.gov/materials.html>; click on "Controlling the Disposition of Solid Materials" under "Key Issues").

As an additional part of its continuing efforts to solicit stakeholder involvement, the NRC staff published on February 28, 2003, a Request for Comments on the scope of a proposed rulemaking and notice of workshop in the Federal Register (68 FR 9595). In this Federal Register Notice, the NRC staff sought stakeholder participation and involvement in identifying alternatives and their environmental impacts that should be considered as part of a rulemaking and analyzed in a GEIS. The NRC staff also announced in this Federal Register Notice its intent to conduct a workshop to solicit new input with a focus on the feasibility of alternatives that would limit where solid materials could be released. The workshop was held at NRC Headquarters in Rockville, MD May 21-22, 2003. A summary of the results of this workshop is available on NRC's web page on Controlling the Disposition of Solid Materials.

Over 2,600 public comment letters and emails were received in addition to the discussion at the workshop. NUREG/CR-6682 Supplement 1 ("Summary and Categorization of Public Comments on Controlling the Disposition of Solid Materials," March 2004) summarizes the comments received as a result of the NRC staff's request for comment and the workshop discussion. Comments were received from various stakeholder groups, including environmental and citizen's groups, members of the general public, scrap and recycling companies, steel and cement manufacturers, hazardous and solid waste management facilities, the U.S. Environmental Protection Agency (EPA), U.S. Department of Energy (DOE), State agencies, Tribal Governments, scientific organizations, international organizations, and NRC licensees and licensee organizations.

The 1999 and 2003 public comments are summarized in Section 2 of this report. All comments received to date have been considered. The comments have been categorized to ease reader understanding of the issues raised.

The scoping process helped to determine the scope of the GEIS, including significant issues to be analyzed in depth. For example, in response to comments received during the scoping process, the GEIS will include an alternative where the potentially clearable material can only be disposed of in a licensed low-level waste (LLW) disposal facility. Issues outside the scope of the DGEIS have been forwarded to appropriate staff and may be discussed in other parts of the rulemaking package.

Section 3 identifies the issues the GEIS will address, and Section 4 identifies those issues that are not within the scope of the GEIS. Although issues raised during the scoping period will be considered in the preparation of the Draft GEIS, some of those issues will either be analyzed in less detail or will not be analyzed at all, depending on their relevance to the proposed action and the anticipated impacts. Issues that will be considered, but not analyzed in detail, are addressed in Section 4.

## 2. SCOPING COMMENT SUMMARY

### 2.1 INTRODUCTION

The comments were extensive and wide-ranging, focusing on specific alternatives and technical issues that should be considered as part of NRC's rulemaking process. In addition, there were numerous comments related to potential impacts on public health and safety as well as on various industries.

Some commenters indicated that there is a significant need to establish a national standard for the release of solid materials, citing a lack of consistency in criteria and problems with implementation under the current system. Others, however, believe that the current system is both protective and easily implementable. These groups cite reports by national and international standards setting bodies that indicate that health risks at dose levels being considered are negligible or trivial. Some commenters suggested that NRC adopt the American National Standards Institute (ANSI) standard N13.12-1999, Surface and Volume Radioactivity Standards for Clearance.

Many commenters stated that there should be no release of solid materials from licensed facilities even if the calculated dose or health risks are low. In particular, potential recipients of solid material, such as scrap, metals, and cement industry representatives, objected to the release of solid materials. These commenters noted that there could be significant negative economic impacts on their industries if consumers had concerns over the presence of radioactivity in products. A large number of citizen groups and members of the public also expressed concern about the health effects of the potential presence of released material in consumer products and recommended that NRC prohibit the release of this material to isolate it from the public. Some of these commenters further suggested that NRC should implement a program to identify and recover all materials previously released under the current regulation.

Commenters also described concerns with a restricted use alternative, citing possible oversight and enforceability issues. A number of commenters discussed the possible alternative of disposal in either EPA-regulated or NRC/Agreement State-licensed disposal facilities. Most commenters believe that disposal in an NRC/Agreement State-licensed disposal facility is the most appropriate alternative.

A number of commenters provided input on the National Environmental Policy Act (NEPA) process which governs the development of the Generic Environmental Impact Statement. Still more commenters weighed in on NRC's rulemaking process.

### 2.2 NO ACTION/CURRENT APPROACH

#### *Advantages of Current Approach*

**Protective:** The current approach protects public health and safety; released materials are monitored; no one has been placed at risk from release of materials; the National Academies report concluded that it protects public health.

**Current approach is useful:** It has been a useful tool for 20 years; there is common understanding on how to use it; it is easier to implement than a dose-based approach because exposure pathways do not have to be calculated; the National Academies report concluded that it is workable.

### ***Disadvantages of Current Approach***

**Criteria not risk-based:** They are currently based on instrument detection capabilities and concentrations in effect since 1974; the NAS report notes that the criteria are not explicitly risk-based.

**Not a good regulatory framework:** The current approach does not provide an adequate or logical regulatory framework, and does not provide clear guidance.

**Not cost-effective and a waste of resources:** The current approach can cause substantial additional cost and resources, especially at decommissioning, and may cause replication of effort from previous submittals. Without clear guidance some material is currently disposed of as radioactive waste even though there is not enough radioactive material to cause an exposure. This is an inappropriate use of resources.

**Implementation is inconsistent:** There can be fluctuations in background, different geometries and nuclides, differences in instrumentation approaches and efficiencies, analytic techniques, and inconsistencies in use of the “non-detectable” guideline. It is slow, resource intensive, can be difficult to implement, and can cause questions. This is also noted in the NAS report.

**Volumetric contamination not considered:** Volumetric contamination is not considered; this is also noted in the NAS report.

**Decision criteria needed:** Materials need to be released from facilities each day (and more material will be available for release in the future because of decommissioning) and improved decision criteria are needed about what should be done with these materials.

**Current standard can be redundant:** It can entail redundancy of oversight between the NRC and State agencies.

**Cumulative Impacts:** Cumulative impacts are not considered.

### ***General Opposition to the Current Approach***

**No records:** There is concern that NRC allows release (and possible recycle) of solid material based on case-by-case considerations under Regulatory Guide 1.86. There is also concern that people had been exposed without their knowledge and whether there are records of material released so far. Any releases should be tracked and records kept available to the public.

**Not safe:** The current approach is unsafe, and unacceptable to the metals industry and the public. There are no scientific data or proof available to show that what has been released so far using Regulatory Guide 1.86 levels has not harmed the public. This approach should cease.

**Warning labels:** There must be warning labels at a minimum so these products could be avoided.

**Outdated:** Regulatory Guide 1.86 is out of date and should not be updated or used because it lacks the full force and legitimacy of a final rule done under the Administrative Procedures Act (APA).

**Being misused:** Regulatory Guide 1.86 was developed based on criteria for decontamination of buildings and not for releasing materials involving intimate public contact. Regulatory Guide 1.86 should not be misused to allow releases into the marketplace or converted to dose basis.

**Do not use:** Regulatory Guide 1.86 should be removed from licenses so that licensees cannot release radioactive wastes into garbage for landfills or the marketplace.

## **2.3 DOSE-BASED REGULATION ON UNRESTRICTED USE**

In general, comments on the dose-based regulation on unrestricted use alternative can best be characterized by stakeholder grouping. Therefore the comments in this section are presented by stakeholder group.

### **2.3.1 Citizen Groups and General Public**

#### ***Unrestricted Release of Contaminated Materials***

**General opposition:** Several commenters generally indicated that they were opposed to releasing materials for unrestricted release.

#### ***Health/Risk Considerations***

**NRC performance goal:** NRC should do its job and abide by its own performance goal of protecting public health and safety for both present and future generations by preventing exposures to unjustified practices; NRC should not shift its responsibility to reducing the burden on industry.

**Precautionary principle:** Based on uncertainties of risk, and unexpected outcomes, the prudent course of action would be to bar distribution of radioactive materials into the public domain.

**Psychological impacts:** NRC should consider impacts on citizens and their confidence; radiation in products will contribute to pessimism about our culture and economic system.

**Cannot reverse releases:** As more is learned about the risks of low-level radiation (e.g., bystander effect), we will not be able to reverse the effects of materials already released.

**Mixing materials:** Large amounts of material will be released and more highly contaminated material will be mixed with this material to ensure compliance with any established standard.

**Other organisms:** Release of this material will increase background levels in the environment and will be bad for the environment; additional analysis and supporting evidence regarding how other organisms are being protected is required.

**No safe dose of radiation:** Low levels of radiation cannot be proven as trivial, and we do not know specific health effects at low doses of radiation. Low levels of radiation can have long term health effects and can sometimes be more harmful per unit of exposure than higher levels of radiation. Every additional exposure, no matter how small, increases the chances for, and numbers of, cancer.

**NRC studies biased:** The studies NRC depends on are biased and not publicly acceptable (e.g., International Commission on Radiological Protection (ICRP) studies). The 2003 Recommendations of the European Commission on Radiological Risk (ECRR) address health effects of low dose radiation and document criticism of the 1988 ICRP low dose models and failures of the Hiroshima study to predict consequences of exposure; this document indicates health risks are 100 times greater than predicted by current radiation limits.

**Other studies cited:** Other studies of health effects of low level radiation were noted which show that there is no safe dose of radiation below which no damage results and have confirmed ways that radiation alters cells. These studies should be considered by NRC; they have been ignored to date. These studies include: (a) indications of effects from depleted uranium in weapons; (b) medical studies that show that radiation is riskier than previously assumed; (c) the book "No Immediate Danger" by Rosalie Bertell documents that there is no safe level of radiation and predicted the increase in certain health effects that we have now (and also "Uncertain Science and Failure of Trust"); (d) studies by Gofman and others conclude that all radioactive contamination is cumulative; (e) those by independent scientists, including Dr. Alice Stewart, Morgenstern, Kadheim, Bulakova, Wing, Feuerhake, Wright, Viel, and the BEIR V Committee; (f) studies of Japanese atomic survivors bear out that radioactivity released slowly over time is more dangerous than a quick high dose; (g) J. Kahn article in NY Times (6/17/03) on lung damage to Chinese workers; and (h) cancer incidence rates are rising, especially at sites with radioactive contamination.

**Long-term risks:** These risks are long term risks and it is not known what the risk would be to future generations, including genetic and reproductive capabilities.

**Linear No Threshold (LNT) model:** NRC has acknowledged the validity of the LNT model of human exposure which holds that any increase in dose, no matter how small results in an increase in risk. Therefore, the NRC's mission to ensure adequate protection of public health and safety must restrict all radioactive material from general commerce and require disposal in a licensed LLW disposal facility.

**Sensitive populations:** Some populations have higher sensitivities to radiation and must be protected, even if their dose is less than the critical group.

**Dose from man-made nuclides:** The risk from man-made nuclides is not comparable to that from naturally occurring ones because internal doses (which can occur from recycled products) can be more damaging than external ones; also, man-made nuclides bond to DNA and certain human organs in ways that naturally occurring ones, to which life on earth has adapted, do not.

**Unwanted risks:** The risks being considered here expose the public without their consent and are unwanted, avoidable, involuntary, and unnecessary (unlike the dose a person gets from medical treatments), even if they are small, especially since the practices are unjustified.

**Cannot accurately predict doses:** Computer models cannot accurately predict all doses to the public (especially when considering the different nuclide behaviors and half-lives and associated risks in the environment and in humans). Doses cannot be measured, and thus projections of reasonable/acceptable risks are meaningless. Also, doses may be higher than estimated because some mills may receive a higher amount of metal from licensees than estimated in NRC's technical analyses. There may be unexpected outcomes and untraceable impacts. RESRAD is not reliable. Not all isotopes present are considered. Validation with data from actual releases should be done. The total quantity of material to be released in commercial products is uncertain and therefore it is unclear how NRC can reasonably evaluate health impacts, including the ability to determine how much is in the environment at any time. Analyses will not be able to determine the total dose, non-fatal cancers, reduced immunities to other health problems, non-cancer health effects, cumulative effects, impacts from multiple exposures, or effects to children or adults working with the materials.

**Worker risks:** Releases of solid materials will expose workers at steel mills, scrap metal facilities, road construction, sewer workers, etc. to potentially significant levels of contamination; they should not be exposed to any additional risk levels. Steel workers are an unprotected workforce from this hazard and are not routinely monitored for radioactive contamination, do not receive hazardous duty pay or long term medical monitoring, and might have to choose between their job security and radiation exposure.

**Risk too high:** The risk of exposure to 1 mrem/yr is that 1 of every 28,600 exposed will have a fatal cancer; these risks are too high, especially when projected over the U.S. population.

**Do not add to background:** The fact that we receive a dose from background does not justify adding more dose even if it is less than background; no dose above background is acceptable.

**Synergistic effects:** We do not know, and analyses will not be able to determine, synergistic interrelationships between dose and other hazardous impacts.

**Other standards:** The fact that there are air and liquid emission standards does not justify allowing more releases of solids into consumer products.

**Current practice is no justification for release:** The fact that material is released now is not a justification for releasing more material.

### ***Consumer Products/Isolation***

**Unnecessary risk:** Introduction of radioactive waste materials into consumer products (in particular products in the home, in home construction or in roadways, or playgrounds) poses unnecessary risks to workers and the public and the potential for multiple exposures.

**No direct benefit:** There are no direct benefits from releasing materials to the public.

**Consumers would be unknowing:** Labels would be needed to identify products made from released material, otherwise people would be exposed without any warning; There would probably not be any labels on the consumer products so there would be no way for consumers to know what dose they are getting.

**Right-to-know and choose:** The individual should have the right to choose the risk to which they are exposed.

### ***Cost-benefit and Liability Considerations***

**No societal benefit:** It should not be assumed that operation and decommissioning of reactors are socially justified nor that the releases are therefore justified. People get no direct personal benefit from the releases.

**Rule aids industry at public expense:** A rule is just an economic aid to the nuclear industry. Reducing costs of compliance to licensees should not be one of NRC's major considerations on this matter. Saving licensees money on waste disposal (for a relatively small amount of material) comes at too high a price, i.e., human health and socioeconomic costs. Most Americans do not have adequate health insurance to deal with the consequences of increased unnecessary radiation exposures. Those generating material should pay for disposal of it as part of the cost of doing business; NRC should protect the public instead.

**Do not transfer problem:** NRC should not transfer its problem of what to do with this material by passing the problem to scrap dealers and steel manufacturers, which could put them at legal and financial risk; consumers would avoid products made from recycled metals, resulting in more resources being expended to make products with virgin uncontaminated ores.

**Burden:** The burden of calculating releases would be reduced if material is simply not released.

**Liability:** There would not be any clear liability as to who is responsible for materials released once they have gotten into the public sector.

### ***Tracking Released Materials***

**Cannot measure doses:** Dose-based release standards cannot be physically measured, verified, or enforced, and each consumer product cannot be monitored. Thus, releases cannot be tracked and consumers will not know their dose from recycled products. So, even though NRC says the dose limit is only 1 mrem/yr, how can this be trusted when it cannot be verified?

**Public will not know dose:** A person would have no way of knowing what products contain radioactive material. There should be labels on any products made so that consumers can know what dose they are getting and can control it.

**Need for safeguards/no detectable radiation:** NRC should not allow releases that are not tested or safeguarded and should not allow detectable materials to be released.

**Security issues:** There should not be additional releases in this time of increased security concerns; radioactive materials released from licensed facilities will make it more difficult for efforts by local, State, and Federal agencies to detect dirty bombs. Materials in the nation's scrap could affect Homeland Security technology where road monitors will be reading levels in vehicles.

**Detectors are not reliable:** It is not clear if detectors can reliably survey materials and protect the public - NRC will not be able to measure releases accurately or enforce criteria because field conditions do not fit computer models and monitoring low levels of radiation near background to assure compliance is difficult and uncertain; large pieces of equipment can have complicated geometries (and workers will tend to avoid these areas - uncertainties are several percent for simple geometries and will be even higher for more complex geometries); non-uniform contamination; hot spots in large piles of scrap metal can be missed; equipment can malfunction; there are problems of false negatives; and there are issues of sorting materials.

**Improper releases:** Improper releases and mistakes cannot be avoided, especially when there are large volumes being handled, there is a lack of resources, and there is a need to survey quickly.

**Multiple exposures:** A person could be exposed to many items because once the material is released it will not be controlled.

**Material in environment:** Released material cannot be tracked especially over long time periods which will be an environmental headache for years to come.

**Penalties:** There should be penalties to those releasing material in violation of any standard.

### ***Public Confidence***

**NRC has a goal of increasing public confidence:** NRC should abide by its own safety goal of increasing public confidence by keeping this material out of the public domain.

**NRC's sincerity in protecting public health is questioned:** NRC tries to downplay hazards associated with this material; people are given incorrect information about potential risks from this material. NRC says it is safe but cancers continue to occur.

**Dose assessments are suspect:** Computer codes, and dose and pathway models are not trusted and can be manipulated so that predicted doses meet limits; supporting analyses for this rulemaking were prepared by nuclear advocates.

**Economics may influence technical accuracy:** Workers at licensed facilities cannot be trusted to detect radiation in releases because of carelessness or because it may not be in the best economic interests of the licensee; this could result in substantial amounts of material being released in violation of whatever standard is set.

**Past issues have contributed to mistrust:** Licensees and DOE cannot be trusted because workers have been misled about radiation hazards in the past and because other rules have not always been followed, and because DOE has failed to manage material safely. Thus, it is not clear if a rule in this area would be followed. There is little public trust in DOE. NRC must consider in its rulemaking the limitations of the entities responsible for releasing materials.

**Failure of orphan source program:** NRC has failed on the orphan source problem and there is no reason to believe that more problems would not occur.

**Unreported releases are problematic:** There have been unreported releases at NRC licensed facilities and NRC must fully disclose all metals that have been released and are currently in consumer products.

### **2.3.2 Metals Industry**

#### ***Release of Contaminated Material***

**Radioactively contaminated scrap metal (from impacted or restricted areas) should not be released into the stream of commerce:** The metals manufacturing industry suggests that the definition of radioactive contaminated scrap metal should be that which originates in impacted or restricted areas. Scrap metal is not considered to be radioactively contaminated if it does not originate from restricted or impacted areas, was never in such areas, and can be certified as never having been exposed to radiation. Scrap metal not originating in impacted or restricted areas can be released providing that NRC requires at least one of the following safeguards: (a) where there is clear process knowledge that the scrap metal is not originating from radiological areas and the license certifies that the scrap has not been radioactively contaminated; (b) stringent radiation surveys of the scrap metal shows it does not exceed dose-based clearance standards or background radiation levels for the area from which it is released (whichever is lower), or (c) the scrap metal is manifested, labeled, and tracked.

**Criteria for release should be agreed upon by stakeholders:** The scrap metals industry noted that any new regulation for the release of material that is contaminated at low levels must be based on criteria acceptable to affected stakeholders. Before criteria could be established, stakeholders should review several issues, including: (a) the effect of contamination on employees and equipment; (b) the capability to detect radioactivity in material; (c) potential uses of recycled material acceptable to affected industries and the general public; and (d) the potential to assure that such material could be used only for the purposes acceptable to the affected industries and the general public. There is probably a substantial amount of material at licensed facilities that has never become contaminated with radioactive material. While this material could be recycled, all affected stakeholders would need to agree on a measurable definition and acceptable means for proving and documenting that such material did not become contaminated by radioactive material and that the material did not become mixed with contaminated material at any time prior to release.

## ***Health and Environmental Considerations***

**Worker health risks:** There may be health risks to workers because of radionuclides in the steel mill (including the baghouse dust), even if in small concentrations, that may build up over time; loss of control of orphan sources; and illicit trafficking of materials.

**Public safety risks:** Steel may be used in applications that might not be safe to the public.

**Lack of environmental benefit:** There would be little environmental benefit of recycling of metals from licensed facilities because the amount of such metal is small compared to the total feedstock and the impact would be less than 1 percent per year and would not affect the amount of mining conducted.

## ***Cost-benefit Considerations***

**Property contamination:** There will be increased risk of property contamination at metals companies, including on equipment and in byproducts, and in generation of mixed wastes.

**New regulatory requirements:** If the steel industry has to handle radioactive material, it may also be required to comply with more stringent regulatory requirements governing worker exposure.

**Legal liabilities:** This would increase metals industry liability in potential civil suits.

**Large economic impacts - product de-selection:** There could be a very large economic impact on steel industries because consumers (who are their customers) do not want products because of concerns, even if only perceived, over presence of radiation and will de-select products. Such impacts could include loss of revenue and jobs if customers refuse to buy products made with metals. The resulting impact on the steel industry could be as high as \$600 million even if there was only a 1 percent reduction in purchases.

**Lack of trust:** Recycling of metal from licensed facilities undermines public trust in the safety of consumer products. Perhaps safe levels can be set, however the marketability of products will be set by public perception and it is unlikely that the public will accept products that they use each day containing what will be characterized in the media as “radioactive material.” There is a sense of risk from uncertainty and the public will feel that any risk is not worth it no matter how low a standard is set, and will not trust government to tell them what is safe.

**Business disruption/orphan sources:** The history of problems with loss of control of orphan sources has resulted in significant decontamination costs at steel mills; the presence of additional radioactivity would affect metals companies ability to detect and intercept orphan sealed sources.

**Need to mine virgin ore:** Public perception could influence industry to mine more virgin ore to vouchsafe that metals used in consumer products do not contain radioactive materials.

**Shifting responsibility:** The issue and problem of what to do with this material should not be shifted to the commercial metals industry but rather dealt with at the source by the generators of the material.

**Small economic benefit to recycle:** The amount of recycled steel from NRC-licensed facilities is so small that the economic advantage of recycling it is small and there exists an oversupply of most of these metals (ferrous metals are not likely to be affected although copper and nickel producers could be).

### ***Acceptance Criteria***

**Steel mill detectors:** Detectors are set at low dose rates that will alarm at levels near an NRC standard that might be promulgated (these detection systems are used because of previous problems with orphan sources). Steel and scrap yard detectors are becoming even more sensitive. The metals industry does not have the capability to distinguish the source of the alarm and hence it will reject the entire shipment.

**Rejection of shipments:** The steel industry would likely reject shipments of material released from NRC licensees even if the material is in compliance with an NRC standard.

**Financial liabilities:** The metals industry cannot take the financial liability of allowing radioactive material into their mills and exposing individuals and incurring economic loss.

### **2.3.3 Cement Industry**

#### ***Release of Contaminated Materials***

**General opposition:** There should be no release of materials for unrestricted uses in commerce and be recycled into concrete and other like products.

#### ***Health/Risk Considerations***

**Public health:** Public exposure to products made with concrete is high, including use of concrete in drinking water reservoirs, tanks, and pipes, in residences, schools, and office buildings, and in driveways, sidewalks and train stations. In addition, there can be exposures to concrete masons in the concrete industry.

**No benefit:** Acceptance of radioactive material has no benefit to the cement and concrete industry but only possible endangerment to the industry's workers and customers.

**No extra doses:** Exposures from other solid materials would add to potential radioactive doses from concrete products. Preventing additional exposure to the public from man-made sources in consumer goods is in the best interest of the public and should be NRC's primary activity in carrying out its Congressional mandate to protect public health and safety.

## ***Cost-benefit Considerations***

**Large economic impact - product de-selection:** Any real or perceived public health risks posed by radioactive consumer goods, regardless of how slight the risk is, will not be tolerated by consumers who will be concerned about health effects despite scientific evidence. Consumers will not find the benefits of recycling by release of solid material from NRC licensees into commerce as persuasive reasons to accept the perceived additional exposures. These consumers will decide not to purchase these goods, as they will not wish to live or work in a building containing material recycled from licensees. This will translate into loss of market for the cement industry and threaten viability of the cement industry. The cement industry wants to be able to fully disclose to customers the origin and any radioactivity level and hazard from material - failure to do so will cause fiscal harm to the cement industry.

**Costs for detectors:** Increased potential for the release of radioactive material for reuse in the cement and concrete industry will cause them to incur significant additional expenses for surveillance for incoming radioactive material as well as management of any radioactive materials. Cement companies do not have the instruments and personnel training necessary to do these surveys and the industry would incur significant expenses for purchase of radioactivity monitoring equipment, training for personnel, facility modifications to segregate material, disposal costs for "orphan" radioactive material, liability insurance, and legal costs.

**Shift of economic burden:** A rulemaking will effectively shift the economic burden of disposal of the solid materials from the NRC licensees to the industries that would receive these wastes as recyclable material. This appears unfair considering that the licensees profited from the producing of these wastes.

**Low economic benefit:** The economic value for used concrete used as a fill material for aggregate is very low compared to virgin materials.

**Public issues:** NRC should practice gaining the public's trust on issues where the potential adverse economic effects are limited to its licensees' businesses before attempting a rulemaking that could have adverse economic effects on businesses outside of the licensees.

## ***Potential for Rejection of Material***

**Need for detectors:** Concrete dealers might begin to use detectors for screening because it is likely they will have similar concerns as the steel manufacturers regarding consumer unwillingness to purchase their products if there are concerns about the products containing radioactivity.

## ***Potential Use of Fly Ash***

**Use of fly ash:** The Issues Paper noted that the dose from use of recycled coal ash in concrete block as permitted by EPA can be about 3 percent of natural background (about 10 mrem/yr). One reason fly ash is used in concrete is that in 1983 the EPA issued guidelines requiring purchase of cement containing fly ash in both government and the private sector. The guidelines were a response to a directive from Congress to provide some relief to companies that generate fly ash in coal generated electricity with regard to disposal of this high volume,

low-hazard waste. Indicating at this time that EPA has set a precedent such that the radioactivity levels in fly ash are appropriate seems egregious. It may be that, if the government had made a greater effort on public participation on this issue originally, the public's sensitivity to unnecessary radiation exposure might have prevented this use of fly ash.

### **2.3.4 Licensees, including Universities, Medical facilities, Fuel Cycle Facilities, and Nuclear Power Plants**

#### ***Safe Criteria Can and Should be Set***

**There is a need for a clear dose-based standard:** A dose-based standard is needed for the unrestricted re-use or disposal of solid material. This standard should clearly define a dose level (1 mrem/yr) at which protection of public health and safety is assured without the need for continued regulatory oversight.

**No unrestricted release for direct recycling:** No generic permission for unrestricted release of licensed solid radioactive material for the purpose of direct recycling should be allowed.

**A regulatory framework is needed for recycling:** A regulatory framework for case-by-case consideration of proposals for recycling of materials so as to consider specific details involved and allow request for public notice (i.e., for general uses or for conditional or restricted uses) should be implemented.

**Guidance is needed:** Regulatory guidance should be developed to describe acceptable methods for demonstrating with reasonable assurance that materials released for reuse or disposal are actually directed to those purposes and not diverted to recycling.

**Specific criteria should be established:** Criteria for unrestricted release of solid materials, based on a dose/risk standard that is inherently safe and cost-effective (like 1 mrem/yr), should be developed.

**Adopt the ANSI N13.12 standard:** NRC should adopt ANSI N13.12, which ensures the public will not receive doses in excess of 1 mrem/yr and does not impose unnecessary regulatory burdens.

**There is a need for flexibility in the standard:** Flexibility for special circumstances currently in 10 CFR 20.2002 should be preserved.

#### ***Health/Risk/Environmental Considerations***

**Risks are trivial:** Safe criteria can be set. The doses and risks being considered are very low and scientific bodies such as the National Council on Radiation Protection and Measurements (NCRP) (see NCRP Report No. 116), the ICRP, and EPA indicate that levels around 1 mrem/yr are negligible or trivial in risk considerations; the NAS recommendations provided similar information.

**Risks may be nonexistent:** There is considerable scientific uncertainty as to whether any risks exist at all at these levels; there may be no risk at these levels. Diagnostic medical procedures

give patients between 500 to 1000 mrem without adverse effects; therapeutic procedures give a dose of 10,000 mrem or more without adverse effects. Health effects below 10 mrem are either too small to be observed or are non-existent.

**Small fraction of background:** The doses being considered would be a small fraction of background variations and would be well below doses received in routine activities of life; everyday sources of radiation (such as environmental radiation, home building materials, travel in airplanes, certain foods) contain radiation levels at or above these levels but do not have a social mandate that they be regulated.

**Suggested standards are a fraction of other standards:** The levels suggested are a fraction of other similar standards including EPA's 4 mrem/yr in drinking water; 10 mrem in air; and CERCLA cleanup standards. In addition, NRC currently has standards of 100 mrem/yr as a public protection value, 25 mrem/yr for decommissioning and 5 mrem/yr in airborne effluents.

**Offsets other impacts:** There is an environmental impact of having to replace the material which is thrown away at a LLW site, instead of reusing it in some way.

### ***Cost-benefit Considerations***

**Cost of LLW disposal is significant and unjustified:** Disposing of very low activity material with low potential risk in LLW burial grounds is very costly and imposes unnecessary financial burden on businesses and the economy. The cost impact of having to send very low activity waste to LLW can have a severe economic impact on small businesses, universities, and medical facilities and hospitals that handle and use radioactive materials. Health care will be negatively affected by a rule that is unreasonably stringent.

**Waste of resources:** Disposing of very low activity in LLW sites poses unnecessary burden on precious natural resources (land at an LLW site) which could be used for more beneficial purposes.

**Societal benefits:** There is a benefit that society has realized from productive use of these materials in medicine, research, product development, and power production. Release of low activity materials is part of that cost-balancing equation. There is a societal benefit in reusing the material.

**International issues:** There will be a large negative economic impact on U.S. trade with other countries if the international community establishes criteria and the U.S. does not have a standard or has a much more stringent standard.

**Reduction of burden:** The regulatory burden of the current system would be reduced because a simple standard could be established, compliance could be easily verifiable, and there would be fewer requests for approval of alternative criteria for disposal.

### ***Public Confidence***

**Clear standard would boost public confidence:** A standard would increase public confidence because there would be clear safety criteria.

## ***Suggested Approaches for Unrestricted Use***

**Base on steel mill detectors:** Materials for release should be sent through portals having the same detection levels as steel mills.

**Record-keeping:** There should be complete and careful record-keeping of releases so that the end user knows the identity of the material. Other comments noted that there is not a need to document every item that enters and exits a restricted or radiation controlled area, and if an item is surveyed to well-defined standards then there is not a benefit to document every release.

**Inventory criteria:** Generators should maintain disposition inventories and verify compliance with the yearly limit prior to disposition.

**ANSI N13.12:** Criteria should be set based on ANSI N13.12 which is a national consensus standard addressing the safe release of solid materials. According to the National Technology Transfer Act, NRC is required to use such a technical standard unless it is inconsistent with applicable law or otherwise impractical. Also, the screening levels in ANSI N13.12 should be used.

**Criteria that is 'safe', 'clean', 'non-rad':** Criteria should be set at, and define, a level at which the material is no longer considered to be radioactive and/or can be defined to be "clean" and should indicate unequivocally that the standard is safe.

**Dose criteria:** Suggestions include: (1) 1 mrem/yr consistent with NCRP; (2) 1-10 mrem/yr; (3) between 1 and 5 mrem/yr consistent with Appendix I to 10 CFR Part 50, 10 CFR Part 20, and 40 CFR 190; (4) 1 mrem/yr and a second level of 10 mrem/yr to allow storage of materials with dose of 10 mrem/yr or less for onsite storage; (5) consistent with EPA drinking water standards and current airborne effluents; and (6) 10 mrem/yr consistent with statistical variation of background in U.S.

**Implementation of standard:** Several issues were discussed: (1) the ability to implement the standard should be considered. The standard must be low enough to protect the public yet not so low as to be unworkable with common field instruments or such that survey costs could be significant; e.g., need to consider if there are hand held instruments that can measure at these levels. It must be clear to the public that whatever standards are developed can be measured so that materials can be controlled to the standard; (2) levels in the range of 1-10 mrem/yr are practical; (3) criteria below 1 mrem/yr may cause detection problems; (4) should address survey procedures; (5) there is a need to consider ability to measure specific nuclides, e.g., natural uranium; (6) the rule should allow process knowledge in evaluating materials in a survey; and (7) for fuel cycle facilities, the standard must consider variability between natural background and how it affects the nuclides they handle.

**International compatibility:** Criteria should be consistent with international standards.

**Site-specific criteria should be established:** Site-specific criteria should be able to be set based on release scenarios.

**Concentration levels:** Criteria should be based on concentration levels that are reasonable and tied to a dose level.

**Clear, practical criteria are important:** Criteria should be practical and clear and the theoretical risk should be balanced by observed risk.

**Use of dose to average member of the critical group:** Criteria should be based on an average member of the critical group and not on a maximally exposed individual.

### 2.3.5 Health Physics Society and Individuals

**Rule should be dose-based and establish a brightline:** A rule should be developed containing a dose-based criteria for unrestricted use of materials that are inherently safe and thus warrant no further control for radioactivity. Rules governing release of solid material should establish a bright line that distinguishes between what is and what is not radioactive from the standpoint of requiring regulatory control.

**Adopt ANSI N13.12:** The use of the dose limits and derived screening criteria of ANSI N13.12 are appropriate: ANSI N13.12 (1) is based on sound science, provides a risk basis, and is protective of public health; (2) contains criteria for release of volumetrically and surgically contaminated materials; (3) is a voluntary consensus standard which the National Technology Transfer and Advancement Act of 1995 requires Federal agencies to use unless inconsistent with applicable law or otherwise impractical; (4) considers detection capability; and (5) allows for clearance on a case-by-case basis.

**Establish instrument performance standards:** Instrument performance standards should be established that readily demonstrate the safety of associated NRC rules on release of solid material.

#### *Health/Risk Considerations*

**Negligible risk:** ANSI N13.12 is consistent with the NCRP and with international scientific organizations which recognize 1 mrem/yr as a negligible individual dose.

**Background levels:** Man-made radioactive material should be considered in comparison with natural background, and material should not be considered radioactive if it does not contribute significantly to the radiation exposure we already receive from background (levels being considered are only 0.3 percent of background);

**Background variation:** People are exposed to wide variations in background each day from place to place with no discernible effect on health. It is illogical to say any amount of radiation is unacceptable because we live in a sea of radiation.

**Small fraction of limits:** Even if a person receives multiple exposures, they will total only a small fraction of 10 CFR Part 20 limits.

### ***Cost-benefit Considerations***

**Waste of resources:** Trying to achieve a zero risk is a waste of finite financial resources which should not be spent on trivial risks when there are other real risks that need addressing.

**Societal benefits:** Nuclear power stations provide safe clean energy and uses of radioactive material in medicine and research is vital to the U.S. economy and public health, and disposition of the materials used is part of that consideration.

### ***Tracking Released Materials***

**Criteria must be measurable:** Values must be detectable and measurable to allow compliance.

### **2.3.6 States, State Organizations, State Employees**

#### ***Suggested Standards***

**Dose-based limits are appropriate:** A regulation limiting unrestricted releases to a dose-based level that is protective of public health and safety is appropriate.

**Adopt ANSI N13.12:** NRC should adopt the procedures and standards of ANSI N13.12. NRC should develop and implement guidance that endorses ANSI N13.12 in implementing a rule.

**Designation as clean is appropriate:** Below a certain level of radioactivity, in a manner similar to DOT, it should be considered that the material is no longer radioactive; levels should be designated as clean and safe for unrestricted use.

**Free release is appropriate in non-impacted areas:** If a facility can demonstrate that an area was not impacted, free release should be allowed.

**Concentration and volumetric limits should be adopted:** A value of 1 mrem/yr was suggested as a dose criteria; specific concentration values should be included for solids similar to 10 CFR Part 20 for liquids and gases. There should also be volumetric limits.

**There is a need for case-by-case determinations:** There should also be case-by-case determinations for concentrations greater than the table values for small volumes with restricted uses by the licensee or other unique cases such that the dose is less than 10 mrem/yr.

**Adopt a dose-based standard for soils:** A standard should be in terms of dose for free release of soils.

#### ***Concerns with Landfills***

**Similar to background:** Levels being considered are near background which we are routinely exposed to.

**Risk is trivial:** Studies of dose do not confirm that any risks exist.

### ***Cost-benefit Considerations***

**LLW disposal creates an unreasonable burden:** The impact of having to dispose of all solid materials as LLW, even if they are at very low levels, would be prohibitive.

**LLW disposal is a waste of funds:** Many licensees are government facilities; spending money on needless disposal will waste money and delay needed cleanups or waste money that could be used for other programs.

**Societal benefit:** All people have benefitted from programs at licensed facilities that generate the solid materials.

**Consumer reaction:** The impact of consumers de-selecting products is overstated because consumers will not be aware of levels.

**Overall impacts:** The amount of contaminated metal to be recovered is very small compared to the overall volume of available clean scrap metal. The economic benefits to a few large licensees in salvaging a relatively small amount of material may not be justified in terms of societal or socioeconomic costs.

## **2.4 DOSE-BASED REGULATION ON CONDITIONAL USE**

### ***Advantages of Restricted Use***

**Limited exposures:** Restricting use to only certain non-licensed uses would result in the material not ending up in consumer uses and would provide a risk-basis for any conditional uses.

### ***Feasibility of Restricted Use***

**Too many possible uses:** Developing a generic radiation criterion may be problematic due to the broad nature of potential conditional uses; conditional use is not covered in ANSI N13.12 because conditional use possibilities are unlimited; conditional uses should be defined for specific cases.

**May not be acceptable to public:** The public will not accept contaminated scrap metal in products in commerce, regardless of what products they are.

**Hard to enforce:** The process of making sure materials went to prescribed use would be difficult to enforce and it is not clear that institutional controls would work to limit where the material goes; scrap generated during operations generally goes to a variety of products and end users.

**Burden on NRC and industry:** The conditional control process would be complicated and a burden on NRC and the nuclear industry; such a process might only work if some entity (like

DOE or NRC) took licensing responsibility to assure that the material is processed as required and is not used for a prohibited purpose.

**Burden on States:** There could be additional burden on State and local regulatory authorities. There would be a need for a system of tracing and accountability. This could be very expensive and could create a new class of licensee that would have to be inspected. There could also be issues that arise when such materials cross State lines.

**Not economically viable:** This approach may not be economically viable because the limited quantities involved from licensed facilities would not be sufficient for a mill to run economically.

**Dependence on market forces:** Market forces should determine if restricted use is practical.

**International commerce:** Unlike some other countries (France did establish restrictions on use), in the U.S. the destination of material cannot be stipulated unless it is designated as a form of hazardous or radioactive waste.

### ***Health and Safety Considerations***

**Risks to workers:** Restricted use in certain ways (e.g., industrial products, construction fill, roads, bridges, airplanes, sewer lines, girders) is unacceptable because it would still result in doses to workers (who usually do not come in contact with radiation hazards) and the public; also impacts on these people would be too hard to predict.

**Responsibility for restrictions:** It is not clear who would have responsibility for restrictions, (i.e., be legally tasked with, be able to take on the expense or liability of enforcing conditions. It is not clear how entities would be selected and/or notified of their responsibilities.

**Trust issues:** Recent history shows that there should not be a presumption of honesty in the industry with regard to restricting the materials' use.

**Restricting use to licensees:** Even restricting material to licensed use would require close monitoring and tracking to assure it does not get released which would be expensive. Also, even within the nuclear industry there could be concerns about additional worker exposure.

**Unauthorized Materials might be released:** There is no assurance that material would be limited to its authorized use immediately upon release or for decades afterward, and would need to be tracked for years. Material is recycled many times over and would eventually be released for unrestricted use after restrictions end before all radionuclides decay. There would be no mechanism to track the end uses of recycled materials to guarantee that they do not get into consumer products and no way for people to know what dose they were getting.

### ***Dose-based Criteria for Unrestricted Use Needed***

**Unrestricted use criteria needed:** Even with restrictions on use, there would still need to be an unrestricted use criteria defined for when the authorized use ended because restricted use is really a delayed release of solid materials for unrestricted use and the material will eventually be released after the restrictions end.

**Just set unrestricted criteria:** NRC should just pursue a solution for an unrestricted use criteria. It is premature and too difficult to try to also pursue a restricted use approach at the same time.

**More useful standard:** Setting an unrestricted use standard would provide a more universal standard with regard to applicability and is the more conservative approach. Although release limits would be lower for unrestricted use, such limits would be more useful and simple to apply under an assumption that the material might wind up at any destination and would not rely on future controls.

**Define where control ends:** Points in the process would need to be defined to indicate where authorized use would begin and licensed control would end.

### ***Suggested Approaches for Restricted Use***

**Set a regulatory process:** A rule should lay out a regulatory framework and process for restricted or conditional use similar to the 10 CFR 20.2002 process so that conditional use situations can be characterized and dealt with on a case-by-case basis rather than in a generic standard. Such a process would require a reasonable demonstration that impacts of unrestricted recycling on the metals industry would be avoided. Such a rule could be written to “not exclude” conditional use and not define conditional uses in detail but require a thorough review and approval process, including an IS, if necessary. This approach would be a more effective way of fostering public confidence.

**Permit conditional recycling:** Recycling should be expressly permitted as a conditional use for material that goes to scrap steel businesses or into consumer products.

**Only allow in licensed use or at DOE:** Material should be conditionally recycled only to another licensed use or within the DOE (e.g., waste containers, shielding blocks, etc). This may be the only acceptable approach. It was suggested that such a scheme can already exist under NRC’s regulations and it is not necessary for NRC to conduct a rulemaking. However, a comment noted that there is too much material potentially available for release for it all to be used as shield blocks at DOE facilities.

**Dedicated facility:** A dedicated facility could be used to melt and handle these materials as a licensed NRC facility. Metals would be refined and melted and also cleaned up by a regulated facility. In this type of scenario, the dedicated melted products could be regulated.

**Other considerations:** In setting restrictions, there is a need to consider such aspects as the type of material, and the type and nature of authorized uses.

### ***Tracking Released Materials***

**System of controls for tracking materials:** It is not clear that the necessary controls can be put into place to monitor and track material released from licensed facilities, and, therefore, it cannot be assured that the steel industry will not be burdened with material with higher levels of contamination.

**Must be practical:** Criteria must be practical to use. Any criteria should indicate how MARSSIM would be applied. Licensees' monitoring capabilities will need to be evaluated and upgraded for demonstrating compliance with dose-based criteria in a rule and guidance.

**Put concentrations in guide:** A standard should not reference activity-concentration limits. These should be in guidance similar to the license termination rule.

**Reporting:** There must be reporting requirements and a strategy to stop release of material if levels exceed limits.

**Liability insurance:** There must be liability insurance for businesses and the public if they are affected economically or socially.

## 2.5 DISPOSAL IN AN EPA-REGULATED LANDFILL

### *Rationale for Disposal in Regulated Landfills*

**Currently protective:** Conditional and other case-by-case releases of radioactive materials, after surveys, to landfills have already taken place under 20.2002; this process has worked well to protect the public, environment, and solid waste facilities.

**NORM allowed:** RCRA (Resource Conservation and Recovery Act) Subtitle D facilities are currently used for management of NORM.

**RCRA Subtitle C disposal is safe:** Disposal in a RCRA Subtitle C facility is safe, viable, and effective in controlling where material goes. RCRA Subtitle C facilities are highly regulated and have appropriate performance assessment, radiation safety programs, and environmental monitoring. Doses would be less than public exposure requirements and much less than background. Existing processes permit NORM to be sent to RCRA Subtitle C facilities (which contributes larger, yet acceptably safe radiation levels). RCRA Subtitle C facilities can be evaluated generically. RCRA Subtitle C has proper treatment, storage, and disposal requirements and subjects its permittees to stringent controls to ensure that hazardous materials are not released to the environment (EPA's RCRA Sect. 3004(a), 40 CFR Parts 264 and 265). These facilities would protect public health and safety and be appropriate for scrap metal. Controls include leachate control, storm water control, prohibition on liquids, collapse prevention, security, inspections, training, quality assurance, closure and post-closure, financial assurance, and deed restrictions.

**RCRA Subtitle D disposal is safe:** Disposal in RCRA D disposal facilities can also be sufficient to isolate scrap metal from the public and provide protection of public health and safety (EPA's RCRA Sect 4001, 40 CFR 258). RCRA D disposal facilities are subject to some but not all of the same requirements as RCRA C facilities, including leachate control, run-off control, groundwater, security, inspection, training, cover material, location, records, closure and post-closure, and financial assurance.

**State issues:** A dose-based standard for disposal at landfills should be permitted as long as it is not prohibited by applicable State, local, or Federal agency requirements.

**Landfill disposal is cost effective:** The NAS report noted that disposal of this material in landfills would be cost-effective.

**Standards exist:** Dose-based standards already exist for this disposal method.

**Limits exposure:** Release to RCRA Subtitle D landfills would limit public exposure, further protect public health and safety and be cost-effective. RCRA sites are suitable because site characteristics and engineered features at these sites will assure protection of public health and safety.

**Scenarios can be modeled:** Landfill scenarios can be modeled because they are comparatively limited and have been modeled for concrete. DOE has already performed analysis of disposal of low concentrations of nuclides in RCRA Subtitle C and D facilities.

**Protects LLW site resources:** Existing LLW site capacity is limited; the ability to send material to EPA-regulated sites safely lets LLW sites appropriately handle more contaminated material.

### ***Health and Safety Considerations***

**Landfills not designed for radioactivity:** No radioactive materials should be allowed in landfills because landfills were never intended and not designed to receive, contain, monitor, or isolate radioactive materials. They can leak into groundwater and drinking water and contaminate soil, air, and plants for generations and cause health risks, especially in nearby towns.

**Time periods for containment:** Even the most technologically advanced landfills leak over time. Also, they have much shorter institutional periods thus allowing long-lived radioactivity to leak soon after required oversight is eliminated.

**Concerns about RCRA Subtitle C sites:** Disposal in a RCRA Subtitle C site would only subject the material to hazardous waste controls and not to controls specific to radioactive wastes which have different characteristics. Also, disposal in a RCRA Subtitle C site could result in mixing radioactive material with hazardous wastes increasing the potential migration of materials and health risks due to synergy between the materials.

**Concerns about RCRA Subtitle D sites:** Standards for RCRA Subtitle D facilities are inadequate to protect the public health and safety from radioactivity that is volatile or not short-lived. There are fewer controls at RCRA Subtitle D sites making leakage more likely.

**Present landfill designs inadequate:** EPA's present landfill requirements are inadequate; radioactivity should not be added.

**Amounts of waste:** There may be no limit on the amount of waste sent to a landfill; landfill managers may not even know radioactive material is being deposited there.

**State issues:** The current case-by-case releases to landfills may cause State or local concerns.

### ***Feasibility, State Issues, Cost-benefit Considerations***

**Increased costs:** A township objected to disposal in RCRA Subtitle D sites and noted that it is implementing a radiation monitoring program for incoming trash to keep out radioactive materials and their task and expense will increase if NRC allows release to landfills. This option can be very costly, and could require licensing of EPA landfills which could be more expensive than LLW disposal.

**Costs of cleanup:** It is not clear who would pay the costs of cleanup and health if a landfill leaked; it is likely that communities would have to pay.

**A license currently being sought:** Another commenter noted that WCS in Texas is currently seeking a State license for this approach.

**Incineration:** Issues of incineration are not discussed in NRC's documents.

**11e.2 material issues:** There would be regulatory issues of disposal of 11e.2 byproduct materials in landfills.

**Landfill disposal would add to existing siting problems:** Most landfill projects are already controversial. An NRC rule in this area, and adding radioactive waste to landfills, could have an impact by making the siting of new landfills more difficult.

**State issues:** Municipal solid waste landfills (RCRA Subtitle D) are regulated by federal, State, and local authorities and even if there are any federal requirements, all landfills still have to comply with State and local requirements. The degree to which States have the ability to handle or dispose of radioactive wastes varies widely and makes it difficult to categorize problems that might result from restricting materials to landfills.

**State requirements:** Many States have specific exclusions for all radioactive waste other than NORM or household products. California legislatures have already rejected this alternative. A rule allowing volumetric contamination in small amounts could cause problems at RCRA Subtitle D sites and with State regulators because controls are not in place at RCRA Subtitle D sites to provide assurance that contamination would not leach (therefore, release concentrations should be sufficiently low to prevent such problems, e.g., NRC has already approved exemptions and general licenses for a number of consumer products containing radioactivity - this information should be added to this evaluation). Most State agencies and local authorities have banned radioactive wastes from municipal landfills or have more stringent requirements than Subtitle D. Therefore not all municipal landfills will be able to accept cleared material. A full assessment of available permitted capacity must be made. It must always be possible for other levels of government to make independent judgement and decisions regarding more stringent standards. Nothing should be preemptive of this basic government right.

**State prohibitions:** Disposal of solid materials that have been released for unrestricted use should be acceptable at municipal waste landfills meeting 40 CFR Part 258, however some States and localities have prohibitions against such disposal; therefore NRC should coordinate with States before bringing waste to a facility to assure it meets acceptance criteria.

**Overlapping responsibilities:** There may be difficulties in overlapping responsibilities between NRC, State and local agencies with regard to impacts on landfill management.

**RCRA Subtitle D sites:** NRC should take care in proposing blanket approval for disposal in RCRA Subtitle D sites since not all of these sites meet 40 CFR Part 258 standards and even those that qualify to accept certain exempt materials do not have to meet any minimum standards for design or groundwater protection as in 40 CFR Part 258 although they have stringent groundwater requirements. EPA has guidelines for industrial waste management but they are not mandatory.

**Potential problems:** Potential problems associated with restricting materials to landfill disposal include: (1) local constraints such as State law or land use permits conflicting with landfill disposal; (2) segregation of released material from natural material is difficult when material goes to a landfill; (3) contaminated concrete may get recycled for use in aggregate by a landfill; (4) a waste acceptance method and risk assessment method should be formalized for both unrestricted use and release for disposal; and (5) minimizing the volume of low-level waste should be an overriding consideration.

### ***Suggestions for Standards***

**No operational changes:** No change to operations and no special features should be needed.

**No changes:** For a release criterion to be accepted, the level should be low enough that there will not be any special monitoring or treatment of leachate, groundwater, or landfill gases, i.e., presence of this material must not change a RCRA Subtitle D landfill into something other than a RCRA Subtitle D landfill. That is, it must be demonstrated that no adverse impacts will result by considering normal operation and closure of solid waste management facilities and by showing the regulators and operators of the facilities that these wastes will not change the operation and closure requirements of the facility. For example, considerations should include whether leachate in the leachate collection system and gas in the gas collection system, and whether groundwater, should be monitored for nuclides and whether the wastewater facility will still accept the leachate. Also a rule would have to consider landfill closure requirements and that the landfill would not be maintained beyond the normal period (for both RCRA C and D facilities).

**Should be at clearance levels:** Material that goes into a RCRA Subtitle D site should be at clearance levels and there should not be any extra controls required; it was noted that a release to landfills is essentially an unrestricted release. At a 1 mrem/yr level, one would not expect to affect operations of landfills. Facilities do not want to manage materials that are regulated as radioactive. A dose criterion of 1 mrem/yr is suggested. Based on this, a table of release concentrations for solids and volume limits could be adopted similar to those in 10 CFR Part 20. A 1 mrem/yr criterion would be sufficiently conservative to protect public health even if all potential exposures are not known.

**Minimizing problems of diversion:** The effect of diversion of material away from a landfill could be minimized by having the same 1 mrem/yr dose limit for recycle and for landfills. Material going to a RCRA Subtitle C site is manifested to make sure it goes where it should.

**Consider unique aspects of facilities:** NRC should consider the unique operation and closure features of landfill facilities. Due to differences in RCRA Subtitle C and D sites, different regulatory approaches for such facilities should be considered, e.g., use of RCRA Subtitle C landfills might be authorized by a generic rule after appropriate evaluation whereas use of RCRA Subtitle D should only be allowed after case-by-case evaluation of specific applications.

**General license:** A general license specifying the required permit requirements to be included in an existing RCRA permit is a more cost-effective and efficient solution; these requirements could be worked out in an EPA/NRC Memorandum of Understanding. NRC should not regulate these facilities.

**Exemptions:** It may be possible to provide exemptions or release concentrations at sufficiently low levels to prevent problems of concerns about radioactive materials in leachate, etc, by use of the approach of exemptions and general licenses in use currently for a number of consumer products.

**NRC licensing:** Some said NRC should license landfill disposal sites; others said NRC should not be involved.

**Estimating limits:** A dose-based set of limits should be derived by licensees for individual landfill characteristics (subject to approval). RESRAD and D&D pathway analyses are needed for implementation.

**ANSI N13.12:** A simple multiple of the ANSI unrestricted release value could be used.

**International harmonization:** Criteria should be consistent with international initiatives and State guidelines.

**Consistency with EPA regulations:** A rule should be consistent with EPA. NRC should adopt EPA risk ranges since EPA seems to have final authority for closure on most sites and 1 mrem/yr should be within what would be acceptable to EPA.

**Case-by-case:** Case-by-case determinations should be allowed at concentrations higher than in a table for small volumes and restricted uses at 10 mrem/yr.

### ***Suggestions for Developing Criteria***

**Needed analyses:** Landfills need to be part of NRC's assessment process, including analysis of operations, leachate collection, air emissions, and closure. NRC should do research to ensure landfills are acceptable for this material.

**Consensus with EPA:** In developing landfill criteria, NRC should consult and develop consensus with EPA in developing a suitable regulatory framework for safe disposal of solid material at RCRA sites. EPA has begun studying this option. NRC should also consult with State agencies, as appropriate.

**Basis needed:** It was also noted that material should not be restricted to landfill disposal unless there is a health and safety basis for not permitting unrestricted use.

**Agency cooperation:** NRC and licensees can work with States regarding this alternative once NRC has established safe levels for release of materials destined for disposal at landfills.

## **2.6 DISPOSAL IN AN NRC/AGREEMENT STATE-LICENSED LOW-LEVEL WASTE DISPOSAL SITE/PROHIBITION**

### ***Advantages of Prohibition on Releases***

**Prohibit any detectable material:** Specifically prohibit de-regulation of any material with detectable radioactivity.

**Isolate material:** Only prohibition where the material is isolated from the public and sent to licensed LLW is reasonable and protective; no additional exposures are acceptable. Material should be prohibited from going to consumer products, industrial products, or landfills and incinerators, etc. In general, comments supporting prohibition also cited the reasons for opposing unrestricted use listed in Section 2.3 of this report.

**Cost Savings:** Prohibition of releases would represent a cost savings for NRC because dose calculations for case-by-case releases would not have to be done.

**Prohibition not addressed:** The prohibition alternative is not fairly addressed in the issues paper.

### ***Disadvantages of Prohibition on Releases***

**Unreasonable costs:** Sending very low contaminated materials to LLW disposal would have the negative impact of incurring very high costs to dispose of this material in LLW, harming society by significantly increasing the cost of goods and services provided by use of nuclear technologies, and depleting limited LLW space unnecessarily without a commensurate increase in protection of public health.

**Unreasonable to ignore background radiation:** It is unreasonable to prohibit releases of such slight amounts because it ignores reality that radiation is a fundamental part of the world we live in, and that there are radiation levels naturally in air, water, food, earth and background which vary widely in space and time; these levels completely overshadow annual exposures being considered here.

**Wasteful of resources:** Prohibition would be wasteful of valuable resources.

**Societal impact:** Biomedical research could be curtailed or stopped if all materials (e.g., boxes for equipment unpacked within controlled areas) have to go to LLW disposal.

**Material excluded:** Any prohibition alternative must consider excluding items that have no history of exposure to licensed radiological operations because these should be of no concern

to NRC, e.g., fences around sites. NRC would need to consider what is the boundary between things that could be released and those that would go to LLW; e.g., would the entire restricted area be affected, including administrative offices, etc.

**International issues:** A standard in European countries of, for example 10 uSv/a (1mrem/yr), would mean that U.S. authorities need to consider what would happen to material imported to the U.S. under an NRC standard which prohibited release, i.e., would NRC have to license such material imported into the U.S.

**Impractical:** Total prohibition could be impractical because more mobile materials might be included along with fixed, discrete items.

## 2.7 OTHER ALTERNATIVES

**Revise Part 61:** The rulemaking should focus on improving storage at Part 61 LLW facilities.

**Start over:** None of the alternatives are any good; NRC should develop better ways to maintain control and stop development of the rulemaking.

**Recapture:** There should also be a full reporting on, identification of, and recapture of any material released so far. There needs to be assurance that previous situations of release where people were not informed would not happen again. Specifically there should be a report on a tracking of health effects subject to review by independent scientists and studies and such information should be provided to the public. Other commenters suggested that the recapture approach be rejected because there is no evidence that any member of the public has been placed at significant risk and that recovering all items is unreasonable. Others noted that orphan source recovery is beyond the scope of this effort.

**Intermediate facility:** Solid material with very low amounts of radioactivity could be sent to an intermediate disposal facility, such as the Envirocare disposal facility in Utah; or some other interim storage facility.

**General license:** An approach that uses general licensing could be used.

**Varying standards:** Different standards could be established for reuse and disposal due to inherent differences between reuse of materials and disposal in landfills. There could also be some mix of restricted and unrestricted options to give licensees flexibility. Different standards could be based on: (a) the fact that material at nuclear facilities is separated based on whether it came from restricted areas or unaffected areas; (b) there is a range of material at nuclear power plants that includes institutional trash, asphalt, concrete, roofing and scrap metals, and materials available for re-use (e.g., trucks, scaffolding, computers) that could be treated differently; (c) some material could be cleared but other material, like potentially recyclable steel, would not be released or could be restricted as to its use once released.

**Pilot program:** Use of a pilot program for control of different materials might be appropriate.

## 2.8 STATE/FEDERAL/INTERNATIONAL ISSUES

### *State and Federal Agency Issues*

**EPA landfill issues:** NRC should consult with EPA and appropriate State agencies to coordinate development of a suitable regulatory framework for disposal of solid materials at RCRA sites

**DOE facilities should be included in analysis:** DOE facilities should be included within the scope of an NRC rulemaking because an NRC rulemaking will affect DOE facilities as DOE will likely try to be consistent with whatever NRC proposes and DOE possesses a large amount of waste material. Also, some material from DOE sites is controlled through NRC and Agreement State licensed facilities. Also, DOE noted that its goal is to maintain standards consistent with standards that apply to the commercial sector.

**Compatibility issues:** There should be consistency between all States to avoid difficulties with interstate commerce. Some noted that a rule must be compatible with State requirements. There was discussion of what authority Agreements States will retain and whether they could continue current practice or be more restrictive. It was noted that many States have set standards for NORM. States should not be required by the level of compatibility to approve conditional use. States should have flexibility in application so that case-by-case evaluation may still be performed by a State.

**Other agencies:** NRC must work with DOE, EPA, the Department of Defense (DOD), and the Department of State (DOS), to establish a uniform system of standards, to harmonize method of calculations and dose/risk standards, and to get public confidence.

**EPA role:** NRC has worked with EPA to develop technical bases and EPA is not developing a standard in this area because of higher priorities related to orphan sources. While some said this is EPA's responsibility and NRC should not do this effort, it was also noted that NRC is within its jurisdiction to develop standards in this area for its licensees.

**Other organizations:** Business and industry representatives and State regulated landfill operators must be involved.

### *International Issues*

**Harmonization is needed:** Any NRC standard should be consistent with the international initiatives.

**Consider international implications:** The international implications of setting a standard should be considered and NRC should consult and coordinate with international agencies and organizations in its rulemaking. Currently, some members of the European Community [European Union] have established clearance criteria that allow for unrestricted use of inherently safe sources of radioactivity; such practices should be evaluated by NRC. NRC should make an effort to assure reasonable consistency between an NRC rule and international initiatives so as to avoid developing an inconsistent NRC standard that can have diverse impacts on international trade or which unnecessarily restricts trans-boundary commerce.

**Availability of material:** Other countries do not have the capability to replace metals as easily as the U.S. and need to develop standards in this area; the U.S. imports material derived from recycled radioactive material.

**NRC leadership:** With regard to international standards setting, NRC should take a leadership role in what a standard should be. Some commenters noted that this should involve taking a lead with regard to the approach suggested by the metals industry and other commenters suggested this should involve an approach of not permitting release.

**Disallow international standards:** NRC should not follow international standards if they permit releases.

**Reject international shipments:** Regardless of what other countries may do, the Customs Service should reject any shipment of metal that sets off a sensor set at background. Commenters suggested that this is needed due to the incidents of illicit tracking of radioactive sources across borders and illegal trade and is needed to better safeguard our borders.

## 2.9 NEPA AND PROCEDURAL ISSUES

### *Stakeholder Involvement*

**Comment period:** The comment period should be extended for this environmental scoping process.

**Burden on stakeholders:** It is an unjustified regulatory burden on the public for them to have to prove negative health effects at low doses.

**Inadequate process:** The enhanced participatory process is not adequate; the Advanced Notice of Proposed Rulemaking process was skipped and there were not enough public meetings. The NRC did not seriously consider critical technical comments by one invited expert participant. The scoping process has not lived up to the NAS recommendations to include the maximum number of stakeholders nor has it seriously addressed concerns of those opposed to unrestricted use.

**Lack of stakeholder involvement:** The Commission said that it held several meetings in 1999-2000, however the public boycotted those meetings.

**Task force:** Commenters noted that NRC should form an advisory task force of stakeholders (of metals industry, licensees, and consumers, convened with NRC assistance), which would report to the NRC on matters like which industries might take which materials and possible criteria based on clarification of critical issues, review of all factors, and dialogue between stakeholders. It should be noted however that the Nuclear Energy Institute (NEI) noted that their comments were developed with assistance of an industry task force of reactor radiation safety managers and Health Physicists, were reviewed by nuclear fuel cycle and materials licensees, and NEI comments reflect insights gained from listening to other stakeholders at public workshops. Also, the Metals Industries Recycling Coalition (MIRC) noted that their comments come from an ad hoc coalition of metals industry trade associations, including

copper, brass, nickel, specialty steels, and steel manufacturers, all of whom represent major recycling industries.

**Basis for decisions:** NRC should not make decisions on unfounded fear. NRC should state clearly that its standard is safe and communicate clearly that NAS says the current practice is safe, so as to not undermine public confidence and possibly do economic harm to licensees.

**Inadequate number of public meetings:** Comments for obtaining additional public input noted that there should be regional workshops in communities, four additional meetings, meetings in each State, evening meetings, and public hearings. Additional meetings should give special attention to tribal interests, relying on State assistance for outreach, using tools like television, magazines, and including having NRC staff meetings be open to the public, chat rooms on specific topics and issues, notifying interested groups by email of meetings, and posting discussions information on the website. It was also noted that NRC should consider having public meetings that concentrate on specific issues and having small group discussions on issues with reports to larger groups. There should also be a systematic method for the public to get questions answered by NRC.

**BRC Policy:** The public has spoken in opposition before on the below regulatory concern (BRC) policy and on other previous efforts in the late 1970's and early 1980's. This resulted in passage of the Energy Policy Act in 1992 revoking BRC. NRC should not try again with this similar effort which will have the same result.

**Individual's rights:** In evaluating any alternative, the right of the individual to decide and choose, or not choose, the risk of exposure should be considered.

**Stakeholder consensus:** Stakeholders should be allowed to agree upon facts and parameters and acceptable methods of dealing with materials and NRC should implement such a finding.

**Other rulemakings:** NRC ignored public comment and did not adopt their recommendations on the decommissioning rulemaking in the early 1990s.

**Need for open process:** Public perception concerns can be treated by following an open public process that addresses public concerns as they are identified by developing a safe practical standard, and by defending the standard as fully protective.

**State issues:** The rights of State and local governments to impose stricter standards and any possible limitations thereon under the interstate commerce clause should be considered.

### ***Conflict of Interest Issues***

**Contractors:** Full disclosure of all contracts and contractors supporting the rulemaking is requested with respect to their histories and potential for conflict of interest (COI). This includes S. Cohen & Associates (SC&A) and other contractors doing work for NRC.

**Independence of other organizations:** Other scientific organizations supporting release of solid materials are not independent of NRC.

**SAIC COI:** SAIC did basic work for NRC in preparing NUREG-1640, but SAIC was found to have a COI; NUREG-1640 should not be used.

### ***Form and Presentation of Material***

The term “radioactive” should be used when referring to the materials being discussed; also, the amounts, long-lived nature, and hazard of the materials, and prior efforts in this area (e.g., BRC), should be more clearly stated.

**Clarity of discussions:** Discussions should be understandable, and make clear NRC’s role and legal authority in this area.

**Clarification of impact:** NRC should clarify whether what it is proposing would result in releasing more material and what would be different in society.

**FAA approach:** It may be appropriate to develop a result similar to when the Federal Aviation Administration (FAA) determines that certain standards and activities are safe.

**Discussion of present situation:** Discussions should make clear that the levels of radiation being discussed are small and that materials are being released every day. The benefits of nuclear technology and the fact that the U.S. imports materials derived from recycled radioactive material should be noted.

### ***Decision-making Process***

**Ignoring prohibition:** The NRC is ignoring written feedback received in the majority of comments demanding a complete prohibition on releasing solid materials.

**Ignoring other studies:** The NRC is not reviewing critically any work done by those opposing release standards or participating in developing standards that prohibit release.

**Harmonization:** The NRC is relying on harmonizing with standards that it itself has participated in.

**Decision is predetermined:** This process has a predetermined outcome and is therefore illegitimate and flawed. The government is doing what industry wants for their economic benefit; and NRC is not seriously considering the option of isolating radioactive wastes and is not evaluating it with the same rigor in its contractor studies or its NEPA analysis - thus the NEPA analysis is flawed. Options in the June 1999 Issues Paper pre-suppose that some releases, either detection-based or dose-based, will take place; and more recently the February 28, 2003 Federal Register Notice and other discussions reiterate the Commission’s support for release of solid materials. Because this process is predetermined, the environmental community boycotted the Fall 1999 public meetings rather than legitimize the process. The process is predetermined because the June 30, 1998, Staff Requirements Memorandum (SRM) directs the NRC staff to promulgate a dose-based rule for clearance of material.

### ***Additional Technical Basis Needed***

**Additional analyses needed:** Until more analyses of technical information and more extensive research and study of effects, etc, are complete, NRC should put this process on hold and suspend releases unless there are ironclad assurances that the plan is totally safe. Otherwise, many situations have been proven to be dangerous after they were allowed or after long term exposure.

**Analysis should be complete before rule is proposed:** The timing of the reports on soil analyses and technical support for NEPA and cost-benefit analyses is very important and these reports should be done before the draft of any rule.

### ***Other Issues***

**Allow market to work:** NRC should set health-based standards and allow the market to work within the bounds of the standard.

**Lawsuit:** There would be a class action suit against NRC if it goes ahead with this plan.

**State regulations will be enforced:** Sixteen States have passed laws and regulations more restrictive than NRC's mostly with intent to continue regulatory control if NRC deregulates.

## **2.10 RULEMAKING PROCESS**

### ***Advantages of NRC's Rulemaking Process***

**Clearly defined standard needed:** A dose-based standard is needed (for unrestricted use or for specific uses such as re-use or landfill disposal) that clearly defines a level: (1) at which protection of public health is assured without the need for continued regulatory oversight or licensing; or (2) that distinguishes between material considered radioactive and non-radioactive from the standpoint of regulatory control; or (3) at which any material released is clean and safe.

**Risk-informed:** A dose-based standard reflects risk-informed regulation and NRC's risk-informed performance philosophy and can be consistent with other dose-based standards currently used to protect the public.

**Consistent and usable:** A national standard is needed that provides consistency, is technically defensible and safe, can be readily implemented, and includes volumetric contamination; standards in various States are different around the country.

**Public confidence:** The rulemaking process would provide for public participation; it could increase public confidence in the regulatory process because the standard would be clear as to safety and would be more consistently applied.

**CRCPD:** The E-23 Committee recommends a rulemaking should be done to develop a dose based standard.

**Cost-effective:** A dose-based standard would be cost effective compared to the status quo of making case-by case determinations and would reduce unnecessary regulatory burden.

**Scientific basis:** A dose-based standard could provide an appropriate scientific basis for consistent regulations.

**International:** A dose-based standard would be supportive of international initiatives.

### ***Disadvantages associated with rulemaking***

**Dose is not measurable:** With a dose-based or risk-based standard, the doses and risks cannot be modeled accurately, or be measured, verified, enforced, or trusted (unlike the current approach which can be measured).

**Deregulation of wastes:** A rulemaking would put standards in place for release that would expand the amount of material the public is exposed to. A rule would result in deregulation and redirection of large amounts of wastes to unlicensed, unregulated destinations, these wastes would have been required under present policies to go to a regulated Part 61 LLW site.

**Contamination of consumer products:** A rulemaking would permit release of large amounts of waste material into consumer products; radioactivity at any level in these products is not acceptable.

**No public benefit:** A rule would only benefit the licensees and there would be no benefit to the general public.

**Lack of trust:** Past failures by NRC in keeping radioactive materials from being improperly released argue against having a release rule.

**Too burdensome:** The cost of analysis and regulatory approval is too great.

**Not accurate:** Volumetric monitoring methods are not perfected.

**Case-by-case reviews:** If a regulation is adopted, would this eliminate the capability to request “case-by-case” reviews?

### ***Scope of Rulemaking***

**Origin of material:** The Federal Register Notice notes that solid material in “restricted” or “impacted” areas are covered by requirements; however the rule should provide for control of all licensed and/or potentially radioactive material regardless of where it is on the site, including licensed material that may be stored in unrestricted or controlled areas.

**Limit rule to volumetric contamination:** NRC might consider only rulemaking for volumetric contamination.

**Criteria should be market-based:** NRC should set health-based standards and let the market work within the bounds of a standard.

**Consistency with license termination rule:** There needs to be a connection between any standard developed and the criteria of the license termination rule.

**Other materials:** NRC should clarify whether this rulemaking applies to liquids and sludges.

### 3. SCOPE OF THE DRAFT GEIS

The National Environmental Policy Act (NEPA) (Public Law 91-90, as amended), and the NRC's implementing regulations for NEPA (10 CFR Part 51) prescribe in general terms what should be included in an IS prepared by the NRC. Regulations established by the Council on Environmental Quality (40 CFR Parts 1500-1508), while not binding on the NRC, provide useful guidance.

The Draft GEIS analysis will include a consideration of the economic, technical, and other benefits and costs of the proposed action, and alternatives to the proposed action. Due consideration will be given to compliance with environmental quality standards and regulations that have been imposed by Federal, State, regional, and local agencies having responsibility for environmental protection, including any applicable zoning and land-use regulations and water pollution limitations or requirements established or imposed pursuant to the Federal Water Pollution Control Act. The environmental impact of the proposed action will be considered in the draft analysis with respect to matters covered by such standards and requirements regardless of whether a certification or license from the appropriate authority has been obtained. While satisfaction of NRC standards and criteria pertaining to radiological effects will be necessary to meet the licensing requirements of the Atomic Energy Act, the draft analysis will, for the purposes of NEPA, consider the radiological effects of the proposed action and alternatives.

The issues to be analyzed in depth in the Draft GEIS include the impacts and costs associated with rule alternatives for controlling the disposition of solid materials at licensed facilities. Information will be developed on (a) types and contamination levels of solid materials present at licensed facilities and potentially available for release; (b) pathways of exposure to, and environmental impacts of, solid materials released from licensed facilities; (c) regulatory alternatives and methods of approach for analysis of the alternatives; and (d) costs and benefits of the alternatives. The Draft GEIS will also include a detailed discussion of the need for the proposed action.

The Draft GEIS will recognize other studies related to the control of solid materials, including the National Academies report completed in March 2002. This report contains nine recommendations on the decision-making process, potential approaches for controlling the disposition of solid materials, and additional technical information needed. In addition, other scientific organizations are engaged in similar processes. Recognized radiation protection standards organizations like NCRP, ICRP, and ANSI have issued findings about possible criteria for controlling the disposition of solid materials. International agencies (such as the International Atomic Energy Agency and the European Commission) as well as other individual nations, are in the process of establishing standards for controlling the disposition of solid materials. These efforts are significant for the NRC because inconsistency in standards between the U.S. and other nations can result in confusion regarding international trade, in particular if materials released under other nations' regulations arrive as imports in the U.S.

The NRC identified reasonable alternatives to the proposed action during scoping. The DGEIS will include consideration of both radiological and nonradiological impacts associated with the proposed action and the reasonable alternatives. The DGEIS also considers necessary

monitoring, potential mitigation measures, unavoidable adverse environmental impacts, short-term uses of the environment and the maintenance and enhancement of long-term productivity, irreversible and irretrievable commitments of resources, and cumulative impacts. The following topical areas and issues will be analyzed in the Draft GEIS.

- **Public and Occupational Health and Safety.** The potential human health impacts of the alternatives on workers and the general public will be evaluated for normal operations (including handling, transfer, inspection activities, and end uses) and decommissioning. Potential exposures to radioactive elements and to chemicals will be considered.
- **Transportation.** The transportation impacts of shipping released materials under each alternative will be discussed. The impacts of transportation will be evaluated in terms of radiological exposure risk to the population during normal transportation (including handling, transfer, and inspection) and under credible accident scenarios. The non-radiological impacts of transportation will also be evaluated.
- **Water Resources.** The Draft GEIS will assess the potential impacts of the alternatives on surface water-and groundwater resources.
- **Air Quality.** Potential air quality impacts of each alternative will be evaluated in the Draft GEIS. The evaluation will include potential impacts for both radiological constituents and other air pollutants.
- **Waste Management.** Waste management was identified as a significant issue by many commenters. The Draft GEIS will document the quantities, types, treatment, and disposal of the various released materials. The Draft GEIS will also consider the disposal capacity impacts associated with the disposal of materials at both EPA-regulated landfills and LLW disposal facilities.
- **Cost-benefit Analysis.** The Draft GEIS will include a cost-benefit analysis that assesses the environmental and other costs and benefits of each of the alternatives.

#### **4. ISSUES OUTSIDE THE SCOPE OF THE DGEIS**

The NRC has made a determination that some issues are associated with small or no impacts. For this reason, these issues will not be addressed in detail in the GEIS. These issues include:

- Soils
- Ecological resources
- Environmental justice
- Land use
- Visual/scenic resources
- Noise
- Historical, archaeological and cultural resources

Also, the GEIS will not address the impacts of terrorism as the staff does not consider these impacts to be reasonably foreseeable as a result of the proposed action.

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## APPENDIX B CURRENT NRC APPROACH

Currently NRC generally addresses the release of solid material on a case-by-case basis using license conditions and existing regulatory guidance. In each case, material may be released from a licensed operation with the understanding and specific acknowledgment that the material may contain very low amounts of radioactivity, but that the concentration of radioactive material is so small that its control through licensing is no longer necessary.

The case-by-case approach includes guidance that is applicable to equipment and material with radioactivity located on the surface or within the material or equipment itself. However, there are differences in the application of this guidance between reactor licensees and materials licensees, which is explained below.

### 1. Release of Solid Materials with Surface Residual Radioactivity

#### 1.1 All Licensees

Criteria which licensees must use in determining whether the material may be released are approved for use by the NRC during the initial licensing or license renewal of a facility, as part of the facility's license conditions or radiation safety program. The licensees' actions must be consistent with the requirements of 10 CFR Part 20 (see e.g., Subpart F of Part 20 (10 CFR 20.1501)). Thus, the licensee performs a survey of the material prior to its release.

#### 1.2 Reactor Licensees

Reactor licensees typically follow a policy that was established by Office of Inspection and Enforcement Circular 81-07 and Information Notice 85-92. Under this approach, reactor licensees must survey equipment and material before its release. If the surveys indicate the presence of AEA material above natural background levels, then no release may occur. If the appropriate surveys have not detected licensable material above natural background levels, the solid material in question does not have to be treated as waste under the requirements of Part 20. The fact that no radioactive material above background is detected does not mean that none is present; there are limitations on detection capability. In practice, the actual detection capability of survey instruments are typically consistent with those contained in Regulatory Guide 1.86.

#### 1.3 Materials Licensees

In the non-reactor materials license context, NRC usually authorizes the release of solid material through specific license conditions. One set of criteria that is used to evaluate solid materials before they are released is contained in Regulatory Guide 1.86, entitled "Termination of Operating Licenses for Nuclear Reactors." A similar guidance document is Fuel Cycle Policy and Guidance Directive FC 83-23, entitled "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Byproduct, Source or Special Nuclear Materials Licenses." Both documents contain a table of surface contamination criteria

1 which may be applied by licensees for use in demonstrating that solid material with surface  
2 contamination can be safely released with no further regulatory control.

3  
4 Although Regulatory Guide 1.86 was originally developed for nuclear power plant licensees, the  
5 surface contamination criteria have been used in other contexts for all types of licensees for many  
6 years. By setting maximum allowable limits for surface contamination, Regulatory Guide 1.86  
7 implicitly reflects the fact that materials with surface contamination below those limits may be  
8 released without adverse effects on the public health and safety.

## 10 **2. Release of Solid Materials with Volumetric Residual Radioactivity**

11  
12 In the case of volumetrically contaminated materials, NRC has not provided guidance like that  
13 found in Reg Guide 1.86 for surface contamination. Instead, NRC has treated these situations on  
14 an individual basis, typically seeking to assure, by an evaluation of doses associated with the  
15 proposed release of the material, that maximum doses are a small percentage of the Part 20 dose  
16 limit for members of the public. Thus, the NRC practice over the years has been to allow the  
17 release of material with slight levels of volumetric contamination based on a case-by-case  
18 evaluation. These evaluations follow guidance discussed in the June 1999 Issues Paper (NRC  
19 1999b) and in three All-Agreement States letters (STP-00-070, STP-01-081, STP-03-003), dated  
20 August 22, 2000, November 28, 2001, and January 15, 2003, respectively.

### 22 **2.1 All Licensees**

23  
24 Licensees have used the specific process set out in 10 CFR 20.2002 to seek approval for  
25 alternate disposal methods of solid material. The release of material using the 10 CFR 20.2002  
26 process is consistent with other disposition provisions in Part 20 that allow for the unrestricted  
27 release of material (e.g., 10 CFR 20.2003 and 10 CFR 20.2005). With regard to evaluation of 10  
28 CFR 20.2002 requests, the guidance that NRC has used to evaluate these requests has evolved  
29 over time in response to increases in technical capabilities and changes in the regulations. In the  
30 mid-1980's, NRC used several documents including NUREG-1101, Vol. 2 (Onsite Disposal of  
31 Radioactive Waste - Methodology for Radiological Assessment of Disposal by Subsurface  
32 Burial), NUREG/CR-3332 (Radiological Assessment - A Textbook on Environmental Dose  
33 Analysis), and NUREG/CR-5512, Vol. 1 (Residual Radioactive Contamination From  
34 Decommissioning). Most of the alternate disposal requests involved burying the waste on-site or  
35 at off-site locations (e.g., landfills). In 1988, NRC promulgated the rule on "General  
36 Requirements for Decommissioning Nuclear Facilities" (Timeliness rule). In part, this rule  
37 required licensees to submit evaluations of inactive areas of sites including former burials under  
38 10 CFR 20.302 and 20.304. Additional clarification was provided in Information Notice 96-47.  
39 In 1996, NRC developed a preliminary Screening Methodology for evaluating former burials (61  
40 FR 56716). After issuance of requirements in Subpart E of 10 CFR 20 in the License  
41 Termination Rule (LTR) in July 1997, NRC concluded that the screening methodology did not  
42 always produce a dose below the unrestricted dose limit when a more rigorous methodology was  
43 used, and the screening methodology was never finalized.

44  
45 The current guidance document that would be used to evaluate doses associated with 20.2002  
46 requests is NUREG-1757, Volume 2 (Consolidated NMSS Decommissioning Guidance:

1 Characterization, Survey, and Determination of Radiological Criteria), dated September 2003.  
2 This NUREG provides guidance on complying with Subpart E of Part 20, and represents the  
3 current state of thinking for dose assessments. The guidance in NUREG 1757, Volume 2, was  
4 based substantially on guidance in NUREG-1727 (NMSS Decommissioning Standard Review  
5 Plan), dated September 2000. Prior to this NUREG being finalized, NRC issued interim  
6 guidance entitled “Preliminary Guidelines for Evaluating Dose Assessments in Support of  
7 Decommissioning,” dated February 11, 1999. Thus, the standard practice over the years has been  
8 to allow the release of material with slight levels of volumetric contamination based on a case-  
9 by-case evaluation.

## 11 **2.2 Reactor Licensees**

12  
13 For reactor licensees, the disposition of volumetrically contaminated materials is being  
14 implemented under the provisions of Information Notice No. 88-22: Disposal of Sludge from  
15 Onsite Sewage Treatment Facilities at Nuclear Power Stations. Certain materials may be  
16 surveyed using a representative sample and gamma spectrometry analytical methods. The  
17 provision requires that materials can be released if no licensed radioactive material above natural  
18 background levels is detected, provided the radiation survey used a detection level that is  
19 consistent with the lower limit of detection values used to evaluate environmental samples. NRC  
20 guidance states that the lower limit of detection (LLD) to be used for radiation surveys is the  
21 “operational state of the art” LLD values given in the Standard Radiological Effluent Technical  
22 Specifications (RETS) for environmental samples taken as part of the licensee’s radiological  
23 environmental monitoring program.

24  
25 The environmental LLDs are contained in Regulatory Guide 4.8, “Environmental Technical  
26 Specifications for Nuclear Power Plants,” and in a Branch Technical Position (NRC 1979).  
27 They are also contained in NUREG-1301, “Offsite Dose Calculation Manual Guidance: Standard  
28 Radiological Effluent Controls for Pressurized Water Reactors,” and NUREG-1302, “Offsite  
29 Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Boiling Water  
30 Reactors.” There are several different acceptable survey applications of the environmental LLDs  
31 and applications have included a variety of environmental media including soils, sediments,  
32 liquids and slurries.

## 34 **2.3 Materials Licensees**

35  
36 For materials licensees, the disposition of volumetrically contaminated materials is being  
37 implemented under the provisions of the December 27, 2002, NRC Memorandum “Update on  
38 Case-Specific Licensing Decisions on Controlled Release of Concrete from Licensed Facilities,”  
39 (referenced in STP-03-003). This memorandum indicates that controlled releases of  
40 volumetrically contaminated concrete may be approved, pursuant to 10 CFR 20.2002, under an  
41 annual dose criterion of a “few mrem.”

## 43 **3. Agreement State Practices for Releasing Solid Materials**

44  
45 As part of the technical basis development for the control of solid materials, NRC obtained  
46 information from the Agreement States on their practices with respect to the release of surficially

1 and/or volumetrically contaminated materials for unrestricted use. The responses indicate the  
2 States vary in their approaches. The types of criteria applied on a case-by-case basis include use  
3 of levels that are indistinguishable from background, use of guidelines similar or equivalent to  
4 Regulatory Guide 1.86, and use of dose-based analyses. The approaches listed below were  
5 identified by one or more Agreement States in their responses to the All Agreement States letter  
6 SP-99-074, dated November 2, 1999:  
7

- 8 • Materials to be released must be indistinguishable from background. The level used for  
9 background could be based on NRC guidance such as Regulatory Guide 1.86.
- 10
- 11 • Radioactive material can only be transferred to persons licensed to receive it. Therefore,  
12 licensees cannot release either surficial or volumetric contaminated solid materials for  
13 unrestricted use.
- 14
- 15 • NRC guidance documents are used to determine, on a case-by-case basis, whether radioactive  
16 materials (e.g., dirt, resins, asphalt, concrete, metals) can be released for unrestricted use.  
17 This includes but is not limited to NRC guidance documents such as Regulatory Guide 1.86,  
18 Policy and Guidance PG-8-08, Policy and Guidance Directive FC 83-23, NUREG/CR 5849,  
19 and computer models such as RESRAD, and DandD.
- 20
- 21 • Regulatory Guide 1.86 is used but the contamination limits for the second group of nuclides  
22 in Table 1 are increased by a factor of ten.
- 23
- 24 • In addition to meeting specific surface contamination limits similar to Regulatory Guide 1.86,  
25 porous materials (e.g., concrete), which are to be released for unrestricted use, shall be  
26 evaluated to determine whether radioactive materials have penetrated to the interior of the  
27 material. If radioactive contamination has penetrated into the material, analysis of the average  
28 concentration, in picocuries per gram, shall be made. The material may be released for  
29 unrestricted use if the radionuclide concentrations do not exceed the limits specified for soil  
30 (which preclude a member of the public from receiving a total effective dose equivalent in  
31 excess of 25 mrem/year from all pathways (excluding radium and its decay products)).  
32
- 33 • Volumetric releases are based upon a concentration equivalent to the 10 CFR Part 20 values  
34 for water converted to grams rather than volume.
- 35
- 36 • Releases can be based on a life-time fatal cancer risk of 1.0E-6. One State identified used a  
37 risk criterion of 1.0E-4.
- 38
- 39 • Use of maximum doses included 1, 10, 15 or 25 mrem/yr.
- 40
- 41 • Allowance of up to 8 pCi/gm of Co-60 in soil. Allowance of 5 pCi/gm of Cs-137 in flue  
42 dust.
- 43
- 44 • Requirements that no licensee may possess, receive, use, or transfer licensed radioactive  
45 material in such a manner as to cause contamination of soil or vegetation in unrestricted areas

1 that causes a member of the public to receive a total effective dose equivalent in excess of 25  
2 mrem/year from all pathways (excluding radium and its decay products).  
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**APPENDIX C  
LETTERS FROM COOPERATING AGENCIES**

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**From:** Richard Ratliff <Richard.Ratliff@tdh.state.tx.us>  
**To:** "Phyllis Sobel" <PAS@nrc.gov>  
**Date:** 9/4/03 12:33PM  
**Subject:** RE: Scope of Work for Clearance Rulemaking

Phyllis, Mr. Michael Whalen with the State of Massachusetts, Radiation Control Program has agreed to represent the states on this work group. His E-mail address is: michael.whalen@state.ma.us ,and his telephone number is: 617-427-2944. I advised Michael of the September 10th conference call. Please let me know if you have any questions. Richard

**CC:** "michael.whalen@state.ma.us" <michael.whalen@state.ma.us>, "Pearce O'Kelley (E-mail)" <okelletp@dhec.sc.gov>, "Ron Fraass (E-mail)" <rfraass@CRCPD.ORG>



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
WASHINGTON, D.C. 20460

JAN 29 2004

OFFICE OF  
AIR AND RADIATION

Mr. Lawrence E. Kokajko, Chief  
Environmental and Performance Assessment Branch  
Office of Nuclear Material Safety and Safeguards  
Nuclear Regulatory Commission  
Washington, DC 20555-0001

Dear Mr. Kokajko:

In response to your letter of invitation we, the U.S. Environmental Protection Agency (EPA), would like to accept your request to become a cooperating agency on the Nuclear Regulatory Commission's (NRC's) development of a rulemaking controlling the disposition of solid materials. We understand this role to be consistent with regulations developed by the Council on Environmental Quality that implement the National Environmental Policy Act (NEPA). More specifically, we expect our involvement to focus on the review of various drafts of the Generic Environmental Impact Statement (GEIS), review of associated documents, and participation on relevant working and managerial steering groups.

By assuming this role as a cooperating agency, EPA believes that it can contribute to the review of the NRC effort. EPA's role as a cooperating agency does not imply EPA's endorsement of NRC's selection of specific approaches, alternatives or options. EPA will conduct independent reviews of the Draft and Final EIS, and associated documents, in accordance with Section 309 of the Clean Air Act, 42 U.S.C. 7609. The following addresses the specific roles of the respective agencies.

EPA understands its responsibilities as a cooperating agency to be as follows:

- ▶ EPA will participate on working groups and managerial steering groups related to this rulemaking effort;
- ▶ EPA will provide timely review of documents and written comments to NRC on the GEIS and associated documents;
- ▶ EPA recognizes that the comments it provides to the NRC are advisory; and
- ▶ Given resource limitations and other practicalities, EPA commits to work within NRC's EIS preparation schedule to the extent practicable.

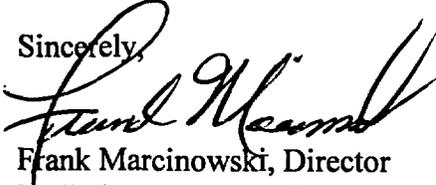
EPA understands NRC responsibilities as the lead agency to be as follows:

- ▶ NRC will forward all comments it receives from working group members during preparation of the draft EIS as well as make available all comments it receives during the formal EIS comment period;

- ▶ NRC will consult with EPA but will retain sole responsibility for selecting the regulatory approach and among regulatory options.
- ▶ NRC will give EPA preliminary copies of the Draft and Final EIS, and associated documents, for review and comment prior to final lead agency approval and distribution of the documents.

The above lists seek to clarify the respective responsibilities and expectations of the two agencies. Adam Klinger will serve as the contact person and he and members of his staff will serve as resources on this effort. He can be reached at 202-343-9378. We have had initial conversations with Phyllis Sobel as the staff project lead and will coordinate accordingly.

We thank you for the opportunity to participate in this manner and believe that such interaction will improve communication and coordination of Federal radiation-related initiatives.

Sincerely,  
  
Frank Marcinowski, Director  
Radiation Protection Division  
Office of Radiation and Indoor Air



Department of Energy  
Washington, DC 20585

DEC 1 8 2003

Martin J. Virgilio, Director  
Office of Nuclear Materials Safety and Safeguards  
U.S. Nuclear Regulatory Commission  
Washington, DC 20555-0001

Dear Mr. Virgilio:

This is in response to the August 6, 2003, letter from Mr. L. Kokajko of your office to Mr. A. Wallo inviting the U.S. Department of Energy (DOE) to participate as a cooperating agency in the U.S. Nuclear Regulatory Commission's (NRC) preparation of the Generic Environmental Impact Statement (GEIS) regarding the control and disposition of certain solid material. We understand that this GEIS is in support of the NRC's enhanced participatory rulemaking on alternatives for controlling the disposition of solid materials that originate in restricted or impacted areas of NRC-licensed facilities, and that have no, or very small amounts of, radioactivity resulting from licensed operations.

For the reasons cited in your letter concerning DOE's experience and efforts in the control and release of property containing residual radioactivity, we agree that it is both reasonable and beneficial for DOE to participate as a cooperating agency in this EIS process. Participating as a cooperating agency will help DOE stay apprised of the relevant issues and provide a mechanism for DOE to contribute its expertise to the review process, while ensuring effective communication between our agencies. Cooperating agency status will also assist DOE in its own EIS process involving DOE scrap metal, which, as your letter correctly notes, is a separate, ongoing effort. As a cooperating agency, DOE will, as appropriate and subject to the availability of personnel resources, participate in the GEIS process by providing requested information and data as available, and reviewing the GEIS and supporting materials.

The Office of Air, Water and Radiation Protection Policy and Guidance will serve as DOE's principal point of coordination for DOE participation in the GEIS. Accordingly, please contact Stephen Domotor (202-586-0871) of that office to initiate coordination and information exchange on the GEIS for the control and disposition of solid material. Please feel free to contact either Mr. Domotor or Mr. Wallo if you or your staff need assistance.

Sincerely,

A handwritten signature in cursive script that reads "Andy Lawrence".

Andy Lawrence  
Deputy Assistant Secretary  
for Environment

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**APPENDIX D**  
**COLLECTIVE DOSE ASSESSMENTS FOR CONCRETE,**  
**STEEL AND TRASH**

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**1. Introduction**

The NRC is considering regulatory requirements for the disposition of solid, potentially clearable materials that are under license by the NRC and its Agreement States. As part of its regulatory decision-making process, the NRC evaluates the advantages and disadvantages associated with a range of alternatives. This appendix assesses potential doses to workers and members of the public that could result from the implementation of the alternatives currently being evaluated. Potential collective doses are estimated for each alternative for concrete, ferrous metals<sup>1</sup>, and trash. The information in this appendix is based on an evaluation of doses analyzed in part in NUREG-1640 (NRC 2003d), which is discussed in Appendix E.

This appendix summarizes the results of a draft report, available on NRC's webpage, entitled, "Collective Doses Associated with Clearance of Materials from NRC/Agreement State - Licensed Facilities," Rev. 2, December 31, 2003 (SC&A 2003). References in this summary pertaining to additional, detailed information correspond to their respective locations in the above referenced collective dose report (SC&A 2003). The objective of the report was to evaluate and compare the amounts and radionuclide characteristics of potentially clearable material (e.g., different types of metals, equipment, tools, concrete, and trash) and their associated radiation health impacts. For this purpose, assessments are made for the collective doses to radiation workers and members of the public that might result for each of the rulemaking alternatives.

The Draft GEIS defines five alternatives, two of which are subdivided into five options, as follows:

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- (1) No Action. This alternative is the baseline for comparison of alternatives and generally corresponds to material radioactivity concentration levels specified in Regulatory Guide 1.86 (USAEC 1974).
  - (2) Unrestricted Release. This alternative places no restrictions on what can be done with material that is released. Considerations for choosing a meaningful range of options for this alternative resulted in specifying 5 dose levels. The options include: zero above background (which was analyzed at 0.03 mrem/yr), 0.1 mrem/yr, 1 mrem/yr, and 10 mrem/yr. A realistic lower-bound dose limit of 0.03 mrem/yr was chosen because it is a small value at, or marginally above, detectable levels. The dose options used the

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<sup>1</sup> In the context of this analysis, "ferrous metals" is used as an all inclusive term for all alloys whose major constituent is iron (Fe). Ferrous metals include such metals as carbon steel, stainless steel, forged steel, galvanized steel, cast iron, etc.

1 normalized doses in NUREG-1640<sup>2</sup> for unrestricted use to derive their respective  
2 radionuclide concentrations in specific materials.

- 3
- 4 (3) Disposal in EPA/State-Regulated Disposal Facility. This alternative places restrictions  
5 on the method of material dispositions. Specifically, material could only be disposed of  
6 in a RCRA Subtitle D landfill at or below the activity concentrations allowable for a  
7 defined dose option. The result is that a greater amount of activity could be released to  
8 landfills than the amount that would be released to general commerce under the  
9 Unrestricted Release Alternative. The options include: zero above background (which  
10 was analyzed at 0.03 mrem/yr), 0.1 mrem/yr, 1 mrem/yr, and 10 mrem/yr. The dose  
11 options used the normalized doses in NUREG-1640 for disposal in a RCRA Subtitle D  
12 landfill to derive their respective radionuclide concentrations in specific materials. The  
13 RCRA Subtitle D regulations encompass both municipal and industrial landfills.  
14 Construction and demolition (C&D) or other industrial waste landfills were included in  
15 the collective dose report (SC&A 2003). For further discussion of EPA/State-regulated  
16 landfills, see Appendix J.
- 17
- 18 (4) Disposal in a LLW Disposal Facility. This alternative is also referred to as the  
19 prohibition alternative, because any of the material considered would be disposed of only  
20 in an NRC-licensed low-level radioactive waste (LLW) disposal facility.
- 21
- 22 (5) Limited Dispositions. In this alternative, solid material would be released, but NRC  
23 would allow only certain authorized dispositions to limit the potential for public  
24 exposure. All materials to be released would undergo a radiation survey and the  
25 measured level of radiation would be compared against the criterion for release for  
26 limited dispositions. Solid materials with measured radiation levels below the established  
27 criterion would be released for pre-approved limited dispositions, while solid materials  
28 with radiation levels above the criterion would be sent to a LLW disposal facility. NRC  
29 regulations in 10 CFR Part 20 would be amended to add a regulation on limited  
30 dispositions. Any requests to release material other than to these limited end uses or at  
31 higher doses would require case-specific approval from NRC.

## 32

### 33 2. Design Objectives and Overall Approach

34

35 The overarching design objectives of this investigation are realism, clear and complete  
36 presentation, accuracy, consistency, and full disclosure of uncertainty in the derivation of the  
37 collective doses associated with each rulemaking alternative. In addition, the approach is  
38 required to be consistent and compatible with the methods used to derive individual normalized  
39 doses as provided in NUREG-1640 (NRC 2003d).

40

41 Consideration was given in the calculation of the collective doses to all categories of  
42 NRC/Agreement State licensees, a full range of exposure scenarios and/or population groups,

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<sup>2</sup> "Radiological Assessments for Clearance of Materials from Nuclear Facilities - Main Report."  
NUREG-1640, Volume 1. Washington, DC: U.S. Nuclear Regulatory Commission, 2003 (NRC 2003d).

1 and a broad range of materials (ferrous metal (including steel), copper, aluminum, concrete, and  
2 trash). Since the number of categories and subcategories of licensees, types of materials, and  
3 exposure scenarios/population groups that can contribute to the collective doses is very large, the  
4 number of categories that are explicitly included was selected based on the following criterion:  
5

- 6 • Capture enough of the categories and volume of material, and associated radionuclide  
7 inventory, and resultant collective doses associated with each rulemaking alternative for the  
8 preponderance of materials considered for disposal. If the exposure scenarios chosen are  
9 realistic, then these collective dose estimates can be used to provide very representative  
10 information on the dose impacts of the alternatives.  
11

12 In the process of performing the analysis, secondary objectives included the following:

- 13 • Disclose which categories of NRC licensees and which materials are anticipated to be  
14 responsible for most of the collective doses.  
15
- 16 • Create a mosaic of exposure categories that reveal the scenarios/population groups that are  
17 anticipated to experience the largest collective doses.  
18

19  
20 These objectives were achieved by using a combination of scoping/screening analyses and  
21 detailed calculations. The scoping calculations were generally deterministic and used to obtain a  
22 reasonable upper bound for the category selected. The detailed calculations could only be done  
23 when significant amounts of information were available, and over a realistic range of scenario  
24 specific situations. Then, performing random sampling over a very large number of potential  
25 exposure realizations, the collective dose can be estimated statistically (Monte Carlo method).  
26 This type of collective dose estimate has significant generic applicability because it is a valid  
27 representation of an average, or expected, value and its attendant range of uncertainty. As  
28 demonstrated through the scoping/screening calculations, steel, concrete, and trash were found to  
29 be the dominant sources of potentially clearable material in terms of volume of material,  
30 radionuclide inventory, and potential collective dose. In addition, the collective doses associated  
31 with end-use products made from recycled released steel were found to be responsible for the  
32 overwhelming majority of the collective doses.  
33

34 The criteria for selecting the categories of recycled products to include in the collective dose  
35 assessment are described in Section 9.1 of the collective dose report (SC&A 2003). The criteria  
36 and methodology used to select categories of recycled products were specifically developed so  
37 as not to underestimate the collective dose. Also, for the collective dose assessment for the No  
38 Action and Unrestricted Release Alternatives it is assumed that the entire available inventory of  
39 solid material was used in the production of recycled products, and that none of the available  
40 inventory of solid material was disposed of in landfills, an assumption that maximizes the  
41 collective dose. Thus, although some specific types of products that could be made from  
42 recycled solid material may not be explicitly included in the collective dose assessment, the  
43 assumption that the entire available inventory of solid material is recycled accounts for the  
44 impact of the recycling on the collective dose (SC&A 2003).  
45

1 All categories of licensees, types of materials, and exposure scenarios/population groups were  
2 addressed, but not to the same level of detail. As indicted above, a primary difference between  
3 the detailed analyses and the scoping/screening analyses results is that the detailed analyses are  
4 considered realistic estimates of the collective doses and sufficiently developed to be provided as  
5 a function of time, while the scoping/screening analyses are considered upper-end estimates of  
6 collective doses and cannot be represented as time dependent.

7  
8 The analytical approach used in estimating collective doses from the use of products involved  
9 tracking and accounting for the inventories of radioactivity as materials moved from the point of  
10 release at licensees, to the incorporation of radioactivity in products or through the environment,  
11 and ultimately to dose receptors. In order to do this, ‘reference’ products (e.g., the generic  
12 category representing cars) were developed that are assumed to be representative of all products  
13 of a given type (e.g., the end product, namely the specific product being considered, such as “a  
14 car”). For example, a reference automobile was assumed that is representative of all types of  
15 automobiles (including pickup trucks, sport utility vehicles, etc.). The total collective dose  
16 remains the same, whether it is distributed over one car, two cars or 50 cars. This methodology  
17 is based on the assumption that, as the end-product concentration for a given amount of released  
18 radioactivity goes down, the number of individuals using that end-product goes up  
19 proportionally. In other words, the product of the concentration times the number of end-product  
20 users is always a constant. Analytically, when all the small contributions are added, it validates  
21 the methodology of calculating the collective dose from a single reference product. That single  
22 reference product is assumed to be representative of all products of that type.

23  
24 For metals, the modeling is a cumulative total of all source terms and pathways having  
25 significance. For example, for power reactors, the source term is available for 50 years (or until  
26 the reactor is decommissioned) and it’s cumulative effects carried out for an additional 250  
27 years. For everything else, because the available data was not sufficiently as refined, bounding,  
28 realistically, conservative estimates were made.

29  
30 Since the detailed analysis employs probabilistic methods, uncertainty in quantities of material  
31 and the collective doses associated with the rulemaking alternatives are explicitly addressed by  
32 assigning uncertainty distributions to the input parameters, which are used throughout the  
33 calculations, and yield results that are presented as uncertainty distributions that disclose the  
34 mean, median, standard error of the mean, and the 5th and 95th percentile values for the results  
35 of the calculations.

36  
37 For further elaboration on methodology, it is emphasized that the scoping/screening analyses do  
38 not employ probabilistic methods to assess uncertainties. Instead, a semi-quantitative  
39 analysis/discussion of the uncertainty in the analysis is provided which discloses the uncertainty  
40 in the quantities of material and collective doses in a less rigorous manner than those used in the  
41 more elaborate Monte Carlo analyses. In general, the scoping/screening analyses are designed to  
42 demonstrate that a given category of licensees, type of material, or exposed population group are  
43 not important contributors to the overall quantities of material or collective doses associated with  
44 each rulemaking alternative. As such, simplifying assumptions are used that provide a high level  
45 of assurance that the collective doses and quantities of materials are not underestimated.

1 As a final point, it is important to recognize that the concept of uncertainty, when addressing  
2 collective doses, is different from the concept of uncertainty when addressing individual doses,  
3 as was done in NUREG-1640. In NUREG-1640, the uncertainty analysis was concerned with  
4 estimating the uncertainty and mean values of the normalized doses to the individuals that  
5 comprise the critical groups. This report is concerned with the mean values and the uncertainty  
6 in the mean of real, but unknown, collective doses to population groups. It is not concerned with  
7 the variability of the doses to the individuals that comprise a given population group.  
8

9 From a statistical perspective, NUREG-1640 (NRC 2003d) is concerned with the mean and  
10 standard deviation of the doses to individuals, while the collective dose report (SC&A 2003) is  
11 concerned with the mean and standard error of the mean of the collective doses to a given  
12 population group. This difference is important because individual variabilities within a  
13 population group “average out” when deriving the collective doses, resulting in uncertainties in  
14 the collective doses for a given population group that are relatively small as compared to the  
15 variabilities and uncertainties associated with the doses to the individuals that comprise the  
16 group.  
17

18 The difference in these two concepts is equivalent to asking the question “what is the variability  
19 of the heights of the individuals that comprise the population of the U.S.,” as opposed to asking  
20 the question “what is the uncertainty in the average height of the individuals of the U.S.  
21 population.” In the case of the former, the variabilities are very large (the range of heights of  
22 adults likely span several feet). In the case of the latter, there is a real, but unknown average  
23 height of adults in the United States. Estimates of that value are based on measurements made  
24 on a sample of the total population, and the uncertainty in that value is probably less than a few  
25 inches.  
26

### 27 **3. Scrap Metal, Concrete, and Other Potentially Clearable Materials**

28  
29 The calculation of the amount and activity of potentially clearable material focused on  
30 commercial nuclear power plants, because they were determined to generate a major fraction of  
31 the total mass of potentially clearable materials from the decommissioning of all licensed  
32 facilities (96 percent of all ferrous metals and 99 percent of all concrete). The total mass of  
33 copper and aluminum from all licensed facilities combined is estimated to be less than 2 percent  
34 of the total mass of ferrous metals from nuclear power plants. Therefore, copper and aluminum  
35 were addressed by a deterministic scoping analysis.  
36

37 Materials from nuclear power plants were characterized as clean, potentially clearable, or  
38 contaminated. Contaminated materials are expected to be disposed of as low-level radioactive  
39 waste (LLW), although some portion may be releasable if decontaminated. It is anticipated that  
40 some fraction of the potentially clearable materials would be disposed in a LLW facility under  
41 one or more of the regulatory alternatives being considered in this study. In addition to ferrous  
42 metals and concrete, the analysis also considered trash generated from operating nuclear power  
43 plants since some of this trash is generated within the restricted or impacted areas.  
44

45 In addition to providing estimates for the expected masses of materials from boiling-water  
46 reactors (BWRs) and pressurized-water reactors (PWRs), the report also develops mass-to-

1 surface area ratios. These ratios were needed to convert mass-based normalized effective dose  
2 equivalents (EDEs) to surficial dose factors. The analysis also determined contamination  
3 distributions needed to assess the impact of various regulatory alternatives on the mass of  
4 releasable materials and presents data on the fractional mix of radionuclides expected in the  
5 potentially clearable materials.

6  
7 It was estimated that about 2 million metric tons of ferrous metals, 20 million metric tons of  
8 concrete, and about 200,000 metric tons of trash might fall within the scope of the proposed rule.  
9 About 45 percent of the radioactivity in these materials is from Co-60, with Cs-137 contributing  
10 another 16 percent.

#### 11 **4. Radionuclide Composition of Releasable Material Produced from Light-Water** 12 **Reactors as a Function of Time**

13  
14  
15 This information is presented, in part, in the form of curves that depict the volume of a given  
16 type of material on the y-axis and the radionuclide levels of the material on the x-axis. Then,  
17 using the normalized doses in NUREG-1640, or the explicitly defined clearance levels defined in  
18 Regulatory Guide 1.86 (USAEC 1974), the quantity of material and radionuclide composition of  
19 the potentially clearable material were calculated for the following four cases:

- 20  
21 • Case A—Use NUREG-1640 material-specific limiting scenario normalized EDEs<sup>3</sup> for  
22 concrete and ferrous metals and trash limiting scenario normalized doses.
- 23  
24 • Case B—Use NUREG-1640 (and trash) material-independent limiting scenario normalized  
25 EDEs.
- 26  
27 • Case C—Use NUREG-1640 Municipal Solid Waste (MSW) landfill (Subtitle D) material-  
28 specific limiting scenario normalized EDEs for ferrous metals and concrete and limiting trash  
29 surrogate normalized doses.
- 30  
31 • Case D—Use NUREG-1640 industrial landfill (Subtitle D) material-specific limiting  
32 scenario normalized EDEs for ferrous metals and concrete and limiting trash surrogate  
33 normalized doses.

34  
35 This was accomplished by dividing the rulemaking alternative (in units of mrem/yr) by the  
36 normalized doses (in units of mrem/yr per pCi/g) to yield the release levels, (in units of pCi/g).  
37 Once the release level is determined for a given material and rulemaking alternative, curves  
38 were used to determine the quantity and radionuclide composition of the releasable material for a  
39 given alternative and case.

---

40  
<sup>3</sup> NUREG-1640 provides normalized doses based either on the recommendations in ICRP  
Publication 26 (ICRP 1977) referred to as Effective Dose Equivalents (EDEs), or on the  
recommendations in ICRP Publication 60 (ICRP 1991) referred to as Effective Dose. This report uses the  
normalized EDEs.

Monte-Carlo calculations were employed to provide statistical representations for the mean value of the total collective dose and its range of uncertainty. The potential variability of the differing radiological source terms was included in these calculations, and the end results incorporate the uncertainty over all variable parameters considered, including this parameter.

The mean values of the total calculated activity in the releasable material are shown in Table D-1 for all four cases analyzed. As Table D-1 shows, the release of trash generates the largest amount of activity for three of the four cases analyzed. Only when the material-independent concentration limit (based on NUREG-1640) is used (i.e., Case B), is the activity generated dominated by the release of concrete. The activity in material released as a function of time is shown in the collective dose report (SC&A 2003).

**Table D-1 Mean Value of Total Activity Released (Ci)**

Case	Regulatory Options				No Action
	0.03 mrem/yr	0.1 mrem/yr	1 mrem/yr	10 mrem/yr	
<b>All Material</b>					
Case A	0.848	3.36	41.14	538.29	4.33
Case B	0.177	0.449	2.23	6.11	
Case C	1.27	4.48	45.55	549.35	
Case D	0.927	3.57	41.99	541.09	
<b>Ferrous Metal</b>					
Case A	0.092	0.395	2.86	12.74	1.76
Case B	0.008	0.048	0.745	4.33	
Case C	0.484	1.46	7.09	23.81	
Case D	0.138	0.550	3.54	15.55	
<b>Concrete</b>					
Case A	0.168	0.401	1.49	1.73	0.243
Case B	0.168	0.401	1.49	1.73	
Case C	0.201	0.460	1.67	1.73	
Case D	0.201	0.460	1.67	1.73	
<b>Trash</b>					
Case A	0.588	2.56	36.79	523.81	2.32
Case B	0.00001	0.00005	0.0015	0.043	
Case C	0.588	2.56	36.79	523.81	
Case D	0.588	2.56	36.79	523.81	

The mean values of the total calculated mass of the releasable material are shown in Table D-2 for all four cases analyzed. As Table D-2 shows, the release of concrete generates the largest mass of material for all of the cases analyzed. The mass of material released as a function of time is shown in SC&A 2003. For the dose options analyzed, there is very little difference in the mass of material released. This is also true for the other three cases analyzed. The reason for this is that there is a large mass of material at very low concentrations that would be released under any regulatory alternative, but as the regulatory alternatives become more liberal, the additional mass of material at the higher releasable concentrations is much less.

**Table D-2 Mean Value of Total Mass of Material Released (million t)**

Case	Regulatory Options				
	0.03 mrem/yr	0.1 mrem/yr	1 mrem/yr	10 mrem/yr	No Action
<b>All Material</b>					
Case A	16.0	19.1	21.9	22.3	
Case B	15.5	18.4	21.4	22.1	18.3
Case C	17.2	19.9	21.2	22.3	
Case D	16.7	19.5	22.0	22.3	
<b>Ferrous Metal</b>					
Case A	0.970	1.49	2.20	2.45	
Case B	0.441	0.786	1.74	2.30	2.06
Case C	1.57	2.00	2.38	2.48	
Case D	1.10	1.62	2.26	2.47	
<b>Concrete</b>					
Case A	15.0	17.6	19.6	19.8	
Case B	15.0	17.6	19.6	19.8	16.2
Case C	15.6	17.9	19.7	19.8	
Case D	15.6	17.9	19.7	19.8	
<b>Trash</b>					
Case A	0.014	0.021	0.041	0.066	
Case B	0.0002	0.0004	0.002	0.006	0.020
Case C	0.014	0.021	0.041	0.066	
Case D	0.014	0.021	0.041	0.066	

In SC&A 2003, Chapter 3 and Appendix A, detailed statistical data analysis was performed to determine the potential amounts of material considered releasable versus their associated levels of (measured) surface radioactivity. This type of distribution provides quantitative information on the shape of the probability distribution that characterizes the range of radioactivity levels likely to be found for the inventory of materials considered for release. The probability of finding contamination was mostly found to be very low and within the range of background radiation (approximately a null amount of radioactive contribution). Some small amount of material was found to increase beyond this, but within a very narrow range. This small increase, while possibly real, might also be partially caused by measurement uncertainty at these very low radiation levels. Beyond that range, there were very small, if any, amounts of material found until a much higher radioactivity level was reached. At this higher level, any materials found would require disposal at an NRC licensed LLW facility. Intuitively, such a probability distribution makes sense because anything that would be considered for release would, from materials process considerations, be expected to have no radioactivity or be at a very low level because of cleanup activities routinely performed as industry practice. Because decontamination is a destructive process, and cleanup efficiencies are usually high, very little, if any radioactivity would be expected to be found for these potentially clearable materials. Beyond this, other potentially radioactive materials would be expected to be at much higher levels, comparable to those requiring LLW disposal. Generally, although from a measurement aspect it is more difficult to demonstrate as well, materials considered for release having volumetric distributions of radioactivity would also be expected to have probability distributions similar to those found for surface radioactivity. Based on all of the above, the total amount of radioactivity from all

1 released materials is expected to be small as compared to that contained in LLW. For example,  
2 the amount of radioactivity shipped to the three operating LLW facilities ranges from 1,400 to  
3 420,000 Curies as annual averages. Regarding release, Table D-1 indicates that the estimated  
4 Curie inventory is expected to range from 0.2 to 549 Curies, over all regulatory options. Because  
5 the collective dose is proportional to the total radioactivity amount available for potential  
6 exposures, it also would be expected to be small.

7  
8 The analysis included the possibility that some small amounts of ferrous scrap could be released  
9 after decontamination, based on operating experience with power reactors. For this to occur, the  
10 initial contamination levels would have to be relatively low and the decontamination factor high  
11 enough in order to meet release criteria. An item, such as a steam generator shell, might be  
12 considered worth decontaminating by licensees, given that such services are already available  
13 commercially. Generally a decontamination factor (DF) of around 10 is what is considered  
14 realistic, although some higher DFs can be achieved in limited specific cases. It is expected,  
15 from the aspect of implementation and cost concerns, that generally, based on process  
16 knowledge, only those contaminated materials that were within the DF range of 10 would be  
17 considered for decontamination. For such cases, it would be expected that any clean material of  
18 this type would be in the very low to none range of radioactivity concentration, and could be  
19 added to the clearance inventory.

## 20 21 **5. Collective Doses Associated with Materials Other than those Modeled for** 22 **Commercial Nuclear Power Plants**

23  
24 In addition to the release of ferrous metal, concrete, and trash from commercial nuclear power  
25 plants, the release of trash and other materials were analyzed for other types of NRC and/or  
26 Agreement State licensees. Also, the release of copper and aluminum from nuclear power plants  
27 was analyzed. Each of these analyses was performed via a screening (or bounding) calculation  
28 that compared the calculated mass and activity of material being analyzed to the mass and  
29 activity of ferrous metal, concrete, and trash from commercial nuclear power plants. The results  
30 of these scoping analyses are summarized below.

31  
32 The development of a reference PWR nuclear power plant revealed that the masses of potentially  
33 clearable copper and aluminum were very small. (The best data for the analysis were from PWR  
34 ferrous metals inventory; BWRs were included via scaling factors.) The analysis also showed  
35 that the incremental radioactivity in releasable copper as compared to ferrous metals released  
36 under Case A was less than 7 percent for the 1 mrem/yr dose option. Similarly, the incremental  
37 radioactivity in aluminum released as compared to ferrous metals released under Case A was less  
38 than 0.5 percent for the 1 mrem/yr dose option. The total collective dose is directly proportional  
39 to the curie content of the released material. Because the addition of the copper's total  
40 radioactivity content is a small percent of the ferrous metal's (7 percent increment), it only has a  
41 small contributing effect to the total collective dose. The incremental increases for copper and  
42 aluminum are within the uncertainty bound of the analysis, and thus were not explicitly included  
43 in the Monte Carlo collective dose calculations but were included in the scoping analyses.

44  
45 It was estimated that the total mass of potentially clearable trash generated by academic,  
46 industrial, government, and other unidentified sources would be about 13.4 times the mass

1 generated by nuclear utilities. However, the activity contained in the much larger volume of the  
2 potentially clearable trash from these other licensees was calculated to be 40 percent of the  
3 activity in clearable trash from nuclear utility licensees. This increase in releasable activity was  
4 not included in the Monte Carlo collective dose calculations but was included in the scoping  
5 analyses and derivation of collective doses.  
6

7 Other nuclear fuel cycle facilities that were analyzed include fuel fabrication facilities, uranium  
8 hexafluoride production facilities, and independent spent fuel storage installations (ISFSI). The  
9 bounding analysis for fuel fabrication facilities shows that exclusion of these facilities  
10 understates the total quantity of radioactivity in released ferrous metals by 3 percent for the 10  
11 mrem/yr dose option, 0.2 percent for the 1 mrem/yr dose option, and has no effect on the  
12 remaining three dose options. Also, during the recycling of ferrous metals, uranium and physio-  
13 chemically-similar elements, such as zirconium and tungsten, especially with respect to their high  
14 refractory properties, partition to the slag and do not contribute to the collective dose in steel  
15 end-use products, such as automobiles and structural steel in buildings. For concrete, the impact  
16 of excluding fuel fabrication facilities on the quantity of radioactivity in released concrete varies  
17 from 6 percent for the zero above background dose option to 0.6 percent for the 10 mrem/yr dose  
18 option. The exclusion does not affect the no action results for concrete. Similar results were  
19 found from the bounding analyses of the other nuclear fuel cycle facilities.  
20

21 Non-nuclear fuel cycle facilities that were analyzed include non-power reactors and medical  
22 centers. For non-power reactors, it was found that the radioactivity levels in released steel and  
23 concrete from all such reactors are very low — a maximum of 0.9 mCi for steel and 12 mCi for  
24 concrete for the 10 mrem/yr steel dose option. These quantities of radioactivity would not affect  
25 the collective dose results calculated elsewhere in the collective dose report (SC&A 2003) to any  
26 measurable degree.  
27

28 The results of the screening analysis for medical centers revealed that the potential volume of  
29 material produced each year by all medical facilities in the U.S. that could be impacted by an  
30 NRC rulemaking addressing release could be as high as 38,000 tons/yr for the prohibition  
31 alternative (because such licensees could find it more feasible to disposition all materials as  
32 prohibited), and the radionuclide inventory in this material is about 1.3 mCi of tritium and 17  
33 mCi of C-14. An upper-bound estimate of the potential collective doses associated with the  
34 release of this material showed that the collective dose from potentially released tritium in trash  
35 from impacted areas of all medical facilities in the U.S. would be <1 person-rem/yr, and the  
36 collective dose from the ingestion of released C-14 would be about 3.3 person-rem/yr. The  
37 actual collective doses are expected to be a very small fraction of these upper-bound values. For  
38 comparison to the calculated collective dose due to nuclear power reactor licensee operation and  
39 decommissioning, the values in Table 5.31 of the collective dose report (SC&A 2003) should be  
40 compared to the Case A collective doses reported in Table D-3.  
41

## 42 **6. Screening of Scenarios**

43  
44 There is a large number of potential exposure scenarios that could be used to evaluate the  
45 collective dose to the general public from the release of ferrous metal scrap and concrete rubble  
46 from NRC- or Agreement State-licensed facilities. A series of screening analyses was performed

1 to eliminate scenarios that would not make a significant contribution to the total collective dose.  
2 These scenarios were selected from the radiological assessments of individuals exposed to  
3 materials released from nuclear facilities as presented in NUREG-1640 and in an earlier EPA  
4 study (Anigstein et al. 2001). Also included were five additional scenarios characterizing the  
5 population exposures to finished steel products.  
6

7 The aim of the analyses was to calculate the collective doses from the release of 1 kt of released  
8 material with a total specific activity of 1 Bq/g, comprising the mix of radionuclides found in  
9 releasable material. These normalized collective doses were then ranked in decreasing order and  
10 the cumulative collective doses were tabulated. The results of the screening analyses show that,  
11 in the case of ferrous metal scrap, only five scenarios, all depicting population exposures to  
12 finished steel products, would make significant contributions to the total collective dose. In the  
13 case of concrete rubble, only the road use scenario plays a significant role in the collective dose  
14 analysis.  
15

16 These screening analyses address most of the exposure scenarios described in NUREG-1640.  
17 Not included in the screening analysis are the scenarios characterizing the consumption of water  
18 from wells and surface runoff infiltrated by leachate from landfills or storage piles. These  
19 scenarios, which do not readily lend themselves to the deterministic screening analyses applied to  
20 the other scenarios, are addressed by the main collective dose analysis described in Section 10.  
21 Another class of scenarios omitted from the screening analyses is the population exposures from  
22 passing trucks carrying released materials. These scenarios are addressed by the main analysis in  
23 Section 10.  
24

## 25 **7. Collective Radiation Exposures to Workers Implementing the Rulemaking** 26 **Alternatives at Light-Water Reactors** 27

28 Two major activities need to be accomplished by radiation workers at licensed facilities when  
29 releasing material: (1) the performance of surveys; and (2) the decontamination of material to  
30 meet acceptable limits if the licensees elect to perform decontamination activities in support of  
31 release (some licensees may deem it not cost-effective to perform any decontamination activities  
32 for the purpose of material release).  
33

34 The analysis of these major activities reveals that the collective exposures from surveying the  
35 entire inventory of releasable ferrous metals, trash, and concrete material for release following  
36 the Multi-Agency Radiation Survey and Site Manual (MARSSIM) (NRC 1997a) approach would  
37 be about 290 person-rem for the entire population of PWRs and BWRs. The overwhelming  
38 majority of this collective dose is due to surveys for trash because of the large surface area to  
39 volume ratio of trash, as compared to concrete and steel.  
40

41 The collective exposure estimates are highly dependent on two variables, the exposure rate and  
42 unit survey effort. If the material is surveyed in place, where exposures could come from a  
43 variety of structures and sources other than the released material, then exposure rates could be  
44 higher by at least a factor of 10. If the potentially clearable material is removed from other  
45 sources of radioactivity, and the release levels are lower than Regulatory Guide 1.86 levels, then  
46 the exposure rates will likely be less than 0.005 mrem/hr above background. Conversations with

1 representatives of the nuclear power industry reveal that, during the license termination process,  
2 the potentially clearable material would be segregated from the more contaminated areas and  
3 placed in low background areas so that the material could be surveyed with the lowest possible  
4 limits of detection. Accordingly, a radiation field of 0.005 mrem/hr above natural background  
5 (as used in this analysis) is consistent with this strategy and consistent with the types of radiation  
6 fields that may be expected from the material that is being surveyed.  
7

8 In theory, the level of effort required to perform surveys would be expected to increase as the  
9 release level is reduced. However, investigations currently being performed by the NRC reveal  
10 that, with the exception of the zero above background dose option, the level of effort to perform  
11 surveys (for the radionuclide mix of concern at light water reactors) is expected to be  
12 approximately the same for all alternatives; i.e., about 3 minutes per square meter surveyed using  
13 conventional pancake probe survey techniques.  
14

15 The collective exposures to workers performing decontamination in support of release is  
16 anticipated to be higher than the exposures from surveys, because decontamination activities are  
17 anticipated to be performed in more highly contaminated areas and require a greater level of  
18 effort per ton of material undergoing release. Estimates of collective dose associated with  
19 decontamination activities in support of release during operations and license termination is  
20 about 300 person-rem to decontaminate steel in the population of PWRs or BWRs. The  
21 estimated exposure rates and labor hours used in this estimate depend on assumptions regarding  
22 how decontamination is performed.  
23

24 The results are unaffected by the rulemaking alternative, because it is assumed that the level of  
25 effort required to decontaminate the material to the release objective is the same for all  
26 rulemaking alternatives. This may not be the case for the very low dose options, such as the  
27 0.1 mrem/yr alternative and the zero above background dose option. If it is determined that the  
28 level of effort required to achieve these criteria is twice as high, then the collective dose would  
29 double. In addition, if it is deemed plausible to decontaminate material that is up to 500,000  
30 dpm/100 cm<sup>2</sup> (i.e., 100 times the limit set by Regulatory Guide 1.86 for Co-60), it is plausible  
31 that the radiation field in the vicinity of the decontamination operations could increase by a factor  
32 of 10 to 0.5 mrem/hr, thereby potentially increasing the collective dose by a factor of 10.  
33

## 34 **8. Radiation Doses to Workers Due to the Disposal of Releasable Materials at Licensed** 35 **Low-Level Radioactive Waste Disposal Facilities** 36

37 A scoping calculation of the collective doses to radiation workers at licensed LLW disposal  
38 facilities due to the licensed disposal of all potentially clearable material was performed. The  
39 approach used took advantage of the large amount of data that has been compiled on actual  
40 collective doses to radiation workers at LLW facilities, along with data characterizing the  
41 quantities of radioactive materials disposed. These data were used to derive empirically  
42 determined normalized collective doses to this population group expressed in terms of person-  
43 rem per curie disposed. This value was then multiplied by the total radionuclide inventory  
44 contained in potentially clearable material to derive the collective dose. In performing these  
45 calculations, C-14 and H-3 were not included in the analyses, since these radionuclides are large  
46 contributors to the number of curies disposed at LLW facilities, but do not contribute to the

1 collective doses to workers. The results reveal that the collective dose to this population group  
2 from the licensed disposal of all potentially clearable material (as may be the case under a  
3 prohibition alternative) is less than 1 person-rem.  
4

5 Because of the incrementally small quantities of radionuclides disposed at licensed facilities  
6 associated with release, as compared to the quantity of radionuclides currently being disposed,  
7 and the fact that the current doses to the nearby populations are a small fraction of the regulatory  
8 standards for offsite exposures set forth in 10 CFR 61 (i.e., 25 mrem/yr (0.25 mSv/yr)), a  
9 separate analysis of offsite exposures in the vicinity of LLW disposal facilities associated with  
10 release was not considered necessary and is not provided.  
11

## 12 **9. Collective Doses to Members of the Public from Recycling and Reuse of Released** 13 **Material**

14  
15 Following release, residual activities in the released material will travel a complex route until  
16 final disposal in a landfill or until the radionuclides decay to stable forms. Along the way, some  
17 individuals will receive some degree of exposure to the radionuclides in the released material.  
18 The exposure scenarios and levels of exposure will vary by radionuclide and the type of released  
19 material (i.e., steel, copper, aluminum, concrete, and trash). This section divides the exposed  
20 population into population groups within which the individual members are anticipated to  
21 experience similar exposure from the released material. In this way, the collective doses to each  
22 population group could be estimated as the product of the average dose rate (i.e., rem/hr) to the  
23 members of each population group times the collective number of person hours of exposure in  
24 the population group.  
25

26 The potential exposure scenarios vary depending on the type of material released, i.e., metal,  
27 concrete, or trash. For metal, the material is assumed to be either recycled or disposed of, as  
28 shown on Figure D-1. If it is recycled, then the potential exposure scenarios involve:  
29 (1) transportation of the material, (2) use of the products produced from the material, (3) the  
30 population surrounding the mill due to air emissions from the mill, (4) use of the slag (as road  
31 beds, and people traveling on those roads), and (5) disposal of the dust produced at the mill, as  
32 shown on the right side of Figure D-1. If the metal is disposed of in a landfill, it is assumed that  
33 it would be transported directly to the landfill, and the only exposures would be during transport  
34 and due to leaching of the material from the landfill, as shown on the left side of Figure D-1. As  
35 demonstrated by the scoping analysis, doses to workers along the released material's path (i.e.,  
36 truck drivers, mill workers, landfill workers, road builders, etc.) do not contribute significantly to  
37 the collective dose, and are therefore not modeled.  
38

39 Similar to Figure D-1 for metal, Figures D-2 and D-3 show the scenarios that are included in the  
40 collective dose model for the release of concrete and trash, respectively. Note that the section  
41 numbers indicated in Figures D-1 through D-3 refer to sections of the collective dose report  
42 (SC&A 2003).  
43  
44

1 Collective dose models were developed, and are described in detail in the report, for each of the  
2 exposure scenarios depicted in Figures D-1 through D-3, as follows:  
3

- 4 • Exposures to Finished Steel Products
  - 5 - Beds
  - 6 - Automobiles
  - 7 - Office Buildings
  - 8 - Office Furniture
  - 9 - Home Appliances
- 10
- 11 • Exposures Due to Disposal of Released Material in a Landfill
  - 12 - Municipal Landfills
  - 13 - Industrial Landfills
- 14
- 15 • Exposures to Released Material Used in Road Construction
  - 16 - Concrete
  - 17 - Slag from Steel Mills
- 18
- 19 • Exposures to Airborne Releases
  - 20 - Steel Mill
  - 21 - Incinerator
- 22
- 23 • Exposures During Transportation
  - 24 - To Steel Mill
  - 25 - To Landfill
  - 26 - To Incinerator
  - 27 - To Road Construction Site

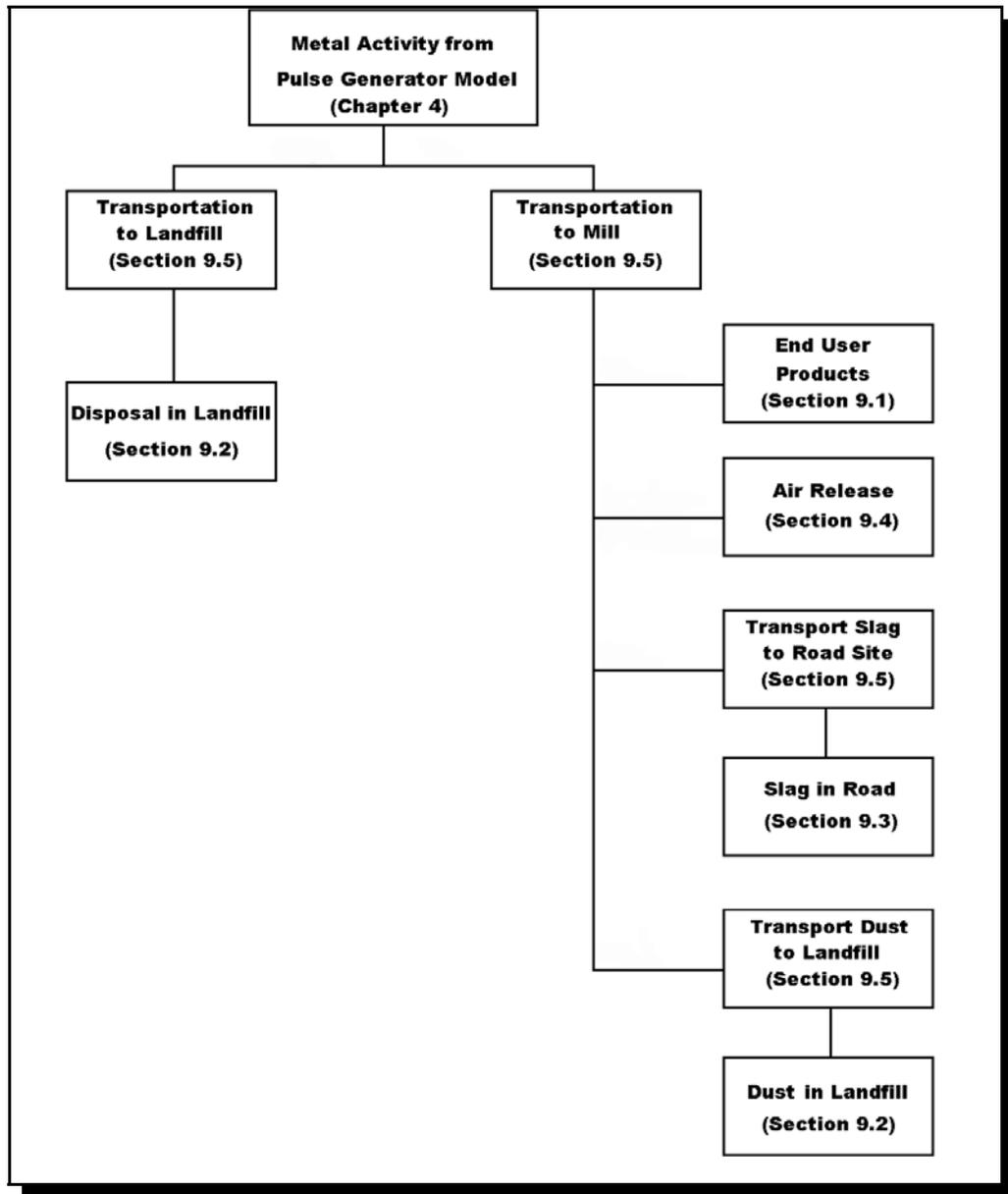


Figure D-1 Integrated Released Metal Collective Dose Model

1  
2

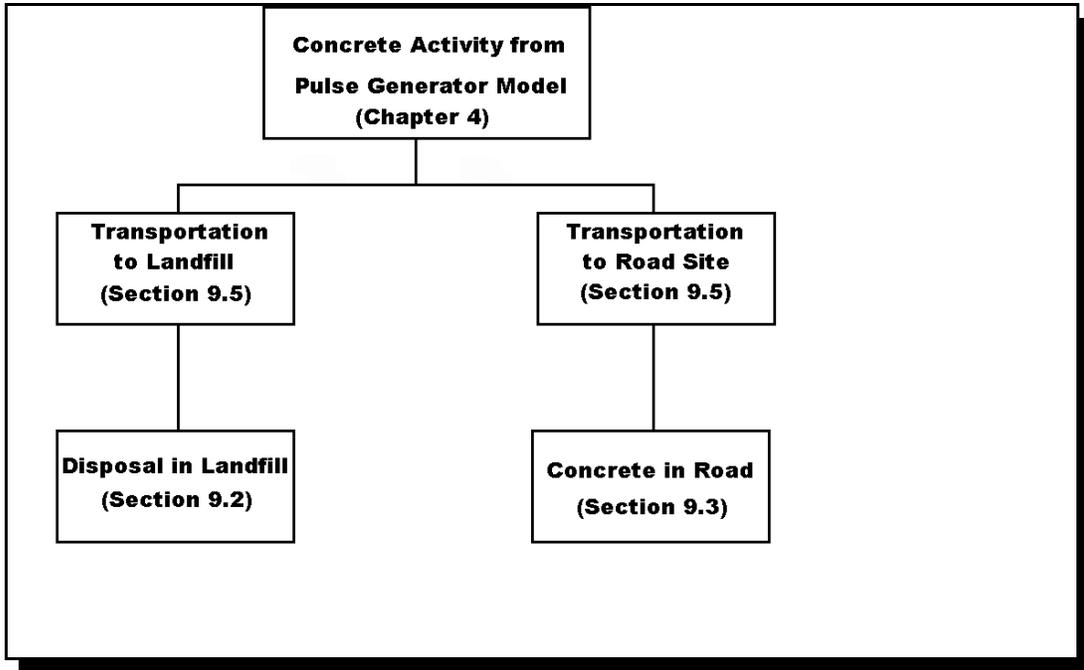


Figure D-2 Integrated Released Concrete Collective Dose Model

1  
2

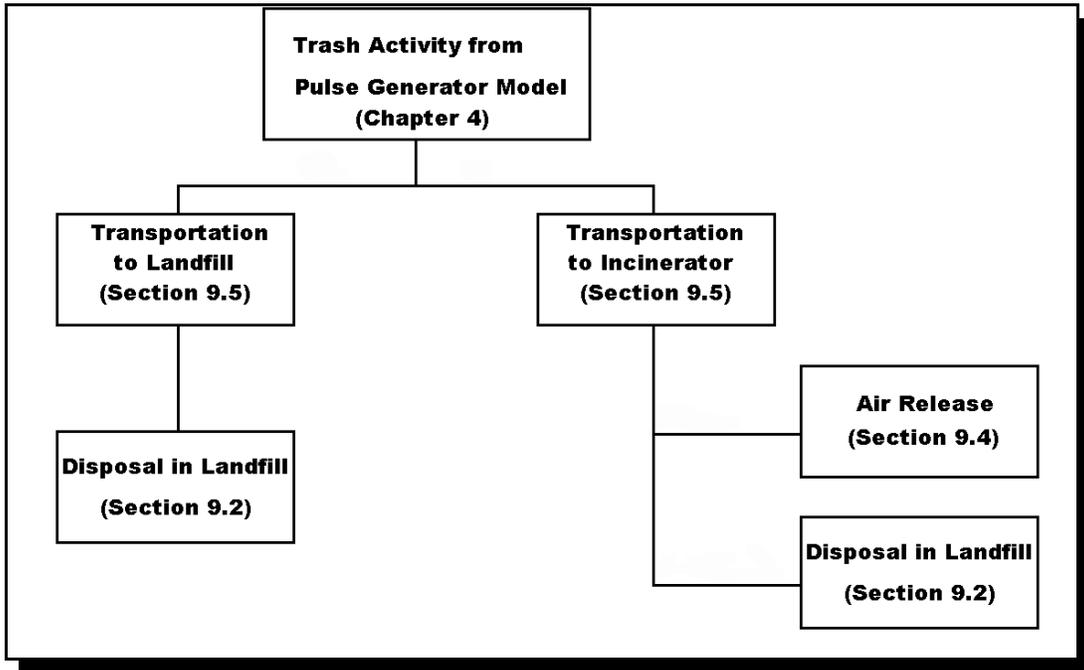


Figure D-3 Integrated Released Trash Collective Dose Model

**9.1 External Collective Doses**

For discussion purposes, the general form of the equation used to calculate the collective dose due to external exposure from radioactivity in released materials is presented:

$$D_{n,i,ext} = E_i O_i DF_{n,i} A_{n,i} \frac{1 - e^{-\lambda_n t}}{\lambda_n} e^{-\lambda_n t} \tag{D-1}$$

where:

- $D_{n,i,ext}$  = collective dose from radionuclide n and product i (person-rem)
- $E_i$  = average exposure duration to product i (hr/yr)
- $O_i$  = average occupancy/usage of product i (people)
- $DF_{n,i}$  = external collective dose factor for radionuclide n and product i (rem/hr per Ci)
- $A_{n,i}$  = activity of radionuclide n that is present in product i (Ci)
- = integrating factor over a one year period for radionuclide n
- $\lambda_n$  = radiological decay constant for radionuclide n (yr<sup>-1</sup>)
- t = time after release when exposure occurs (yrs)

To calculate the total collective dose, the terms in Equation D-1 would need to be evaluated for each specific case and summed over all cases for each of the times, products, radionuclides, and licensees.

One of the keys to evaluating the terms in Equation D-1 is to identify or calculate the appropriate values for the various parameters. The EPA’s Exposure Factors Handbook (EPA 1987) was used as the primary source of most of the exposure duration data. The occupancy factors came from various sources, depending on which type of product was being modeled. For example, the occupancy factor for automobiles was taken from the 1995 Edition of “Nationwide Personal Transportation Survey.” (DOT 1997)

Perhaps the most important parameter is the product-specific dose factor ( $DF_{n,i}$ ). In short, single reference products were developed for each type of end product (including their mass and geometry) and the MCNP computer program was used to calculate dose factors for each reference product. See Sections 9.1.2 through 9.1.7 of the collective dose report (SC&A 2003) for the specifics of how the dose factors were developed for each end-use product.

**9.2 Collective Doses Due to Food**

The general form of the equation used to calculate the collective dose due to the consumption of food and water containing residual radioactivity from released material is:

$$D_{n,i,ing} = DF_n A_{n,i} e^{-\lambda_n t} \tag{D-2}$$

where:

- $D_{n,i,ing}$  = collective dose from radionuclide n and product i (person-rem),
- $DF_n$  = ingestion dose conversion factor for radionuclide n (rem/Ci),



1 population. Also, even those radionuclides with long half-lives that travel relatively fast through  
 2 the unsaturated zone (e.g., I-129 and C-14) take more than the 250 years to reach the accessible  
 3 environment, which is the maximum assessment period of the analysis (SC&A 2003). The  
 4 contribution of the longer-lived radionuclides beyond 250 years is a very small fraction of the  
 5 total collective dose associated with all radionuclides.

6  
 7 Case C2 used the same activity release distribution as calculated for Case C, but assumed that all  
 8 trash would first be sent to an incinerator, with the resulting ash and any air pollution control  
 9 device media being sent to a landfill (i.e., any activity that is not released via the stack of the  
 10 incinerator was assumed to go to a landfill). Comparing the Case C2 to Case C collective doses  
 11 in Table D-3 shows that the portion of the released activity that escapes the incinerator's air  
 12 pollution control device results in exposures that are about three orders of magnitude higher than  
 13 if the released activity is sent directly to a landfill.

14  
 15 As with the activity and mass results, additional details regarding the calculated collective doses  
 16 resulting from material being released are provided in the collective dose report (SC&A 2003),  
 17 including a breakdown that provides the mean, standard deviation, median, 5<sup>th</sup> percentile and 95<sup>th</sup>  
 18 percentile values annually for each material type, regulatory option, case analyzed, and year of  
 19 the analysis.

20  
 21 **Table D-3 Mean Collective Dose Results (person-rem)**

Case ID	Regulatory Options				
	0.03 mrem/yr	0.1 mrem/yr	1 mrem/yr	10 mrem/yr	No Action
<b>All Material</b>					
Case A	2.07E+02	8.88E+02	6.40E+03	2.84E+04	3.93E+03
Case B	2.16E+01	1.13E+02	1.68E+03	9.68E+03	3.93E+03
Case C	1.20E-01	3.46E-01	1.70E+00	6.43E+00	3.78E-01
Case C2	1.62E+01	7.01E+01	1.01E+03	1.44E+04	6.35E+01
Case D	5.29E-02	1.69E-01	1.01E+00	4.82E+00	3.78E-01
<b>Ferrous Metal</b>					
Case A	2.05E+02	8.81E+02	6.38E+03	2.84E+04	3.92E+03
Case B	1.88E+01	1.07E+02	1.66E+03	9.65E+03	3.92E+03
Case C	9.42E-02	2.84E-01	1.38E+00	4.63E+00	3.43E-01
Case C2	9.42E-02	2.84E-01	1.38E+00	4.63E+00	3.43E-01
Case D	2.70E-02	1.07E-01	6.86E-01	3.02E+00	3.43E-01
<b>Concrete</b>					
Case A	2.76E+00	6.54E+00	2.39E+01	2.78E+01	3.91E+00
Case B	2.76E+00	6.54E+00	2.39E+01	2.78E+01	3.91E+00
Case C	2.41E-02	5.53E-02	2.00E-01	2.09E-01	2.92E-02
Case C2	2.41E-02	5.53E-02	2.00E-01	2.09E-01	2.92E-02
Case D	2.41E-02	5.53E-02	2.00E-01	2.09E-01	2.92E-02

**Table D-3 Mean Collective Dose Results (person-rem)  
(continued)**

Case ID	Regulatory Options				
	0.03 mrem/yr	0.1 mrem/yr	1 mrem/yr	10 mrem/yr	No Action
	<b>Trash</b>				
Case A	1.77E-03	6.90E-03	1.24E-01	1.58E+00	6.60E-03
Case B	2.71E-08	1.49E-07	4.75E-06	1.19E-04	6.60E-03
Case C	1.77E-03	6.90E-03	1.24E-01	1.58E+00	6.60E-03
Case C2	1.60E+01	6.98E+01	1.01E+03	1.44E+04	6.31E+01
Case D	1.77E-03	6.90E-03	1.24E-01	1.58E+00	6.60E-03

## 11. Collective Doses for IAEA RS-G-1.7 Clearance Levels

This section addresses collective doses for the IAEA clearance levels, which were published in Radiation Safety Guide No. RS-G-1.7 (IAEA 2004). As was described earlier, all collective doses were initially derived using release levels from NUREG-1640 and its supplement on trash (NRC 2003c, 2005c). The IAEA clearance levels are based on a deterministic analysis, while NUREG-1640 release levels were developed using a Monte Carlo method. As is noted earlier, the Draft GEIS focuses on impacts associated with materials that are expected to be released from nuclear power plants. As a result, radionuclide distributions and their relative fractions (mix) reflect those commonly found at both pressurized and boiling water reactors. Because the amounts of materials expected to be released from nuclear power plants are dominant, the Draft GEIS assumes that impacts associated with such releases are bounding and envelope those of other types of licensees.

The derivation of collective doses based on IAEA clearance levels relies on the application of adjustment factors to scale the collective doses derived from NUREG-1640. The adjustment factors take into consideration differences between the release levels of NUREG-1640 and clearance levels of the IAEA safety guide. The adjustment factors were developed for each type of material considered in the Draft GEIS (metals, concrete, and trash). Two other methods were considered but rejected as the chosen method provides reasonable estimates of adjusted collective doses given the differences in the modeling approaches between NUREG-1640 and the IAEA safety guide and associated uncertainties in model assumptions and parameters. One method considered the use of a qualitative analysis, where the discussions would address only the direction and magnitude of changes in collective doses by comparing the release and clearance levels of the most commonly found radionuclides (e.g., C-14, Co-60, Sr-90, or Cs-137). This method was not used because it does not offer the means to quantify differences in collective doses. Another method considered a series of duplicate Monte Carlo analyses of all collective doses by applying the IAEA clearance levels without using any information from NUREG-1640. This method was rejected because of the necessity to develop probability distribution functions for the assumptions and parameters used in the IAEA deterministic analysis.

The development of the adjustment factors is based on a procedure described in MARSSIM (NUREG-1575, Sect. 4.3.4, p.4-9 (NRC 2001)). The procedure involves deriving a gross activity concentration,  $C_{ga}$ , taking into account the release or clearance level of each radionuclide

1 assumed to be present in each type of material and their relative fractions (SC&A 2003). The  
 2 expression is:

3  
 4 
$$C_{ga} = 1 / [(f_1/CL_1) + (f_2/CL_2) + \dots + (f_n/CL_n)]$$

5  
 6  $C_{ga}$  = gross activity concentration of the radionuclide mix, given the relative fraction of  
 7 each radionuclide and IAEA clearance or NUREG-1640 release level, pCi/g

8  $CL_i$  = clearance or release level, pCi/g, for radionuclide i, for a given dose, and relative  
 9 fraction  $f_n$

10  $f_n$  = radionuclide fraction, unitless

11  
 12 The calculation is performed twice, once for NUREG-1640 release levels, and again for the  
 13 clearance levels of IAEA RS-G-1.7. The resulting gross activity concentrations are compared  
 14 and ratioed to derive an adjustment factor, as follows:

15  
 16 
$$AF = C_{ga, IAEA} / C_{ga, NUREG-1640}$$

17  
 18 As derived using NUREG-1640, the collective doses are best estimates, based on a Monte Carlo  
 19 analysis, and, consequently, the results reflect uncertainties associated with the statistical  
 20 distributions of model parameters, including radionuclide mix. For example, it is known that the  
 21 distribution of radionuclides and their relative mix would vary among nuclear power plants. At  
 22 some power plants, Cs-137 may be more prevalent than Co-60, for instance. At other plants, the  
 23 opposite may be true given different operational histories. A limited sensitivity analysis was  
 24 conducted to assess differences in adjustment factors when changes are made to the radionuclide  
 25 mix. Of the 17 radionuclides making up the mix used in the collective dose analysis, three  
 26 comprise nearly 80% of the activity; they are Fe-55, Co-60, and Cs-137. New adjustment factors  
 27 were derived for the entire distribution of 17 radionuclides by interchanging the relative fractions  
 28 of these three radionuclides. These changes mimic alternate conditions where the relative mix  
 29 may be different.

30  
 31 Table D-4 presents the resulting changes in gross activity concentrations and corresponding  
 32 adjustment factors. A review indicates that the resulting adjustment factors vary from 1.2 to 2.3  
 33 over all four cases, with an average of  $1.9 \pm 0.5$ . For the three alternate cases, the adjustment  
 34 factors vary from 1.2 to 2.2, with an average of  $1.7 \pm 0.5$ . The results indicate that changes up to  
 35 a factor of three in the relative mix (0.46/0.15) yield lower adjustment factors than the base case.  
 36 Lower adjustment factors imply that collective doses normalized to RS-G-1.7 clearance levels  
 37 would be in closer agreement to those derived using the release levels of NUREG-1640.

38  
 39 In light of the above discussions, the uncertainties associated with collective doses derived using  
 40 NUREG-1640 release levels are not translatable with the adjustment factors developed herein.  
 41 As a result, collective doses representing IAEA clearance levels are assumed to be best single  
 42 estimates, given the lack of information on the derivation of the IAEA clearance levels.

**Table D-4 Adjustment Factors Versus Changes in Relative Mix of Three Radionuclides**

Parameters	Radionuclide Mix			
	Base Case	Case 1	Case 2	Case 3
Fe-55	0.18	0.18	0.46	0.15
Co-60	0.46	0.15	0.18	0.46
Cs-137	0.15	0.46	0.15	0.18
RS-G-1.7 gross activity concentration (pCi/g)	3.8	3.8	6.3	3.7
NUREG-1640 gross activity concentration (pCi/g)	1.7	3.1	3.5	1.7
Adjustment factor (RS-G-1.7 / NUREG-1640)	2.3	1.2	1.8	2.2
Ratio of adjustment factors to the base case	1	0.52	0.78	0.96

Table D-5 summarizes the results and presents the adjustment factors for each material (concrete, steel, and trash) and a material independent case. A review of the results reveals some differences in adjustment factors, with NUREG-1640 and RS-G-1.7 being alternatively more limiting depending on the type of material. For concrete, the results indicate that RS-G-1.7 yields a more liberal gross activity concentration (3.8 pCi/g), while NUREG-1640 is more permissive for steel (9.1 pCi/g) and trash (4,070 pCi/g). For the material independent case, NUREG-1640 is limiting at 1.7 pCi/g. The adjustment factors for concrete and the material independent case are identical. This is because the material independent case is based on the most limiting clearance levels, which are those assigned to concrete. It should be noted that the results for trash are not directly comparable as RS-G-1.7 does not address materials that fit the definition of trash generated by nuclear power plants. Accordingly, the adjustment factor for trash is arbitrarily assigned to unity. In addition, the adjustment factor for concrete is rounded off since the method used and the data do not provide this level of precision.

**Table D-5 Derived and Applied IAEA RS-G-1.7 and NUREG-1640 Adjustment Factors**

Case	Concrete	Ferrous Metals	Trash	Material Independent
RS-G-1.7 gross activity concentration (pCi/g)	3.8	3.8	3.8	3.8
NUREG-1640 gross activity concentration (pCi/g)	1.7	9.1	4,070	1.7
Derived adjustment factors (RS-G-1.7 / NUREG-1640)	2.3	0.4	0.001	2.3
Limiting case	NUREG-1640	RS-G-1.7	RS-G-1.7	NUREG-1640
Applied adjustment factors	2	0.4	1	2

The adjustment factors are used to scale the collective doses generated with the release levels of NUREG-1640. The results imply that RS-G-1.7 collective doses for concrete are expected to be higher than that of NUREG-1640 release levels by a factor of about two. An adjustment factor of two is assigned to the case illustrating releases of material based on the most restrictive release criteria (i.e., material independent case). However, collective doses for ferrous metals, based on

1 RS-G-1.7 clearance levels, are expected to be lower by a factor of about 0.4. For trash, collective  
2 doses are assumed to be identical since an adjustment factor of one was arbitrarily assigned to  
3 trash.  
4

## 5 **12. Collective Doses Associated with the Reuse of Equipment**

6

7 Collective doses associated with the reuse of equipment were evaluated for two categories of  
8 equipment, large and small. The approach used in estimating collective doses relies on a scoping  
9 analysis as practices associated with the reuse of equipment are known to be highly variable.  
10 For example, it is known that different types of equipment and tools are used in radiologically  
11 controlled areas and later taken out. The types of equipment that could be potentially released  
12 from nuclear facilities for reuse in an environment free of radiological controls ranges from  
13 small items, such as hand tools, to very large ones, such as mechanized equipment and industrial  
14 vehicles. The following are examples of potentially reusable equipment, tools, and  
15 miscellaneous items:  
16

- 17 • small hand tools (wrenches, screw drivers, etc.) and power tools (drills, saws, etc.)
- 18
- 19 • electrical equipment, such as control panels, motors, pumps, and generators
- 20
- 21 • office furniture (desks, chairs, filing cabinets, etc.) and office equipment (copiers, computers,  
22 printers, fax machines, etc.)
- 23
- 24 • construction equipment, such as scaffolding, noise or dust-control barriers, wheelbarrows,  
25 etc.
- 26
- 27 • mechanized equipment, such as trucks, backhoes, bulldozers, and other vehicles
- 28
- 29 • materials and supplies for use in their original forms, but taken out as excess, such as piping,  
30 tubing, electrical wiring, floor covering, ductwork, sheet metal, pipe hangers, light fixtures,  
31 wall board, and sheet glass.  
32

33 It should be noted that these examples are assumed to characterize as well the profile of  
34 equipment, tools, and miscellaneous items that may be released by other types of licensees.  
35

36 It is recognized that the release of equipment is an extremely dynamic process involving different  
37 types of facilities and activities, such as routine operations, research and development, major and  
38 minor power plant outages, refurbishment, decommissioning, etc. In addition, this process is  
39 taking place simultaneously at thousands of facilities across the nation and conducted every hour  
40 of the day and every day of the week. As a result, it is not possible to define what types of  
41 objects and how many are routinely used in radiologically controlled areas, and what fraction is  
42 surveyed and released for reuse *versus* those that are discarded as LLW.  
43

44 As is noted earlier, the GEIS focuses on impacts associated with materials that are expected to be  
45 released from nuclear power plants. As a result, radionuclide distributions and their relative  
46 fractions reflect those commonly found at both pressurized and boiling water reactors. Because

1 the amounts of equipment and tools being routinely released from nuclear power plants are  
2 dominant, the GEIS assumes that impacts associated with such releases are bounding and  
3 envelope those of other types of licensees.  
4

5 In practice, equipment and tools are surveyed before being taken out of radiologically controlled  
6 areas. The survey consists of conducting a scan with a portable radiation survey meter (e.g., gas  
7 flow proportional detector) and taking wipes to assess the presence of removable surface  
8 activity. The presence of radioactivity on wipes is evaluated using separate instrumentation  
9 (e.g., bench top beta or alpha particle counter). Some survey methods involve the introduction  
10 of the item into an instrument (e.g., gamma tool monitor) that measures radioactivity *in toto* from  
11 all external and internal surfaces. Depending on the results of the survey, the items are either  
12 cleaned to meet release criteria, not taken out of the controlled area and set aside for later use in  
13 the same work area, or simply discarded as LLW. Together, these ALARA practices are  
14 expected to mitigate the presence of residual radioactivity on released items and should result in  
15 residual levels that are well below release criteria.  
16

17 Dose factors and their corresponding release levels, for both large and medium-sized equipment,  
18 were taken from the NUREG-1640 Supplement on Reuse (NRC 2005d). In addition, the analysis  
19 includes the clearance criteria approved by the International Atomic Energy Agency (IAEA) in  
20 "Radiation Safety Guide RS-G-1.7" (IAEA 2004). Since the IAEA criteria present only  
21 volumetric clearance levels, surficial clearance levels were derived by applying a mass-to-surface  
22 ratio (from NUREG-1640) to the IAEA clearance levels (NRC 2003d). This aspect is discussed  
23 later. The case addressing the No Action Alternative (status quo) assumes that current practices  
24 result in an annual dose of about 1 mrem. This is because the release level of 6,980 dpm/100  
25 cm<sup>2</sup>, derived for Co-60 and small equipment, is not much different than the 5,000 dpm/100 cm<sup>2</sup>  
26 limit defining current practices, i.e., both yield an annual dose of about 1 mrem (see discussion  
27 in Appendix B discussing current practices). However, for large equipment with a limit of 600  
28 dpm/100 cm<sup>2</sup>, the difference is attributed to the scenario developed in the Supplement to  
29 NUREG-1640 (NRC 2005d). This scenario considers a driver in a cab of a vehicle with all  
30 internal surfaces having residual radioactivity levels at the release criteria for Co-60.  
31

32 Given that no specific information is available on the type of equipment that might be released  
33 for reuse and the frequency of their reuse, the analysis applies broad assumptions in estimating  
34 collective doses. The dose factors developed for the file cabinet are assumed to be representative  
35 of medium-sized equipment, such as bookcases, lockers, tool cabinets, outer cases of welding  
36 machines, work benches, and other objects with similar geometries, dimensions, and surface  
37 areas. In addition, the dose factors derived for the file cabinet are assigned to hand tools and  
38 other similar small objects. This approach is deemed to be generically appropriate because it  
39 relies on the full range of exposure pathways (i.e., external, inhalation, and incidental ingestion)  
40 that workers would encounter while using smaller equipment, hand tools, and small items (NRC  
41 2005d). Another justification for this approach involves the difficulty in defining a  
42 representative set of items that would be typical of hand tools routinely subjected to release.  
43 Defining a representative set of hand tools would imply a degree of specificity that would be  
44 difficult to justify since alternate cases could be made with equally powerful technical arguments.  
45

1 Another complication revolves around defining the inventory of residual radioactivity associated  
2 with released equipment and materials. The inventory is directly proportional to the surface area  
3 ( $\text{cm}^2$ ) of each item and release level (dpm per  $100 \text{ cm}^2$  or  $\text{pCi}/\text{cm}^2$ ) for a given dose level. The  
4 product of the two would yield the inventory (dpm or  $\text{pCi}$ ). However, this is not a simple  
5 problem since first one would need to identify all types of equipment or items that might be  
6 released, and define the surface area of each item. The surface area is also difficult to determine.  
7 For example, should the area include all surfaces (external and internal) or just external? Are  
8 there areas that are inaccessible to the survey method but are suspected of having some residual  
9 levels of activity? How would one define the total surface of inaccessible areas? Should  
10 equipment or items characterized by complex physical configurations be released using only  
11 volumetric release levels? What fraction of equipment and items used by the nuclear industry  
12 could be considered complex in configuration? Given the lack of specific information in  
13 addressing these questions and associated uncertainties, even if they were answerable, the  
14 scoping analysis applies the release level as a surrogate for the inventory of residual radioactivity.  
15 For example, if one were to assume that  $3,000 \text{ dpm}/100 \text{ cm}^2$  were associated with an annual dose  
16 of 1 mrem, then it follows that  $300 \text{ dpm}/100 \text{ cm}^2$  would result in an annual dose of 0.1 mrem,  
17 other aspects being equal. This ratioing is applied to each dose level and its corresponding  
18 release level; thereby, leading to a comparison of collective doses relative to the 1 mrem dose  
19 option and its release level.  
20

21 In converting the volumetric IAEA criteria to surficial release levels, a mass-to-surface ratio is  
22 defined using the information presented in Appendix A to NUREG-1640 (NRC 2003d). In  
23 simple terms, the mass-to-surface ratio ( $\text{gram}/\text{cm}^2$ ) is defined as the total mass (grams) of an  
24 object divided by its total surface area ( $\text{cm}^2$ ), or equivalently, the product of the density and its  
25 effective thickness, i.e.,  $\text{gram}/\text{cm}^3 \times \text{cm}$ . A review of the data presented in NUREG-1640  
26 indicates that mass-to-surface ratios vary significantly, depending on the type of equipment or  
27 item. For equipment with complex configuration, one would expect that there may be portions  
28 of the equipment with different features, each with its own mass-to-surface ratio. For example, a  
29 tank might have four mass-to-surface ratios, one for the wall making up the body of the tank,  
30 another for access openings and connection flanges, another for its support skid, and a fourth one  
31 that is an overall average for all features of the tank. Table D-6 illustrates the variability of mass-  
32 to-surface ratios for some ferrous metal components found at typical power plants.  
33

34 A review indicates that ratios vary from about 2 to nearly  $80 \text{ g}/\text{cm}^2$ , with an overall average of  
35 about  $5 \text{ gm}/\text{cm}^2$  as being representative of both types of plants. It is recognized that there may  
36 be circumstances when mass-to-surface ratios will be different. For example, some types of  
37 ventilation ductwork may be built with a thinner gauge of sheet metal or a valve body may be  
38 made of cast iron with thicker walls, all resulting in different ratios than that listed here.  
39 However, such case-specific differences are not expected to yield a much different average as the  
40 associated amounts of metal for such extreme cases are expected to make up a small fraction of  
41 the total inventory of released ferrous metals. Accordingly, the value of  $5 \text{ gm}/\text{cm}^2$  is assumed to  
42 be a representative estimate for the purpose of bounding collective doses.  
43  
44

**Table D-6 Mass-to-Surface Ratios for Some Steel Components Found at Power Plants**

Item/Component	Minimum (gm/cm <sup>2</sup> )	Maximum (gm/cm <sup>2</sup> )	Average (gm/cm <sup>2</sup> )	Notes
Tanks				
BWR	2.2	54.3	9.8	
PWR	2.6	52.9	11.3	
Piping				
BWR	5	56.6	13	
PWR	2.5	27.6	6	
Rebars	1.9	11.3	5.4	Over 11 sizes
HVAC Ductwork				
BWR	--	--	1.3	Average
PWR	--	--	1.1	“ ”
Valves				
BWR	10.3	79.9	38	External surfaces only
PWR	10.3	63.2	29.5	“ ” “
Structural steel	3.8	21.9	10	Total surface area
Pipe hangers	1.8	19.9	7.5	Weighted average
Heat Exchangers				
BWR	--	--	2.5	Aggregate average
PWR	--	--	3.1	“ ”
Overall average				
BWR	--	--	4.5	Aggregate average
PWR	--	--	5.1	“ ”

In light of the lack of specific information, average collective doses were estimated using the following general expression:

$$D_{ave} = L (C_{RU}/C_{RL}) W K N_e IF_i D_i R^{-1} \quad \text{Eq. 1}$$

where:

- D<sub>ave</sub> = average collective dose, person-rem, with each nuclide at the release level
- L = dose limit, mrem/year, corresponding to release level, dpm/100 cm<sup>2</sup>, summed over all radionuclides I
- C<sub>RU</sub> = reuse release level, dpm/100 cm<sup>2</sup>, for dose limit, mrem/yr, summed over all radionuclides I
- C<sub>RL</sub> = reference release level, dpm/100 cm<sup>2</sup>, for reference dose limit of 1 mrem/yr, summed over all radionuclides I
- W = effective workforce assumed to reuse equipment, persons
- K = conversion factor, 10<sup>-3</sup> rem per mrem

- 1  $N_e$  = number of equipment or items assumed to be release and reused  
2  $IF_i$  = integrating factor for radionuclide I, integrated over useful life of equipment, yr  
3  $IF_i = [1 - \exp(-\lambda t_a)] / \lambda$ , where;  
4  $t_a$  = time of integration for assessment period, year  
5  $\lambda_i$  = decay constant for radionuclide, I  
6  $D_i$  = decay factor from time of release to beginning of assessment period, as defined  
7 below  
8  $D_i = \exp(-\lambda t_s)$ , where;  
9  $t_s$  = elapsed time from release to beginning of assessment period, year  
10  $R$  = activity profile adjustment factor, max-to-mean surface residual radioactivity  
11 levels, unitless  
12

13 The number of work-hours that workers are assumed to handle reused items is based on 2,080  
14 hours per year adjusted for the fact that about 25% of the time is spent on administrative and  
15 support functions that do not require the use of any equipment. In addition, the analysis assumed  
16 that some equipment that are used are not a product of release, meaning that such equipment is  
17 of other origins and were never introduced in any radiologically controlled areas. This fraction  
18 was assumed to be 25% for both large and small equipment, lacking specific data. Given that  
19 such equipment is expected to have a productive life cycle, a useful life of 14 years was assigned  
20 for large equipment and three years for small equipment. The duration of the useful life of  
21 equipment is driven by operational conditions and economic considerations, taking into account  
22 replacement costs and cost of repairs, amortization, and cost of money. These factors are  
23 expected to be different among facilities. For large equipment, the useful life is assumed to be  
24 twice that of the typical amortization schedule of seven years for capital expenditures. This  
25 assumes that once amortized, the equipment is used for another seven years before being  
26 declared worn out and discarded. For small equipment, such as hand tools, the useful life (3  
27 years) assumes that once worn out, these items are discarded given that replacement costs are  
28 usually less than repair costs.  
29

30 The determination of the number of workers using equipment and items after release is  
31 complicated by the lack of information characterizing practices at various facilities. For  
32 example, the type of equipment and tools used during routine operation is expected to be  
33 different than that used during maintenance or plant outages. Similar differences would be  
34 expected between refurbishment and decommissioning. In all cases, the size of the work force  
35 would vary as well. Lacking specific information, the approach considers occupationally  
36 exposed workers as a surrogate for the population that might be using released equipment and  
37 tools. The worker population that uses equipment and tools in radiologically controlled areas can  
38 be considered to be the same population that uses released equipment. This assumption is valid  
39 because once equipment and tools are released and workers are out of a radiologically controlled  
40 area, it does not matter whether the use of the equipment is associated with the same worker or  
41 any other worker. The analysis is insensitive to the origin of the worker, and considers only that  
42 a “worker” uses equipment and tools that have been released. Accordingly, the use of radiation

workers is deemed to be a surrogate in determining the size of the workforce as there is some information on the number of workers employed by the nuclear industry.

The number of workers is based on the NRC REIRS database (NRC,2003e). A review of the database indicates that about 108,000 workers at reactors and 11,800 at materials sites are badged and report exposures under the provisions of 10 CFR Part 20.2206. The number of workers from Agreement State (AS) licensees was estimated by ratioing the number of licenses between the AS and NRC data. Based on NUREG-1350 (NRC 2002c), the ratio was estimated to be 3.3 (16,253/4,922), thereby giving a total of material 38,900-badged workers. The total size of the workforce of both NRC and AS licensees is estimated to be 150,000 workers (108,000 + 38,900, rounded off). A further evaluation of the database indicates that for about 50% of the workforce, all exposures or doses are reported as “non-measurable.” This information indicates that a portion of the workforce, although required to be badged, perform duties in radiologically control areas that may not require “hands-on” activities. Such types of workers may include supervisors, security, engineers, inspectors, janitors, etc. Accordingly, some of that workforce might not perform “hands-on” functions in radiologically control areas and it is then unlikely that they would be using released equipment. Nevertheless, it is assumed that 25% of the work force is using large equipment, and 75% of the workforce is using small equipment, including hand tools and small items. The resulting assumptions and estimate of the size of the work force using released equipment are summarized in Table D-7.

**Table D-7 Major Assumptions Used in Deriving Collective Doses Due to Reuse**

Parameter	Large Equipment	Small Equipment	Notes
Annual work-hours	2,080	2,080	Assumes a full work year
Admin./Support functions	0.25	0.25	Time away from released equipment
Equipment distribution	0.25	0.25	Fraction of time using equipment of other origins
Annual work-hours per worker	1,040	1,040	Contact time with released equipment
Size of work force	150,000	150,000	Potential number of workers using equipment
Incidental workers	0.25	0.75	Fraction using released equipment
Effective work force	19,000	56,000	Aggregate number of workers using released equipment
Equipment useful life (years)	14	3	Time over which dose is integrated
Elapsed time from release to start of exposure (years)	0	0	Assumes no radioactive decay before use
Number of pieces of equipment in use per person	1	1	Dose multiplier - see text for details

Collective doses are based on the presence of 17 radionuclides commonly found at nuclear power plants, as beta, gamma, and alpha emitters (Table 3.21, SC&A 2003). No credit is taken for radioactive decay from the time of release to the beginning of the assessment period. Three sets of radionuclide distribution-weighted gross activity release levels were derived for both, large and small equipment, and one using IAEA Radiation Safety Guide RS-G-1.7 for both small and large equipment.

Release levels were derived for both small and large equipment using a procedure described in MARSSIM (NUREG-1575, Section 4.3.4, page 4-9 (NRC 2001a)). The procedure involves deriving a gross activity concentration,  $C_{RU}$ , taking into account the release or clearance level of each radionuclide assumed to be present and its relative fraction (SC&A 2003). The expression is:

$$C_{RU} = \sum C_i \quad \text{Eq. 2}$$

where

$C_{RU}$  = release level, dpm/100 cm<sup>2</sup>, for dose limit, mrem/yr, summed over all radionuclides I

$C_i$  = weighted concentration for the given mix and dose option, where;

$C_i = 1 / [(F_1/L_1) + (F_2/L_2) + \dots (F_n/L_n)]$

$F_n$  = relative fraction of radionuclide I, unitless

$L_n$  = limit for radionuclide I, and given dose option

Collective doses were adjusted to represent average surface activity profiles of equipment being released. The adjustment applies a correction factor, max-to-mean surface residual radioactivity levels to release criteria. A single average factor was used in the calculation as opposed to applying a factor for each dose option. This approach was used because there is not enough information to develop a more definitive activity profile at each dose option.

The factors are as follows:

	<b>Dose Options</b>	<b>Max-to-mean factor</b>
	10 mrem/yr	21.6
	1.0 mrem/yr	7.1
	No action, 1 mrem/yr	5.4
	0.1 mrem/yr	3.3
	0.03 mrem/yr	2.6
	<b>Average factor</b>	<b>8</b>

These observations indicate that residual radioactivity profiles on equipment and tools can vary depending on licensee practices. This analysis assumes that residual radioactivity profiles are characterized by a continuous spectrum, bounded by a range defined by non-detectable levels on

1 the low side and release levels on the high side. Within this spectrum, the average is assumed to  
2 be the best single estimate of residual radioactivity levels. It should be noted that other max-to-  
3 mean factors might in fact be observed in isolated instances, depending on the situation of a  
4 specific licensee, and it may be difficult to narrow these ranges and provide a more robust  
5 estimate of the variability and best estimate of the average. Nevertheless, it is not plausible to  
6 assume that equipment and tools would be characterized only by higher activity profiles and  
7 would be released routinely by every licensee. Accordingly, this adjustment yields average  
8 collective doses for the exposed population of workers and not doses to the average member of  
9 the critical group.

10  
11 The number of pieces of equipment being reused by each worker after release could be different  
12 between small and large equipment. The collective dose is assumed to be directly proportional  
13 to the total number of items being used at any one time. In considering large equipment, such as  
14 vehicles and mechanized equipment, it is assumed that a worker can only operate one piece of  
15 equipment at a time. Accordingly, the dose multiplier is assumed to be one for such a case. For  
16 small equipment, such as hand or small power tools, etc., it is conceivable that a worker could  
17 use a number of items or at least be surrounded by several such small tools while working.  
18 Accordingly, the dose multiplier could be greater than one in such instance. As noted earlier,  
19 the dose factors derived for the file cabinet are assigned to hand tools and other similar small  
20 objects. The large surface area of the file cabinet is assumed to represent a collection of small  
21 tools. For example, the surface area of a typical screw driver was estimated to be about 120 cm<sup>2</sup>.  
22 Other tools could be physically larger than a screw driver, such as power tools, shovel, etc.  
23 Accordingly, the large surface area of the filing cabinet (about 3 m<sup>2</sup>) makes up for the presence  
24 of numerous smaller tools being used or located in the immediate vicinity of a worker. For  
25 example, if the average total surface area of an average hand tool were 1,000 cm<sup>2</sup>, this would  
26 correspond to the exposure associated with approximately 30 tools, based on the surface area of  
27 the file cabinet (derived as: 3 m<sup>2</sup> x 10<sup>4</sup> cm<sup>2</sup>/m<sup>2</sup> ÷ 1,000 cm<sup>2</sup>) with other factors being equal. This  
28 approach is deemed to be adequately conservative as it retains the full range of exposure  
29 pathways (i.e., external, inhalation, and incidental ingestion) that workers would encounter while  
30 using hand tools and other small items. Accordingly, the dose multiplier for hand tools and small  
31 items is assumed to be one as well.

32  
33 The results are presented in Tables D-8 and D-9. A review of the results indicates that for large  
34 equipment, collective doses vary from less than 1 to about 150 person-rems. For small  
35 equipment collective doses range from less than 1 to about 160 person-rems. At a release dose of  
36 1 mrem/year, collective doses are about 15 person-rems for large equipment and 16 person-rems  
37 for small equipment.

38  
39 The reason for the small differences in doses is the influence of competing factors. The  
40 competing factors include the useful life of equipment, 14 years for large equipment and 3 years  
41 small equipment; number of workers assumed to use released equipment, 19,000 for large  
42 equipment and 56,000 for small equipment; and assumed average residual surface radioactivity  
43 profiles, 140 dpm/100 cm<sup>2</sup> for large equipment and 1,600 dpm/100 cm<sup>2</sup> for small equipment. A  
44 shorter useful life tends to result in lower collective doses, a higher number of worker yields  
45 higher collective doses, and higher residual radioactivity profiles result in increased collective

**Table D-8 Collective Doses Associated with the Reuse of Large Equipment From Nuclear Power Reactors**

Reg. Dose Option	Assumed Criteria Profile (dpm/100 cm <sup>2</sup> )		Collective Doses (person-rem)
	Mean	Max	Mean
IAEA RS-G-1.7	530	4,200	56
10 mrem/yr	1,400	11,000	150
1 mrem/yr	140	1,100	15
No action/Status quo	630	5,000	66
0.1 mrem/yr	14	110	1.5
0.03 mrem/yr	4.2	34	0.4

**Note:** Mean and max profile based on SC&A 2003, Table 4.4, p.4-8 and 4-9.  
 Collective doses are expressed only as averages since collective doses reflect impacts to the expected population of workers and not to the average member of the critical group.  
 For the “no action” case, the regulatory dose is assumed to be the same as the 1 mrem/yr option.  
 The IAEA volumetric criteria were converted to surficial limits using a mass-to-surface ratio of 5 g/cm<sup>2</sup>.

**Table D-9 Collective Doses Associated with the Reuse of Small Equipment From Nuclear Power Reactors**

Reg. Dose Option	Assumed Criteria Profile (dpm/100 cm <sup>2</sup> )		Collective Doses (person-rem)
	Mean	Max	Mean
IAEA RS-G-1.7	530	4,200	5
10 mrem/yr	16,000	130,000	160
1 mrem/yr	1,600	13,000	16
No action/Status quo	630	5,000	6
0.1 mrem/yr	160	1,300	1.6
0.03 mrem/yr	49	390	0.5

**Note:** Mean and max profile based on SC&A 2003, Table 4.4, p.4-8 and 4-9.  
 Collective doses are expressed only as averages since collective doses reflect impacts to the expected population of workers and not to the average member of the critical group.  
 For the “no action” case, the regulatory dose is assumed to be the same as the 1 mrem/yr option.  
 The IAEA volumetric criteria were converted to surficial limits using a mass-to-surface ratio of 5 g/cm<sup>2</sup>.

doses. Another reason for differences is that collective doses, based on IAEA and NUREG-1640 clearance and release levels, reflect different analytical approaches. The IAEA clearance levels are based on a deterministic analysis, while NUREG-1640 release levels were developed using a Monte Carlo method.

As was noted earlier, a simplified approach was used in assessing collective doses and several assumptions were made without the benefit of supporting information. As a result, the collective dose estimates incorporate some uncertainties. The uncertainties are associated with the

1 characterization of practices involving the release and reuse of equipment; the types of  
 2 equipment that may be released *versus* those may be discarded as radioactive waste; physical  
 3 features of released equipment and small items; how equipment are used after having being  
 4 released; variation in the distribution of radionuclides and relative mix and their combined effect  
 5 on the total inventory of residual radioactivity; and size of the workforce postulated to use  
 6 equipment that have been released. In all cases, values were assigned to parameters using  
 7 engineering judgement without the benefit of supporting data from licensees. Finally, the  
 8 assessment focuses on the nuclear power industry because of the larger workforce and greater  
 9 amounts of equipment being released and reused. However, it is recognized that the reuse of  
 10 released equipment and materials is occurring in other industrial sectors, but the amounts of  
 11 materials subject to release and associated workforce are expected to be smaller than that of the  
 12 nuclear power industry. Accordingly, the collective doses estimated in this analysis are assumed  
 13 to be bounding, even though there may be isolated differences in some instances, such as  
 14 radionuclide distribution, type of equipment, and size of the workforce, among others.

15  
 16 **13. Collective Doses for Trash Incineration Workers**

17  
 18 As with prior assessments, a scoping analysis was performed to assess collective doses to  
 19 incinerator workers processing trash released from nuclear power reactors. The amounts of trash  
 20 and levels of residual radioactivity reflect estimates associated with each regulatory dose option  
 21 described earlier. Collective doses were estimated using the following general expression:  
 22

$$D_{iw} = E_{iw} C_i L T W K$$

23  
 24 where:

- 25  
 26  $D_{iw}$  = collective dose due to incineration, person-rem  
 27  $E_{iw}$  = dose rate during handling, mrem/yr per pCi/g, summed over all nuclides  
 28  $C_i$  = trash gross activity concentration, pCi/g  
 29  $L$  = trash labor productivity rate, person-hours per ton of trash  
 30  $T$  = tonnage of trash, metric tons  
 31  $W$  = work hours per year, 2,000 hours  
 32  $K$  = conversion factor,  $10^{-3}$  rem per mrem  
 33

34 The total trash tonnage and concentrations are based on data presented in Table 4.4 of the SC&A  
 35 report (SC&A 2003). The productivity factor to process trash is based on a labor rate of 0.5  
 36 person-hour per ton, assuming an incinerator with an average design capacity of 500 tons per day  
 37 (NRC 1984). The levels of effort to process trash were estimated to range from 7,000 to 33,000  
 38 person-hours. The dose factor is estimated to be  $2.44 \times 10^{-4}$  mrem/year per pCi/g, assuming the  
 39 combined presence of 17 radionuclides, as beta, gamma, and alpha emitters (SC&A 2003, NRC  
 40 2005c). The presence of these radionuclides reflects a specific mix based on nuclear utility data.  
 41 Four radionuclides make up most (about 83 percent) of the activity assumed to be present in  
 42 trash; they are, in decreasing order, Co-60, Fe-55, Cs-137, and Cs-134. The dose factor assumes

2,000 hours per work year. The dose factor includes various functions, such as handling of the trash, loading the incinerator with trash, and during routine servicing or maintenance. The gross activity concentrations of the trash define two conditions, mean and maximum. The conditions reflect a distribution of trash concentrations truncated at the upper end by activity levels defined for each regulatory dose option. Activity levels above these are assumed to be out of the realm of possible release since higher concentrations would warrant classifying trash as low-level radioactive waste. The mean concentration is assumed to represent a trash concentration within the distribution defined at its lower bound by essentially non-detectable levels and the regulatory dose option for upper activity levels. The maximum concentration represents the upper end of the distribution of activity levels, as defined for each regulatory dose option.

The results are presented in Table D-10. The results indicate that collective doses are low, expected to be less than 0.03 person-rem for the 10 mrem/year dose option. All other collective doses are lower by orders of magnitude. Collective doses are expected to vary because of several factors. As described earlier, the amounts of released trash are expected to vary, both among power plants and as a function of time. Similarly, the levels of residual radioactivity and the associated mix of radionuclides will vary as well. For example, the spectrum of radionuclides associated with a major plant outage is different than that found during routine operations. Moreover, the handling and processing rates of trash at incinerators are anticipated to differ, thereby yielding working conditions that might differ from that assumed here in deriving dose factors. Finally, this analysis assumes that all trash generated by power plants would be incinerated, while this is not expected in practice since not all landfills use incineration as a precursor to disposal. For example, only landfills servicing large metropolitan centers are expected to use incineration. For rural areas, trash is typically buried as there may not be enough of a trash volume to warrant the use of incineration. It is expected that these variations would negate one another, thereby leading to conditions where concentrations might be higher, but are associated with smaller quantities of trash. Accordingly, it is expected that the collective doses estimated in this analysis represent central estimates, while recognizing that at times doses may be slightly lower or higher depending on specific conditions.

**Table D-10 Collective Doses of Incinerator Workers Processing Trash from Nuclear Power Reactors**

Reg. Dose Option	Trash Tonnage (metric tons)	Mean and Maximum Trash Gross Concentration (pCi/g)		Person hours	Collective Doses (person-rem)
		Mean	Max		Mean
10 mrem/year	66,000	7,825	41,604	33,000	3.2 E-02
1 mrem/year	41,000	898	4,160	20,500	2.3 E-03
No action	20,000	114	382	10,000	1.4 E-04
0.1 mrem/year	21,000	121	416	10,500	1.6 E-04
0.03 mrem/year	14,000	43	125	7,000	3.7 E-05

**Note:** Trash tonnage and gross concentrations taken from SC&A 2003, Table 4.4. Labor hours based on 0.5 person-hour per ton and an average incinerator design capacity of 500 tons per day. The trash processing rate is taken from NUREG/CR-3585, Table C-4.

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## APPENDIX E MISCELLANEOUS DOSE TOPICS

This appendix discusses the following dose topics:

- The dose assessment analysis in NUREG-1640 and a comparison of those results to international guidance.
- Sources and typical annual doses from background radiation.
- Collective dose due to background radiation.
- Exposures from multiple sources derived from the release of materials from licensees.

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### **E-I RADIOLOGICAL ASSESSMENTS FOR THE RELEASE OF MATERIALS, INCLUDING COMPARISON OF NUREG-1640 RESULTS WITH INTERNATIONAL GUIDANCE**

#### **1. INTRODUCTION**

The U.S. Nuclear Regulatory Commission (NRC) has independently assessed potential doses to individuals that could result from the release of solid materials, with the results expressed as normalized activity levels, as Bq/g and Bq/cm<sup>2</sup>. The analyses were conducted for ferrous metals, copper, aluminum, and concrete, with the results reported in NUREG-1640 (NRC 2003d). One of the main objectives of these assessments was to identify the critical group and quantify the mean dose to that group using realistic exposure scenarios. Normalized dose factors were calculated for 115 radionuclides and for each material. These assessments are intended to be supporting of the technical basis for a rulemaking on controlling the disposition of solid materials. The design objectives, the analytical approach, and results of the analyses were compared to guidance from the European Commission (EC) and International Atomic Energy Agency (IAEA). The results of these comparisons are briefly described below.

#### **2. DESIGN OBJECTIVES FOR ANALYSES AND ANALYTICAL APPROACH IN NUREG-1640**

The establishment of design objectives for the dose assessment analysis were defined at the beginning of the process, provided the basis for numerous decisions in structuring calculations and the means for narrowing down the scope of evaluations in selecting appropriate input parameters.

##### **2.1 Design Objectives**

The design objectives of estimating potential doses to individuals arising from the release of materials included independent assessments of U.S. industry practices in a realistic, i.e., non-conservative, approach, that takes into account, to the extent practicable, variations in industrial practices. The results of such assessments could be used as part of a technical basis in a rulemaking on controlling the disposition of solid materials, taking into account public comments

1 received on earlier proposed regulations. Regarding implementation, results for both mass-based  
2 and surface-based release levels were considered in the overall objective. Moreover,  
3 comparisons with existing U.S. regulations, guidance, and practices, along with international  
4 clearance guidance, were considered in the design objective in calculating radionuclide  
5 concentrations using ICRP 30 (ICRP 1979) and ICRP 60 (ICRP 1991) based dosimetry (ICRP  
6 1975, 1979, 1990, 1994). Overriding design objectives were to identify the critical group for  
7 generic release levels and to quantify that group's mean potential dose on a normalized unit  
8 concentration basis. Because materials released from a nuclear facility may be characterized by  
9 a wide spectrum of radionuclides, the assessments consider exposures from direct radiation,  
10 inhalation, and ingestion to adults making up the critical group for each scenario. Thus, it was  
11 not a design objective to assess doses to infants and children or to the skin.

12  
13 Another design objective was to build into the structure of the analyses breadth of scenarios,  
14 robustness, and adaptability, so that the licensees could use the generic analyses to support case-  
15 specific analyses.

## 16 17 **2.2 Analytical Approaches**

18  
19 In general the analytical approaches were guided by the design objectives. Key approaches that  
20 characterize these assessments are described below.

### 21 22 **2.2.1 Probabilistic analysis**

23  
24 A probabilistic analysis approach was adopted for several reasons. It enables one to take into  
25 account variations in input parameters encountered in real situations from which mean values  
26 and uncertainties can be estimated. The mean values were considered the most appropriate  
27 estimators of normalized dose to an individual for each scenario. The means were ranked to  
28 identify the critical groups on a radionuclide-by-radionuclide basis. Ferrous metals, copper,  
29 aluminum, and concrete were specifically analyzed because these materials were judged to  
30 comprise the great majority of mass likely to be candidate materials for release.

31  
32 For the various possible pathways considered, realistic choices for their parameters were  
33 evaluated using a Monte Carlo statistical averaging technique. The results provide estimates of  
34 the collective dose average values and associated uncertainties. Distributions of variable  
35 parameters were established based on the quality of the data using literature research for the  
36 identified variables (EPA 1994). The ranges of parameters were kept realistic, and were often  
37 found to be as uniform, triangular, or beta distributions. The estimation of doses, radionuclide  
38 concentrations, or other intermediate parameters involved between 5,800 and 10,000 realizations  
39 or calculations, with each set of results forming a probability distribution. The mean values and  
40 the 5<sup>th</sup>, 50<sup>th</sup>, 90<sup>th</sup>, and 95<sup>th</sup> percentile values of each distribution are listed in NUREG-1640 (NRC  
41 2003d). In all cases where an intermediate parameter is calculated using Monte Carlo sampling  
42 methods, each of the calculated values is used as input to the next step in the calculation. For  
43 example, in using 10,000 realizations to estimate a dose, each realization uses each of 10,000  
44 radionuclide concentrations in succession. Calculations were performed with spreadsheets using  
45 commercially available software.

1 2.2.2 Radionuclides  
2

3 A total of 115 radionuclides were included in the analysis based on an evaluation of the nuclear  
4 industry. In general, the radionuclides correspond to those reported in low-level radioactive  
5 waste from a broad variety of facilities, in studies of radionuclide inventories found at nuclear  
6 power reactors, neutron activation products, radioactive decay progenies, and those listed in the  
7 EC publication Radiation Protection 89 (RP 89) (European Commission 2000a).  
8

9 2.2.3 Chemical forms and particle sizes  
10

11 In order to meet the design objective of realistic dose assessments, each scenario was analyzed to  
12 determine the most likely chemical form and particle size distributions in the medium of concern  
13 and scenario. The appropriate corresponding dose conversion factors or dose coefficients were  
14 then used for that calculation.  
15

16 2.2.4 Assessment of radionuclides on the surface  
17

18 The critical parameter for assessing the potential doses from radionuclides on the surface of  
19 released materials is the mass-to-surface ratio, which is defined as the mass of the component  
20 divided by the exposed surface area of that component. Mathematical distributions of mass-to-  
21 surface ratios were developed from data derived from site visits and from reports on metal scraps  
22 likely to be released from commercial nuclear power plants undergoing dismantlement. Rebar,  
23 structural steel, and pipe hangers account for most of the mass of ferrous metals likely to be a  
24 candidate for release. Similar distributions were developed for copper and aluminum. For  
25 concrete, distributions were developed similarly, however, due to the considerable wall  
26 thicknesses found at nuclear facilities - especially nuclear power plants - the mean ratio is  
27 significantly higher, namely, 280 g/cm<sup>2</sup> compared to 5 g/cm<sup>2</sup> for ferrous metals. Values from the  
28 appropriate mass-to-surface ratio distribution were selected at random during the Monte Carlo  
29 analysis and divided into the mass-based normalized dose factor to yield the surficial normalized  
30 dose. The distributions of the radionuclides were considered to be uniform over all surfaces. In  
31 many cases, this assumption leads to an unrealistic overestimate; however, the situations vary so  
32 greatly that a generic analysis was judged not feasible. Therefore, if a less conservative  
33 assessment were desired, case-specific factors would have to be taken into account.  
34

35 2.2.5 Scenario selection  
36

37 Scenarios were generally selected as realistic candidates to identify the critical group. Some  
38 scenarios were selected for analysis because there had been questions raised in public meetings  
39 concerning the potential exposures associated with them - especially for consumer products. A  
40 third category of scenarios was developed to assess bounding cases where scrap in a single melt  
41 was entirely composed of released metal scraps. A significant amount of research was conducted  
42 to ensure that the models reflected current U.S. practices for handling scrap metals and concrete  
43 for reuse. Because metal refining processes can cause radionuclides to partition to by-products,  
44 scenarios covered not only scrap, but also refined metal, slag or dross, dust, airborne emissions,  
45 and drinking water downstream from a landfill, among others. In all, eighty-six scenarios were  
46 analyzed among the four materials.  
47

1 2.2.6 Partitioning of radionuclides in refining processes  
2

3 The distribution of impurities during melting and refining of ferrous metals can be influenced by  
4 numerous physical and chemical factors. The partitioning of radionuclides was determined by a  
5 combination of considerations. Generally, thermodynamic calculations were used to determine  
6 whether an element was likely to partition to the slag or to the melt. Vapor pressures of the more  
7 volatile elements and their oxides were used to predict concentration in the dust. These  
8 theoretical considerations were supplemented with a review of the literature to obtain realistic  
9 data. The convention was adopted that, if an element tends to remain in the melt, 1% is assumed  
10 to be physically entrained and transported to the dust due to the turbulence of the melting and  
11 refining processes. Similarly, if an element tends to partition to the slag, 5% is assumed to be  
12 transported to the dust. Detailed discussions and references are presented in the appendices to  
13 NUREG-1640.  
14

15 **3. RESULTS AND COMPARISONS**  
16

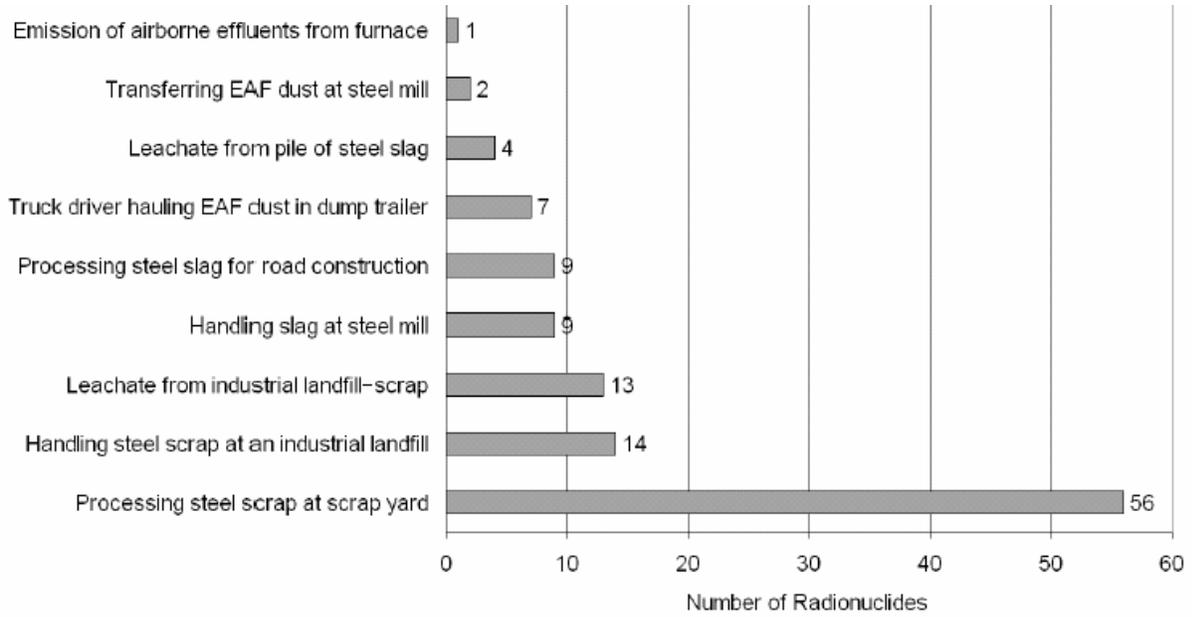
17 Detailed probabilistic results are presented in NUREG-1640 for each scenario and each material.  
18 In the discussions that follow, the means of the effective dose realizations were used to determine  
19 the critical group and for comparison with EC and IAEA guidance. It should be noted that these  
20 comparisons address normalized dose factors to individuals within critical population groups,  
21 and should not be confused with collective dose, which is the focus of Chapter 3 of the Draft  
22 GEIS. Collective doses to a population are used to compare the relative impacts of alternatives.  
23

24 **3.1 Results**  
25

26 For ferrous metals, most critical groups are workers, for example processing either scrap metals  
27 or melt products. The use of consumer products containing ferrous metals does not rise to a  
28 threshold at which exposures to a specific critical group might be limiting. Other critical groups  
29 are controlling for a very few radionuclides associated with exposures from atmospheric releases  
30 or drinking water. The scenarios and doses of scrap metal handlers and processors cover the  
31 majority of radionuclides and are controlling in defining release levels.  
32

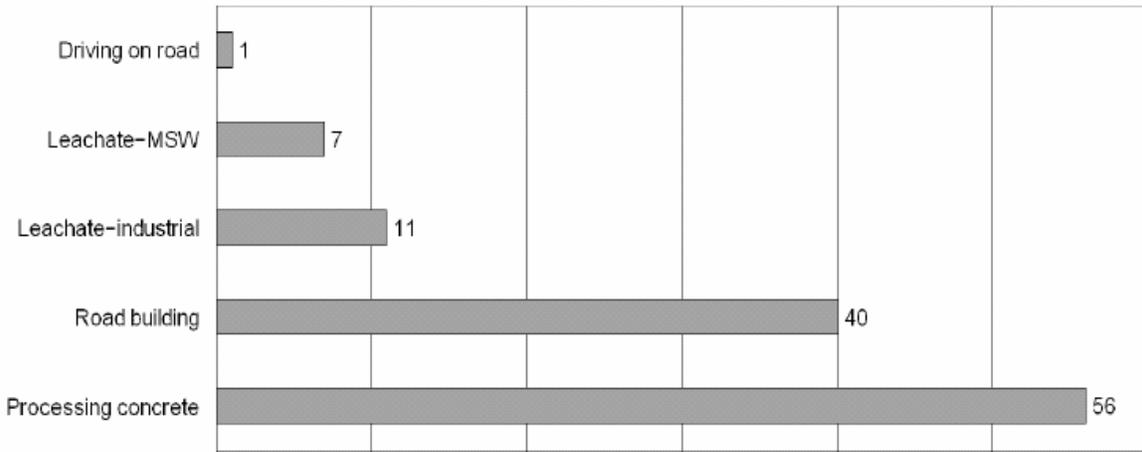
33 The overall critical groups, on a radionuclide basis, were defined by scenarios for the release of  
34 ferrous metals and concrete. These scenarios were almost all from workplace exposures. Thus,  
35 controlling hypothetical doses to workers would also control the hypothetical doses to  
36 consumers, and would result in lower doses to consumers. Figure E-1 shows the critical group  
37 scenarios for ferrous metals and the number of radionuclides for which that scenario defines the  
38 critical group. Electric arc furnace is abbreviated as EAF in the scenario descriptions.  
39

40 Figure E-2 shows the critical group scenarios for concrete. In the scenario description, a  
41 municipal solid waste (MSW) landfill with leachates refers to drinking water from a well down-  
42 gradient or an industrial landfill where the leachates have reached ground water. One-thousand  
43 years after disposal was arbitrarily selected as a time interval when considering ingestion of  
44 ground water.



**Figure E-1 Critical Group Exposure Scenarios and Defining Number of Radionuclides for the Release of Ferrous Metals**

1  
2  
3  
4  
5

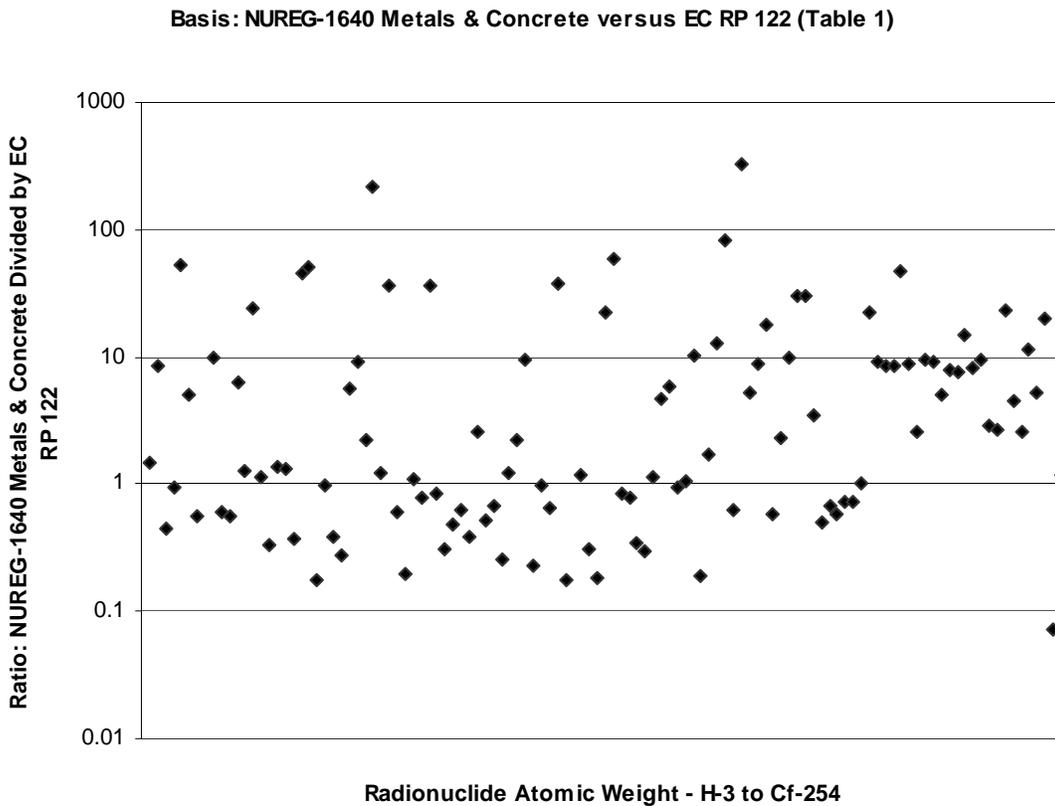


**Figure E-2 Critical Group Exposure Scenarios and Defining Number of Radionuclides for the Release of Concrete**

6  
7  
8  
9

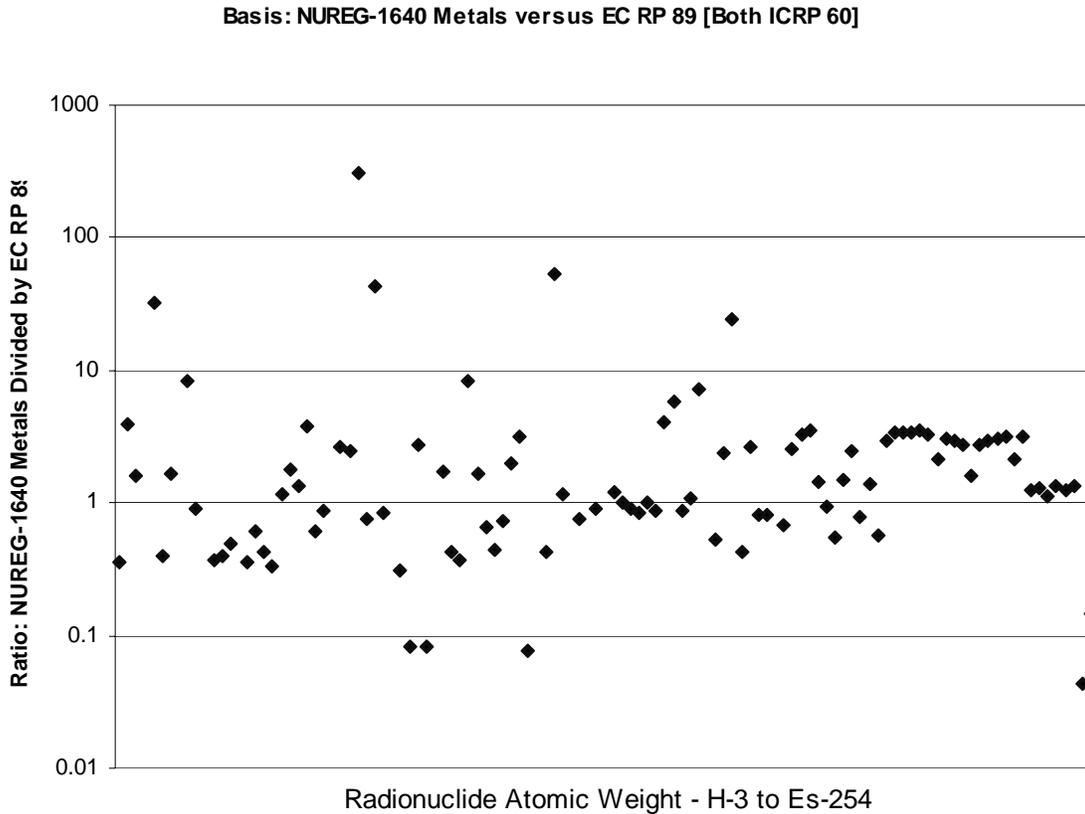
3.2 Comparisons

Figure E-3 presents a comparative scatter-plot of effective dose factors from NUREG-1640 on a 10  $\mu$ Sv (1 mrem) in a year basis using the values from EC Radiation Protection 122 (RP 122) (European Commission 2000b). The results are presented in order of increasing radionuclide atomic weight, from tritium to Cf-252. On a radionuclide-by-radionuclide basis, the NUREG-1640 most restrictive (overall critical group) results were divided by the RP 122 values. Thus, when the ratios are greater than one, the NUREG-1640 values are less restrictive than the RP 122 values. Most of the calculations comparing NUREG-1640 with the EC's RP 122 are within a factor of ten of one another.



**Figure E-3 Radionuclide-by-Radionuclide Comparisons of Values from NUREG-1640 to EC RP 122.**

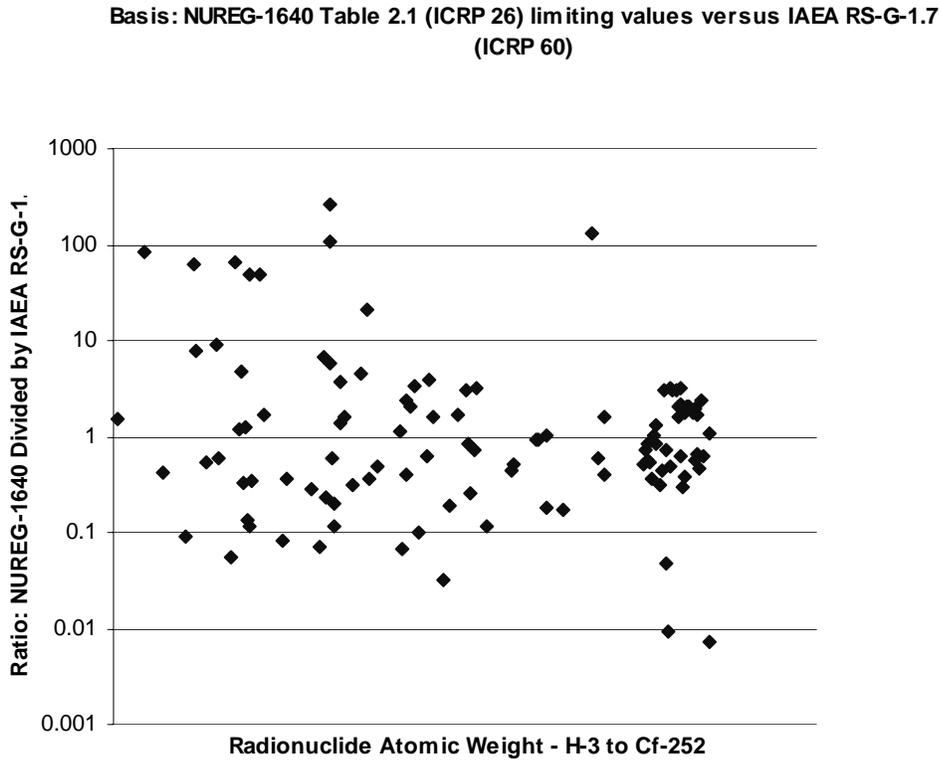
Figure E-4 illustrates a similar comparison with the guidance in the EC's RP 89, which is limited to the recycling of metals from the dismantling of nuclear installations (European Commission 2000a). For this comparison, the NUREG-1640 results for concrete were not included, and the effective dose calculations were used to have a consistent dosimetry system. Most of the results are within a factor of three on a radionuclide-by-radionuclide basis. Only four of the results from EC RP 89 are more restrictive by a factor greater than ten. The differences in the results would require a more detailed evaluation and comparison of the models and assumptions, and could partially reflect a different characterization of industrial practices.



**Figure E-4 Radionuclide-by-Radionuclide Comparisons of Values from NUREG-1640 to EC RP 89**

Figure E-5 presents a comparative display of the results between NUREG-1640 and IAEA Radiation Safety Guide No. RS-G-1.7 clearance levels (IAEA 2004). The IAEA clearance levels are based on a 10  $\mu$ Sv in a year dose limit. For NUREG-1640, values used in the comparison are based on the most restrictive (overall critical group). The NUREG-1640 results were divided by the corresponding IAEA radionuclide values. As before, when ratios are greater than one, the NUREG-1640 values are less restrictive than the IAEA values. Most of the ratios between NUREG-1640 and IAEA are within a factor of ten of one another.

Most of the calculations comparing NUREG-1640 with the EC's RP 122 or IAEA's RS-G-1.7 guidance are within a factor of ten of one another. For those radionuclides where ratios are greater than one, RP-122 or RS-G-1.7 is more restrictive than NUREG-1640. Generally, ratios less than ten are considered good agreement by modelers because of the uncertainties in making such estimates taking into account, to the extent practicable, variations in modelling complex industrial processes. In part, the variability is attributed to differences in code models; scenarios and exposure pathways describing industrial practices; assumptions and parameters; incorporation of radon and its decay products; adjustments of EC and IAEA clearance values with that of other exemptions to ensure compatibility; and process used in rounding of RP 122 and IAEA values to the nearest power of ten.



**Figure E-5 Radionuclide-by-Radionuclide Comparisons of Values from NUREG-1640 to IAEA RS-G-1.7**

The consequence of erring by a factor of ten, with a release criterion based on a 10  $\mu\text{Sv}$  (1 mrem) per year dose limit, could mean that a hypothetical individual might receive a dose of 100  $\mu\text{Sv}$  (10 mrem) in a year, which is a small fraction of the 1,000  $\mu\text{Sv}$  (100 mrem) per year dose limit that is considered protective of public health and safety (see 10 CFR Part 20, Subpart D - Radiation Dose Limits for Individual Members of the Public).

The above discussions addressed comparisons of individual radionuclides, but in implementation, two or more radionuclides may be present in materials that may be released. In such instances, the dose contribution of each radionuclide must be accounted for such that the total dose due to all radionuclides does not exceed the release criteria. This consideration is a requirement of NRC regulations in applying the sum-of-the-ratio. The sum of the ratios of each radionuclide present in materials cannot exceed unity when summed up over all radionuclides, i.e., unity rule. The ratio for a radionuclide is expressed as the concentration of that radionuclide divided by its limit. An example is used to compare differences between NUREG-1640 and RS-G-1.7 release levels when multiple radionuclides are present. The example considers radionuclides and their relative fractions for those radionuclides commonly found in materials generated by nuclear power plants. Typically, 17 radionuclides make up most of the residual activity expected to be found in materials subjected to release, with Fe-55, Co-60, and Cs-137 comprising nearly 80% of the total activity. The following tabulation presents the results of the comparison using the unity rule for all 17 radionuclides.

Case	Concrete	Ferrous Metals
RS-G-1.7 residual gross activity concentration, Bq/g (pCi/g)	0.14 (3.8)	0.14 (3.8)
NUREG-1640 residual gross activity concentration, Bq/g (pCi/g)	0.063 (1.7)	0.34 (9.1)
Ratio of residual concentrations (RS-G-1.7 ÷ NUREG-1640)	2.3	0.4
Restrictive case	NUREG-1640	RS-G-1.7

The results reveal that NUREG-1640 and RS-G-1.7 are alternatively more limiting depending on the type of material. For concrete, the results indicate that RS-G-1.7 yields a less restrictive gross activity concentration (0.14 Bq/g or 3.8 pCi/g), while NUREG-1640 is more permissive for metals (0.34 Bq/g or 9.1 pCi/g). In either case, the differences are less than about a factor of two, which is in very close agreement, especially at these low dose levels. This example illustrates that the differences identified earlier on a radionuclide-by-radionuclide basis are expected to be even less pronounced in implementation or actual practice.

Regarding the possibility of imports, it is estimated that should the IAEA’s RS-G-1.7 become an international standard, resulting industry practices might result in annual doses also on the order of 10 µSv, other things being equal. It should be noted that the types and amounts of materials that may be imported is uncertain, but they primarily consist of equipment, parts, and tools used by the nuclear industry. For example, companies involved in servicing power reactors and fuel fabrication facilities ship materials between service centers and power reactors or fabrication plants. As a result, the shipments involve the transfer of materials only between industrial facilities, and exposures to members of the public are very unlikely given that there is no subsequent applications of such materials within the public sector. Moreover, it is not realistic to expect that the nuclear industry would import materials and equipment specifically for disposal in U.S. landfills as the costs of doing so would be prohibitive. Consequently, doses to the public are expected to be a very small fraction of the limit being considered by this rulemaking, i.e., 10 µSv (1 mrem) per year.

### 3.3 Reuse and Trash

Additional assessments of normalized doses are addressed as supplemental reports to NUREG-1640 (NRC 2005c,d). Specific analyses of the reuse of various kinds of equipment range from small tools (e.g., hand tools) to large industrial equipment with operators assumed to be exposed in an enclosed environment, e.g., in the cab of a truck. Regarding trash, the amounts expected to be shipped for disposal in landfills is expected to be a very small fraction of that estimated for ferrous metals and concrete. Considering the practices of the nuclear industry, it is not realistic to expect that U.S. or European licensees would ship trash and other non-salvageable materials across international borders just for disposal. This is deemed impractical because of costs and regulatory constraints. Because of the reuse of tools and equipment or release of trash for disposal in landfills results in little or no residual radioactivity originating from licensed nuclear facilities, these scenarios are not included in comparisons with international guidance.

**E-II SOURCES AND TYPICAL ANNUAL DOSES FROM BACKGROUND RADIATION**

**1. INTRODUCTION**

Background is comprised of various sources of ionizing radiation. These sources collectively produce an average total effective dose equivalent of about 3 mSv/yr (300 mrem/yr) to a U.S. resident. For comparison, the estimate of the average U.S. radiological dose from background is similar to the world average estimate of 2.4 mSv/yr (240 mrem/yr). NUREG-1501 (NRC 1994a) contains a detailed discussion of sources, levels, and variability of background; the following discussion summarizes Section 2 of NUREG-1501. Additional information can be found in two reports issued by the National Council on Radiation Protection and Measurements (NCRP 1987a, b).

**2. SOURCES OF EXTERNAL RADIATION**

Radiological doses from background typically range between 1 mSv/yr (100 mrem/yr) and 10 mSv/yr (1,000 mrem/yr) in the United States. Although greater radiological doses are possible for people living in houses with very high radon concentrations, 10 mSv/yr could be taken as a practical maximum, with a few rare exceptions. Table E-1 provides a breakdown of the sources of natural background. In addition to the amounts in Table E-1, relatively minor contributors to the dose from background (less than 1 percent each) are cosmogenic radionuclides, created by the interaction of cosmic rays with otherwise stable elements present on earth, and man-made fallout radionuclides from nuclear weapons testing. Cosmogenic radionuclides include H-3, C-14, Ar-41, etc. (NCRP 1987a). Radionuclides from weapons fallout include H-3, C-14, Sr-90, Cs-137, Pu-239, etc. (NCRP 1987a).

**Table E-1 Comparison of the Principal Components of Background Between Estimated Populations of the United States and the World**

Component	Annual Effective Dose Equivalent (mSv)		
	U.S. Mean <sup>1</sup>	World Mean <sup>2</sup>	World Range <sup>2</sup>
Cosmic	0.27	0.36	0.3 – 2.0
Indoor radon and progeny	2.0	1.1	0.3 – 5.0
Internal (other inhaled, ingested)	0.4	0.5	0.2 – 1.0
Terrestrial gamma	0.28	0.41	0.2 – 1.0
<b>Totals (rounded)</b>	<b>3.0</b>	<b>2.4</b>	<b>1.5 – 6.0</b>

1. NCRP 1987a.  
 2. UNSCEAR 1988.  
 1 mSv = 100 mrem

Background produces radiological doses to the U.S. population that are highly variable between locations (spatial) and also over time at the same place (temporal). For example, cosmic radiation is modulated by the 11-year solar cycle and typically varies about 10 percent at the

1 same location, but at different times. Temporal variability of background is also tied to  
 2 atmospheric circulation and precipitation patterns that affect the distribution of cosmogenic and  
 3 fallout radionuclides. Short-term changes in external gamma exposure arise from redistribution  
 4 of radon decay products in the atmosphere and washout with precipitation, resulting in changes  
 5 ranging from a few percent to more than 200 percent over the course of a day or season. Even  
 6 larger variations in indoor radon concentrations can occur because of differential air pressures in  
 7 buildings and resulting changes in ventilation rates. Indoor levels of gamma radiation typically  
 8 vary by about 50 percent due to the use of different construction materials. Outdoors, changes in  
 9 soil moisture and snow cover cause external gamma radiation levels to vary seasonally by 10 to  
 10 50 percent at the same location. The concentration of radionuclides that produce internal doses,  
 11 such as Pb-210 in body tissues, has been observed to vary by about a factor of three throughout  
 12 the United States. Spatial variability of cosmic radiation is observed to be as much as 200  
 13 percent, depending greatly on altitude and to a lesser extent on latitude.

14  
 15 **3. SOURCES OF NATURAL RADIOACTIVITY IN MATERIALS**

16  
 17 Nearly all materials contain naturally occurring radioactivity due to the presence of terrestrial  
 18 radionuclides, such as K-40, Rb-87, Th-232, and U-238, and cosmogenic radionuclides, such as  
 19 C-14, H-3, Be-7, and Na-22. The concentration of these radionuclides in soil, water, air, and  
 20 living matter can vary widely throughout the country because of geological processes, climatic  
 21 changes, weather, and human activities. For example, concentrations of uranium and thorium in  
 22 the soil range from as little as one-tenth to as much as four times the average value. Data  
 23 contained in Table E-2 illustrate a typical range of natural radionuclide concentrations in soil  
 24 throughout the United States and the world.

25  
 26 **Table E-2 Typical Ranges in Average Concentration of Background Radionuclides**  
 27 **(Bq per kg)**

28

29 <b>Material</b>	<b>Uranium-238</b>	<b>Thorium-232</b>	<b>Potassium-40</b>	<b>Reference</b>
30 Bauxite ore	250	200	n/a	UNSCEAR 1988
31 Coal, U.S.	18 (1–540)	21 (2–320)	52 (1–710)	Beck et al 1980a,b
32 Copper ore	30–80	23–110	n/a	UNSCEAR 1988
33 Crustal rock, U.S.	36	44	850	NCRP 1987a
34 Oil shale	56 (37–74)	24 (19–37)	481 (185–962)	Gogolak 1982
35 Phosphate fertilizer, U.S.	9200	n/a	n/a	UNSCEAR 1988
36 Soil, worldwide	25 (10–50)	25 (7–50)	370 (100–700)	UNSCEAR 1988
37 Soil, U.S.	37 (4–141)	36 (4–126)	n/a	Myrick 1983

38 1 Bq = 27.027 pCi

39  
 40 The concentration of the principal gamma-emitting radionuclides in soil is directly related to the  
 41 external gamma radiation levels in a locale. On a nationwide scale, the concentrations of  
 42 terrestrial radionuclides vary widely, which is reflected in the grouping of external gamma  
 43 radiation levels into three regions:

- 1 • The Atlantic and Gulf coastal plains, which average about half of the level seen for Middle  
2 America (0.23 mGy/yr or 23 mrad/yr);  
3
- 4 • Middle America, which has an average level of 0.46 mGy/yr (46 mrad/yr); and  
5
- 6 • The Denver, Colorado area, which has an average level about twice that of Middle America  
7 (0.9 mGy/yr or 90 mrad/yr).  
8

9 Throughout the United States, concentrations of naturally occurring radionuclides in ground  
10 water can also vary widely. In certain areas of the midwest, for example, the concentration of  
11 uranium in water (13 mBq/l or 0.35 pCi/l) is 35 times greater than that found in some eastern  
12 States (0.37 mBq/l or 0.01 pCi/l), but even greater concentrations are reported in western areas  
13 of the country, where natural uranium concentrations in ground water (130 mBq/l or 3.5 pCi/l)  
14 are 350 times that of eastern ground water.  
15

16 On a smaller scale, such as within an individual State, background radioactivity levels can vary  
17 even more. For example, in a particular location in northwestern New Jersey, external gamma  
18 radiation levels triple across a small field and, at a nearby rock outcropping, the average soil  
19 concentration of naturally occurring radionuclides increases one-hundred-fold, yet 99 km (62  
20 miles) away from this location, gamma radiation levels fall to less than 10 percent of the regional  
21 average due to the presence of sandy beaches.  
22

#### 23 **4. MAN-MADE SOURCES OF RADIOACTIVITY**

24  
25 Spatial variability in the concentration of background radionuclides can also be caused by human  
26 activities. Fallout from a nuclear weapon test can change background abruptly and require a few  
27 months to a few decades to decay. Such testing has correspondingly increased the spatial  
28 variability of background because the distribution of fallout radionuclides in the United States is  
29 not homogeneous. The deposition of weapons fallout is dependent on meteorological conditions.  
30 Mining and milling have also increased the spatial variability of background by redistributing  
31 the preexisting concentrations of naturally occurring radionuclides in a locale. Another human  
32 activity that affects the spatial distribution of background is the combustion of fossil fuels which  
33 produces ash that redistributes natural radioactivity from the ground to the air.  
34

35 In addition to naturally occurring sources of radiation, nuclear technology has led to the creation  
36 of man-made radionuclides that contribute to the background radiological dose. Man-made  
37 sources of ionizing radiation exposure account for 18 percent of the total radiological dose to the  
38 U.S. population. Of the man-made sources, medical x-ray examinations are the largest source of  
39 exposure, producing 11 percent of the total dose (0.39 mSv/yr or 39 mrem/yr). Nuclear medicine  
40 procedures account for 4 percent of the total population dose, followed by consumer products (3  
41 percent), weapons test fallout (less than 1 percent) and occupational exposures (less than 1  
42 percent). On average, however, 82 percent of the total dose to the U.S. population comes from  
43 naturally occurring radiation sources. The magnitude and variability of radiation doses is directly  
44 proportional to the background level that individuals are exposed to and the activities in which  
45 they are engaged. Because of their widely varying and ubiquitous characteristics, radiation doses  
46 to U.S. residents from background, in turn, vary widely, as well.

**E-III POPULATION COLLECTIVE DOSE DUE TO BACKGROUND RADIATION**

As was noted earlier, individual doses from background radiation typically range between 1 mSv/yr (100 mrem/yr) and 10 mSv/yr (1,000 mrem/yr) in the United States. It is sometime necessary to assess radiation exposures to an entire population, as compared to just one individual member (NCRP 1995). In simple terms, the collective dose of a population is the sum of the dose received by each individual within that population group. An important distinction in the concept of collective dose is that it addresses members of population groups and not members of the critical group as is defined in the context of regulatory dose limits. Collective dose is derived as:

$$S = \sum H_i P_i$$

where:

S = collective to the population

$H_i$  = dose to each individual in group i

$P_i$  = population group i

Collective dose is expressed in person-rem or person-sievert. For example, lets assume that the annual doses to members of two groups of individuals are 0.8 and 1.2 mSv each, with a population of 1,250 and 800 persons in each group, respectively. For this example, the collective dose of each group is estimated as:

$$0.8 \text{ mSv} \times 1,250 \text{ persons} = 1,000 \text{ person-mSv}$$

$$1.2 \text{ mSv} \times 800 \text{ persons} = 960 \text{ person-mSv}$$

The results indicate that although doses and population sizes are different, the resulting collective doses are essentially identical. This example also illustrates the competing effects of individual doses and sizes of populations on the collective dose. In this example, the differences in doses and sizes of the populations nearly cancel one another out.

It can be seen that collective dose may be a useful index in differentiating dose impacts when population sizes and doses vary. However, a number of inherent limitations have been identified in the application of collective dose (NCRP 1995). Of specific interest, is whether there is a justification for excluding negligible individual doses from collective dose calculations. The NCRP notes that all doses should be included in assessing collective doses and "there is no conceptual basis for excluding any individual doses, however small." However, the NCRP recognizes that there may be legitimate practical limitations for doing so. Another issue addresses itself to uncertainties in the types of exposed populations, size of the exposed populations, and exposure pathways, among others. Regarding uncertainties in the underlying components on which collective doses are based, the NCRP states that collective doses should not be used when the uncertainty in the number of individuals summed in the population component of the dose is large, i.e., greater than one order of magnitude. Similar care should be considered in evaluating the other components used in calculating collective doses. Finally, there may be a justification in identifying a collective dose threshold below which it should be recognized that there may be no significant impacts, nor risks. The NCRP recommends a

1 threshold based on 10 percent of the reciprocal of the risk coefficient. Using the NCRP  
2 approach, the collective dose threshold for a risk coefficient of  $4 \times 10^{-2}$  per Sv ( $4 \times 10^{-4}$  per rem)  
3 would be 2.5 person-sievert (250 person-rem), used here only as an illustrative example.  
4 Chapter 3 of the GEIS addresses collective doses in the context of the alternatives.

5  
6 The collective dose to the U.S. population associated with background radiation has been  
7 estimated using typical sources of radioactivity and resulting radiation doses. The annual  
8 collective dose from background radiation in the United States is estimated to be about 840,000  
9 person-Sv (84 million person-rem), assuming an annual average effective dose equivalent of 3  
10 mSv (300 mrem) and a population of about 280 million (NCRP 1987b, 1995).  
11  
12

1 **E-IV EXPOSURES FROM MULTIPLE SOURCES DERIVED FROM THE RELEASE**  
2 **OF MATERIALS FROM LICENSEES**

3  
4 **1. INTRODUCTION**

5  
6 Assessment of the potential doses to an individual that could arise from the release of materials  
7 from a licensed facility were performed according to particular activities, called scenarios. The  
8 scenarios involved the transport, processing, refining, consumer use, and disposal of these  
9 materials. Conceptually, multiple scenarios could apply to the same individual, and this potential  
10 raises the question of what would be the exposure and the probability of such an occurrence.  
11 That is, what would be the consequence and the frequency of multiple scenarios affecting the  
12 same individual—the risk. The possibility of multiple scenarios concurrently applying to an  
13 individual implies that the individual would be exposed to very low levels of radioactivity from  
14 more than one source, for example from a vehicle’s engine block and recycled concrete in a  
15 roadbed. The range of potential doses from multiple exposures, should they occur, and the  
16 potential for their occurrence are assessed below.  
17

18 Many exposure scenarios were assessed for each radionuclide and each material to evaluate those  
19 circumstances that could lead to the greatest exposures following the release of materials [see  
20 NUREG-1640 (NRC 2003d)]. These scenarios are the critical group scenarios for that material.  
21 The scenario that yielded the greatest exposure to an individual in a year, regardless of the  
22 material, was identified for each radionuclide on a per unit of radioactivity basis. This scenario  
23 is not only the critical group scenario for that material and radionuclide, but also the overall  
24 critical group scenario for that radionuclide. For example, road building with recycled concrete  
25 is the scenario that potentially gives the greatest exposure for Co-60 for each Bq per gram. Other  
26 scenarios involving the processing, refining, consumer use, and disposal of iron, steel, copper,  
27 and aluminum gave less potential exposure from Co-60 for each Bq/g.  
28

29 **2. MULTIPLE POTENTIAL EXPOSURES**

30  
31 Several hypothetical situations could arise where an individual could be exposed from the release  
32 of several different types of materials, products made from them, disposals in landfills, or reuse  
33 of equipment once released. There could be multiple radionuclides involved, or multiple kinds  
34 of materials released, or multiple concurrent scenarios. Such scenarios might include multiple  
35 facilities releasing materials, processing released materials while using consumer products made  
36 from released materials, reuse of tools and equipment, or disposal of materials from multiple  
37 licensees in one landfill. The potential exposures from these hypothetical situations are  
38 examined below.  
39

40 **2.1 Multiple Radionuclides and the Sum of the Fractions Rule**

41  
42 The standard regulatory approach for implementing limits involving multiple radionuclides  
43 requires that the sum of the fractional concentrations, the nuclide concentration divided by the  
44 concentration limit for each respective nuclide, be kept less than one. This is often known as the  
45 “sum-of-the-ratios rule,” and is described in footnote 4 to App. B of 10 CFR Part 20. Use of this

rule limits the contribution to the overall exposure of an individual from any one radionuclide to a fraction of the overall allowed level when more than one radionuclide is present.

**2.2 Multiple Materials - Implementation Based on the Overall Critical Group Scenario for Each Radionuclide**

Implementation of a regulation for the release of solid materials would likely be dose-based. Thus, to ensure that individuals would be protected regardless of the material being released, the release criteria of a particular radionuclide, for example, Co-60, would be based on the most restrictive scenario for that radionuclide and critical group scenario. Then, that concentration would be applied to all materials. In this case, the same concentration that could give a certain dose, say 10 µSv (1 mrem) in a year, for road building with recycled concrete, would also be applied to the release of iron, steel, copper, and aluminum with associated Co-60. That concentration would give less than 10 µSv in a year for any of these other materials, even in the most restrictive scenario for other materials. For every other scenario, the potential dose actually would be less than 10 µSv in a year because the release criteria would be a lower concentration than could result in 10 µSv in a year. The effects of these small doses are bounded and addressed in the following discussions. The most restrictive scenarios of all materials do not include any scenario from the assessments of copper or aluminum, because their contributions are much smaller when compared to the most restrictive ones listed in Table E-3. For materials with radionuclides only on the surface (surface concentrations as compared to the previous discussion on volume concentrations), the overall critical group scenarios are limited to steel and copper. Concrete scenarios disappear from this latter list due to the mixing of the surficial radionuclides in rubble. That is, there is usually a greater relative thickness of concrete - mass to surface ratios - in buildings and structures.

**Table E-3 Overall Critical Group Scenarios Bq/g Basis**

<b>Iron &amp; Steel</b>	
SCENARIO	
Processing steel at scrap yard	
Leachate from steel slag	
Handling slag at steel mill	
Processing steel slag for road construction	
Emission of airborne effluents from furnace	
<b>Concrete</b>	
SCENARIO	
Processing concrete	
Road building	
Leachate–industrial	
Leachate–Municipal solid waste	
Truck driver	

1  
2 **2.3 Multiple Concurrent Scenarios**  
3

4 Hypothetically, it is possible that an individual could be exposed through multiple concurrent  
5 scenarios. A hypothetical example is given to illustrate this possibility. The approach that is  
6 used to illustrate this hypothetical example is to add a number of scenarios to maximize the  
7 potential dose to an individual. For reasons described later, the likelihood of such multiple  
8 concurrent exposures becomes vanishingly small as the number of potential concurrent scenarios  
9 increases.  
10

11 Some combinations of scenarios can be ruled out, because they are impossible or very highly  
12 unlikely. For example, it is impossible to be in two places at once, there are only twenty-four  
13 hours a day, some scenarios take place in different years after release, and there is a very low  
14 percentage of the population who are fully employed concurrently in two or more jobs covered  
15 by these scenarios. For example, it is reasonable to assume that it is very highly unlikely that the  
16 same individual would be employed at the same time during an entire year as full-time road  
17 builder using processed concrete and also as a full-time slag handler at a copper refinery where  
18 both facilities are processing released materials during that year.  
19

20 However, other combinations of scenarios are possible and these merit analysis. From Table E-  
21 3, a hypothetical set of concurrent scenarios that are also credible can be assembled with only  
22 two scenarios. A full-time job and residing downwind from a refinery could occur concurrently.  
23 Hypothetically, the expected exposure (from two scenarios) could be up to 20  $\mu\text{Sv}$  (2 mrem) in a  
24 year, if the limit for release were based on 10  $\mu\text{Sv}$  (1 mrem) in a year. More credible conjunction  
25 of concurrent scenarios can be hypothesized if the less-than-overall-critical group scenarios are  
26 added. However, the hypothetical exposures from each of the other scenarios would be expected  
27 to add less than the dose upon which release would be based, e.g., less than 10  $\mu\text{Sv}$  in a year.  
28

29 A hypothetical road builder using processed concrete material with associated cobalt-60 could  
30 drive to work over a roadbed made from aggregate with associated thorium-232. He could live  
31 within the area that is in the effluent pathway of a refining furnace. Furthermore, he could drive  
32 a truck with an aluminum engine block, and use aluminum cookware and jewelry made from  
33 recycled metals. Hypothetically, if a release regulation were to limit the mean individual dose to  
34 the critical group to, for the purposes of clarity and illustration, 10  $\mu\text{Sv}$  in a year from release,  
35 and if the implementation of the regulation takes into account the practices described above, as  
36 shown in Table E-4, the dose to the hypothetical individual, calculated from the results in  
37 NUREG-1640 (NRC 2003d), would be approximately 30  $\mu\text{Sv}$  (3 mrem) in a year or three percent  
38 of the public dose limit, which is 1,000  $\mu\text{Sv}$  (100 mrem) in a year (see Subpart D to 10 CFR Part  
39 20).  
40

41 As shown in Table E-4, even when, for illustrative purposes, an extremely conservative and  
42 highly implausible situation is considered for estimating individual dose, where six hypothetical  
43 exposures occur concurrently, the resulting dose is only 30  $\mu\text{Sv}$  in a year. The underlying  
44 assumption for making the above dose estimate assumed that several different licensed facilities  
45 that use different radionuclides come together to make this situation possible and all these

**Table E-4. Hypothetical Multiple Concurrent Scenarios**

Scenario	Nuclide	Material	Dose <sup>1</sup> (μSv in a year)
Road builder	Cobalt-60	Concrete	10
Driving on road	Thorium-232	Concrete	10
Air borne emissions	Iodine-125	Steel	10
Aluminum engine block	Cobalt-60	Aluminum	0.009
Aluminum cookware	Protactinium-231	Aluminum	0.008
Copper object on body	Silver-108m	Copper	0
			<b>Total 30.017</b>

<sup>1</sup>NUREG-1640, mass based mean effective dose.

facilities released materials at the maximum release concentration levels. A more realistic estimate of the dose to this hypothetical individual would be significantly less than 10 μSv in a year from each of the six scenarios, and a more realistic cumulative total dose would be less than 30 μSv in a year. This is much more than adequate protection of the public because, for adequate protection of the public, NRC requires that each licensee conduct operations so that the total effective dose equivalent to individual members of the public from the licensed operation does not exceed 1,000 μSv in a year.

#### 2.4 Potential for Occurrence of Multiple Concurrent Scenarios

The potential for the same individual to be involved in concurrent scenarios is physically constrained by the relatively limited amount of materials that could be released from licensed facilities. Geographical distances between licensees and the different locations where the scenarios could occur also decrease the potential for concurrent scenarios to affect a single individual. From the above lists of scenarios that could result in the highest doses, it can be seen that many involve specialized industrial processing. There are not many of these processors in the country, and thus, only a limited number of individuals could be affected by those scenarios. Such individuals would likely be affected by only one processing scenario. The more likely scenarios that could affect these processors would involve consumer products or use of public roads. The potential that a particular consumer product made from released materials is used by the same hypothetical individual depends on the number of such products made, the total number of these products made from released materials and the fraction of those made that are in use.

The potential for a processor to be affected by additional scenarios is the serial multiplication of each additional scenario. While it is difficult to estimate the actual probability of a particular scenario<sup>1</sup>, an example can illustrate that with each additional scenario, the potential for all the

<sup>1</sup> Data are usually not available to calculate the probability, however, an example of an approach to make such an estimate illustrates that the probabilities of these scenarios is usually small. Consider the probability of an auto with a cast-iron engine block containing radionuclides that were released in steel. From NUREG-1640, the fraction of iron castings that are used for the auto and truck industry is 0.5. The  
(continued...)

1 scenarios occurring together becomes smaller. Even with only a few scenarios, this potential is  
2 very small. For example, in the illustrative case above, six scenarios were hypothetically  
3 aggregated. A relatively large estimate of the likelihood that any of the additional scenarios  
4 would affect the hypothetical road builder above would be one-in-a-hundred, or 0.01. If only  
5 one additional scenario affected the hypothetical road builder, then there would be an estimated  
6 one-in-a-hundred chance that this individual would be exposed to as much as 20  $\mu\text{Sv}$  in a year.  
7 The potential for two additional scenarios would be estimated as  $0.01 \times 0.01 = 0.0001$  or one-in-  
8 ten-thousand in a year to be exposed to something less than 30  $\mu\text{Sv}$  in a year. Repeating this  
9 process for each additional scenario in our hypothetical example above gives an estimate of one-  
10 in-ten-thousand million that this hypothetical individual would be exposed to less than 30  $\mu\text{Sv}$  in  
11 a year. Considering that the population of the U.S. is approximately 280 million, this is a very  
12 small potential as the probability indicates that no one individual in the entire U.S. is likely to be  
13 affected by six concurrent scenarios.

## 14 **2.5 Landfill Disposal**

17 Materials released from licensed facilities may be disposed of in regulated landfills. The types  
18 of disposal facilities include municipal solid waste (MSW) landfills, industrial landfills (IL), and  
19 construction and demolition (C&D) landfills. Collectively, these facilities are referred to as  
20 Subtitle D landfills under EPA regulations. Municipal solid waste landfills are regulated under  
21 40 CFR Part 258, and industrial landfills and construction and demolition landfills are regulated  
22 under 40 CFR Part 257. In addition, State and local agencies regulate landfill siting, design and  
23 construction, operation, surface and ground water monitoring and corrective action, closure and  
24 post-closure care, and financial assurance. Municipal solid waste landfills are required to install  
25 a cap upon closing each disposal cell, and a composite bottom liner and a leachate collection  
26 system. Performance standards include requirements to limit the amounts of leachate  
27 accumulations at the bottom of disposal cells, specifications on leachate release rates out of  
28 landfills, and chemical concentration limits in ground water. Industrial landfills are not required  
29 to have bottom liners and leachate collection systems. However, all landfills are required to  
30 operate in a manner that will not cause discharges of pollutants into surface water or ground  
31 water in violation of the requirements of the Clean Water Act and Safe Drinking Water Act.

32  
33 Such requirements are expected to mitigate exposures and doses to both landfill workers and  
34 nearby members of the public. For example, MSW landfills are required to place a daily soil  
35 cover over wastes. The presence of a soil cover is expected to reduce worker exposures from  
36 external radiation, dust inhalation, and incidental ingestion of materials. The cover is also

---

<sup>1</sup> (...continued)

fraction of all scrap that is used for casting is 0.2. If all the scrap that could potentially be released from the nuclear industry were to be used in one year, it would be one-thousandth of all the scrap used that year. Thus, the fractional mass of released metal in new engine blocks would be one-ten-thousandth. This fraction can be used as an estimate of the probability of getting a new engine block with released metal. That probability is then multiplied by the probability that the hypothetical individual is driving a new auto. Therefore, an estimate for the probability of a single scenario occurring of one-in-one-hundred is likely an overestimate, but it is useful to illustrate a conservative upper bound of the probability.

1 expected to reduce fugitive dust emissions and airborne materials at downwind locations,  
2 thereby reducing inhalation exposures to nearby residents. The control of leachate discharges,  
3 landfill closure, and the post-closure care and monitoring periods are part of the process required  
4 to mitigate impacts on surface and ground water. These requirements are designed to minimize  
5 discharges from closed disposal cells and reduce or eliminate impacts on nearby usable surface  
6 and ground water resources.  
7

8 In considering the disposal of materials from multiple licensees, although possible, the dumping  
9 of released materials is expected to be governed by several factors. First, the disposal of  
10 materials is driven by the availability of nearby landfills, disposal capacity of each landfill, and  
11 restrictions placed by each landfill on the types of wastes it may accept. As a result, it is  
12 expected that in some cases, disposals will be shared by two or more landfills, and in other  
13 instances, disposals may be confined to a regional, and possibly larger, landfill. Second, the  
14 sequence in which shipments of released materials are sent for burial can be considered as  
15 independent events, with shipments occurring on a schedule driven by the need of each licensee.  
16 The likelihood that two licensees might ship materials at the same time and arrive at the landfill  
17 for disposal also at the same time is very unlikely. Third, the disposal process at landfills is often  
18 organized by disposal cells, where burials are segregated by types of wastes and volumes. In  
19 such instances, materials sent by two licensees would most likely be dumped in separate disposal  
20 cells, and processed by different work crews. Together, these factors are anticipated to minimize  
21 exposures to both workers and members of the public.  
22

23 In light of regulatory requirements imposed on the operation and closure of landfills, and post-  
24 closure monitoring, doses to both landfill workers and nearby residents are expected to be well  
25 below the release limit. Other factors that are expected to contribute to still lower doses include  
26 the remote possibility of multiple disposals occurring at every single landfill, the segregation of  
27 materials by disposal cells, and disposal activities being conducted by different work crews.  
28 Finally, the application of the most limiting unrestricted release scenario and its corresponding  
29 radionuclide concentrations as release criteria would tend to result in doses that are less than 10  
30 uSv (1 mrem) per year, even when considering multiple disposal events at a single landfill.  
31

## 32 **2.6 Equipment Reuse**

33

34 The type of equipment that could be released from nuclear facilities for reuse in an environment  
35 free of radiological controls ranges from small items, such as hand tools, to very large ones, such  
36 as mechanized equipment and industrial vehicles. The release of equipment is a dynamic process  
37 involving different types of facilities and activities, such as routine operations, research and  
38 development, and plant outages, refurbishment, and decommissioning. In addition, this process  
39 is taking place simultaneously at thousands of facilities across the nation and being conducted  
40 every day. As a result, it is not readily possible to define what types of items and how many are  
41 routinely used in radiologically controlled areas, what fraction is surveyed and released for reuse  
42 versus those that are discarded as low-level radioactive waste, and assign representative residual  
43 radioactivity levels by radionuclides and relative mix for all licensees.  
44

45 Doses to workers using tools and equipment that have been released depend on several factors.  
46 For example, the dose is directly proportional to the number of hours that a worker is assumed to

1 handle reused items. Time spent on other activities that do not require the use of any equipment  
2 that was released would result in lower doses. Another consideration is whether other equipment  
3 and tools may be available that are not a product of release, i.e., equipment of other origins that  
4 were never introduced in radiologically controlled areas. For equipment that have been released,  
5 the duration of exposure to workers is confined to its useful life-cycle. The useful life of  
6 equipment is driven by operational conditions and economic considerations, taking into account  
7 replacement and repair costs. These factors are expected to be different among facilities. For  
8 large equipment (e.g., trucks), the useful life is typically much longer than that of small  
9 equipment, such as hand tools. The useful life of small equipment is much shorter as these items  
10 are discarded given that replacement costs are usually less than repair costs. Also, the dose is  
11 directly proportional to the total number of items being used by a worker at any one time. For  
12 large equipment, such as mechanized equipment, a worker can only operate one piece of  
13 equipment at a time. However, for small equipment, such as hand tools, it is conceivable that a  
14 worker could use a number of items or at least be surrounded by several such small tools while  
15 working. Other mitigative measures are associated with different practices among licensees,  
16 such as whether equipment and tools are protected (by wrapping in plastic) before being  
17 introduced in controlled areas; the types of administrative controls used for releasing equipment;  
18 conditions on the types of equipment that may be released *versus* those that are discarded as  
19 radioactive waste; and the application of constraints on how equipment may be used after having  
20 being released.

21  
22 In practice, licensees control equipment and tools that are introduced in radiologically controlled  
23 areas. In some instances, licensees supply all equipment and tools for use in controlled areas,  
24 thereby minimizing the constant flux of equipment being processed in and out of such areas.  
25 Also, equipment and tools are surveyed before being taken out of radiologically controlled areas.  
26 Such surveys consist of conducting scans with a radiation survey meter and taking wipes to  
27 assess the presence of removable surface activity. The presence of radioactivity on wipes is  
28 evaluated using separate instrumentation. Some survey methods involve the introduction of the  
29 item into an instrument that measures radioactivity from all external and internal surfaces.  
30 Depending on the results of the survey, the items are either cleaned to meet release criteria, not  
31 taken out of the controlled area and set aside for later use in the same work area, or simply  
32 discarded as low-level radioactive waste. Moreover, experience has shown that cleaning efforts  
33 involve a process in which residual radioactivity levels are removed to non-detectable levels, as  
34 opposed to cleaning to a level that just meets release criteria. In recognition of operational  
35 practices and application of ALARA by licensees, it is expected that the presence of residual  
36 radioactivity on released equipment would be well below release criteria and should result in  
37 doses that are less than 10 uSv (1 mrem) per year, even when considering the use of multiple  
38 small items.

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1  
2  
3

1 **APPENDIX F**  
2 **CHARACTERIZATION OF SOLID MATERIALS**  
3

4 **Introduction**  
5

6 This appendix provides supporting information for Chapter 3 on the types of NRC licensed  
7 facilities and inventory estimates for materials released for each alternative.  
8

9 Table F-1 lists commonly reported radionuclides for all licensees. For nuclear power plants, the  
10 radionuclide profile and relative fraction of each radionuclide are based on site characterization  
11 results and some low-level waste data. A single inventory was derived for all reactors, both  
12 operating and shutdown. The radioactivity profile assumed the presence of 17 radionuclides, as  
13 beta and gamma emitters, and transuranics. The most predominant radionuclides, comprising  
14 about 96% of expected residual radioactivity levels, are Mn-54, Co-58, Co-60, Ni-63, Fe-55, Cs-  
15 134, and Cs-137. For all other licensees, the listing is meant only to be illustrative of some of  
16 the most common radionuclides, while recognizing that radioactivity profiles in materials  
17 designated for release are expected to vary. It should be noted that the types and amounts of  
18 radioactive materials authorized under a license are not always reliable predictors of radionuclide  
19 distributions that might be found in potentially clearable material. The uncertainty about the  
20 presence of radionuclides and their relative fractions in any material is dependent on the license  
21 specifying types of radionuclides and their chemical and physical properties, processes or events  
22 leading to the release of materials, use of material control measures, and radioactive decay.  
23

24 This Draft GEIS is focused on controlling the disposition of solid materials that are present in  
25 areas in NRC-licensed facilities where radioactive materials are used or stored. These areas are  
26 generally referred to as either restricted or impacted<sup>1</sup> areas. Despite its location in these restricted  
27 or impacted areas, much of this solid material has no, or very little, radioactivity resulting from  
28 licensed operations because (1) the material was not exposed to radiation, or (2) the material was  
29 exposed to radioactivity only minimally, or (3) it has been decontaminated. In this Draft GEIS,  
30 these solid materials are referred to as “potentially clearable” materials. These solid materials  
31 can include furniture and ventilation ducts in buildings; metal equipment and ferrous metals and  
32 copper pipes; wood, paper and glass; laboratory materials (gloves, beakers, etc); routine trash;  
33 site fences; concrete; soil; or other similar materials.  
34

35 Other solid materials in these restricted or impacted areas can contain more appreciable levels of  
36 radioactivity. However, these are separated from those materials with no, or very small amounts  
37 of radioactivity at the licensed facility and are required to be disposed at licensed low-level  
38 waste (LLW) disposal sites under NRC’s existing regulations in 10 CFR Part 61. Solid materials  
39 containing appreciable levels of radioactivity are not the subject of the Proposed Action. These  
40 materials are referred to as “activated” or “contaminated.”

---

<sup>1</sup> A restricted area is defined in the NRC regulations at 10 CFR 20.1003 as an area to which access is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. An impacted area is defined in 10 CFR 50.2 as an area with some reasonable potential for residual radioactivity in excess of natural background or fallout levels.

Table F-1 Radionuclides Expected in Potentially Clearable Materials

Radionuclide	Power Reactors & ISFSIs	Research Reactors	Fuel Cycle Facilities & U-Mills	All Material Licensees	Complex Sites
H-3	x	x		x	
C-14	x	x		x	
P-32, P-33				x	
S-35				x	
Mn-54	x	x		x	
Cr-51				x	
Fe-55, Fe-59	x	x		x	
Co-57, Co-58, Co-60	x	x		x	
Ni-63	x	x		x	
Zn-65	x	x			
Ga-67				x	
Sr-89, Sr-90	x	x		x	
Tc-99	x	x	x	x	
Tc-99m				x	
Ru-106	x	x			
Ag-110m	x	x			
In-111				x	
Sb-125	x	x		x	
I-123, I-125, I-129, I-131	x	x		x	
Cs-134, Cs-137	x	x		x	
Ce-144	x	x			
Eu-152, Eu-154, Eu-155	x	x			
Ir-192				x	
Tl-201				x	
Ra-226, Po-210				x	x
U-238, U-234, U-235			x	x	x
Pu-238, Pu-239, Pu-240, Pu-241	x	x	x	x	
Am-241	x	x	x	x	
Cm-243, Cm-244	x	x	x		
Natural-U			x	x	x
Natural-Th			x	x	x
Enriched-U and Depleted -U			x	x	

Note: All "material licensees" include manufacturers of sealed sources and radio-labeled compounds, nuclear pharmacies, R&D facilities, academic institutions, medical centers, nuclear laundries, government laboratories, decontamination services, and commercial service organizations supporting licensees.

1 Solid materials not located in restricted or impacted areas, and considered to be free of  
2 radioactivity resulting from licensed operations, are not currently required to be part of a  
3 disposition radiological survey program. Such materials can include furniture, glass bottles,  
4 paper, equipment, or trash in administrative buildings or office areas. This rulemaking does not  
5 propose to alter this approach and, therefore, these materials also are not the subject of the  
6 Proposed Action. In this Draft GEIS, these materials are referred to as “clean.”  
7

8 Contamination is characterized by a large mass of potentially clearable material and a large mass  
9 of materials with very high contamination levels (SC&A 2003). Little material is expected to  
10 have intermediate contamination levels. The high end contamination is typically associated with  
11 areas where contamination is inevitable (e.g., areas with equipment used to process nuclear  
12 materials).  
13

### 14 **Description of NRC-Licensed Facilities**

15  
16 The facilities that generate the solid materials and are the subject of this Draft GEIS are all  
17 licensed facilities (about 21,000 sites/facilities) and include the following:  
18

- 19 • Commercial Nuclear Power Reactors
  - 20 - Currently licensed (104)
  - 21 - Formerly licensed, excluding reactors which have largely completed DECON<sup>2</sup> (17)
- 22 • Non-Power Licensed Reactors (36)
- 23 • Fuel Cycle Facilities
  - 24 - Uranium mills and *in situ* leach facilities (16)
  - 25 - Conversion/enrichment plants (4)
  - 26 - Fuel fabrication plants (7)
  - 27 - Independent spent fuel storage installations (28)
- 28 • Material Licensees (21,000)
- 29 • Complex Materials Decommissioning Sites (43<sup>3</sup>)  
30

31 The number of licensed facilities is constantly changing because every year new facilities  
32 receive operating licenses and some licenses are terminated. This listing of facilities is based  
33 primarily on data compiled by the NRC in its *2002 Information Digest* (NRC 2002c) and as such  
34 represents a snapshot at that instant in time.  
35

---

<sup>2</sup> DECON is an NRC Classification for nuclear facilities in which “the equipment, structures, and portions of a facility and site that contain radioactive contaminants are removed or decontaminated to a level that permits termination of the license after cessation of operations.”

<sup>3</sup> Formerly known as SDMP sites. The number of sites indicated does not include reactor sites. The NRC has eliminated the designations of the “Site Decommissioning Management Plan (SDMP),” “SDMP Program,” or “SDMP sites.” (Federal Register, June 17, 2004, Vol. 69, No. 116, p. 33946). Such sites are now referred to as “complex decommissioning sites.”

## 1. Commercial Nuclear Power Reactors

Commercial nuclear power reactors include boiling water reactors (BWRs) and pressurized water reactors (PWRs). In order to characterize the solid materials that could be released from commercial nuclear power reactors, reference facilities were developed for both BWRs and PWRs and the results were scaled to cover all the reactors (SC&A 2003).

### Reference Boiling Water Reactor

The reference BWR consists of three principal buildings where radioactive contamination may be present: the Reactor Building, the Turbine Generator Building, and the Radwaste and Control Building.

The Reactor Building contains the nuclear steam supply system and its supporting systems. It is constructed of reinforced concrete capped by metal siding and roofing supported by structural ferrous metals. The building surrounds the primary containment vessel, which is a free-standing ferrous metals structure. The exterior dimensions of the Reactor Building are approximately 42 m by 53 m in plan, with 70 m above grade and 10.6 m below grade to the bottom of the foundation.

The Turbine Generator Building, which contains the power conversion system equipment and supporting systems, is constructed of reinforced concrete capped by ferrous metals-supported metal siding and roofing. This structure is approximately 60 m by 90 m in plan and 42.5 m high.

The Radwaste and Control Building houses, among other systems, the condenser offgas treatment system, the radioactive liquid and solid waste systems, the condensate demineralizer system, the reactor water cleanup demineralizer system, and the fuel-pool cooling and cleanup demineralizer system. The building is constructed of reinforced concrete and structural ferrous metals and has metal siding and roofing. This structure is approximately 64 m by 49 m in plan and 32 m in overall height.

Several additional buildings make up the reference BWR complex. These include the Diesel Generator Building, Service Building, Circulating Water Pump House, Spray Pond Complex, Makeup Water Pump House, the yard, and other buildings (i.e., Office Building, Warehouse, Guard House, and Gas Bottle Storage Building). These buildings are assumed not to be radioactively contaminated. They would generally fall into the clean category in the MARSSIM definition of a non-impacted area.

### Reference Pressurized Water Reactor

The principal structures at the reference PWR power station are the Reactor Building, Fuel Building, Auxiliary Building, Control Building, and Turbine Building.

The Reactor Building houses the nuclear steam supply system. Since its primary purpose is to provide a leak-tight enclosure for normal as well as accident conditions, it is frequently referred to as the containment building. Major interior structures include the biological shield,

1 pressurizer cubicles, and a ferrous metals-lined refueling cavity. Supports for equipment,  
2 operating decks, access stairways, grates, and platforms are also part of the containment structure  
3 internals. The Reactor Building is in the shape of a right circular cylinder approximately 64 m  
4 tall and 22.5 m in diameter. It has a hemispherical dome, a flat base slab with a central cavity,  
5 and an instrumentation tunnel.

6  
7 The Fuel Building, approximately 27 m tall and 19 m long by 54 m wide, is a ferrous metals-  
8 reinforced concrete structure with four floors. This building contains the spent-fuel storage pool  
9 and its cooling system, much of the chemical and volume control system, and the solid  
10 radioactive waste handling equipment. Major ferrous metals structural components include fuel  
11 storage racks and liners, support structures for fuel handling, and components, ducts, and piping  
12 associated with air conditioning, heating, cooling, and ventilation.

13  
14 The Auxiliary Building, approximately 30 m tall with lateral dimensions of 19 m by 35 m, is a  
15 ferrous metals and reinforced concrete structure with two floors below grade and four floors  
16 above grade. Principal systems contained in the Auxiliary Building include the liquid radioactive  
17 waste treatment systems, the filter and ion exchanger vaults, waste gas treatment system, and the  
18 ventilation equipment for the Reactor, Fuel, and Auxiliary Buildings.

19  
20 Other major building structures with substantial inventories of metals include the Control  
21 Building and Turbine Building. The principal contents of the Control Building are the reactor  
22 control room, as well as process and personnel facilities. The principal systems in the Turbine  
23 Building are the turbine generator, condensers, associated power production equipment, steam  
24 generator auxiliary pumps, and emergency diesel generator units.

## 26 **2. Non-Power Reactors**

27  
28 Non-power reactors (NPRs) come in many varieties and forms, with most being either pool-type  
29 or tank-type. Many are located at universities and research organizations. Pool-type reactors  
30 have a core immersed in an open pool of water. The pools typically provide about 20 ft of water  
31 above the core to allow cooling and radiation shielding. At pool-type NPRs, the operating core  
32 and fuel can be observed through the pool water. Tank-type reactors have a core in a tank with  
33 water, sealed at the top. Non-power reactors are also categorized by fuel type: plate-type fuel,  
34 TRIGA (Training, Research, Isotopes, General Atomics), or AGN (Aerojet General Nucleonics).  
35 Plate-type fuel consists of several thin plates containing a uranium mixture clad with aluminum  
36 formed into an assembly. This geometry promotes efficient heat removal and the ability to  
37 provide a high-neutron density. TRIGA fuel is in the shape of rods and consists of a uranium and  
38 zirconium hydride mixture. AGNs are compact, self-contained, low-power (<5 watts) tank-type  
39 reactors. The 10-in diameter core consists of uranium oxide powder embedded in a polyethylene  
40 moderator.

## 42 **3. Uranium Mills**

43  
44 Nuclear fuel cycle facilities include uranium mills, uranium hexafluoride production facilities,  
45 fuel fabrication facilities, and uranium enrichment facilities.

1 NRC currently licenses 16 uranium recovery facilities<sup>4</sup> under 10 CFR Part 40, including  
2 12 conventional uranium mills and 4 *in situ* leach facilities. In addition, some milling sites are  
3 licensed by Agreement States. Most conventional uranium mills have been shut down and are  
4 undergoing decommissioning. These mills are not likely to be significantly affected by any  
5 future NRC regulations relating to the release of solid materials from regulatory control, since  
6 dismantlement will likely be well advanced or completed prior to any rulemaking. One  
7 conventional mill is on standby status and two are operating. Based on the likely approach to  
8 decommissioning, where there is little or no salvageable equipment and most materials are buried  
9 in onsite tailings piles or at other approved sites, the quantities of potentially clearable materials  
10 from uranium mills are expected to be small. Some licensees may attempt to sell or transfer  
11 larger items such as tanks, and office trailers and construction equipment.  
12

13 Of the four NRC-licensed *in situ* leach facilities, one has been shut down and is undergoing  
14 decommissioning. The shutdown facility is unlikely to be affected by the Proposed Action, since  
15 dismantlement is expected to be largely completed prior to issuance of any final rule. Two *in*  
16 *situ* leach facilities are operating, one is decommissioning, and one is not yet built. Some large  
17 resin and chemical tanks and pumps may be available for recycle/reuse when these facilities are  
18 ultimately decommissioned. Contaminated equipment and plastic piping are likely to be  
19 disposed of in tailings piles or at other licensed disposal sites. Disposition of structures and clean  
20 equipment could be affected by the Proposed Action.  
21

#### 22 **4. Uranium Hexafluoride Production Facilities**

23  
24 Most nuclear reactors require uranium to be enriched from its natural isotopic composition of  
25 approximately 0.7 percent U-235 (most of the rest being U-238) to 3.5-4 percent U-235. To  
26 enrich uranium in a diffusion plant, it must first be converted to a gaseous form, and the standard  
27 way of achieving this is to convert the uranium oxides to uranium hexafluoride (UF<sub>6</sub>). The  
28 reference UF<sub>6</sub> production facility consists of a main building, a solvent extraction facility, a  
29 warehouse, a cooling tower, retention lagoons, and other storage areas.  
30

31 The only operating UF<sub>6</sub> conversion facility in the United States is managed by Honeywell in  
32 Metropolis, Illinois. The Sequoyah Fuels Corporation facility in Gore, Oklahoma, was shut  
33 down in 1993 and is currently awaiting decommissioning. The NRC license for the Honeywell  
34 facility expires on June 30, 2005. Closure of that facility at that time would force reliance on  
35 foreign sources of conversion capacity. To ensure continued domestic UF<sub>6</sub> production capability,  
36 the Honeywell license would need to be renewed, or a new facility would need to be constructed  
37 and licensed to operate by June 2005. However, DOE is currently in the construction phase for a  
38 UF<sub>6</sub> conversion facility on the site of the existing Portsmouth Gaseous Diffusion Plant (uranium  
39 enrichment plant) in Portsmouth, Ohio. It is not yet clear exactly when this facility will be  
40 operational.  
41

---

<sup>4</sup> A uranium mill tailings waste disposal facility in South Clive, Utah, is also licensed under the regulation.

1 **5. Uranium Enrichment Facilities**

2  
3 DOE leases uranium enrichment facilities in Paducah, Kentucky, and Portsmouth, Ohio, to the  
4 U.S. Enrichment Corp. These facilities are administered under NRC regulations at 10 CFR Part  
5 76. DOE's K-25 enrichment facility in Oak Ridge, Tennessee, has been shut down and is  
6 undergoing decommissioning. The Portsmouth plant was shut down in March 2001 and DOE  
7 plans to keep the plant in a cold standby basis permitting rapid reopening. Recently, both  
8 Louisiana Energy Services (Lea County, New Mexico) and USEC, Inc. (site of the current  
9 Portsmouth Gaseous Diffusion Plant) have submitted license applications to the NRC to  
10 construct and operate a gas centrifuge uranium enrichment facility. The gas centrifuge uranium  
11 enrichment process uses a large number of rotating cylinders in series to enrich uranium in its U-  
12 235 isotope. Since DOE has responsibility for decommissioning and dismantling these plants,  
13 they are not considered here.

14  
15 **6. Fuel Fabrication Facilities**

16  
17 Fabrication is the final step in the process used to produce uranium fuel. This process converts  
18 enriched  $UF_6$  into a solid form of uranium suitable for use in a nuclear reactor. Fabrication of  
19 reactor fuel consists of three basic steps: the chemical conversion of  $UF_6$  to uranium dioxide  
20 ( $UO_2$ ) powder; the ceramic process that converts  $UO_2$  powder to pellets; and the mechanical  
21 process that loads the fuel pellets into rods and constructs finished fuel assemblies.

22  
23 There are six uranium fuel fabrication facilities currently licensed to operate by the NRC, plus  
24 one in decommissioning and a mixed oxide (MOX) fuel fabrication facility currently under  
25 development. An application has been submitted to NRC for authority to construct a MOX  
26 facility. The application is under review by the NRC. The reference uranium fuel fabrication  
27 facility is based primarily on the Global Nuclear Fuel facility in Wilmington, North Carolina.

28  
29 **7. Independent Spent Fuel Storage Installations (ISFSI)**

30  
31 An ISFSI is a complex designed and constructed for the interim storage of spent nuclear fuel. As  
32 of August 2003, there are 28 licensed facilities. In addition, there are 19 soon-to-be-built or  
33 operational facilities and a further four being considered in addition to the proposed Private Fuel  
34 Storage facility in Tooele, UT. There is also a single wet storage facility in Morris, Illinois,  
35 operated by the General Electric Company.

36  
37 ISFSIs may be initially licensed for a period of up to 20 years. The license may also be renewed  
38 for an additional 20 years. Therefore, it is expected that the materials contained in the above  
39 ISFSIs would be available for release 20 or 40 years after the ISFSI start-up dates. However, a  
40 recent study has determined that extending the storage period to 100 years would have no adverse  
41 impacts (Einziger et al. 1998). Conversely, fuel may be removed from storage prior to the end of  
42 the licensed lifetime of the ISFSI, if a high-level waste (HLW) repository becomes available.  
43 Spent fuel may be stored in either a wet or dry environment; the various techniques include:  
44 Concrete Casks, Horizontal Storage Modules (HSM), Metal Casks, Pool (Wet) Storage, and  
45 Modular Vault Dry Storage (MVDS).

1 **8. Materials Licensees**

2  
3 The NRC Information Digest (NRC 2002c) indicates a total of 21,175 medical, academic and  
4 industrial materials licensees in the United States. Of these, 23 percent are NRC licensees and  
5 77 percent are licensed by Agreement States.

6  
7 Profiles were prepared of materials licensees potentially affected by the Proposed Action (SC&A  
8 2003). These profiles do not include those licenses that authorize only possession and use of  
9 licensed materials in sealed sources or other non-dispersible forms, such as plated disks and foils  
10 because for these licensees, operation and decommissioning would normally entail no  
11 decontamination efforts. At decommissioning the licensed source would simply be removed from  
12 the facility and disposed of in accordance with NRC regulations. Elimination of these types of  
13 licensees resulted in a population of 3,017 non-reactor licenses that are potentially affected by  
14 the Proposed Action. Based on this understanding of the universe of potentially affected non-  
15 reactor, non-sealed source NRC licensees, this section addresses four broad categories of  
16 licensees: large medical centers, research and development laboratories, nuclear pharmacies  
17 (including both manufacturers and regional and local distributors), and manufacturers of sources  
18 and radio-labeled compounds.

19  
20 Large Medical Centers

21  
22 The inventory of materials in the reference room of a large medical center is about 2,300 kg  
23 (5,000 lb). The total inventory of materials in large medical centers in the U.S. is about 440,000  
24 metric tons (480,000 tons). Much of this mass would be trash (e.g., plaster board, floor tiles)  
25 rather than recyclable materials. Items such as refrigerators and storage cabinets could  
26 potentially be released for reuse.

27  
28 Research and Development Laboratories

29  
30 In many respects, research and development (R&D) laboratories are similar to the research  
31 laboratories at large medical facilities. R&D facilities using radioactive materials cover a broad  
32 range of activities, including the use of laboratories or health treatment facilities that use  
33 radioisotopes. Both short-lived ( $^3\text{H}$ ) and long-lived isotopes ( $^{14}\text{C}$ ) may be used. The reference  
34 R&D laboratory facility includes rooms for synthesis of labeled compounds and for preparing  
35 radioactive samples, a laboratory, a counting room, and a storage room. In addition to the  
36 contaminated structural material, the reference R&D facility also contains furniture and  
37 equipment.

38  
39 Nuclear Pharmacies

40  
41 The NRC issues commercial nuclear pharmacy licenses pursuant to 10 CFR Part 30 and  
42 10 CFR 32.72, for the possession and use of radioactive materials for the manufacture,  
43 preparation, or transfer for commercial distribution of radiopharmaceuticals (radioactive drugs)  
44 containing byproduct material for medical use under Part 35. Radiopharmaceuticals produced  
45 from NORM or accelerator-produced radionuclides are not within the regulatory authority of the  
46 NRC, although they may be subject to State licensing requirements. Preparation includes the

1 making of radiopharmaceuticals from reagent kits and from raw materials. Typically, nuclear  
2 pharmacies are also authorized to transfer for commercial distribution (per 10 CFR 31.11) in  
3 vitro test kits, radiopharmaceuticals to licensees authorized to possess them for other than human  
4 medical use (i.e., veterinary medicine and research licensees), and radiochemicals to those  
5 licensees authorized to possess them, pursuant to 10 CFR Part 30. Additionally, nuclear  
6 pharmacies are authorized to redistribute (transfer) sealed sources for calibration and medical use  
7 initially distributed by a manufacturer licensed pursuant to 10 CFR 32.74. The NRC database  
8 identifies 52 nuclear pharmacies.

9  
10 For nuclear pharmacies, decommissioning for license termination will typically involve the  
11 removal of all sealed sources and depleted uranium and maintenance of active radiological  
12 control of the facility until the longest half-life material used at the facility have decayed to an  
13 acceptable level. A confirmatory survey after the appropriate elapsed time would then complete  
14 decommissioning efforts. Nuclear pharmacies are not expected to be significant sources of  
15 potentially clearable materials for recycle or reuse.

#### 16 Manufacturers of Sources and Radio-Labeled Compounds

17  
18  
19 The sealed source manufacturing process is a hand operation that is carried out in buildings  
20 which contain a number of small laboratories, each of which is devoted to a specific process  
21 and/or isotope. The reference sealed source manufacturer is a laboratory which processes <sup>137</sup>Cs  
22 and <sup>60</sup>Co. Contaminated facilities associated with the reference sealed source manufacturer  
23 include: hot cells, fume hoods, workbenches, sinks, laboratory floor and wall areas, and building  
24 areas used for storage of waste drums. The Commission's license tracking system identified 63  
25 sealed source and radio-labeled compound manufacturers licensed by the NRC. As is the case  
26 for R&D labs, the individual facilities that make up this category are very diverse. Not all  
27 facilities within this category manufacture Co-60 sealed sources. Some facilities manufacture  
28 radio-labeled compounds and therefore may have more in common with the hospital and R&D  
29 laboratories.

### 30 31 **9. Complex Materials Decommissioning Sites**

32  
33 Forty-three complex (not routine) materials decommissioning sites are currently being  
34 remediated. At many of these locations, the only issue is soil with elevated levels of  
35 radioactivity. In addition, building materials and slags will be released during cleanup  
36 operations. Some of the slags may be processed for metals recovery.

### 37 38 **Inventories of Solid Materials for the Rulemaking Alternatives**

39  
40 This section summarizes the characteristics of solid materials generated largely from commercial  
41 nuclear reactor facilities and considered in the collective dose assessment (SC&A 2003).  
42 Material characteristics are provided in terms of the total mass (tons) of each material (ferrous  
43 metals, concrete, and trash) released from commercial reactor facilities and the total activity  
44 (curies) for each alternative. SC&A 2003 describes the detailed information for these inventory  
45 estimates.

**1. No Action Alternative**

The total mass and activity of material generated from commercial nuclear reactor facilities forms the baseline solid material inventory for all the alternatives. Under the No Action Alternative, for example, a total of 2.06 million tons of ferrous metals generated from commercial nuclear reactor facilities would be released for recycling, out of a total estimated amount of scrap ferrous metals generated of approximately 2.5 million tons. The remaining 0.44 million tons of ferrous metals generated from commercial nuclear reactor facilities but not released for recycling would be disposed of as LLW in a licensed disposal facility. Similar calculations apply to the other materials (concrete and trash).

Table F-2 provides an estimate of the total mass and total activity of solid material released from commercial reactor facilities under the No Action Alternative. For the No Action Alternative, the mass of material released is dominated by concrete, which represents approximately 90 percent of the total mass. However, the total activity of the material is represented primarily by the ferrous metals and trash, which represent almost 94 percent of the total activity.

**Table F-2 Total Activity and Total Mass of Material Released from Commercial Nuclear Reactor Facilities: No Action Alternative**

No Action Alternative	Activity (Ci)	Mass (million tons)
Ferrous metals	1.76	2.06
Concrete	0.24	16.20
Trash	2.32	0.02
Aluminum	0.0008	0.000173
Copper	0.043	0.005326
<b>Total for All Materials</b>	<b>4.36</b>	<b>18.29</b>

Source: SC&A 2003, Tables 5.8, 10.3, 10.4, and 10.7.

**2. Unrestricted Release Alternative**

Tables F-3 and F-4 provide estimates of the total mass and total activity of solid material released from commercial reactor facilities under the Unrestricted Release Alternative. The values in these tables are based on summations from statistical sampling and mean (average) values are used. Mass and activity values are reported for both material-specific and material-independent cases. The material-specific case applies different radionuclide concentration limits to the different materials for each radionuclide, while the material-independent case applies the same radionuclide concentration limit to all of the materials for each radionuclide.

The material-specific case employs NUREG-1640 (NRC 2003d) normalized doses that are specific to each type of material (i.e., ferrous metals, concrete, and trash) and each radionuclide. This approach derives the maximum radionuclide concentration in each material. For example, the radionuclide concentration for Co-60 for the 1 mrem/yr dose option differs for ferrous metals, concrete, and trash; i.e., the allowable radionuclide concentration at which material could be released for unrestricted release differs depending on the material.

**Table F-3 Total Mass (million tons) of Material Released from Commercial Nuclear Reactor Facilities: Unrestricted Release Alternative**

	Dose Option				RS-G-1.7 <sup>1</sup>
	0.03 mrem/yr	0.1 mrem/yr	1 mrem/yr	10 mrem/yr	
<b>Ferrous metals</b>					
Unrestricted/Material-Specific	0.970	1.490	2.20	2.45	
Unrestricted/Material-Independent	0.441	0.786	1.74	2.30	1.74
<b>Concrete</b>					
Unrestricted/Material-Specific	15.0	17.6	19.6	19.8	
Unrestricted/Material-Independent	15.0	17.6	19.6	19.8	19.6
<b>Trash</b>					
Unrestricted/Material-Specific	0.014	0.021	0.041	0.066	
Unrestricted/Material-Independent	0.0002	0.0004	0.002	0.006	0.002
<b>Total for All Materials</b>					
Unrestricted/Material-Specific	16	19.1	21.9	22.3	
Unrestricted/Material-Independent	15.5	18.4	21.4	22.1	21.4

<sup>1</sup> Based on calculations by NRC, the mass of material for the RS-G-1.7 dose option is assumed to be the same as for the 1 mrem/yr dose option.

Source: SC&A 2003, Tables 10.3 and 10.7.

**Table F-4 Total Activity (Curies) Released from Commercial Nuclear Reactor Facilities: Unrestricted Release Alternative**

	Dose Option				RS-G-1.7 <sup>1</sup>
	0.03 mrem/yr	0.1 mrem/yr	1 mrem/yr	10 mrem/yr	
<b>Ferrous metals</b>					
Unrestricted/Material-Specific	0.092	0.395	2.86	12.74	
Unrestricted/Material-Independent	0.008	0.048	0.745	4.33	1.49
<b>Concrete</b>					
Unrestricted/Material-Specific	0.168	0.401	1.49	1.73	
Unrestricted/Material-Independent	0.168	0.401	1.49	1.73	2.98
<b>Trash</b>					
Unrestricted/Material-Specific	0.588	2.56	36.79	523.81	
Unrestricted/Material-Independent	0.00001	0.00005	0.0015	0.043	0.003
<b>Total for All Materials</b>					
Unrestricted/Material-Specific	0.865	3.40	41.32	538.60	
Unrestricted/Material-Independent	0.194	0.497	2.43	6.42	4.86

<sup>1</sup> Based on calculations by NRC, the total activity release for the RS-G-1.7 material-independent scenario is assumed to be two times that of the total activity released for the 1 mrem/yr dose option.

Source: SC&A 2003, Tables 5.8 and 10.7.

1 For the material-independent case, the most limiting normalized doses in NUREG-1640 are used  
2 to define the radionuclide concentration level and, as a result, the levels that correspond to a  
3 given radionuclide are the same for all materials. For example, the presence of Co-60 in concrete  
4 (used in road building) results in the most limiting dose factor as compared to the presence of  
5 Co-60 in ferrous metals, copper, or aluminum. The material-independent case is thus more  
6 restrictive than the material-specific case and the quantity of material and the collective radiation  
7 doses to the members of the public are lower for the material-independent case. More details  
8 can be found in Appendix D for both cases - material-specific results (Case A) and material-  
9 independent results (Case B) (see Tables D-1 to D-3).

10  
11 For the Unrestricted Release Alternative using a material-specific case, as for the No Action  
12 Alternative, the mass of material released is dominated by concrete, which represents  
13 approximately 90 percent of the total mass. The total activity of the material is represented  
14 primarily by the ferrous metals and trash, which represent approximately 95 percent of the total  
15 activity, for the 1 mrem/year dose option.

16  
17 Using a material-independent case, concrete is the limiting material for radionuclide  
18 concentrations and the total mass of ferrous metals and the total mass and activity of trash  
19 released are lower than amounts that would be released under material-specific conditions.  
20 Using a material-independent case, the ferrous metals and concrete released represent greater  
21 than 99 percent of the activity, and trash represents less than 0.1 percent of the activity.

### 22 **3. EPA/State-Regulated Disposal Alternative**

23  
24  
25 Tables F-5 and F-6 provide estimates of the total mass and total curies of solid material released  
26 from commercial nuclear reactor facilities under the EPA/State-Regulated Disposal Alternative.  
27 The values in these tables are based on summations from statistical sampling and mean (average)  
28 values are used. For the EPA/State-Regulated Disposal Alternative without trash incineration, as  
29 for the No Action Alternative and Unrestricted Release Alternative, the mass of material released  
30 is dominated by concrete, which represents 93 percent of the total mass. The total activity of the  
31 material released is represented primarily by the ferrous metals and trash, which represent almost  
32 95 percent of the total activity, for the 1 mrem/year dose option. The mass and activity released  
33 for the EPA/State-Regulated Disposal Alternative with and without trash incineration are  
34 assumed to be the same.

### 35 **4. Low-Level Waste (LLW) Disposal Alternative**

36  
37  
38 Under the LLW Disposal Alternative, none of the potentially clearable solid material would be  
39 released for either unrestricted use or EPA/State-regulated disposal. All of the material would be  
40 classified as LLW and would be transported to and disposed of in a LLW disposal facility. The  
41 total mass and activity of material that would be disposed of in LLW disposal facilities under this  
42 Alternative is summarized in Table F-7.

**Table F-5 Total Activity (Curies) Released from Commercial Nuclear Reactor Facilities: EPA/State-Regulated Disposal Alternative**

	Dose Option				
	0.03 mrem/yr	0.1 mrem/yr	1 mrem/yr	10 mrem/yr	RS-G-1.7 <sup>1</sup>
<b>Ferrous metals</b>	0.484	1.46	7.09	23.81	14.18
<b>Concrete</b>	0.201	0.460	1.67	1.73	3.34
<b>Trash</b>	0.588	2.56	36.79	523.81	73.58
<b>Total for All Materials</b>	1.29	4.53	45.74	549.67	91.48

<sup>1</sup> Based on calculations by NRC, the total activity release for the RS-G-1.7 material-independent scenario is assumed to be two times that of the total activity released for the 1 mrem/yr dose option.

Source: SC&A 2003, Tables 5.8 and 10.4.

**Table F-6 Total Mass (million tons) of Material Released from Commercial Nuclear Reactor Facilities: EPA/State-Regulated Disposal Alternative**

	Dose Option				
	0.03 mrem/yr	0.1 mrem/yr	1 mrem/yr	10 mrem/yr	RS-G-1.7 <sup>1</sup>
<b>Ferrous metals</b>	1.57	2.00	2.38	2.48	2.38
<b>Concrete</b>	15.6	17.9	19.7	19.8	19.7
<b>Trash</b>	0.014	0.021	0.041	0.066	0.041
<b>Total for All Materials</b>	17.2	19.9	21.2	22.3	21.2

<sup>1</sup> Based on calculations by NRC, the mass of material for the RS-G-1.7 dose option is assumed to be the same as for the 1 mrem/yr dose option.

Source: SC&A 2003, Tables 10.3 and 10.7.

**Table F-7 Mass and Radioactivity of Materials Released from Commercial Nuclear Reactor Facilities: LLW Disposal Alternative**

Material	Total Mass (tons)	Contained Radioactivity (Ci)
D&D Ferrous metals	2,117,906	11
D&D Ferrous metals (Decon)	285,212	284
Operating Ferrous metals	95,793	95.3
<b>Total Ferrous metals</b>	2,498,911	390.3
D&D Concrete	19,877,341	1.74
Trash	323,023	2,560
Aluminum	212	0.006
Copper	6,584	0.31
<b>Total</b>	22,706,071	2,951

Source: SC&A 2003, Tables 5.8, 8.6, and 10.3.

## 5. Limited Dispositions Alternative

The mass and activity of concrete recycled under the Limited Dispositions Alternative would be the same as for the Unrestricted Release Alternative. The mass and activity of other disposed materials would be the same as for the EPA/State-Regulated Disposal Alternative.

### Characterization of Solid Materials Generated from Licensed Facilities Other than Commercial Reactors

The mass and activity values described above and the collective dose results are based on material generated only from commercial nuclear reactor facilities. This is because smaller amounts of solid materials would be generated from licensed facilities other than commercial nuclear reactor facilities and released for either recycling or disposal. Trash is the significant material for these other licensed facilities and, therefore, ferrous metals and concrete are not included here. Table F-8 provides a summary of the total estimated mass and activity of trash generated from licensed facilities other than commercial nuclear reactor facilities for the No Action and Unrestricted Release Alternatives.

**Table F-8 Comparison of Mass and Activity of Trash Released from Commercial Nuclear Reactor Facilities with Trash Generated from Other Licensed Facilities**

Alternative and Dose Option	Total Activity Released (Ci)			Total Mass Released (million t)		
	Nuclear reactors	Other licensees	Total	Nuclear reactors	Other licensees	Total
<b>No Action</b>	2.32	0.976	3.296	0.02	0.273	0.293
<b>Unrestricted Release</b>						
RS-G-1.7	73.6	30.8	104.4	0.041	0.549	0.59
10 mrem/yr	524	220	744	0.066	0.886	0.952
1 mrem/yr	36.8	15.4	52.2	0.041	0.549	0.59
0.1 mrem/yr	2.56	1.08	3.64	0.021	0.282	0.303
0.03 mrem/yr	0.588	0.247	0.835	0.014	0.183	0.197

Source: SC&A 2003, Table 5.6.



1 applications (7 percent) [USGS 2000a; USGS 1998a]. USGS allocated these applications into  
2 three general categories for the purposes of developing a material flow analysis: road base and  
3 other related applications; bituminous concrete; and cement concrete.  
4

5 While recycled concrete is used to a limited extent as an aggregate in portland cement concrete  
6 for highway construction, no general usage of this recycled material as an aggregate for concrete  
7 used in building construction was identified. A representative of Southern Crushed Concrete  
8 Inc.—a company that recycles concrete—knew of no use of recycled concrete as aggregate in  
9 new concrete mixes for buildings. He believed that recycled aggregate was not used in buildings  
10 because of structural concerns as compared to concrete with virgin aggregate. The company had  
11 been involved in a highway project in Texas, where 30 percent of the virgin aggregate was  
12 replaced with aggregate from recycled concrete (Miller 2001). The view that reclaimed concrete  
13 was not used as an aggregate in concrete used to construct buildings was confirmed by an official  
14 of the Construction Materials Recycling Association (Turley 2002). Therefore analysis of  
15 recycling of concrete to make building material is not included in the Draft GEIS.  
16

17 General Public exposure pathways for use of the concrete rubble for road construction include  
18 direct radiation exposure to drivers on roads built using recycled concrete and exposure to  
19 surface water/drinking water affected by leachate from landfill disposal of concrete dust  
20 generated by concrete recycling activities. Drivers on roads built using recycled concrete would  
21 be exposed to direct radiation from the radionuclide content of the material, but would not be  
22 exposed through inhalation or ingestion. Persons in the vicinity of landfills where concrete dust  
23 generated by concrete recycling activities was disposed of would be exposed through ingestion  
24 of surface water or drinking water affected by leachate from landfill concrete dust disposal,  
25 however, these exposure pathways are not included in the collective dose assessment because it  
26 is assumed that 100 percent of the activity in the released concrete is contained in the recycled  
27 material used for road bed, and this single exposure pathway would result in a higher collective  
28 dose than dividing the activity among multiple pathways. General Public exposure parameters  
29 for the No Action Alternative, Unrestricted Release Alternative, and Limited Dispositions  
30 Alternative for concrete are listed in Table G-1.  
31  
32  
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42

**Table G-1 Concrete End Use General Public Exposure Parameters**

	Product mass (t)	Mass of material (t)	Fraction of material (%)	Occupancy	Exposure Duration (person-h/y)	
					Individual	Integrated
No Action Alternative, Unrestricted Use Alternative, and Limited Dispositions Alternative	—	385	38.5	—	—	2,154

a - Recycled concrete material  
Source: NUREG-1640 (NRC 2003d).

**Ferrous Metal**

The affected General Public groups for the No Action and Unrestricted Release Alternatives for ferrous metal are based on the anticipated end uses for recycled ferrous metal. General Public exposure pathways for the collective dose assessment are limited to direct radiation exposure from use of end use products containing recycled ferrous metal and use of byproducts (e.g., furnace slag cement) generated by recycling processes. Recycling of scrap ferrous metal could also result in General Public radionuclide exposure through air emissions and surface water and groundwater discharges from generation and handling of scrap ferrous metal at the licensed facility site, recycling of the scrap ferrous metal into finished recycled ferrous metal, processing of the finished ferrous metal into end use products (e.g., automobiles, home appliances, building materials), and processing and landfill disposal of wastes (e.g., EAF baghouse dust) generated by ferrous metal recycling processes. General Public exposure parameters are listed in Table G-2. The affected General Public groups for disposal of ferrous metal under the Limited Dispositions Alternative are discussed under the EPA/State-Regulated Disposal Alternative.

**Table G-2 Ferrous Metal End Uses and General Public Exposure Parameters**

	Product mass (t)	Mass of material (t)	Fraction of material (%)	Occupancy	Exposure Duration (person-h/y)	
					Individual	Integrated
No Action Alternative and Unrestricted Release Alternative						
Driving on slag road	—	35.8	30.6	—	—	125
Slag cement basement	61.2	4.5	3.0	1.78	4,200	430
Occupying automobile	0.927	253	28.1	1.59	351	153,000
Office building	7.18	427	47.4	16	2,000	1,900,000
Office furniture	0.544	9	1.0	3	2,000	99,200
Home appliances	0.288	93.6	10.4	1.78	633	464,000
Sleeping on bed	0.037	11.4	0.8	1.78	3,180	1,100,000
Sailor—operations	17,900	9	0.6	447	—	—
Sailor—deck duty	17,900	9	0.6	200	—	—

Source: NUREG-1640 (NRC 2003d)

The selection of specific end uses of recycled ferrous metal for analysis in the Draft GEIS is based on research into the disposition of recycled ferrous metal in commerce. The dose assessment calculations are based on the percentages of finished recycled ferrous metal that is used in various end uses. The total mass and activity of recycled ferrous metal generated from licensed facilities under the No Action and Unrestricted Release Alternatives is distributed amongst the various end uses for the purposes of the dose assessment. The percentages of finished ferrous metal used in various end uses is based on analysis of data on steel end-use markets obtained from the 2001 American Iron and Steel Institute (AISI) report AIS 16, “Shipments of Steel Products by Market Classification” (AISI, 2001). The AIS 16 report data, as reported and applied for the purposes of the collective dose assessment, are summarized in Table G-3.

The AIS 16 report provides a breakdown of the categories and subcategories of end use products and applications in which finished steel was used in 2001. The AIS 16 report data indicate that the construction and automotive sectors are responsible for over two-thirds of total domestic steel consumption. The subcategory data for the automotive category indicate that the majority of the steel is used in “vehicles, parts and accessories,” therefore “Automobile Users” was selected as the representative “affected environment” for this end use category. The Automobile User end use encompasses the Shipbuilding and Aircraft categories and the “passenger car” Rail Transportation sub-categories, as these are also transportation-related categories. This resulted in the steel consumption percentage for the Automobile User end use increasing from 14.2 percent to 28.1 percent, as shown in Table G-3.

**Table G-3 Steel Mass/Activity Distribution**

Category	AIS 16 Data	Adjusted Percentage	End Use
1 Steel for converting and processing	10.4%	—	—
2 Forgings (NEC)	0.7%	—	—
3 Industrial fasteners	0.4%	0.7%	Building
4 Steel service centers & distributors	27.4%	—	—
5 Construction & contractors' products	21.8%	43.1%	Building
7 <sup>a</sup> Automotive	14.2%	28.1%	Automobile
8 Rail transportation	1.0%	2.0%	Rails, Freight Railcars <sup>b,d</sup>
9 Shipbuilding and marine equipment	0.3%	0.6%	Automobile
10 Aircraft & aerospace	0.0%	0.0%	Automobile
11 Oil & gas industry	3.0%	5.9%	Equipment <sup>d</sup>
12 Mining, quarrying, and lumbering	0.2%	0.3%	Equipment <sup>d</sup>
13 Agriculture	0.7%	1.3%	Building
14 Machinery, industrial equipment & tools	1.5%	2.9%	Building
15 Electrical equipment	1.7%	3.4%	Equipment <sup>d</sup>
16 Appliances, utensils, & cutlery	1.8%	3.6%	Miscellaneous
17 Other domestic and commercial equipment	0.7%	1.5%	Miscellaneous
18 Containers, packaging and shipping equipment	3.3%	6.5%	Miscellaneous <sup>c</sup>
19 Ordnance & other military	0.0%	0.1%	Equipment <sup>d</sup>
20 Export	2.6%	—	—
Non-classified Shipments	8.4%	—	—
Total	100.0%	100.0%	—

<sup>a</sup> AIS 16 does not contain a category 6.

<sup>b</sup> Except for the "Passenger Rail Car" subcategory, which is allocated to the "Automobile" Category

<sup>c</sup> Except for the "Compressed Gas Cylinders" subcategory, which is assumed to have No General Public Dose

<sup>d</sup> There is No General Public Dose associated with equipment

Source: AISI 2001.

The subcategory data for the construction category do not specify which subcategories of construction used the majority of steel, only that the steel was used in "general construction." Therefore, "Office Workers" was selected to be the representative "affected environment" for the construction category. Office Workers would typically spend approximately one fourth of their time within the office building. Other general construction projects (e.g., bridges) would have few, if any, people in the vicinity for any length of time. The Office Worker end use encompasses other work place-related categories, including Industrial Fasteners, Agriculture, and Machinery. This resulted in the steel consumption percentage for the Office Worker end use increasing from 43.1 percent to 48.0 percent.

1 Several categories included in the AIS 16 report data involve utilization of steel in end use  
2 locations that are essentially removed from contact with the general public. Examples include  
3 “Oil & Gas Industry”, ‘Mining”, ‘Electrical Equipment” (e.g., transmission towers), Rail  
4 Transportation (subcategories other than passenger rail cars), and Containers (compressed gas  
5 cylinder subcategory). These categories are assumed to have no significant potential for public  
6 exposure.  
7

8 The remaining end use categories in the AIS 16 report are Appliances, Utensils, and Cutlery;  
9 Other Domestic and Commercial Equipment; and Containers, Packaging and Shipping  
10 Equipment. Three end use scenarios have been selected to represent these three categories. The  
11 Appliances, Utensils, and Cutlery category is represented by Home Appliances, specifically use  
12 of domestic kitchen ranges, dishwashers, and refrigerators manufactured from recycled steel  
13 scrap in a residential kitchen. This end use was selected for analysis because a kitchen range,  
14 dishwasher, and refrigerator collectively contain a large amount of steel (as opposed to kitchen  
15 utensils, cookware, and cutlery) and the primary exposure pathway from steel is direct radiation  
16 exposure, not leaching of radionuclides from the steel article into prepared food (USGS 2000a),  
17 and also because persons in a residential location spend a significant amount of their time at  
18 home in the kitchen.  
19

20 The Other Domestic and Commercial Equipment category is represented by two subcategories -  
21 Domestic Beds and Office Furniture. The Domestic Beds end use includes a bed frame, box  
22 spring, and mattress, manufactured from recycled steel and used in a residential bedroom. This  
23 end use was selected for analysis because persons in a residential location would spend  
24 approximately one third (8 hours) of their time sleeping. The Office Furniture end use includes  
25 office desks and cabinets manufactured from recycled steel scrap and used in a typical office  
26 environment. This end use was selected for analysis because typical office workers would spend  
27 approximately one-fourth of their time at work, and office furniture contains a significant  
28 amount of steel. The percentage of steel utilization from these three AIS 16 report categories  
29 (including the amount of steel reported in the Containers, Packaging and Shipping Equipment  
30 category, other than the compressed gas cylinder subcategory) was apportioned to the three end  
31 uses selected for analysis based upon the actual amount of steel used in bed and office furniture  
32 production, as reported in the subcategory data, with the remainder of the steel consumption  
33 being allocated to the home appliances end use, which is not reported as a separate subcategory  
34 in the AIS 16 report.  
35

36 The end uses selected for analysis, along with the fraction of activity (i.e., steel) allocated to  
37 each end use, are shown in Table G-4. This Draft GEIS has not attempted to categorize every  
38 potential end use of recycled ferrous metal, because the number of end uses is too diverse to  
39

1                    **Table G-4 Final Ferrous metal Mass/Activity Distribution**

2	<b>End Use</b>	<b>Fraction</b>	<b>Tons (2001)</b>
3	Building	48.0%	46,290,974
4	Automobile	28.8%	27,777,647
5	Miscellaneous	11.4%	10,990,447
	Home Appliances	9.6%	9,233,301
6	Bed Springs	0.8%	754,650
	Office Furniture	1.0%	1,002,496
7	Negligible dose to general public <sup>1</sup>	11.8%	11,345,338
8	Total	100.0%	96,404,406

9  
10 facilitate a collective dose analysis. The end uses are intentionally categorized into broad  
11 categories that represent the most common uses of recycled scrap ferrous metal and a reasonable  
12 estimate of the resultant collective dose exposures associated with those end uses.

13  
14 Recycling of scrap ferrous metal involves smelting operations and other processes that generate  
15 airborne emissions, including particulate emissions from ferrous metal recycling furnace air  
16 emissions control equipment. The collective dose assessment includes transport of radionuclides  
17 that are not removed from the furnace gas by the air emissions control equipment and that are  
18 emitted to the atmosphere. These particulate radionuclides are assumed to deposit on the ground  
19 in the vicinity of the steel mill and result in exposure through both inhalation of the particulate  
20 and direct radiation from radionuclides deposited on the ground. Deposited radionuclides also  
21 result in General Public exposure through uptake of radionuclides from the soil into food,  
22 including meat, milk, and vegetables.

23  
24 Recycling furnace operations also generate Electric Arc Furnace (EAF) baghouse dust and  
25 furnace slag waste products. Furnace slag may either be disposed of in landfills or used to make  
26 furnace slag cement. Furnace slag cement is typically used in road building and building  
27 construction, and drivers on roads built using furnace slag cement and occupants of buildings  
28 built using furnace slag cement would be exposed to direct radiation from the radionuclide  
29 content of the material. The exposure pathway for drivers on roads built using furnace slag  
30 cement is similar to the exposure pathway for drivers on roads built using recycled concrete.

31  
32 Furnace slag, if not recycled into end use products, is typically disposed of in Subtitle D landfills,  
33 while EAF baghouse dust may be disposed of either in Subtitle D landfills or Subtitle C landfills,  
34 depending upon whether the EAF baghouse dust is treated prior to disposal. The landfill disposal  
35 of furnace slag and EAF baghouse dust generated from ferrous metal recycling processes could  
36 contribute radionuclides to leachate generated from the landfills in which those materials are

---

<sup>1</sup> Does not include disposal.

1 disposed. Migration of leachate to persons in the vicinity of landfills represents public exposure  
2 pathways for ferrous metal recycling.

3  
4 Transportation of scrap ferrous metal from the points of generation to the ferrous metal recycling  
5 facilities, and transportation of finished ferrous metal and associated waste materials from the  
6 recycling facilities to the point of end use or disposal has the potential to expose persons along  
7 the transportation routes to direct radiation from the radionuclide content of the materials.  
8 Transportation of end use products also has the potential to expose persons to direct radiation.  
9 General Public exposure to direct radiation along material transportation routes represent public  
10 exposure pathways for ferrous metal recycling.

### 11 Aluminum

12  
13  
14 As discussed above, the overall collective dose associated with released aluminum for the No  
15 Action and Unrestricted Release Alternatives, including both Non-Licensed Facility Workers and  
16 the General Public is evaluated for the No Action, Unrestricted Release, EPA/State-Regulated  
17 Disposal, and Limited Dispositions Alternatives using a screening model, because the collective  
18 dose associated with the small amount of aluminum generated would be minimal as compared to  
19 the collective dose associated with ferrous metal.

### 20 Copper

21  
22  
23 As discussed above, the overall collective dose associated with released copper, including both  
24 Non-Licensed Facility Workers and the General Public is evaluated for the No Action,  
25 Unrestricted Release, EPA/State-Regulated Disposal, and Limited Dispositions Alternatives  
26 using a screening model, because the collective dose associated with the small amount of copper  
27 generated would be minimal as compared to the collective dose associated with ferrous metal.

### 28 Trash

29  
30  
31 The affected General Public groups for the No Action, Unrestricted Release, EPA/State-  
32 Regulated Disposal, and Limited Dispositions Alternatives for trash are based on the anticipated  
33 transportation to and disposal of trash in an EPA/State-regulated Subtitle D landfill. The  
34 radionuclide transport and exposure pathways for Subtitle D landfill disposal of trash are the  
35 same as for Subtitle D landfill disposal of concrete, ferrous metal, aluminum, and copper,  
36 described above, and include surface water and groundwater transport pathways. The collective  
37 dose from the incineration of trash is not assessed under the No Action Alternative, Unrestricted  
38 Release Alternative, and Limited Dispositions Alternative, but is assessed under the EPA/State-  
39 Regulated Disposal Alternative discussed below.

### 40 *Non-Licensed Facility Workers*

41  
42  
43 These workers are members of the public who may experience work-related exposure while  
44 handling or otherwise encountering released material at their place of employment. Examples of  
45 these individuals include workers in scrap yards, iron and steel mills, EPA/State-regulated

landfills, and EPA/State-regulated incinerators; truck drivers transporting released material; and building and road construction workers utilizing released material or byproducts of processing released material. Truck drivers transporting LLW to LLW disposal facilities are not workers situated at licensed facilities and are therefore categorized for the purposes of the Draft GEIS as Non-Licensed Facility Workers.

Concrete

Non-Licensed Facility Worker activities and groups of affected workers for the No Action, Unrestricted Release, and Limited Dispositions Alternatives for concrete are based on a single end use for recycled concrete, use as road building material. Non-Licensed Facility Worker activities include processing of the concrete rubble into road building material at satellite facilities, transportation of concrete rubble, and application of the road building material. Disposal of concrete dust generated from concrete recycling activities and transportation of wastes generated from processing and road building activities are not included in the collective dose assessment. The amount of concrete dust that can become airborne depends mainly on its moisture content, physical properties, and engineered measures used to minimize such releases. The analysis assumed that the amounts of materials released via fugitive emissions are small, such releases are short-lived in duration, and long-term exposures associated with end uses are dominant in terms of collective doses. One hundred percent of the activity in the concrete is assumed to contribute to the collective dose through its end use application. Non-Licensed Facility Worker activities and parameters for concrete are listed in Tables G-5 and G-6.

**Table G-5 Non-Licensed Facility Workers Activity Characteristics - Concrete**

No Action Alternative, Unrestricted Release Alternative, and Limited Disposition Alternative	Fraction of material (%)	Nominal productivity (t/y)	Work year (h/y)	Work hours per kt of material
<b>Process Activities</b>				
Processing concrete rubble at satellite facility	100	42,525	1,500	29.4
Building road using recycled concrete	50	22,250	1,500	19.5

a Anigstein et al. 2001, Chapter 5  
 b Tons of scrap consumed by EAF per worker per year  
 Source: NUREG-1640 (NRC 2003d)

**Table G-6 Non-Licensed Facility Workers Activity Characteristics - Concrete**

	Distance (mi)	Speed (mph)	Fraction of material (%)	Total mass of material (t)	Work hours per kt of material
No Action Alternative, Unrestricted Release Alternative, and Limited Disposition Alternative					
Transportation Activities					
Truck driver hauling concrete rubble	231	50	100	1,000	231

a Average duration of trip = 1¼ h

b Based on 58 percent of ferrous metal scrap being consumed by EAF mills and assuming that the dust is evenly divided between the two representative types of truck trailers

c Comprises 4.40 h driving, 3.74 h sleeping in berth, 0.08 h standing by during loading and unloading

Source: NUREG-1640 (NRC 2003d)

Materials Recycling Association (Turley 2002). Therefore analysis of recycling of concrete to make building material is not included in the Draft GEIS.

### Ferrous Metal

Non-Licensed Facility Worker activities and groups of affected workers for the No Action and Unrestricted Release Alternatives for ferrous metal are based on the anticipated end uses for recycled ferrous metal and the anticipated processes that would be used in recycling ferrous metal. Non-Licensed Facility Worker activities for ferrous metal include activities associated with transporting the ferrous metal scrap to recycling facilities, recycling of the scrap into finished recycled ferrous metal, processing of the finished ferrous metal into end use products (e.g., automobiles, home appliances, building materials), installation of end use products (e.g., building materials), processing and disposal of wastes (e.g., EAF baghouse dust) generated by recycling processes, processing and use of byproducts (e.g., furnace slag) generated by recycling processes, and transportation of the materials, byproducts, and wastes generated from these activities. Non-Licensed Facility Worker activities and parameters for ferrous metal are listed in Tables G-7 and G-8. The affected Non-Licensed Facility Worker groups for disposal of ferrous metal under the Limited Dispositions Alternative are discussed under the EPA/State-Regulated Disposal Alternative.

### Aluminum and Copper

Inventory information on other metals, besides ferrous, indicated these were primarily copper or aluminum, and present in insignificant amounts as compared to ferrous metals. Non Licensed Facility Worker activities for aluminum and copper that would contribute to the collective dose are similar to those for ferrous metal. NUREG-1640 considers dose factors for both copper and aluminum for individual dose estimating purposes. However, regarding collective dose, the detailed results were developed for ferrous metal and the small amounts of copper and aluminum inventory were evaluated using a scoping analysis. A detailed dose assessment was not

**Table G-7 Non-Licensed Facility Worker Activity Characteristics – Ferrous metal**

No Action Alternative and Unrestricted Release Alternative	Fraction of material (%)	Nominal productivity (t/y)	Work year (h/y)	Work hours per kt of material
<b>Process Activities</b>				
Processing steel scrap at scrap yard	100	1,568–1,950	1,500	323
Handling slag at steel mill	100	400 <sup>b</sup>	1,000	200
Handling metal product at steel mill or foundry	100	400 <sup>b</sup>	1,500	300
Crane operator (at EAF mill) <sup>a</sup>	100	400 <sup>b</sup>	1,750	350
EAF furnace operator <sup>a</sup>	100	400 <sup>b</sup>	1,750	350
Operator of continuous caster (at EAF mill) <sup>a</sup>	100	400 <sup>b</sup>	1,750	350
Transferring EAF dust at steel mill	58	—	—	0.324
EAF Baghouse maintenance	58	—	27.5	0.024
Processing EAF dust	58	4,990	1,000	1.73
Processing steel slag for road construction	30.6	6,111	1,000	5.86
Handling BOF/foundry dust at landfill	42	4,067	1,500	1.57
Handling slag at landfill	61.5	4,067	1,500	26.6
Handling EAF dust at landfill	58	4,067	1,500	1.29
Building road using steel slag	30.6	35,328	2,000	2.02

a Anigstein et al. 2001, Chapter 5

b Tons of scrap consumed by EAF per worker per year

Source: NUREG-1640 (NRC 2003d)

**Table G-8 Non-Licensed Facility Workers Activity Characteristics - Ferrous metal**

No Action Alternative and Unrestricted Release Alternative	Distance (mi)	Speed (mph)	Fraction of material (%)	Total mass of material (t)	Work hours per kt of material
<b>Transportation Activities</b>					
Truck driver hauling steel scrap	<sup>a</sup>		100	1,000	62.5
Truck driver hauling slag	60	45	100	117	10
Truck driver hauling EAF dust in dry bulk trailer	1,022	50	29 <sup>b</sup>	4.31	4.4
Truck driver hauling EAF dust in dump trailer	1,022	50	29 <sup>b</sup>	4.31	8.22 <sup>c</sup>
Truck driver hauling steel products	276	50	100	900	248

a Average duration of trip = 1¼ h (as reported in NUREG-1640 (NRC 2003d).

b Based on 58 percent of steel scrap being consumed by EAF mills and assuming that the dust is evenly divided between the two representative types of truck trailers

c Comprises 4.40 h driving, 3.74 h sleeping in berth, 0.08 h standing by during loading and unloading

Source: NUREG-1640 (NRC 2003d)

1 performed for aluminum and copper because of the small amount of aluminum and copper  
2 generated compared to ferrous metal. The results indicate that collective dose for copper and  
3 aluminum are about one to two orders of magnitude lower than that of ferrous metals for all  
4 alternatives.

#### 5 6 Trash

7  
8 Non-Licensed Facility Worker activities for trash for the No Action, Unrestricted Release, and  
9 Limited Dispositions Alternatives include truck drivers transporting trash to EPA/State-regulated  
10 disposal facilities and the EPA/State-regulated disposal facility workers that dispose of the trash  
11 at the facility. There are no end uses for trash other than EPA/State-regulated disposal  
12 considered in the Draft GEIS, and therefore Non-Licensed Facility Worker activities for trash are  
13 similar to those described below for trash for the EPA/State-Regulated Disposal Alternative.  
14 NRC has assumed that trash generated from licensee facilities will not be reused in commerce  
15 and will not be recycled into commerce. Sorting and handling of the trash may be conducted  
16 prior to transportation and disposal. The exposure parameters for these activities are anticipated  
17 to be similar to the activities conducted by survey workers for trash and result in similar exposure  
18 to Non-Licensed Facility Workers as for Licensed-Facility Workers.

## 19 20 **2. EPA/State-Regulated Disposal Alternative**

### 21 22 *Non Licensed Facility Workers*

#### 23 24 Concrete

25  
26 Non-Licensed Facility Worker activities and groups of affected workers for the EPA/State-  
27 Regulated Disposal Alternative for concrete are based on the activities associated with  
28 processing and transportation and disposal of concrete in a EPA/State-regulated Subtitle D  
29 landfill. These include activities associated with processing concrete rubble at satellite facilities,  
30 transportation of the concrete rubble to the landfill, and unloading and disposal of the concrete  
31 rubble by landfill workers. Non-Licensed Facility Worker activities and parameters for the  
32 EPA/State-Regulated Disposal Alternative for concrete are listed in Tables G-9 and G-10.

#### 33 34 Ferrous metal

35  
36 Non-Licensed Facility Worker activities and groups of affected workers for the EPA/State-  
37 Regulated Disposal Alternative, and also the Limited Dispositions Alternative, for ferrous metal  
38 are based on the activities associated with transportation and disposal of ferrous metal scrap in a  
39 EPA/State-regulated Subtitle D landfill. These include activities associated with transportation  
40 of the ferrous metal scrap to the landfill, and unloading and disposal of the ferrous metal scrap  
41 by landfill workers. Non-Licensed Facility Worker activities and parameters for the EPA/State-  
42 Regulated Disposal Alternative and Limited Dispositions Alternative for ferrous metal are listed  
43 in Tables G-11 and G-12.

**Table G-9 Non-Licensed Facility Worker Activity Characteristics – Concrete**

EPA/State-Regulated Disposal Alternative	Fraction of material (%)	Nominal productivity (t/y)	Work year (h/y)	Work hours per kt of material
Process Activities				
Processing concrete rubble at satellite facility	100	42,525	1,500	29.4
Handling concrete rubble at landfill	50	4,067	1,500	184

a Anigstein et al. 2001, Chapter 5  
Source: NUREG-1640 (NRC 2003d)

**Table G-10 Non-Licensed Facility Worker Activity Characteristics – Concrete**

EPA/State-Regulated Disposal Alternative	Distance (mi)	Speed (mph)	Fraction of material (%)	Total mass of material (t)	Work hours per kt of material
Transportation Activities					
Truck driver hauling concrete rubble	231	50	100	1,000	231

Source: NUREG-1640 (NRC 2003d)

**Table G-11 Non-Licensed Facility Worker Activity Characteristics – Ferrous metal**

EPA/State-Regulated Disposal Alternative and Limited Dispositions Alternative	Fraction of material (%)	Nominal productivity (t/y)	Work year (h/y)	Work hours per kt of material
Process Activities				
Handling ferrous metal scrap at a Subtitle D landfill	100	4,067	1,500	368

a Anigstein et al. 2001, Chapter 5  
Source: NUREG-1640 (NRC 2003d)

**Table G-12 Non-Licensed Facility Worker Activity Characteristics – Ferrous metal**

EPA/State-Regulated Disposal Alternative and Limited Dispositions Alternative	Distance (mi)	Speed (mph)	Fraction of material (%)	Total mass of material (t)	Work hours per kt of material
Truck driver hauling ferrous metal scrap	<sup>a</sup>		100	1,000	62.5

<sup>a</sup> Average duration of trip = 1¼ h (as reported in NUREG-1640 (NRC 2003d).  
Source: NUREG-1640 (NRC 2003d)

Aluminum and Copper

As discussed above, the overall collective dose associated with released aluminum and copper for both Non-Licensed Facility Workers and the General Public is evaluated for the No Action, Unrestricted Release, EPA/State-Regulated Disposal, and Limited Dispositions Alternatives using a screening model because the collective dose associated with the small amount of aluminum and copper generated would be minimal as compared to the collective dose associated with ferrous metal.

Trash

Non-Licensed Facility Worker activities and groups of affected workers for the EPA/State-Regulated Disposal Alternative for trash are based on the activities associated with transportation and disposal of trash in an EPA/State-regulated Subtitle D landfill and also with processing of trash in an EPA/State-regulated incinerator and subsequent disposal of incinerator ash in an EPA/State-regulated Subtitle D landfill. These include activities associated with transportation of trash to the landfill and unloading and disposal of the trash by landfill workers, and transportation of trash to the incinerator, processing of the trash in the incinerator, and disposal of the incinerator ash by landfill workers.

The collective dose assessment for trash for Non-Licensed Facility Workers accounts for work activities involving truck drivers hauling trash, trash disposal in a landfill, trash incineration and ash disposal in a landfill, and a crane operator loading trash into an incinerator.

Based on light water reactor (LWR) industry practices, separate waste streams for various types of scrap metals (e.g., plastic, wood, glass, etc.) are not considered for recycling. First, these materials may be thrown into a trash bin for disposal in landfills and not sorted out as is done for residential trash and recyclables. Secondly, the composition of LWR trash primarily (90 percent), in decreasing order, consists of plastics that are not of recyclable grades, paper, PVC, cloth, rubber, absorbent materials, and wood. Consequently, no analysis was made for separate types of trash. Only the composite category defined as “trash” was considered and analyzed for landfill disposal and incineration.

1 *General Public*

2  
3 Potential exposure of the General Public associated with the EPA/State-Regulated Disposal  
4 Alternative for trash includes both disposal of the trash in Subtitle D landfills and disposal of the  
5 trash by incineration in EPA/State-regulated incinerators, and subsequent disposal of the  
6 incinerator ash in an EPA/State-regulated landfill.

7  
8 Concrete

9  
10 General Public exposure parameters for the EPA/State-Regulated Disposal Alternative for  
11 concrete is based on the radionuclide transport pathways associated with disposal of this material  
12 in an EPA/State-regulated Subtitle D landfill. NRC has assumed that concrete is not incinerable  
13 and that all EPA/State-regulated disposal of concrete would be to Subtitle D landfills.  
14 Radionuclide transport pathways associated with Subtitle D landfill disposal include  
15 groundwater and surface water transport pathways by which radionuclides could be transported  
16 from the landfill to the General Public. Processing of concrete, transportation of the concrete  
17 rubble to the landfill, and unloading of the concrete rubble by landfill workers have the potential  
18 to create fugitive dust emissions, however, these potential transport pathways are not evaluated  
19 in the collective dose assessment. The collective dose assessment is based on the assumption that  
20 one hundred percent of the activity associated with the released concrete transported to the  
21 General Public is transported through groundwater and surface water transport pathways and  
22 subsequently to drinking water and irrigation water. The collective dose assessment is based on  
23 exposure of the General Public through consumption of drinking water and consumption of food,  
24 including meat, milk, and vegetables, grown with irrigation water. This assumption provides for  
25 a higher collective dose than would partitioning the transport between the groundwater and  
26 surface water transport pathways and the air (fugitive dust) pathway.

27  
28 Ferrous Metal, Aluminum, and Copper

29  
30 General Public exposure parameters for the EPA/State-Regulated Disposal Alternative and the  
31 Limited Dispositions Alternatives for ferrous metal, aluminum, and copper are based on the  
32 radionuclide transport pathways associated with disposal of these materials in a EPA/State-  
33 regulated Subtitle D landfill. NRC has assumed that these solid materials are not incinerable and  
34 that all EPA/State-regulated disposal of these materials under the EPA/State-Regulated Disposal  
35 Alternative and the Limited Dispositions Alternative would be to Subtitle D landfills.  
36 Radionuclide transport pathways associated with Subtitle D landfill disposal include  
37 groundwater and surface water transport pathways by which radionuclides could be transported  
38 from the landfill to the General Public. The collective dose assessment is based on exposure of  
39 the General Public through consumption of drinking water and consumption of food, including  
40 meat, milk, and vegetables, grown with irrigation water. This assumption provides for a higher  
41 collective dose than would partitioning the transport between the groundwater and surface water  
42 transport pathways and the air (fugitive dust) pathway.

1 Trash

2  
3 The radionuclide transport and exposure pathways for Subtitle D landfill disposal of trash are the  
4 same as for Subtitle D landfill disposal of concrete, ferrous metal, aluminum, and copper,  
5 described above, and include surface water and groundwater transport pathways. The  
6 radionuclide transport and exposure pathways for incineration of trash include exposures  
7 associated with air emissions from trash incineration and exposures associated with releases of  
8 landfill leachate to surface water and groundwater from landfill disposal of both trash and  
9 incinerator ash.

10  
11 The collective dose assessment for incineration of trash includes transport of radionuclides that  
12 are not removed from the incinerator off gas by the air emissions control equipment and that are  
13 emitted to the atmosphere. These particulate radionuclides are assumed to deposit on the ground  
14 in the vicinity of the incinerator and result in General Public exposure through both inhalation of  
15 the particulate and direct radiation from radionuclides deposited on the ground. Deposited  
16 radionuclides also result in General Public exposure through uptake of radionuclides from the  
17 soil into food, including meat, milk, and vegetables.

18  
19 **3. Radiological Impact Assessment Methodology**

20  
21 An assessment of the potential radiation dose to critical groups was conducted in NUREG-1640.  
22 A critical group is defined as the group receiving the highest mean dose from among all of the  
23 exposure pathways associated with the given type of material (e.g., ferrous metal, concrete,  
24 trash) for the Alternative. The critical group for a given material and a given Alternative may be  
25 a group of members of the General Public exposed to radiation from end use products made from  
26 recycled material, or a group of Non-Licensed Facility Workers exposed to radiation from  
27 disposal of the materials in Subtitle D landfills. The critical group dose assessment for the  
28 Limited Dispositions Alternative for concrete is based on use of recycled concrete in road bed, as  
29 are the assessments for the No Action and Unrestricted Release Alternatives. The critical group  
30 dose assessment for ferrous metal, concrete, aluminum, and trash for the Limited Dispositions  
31 Alternative is based on disposal of these materials in an EPA/State-regulated landfill. The level  
32 of radiation exposure to the critical group is directly related to the dose limit associated with the  
33 Alternative. For a dose limit of 1 mrem/yr, for example, no critical group would experience a  
34 radiation dose greater than 1 mrem/yr.

35  
36 Collective dose considers the amount of radiation, time of exposure, and number of individuals  
37 exposed and is reported in units of “person-rem.” The collective dose report (SC&A 2003)  
38 provided estimates of collective doses to the Licensed Facility Workers, Non-Licensed Facility  
39 Workers, and the General Public. Details of this collective dose assessment are provided in  
40 Appendix D.

1 Concrete

2  
3 Figure G-1 illustrates the radiation exposure scenarios for concrete for all the Alternatives. The  
4 collective dose assessment for concrete for the No Action, Unrestricted Release, and Limited  
5 Dispositions Alternatives evaluates the collective dose associated with the recycling of concrete  
6 into road bed material. The collective dose assessment for concrete for the EPA/State-Regulated  
7 Disposal Alternative evaluates the collective dose associated with disposal of the concrete in  
8 Subtitle D landfills.

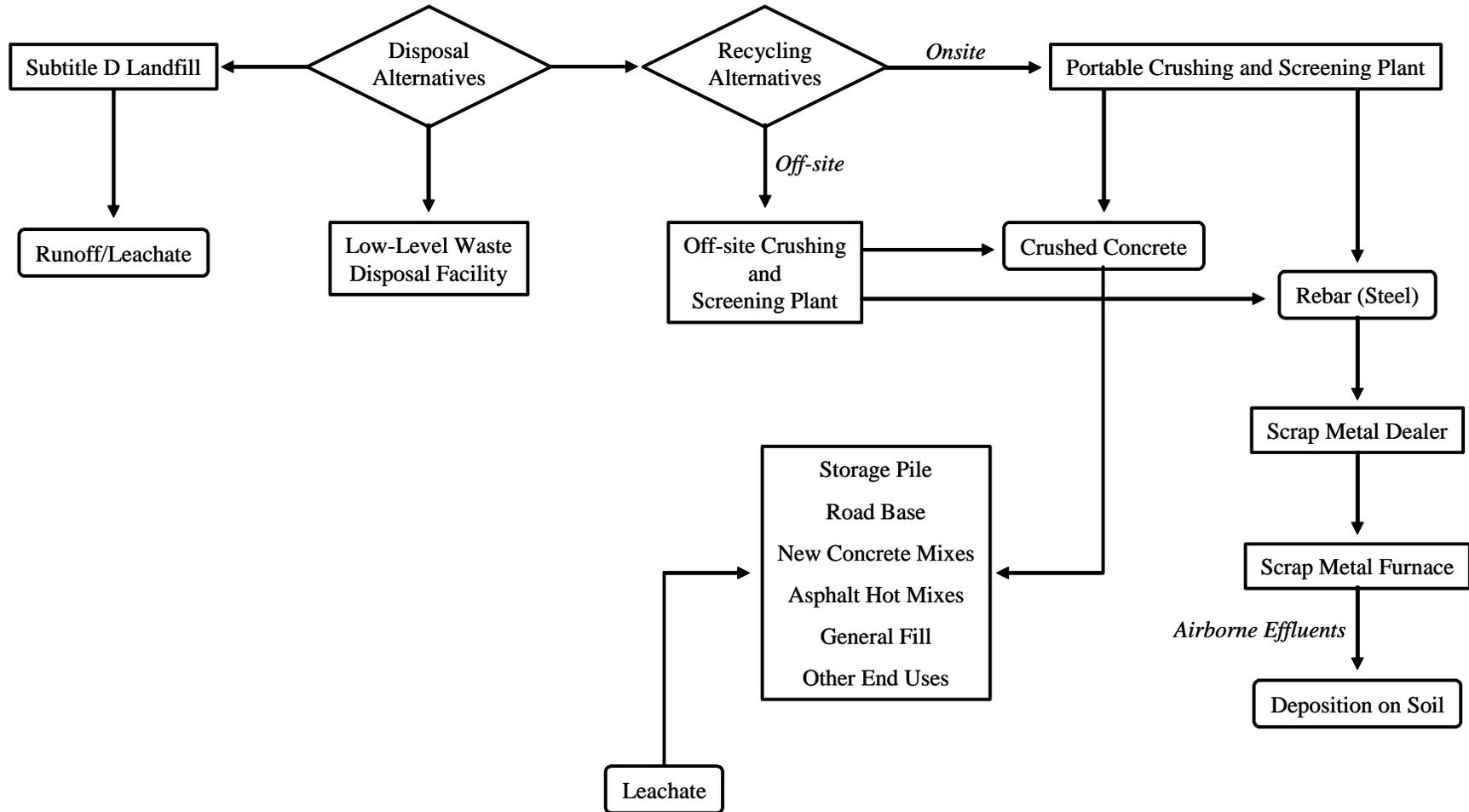
9  
10 Ferrous Metal

11  
12 Figure G-2 illustrates the radiation exposure scenarios for ferrous metal for all the alternatives.  
13 The collective dose assessment for ferrous metal for the No Action and Unrestricted Release  
14 Alternatives evaluates the collective dose associated with the recycling of ferrous metal into  
15 various end use products. The collective dose assessment for ferrous metal for the EPA/State-  
16 Regulated Disposal and Limited Dispositions Alternatives evaluates the collective dose  
17 associated with disposal of the ferrous metal in Subtitle D landfills.

18  
19 Trash

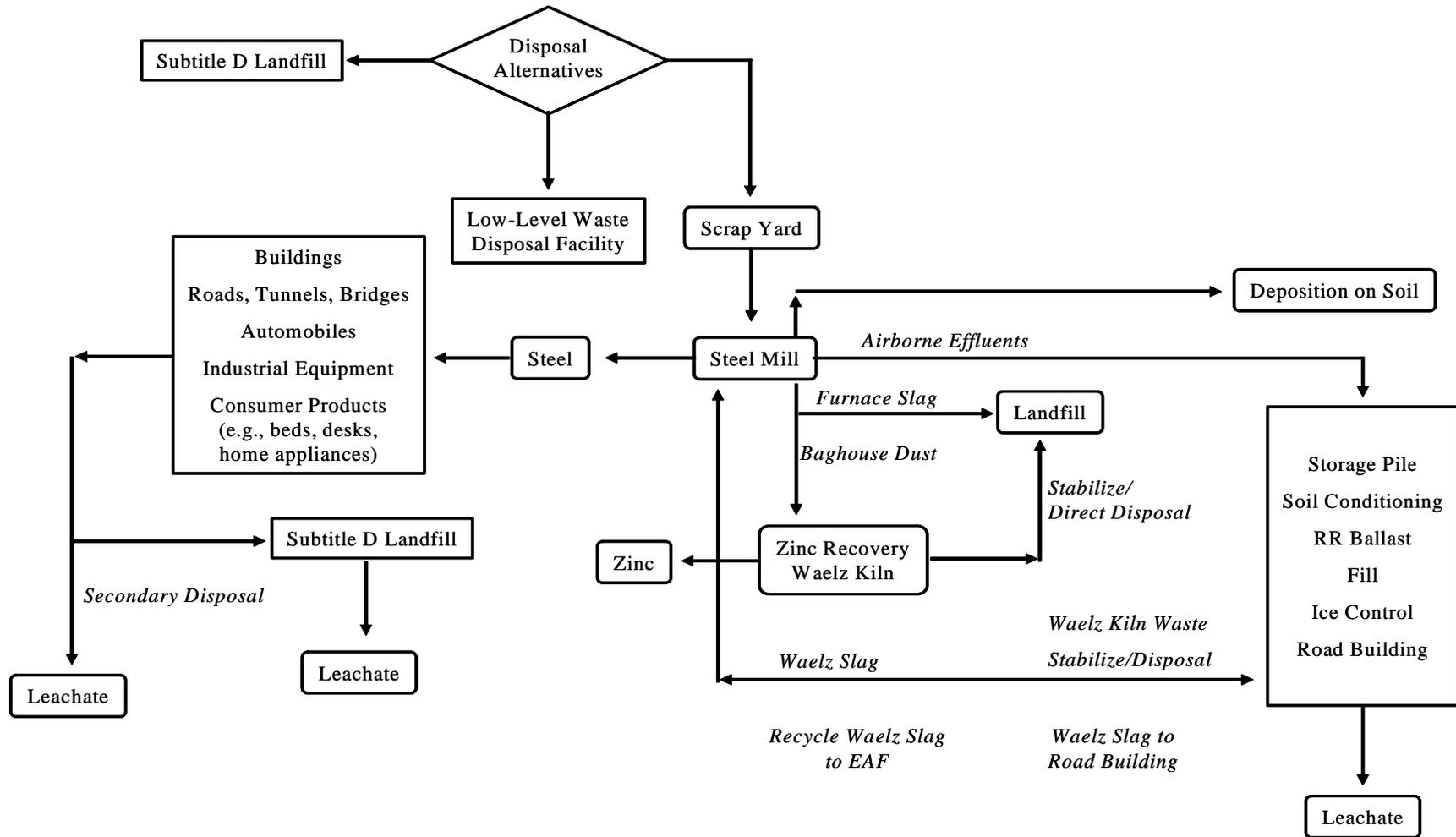
20  
21 Figure G-3 illustrates the radiation exposure scenarios for trash for all the alternatives. The  
22 collective dose assessment for trash for the No Action, Unrestricted Release, and Limited  
23 Dispositions Alternatives evaluates the collective dose associated with the disposal of trash in an  
24 EPA/State-regulated Subtitle D landfill. The collective dose assessment for trash for the  
25 EPA/State-Regulated Disposal Alternative evaluates the collective dose associated with disposal  
26 of the trash in Subtitle D landfills and with disposal of the trash in an EPA/State-regulated  
27 incinerator and subsequent disposal of the incinerator ash in an EPA/State-regulated landfill.  
28 There are no recycling or reuse scenarios for trash included in the collective dose assessment.  
29 Even if there were some recycling of this trash, its amount, compared to the much larger volumes  
30 of other materials intended for recycling, would be insignificant in terms of collective doses.  
31 The collective dose assessment accounts for work activities involving truck drivers hauling trash,  
32 trash disposal in a landfill, trash incineration and ash disposal in a landfill, and crane operator  
33 loading trash into an incinerator. Doses to offsite receptors consider the impacts associated with  
34 effluent discharges from landfill and incinerator operations.

1



2

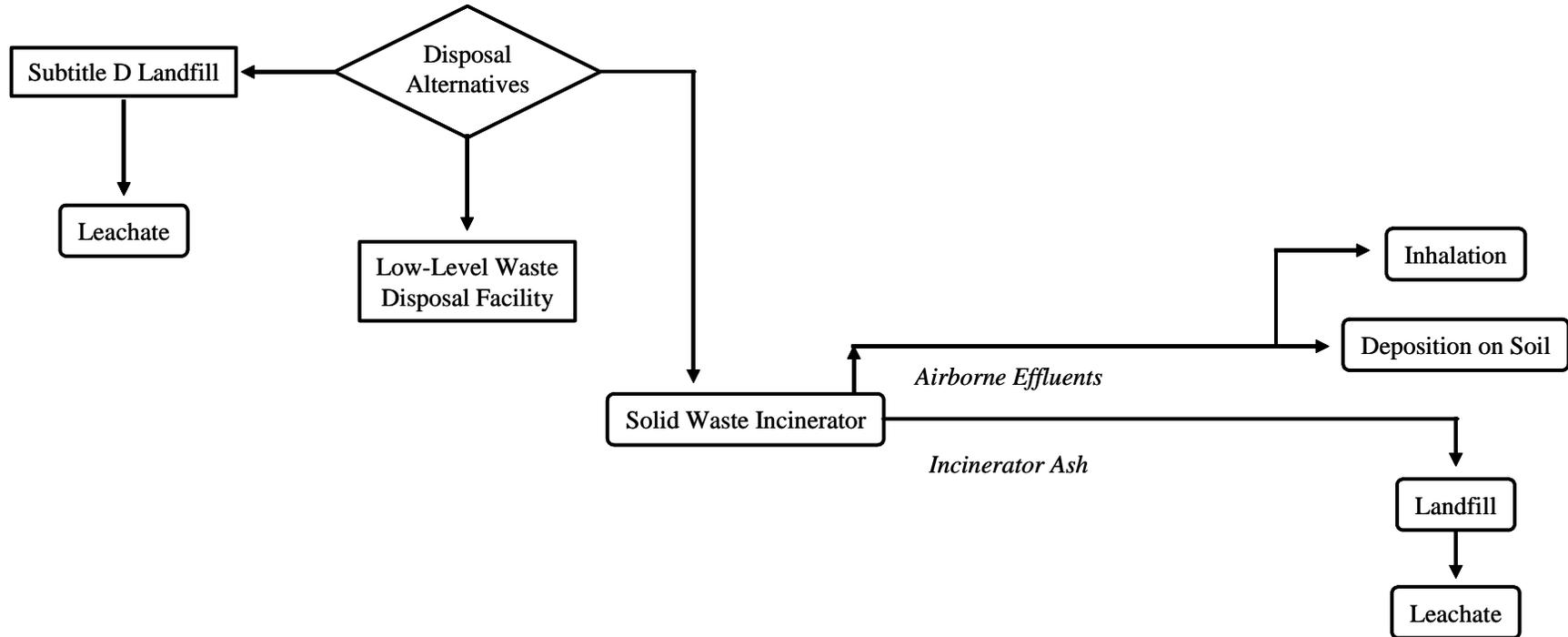
**Figure G-1 Potential Exposure Scenarios for Concrete**



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Figure G-2 Potential Exposure Scenarios for Ferrous Metal

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4  
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**Figure G-3 Potential Exposure Scenarios for Trash**

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## APPENDIX H

### WATER RESOURCES - SUPPLEMENTAL INFORMATION

This appendix provides supporting information for Section 3.4 (Water Resources). Sections 1 to 3 discuss potential exposure pathways. Section 4 describes the affected environment and Section 5 describes environmental consequences.

#### 1. Exposure Pathways for the No Action and Unrestricted Release Alternatives

The affected environment for the No Action and Unrestricted Release Alternatives includes all waters which come into contact with the materials released from a licensed site during the generation and handling of the materials on the licensed facility site; processing at a recycling facility; handling and disposal of byproducts and waste products from those processing activities; and the handling and utilization of end use products.

These waters potentially lead to direct exposure to the wastewater, runoff or leachate, or represent potential paths for contaminants to enter ground water or surface water from leachate or runoff during processing or in connection with end use products such as concrete roadbed material. Runoff includes waters which come in contact with the subject material or its residue and traverses over the ground, along natural or manmade drainage channels, or collects in natural or manmade catchment areas. Leachate includes waters which come in contact with the subject material and percolate to a containment barrier and which may be removed, processed, or otherwise managed by facility personnel. Both runoff and leachate may eventually reach surface water bodies or ground-water aquifers and escape beyond the limits of the delineated work area, i.e., the operational or physical limits bounding Non-Licensed Facility Worker exposures.

##### 1.1 Concrete

Potential exposure pathways for the No Action and Unrestricted Release Alternatives for concrete are based on crushing, screening, and recycling the processed concrete as aggregate for a variety of end uses, e.g. general fill, road base material, new concrete and asphalt mixes. Crushing and screening of the concrete is also anticipated to occur under the EPA/State-Regulated Disposal, LLW Disposal, and Limited Dispositions Alternatives, and the affected environment and potential water quality impacts associated with these activities are common to all of the Alternatives. The following sections describe the affected environment for potential Non-Licensed Facility Workers, General Public, and non-radiological ecological exposures.

##### Non-Licensed Facility Worker Exposure

Potential exposure pathways for concrete for Non-Licensed Facility Workers include activities associated with the handling of concrete at the licensee facility site or at offsite satellite facilities; recycling of the concrete into aggregate and subsequent reuse; and disposal of concrete dust generated from concrete recycling.

Ingestion of drinking water from onsite ground-water wells or surface water sources has not been included as a Non-Licensed Facility Worker exposure pathway. Non-radiological water-related

1 potential Non-Licensed Facility Worker exposures are limited to skin irritation through direct  
2 skin contact with highly alkaline water. The pH of cement falls between 12 and 13, which is  
3 highly caustic. Runoff and leachate from crushed concrete would have lower pH values. NPDES  
4 permits typically limit the maximum pH of discharges to 9.0, but higher values could exist prior  
5 to the discharge point.

6  
7 End uses of recycled concrete aggregate such as road bed construction material, general fill, or  
8 other applications with a high specific surface area may continue to generate leachate or runoff  
9 with elevated pH. End uses which bind the recycled concrete aggregate in cement or asphalt  
10 would not produce such leachate or runoff from the aggregate itself.

### 11 General Public Exposure

12  
13  
14 Potential General Public exposure pathways include the use of ground water, or surface water fed  
15 by ground-water flow, as a drinking water supply from a source located near the site of activities  
16 associated with handling of concrete at the licensee facility site or at offsite satellite facilities;  
17 recycling of the concrete as aggregate; end use of recycled concrete aggregate; and disposal of  
18 concrete dust generated from concrete recycling.

19  
20 Potential non-radiological, General Public exposures include ingestion of water with high pH,  
21 and perhaps elevated levels of calcium, aluminum, or iron. Standard monitoring of public  
22 drinking water supplies limits the risk of exposure to elevated levels of these constituents. Since  
23 significant exposure by direct runoff flows into surface waters would be precluded by NPDES  
24 controls, the remaining pathway is ground-water flow to a surface water body. Private ground  
25 water wells or private surface water supplies fed from a ground water source remain potential  
26 exposure pathways for ingestion.

### 27 Ecological Exposure

28  
29  
30 Potential non-radiological ecological exposure pathways include the existence of aquatic or  
31 riparian animals living in or along surface water bodies at or near the site of activities associated  
32 with handling of concrete at the licensee facility site or at offsite satellite facilities; recycling of  
33 the concrete as aggregate; end use of recycled concrete aggregate; and disposal of concrete dust  
34 generated from concrete recycling.

35  
36 Aquatic and riparian animals face potential exposure to water containing high pH, and perhaps  
37 elevated levels of calcium, aluminum, or iron. Since significant exposure by direct runoff flows  
38 into surface waters is precluded by NPDES controls, the remaining pathway is ground-water flow  
39 to a surface water body.

## 40 **1.2 Ferrous Metal**

41  
42  
43 Potential exposure pathways for the No Action and Unrestricted Release Alternatives for ferrous  
44 metal are based on the anticipated end uses for recycled ferrous metal and the anticipated  
45 processes that would be used in recycling ferrous metals. The following sections describe the

1 affected environment for potential Non-Licensed Facility Worker, General Public, and ecological  
2 exposures.

3  
4 Non-Licensed Facility Worker Exposure

5  
6 Potential Non-Licensed Facility Worker exposure pathways for ferrous metal include activities  
7 associated with the handling of scrap ferrous metal at the licensed facility site; recycling of the  
8 scrap into finished recycled ferrous metal; processing into end use products (e.g., automobiles,  
9 home appliances, building materials); installation of end use products (e.g., building materials);  
10 processing and use of byproducts (e.g., furnace slag, electric arc furnace (EAF) baghouse dust)  
11 generated by recycling processes; and disposal of wastes (e.g., EAF baghouse dust) generated by  
12 recycling processes.

13  
14 Locations used for materials handling at the licensee facility or laydown areas for scrap  
15 stockpiling, segregation, loading, unloading, or other handling at the recycling facility have the  
16 potential to generate both leachate and surface water runoff. The total volume of runoff plus  
17 leachate will depend on natural precipitation and water used for dust suppression. The division  
18 between runoff and leachate will depend on the drainage systems and details in the laydown  
19 areas. All outdoor ferrous metal recycling activities have the potential to contaminate ground  
20 water or surface water, either by the escape of leachate past the barrier systems, if any, or by  
21 runoff which escapes the delineated work area.

22  
23 Several processes in metal recovery and recycling involve process water for cooling or dust  
24 control. Wet cleaning systems remove basic oxygen furnace (BOF) dust in a slurry form. Ferrous  
25 metal mills may use water or water based fluids for pickling or cooling. End use manufacturing  
26 processes often use water for cleaning or cooling.

27  
28 Byproduct materials from ferrous metal production also require substantial quantities of water  
29 for processing. Ground granulated blast-furnace slag (GGBFS) production requires rapid water  
30 quenching to control slag crystal growth and particle size. By contrast, air-cooled blast furnace  
31 slag (ACBFS) production mechanically crushes and screens the larger slag skulls resulting from  
32 the slower cooling process. Water is used to suppress dust in the crushing operation. Slag piles  
33 are intentionally exposed to precipitation to hydrate residual lime and therefore reduce potential  
34 future volumetric instability in construction applications. Uses of slag in portland cement  
35 concrete products include road base courses and structural building concrete, including  
36 residential slabs and foundations. Slag asphalt is also used as a pavement alternative to standard  
37 hot mix asphalt.

38  
39 Ingestion of drinking water from onsite ground-water wells or surface water sources has not been  
40 included as a Non-Licensed Facility Worker exposure pathway. Potential Non-Licensed Facility  
41 Worker exposures from runoff or leachate generated by contact with ferrous metal scrap are  
42 expected to be limited to oils and greases on non-structural components such as pumps and other  
43 machinery. Potential Non-Licensed Facility Worker process water exposures are limited to  
44 dermal exposure through direct skin contact.

1 General Public Exposure

2  
3 Potential General Public exposure pathways include the use of ground water or surface water as  
4 a drinking water supply from a source located near the site of activities associated with handling  
5 of scrap ferrous metal at the licensee facility site; recycling of the scrap into finished recycled  
6 ferrous metal; processing of the finished ferrous metal into end use products; processing and use  
7 of byproducts generated by recycling processes; and disposal of wastes generated by recycling  
8 processes.

9  
10 Potential non-radiological General Public exposures from ferrous metal include ingestion of  
11 water containing contamination from oils and grease, and containing elevated levels of iron,  
12 manganese, or other metals. Standard monitoring of public drinking water supplies limits the risk  
13 of exposure to elevated levels of these constituents. Since significant exposure by direct runoff  
14 flows into surface waters is precluded by NPDES controls, the remaining pathway involves  
15 ground-water flow to a surface water body. Private ground water wells or private surface water  
16 supplies fed from a ground water source remain potential exposure pathways for ingestion.

17  
18 Ecological Exposure

19  
20 Potential ecological exposure pathways for ferrous metal include the existence of aquatic or  
21 riparian animals living in or along surface water bodies at or near the site of activities associated  
22 with handling of scrap ferrous metal at the licensee facility site; recycling of the scrap into  
23 finished recycled ferrous metal; processing of the finished ferrous metal into end use products;  
24 processing and use of byproducts generated by recycling processes; and disposal of wastes  
25 generated by recycling processes.

26  
27 Aquatic and riparian animals face potential non radiological exposure to water containing  
28 elevated levels of metals, such as manganese and chromium. Since significant exposure by direct  
29 runoff flows into surface waters is excluded by NPDES controls, the remaining pathway is  
30 ground-water flow to a surface water body.

31  
32 **1.3 Aluminum**

33  
34 Potential exposure pathways for the No Action and Unrestricted Release Alternatives for  
35 aluminum are based on the anticipated end uses for recycled aluminum and the anticipated  
36 processes that would be used in recycling aluminum. The following sections describe the affected  
37 environment for potential Non-Licensed Facility Worker, General Public, and ecological  
38 exposures in the secondary aluminum industry.

39  
40 Non-Licensed Facility Worker Exposure

41  
42 Potential Non-Licensed Facility Worker exposure pathways include activities associated with  
43 handling of scrap aluminum at the licensee facility site; recycling of the scrap into finished  
44 recycled aluminum; processing of the finished aluminum into end use products (e.g.,  
45 automobiles, home appliances, building materials); installation of end use products (e.g., building

1 materials); processing of byproducts (e.g., furnace dross) generated by recycling processes; and  
2 disposal of wastes (e.g., baghouse dust) generated by recycling processes.

3  
4 Locations used for material handling at the licensee facility or laydown areas for scrap  
5 stockpiling, segregation, loading, unloading, or other handling at the recycling facility have the  
6 potential to generate both leachate and surface water runoff. Secondary aluminum processing  
7 includes scrap shredding; scrap drying, delacquering, or decoating; thermal chip drying, furnace  
8 operations, in-line fluxing; and dross cooling.

#### 9 10 General Public Exposure

11  
12 Potential General Public exposure pathways include the use of ground water or surface water as  
13 a drinking water supply from a source located near the site of activities associated with the  
14 handling of scrap aluminum at the licensee facility site; recycling of the scrap into finished  
15 recycled aluminum; processing of the finished aluminum into end use products; installation of  
16 end use products; processing of byproducts generated by recycling processes; and disposal of  
17 wastes generated by recycling processes.

18  
19 Potential non-radiological General Public exposures include ingestion of leachate-contaminated  
20 water containing elevated levels of lead, copper, cadmium, and other metals. Standard  
21 monitoring of public drinking water supplies limits the risk of exposure to elevated levels of  
22 these constituents. Since significant exposure by direct runoff flows into surface waters is  
23 excluded by NPDES controls, the remaining pathway involves ground-water flow. Private  
24 ground water wells or private surface water supplies fed from a ground water source remain  
25 potential exposure pathways for ingestion.

#### 26 27 Ecological Exposure

28  
29 Potential ecological exposure pathways for aluminum include the existence of aquatic or riparian  
30 animals living in or along surface water bodies at or near the site of activities associated with the  
31 handling of scrap aluminum at the licensee facility site; recycling of the scrap into finished  
32 recycled aluminum; processing of the finished aluminum into end use products; installation of  
33 end use products; processing of byproducts generated by recycling processes; and disposal of  
34 wastes generated by recycling processes. Since significant exposure by direct runoff flows into  
35 surface waters is excluded by NPDES controls, the remaining pathway is ground-water flow to a  
36 surface water body.

### 37 38 **1.4 Copper**

39  
40 Potential exposure pathways for the No Action and Unrestricted Release Alternatives for copper  
41 are based on the anticipated end uses for recycled copper and the anticipated processes that  
42 would be used in recycling copper. The following sections describe the affected environment for  
43 potential Non-Licensed Facility Worker, General Public, and ecological exposures.

1 Non-Licensed Facility Worker Exposure

2  
3 Potential Non-Licensed Facility Worker exposure pathways for copper include activities  
4 associated with the handling of scrap copper at the licensee facility site; recycling of the scrap  
5 into finished recycled copper; processing of the finished copper into end use products (e.g.,  
6 water pipes); processing of byproducts (e.g., furnace slag) generated by recycling processes; and  
7 disposal of wastes (e.g., baghouse dust) generated by recycling processes.  
8

9 Non-radiological water-related potential Non-Licensed Facility Worker exposures from copper  
10 scrap are limited to dermal exposure.  
11

12 General Public Exposure

13  
14 Potential General Public exposure pathways for copper include the use of ground water or  
15 surface water as a drinking water supply from a source located near the site of activities  
16 associated with the handling of scrap copper at the licensee facility site; recycling of the scrap  
17 into finished recycled copper; processing of the finished copper into end use products; processing  
18 of byproducts generated by recycling processes; and disposal of wastes generated by recycling  
19 processes. Since significant exposure by direct runoff flows into surface waters is excluded by  
20 NPDES controls, the remaining pathway involves ground-water flow. Private ground-water  
21 wells or private surface water supplies fed from a ground water source remain potential exposure  
22 pathways for ingestion.  
23

24 Ecological Exposure

25  
26 Potential ecological exposure pathways for copper include the existence of aquatic or riparian  
27 animals living in or along surface water bodies at or near the site of activities associated with the  
28 handling of scrap copper at the licensee facility site; recycling of the scrap into finished recycled  
29 copper; processing of the finished copper into end use products; processing of byproducts  
30 generated by recycling processes; and disposal of wastes generated by recycling processes. Since  
31 significant exposure by direct runoff flows into surface waters is excluded by NPDES controls,  
32 the remaining pathway is ground-water flow to a surface water body.  
33

34 **1.5 Trash**

35  
36 This analysis assumes that the disposition of trash under all alternatives would be limited to  
37 disposal, and that there are no other anticipated end uses for trash. Specifically, recycling options  
38 have been excluded from this analysis because it is unlikely that trash from operations would be  
39 recycled. Therefore, there are no potential exposure pathways under the No Action and  
40 Unrestricted Release Alternatives other than those described for the EPA/State-Regulated  
41 Disposal Alternative in Section 2.  
42

43 **2. Exposure Pathways for the EPA/State-Regulated Disposal Alternative**

44  
45 The affected environment for the EPA/State-Regulated Disposal Alternative includes all waters  
46 which come into contact with the materials released from a licensed site during the release and

1 handling of the materials on the site; transportation of the materials to a disposal facility;  
2 processing or placement of the materials at the disposal facility; and subsequent operation of the  
3 disposal facility. The analysis begins at the point that the material has been released. The  
4 disposal facilities considered under the EPA/State-Regulated Disposal Alternative are limited to  
5 EPA/State-regulated Subtitle D solid waste landfills, and EPA/State-regulated solid waste  
6 incinerators for trash.

## 7 8 **2.1 Subtitle D Landfill Disposal**

9  
10 Disposal in EPA/State-regulated Subtitle D landfills presents similar potential non-radiological  
11 exposure pathways for concrete, ferrous metal, aluminum, copper, and trash; however, the nature  
12 of the potential exposures depends on the contaminants present in each material. This section  
13 describes the affected environment for potential Non-Licensed Facility Worker, General Public,  
14 and ecological exposures.

15  
16 Potential pathways for disposal in an EPA/State-regulated Subtitle D landfill include runoff or  
17 leachate from material piles at the licensee facility during sorting, stockpiling, handling, and  
18 loading activities; leachate collected at the material disposal facility; and collected leachate  
19 escaping and contaminating surface waters. Landfill leachate escaping an engineered landfill  
20 barrier system and entering ground water is not considered a significant pathway.

21  
22 The above pathways present potential exposures risks from leachate or runoff during processing  
23 or in connection with disposal. Both runoff and leachate may eventually reach surface water  
24 bodies and escape beyond the limits of the delineated work area, i.e. the operational or physical  
25 limits bounding Non-Licensed Facility Worker exposures.

26  
27 Subtitle D of the Resource Conservation and Recovery Act (RCRA) of 1976 (42 USC 82,  
28 Subchapter IV) authorized regulation of State or regional solid waste plans. RCRA Subtitle D  
29 covers solid wastes, including hazardous wastes specifically excluded from RCRA Subtitle C.  
30 The promulgated solid waste regulations appear in 40 CFR Part 190 to 282, with Part 257  
31 (Criteria For Classification Of Solid Waste Disposal Facilities And Practices) and Part 258  
32 (Criteria For Municipal Solid Waste Landfills) specifying the siting, design, operational,  
33 monitoring, and closure requirements. Subtitle D landfills that receive or have received any  
34 industrial waste from facilities requiring an NPDES discharge permit are themselves required to  
35 have an NPDES discharge permit. Subtitle D landfills have additional restrictions on run-on and  
36 run-off control, discharges to surface water bodies, and contamination of ground water.

### 37 38 Non-Licensed Facility Worker Exposure

39  
40 For disposal in an EPA/State-regulated Subtitle D landfill, potential Non-Licensed Facility  
41 Worker non-radiological exposure pathways involving water resources for concrete, ferrous  
42 metal, aluminum, copper, and trash result from activities associated with release and disposal of  
43 these materials. These include activities associated with the handling of the materials at the  
44 licensee facility site, and placement and storage of the materials at an EPA/State-regulated  
45 Subtitle D landfill. Potential exposure pathways involving the transportation of materials are not  
46 considered significant.

1 Non-radiological water-related potential Non-Licensed Facility Worker exposures are limited to  
2 dermal exposure to leachate or runoff water. Leachate or runoff from aluminum or copper is not  
3 expected to cause skin irritation. Leachate or runoff from concrete may have elevated pH and  
4 cause irritation or rashes due to its caustic nature. Leachate or runoff from ferrous metal may  
5 contain oils or greases which can cause skin irritation following prolonged exposure. The precise  
6 characteristics of the leachate or runoff from trash will depend on the components of the trash,  
7 but may be similar to leachate from municipal solid waste. Since the contact time is hours or  
8 days, instead of months or years, the contaminant concentrations would be much lower. Leachate  
9 and runoff from trash piles is apt to contain more biological pathogens.

10  
11 Municipal solid waste landfill leachates characteristically exhibit slight acidity (pH>4.5), and  
12 contain elevated levels of ammonia, chlorides, zinc, copper, cadmium, lead, nickel, chromium,  
13 and mercury. Organic compounds detected in Subtitle D landfill leachate include organic acids,  
14 ketones, aromatic compounds, chlorinated aromatic compounds, ethers, phthalates, halogenated  
15 aliphatic compounds, alcohols, amino-aromatic compounds, nitro-aromatic compounds, phenols,  
16 heterocyclic compounds, pesticides, sulfur substituted aromatic compounds, polyaromatic  
17 hydrocarbons, polychlorinated biphenyls, and organophosphates (Reinhart et al. 1998). In  
18 sufficient concentration, several of these can cause an acute skin reaction. In lower  
19 concentrations, compounds such as PCBs, pesticides, and organophosphates can cause serious  
20 chronic health problems.

#### 21 General Public Exposure

22  
23  
24 For disposal in an EPA/State-regulated Subtitle D landfill, potential General Public non-  
25 radiological exposure pathways involving water resources for concrete, ferrous metal, aluminum,  
26 copper, and trash are based on the activities associated with release of these materials at the  
27 licensee facility, and disposal of these materials in an EPA/State-regulated Subtitle D landfill.  
28 These pathways include the use of ground water or surface water as a drinking water supply  
29 from a source located near the site of activities associated with the handling of the materials at  
30 the licensee facility site, and placement and storage of the materials at the landfill/disposal  
31 facility. Ingestion of drinking water from ground-water wells or surface water sources along  
32 transportation routes has not been included as a General Public pathway.

33  
34 Potential non-radiological, water-related, General Public exposures from concrete material piles  
35 include ingestion of water with high pH, and perhaps elevated levels of calcium, aluminum, or  
36 iron. Exposures from ferrous metal material piles include ingestion of water containing  
37 contamination from oils and grease, and containing elevated levels of iron, manganese, or other  
38 metals. The aluminum and copper scrap is not anticipated to be contaminated with oils, grease,  
39 or other hazardous substances. The composition of runoff or leachate from trash is unknown, but  
40 can be expected to contain harmful contaminants. Leachate from landfills may contain  
41 concentrated metals, and hazardous organic and inorganic compounds. Standard monitoring of  
42 public drinking water supplies limits the risk of exposure to elevated levels of harmful  
43 constituents. Since significant exposure by direct runoff flows into surface waters is excluded by  
44 NPDES controls, the remaining pathway involves ground water. Private ground water wells or  
45 private surface water supplies fed from a ground water source remain potential exposure  
46 pathways for ingestion.

1 Ecological Exposure

2  
3 For disposal in an EPA/State-regulated Subtitle D landfill, potential ecological non-radiological  
4 exposure pathways involving water resources for concrete, ferrous metal, aluminum, copper, and  
5 trash are based on the activities associated with release of these materials at the licensee facility,  
6 and disposal of these materials in an EPA/State-regulated Subtitle D landfill. The potential  
7 pathways include exposure of aquatic or riparian animals living in or along surface water bodies  
8 at or near the site of activities associated with the handling of the materials at the licensee facility  
9 site, and placement and storage of the materials at the landfill/disposal facility. Exposure along  
10 transportation routes has not been included as an ecological pathway.

11  
12 Aquatic and riparian animals face potential non-radiological exposure to runoff or leachate from  
13 material piles containing high pH from concrete, oils and greases from ferrous metal, and various  
14 organic and inorganic compounds from trash. Aluminum and copper scrap is not anticipated to  
15 be contaminated with oils, grease, or other hazardous substances. Leachate from landfills may  
16 contain concentrated metals, and hazardous organic and inorganic compounds. Since significant  
17 exposure by direct runoff flows into surface waters is excluded by NPDES controls, the  
18 remaining pathway is ground-water flow to a surface water body. Potential ecological exposures  
19 to ground water extracted from a well and used for irrigation are not considered significant.

20  
21 **2.2 EPA-Regulated Incineration of Trash**

22  
23 Potential exposure pathways for trash are based on the anticipated processes that would be used  
24 in disposing of trash in an EPA/State-regulated incineration facility. This section describes the  
25 affected environment related to incineration of trash for potential Non-Licensed Facility Worker,  
26 General Public, and ecological exposures involving water resources.

27  
28 The EPA regulations pertaining to incineration, 40 CFR Part 60 - Standards of Performance for  
29 New Stationary Sources, deal primarily with air emissions. 40 CFR Part 240 - Guidelines for the  
30 Thermal Processing of Solid Wastes, Section 240.204-1 additionally requires that all waters  
31 discharged by a solid waste thermal processing facility “shall be sufficiently treated to meet the  
32 most stringent of applicable water quality standards, established in accordance with or effective  
33 under the provisions of the Federal Water Pollution Control Act, as amended.”

34  
35 Solid waste combustion facilities typically generate process wastewater from the tipping floor  
36 runoff system, pollution control systems, and ash quenching. These process wastewaters can  
37 often be recycled for ash quenching. Typical facilities use a few gallons per ton of waste burned  
38 (EPA 1995).

39  
40 Non-Licensed Facility Worker Exposure

41  
42 Potential Non-Licensed Facility Worker exposure pathways for EPA/State-regulated incineration  
43 of trash include activities associated with release and combustion of the trash. Incinerator ash  
44 would subsequently be disposed in an ash landfill.

1 Runoff and leachate from trash could contain many of the same contaminants as Subtitle D  
2 landfill leachate, but since the contact time is hours or days, instead of months or years, the  
3 contaminant concentrations are much lower. Leachate and runoff from trash piles is apt to  
4 contain more biological pathogens.

#### 5 6 General Public Exposure

7  
8 Potential General Public exposure pathways for EPA/State-Regulated Incinerator disposal of  
9 trash include activities associated with release and combustion of trash in an incinerator.  
10 Incinerator ash would subsequently be disposed in an ash landfill.

11  
12 Standard monitoring of public drinking water supplies limits the risk of exposure to elevated  
13 levels of harmful constituents. Private ground water wells or private surface water supplies fed  
14 from a ground water source remain potential exposure pathways for ingestion.

#### 15 16 Ecological Exposure

17  
18 Potential non radiological ecological exposure pathways involving water resources for trash  
19 incineration include the exposure of aquatic or riparian animals living in or along surface water  
20 bodies at or near the site of activities associated with release, combustion of trash in an  
21 incinerator, and subsequent disposal of the incinerator ash in an ash landfill.

22  
23 Leachate or runoff from trash piles at the licensee facility may pick up harmful contaminants.  
24 Since significant exposure by direct runoff flows into surface waters is excluded by NPDES  
25 controls, the remaining pathway involves ground water. Ground-water contamination at  
26 incineration sites has proved rare.

### 27 28 **3. Exposure Pathways for the LLW Disposal Alternative**

29  
30 The affected environment for the LLW Disposal Alternative includes all waters which come into  
31 contact with materials released from licensed facilities, including release and handling of the  
32 materials on the site; transportation of the materials to a LLW disposal facility; and placement of  
33 the materials at the disposal facility. The analysis begins at the point that the material has been  
34 released. LLW disposal facility regulations appear in 10 CFR Part 61.

35  
36 The LLW Disposal Alternative presents non-radiological exposure pathways similar to those  
37 discussed for EPA/State-regulated Subtitle D landfills, but the performance of the leakage  
38 barriers, the leachate management system, and the operational practices may differ. Potential  
39 exposure pathways include runoff or leachate from material piles at the licensee facility during  
40 sorting, stockpiling, handling, and loading activities; leachate collected at the disposal facility;  
41 and collected leachate escaping and contaminating surface waters.

42  
43 Potential non-radiological exposure pathways for the EPA/State-Regulated Disposal Alternative  
44 and LLW Disposal Alternative for concrete, ferrous metal, aluminum, copper, and trash are  
45 similar; but the nature of the potential exposures depends on the contaminants present in each

1 material. This section describes the affected environment for potential Non-Licensed Facility  
2 Worker, General Public, and ecological exposures.

3  
4 Non-Licensed Facility Worker Exposure

5  
6 Potential Non-Licensed Facility Worker (i.e., truck drivers) non-radiological exposure pathways  
7 involving water resources for the LLW Disposal Alternative for concrete, ferrous metal,  
8 aluminum, copper, and trash are based on the activities associated with the disposal of these  
9 materials in an LLW disposal facility. This includes activities associated with the handling,  
10 placement, and storage of the materials at the licensed disposal facility. Potential water-related  
11 Non-Licensed Facility Worker exposure pathways involving the transportation of materials are  
12 not considered significant.

13  
14 Non-radiological water-related potential Non-Licensed Facility Worker exposures are limited to  
15 contact with leachate or runoff water. However, truck drivers would not be assumed to be  
16 exposed to either leachate or runoff water. Leachate or runoff from aluminum or copper is not  
17 expected to cause skin irritation.

18  
19 General Public Exposure

20  
21 Potential General Public non-radiological exposure pathways involving water resources for  
22 concrete, ferrous metal, aluminum, copper, and trash are based on the activities associated with  
23 release, and disposal of these materials in LLW disposal facility. These pathways include the use  
24 of ground water or surface water as a drinking water supply from a source located near the site of  
25 activities associated with the handling of the materials at the licensee facility site, and placement  
26 and storage of the materials at the landfill/disposal facility. Ingestion of drinking water from  
27 ground-water wells or surface water sources along transportation routes has not been included as  
28 a General Public pathway.

29  
30 Potential non-radiological, water-related, General Public exposures from concrete material piles  
31 include ingestion of water with high pH, and perhaps elevated levels of calcium, aluminum, or  
32 iron. Exposures from ferrous metal material piles include ingestion of water containing  
33 contamination from oils and grease, and containing elevated levels of iron, manganese, or other  
34 metals. The aluminum and copper scrap is not anticipated to be contaminated with oils, grease,  
35 or other hazardous substances. The composition of runoff or leachate from trash is unknown, but  
36 can be expected to contain harmful contaminants. Leachate from landfills may contain  
37 concentrated metals, and hazardous organic and inorganic compounds. Since significant  
38 exposure by direct runoff flows into surface waters is excluded by NPDES controls, the  
39 remaining pathway is ground-water flow to a surface water body. Standard monitoring of public  
40 drinking water supplies limits the risk of exposure to elevated levels of harmful constituents.  
41 Private ground water wells or private surface water supplies fed from a ground water source  
42 remain potential exposure pathways for ingestion.

1 Ecological Exposure

2  
3 For disposal in LLW disposal facility, potential ecological non-radiological exposure pathways  
4 involving water resources for concrete, ferrous metal, aluminum, copper, and trash are based on  
5 the activities associated with release of these materials at the licensee facility, and disposal of  
6 these materials in a LLW disposal facility. The potential pathways include exposure of aquatic or  
7 riparian animals living in or along surface water bodies at or near the site of activities associated  
8 with the handling of the materials at the licensee facility site, and placement and storage of the  
9 materials at the landfill/disposal facility. Exposure along transportation routes has not been  
10 included as an ecological pathway.

11  
12 Aquatic and riparian animals face potential non-radiological exposure to runoff or leachate from  
13 material piles containing high pH from concrete, oils and greases from ferrous metal, and various  
14 organic and inorganic compounds from trash. Aluminum and copper scrap is not anticipated to  
15 be contaminated with oils, grease, or other hazardous substances. Leachate from landfills may  
16 contain concentrated metals, and hazardous organic and inorganic compounds.

17  
18 NRC regulations for disposal facility performance objectives (10 CFR 61.41) address only  
19 radiological discharge restrictions. However, 10 CFR 51.10 states “In accordance with section  
20 511(c)(2) of the Federal Water Pollution Control Act (86 Stat. 893, 33 U.S.C 1371(c)(2)) the  
21 NRC recognizes that responsibility for Federal regulation of nonradiological pollutant discharges  
22 into receiving waters rests by statute with the Environmental Protection Agency.” Since  
23 significant exposure by direct runoff flows into surface waters is excluded by NPDES controls,  
24 the remaining pathway is ground-water flow to a surface water body. Potential ecological  
25 exposures to ground water extracted from a well and used for irrigation are not considered  
26 significant.

27  
28 **4.0 Affected Environment**

29  
30 This section describes the affected environment under all the Alternatives. In addition to workers  
31 and the general public, ecological receptors are also addressed.

32  
33 Surface Water

34  
35 The affected environment for surface water includes Licensed and Non-Licensed Facility  
36 Workers potentially exposed to wastewater, runoff, or collected leachate either created by direct  
37 contact with the materials released from a licensed site during the generation, handling,  
38 processing, usage, or disposal of the released materials; or created by direct contact with any  
39 byproducts, end use products, or waste products derived from the released materials. Activities  
40 which may generate wastewater, runoff, or leachate include material handling and stockpiling at  
41 licensed facilities; material handling and stockpiling at recycling facilities; recycling processing  
42 at manufacturing facilities; end use of recycled concrete aggregate or ferrous metal slag; disposal  
43 in an EPA/State-regulated Subtitle D landfill; disposal of ash from an EPA/State-regulated  
44 incinerator; and disposal in a LLW disposal facility.

1 For the purposes of this discussion, wastewater, runoff, and leachate include flows that are  
2 generated and handled in engineered environments, effectively separate from the natural  
3 environment, and are considered to be controlled flows. In general, these industrial discharges  
4 require NPDES permits under 40 CFR Part 122. Wastewater refers to water or water-based  
5 fluids directly used in the material processing (e.g. cooling or wash water) and either reused or  
6 discharged. Runoff refers to water which comes into contact with the materials (e.g. via  
7 precipitation or dust control spray) and is later collected in the facility stormwater system and  
8 handled as storm water discharge associated with industrial activity as defined by 40 CFR  
9 122.26(b)14. Leachate refers to water which comes into contact with and percolates through the  
10 materials, and which may be retained by an engineered barrier system (e.g. landfill liner),  
11 collected, processed and discharged. These wastewater, runoff, and collected leachate discharges  
12 may be treated onsite, sent to a Publicly Owned Treatment Facility (POTW) or other offsite  
13 treatment facility, or discharged directly into surface waters in accordance with each facility's  
14 point source discharge permits. Any potential non-radiological exposures following treatment  
15 and post-treatment discharge are considered insignificant.

16  
17 The affected environment for surface water also includes the General Public and Ecological  
18 Receptors potentially exposed to surface water bodies into which wastewater, runoff, or collected  
19 leachate flows or is discharged, either directly or through a ground-water pathway. Natural or  
20 manmade surface water bodies may be either offsite or onsite but lie outside the area of industrial  
21 activity. NPDES stormwater restrictions preclude contaminated discharges proceeding directly  
22 into surface waters in sufficient volume, frequency, or concentration to significantly impact such  
23 waters, therefore the only remaining exposure pathway is ground-water flow to a surface water  
24 body. A surface water body fed by impacted ground water is unlikely to cause non-drinking water  
25 impacts to the General Public due to dilution or, in its absence, due to the limited expected  
26 exposure from a stagnant water body. The affected environment for surface water includes  
27 aquatic or riparian animals or vegetation living in or along ground-water fed surface water  
28 bodies at or near the site of activities associated with the release, handling, processing, usage, or  
29 disposal of the released materials.

### 30 *Concrete*

31  
32  
33 All Alternatives generate potential surface water exposure pathways from concrete handling,  
34 stockpiling, and loading at the licensee facility and disposal of all or part of the concrete in LLW  
35 disposal facilities. All Alternatives except the LLW Disposal Alternative generate additional  
36 potential surface water exposure pathways from concrete disposal in an EPA/State-regulated  
37 landfill. The No Action, Unrestricted Release, and Limited Dispositions Alternatives generate  
38 additional potential surface water exposure pathways from concrete handling and stockpiling at  
39 recycling facilities, recycling processing, and concrete end use activities.

40  
41 All outdoor locations used for concrete handling at the licensee facility or laydown areas for  
42 concrete stockpiling, segregation, loading, unloading, or other handling at the recycling facility,  
43 have the potential to generate both leachate and surface water runoff. The total volume of runoff  
44 and leachate will depend on natural precipitation and water used for dust suppression. The  
45 division between runoff and leachate will depend on the drainage systems and details in the  
46 laydown areas.

1 Under the No Action, Unrestricted Release, and Limited Dispositions Alternatives, activities may  
2 include crushing, screening, and recycling of the concrete into aggregate and subsequent reuse,  
3 and disposal of concrete dust generated from concrete recycling. Potential uses for recycled  
4 concrete aggregate include general fill, road base material, aggregate for new concrete and  
5 asphalt mixes. Crushing of the concrete is also anticipated to occur under the EPA-Regulated  
6 Disposal Alternative and the LLW Disposal Alternative, but only to the extent required to  
7 facilitate transportation.

8  
9 *Ferrous Metal*

10  
11 All Alternatives generate potential surface water exposure pathways from ferrous metal  
12 handling, stockpiling, and loading at the licensee facility and disposal of all or part of the ferrous  
13 metal in LLW disposal facilities. All Alternatives except the LLW Disposal Alternative generate  
14 additional potential surface water exposure pathways from ferrous metal disposal in an  
15 EPA/State-regulated landfill. The No Action and Unrestricted Release Alternatives generate  
16 additional potential surface water exposure pathways from ferrous metal handling and  
17 stockpiling at recycling facilities, recycling processing, and ferrous metal end use activities.

18  
19 Potential surface water exposure pathways for Licensed and Non-Licensed Facility Workers  
20 include exposure to runoff and collected leachate during scrap ferrous metal handling and  
21 stockpiling activities. These activities may occur at the licensed facility site or off-site. All  
22 outdoor locations used for material handling at the licensee facility or off-site; or laydown areas  
23 for scrap stockpiling, segregation, loading, unloading, or other handling at the recycling facility  
24 have the potential to generate both leachate and surface water runoff. The total volume of runoff  
25 plus leachate will depend on natural precipitation. The division between runoff and leachate will  
26 depend on the drainage systems and details in the laydown areas.

27  
28 Potential surface water exposure pathways for Workers at Non Licensed Facilities also include  
29 activities associated with recycling of scrap into finished recycled ferrous metal; processing of  
30 the finished ferrous metal into end use products (e.g., automobiles, home appliances, building  
31 materials); installation of end use products (e.g., building materials); processing and use of  
32 byproducts (e.g., furnace slag, EAF baghouse dust) generated by recycling processes; and  
33 disposal of wastes (e.g., EAF baghouse dust) generated by recycling processes.

34  
35 Several processes in ferrous metal recovery and recycling involve process water for cooling or  
36 dust control. Wet cleaning systems remove BOF or EAF dust in a slurry form. Ferrous metal  
37 mills may use water or water based fluids for pickling or cooling. End use manufacturing  
38 processes often use water for cleaning or cooling.

39  
40 Byproduct materials from ferrous metal production also require substantial quantities of water for  
41 processing. Ground granulated blast-furnace slag production requires rapid water quenching to  
42 control slag crystal growth and particle size. By contrast, air-cooled blast furnace slag production  
43 mechanically crushes and screens the larger slag skulls resulting from the slower cooling process.  
44 Water is used to suppress dust in the crushing operation. Slag piles are intentionally exposed to  
45 precipitation to hydrate residual lime and therefore reduce potential future volumetric instability  
46 in construction applications. Uses of slag in portland cement concrete products include road base

1 courses and structural building concrete, including residential slabs and foundations. Slag asphalt  
2 is also used as a pavement alternative to standard hot mix asphalt.

### 3 *Trash*

4  
5  
6 All the Alternatives generate potential surface water exposure pathways from trash handling,  
7 stockpiling, and loading at the licensee facility and disposal of all or part of the trash in LLW  
8 disposal facilities. All Alternatives except the LLW Disposal Alternative generate additional  
9 potential surface water exposure pathways from trash disposal in an EPA/State-Regulated  
10 Subtitle D landfill or disposal of ash from an EPA/State-regulated incinerator.

11  
12 This analysis assumes that the disposition of trash under all alternatives would be limited to  
13 disposal, and that there are no other anticipated end uses for trash. Specifically, recycling options  
14 have been excluded from this analysis because it is unlikely that trash would be recycled. The  
15 potential surface water exposure pathways under the No Action, Unrestricted Release, and  
16 Limited Dispositions Alternatives are the same as those described for the EPA-Regulated  
17 Disposal Alternative.

18  
19 The surface water affected environment for trash includes all runoff and collected leachate  
20 derived from waters which come into contact with the trash released from a licensed site during  
21 the release and handling of the trash on the site; transportation of the trash to a disposal facility;  
22 processing or placement of the trash at the disposal facility; and subsequent operation of the  
23 disposal facility. The disposal facilities considered are limited to EPA-regulated Subtitle D solid  
24 waste landfills, EPA-regulated solid waste incinerators for trash, and LLW disposal facilities.

25  
26 Potential surface water exposure pathways for disposal in an EPA/State-regulated Subtitle D  
27 landfill or a LLW disposal facility include runoff or leachate from trash piles at the licensee  
28 facility during sorting, stockpiling, handling, and loading activities; and collected leachate at the  
29 material disposal facility.

30  
31 Potential Non-Licensed Facility Worker exposure pathways involving surface water for  
32 EPA/State-regulated incineration of trash include activities associated with generation and  
33 combustion of the trash. Solid waste combustion facilities typically generate process wastewater  
34 from the tipping floor runoff system, pollution control systems, and ash quenching. Process  
35 wastewater can often be recycled for ash quenching, reducing the total water volume required.  
36 Typical facilities use a few gallons per ton of waste burned (EPA 1995). Incinerator ash would  
37 subsequently be disposed in an ash landfill. Ash landfill leachate could contribute to additional  
38 surface water exposures.

### 39 Ground Water

40  
41  
42 Ground water refers to any water in the soil interstitial pore spaces, including water found in  
43 phreatic aquifers, confined aquifers, and the vadose zone, but excluding pore water in any soil  
44 excavated. Process wastewater, surface runoff, or leachate which is not retained by or escapes  
45 barrier systems and subsequently seeps into the soil becomes ground water for the purposes of  
46 this discussion. The affected environment for ground water includes Workers at Licensed

1 Facilities, Workers at Non Licensed Facilities, the General Public, and Ecological Receptors  
2 potentially exposed to compromised ground water. Ground water which discharges into a surface  
3 water body is considered surface water and has been previously discussed. Drinking water  
4 issues, even if the water is obtained from ground-water wells, are discussed separately.

5  
6 Ground-water wells may be used at Licensed Facilities or Non-Licensed Facilities as a source for  
7 process water or dust suppression water. Due to mixing and dilution with unaffected ground  
8 water, concentrations of contaminants in extracted ground water will be lower than the  
9 concentrations in the escaped wastewater, runoff, and leachate.

10  
11 Ground-water wells may be used beyond the boundaries of Licensed Facilities and Non Licensed  
12 Facilities for agricultural or residential water supply. Standard monitoring of public water  
13 supplies limits the risk of exposure to elevated levels of harmful constituents. However, private  
14 ground-water wells remain potential exposure pathways. The General Public faces potential non-  
15 drinking water exposures to affected ground water through dermal contact only. Ground water  
16 has little to no ecological influence until it is extracted from a well.

### 17 18 Drinking Water

19  
20 The affected environment for drinking water includes Workers at Licensed Facilities, Workers at  
21 Non Licensed Facilities, and the General Public. Process wastewater, surface runoff and  
22 leachate have the potential to escape their engineering controls and seep into the underlying soil,  
23 becoming ground water. This ground water may be extracted from wells, or it may discharge  
24 into surface water bodies. Ground water or surface water bodies may be used as sources for  
25 drinking water.

26  
27 Standard monitoring and treatment of public drinking water supplies limits the risk of exposure  
28 to elevated levels of contaminants from the Alternatives. Ingestion of drinking water from onsite  
29 ground-water wells has not been included as an exposure pathway for Workers at Licensed  
30 Facilities or Workers at Non Licensed Facilities. Wells on industrial property regularly serving  
31 more than 25 persons are regulated as public water supplies. Drinking water wells on industrial  
32 property, especially in industries with potential sources of contamination, are usually monitored  
33 regularly for water quality and are not considered to be a significant exposure pathway.

34  
35 Ingestion of drinking water from private ground-water wells or private surface water supplies  
36 may lead to potential exposures. Since significant exposure by direct runoff flows into surface  
37 waters would be precluded by NPDES controls, only surface water bodies fed from a ground-  
38 water source are potential exposure pathways. Surface water bodies with low enough turnover  
39 and dilution to be impacted by ground-water flow would generally be unattractive candidates for  
40 a drinking water source. In areas of the country where alternative surface water supplies are rare,  
41 precipitation is also generally low, so initial leachate and runoff contamination of ground-water  
42 supplies will be minimal.

1       **5.0     Environmental Consequences**  
2

3       Environmental consequences for Workers at Licensed Facilities and Workers at Non Licensed  
4       Facilities are limited to dermal exposure to surface water in the form of process wastewater,  
5       runoff, and collected leachate. There are not anticipated to be any significant ground-water or  
6       drinking water impacts to workers.  
7

8       The General Public does not face any significant environmental consequences from any of the  
9       Alternatives related to surface water. The General Public may experience impacts from dermal  
10      exposure to ground water extracted from a private well, or ingestion of drinking water from a  
11      private ground-water well or private ground-water fed surface water body. However such  
12      exposure is expected to be minimal due to the low probability of the simultaneous occurrence of  
13      the combination of factors required, e.g. high runoff or leachate volumes, high runoff or leachate  
14      concentrations, limited ground-water dilution, the presence of a drinking water well  
15      downgradient of and close to the runoff or leachate source, and a combination of ground-water  
16      gradient and permeability conducive to ground-water mobility.  
17

18      Ecological receptors only face potential environmental consequences from surface water in  
19      ground-water fed surface water bodies. Ground water extracted from a well and used for  
20      agricultural or residential irrigation is not considered a significant pathway for ecological  
21      impacts.  
22

23      Water quality effects are primarily associated with point source and area source water discharges  
24      from the storage, handling, and processing of solid materials. For the No Action and  
25      Unrestricted Release Alternatives, the effects are generated mostly by runoff discharges from  
26      rubblization of concrete and runoff and process wastewater discharges from recycling of ferrous  
27      metal. The incremental quantity of these discharges would be small as compared to the overall  
28      amount of discharges generated from the total amount of concrete and ferrous metal being  
29      recycled annually in the U.S. The impact on water quality would be equally small. Similarly,  
30      the quantity of additional leachate and potential effects on ground water associated with disposal  
31      of solid materials under the EPA/State-Regulated Disposal and LLW Disposal Alternatives  
32      would be small compared with the overall amount of leachate being generated annually by these  
33      facilities. Therefore the overall effects on water quality associated with all of the alternatives  
34      would be small when compared with other sources of discharges. The quantities of materials  
35      released and therefore the volumes of surface water potentially impacted will differ between the  
36      alternatives. The contaminant concentrations in impacted waters may also be higher in scenarios  
37      in which greater volumes of material are released.  
38

39      **5.1     No Action Alternative**  
40

41      The surface water, ground water, and drinking water environmental consequences for the No  
42      Action Alternative are identical in nature to those discussed below under the Unrestricted  
43      Release Alternative.  
44

1     **5.2     Unrestricted Release Alternative**

2  
3     The Unrestricted Release Alternative includes all activities associated with material handling,  
4     stockpiling, and loading at licensee facilities; material unloading, handling, stockpiling, and  
5     loading at recycling facilities; transportation of released materials; processing at recycling or  
6     manufacturing facilities; handling and utilization of end use products; handling and disposal of  
7     byproducts and waste products from processing activities; and direct disposal of released  
8     materials.

9  
10    **5.2.1   Surface Water**

11  
12    Activities under the Unrestricted Release Alternative generate surface water runoff or leachate, or  
13    use water directly in recycling processes to convert the materials into marketable products. The  
14    waters which contact the materials or their byproducts have the potential to acquire contaminants  
15    or deleterious characteristics. These waters may eventually contact Workers at Licensed  
16    Facilities, Workers at Non Licensed Facilities, the General Public, or ecological receptors.

17  
18    Concrete

19  
20    Surface water impacts related to concrete under the Unrestricted Release Alternative stem from  
21    runoff or leachate generated by precipitation or water used for dust suppression. The precipitation  
22    becomes alkaline through contact with the concrete rubble or its residual byproducts. The  
23    increased alkalinity of the water depends on the specific surface area of the concrete and the  
24    duration of the water-concrete contact. Runoff would remain in contact with the concrete rubble  
25    piles for minutes or hours. Leachate could accumulate and concentrate for weeks or months.

26  
27    This analysis considers four likely stages in the concrete recycling process:

- 28  
29    •   Concrete separated from other materials, aggregated, and stockpiled;
- 30  
31    •   Concrete crushed and screened to create a more useable product, or crushed to facilitate  
32       transportation;
- 33  
34    •   Crushed concrete recycled as concrete aggregate and concrete rubble as fill material; and
- 35  
36    •   Concrete dust from the crushing operation disposed in a landfill.

37  
38    The quantity of runoff or leachate generated depends primarily upon the amount of precipitation  
39    and the areal extent of the piles of concrete rubble, recycled concrete aggregate, or concrete dust.  
40    The impact is on water quality, specifically the pH of the water. The results for pH from reported  
41    NPDES discharges generally do not exceed 9.0, but higher values could exist prior to the  
42    discharge point. The pH of cement itself falls between 12 and 13. A leaching study of  
43    construction and demolition waste reports concrete leachate consistently with pH between 11 and  
44    12 (Townsend 1998), which is strongly alkaline. Table H-1 provides estimates of the pH of the  
45    runoff and leachate waters for concrete for the Unrestricted Release Alternative.

**Table H-1 Estimated pH for Concrete Runoff and Leachate - Unrestricted Release Alternative**

Affected Waters	Exposure Location	Estimated pH
<u>Material Generation</u>		
Runoff from material piles	Licensee Facility	9.5
Leachate collected from material piles	Licensee Facility	11
<u>Concrete Recycling</u>		
Runoff from material piles	Recycling Facility	10.1
Leachate collected from material piles	Recycling Facility	11.51
<u>Concrete End Use</u>		
Runoff from Recycled Concrete Aggregate in road construction	Road Construction Site	9.5
Runoff from Recycled Concrete Aggregate in general fill	Area of fill	9.5
<u>Concrete Dust Disposal</u>		
Collected landfill leachate	Industrial Landfill	12

<sup>1</sup> Concrete at recycling facilities is assumed to have a greater specific surface area than concrete at the licensee facility due to additional crushing

Licensed and Non-Licensed Facility Workers may suffer acute and chronic skin impacts from contact with leachate waters. Normal human skin is slightly acidic with a pH between 4.5 and 5.5. Leachate with a pH of 11.5 is 1 million to 10 million times as alkaline as skin. Strongly alkaline material is caustic and corrosive to skin, eyes, and mucous membranes. Prolonged or repeated contact with runoff waters would produce less severe irritation due to the generally lower pH, but may still lead to chronic skin irritation. However, such exposure is unlikely to occur because workers would avoid contact with leachate or wear personal protective equipment in conducting activities.

End uses of recycled concrete aggregate such as road bed construction material, general fill, or other applications with a high specific surface area may continue to generate leachate or runoff with elevated pH. End uses which bind the recycled concrete aggregate in cement or asphalt would not produce such leachate or runoff from the aggregate itself.

Leachate or runoff that seeps into ground water and ultimately reaches a surface water body, especially a small pond, could raise the pH of the surface water body. Aquatic and riparian animals and vegetation face potential exposure to water containing pH in excess of 8 in surface water bodies impacted by high pH ground water. Waters with elevated pH depress biological activity, and pH in excess of 8 can be detrimental to fish. Reducing water with a pH of 12 to a pH of 8 would require dilution by a factor of 10,000. Nevertheless, such exposure is expected to be minimal due to the low probability of the simultaneous occurrence of the combination of factors required and the natural acidity of the majority of lakes and ponds.

There are no anticipated surface water impacts to the General Public from concrete-related activities.

Ferrous Metal

Surface water impacts related to ferrous metal under the Unrestricted Release Alternative stem from runoff or leachate generated by precipitation, and from ferrous metal recycling process wastewater discharges. Table H-2 identifies the contaminants of concern in the waters associated with various ferrous metalmaking activities.

**Table H-2 Ferrous Metal Exposure Pathways for Surface Water – Unrestricted Release Alternative**

Affected Waters	Exposure Location	Contaminants
<u>Material Generation</u>		
Runoff from material piles	Licensee Facility	oils and grease
Leachate collected from material piles	Licensee Facility	oils and grease
<u>Scrap Recycling</u>		
Runoff from scrap piles	Recycling Facility/Ferrous metal Mill	oils and grease
Leachate collected from scrap piles	Recycling Facility/Ferrous metal Mill	oils and grease
Blast furnace wastewater	Ferrous metal Mill	high pH, zinc
EAF Dust process wastewater	Ferrous metal Mill	lead, cadmium
EAF Dust stabilization wastewater	Ferrous metal Mill	lead, cadmium
Runoff from slag pile	Ferrous metal Mill	pH = 7.5 to 9.5
Leachate collected from slag pile	Ferrous metal Mill	pH = 8 to 11
<u>Slag End Use</u>		
Ground granulated blast-furnace slag or crushed slag cement production (runoff or process water)	Cement plant	high pH, metals
Ground granulated blast-furnace slag or crushed slag asphalt production (runoff or process water)	Asphalt plant	high pH, metals
Slag cement or slag asphalt in roads (runoff, dust suppression water)	Road Construction Site	high pH, metals
Air-cooled blast furnace slag for embankments and fills (runoff, dust suppression water)	Earthwork, landscaping site	high pH, metals
<u>EAF Dust Secondary Processing</u>		
EAF dust process wastewater	Processing facility	lead, cadmium
<u>Residue disposal</u>		
EAF dust landfill collected leachate	Industrial Landfill	lead, cadmium
Slag landfill collected leachate	Industrial Landfill	high pH, metals

1 Licensed and Non-Licensed Facility Workers may suffer skin disorders from contact with runoff  
2 or leachate waters from piles of scrap ferrous metal. The quantity of runoff or leachate generated  
3 during each process or activity depends primarily upon the amount of precipitation and the areal  
4 extent of the piles of ferrous metal scrap at the licensee facilities and recycling facilities. Runoff  
5 and leachate from ferrous metal scrap piles may contain oils and grease from nonstructural  
6 components such as pumps and other machinery. The oils and grease may cause skin irritation if  
7 the exposures are extended, but adherence to safe work practices and the use of personal  
8 protective equipment such as gloves and appropriate work clothing would minimize direct  
9 exposure.

10  
11 Workers at Non-Licensed Facilities may suffer skin disorders from contact with runoff or  
12 leachate waters from ferrous metal slag or EAF baghouse dust. Ferrous metal slag leachate can  
13 have pH values as high as 11, which is strongly alkaline and can cause damage to skin, eyes, and  
14 mucous membranes. EAF baghouse dust can have high concentrations of zinc and other metals,  
15 but the impact would be limited by the peak expected annual production of 36 tons/year.

16  
17 There are no anticipated surface water impacts to the General Public from ferrous metal-related  
18 activities.

19  
20 Potential ecological impacts involving surface water for the Unrestricted Release Alternative for  
21 ferrous metal include the existence of aquatic or riparian animals or vegetation living in or along  
22 surface water bodies at or near the site of activities associated with handling of scrap ferrous  
23 metal at the licensee facility site; recycling of the scrap into finished recycled ferrous metal;  
24 processing of the finished ferrous metal into end use products; processing and use of byproducts  
25 generated by recycling processes; and disposal of wastes generated by recycling processes.  
26 Leachate or runoff that seeps into ground water and ultimately reaches a surface water body,  
27 especially a small pond, could raise the pH or metal content of the surface water body. Aquatic  
28 and riparian animals or vegetation face potential exposure to water containing elevated levels of  
29 metals, such as manganese and chromium. Waters with elevated pH depress biological activity,  
30 and pH in excess of 8 can be detrimental to fish. The low probability of the simultaneous  
31 occurrence of the combination of factors required to affect surface water chemistry through  
32 ground-water flow limits the potential for impacts from indirect discharges, and the mild acidity  
33 of the majority of lakes and ponds provides natural protection against the most likely impact, an  
34 increase in pH level.

### 35 36 Trash

37  
38 The surface water impacts from trash for the Unrestricted Release Alternative are the same as  
39 those described for the EPA/State-Regulated Disposal Alternative.

### 40 41 **5.2.2 Ground Water**

42  
43 Activities under the Unrestricted Release Alternative can impact through the escape of process  
44 wastewater, leachate, or runoff past engineering barriers and seepage into the soil.

1 Concrete

2  
3 Licensed Facility and Non-Licensed Facility Workers are not anticipated to have any significant  
4 concrete-related non-drinking water impacts from ground water. It is unlikely that even workers  
5 routinely involved in activities involving sprayed water, such as dust suppression on concrete  
6 rubble piles, would suffer skin or eye irritation because the high volumes of water required for  
7 these activities would generally dilute to low levels any deleterious components in the small  
8 volumes of escaped runoff or leachate.

9  
10 The General Public may face impacts from ground water extracted from residential wells and  
11 used for bathing or swimming. The pH of runoff and leachate from concrete-related activities  
12 varies from 9.5 to 12. Reducing ground water with a pH of 12 to a pH of 8.0 would require  
13 dilution by a factor of 10,000. The Center for Disease Control warns that swimming pool water  
14 with a pH above 8.0 may cause skin and eye irritation. Ground water that reaches a private well  
15 could exceed that standard, but the low probability of the simultaneous occurrence of the  
16 combination of factors required minimizes the risk of exposure.

17  
18 Ferrous Metal

19  
20 Licensed Facility and Non-Licensed Facility Workers are not anticipated to have any significant  
21 non-drinking water impacts from ground water. It is unlikely that even workers routinely  
22 involved in activities involving sprayed water, such as slag quenching, would suffer skin or eye  
23 irritation because the high volumes of water required for these activities would generally dilute to  
24 low levels any deleterious components in the small volumes of escaped runoff or leachate.

25  
26 The General Public may face impacts from ground water extracted from residential wells and  
27 used for bathing or swimming. Leachate from slag may have a pH as high as 11. Reducing  
28 ground water with a pH of 11 to a pH of 8.0 would require dilution by a factor of 1,000.  
29 Swimming pool water with a pH above 8.0 may cause skin and eye irritation. Ground water that  
30 reaches a private well could exceed that standard, but the low probability of the simultaneous  
31 occurrence of the combination of factors required minimizes the risk of exposure.

32  
33 Trash

34  
35 This analysis assumes that the disposition of trash under all the Alternatives would be limited to  
36 disposal, and that there are no anticipated recycling or other end uses for trash because it is  
37 unlikely that trash would be recycled. Therefore, there are no potential exposure pathways under  
38 the Unrestricted Release Alternative for trash other than those described below for the  
39 EPA/State-Regulated Disposal Alternative.

40  
41 **5.2.3 Drinking Water**

42  
43 Licensed and Non-Licensed Facility Workers are not anticipated to have any significant drinking  
44 water impacts. Impacts to the General Public are discussed below.

1 Concrete

2  
3 Potential General Public drinking water exposure pathways involving concrete related activities  
4 include the use of ground water, or surface water fed by ground-water flow, as a drinking water  
5 supply from a source located near the site of activities associated with handling of concrete at a  
6 licensee facility, handling of concrete at a recycling facility, recycling of the concrete as  
7 aggregate, end use of recycled concrete aggregate, disposal of concrete dust generated from  
8 concrete recycling, or direct disposal of concrete. Potential impacts include ingestion of water  
9 with high pH, and perhaps elevated levels of calcium, aluminum, or iron. Reducing water with a  
10 pH of 12, typical of concrete dust leachate, to the upper limit of the National Secondary Drinking  
11 Water Standards, pH = 8.5, would require dilution by a factor of over 3,000. Ground water that  
12 reaches a private well could exceed the standard, but General Public exposure to impacted  
13 drinking water from a private ground-water well or private ground-water fed surface water body  
14 is expected to be minimal due to the low probability of the simultaneous occurrence of the  
15 combination of factors required.

16  
17 Ferrous Metal

18  
19 Potential General Public exposure pathways involving water resources include the use of ground  
20 water or surface water as a drinking water supply from a source located near the site of activities  
21 associated with handling of scrap at the licensee facility site; recycling of the scrap into finished  
22 recycled product; processing of the finished material into end use products; processing and use  
23 of byproducts generated by recycling processes; and disposal of wastes generated by recycling  
24 processes. Potential impacts include ingestion of water containing contamination from oils and  
25 grease, and containing elevated levels of iron, manganese, or other metals. Reducing water with  
26 a pH of 11, typical of ferrous metal slag leachate, to the upper limit of the National Secondary  
27 Drinking Water Standards would require dilution by a factor of over 300. Ground water that  
28 reaches a private well could exceed the standard, but exposure to impacted drinking water from a  
29 private ground-water well or private ground-water fed surface water body is expected to be  
30 minimal due to the low probability of the simultaneous occurrence of the combination of factors  
31 required.

32  
33 Trash

34  
35 This analysis assumes that the disposition of trash under all Alternatives would be limited to  
36 disposal, and that there are no other anticipated end uses for trash. Specifically, recycling options  
37 have been excluded from this analysis. Therefore, there are no potential exposure pathways  
38 under the Unrestricted Release Alternative for trash other than those described below for the  
39 EPA/State-Regulated Disposal Alternative.

40  
41 **5.3 EPA/State-Regulated Disposal Alternative**

42  
43 Under the EPA/State-Regulated Disposal Alternative all of the potentially clearable concrete,  
44 ferrous metal, and trash would be disposed of in EPA/State-regulated Subtitle D landfills. Some  
45 or all of the trash could be disposed in EPA/State-regulated incinerators. These disposal options

1 are also available under the No Action, Unrestricted Release, and Limited Dispositions  
2 Alternatives.

### 3 4 **5.3.1 Surface Water**

#### 5 6 Subtitle D Landfill Disposal of Concrete, Ferrous Metal, and Trash

7  
8 Under the EPA/State-Regulated Disposal Alternative, released concrete, ferrous metal, and trash  
9 would be disposed in EPA/State-regulated Subtitle D landfills. Workers at Licensed Facilities  
10 would face similar surface water impacts during material generation, segregation, and stockpiling  
11 of ferrous metal at the licensee facility as those incurred under the Unrestricted Release  
12 Alternative. Concrete could have lower water-related impacts under the EPA/State-Regulated  
13 Disposal Alternative because less crushing and screening could be performed at the licensee  
14 facility than under the Unrestricted Release Alternative, reducing the specific surface area of the  
15 concrete rubble and the likelihood for pH impacts to runoff and leachate.

16  
17 Surface water impacts to Workers at Licensed Facilities include contact with runoff or collected  
18 leachate from trash piles during handling, stockpiling, or loading activities. Surface water  
19 impacts to Workers at Non Licensed Facilities from trash are limited to contact with runoff  
20 produced during the processing or placement of the trash at the landfill and leachate collected  
21 during subsequent operation of the landfill.

22  
23 The precise characteristics of the runoff from trash will depend on the components of the trash,  
24 but may be similar to leachate from municipal solid waste. Since the contact time for runoff is  
25 hours or days, instead of the months or years for leachate, the contaminant concentrations in  
26 runoff are expected to be much lower than the concentrations in leachate. Runoff from trash piles  
27 is apt to contain more biological pathogens than leachate.

28  
29 Municipal solid waste landfill leachates characteristically exhibit slight acidity (pH>4.5), and  
30 contain elevated levels of ammonia, chlorides, zinc, copper, cadmium, lead, nickel, chromium,  
31 and mercury. Organic compounds detected in Subtitle D landfill leachate include organic acids,  
32 ketones, aromatic compounds, chlorinated aromatic compounds, ethers, phthalates, halogenated  
33 aliphatic compounds, alcohols, amino-aromatic compounds, nitro-aromatic compounds, phenols,  
34 heterocyclic compounds, pesticides, sulfur substituted aromatic compounds, polyaromatic  
35 hydrocarbons, polychlorinated biphenyls, and organophosphates (Reinhart et al. 1998). In  
36 sufficient concentration, several of these can cause an acute skin reaction. In lower  
37 concentrations, compounds such as PCBs, pesticides, and organophosphates can cause serious  
38 chronic health problems. However, such exposures are unlikely to occur because workers would  
39 avoid contact with leachate and wear personal protective equipment when conducting activities  
40 that could lead to leachate contact.

41  
42 There are no anticipated surface water impacts to the General Public from EPA/State-regulated  
43 disposal of concrete, ferrous metal, or trash.

44  
45 Potential ecological receptors include aquatic or riparian animals and vegetation living in or  
46 along surface water bodies at or near the site of activities associated with handling of materials at

1 the licensee facility site; and disposal of material in an EPA/State-regulated landfill. Leachate  
2 from landfills may contain concentrated metals, and hazardous organic and inorganic  
3 compounds. Leachate or runoff that seeps into ground water and ultimately reaches a surface  
4 water body, especially a small pond, could alter the pH of or introduce organic and inorganic  
5 compounds into the surface water body.

### 6 EPA/State-Regulated Incineration of Trash

7  
8  
9 The surface water impacts to Workers at Licensed Facilities from trash are the same whether the  
10 disposal destination is an EPA/State-regulated Subtitle D landfill disposal or an EPA/State-  
11 regulated incinerator, and include contact with runoff or collected leachate from trash piles  
12 during handling, stockpiling, or loading activities. Activities associated with EPA/State-regulated  
13 incineration of trash have different potential surface water impacts for Workers at Non Licensed  
14 Facilities. The process wastewater from the tipping floor runoff system contains many of the  
15 components found in MSW landfill leachate, but since the contact time is hours or days, instead  
16 of months or years, the contaminant concentrations are much lower. Tipping floor runoff water is  
17 apt to contain more biological pathogens than MSW leachate. Process wastewater from pollution  
18 control systems will develop acidic characteristics, primarily from SO<sub>2</sub> in the combustion gases.  
19 Extended dermal contact with these waters can cause skin irritation. Such exposures are unlikely  
20 to occur because workers would avoid contact with process wastewater and wear personal  
21 protective equipment when conducting activities that could lead to contact.

22  
23 There are no anticipated surface water impacts to the General Public from EPA/State-regulated  
24 incineration of trash. Ground-water contamination at incineration sites has proven rare, so  
25 impacts to aquatic or riparian animals at or near ground-water fed surface water bodies are not  
26 expected.

### 27 **5.3.2 Ground Water**

28  
29 Licensed and Non-Licensed Facility Workers are not anticipated to have any significant non-  
30 drinking water impacts from ground water. No activities associated with the handling,  
31 stockpiling, transportation, placement of trash in an EPA/State-regulated landfill, or placement of  
32 incinerator ash in an ash landfill would require the use of ground water. Solid waste combustion  
33 facilities typically use water for cleaning the tipping floor, pollution control systems, and ash  
34 quenching. Ground-water contamination at incineration sites has proved rare, so worker contact  
35 with ground water extracted for these uses is not expected to cause any significant impacts.

36  
37  
38 The General Public may experience non-drinking water ground-water impacts from water  
39 extracted from private residential wells located near licensee facilities, EPA/State-regulated  
40 Subtitle D landfills, or incinerator ash landfills. Standard landfill ground-water monitoring helps  
41 to reduce this risk. MSW landfill leachates characteristically contain elevated levels of ammonia,  
42 chlorides, zinc, copper, cadmium, lead, nickel, chromium, and mercury. Organic compounds  
43 detected in Subtitle D landfill leachate include organic acids, ketones, aromatic compounds,  
44 chlorinated aromatic compounds, ethers, phthalates, halogenated aliphatic compounds, alcohols,  
45 amino-aromatic compounds, nitro-aromatic compounds, phenols, heterocyclic compounds,  
46 pesticides, sulfur substituted aromatic compounds, polyaromatic hydrocarbons, polychlorinated

1 biphenyls, and organophosphates (Reinhart et al. 1998). In sufficient concentration, several of  
2 these can cause an acute skin reaction. In lower concentrations, compounds such as PCBs,  
3 pesticides, and organophosphates can cause chronic health problems. General Public dermal  
4 exposure to impacted water from a private ground-water well is expected to be minimal due to  
5 the low probability of the simultaneous occurrence of the combination of factors required.  
6

### 7 **5.3.3 Drinking Water**

8  
9 For disposal in an EPA-regulated Subtitle D landfill, potential General Public impacts are based  
10 on the use of a private ground-water or surface water source as a drinking water supply from a  
11 source located near the site of activities associated with the handling of the materials at the  
12 licensee facility site, placement and storage of the materials at the landfill, or placement of ash  
13 from trash incineration in a landfill.  
14

15 The composition of runoff or leachate from trash varies, but can be expected to contain a host of  
16 harmful contaminants. MSW landfill leachates characteristically exhibit slight acidity (pH>4.5),  
17 and contain elevated levels of ammonia, chlorides, zinc, copper, cadmium, lead, nickel,  
18 chromium, and mercury. Organic compounds detected in Subtitle D landfill leachate include  
19 organic acids, ketones, aromatic compounds, chlorinated aromatic compounds, ethers, phthalates,  
20 halogenated aliphatic compounds, alcohols, amino-aromatic compounds, nitro-aromatic  
21 compounds, phenols, heterocyclic compounds, pesticides, sulfur substituted aromatic  
22 compounds, polyaromatic hydrocarbons, polychlorinated biphenyls, and organophosphates  
23 (Reinhart et al. 1998). Many of these components, if ingested, can cause health problems.  
24

25 Incineration of trash in an EPA/State-regulated incinerator generates ash which is disposed in an  
26 ash landfill. Leachate from incinerator ash may contain high concentrations of metals.  
27

28 General Public exposure to impacted drinking water from a private ground-water well or private  
29 ground-water fed surface water body is expected to be minimal due to the low probability of the  
30 simultaneous occurrence of the combination of factors required.  
31

### 32 **5.4 Low-Level Waste Disposal Alternative**

33  
34 Under the LLW Disposal Alternative, all of the potentially clearable materials released from  
35 licensed facilities would be transported and placed in a LLW disposal facility.  
36

37 For the purposes of this analysis, all potentially clearable solid materials released by licensed  
38 facilities are assumed to be sent to a disposal facility in Clive, Utah (Section 2.4.4). The  
39 Envirocare disposal facility incorporates waste cells constructed over naturally clayey soils. A 2-  
40 foot thick layer of compacted clay lines the bottom of each cell. The Envirocare facility is  
41 located in a remote desert location with an arid to semi-arid climate. The site is over 20 miles  
42 from the nearest permanent human habitation.  
43

1 **5.4.1 Surface Water**

2  
3 Surface water impacts to Workers at Licensed Facilities under the LLW Disposal Alternative  
4 include contact with runoff or collected leachate from trash piles during handling, stockpiling, or  
5 loading activities, as well as contact with runoff at the disposal facility.  
6

7 The concentrated placement of all the released materials in a single location would concentrate  
8 the surface water related impacts in the vicinity of the disposal facility. The volume of additional  
9 waste at a single facility would likely require the opening of additional cells and the increase in  
10 areal extent would increase the potential for runoff generation. Based on a peak annual disposal  
11 volume of 2.3 million tons (2.1 metric tons) and an estimated average bulk specific gravity of  
12 2.0, the peak annual volume of materials equals 1.05 million cubic meters. Assuming a typical  
13 cell depth of 15 meters, the peak annual volume would require the opening of about 7 hectares of  
14 new disposal cells annually. Annual rainfall in Clive, Utah is about 3.0 cm/year (7 in/year). The  
15 volume of water which would fall on 7 hectares equals about 21,000 m<sup>3</sup>/year. Actual leachate  
16 generation would be significantly less due to the potential evaporation rate of 152 cm/year (60  
17 in/year), and placement of interim covers.  
18

19 The runoff would need to be removed from the cells and evaporated onsite. The exact  
20 constituents of the runoff depend on the segregation or mixing of waste types at the disposal  
21 facility. Runoff from trash would be expected to exhibit characteristics similar to MSW leachate.  
22 MSW leachate is typically acidic, and contains a wide variety of organic chemicals, inorganic  
23 chemicals, and pathogens. Runoff from areas of concrete disposal would have a higher pH. The  
24 high evaporation rates at the Envirocare facility would have the effect of concentrating the  
25 contaminants, except volatile components, in the remaining runoff thus increasing the potential  
26 dermal exposure hazards. Rigorous worker training at the Envirocare facility, adherence to safe  
27 work practices, and the use of personal protective equipment such as gloves and appropriate  
28 work clothing would minimize direct exposure.  
29

30 There are no anticipated surface water impacts to the General Public from the LLW Disposal  
31 Alternative.  
32

33 Potential ecological impacts involving surface water for the LLW Disposal Alternative depend  
34 on the existence of aquatic or riparian animals living in or along surface water bodies at or near  
35 the site of activities associated with handling of materials at the licensee facility site and disposal  
36 of material in the Envirocare facility. Since there are no ground-water fed surface water bodies  
37 in the vicinity of the Envirocare facility, there are no anticipated ecological impacts at or near the  
38 disposal facility.  
39

40 **5.4.2 Ground Water**

41 Workers at the Envirocare disposal facility are unlikely to use ground water in ways which  
42 would lead to non-drinking water ground-water impacts. There are no General Public impacts  
43 expected from non-drinking water ground water use at the disposal facility or offsite as the  
44 nearest residence is 20 miles from the Envirocare site.  
45  
46

1 **5.4.3 Drinking Water**

2  
3 Workers at the Envirocare disposal facility are unlikely to use ground water in ways which  
4 would lead to drinking water impacts. There are no General Public impacts expected from use of  
5 drinking water at the disposal facility or offsite, as the nearest residence is 20 miles from the  
6 Envirocare site.

7  
8 **5.5 Limited Dispositions Alternative**

9  
10 The following sections describe the environmental impacts associated with the Limited  
11 Dispositions Alternative.

12  
13 **5.5.1 Surface Water**

14  
15 The surface water environmental consequences for concrete are identical in nature to those  
16 discussed under the Unrestricted Release Alternative (Section 5.2.1).

17  
18 Surface water impacts for ferrous metal and trash are identical in nature to those discussed under  
19 the EPA/State-Regulated Disposal Alternative (Section 5.3.1).

20  
21 **5.5.2 Ground Water**

22  
23 The ground-water environmental consequences for concrete are identical in nature to those  
24 discussed under the Unrestricted Release Alternative (Section 5.2.2). Ground-water impacts for  
25 ferrous metal and trash are identical in nature to those discussed under the EPA/State-Regulated  
26 Disposal Alternative (Section 5.3.2).

27  
28 **5.5.3 Drinking Water**

29  
30 The drinking water environmental consequences for concrete are identical to those discussed  
31 under the Unrestricted Release Alternative (Section 5.2.3). Drinking Water impacts for ferrous  
32 metal and trash are identical in nature to those discussed under the EPA/State-Regulated  
33 Disposal Alternative (Section 5.3.3).

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## APPENDIX I

### AIR QUALITY - SUPPLEMENTAL INFORMATION

This appendix provides supporting information for Section 3.5 (Air Quality). Section 1 describes the affected environment, Section 2 describes the air emissions from each alternative, and Section 3 discusses the environmental consequences.

#### **1.0 Affected Environment**

The affected environment, as defined for the purposes of the air quality impact assessment, includes the ambient air affected by non radiological air pollutants emitted from activities associated with the release, handling, processing, transportation, and disposal of solid materials generated from licensed facilities under the Alternatives, and the General Public potentially exposed to such non radiological air pollutants. The affected environment also includes environmental receptors potentially affected by air emissions from activities associated with the Alternatives.

This section describes the environmental setting and baseline national air emissions to which air emissions associated with the Alternatives are compared in the environmental consequences analysis and also includes a discussion of baseline ambient air quality. National air emissions rather than baseline ambient air quality, is used as the baseline for assessment of air quality impacts because site-specific baseline ambient air quality cannot be determined for the Draft GEIS.

#### **1.1 Baseline Ambient Air Quality**

Air quality is assessed by measurements collected at thousands of air quality monitoring stations around the country, and these monitoring data are used to assess baseline ambient air quality associated with site-specific actions. Management of air quality is generally conducted on a local or regional scale and is achieved by controlling air emissions sources within the area that contribute to violations of the NAAQS. Potential air quality environmental consequences of site-specific actions are generally compared to baseline ambient air quality data. However, site-specific analyses cannot be conducted for the Alternatives, as the specific quantities of licensee-released materials that would flow into and through each air quality management area, and the affect of those activities on associated local air concentrations, cannot be estimated. Therefore, the air emissions estimated for each of the Alternatives are compared to total national emissions for each air pollutant for which there is an ambient air quality standard, and no site-specific baseline ambient air quality data are included in the Draft GEIS.

#### **1.2 Emissions**

Management of air quality is achieved by controlling sources that contribute the air pollutants associated with each air quality standard. Emissions from air emissions sources are typically estimated using emission factors. An emission factor is a parameter that describes the air pollutant emission rate of a particular process in terms of some common and easily quantified activity that is directly related to the emissions activity. For example, emissions from secondary

1 ferrous metal processing (recycling) are estimated by applying an emission factor that represents  
2 the average emission rate of particulate matter for each ton of scrap ferrous metal processed. If  
3 the total tons of scrap ferrous metal to be processed in a ferrous metal mill is known, the total  
4 emissions resulting from the process can be estimated by multiplying the total tons throughput by  
5 the emission factor in units of pounds of emissions per ton of ferrous metal processed.  
6

7 Many of the processes associated with the Alternatives are regulated to ensure that emissions are  
8 controlled to specified levels. The types and performance of air pollution control equipment in  
9 use at any given facility will differ. Typically, air pollutant emission factors are expressed as the  
10 uncontrolled emission rate, and the result of the estimate produced for any specific facility is  
11 adjusted to account for the control efficiency of the air pollution control system.  
12

13 Air quality management programs are typically implemented on a local or urban area scale.  
14 Information on the specific rates of activities conducted within the specific local or urban scale  
15 air quality management areas is required to complete these local analyses. Activity rate data  
16 would include, for example, total vehicle miles traveled in the area each year, or the total tons of  
17 ferrous metal produced in the area each year. However, the quantities of licensee-released  
18 materials that would flow into and through each air quality management area for each of the  
19 Alternatives cannot be estimated for the Draft GEIS, and, therefore, no site-specific or  
20 region-specific air quality analyses can be conducted. Since the affect of meteorology and  
21 climatology on environmental impacts is only relevant for local analyses, it is not meaningful to  
22 discuss meteorology and climatology in this study.  
23

24 Since air emissions associated with activities conducted under each Alternative can only be  
25 estimated on a national scale, the total national emissions (in units of tons per year) of each  
26 pollutant for each process and activity associated with each Alternative is used as the  
27 environmental setting (air quality baseline) for the purposes of evaluating the air quality impacts  
28 of the Alternatives. The national emissions of each pollutant from each industry sector and  
29 process (e.g., ferrous metal production) are included in the EPA National Emissions Inventory  
30 (NEI) (EPA 2004a). The same emission factors used by EPA to prepare the NEI are applied to  
31 appropriate estimates of the material flow through each process to estimate the incremental  
32 effects on air quality associated with each Alternative.  
33

34 The NEI, used in this Draft GEIS to establish the affected environment, is prepared annually by  
35 the Emission Factors and Inventories Group (EFIG) within the EPA Office of Air Quality  
36 Planning and Standards (OAQPS). The development of the annual NEI by EPA is a requirement  
37 of the Clean Air Act. The EPA coordinates closely with State air quality planning agencies to  
38 ensure that the database is as accurate as possible and that local conditions are represented to the  
39 extent possible. The EPA NEI database is available at <http://www.epa.gov/ttn/>  
40 [chief/net/1999inventory.html](http://www.epa.gov/ttn/) (EPA 2004a). Emissions estimates are available in the NEI for  
41 each of the specific process activities that can be quantified, as well as for the equipment and  
42 transportation activities that are associated with the Alternatives.  
43

44 The total national emissions (in units of tons per year) of each pollutant for each process and  
45 associated activity is used as the environmental setting (air quality baseline) for the purposes of  
46 evaluating the air quality impacts of the alternatives. The national emissions of each pollutant

from each industry sector and process (e.g., ferrous metal production) are included in the NEI. A summary of national emissions by source activity for the processes related to the alternatives for 1999 is provided in Table I-1. The annual period 1999 is used as the baseline measure because it is the most recent annual, national, air emissions inventory that has received extensive quality assurance.

**Table I-1 National Annual Air Metric Emissions from Specific Processes for 1999  
(metric tons per year)**

Source Category	SO <sub>2</sub>	VOC	PM10	PM2.5	NO <sub>x</sub>	CO
Concrete Recycling	10	43	51	47	115	200
Secondary Ferrous Metal Production	7,997	3,361	7,609	7,074	5,326	22,346
Secondary Copper	48	336	1,833	1,792		
Secondary Aluminum	1,272	18,068	11,640	11,148	2,745	1,701
Subtitle D Landfills	1	1,393	609	250	13	65
Solid Waste Incinerators	11,852	1,190	2,393	2,128	30,127	10,775

Source: EPA NEI database at <http://www.epa.gov/ttn/chief/net/1999inventory.html>.

## 2.0 Air Emissions From Alternatives

The EFIG maintains a compilation of the recommended emission factors for use in estimating emissions from various air emissions source types, including air emissions processes and activities associated with each Alternative. The record of emission factors for stationary sources is the Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume 1: Stationary Point and Area Sources <http://www.epa.gov/ttn/chief/ap42/index.html> (EPA 2003e). Emission factors for highway mobile sources (e.g., diesel trucks) are developed by use of the MOBILE6 model that is maintained and updated by the EPA Office of Transportation and Air Quality (OTAQ) (EPA 2003f). Emission factors for mobile sources are dependent on the vehicle type, vehicle age, and speed, among other influences. Highway emission factors for heavy duty trucks that would be used to transport materials under the Alternatives will be developed using the MOBILE6 model. Input conditions representative of the average conditions anticipated for transportation of materials under the Alternatives will be selected to derive these average emission factors. The emission factors will then be applied to estimates of the total miles of transport required for each of the alternatives.

Emissions from heavy equipment operations are estimated by the use of another model developed by OTAQ called the NONROAD model (EPA 2003g). This model includes assumptions about the distribution and activity levels of various types of off road mobile sources. The output of the model provides estimates for specific types of equipment. Emissions from non-road heavy equipment (e.g., ferrous metal scrap pile loaders), are developed by applying an estimate of the total anticipated hours of operation for a representative type of heavy equipment that is commonly used for the particular type of process. The appropriate emission factor for that type of heavy equipment is used to derive a reasonable estimate of the air emissions for each Alternative.

1     **2.1     Concrete**

2  
3     Fugitive Particulate Emissions

4  
5     Concrete released from licensed facilities for the No Action, Unrestricted Release, and Limited  
6     Dispositions Alternatives would be broken up to remove ferrous metal reinforcing bars, and to  
7     create pieces in size ranges that can be moved and loaded onto trucks at the licensed facilities.  
8     These size-reduction processes can emit fugitive dust. Additional fugitive releases may be  
9     generated as the material is loaded into trucks for removal from the site. Similarly, other size-  
10    reduction processes at transfer station operations at which concrete rubble is processed are also  
11    potential sources of fugitive dust emissions. The fugitive dust generated by these mechanical  
12    activities includes mass in the smaller size range (<2.5 µm diameter particles) and has the  
13    potential to be transported to downwind receptor locations. Most of the particles larger than 10  
14    µm are removed from the atmosphere by gravitational settling near the air emission source and  
15    are not generally considered in air quality analyses. Depending upon wind speed and direction  
16    and other atmospheric conditions, populations living close to the licensee’s facility or to other  
17    facilities where concrete rubble is processed for size reduction could be exposed to ambient air  
18    concentrations of fugitive dust. Such exposures would depend upon the hours of operation of the  
19    processes and dust suppression measures that are applied during the process.

20  
21    Combustion Source Emissions

22  
23    Movement and size-reduction of concrete would involve use of heavy equipment, such as dozers  
24    and loaders. Such equipment is commonly powered by diesel engines. Diesel engines emit NO<sub>x</sub>  
25    and VOC, the precursors of ozone, CO, particulate matter in the fine size fraction, and CO<sub>2</sub>. The  
26    precursors of ozone and the particulate matter emissions have the potential to combine with other  
27    pollutants generated by mobile and stationary sources in the general area to affect regional air  
28    quality.

29  
30    Transportation Emissions

31  
32    Under the No Action and Unrestricted Release Alternatives large pieces of concrete would be  
33    loaded into heavy duty trucks or rail cars at the licensee facility for transport to the concrete  
34    recycling process facilities. Transport of concrete rubble does not have a high potential to  
35    generate fugitive emissions, however, transportation of crushed aggregate suitable for use at a  
36    roadway construction site could contribute fugitive emissions during transport if the truck trailer  
37    is not securely covered. Truck engines used to transport materials would emit NO<sub>x</sub>, VOC, CO,  
38    particulate matter in the fine size range and CO<sub>2</sub>. The General Public along the transportation  
39    routes would be exposed to the diesel combustion exhaust and any fugitive emissions released.

40  
41    Process Emissions

42  
43    Once the concrete reaches the concrete recycling process site, additional mechanical processing  
44    would be conducted to further reduce the concrete rubble into the appropriate aggregate size  
45    range for end use as road bed fill. The process involves grinding and crushing and would  
46    generate fugitive dust. Wind erosion could result in the generation of fugitive particulate

1 emissions from aggregate storage piles. The mass of emissions would depend on the length of  
2 time the storage pile remains undisturbed, the moisture content of the aggregate, and the wind  
3 speed. The potential for population exposure would depend upon the wind speed and direction  
4 and the distance between the facility and human receptors.  
5

6 Table I-2 summarizes air emission sources, processes and activities by material type (concrete,  
7 ferrous metal and trash disposal) for the No Action, Unrestricted Release and Limited  
8 Disposition Alternatives.  
9

## 10 **2.2 Ferrous Metal, Aluminum, and Copper**

11  
12 Processing of ferrous metal, aluminum, and copper for recycling under the No Action and  
13 Unrestricted Release Alternatives involves similar activities with similar air emissions  
14 characteristics. Similar processes and activities are associated with the release of the materials at  
15 the licensee sites and the transport of the materials to the recycling facilities. There are specific  
16 differences in the magnitude and constituents of air emissions from the recycling processes for  
17 ferrous metal, aluminum, and copper as a result of the furnace types used to melt the scrap and  
18 the characteristics of the metals themselves, but the process activities for the secondary metals  
19 processing are similar for all three materials. This section provides a generic description of the  
20 process and the specific emissions characteristics for the different kinds of furnaces used to melt  
21 metal scrap.  
22

### 23 Fugitive Particulate Emissions

24  
25 Fugitive dust emissions sources associated with the processing of the metal scrap at the licensed  
26 facility are associated with the bulk loading of the scrap metal into trucks or railcars. These  
27 processes have only a minimal potential for dispersion of the fugitive emissions from the  
28 licensed facility site because the emissions are characterized by large particle sizes that settle  
29 under gravitational influences and do not tend to disperse from the source.  
30

### 31 Process Emissions

32  
33 Several different types of cutting machines or shredders might be used to reduce the size of the  
34 scrap metal pieces for transport either at the licensed facility site or at secondary processing  
35 facilities. The scrap metal processing could result in metal fumes emissions. Ozone precursors  
36 would be generated from the diesel or gasoline engines used to power the equipment.  
37

38 While the processes that are used at the recycling facilities to recycle ferrous metal, aluminum,  
39 and copper are conceptually the same, different types of furnaces are used for each metal.  
40 Therefore, different emission rates and constituents are associated with each metal recycling  
41 process. The scrap metal is processed by reducing the scrap to the molten state in a furnace,  
42 separating the impurities from the metal, and casting the recovered metal into intermediate or  
43 final products. Recovered metal is often cast into ingots that would then be further processed into  
44 finished materials (e.g., automobile engine blocks) at some other facility, or cast into new  
45 products at the recycling facility site.  
46

**Table I-2 Air Emissions Sources, Processes, and Activities Associated with No Action, Unrestricted Release, and Limited Dispositions Alternatives**

<b>Material</b>	<b>Activity</b>	<b>Air Emissions Source</b>	<b>Exposed General Public</b>
<b>Concrete</b> (No Action, Unrestricted Release, and Limited Dispositions Alternatives)	Crushing/Grinding	Fugitive Dust	Vicinity of licensed facility
	Loading for Transport	Fugitive Dust Heavy Equipment Engine Emissions	Vicinity of licensed facility, and incremental contribution to urban and regional air quality inventory
	Transport to Road Bed Material Processing Facility	Fugitive Dust Heavy-Duty Truck Highway Emissions	Along the transportation route, and incremental contribution to urban and regional air quality inventory
	Unloading/Storage Piles	Fugitive Dust Heavy Equipment Engine Emissions	Vicinity of processing facility, and incremental contribution to urban and regional air quality inventory
	Processing into Road Bed Material	Fugitive Dust Heavy Equipment Engine Emissions	Vicinity of processing facility, and incremental contribution to urban and regional air quality inventory
	Transport to Road Building Site	Fugitive Dust Heavy-Duty Truck Highway Emissions	Along the transportation route, and incremental contribution to urban and regional air quality inventory
	Final Use - Roadbed Construction	Fugitive Dust Heavy Equipment Engine Emissions	Near road construction site, and incremental contribution to urban and regional air quality inventory
	Disposal of Concrete Dust in Landfill	Fugitive Dust Heavy Equipment Engine Emissions	Vicinity of landfill, and incremental contribution to urban and regional air quality inventory

**Table I-2 Air Emissions Sources, Processes, and Activities Associated with No Action, Unrestricted Release, and Limited Dispositions Alternatives (continued)**

<b>Material</b>	<b>Activity</b>	<b>Air Emissions Source</b>	<b>Exposed General Public</b>
<b>Ferrous Metal, Copper, Aluminum</b> (No Action and Unrestricted Release Alternatives)	Sorting/sizing for removal	Torches and Cutting Tools Heavy Equipment Engine Emissions	Vicinity of licensed facility, and incremental contribution to urban and regional air quality inventory
	Loading for Transport	Heavy Equipment Engine Emissions	Vicinity of licensed facility, and incremental contribution to urban and regional air quality inventory
	Transport to Recycling Facility	Heavy-Duty Truck Highway Emissions	Along the transportation route, and incremental contribution to urban and regional air quality inventory
	Unloading/Storage/Preparation for Recycling	Torches and Cutting Tools Heavy Equipment Engine Emissions	Vicinity of processing facility, and incremental contribution to urban and regional air quality inventory
	Smelting/Refining	Furnace	Vicinity of processing facility
	Transport to Secondary Casting	Heavy-Duty Truck Highway Emissions	Along the transportation route, and incremental contribution to urban and regional air quality inventory
	Secondary Melting casting	Furnace	Vicinity of secondary processing facility
	Molding/cutting/shaping in new use	Torches and Cutting Tools	Near reuse manufacturing facility
	Transport of Final Product to point of use	Heavy-Duty Truck Highway Emissions	Along the transportation route, and incremental contribution to urban and regional air quality inventory
<b>Trash Disposal</b> (No Action, Unrestricted Release, and Limited Dispositions Alternatives)	Transport of Recycling Process wastes to Landfill	Heavy-Duty Truck Highway Emissions	Along the transportation route, and incremental contribution to urban and regional air quality inventory
	Unloading and disposal of trash at EPA/State-regulated landfill	Heavy Equipment Engine Emissions	Vicinity of landfill or disposal facility
	Disposal in EPA/State-regulated landfill	Heavy Equipment Engine Emissions	Vicinity of landfill or disposal facility

1 The principal air pollutant emitted from any type of secondary metals processing activity is  
2 particulate matter. The particulate matter results from the condensation of metal fumes that are  
3 emitted from the molten metal processes when they are released into the ambient air. The  
4 resulting particulate matter is primarily in the form of metal oxides. These metal oxide  
5 emissions form in the small size ranges that can disperse from process stacks and vents into the  
6 ambient air and then disperse from the facility location. Particulate emissions from secondary  
7 metal processing facilities are subject to air quality regulations and subject to air emissions  
8 control requirements.

9  
10 Processing and disposal of the impurities generated as slag from these furnaces can also cause  
11 emissions of particulate matter. These processes are conducted in ways that minimize the release  
12 of air pollutants.

### 13 Ferrous Metal

14  
15  
16 Scrap ferrous metal is recycled by incorporating scrap into a furnace along with virgin ferrous  
17 metal scrap (i.e., scrap ferrous metal generated at the ferrous metal mill from ferrous metal  
18 processing) and pig iron. The mixture is melted and impurities are extracted. The final ferrous  
19 metal melt is tapped and used to form either cast products, ingots or rolled sheets for use in a  
20 variety of applications. The furnaces used to process scrap ferrous metal can be part of an  
21 integrated ferrous metal mill where iron ore is processed in addition to ferrous metal, but it is  
22 more often completed at specialty iron and ferrous metal foundries that concentrate on secondary  
23 ferrous metal processing. Most of the furnaces used to process ferrous metal do not use external  
24 heat sources. The main types of secondary ferrous metal furnaces are basic oxygen furnaces and  
25 electric arc furnaces (EAF). Scrap ferrous metal may also be melted directly in a foundry. In the  
26 blast furnace process, molten pig iron from a blast furnace is used to melt the scrap. Scrap may  
27 also be melted by heat generated through electrical resistance in EAFs. Oxygen lancing is often  
28 used to remove impurities by forming oxides that create the furnace slag. The oxidation  
29 reactions are exothermic and create additional heat for the process. Some smaller foundries use  
30 gas fired furnaces to melt scrap ferrous metal. The primary air pollutant emissions from ferrous  
31 metal furnaces are particulate matter resulting from fumes released by the melt. These fumes are  
32 most commonly in the form of metal oxides. Ferrous metal blast furnaces and foundries emit  
33 combustion products from combustion of fuel to provide heat to melt the ferrous metal. EAF  
34 furnaces result in secondary emissions of combustion products from generation of electricity.

### 35 Aluminum

36  
37  
38 Aluminum scrap is processed primarily in reverberatory furnaces. Reverberatory furnaces are  
39 generally natural gas fired immediately above the melt and have a curved roof that redirects the  
40 rising heat back into the melt. Emissions from the furnace fuel use are estimated as a separate  
41 process. The primary emissions from aluminum recycling are particulate matter resulting from  
42 fumes released by the melt, and combustion products from burning of natural gas.

1 Copper

2  
3 Copper scrap may be processed in cupola furnaces, reverberatory furnaces, or electric arc  
4 furnaces. Copper scrap is generally mixed with virgin copper and clean scrap. The pure metal is  
5 separated from the impurities and tapped to form ingots or in some applications is cast directly  
6 into new products, such as copper pipe. The copper recycling processes emits metal fume  
7 particulate matter and combustion emissions.  
8

9 **2.3 Trash**

10  
11 Under the No Action, Unrestricted Release, EPA/State-Regulated Disposal, and Limited  
12 Dispositions Alternatives, trash released from licensed facilities is assumed to be directly  
13 disposed in a Subtitle D landfill. Air emissions sources and emission factors associated with  
14 disposal of trash are discussed in Section 3.3.  
15

16 **3.0 Environmental Consequences**

17  
18 Total national air emissions (in units of tons per year) from processes and activities associated  
19 with the Alternatives are estimated using emission factors. For example, the total amount of  
20 particulate matter (PM) associated with the recycling of ferrous metal under the Unrestricted  
21 Release Alternative is estimated by multiplying the total amount of ferrous metal released from  
22 licensed facilities that is recycled in ferrous metal mills (in units of tons per year) by a factor for  
23 the amount of particulate matter emitted per ton of ferrous metal recycled (in units of mass  
24 particulate matter per ton ferrous metal processed). The same emission factors used to prepare  
25 the NEI are applied to appropriate estimates of the material flow through each process to estimate  
26 the incremental effects on air quality associated with each Alternative.  
27

28 Approximately 15 to 20 million tons of concrete and approximately 2 million tons of ferrous  
29 metal would be released from licensed commercial nuclear reactor facilities under any of the  
30 Alternatives (Appendix F). It is assumed that all of the concrete would be sent for recycle as  
31 road-bed. The amount of ferrous metal is compared to approximately 82 million metric tons per  
32 year in the United States. Conversely, approximately 6,600 metric tons of copper and 200 tons  
33 of aluminum are anticipated to be released from commercial nuclear reactor facilities.

34 Therefore, air quality impacts associated with recycling and disposal of aluminum and copper  
35 are not discussed quantitatively in the Draft GEIS. Less than 0.07 million tons of trash would be  
36 released from licensed nuclear reactor facilities, and less than 0.9 million tons of trash is  
37 anticipated to be released from licensed facilities other than commercial nuclear reactors. This  
38 compares with estimates of approximately 209 million tons per year of municipal solid waste.  
39 The air quality impact analysis for trash is based on the disposal of trash in either EPA/State-  
40 regulated landfills, EPA/State-regulated incinerators, or LLW disposal facilities. Trash is not  
41 assumed to be recycled or reused under any of the Alternatives.  
42

43 Sources and activities associated with the Alternatives to which NESHAP standards apply are  
44 shown in Table I-3. Process emissions of hazardous air pollutants (HAPs) would be released  
45 from the recycling of ferrous metal under the No Action and Unrestricted Release Alternatives,  
46 The emission factors for HAPs for ferrous metal recycling are small compared to the emission

**Table I-3 Summary Table – Total Air Emissions from Alternatives  
(metric tons)**

<b>Total Emissions</b>					
<i>No Action Alternative and Unrestricted Release Alternative</i>	PM <sub>10</sub>	SO <sub>2</sub>	NO <sub>x</sub>	VOC	CO
Concrete (recycling)	1,219	Neg.	4,654	1,132	910
Ferrous metal (recycling)	8,362	2,905	7,248	4,614	--
Trash (landfill disposal)	67	Neg.	186	94	94
<b>TOTAL EMISSIONS</b>	<b>9,648</b>	<b>2,905</b>	<b>12,124</b>	<b>5,839</b>	<b>1,004</b>
<i>EPA/State-Regulated Disposal Alternative</i>					
Concrete (landfill disposal)	1,210	Neg.	4,583	1,132	910
Ferrous metal (landfill disposal)	36	Neg.	776	60	326
Trash (landfill disposal)	67	Neg.	186	94	94
Trash (incineration)	171	117	337	94	157
<b>TOTAL EMISSIONS</b>	<b>1,417</b>	<b>117</b>	<b>5,696</b>	<b>1,285</b>	<b>1,394</b>
<i>Limited Dispositions Alternative</i>					
Concrete (recycling)	1,219	Neg.	4,646	1,132	910
Ferrous metal (landfill disposal)	36	Neg.	776	60	326
Trash (landfill disposal)	67	Neg.	186	94	94
<b>TOTAL EMISSIONS</b>	<b>1,320</b>	<b>Neg.</b>	<b>5,570</b>	<b>1,285</b>	<b>1,330</b>
<i>LLW Disposal Alternative</i>					
<b>TOTAL EMISSIONS</b>	<b>93</b>	<b>7</b>	<b>889</b>	<b>94</b>	<b>94</b>
<b>Annual Emissions</b>					
<i>No Action Alternative and Unrestricted Release Alternative</i>					
Annual Emissions (metric tons/year)	205	62	258	124	21
<i>EPA/State-Regulated Disposal Alternative</i>					
Alternative Not Including Trash Incineration					
Annual Emissions (metric tons/year)	28	Neg.	118	26	28
Alternative Including Trash Incineration					
Annual Emissions (metric tons/year)	30	3	121	27	30
<i>LLW Disposal Alternative</i>					
Annual Emissions (metric tons/year)	2	0.2	19	2	2
<i>Limited Dispositions Alternative</i>					
Annual Emissions (metric tons/year)	33	Neg.	139	32	33

Neg = Negligible

1 factors for the criteria (NAAQS) air pollutants for ferrous metal recycling, in terms of emissions  
2 per ton of ferrous metal recycled. Therefore, the HAP emissions from ferrous metal recycling  
3 would be small as compared to the total inventory of HAPs emitted on a national basis.  
4 Similarly, the HAP emissions associated with disposal of material in Subtitle D landfills or  
5 EPA/State-regulated incinerators would also be small as compared to the total inventory of HAPs  
6 emitted from landfill disposal and incineration of solid waste. In addition, the facilities where  
7 these materials would be processed are already subject to HAP emissions limitation standards  
8 whether or not the materials from licensed facilities are processed. Therefore, HAP emissions  
9 from ferrous metal recycling and landfill disposal and incineration of wastes generated from  
10 ferrous metal recycling are not discussed quantitatively in the DGEIS.  
11

### 12 **3.1 No Action Alternative**

13  
14 Air emissions sources, processes, and activities that are anticipated to contribute air pollutant  
15 emissions for the No Action, Unrestricted Release, and Limited Dispositions Alternatives for  
16 each material are listed in Table I-4. Air emissions sources, processes, and activities associated  
17 with the No Action Alternative are similar to those for the Unrestricted Release Alternative for  
18 recycling of concrete, ferrous metal, aluminum, and copper and disposal of trash. Under the  
19 Limited Dispositions Alternative, concrete would be recycled and other material would be  
20 disposed of in landfills. Air emissions associated with the No Action Alternative would be  
21 similar to those for the Unrestricted Release Alternative based on the amount of solid material  
22 that would be released and potentially recycled under these two Alternatives. For the purposes of  
23 the air emissions environmental consequences analysis it is assumed that all of the released solid  
24 material for both the No Action and Unrestricted Release Alternatives are recycled and that none  
25 is disposed of, and for the Limited Dispositions Alternative, it is assumed that all of the concrete  
26 is recycled. These assumptions maximize the air emissions estimated for the Alternatives.  
27 Sources, activities, and air emissions for the Unrestricted Release Alternative are presented in  
28 Section 3.2 below.  
29

### 30 **3.2 Unrestricted Release Alternative**

31  
32 As discussed in Section 3.1, air emissions sources, processes, and activities for the No Action  
33 Alternative are similar for those for the Unrestricted Release Alternative with respect to the  
34 recycling of concrete, ferrous metal, aluminum, and copper and disposal of trash and also for the  
35 Limited Dispositions Alternative for concrete and trash (Table I-4). The activities that result in  
36 air emissions for each of the materials assessed can be grouped in four general categories:  
37 materials processing, heavy equipment operation, recycling operations, and transportation. Each  
38 of the materials must be segregated and sized to allow transportation from the site. These  
39 processes require the use of heavy equipment, such as crushers, and equipment to load the  
40 processed materials into trucks or railcars. The materials are then transported to appropriate  
41 processing or disposal facilities by trucks or railroad. Similar types of heavy equipment are used  
42 to unload the materials at a suitable processing or disposal facility. At a processing facility the  
43 materials are used as feed stock for the process that results in the recyclable materials. Finally,  
44 the processed materials and unwanted waste products from the processing activity must be  
45 transported to the end use site or to the appropriate disposal site. These processes and their  
46 associated air emissions are described below for each of the solid materials.

**Table I-4 Air Emissions Sources, Processes, and Activities Associated with No Action, Unrestricted Release, and Limited Dispositions Alternatives**

	<b>Activity</b>	<b>Regulated Pollution</b>	<b>Exposure Location</b>
Concrete	Crushing/Grinding	Fugitive Dust Heavy Equipment Engine Emissions	Vicinity of licensed facility; Vicinity of the processing facility
	Loading, Unloading, Storage Piles	Fugitive Dust Heavy Equipment Engine Emissions	Vicinity of licensed facility; Vicinity of the processing facility
	Transportation from licensed facility and to final use site, or to landfill	Fugitive Dust	Along the transportation route, and incremental contribution to urban and regional air quality inventory
		Heavy-Duty Truck Highway Emissions	
	Final Use - Roadbed Construction	Fugitive Dust Heavy Equipment Engine Emissions	Near road construction site, and incremental contribution to urban and regional air quality inventory
Disposal of Concrete Dust in Landfill	Fugitive Dust Heavy Equipment Engine Emissions	Vicinity of landfill, and incremental contribution to urban and regional air quality inventory	
Ferrous metal	Sorting/sizing for removal	Torches and Cutting Tools Heavy Equipment Engine Emissions	Vicinity of licensed facility
	Loading and unloading	Heavy Equipment Engine Emissions	Vicinity of licensed facility, and vicinity of processing facility
	Transportation between processing facilities, or landfill (for Limited Dispositions Alternative)	Heavy-Duty Truck Highway Emissions	Along the transportation route, and incremental contribution to urban and regional air quality inventory
	Smelting/Refining/Casting	Furnace	Vicinity of processing facility
	Molding/cutting/shaping in new use	Torches and Cutting Tools	Near reuse manufacturing facility
	Transport of Final Product to point of use	Heavy-Duty Truck Highway Emissions	Along the transportation route, and incremental contribution to urban and regional air quality inventory
Trash	Loading and unloading for transport	Heavy Equipment Engine Emissions	Vicinity of licensed facility, and vicinity of processing facility
	Transportation from licensed facility to waste incinerator or landfill	Heavy-Duty Truck Highway Emissions	Along the transportation route, and incremental contribution to urban and regional air quality inventory
	Disposal in EPA/State-Regulated Landfill	Heavy Equipment Engine Emissions	Vicinity of the landfill

1 Transportation

2  
3 Transportation of the intermediate and completely processed concrete aggregate, ferrous metal,  
4 and trash will contribute exhaust emissions from truck engines. Exhaust emissions from heavy  
5 duty diesel trucks are calculated by the application of emission factor models that represent the  
6 distribution of truck engines in service. Those emission factors are applied to estimates of the  
7 miles traveled by trucks with each engine type.  
8

9 There is also a possibility of fugitive dust emissions from the load. A cover is required for trucks  
10 and railcars that are transporting these types of materials to limit the fugitive dust emissions and  
11 the contributions from this type of activity are assumed to be negligible. There is no approved or  
12 recommended method to estimate these emissions. Therefore, fugitive emissions are not  
13 included in the emissions estimate from transportation processes.  
14

15 Air emissions estimates for transportation activities associated with the Unrestricted Release and  
16 Limited Dispositions Alternatives represent the total emissions expected for transportation of all  
17 of the materials to be released from licensed facilities. Material specific estimates used in this air  
18 quality analysis were estimated by allocating the transportation emissions based on the relative  
19 quantities of the materials. Table I-5 summarizes the allocation of the transportation emissions  
20 for concrete, ferrous metal and trash. Total emissions for all heavy duty diesel trucks for 1999,  
21 the most recent year for which data have been published by EPA, is 2,390,000 metric tons per  
22 year for NO<sub>x</sub>, and 130,909 metric tons per year for PM10. The average annual national emissions  
23 for NO<sub>x</sub> and PM10 for transportation of concrete are well under 0.001 percent of total heavy duty  
24 diesel emissions and are insignificant from an air quality management perspective.  
25

26 **Table I-5 Unrestricted Release and Limited Dispositions Alternatives**  
27 **Transportation Emissions**

Material	Quantity Released (10 <sup>6</sup> tons) <sup>1</sup>	Material Mass Fraction	Total Emissions (metric tons/year)			
			NO <sub>x</sub>	PM10	SO <sub>2</sub>	CO <sub>2</sub>
Concrete (metric tons)	20	0.89	5	0.2	Neg.	5,062
Ferrous metal (metric tons)	2	0.11	0.62	0.02	Neg.	626
Trash (metric tons)	0.066	0.003	0.12	Neg.	Neg.	17
Unrestricted Release Alternative Total (metric tons)	22	1	6	0.22	0.05	5,075
Total US Annual Emissions <sup>2</sup>	–	–	2,390,900	130,909	90,909	na

35 <sup>1</sup>Solid Material Generated by Commercial Nuclear Power Reactors.

36 <sup>2</sup> (EPA 2004a) NEI Total emissions for all heavy duty diesel engines in 1999. CO<sub>2</sub> emissions are not reported in the NEI  
37 totals.

1 Concrete

2  
3 Initially, large pieces of reinforced concrete are generated during the demolition process. These  
4 large pieces must be broken up into smaller pieces that can be loaded into trucks and to remove  
5 the ferrous metal reinforcing bars. The concrete that is targeted for disposal is loaded into trucks  
6 for transportation to landfills. The concrete that is to be used as road bed aggregate is loaded  
7 into trucks for transport to a facility that will break the pieces into smaller sizes, using similar  
8 equipment as that used at the licensed facility. Finally, the sized aggregate is transported to the  
9 road construction site, and the unusable pieces to a disposal facility.

10  
11 *Concrete Rubbilization*

12  
13 The size-reduction processes can emit fugitive dust. Additional fugitive releases may be  
14 generated as the material is loaded into trucks for removal from the site. Similarly, other size-  
15 reduction processes at transfer station operations at which concrete rubble is processed are also  
16 potential sources of fugitive dust emissions. The fugitive dust generated by these mechanical  
17 activities includes mass in the smaller size range (<10 µm diameter particles) and has the  
18 potential to be transported to downwind receptor locations. Most of the particles larger than 10  
19 µm are removed from the atmosphere by gravitational settling near the air emission source and  
20 are not generally considered in air quality analyses. Depending upon wind speed and direction  
21 and other atmospheric conditions, populations living close to the licensee's facility or to other  
22 facilities where concrete rubble is processed for size reduction could be exposed to ambient air  
23 concentrations of fugitive dust. Such exposures would depend upon local meteorological  
24 conditions, the hours of operation of the processes, and dust suppression measures that are  
25 applied during the process.

26  
27 Fugitive dust emissions from these types of operations are typically controlled by wetting the  
28 materials or some other dust suppression method. Emissions from these activities are low and  
29 estimates are not included as a separate source category in routine air emissions inventories.  
30 Emission factors for stone and aggregate crushing, screening and secondary crushing processes  
31 are used as a surrogate to represent an estimate of the contribution of these processes to air  
32 emissions loads. Emission factors for fugitive dust emissions in the PM10 size range from the  
33 crushing processes range from 0.0007 to 0.015 expressed in units of lbs/ton of processed  
34 material. The emission factors for fugitive dust during loading and unloading processes range  
35 from 0.000016 to 0.0001 (lb/ton loaded or unloaded). Emission factors for the 2.5 µm size range  
36 have not been finalized for many of these processes. EPA estimates PM2.5 emissions in the NEI  
37 by applying size fraction assumptions to source categories that lack a PM2.5 emission factor.  
38 Emissions of PM10 associated with the Alternatives are compared to annual PM2.5 emissions  
39 estimates to provide a conservative assessment of the potential air impacts.

40  
41 Total fugitive dust emissions generated by crushing and sorting the concrete is estimated to be  
42 157.5 metric tons if all 19.8 million tons of the concrete is completely processed into road bed  
43 aggregate. This total assumes two loading and unloading operations (one at the licensed facility  
44 and one at the aggregate processing facility). Emissions are smaller for the concrete that is  
45 disposed in a landfill because less crushing and screening is required. If it is assumed that these  
46 operations will occur uniformly over a 47 year period, the annual emissions are 3.35 metric tons

1 per year. The annual emissions of the smaller size fraction PM<sub>2.5</sub> represented in the 1999 NEI  
2 inventory (EPA 2004a) for crushing and screening processes is 46.2 short tons.

### 3 4 *Heavy Equipment Operation*

5  
6 A variety of types of equipment that use heavy duty diesel engines can be used to process the  
7 concrete. These engines emit particulate matter in both size ranges, oxides of nitrogen (NO<sub>x</sub>),  
8 carbon monoxide (CO), volatile organic compounds (VOC), and small amounts of HAP  
9 pollutants. The emission factors for these engines are represented in units of grams per  
10 horsepower-hour. The following assumptions were used to develop emissions estimates for the  
11 heavy equipment engines. Primary crusher engines rated at 200 horsepower can process 10 short  
12 tons of concrete per hour. Bull dozers rated at 100 horsepower can create piles of concrete at a  
13 rate of 10 short tons per hour. Finally, front end loaders rated at 100 horsepower, can load five  
14 tons of concrete per hour into trucks. These assumptions result in emissions estimates of 1,050  
15 metric tons of particulate matter, 4,376 metric tons of NO<sub>x</sub>, 910 metric tons of CO, and 1,132  
16 metric tons of VOC.

### 17 18 *Road Bed Construction*

19  
20 The aggregate produced from recycled concrete is assumed to be incorporated into road bed  
21 underlayment during road construction. Following road way preparation, and before paving, this  
22 aggregate is spread on the road bed to serve as a support for the paving materials, and to stabilize  
23 the materials under the asphalt or concrete used as paving material. There is a potential for  
24 fugitive dust emissions during these processes, but in most cases dust suppression methods are  
25 applied during road construction. EPA has not published recommended emissions estimation  
26 methods or emission factors for this activity, and typically emissions from these processes are  
27 not included in standard air emissions inventories. Since emissions are expected to be minimal,  
28 and there is no recommended estimation method, emissions from this activity are not addressed  
29 quantitatively in this Draft GEIS.

30  
31 Overall criteria pollutant emissions from processing and transportation of concrete released from  
32 licensed facilities under the Unrestricted Release and Limited Dispositions Alternatives  
33 represents a small fraction of the total national emissions associated with processing and  
34 transportation of concrete generated from all demolition and concrete recycling operations  
35 nationwide. A comparison of total estimated criteria pollutant emissions associated with the  
36 Unrestricted Release and Limited Dispositions Alternatives and total national emissions is shown  
37 in Table I-6. Overall emissions from recycling of concrete released from licensed facilities is  
38 estimated to be 0.2 percent or less of national emissions from concrete recycling.

### 39 40 Ferrous Metal

41  
42 Processing ferrous metal for recycling under the Unrestricted Release Alternative involves the  
43 same general categories of emission sources as those described for concrete. Ferrous metal  
44 would not be recycled under the Limited Dispositions Alternative, but would be disposed of in  
45 landfills. Air emissions from landfill disposal of ferrous metal are included in Section 3.3. The  
46 process of breaking the concrete into smaller pieces to remove ferrous metal reinforcing bars is

**Table I-6 Unrestricted Release and Limited Dispositions Alternatives  
Emissions from Concrete Recycling (metric tons)**

	PM <sub>10</sub>	VOC	NO <sub>x</sub>	CO
Concrete Rubblization (metric tons)	158	Not applicable	Not applicable	Not applicable
Heavy Equipment Operation (metric tons)	1,050	1,132	4,376	910
Transportation (metric tons)	10	Not available	278	Not available
Road Bed Construction	[emission factors for road bed construction unavailable]			
Total Emissions (metric tons)	1,219	1,132	4,654	910
Annual Emissions (metric tons/year)	26	24	99	19
National Average Emissions (metric tons per year, all heavy duty diesel highway vehicles)	145,152	36,817	1,404,080	217,531
Percent of National Average	0.02	<0.01	< 0.01	<0.01

(1) Total emissions are projected to occur over a period of 47 years.

the same process described for concrete and no additional fugitive dust emissions would be generated solely because of the extraction of ferrous metal reinforcing bars. Heavy equipment will be used to load the ferrous metal into trucks, transportation sources will create air emissions during the transport of the ferrous metal, and emissions result from the furnaces where the ferrous metal is melted to be recast into ingots, sheets, rolls or bars.

### *Smelting Furnace*

The recycled ferrous metal scrap is assumed to be recycled in one of three specific furnace types. Since it is not possible to determine the exact flow of ferrous metal to different reprocessing facilities, an average emission factor has been used. The average emission factor is based on the assumption that all of the recycled ferrous metal scrap is processed in one of the three primary furnace types used in commercial ferrous metal recycling. The three types of furnaces are electric arc furnace, the basic oxygen furnace (or an oxygen lanced foundry), and the open hearth foundry furnace. NUREG-1640 provides an estimate of the percent of scrap ferrous metal recycled in the U.S. that flows through each of these major recycling furnace types. Table I-7 summarizes the PM10 emission factors for each furnace type (EPA Compilation of Emission Factors, EPA Publication AP-42). NRC has assumed for the purposes of the air emissions impact assessment that the percent of ferrous metal scrap throughput directed to each furnace type for the licensee-released scrap ferrous metal is the same as that for the U.S. as a whole. The percent throughput estimate is used as a weighting factor for each process-specific particulate emission factor to derive a weighted average emission factor for the scrap ferrous metal smelting process. This factor is multiplied by the estimated total tonnage of scrap ferrous metal to be released under the Unrestricted Release Alternative to derive the emission rate for the smelting process. The weighting calculation for the particulate emission factor is summarized in Table I-7.

**Table I-7 Ferrous Metal Scrap Smelting Particulate Emission Factor Derivation**

Furnace Type	Emission Factor (lb/ton)	Fractional Throughput	Weighting Contribution
Electric Arc Furnace	13	0.581	7.553
Open Hearth Foundry	11	0.216	2.376
Oxygen Lanced Foundry	10	0.203	2.03
Weighted Average emission factor			11.959 lb/ton (5.98 kg/MG)

Application of the weighted average emission factor, and assuming that all 2.45 million tons of ferrous metal is recycled yields a total emission estimate for uncontrolled particulate matter of 13,319 metric tons. Typically, ferrous metal furnaces employ a particulate matter control device that achieves an average of 95 percent control efficiency. Applying that level of control yields 666 metric tons of particulate matter from the furnace operation. Additional particulate matter emissions result when metal fumes condense during the pours to form ingots, rolls, or sheets of ferrous metal that can be used in further processing. The emission factor for that process is 2.8 lb/ton (1.4kg/MG). Since it is more difficult to control those emissions resulting from the pours, no control efficiency is applied to the emissions from that process. It is assumed that the complete processing of recycled ferrous metal requires two melts and two pours. The first set of melt and pour is assumed to create an ingot, roll of sheet output, convenient for storage and transport to a second processing site where some final use product is cast. The total emissions of particulate matter for the recycling operation is 8,362 metric tons or 178 metric tons per year. That total represents 8.8 percent of the total annual particulate matter emissions from secondary ferrous metal production in the 1999 NEI inventory.

The emissions of SO<sub>2</sub>, NO<sub>x</sub>, CO and VOC associated with ferrous metal furnaces is dependent on the fuels used, and other operating characteristics of the furnaces. The emissions of these other air pollutants are assumed to change by the same 8.8% factor that was calculated for particulate matter.

#### *Heavy Equipment Operation*

Heavy equipment powered with heavy duty diesel engines are used to collect the scrap ferrous metal at the demolition site, transfer the ferrous metal to trucks or rail cars, and to transfer the ferrous metal to the feed stock at the ferrous metal processing furnaces. Similar types of equipment as those described for the removal of concrete are used to remove the ferrous metal. The estimate for emissions from heavy equipment used to process ferrous metal assumes that a bull dozer rated at 100 horsepower can aggregate 2 short tons of scrap ferrous metal per hour, and that a front end loader can transfer 20 short tons of ferrous metal per hour into trucks or rail cars. The total emissions assume two cycles of the transfer process, one at the licensed facility and one at the processing facility.

Summary

Overall criteria pollutant emissions from processing and transportation of ferrous metal released from licensed facilities under the Unrestricted Release Alternative represents a small fraction of the total national emissions associated with processing and transportation of ferrous metal generated from all ferrous metal recycling operations nationwide. A comparison of total estimated criteria pollutant emissions associated with the Unrestricted Release Alternative and total national emissions is shown in Table I-8. The emissions resulting from the smelting operation may approach 8% of the emissions from a typical year of ferrous metal processing. Overall emissions from the transportation and recycling of ferrous metal released from licensed facilities are estimated to be <0.01 percent of the average annual emissions that result from the combined effect of heavy equipment, heavy-duty highway diesel engines and recycling.

**Table I-8 Unrestricted Release Alternative  
Air Emissions from Ferrous Metal Recycling  
(metric tons)**

	PM <sub>10</sub>	SO <sub>2</sub>	VOC	NO <sub>x</sub>
Smelting Furnace	8,325	2,905	4,554	7,022
Heavy Equipment Operation	36	-	60	772
Transportation	0.864	NA	NA	2,294
Total Emissions	8,362	2,905	4,614	7,248
Total Emissions (metric tons/year)	178	62	98	154
National Average Emissions (metric tons per year)	43,999	9,121	33,538 <sup>(1)</sup>	547,788
Percent of National Average	0.4	0.67	2.9	<0.01

(1) Secondary ferrous metal production only.

Trash

Under the No Action, Unrestricted Release, and Limited Dispositions Alternatives, trash would be disposed of in an EPA/State-regulated landfill. No recycling or reuse of trash is anticipated under any Alternative. Air emissions from trash landfill disposal and trash incineration are discussed under the EPA/State-Regulated Disposal Alternative in Section 3.3.

**3.3 EPA/State-Regulated Disposal Alternative**

The EPA/State-Regulated Disposal Alternative has similar emissions characteristics to the No Action, Unrestricted Release, and Limited Dispositions Alternatives with respect to handling and transportation of the materials released at licensed facilities. Under the No Action, Unrestricted Release, and Limited Dispositions Alternatives and the EPA/State-Regulated Disposal Alternative, materials released from licensed facilities would be processed to size and sorted at the licensed facility, and then transported from the licensed facility. These activities and their emissions characteristics would be identical for the EPA/State-Regulated Disposal Alternative.

1 However, under the EPA/State-Regulated Disposal Alternative, all of the materials would be  
2 disposed rather than recycled. Mobile source emissions and fugitive dust emissions would be  
3 associated with the placement of the materials in EPA/State-regulated disposal facilities.  
4

#### 5 Concrete and Ferrous Metal

6  
7 Under the EPA/State-Regulated Disposal Alternative solid materials would not be recycled but  
8 would be transported to an EPA/State-regulated landfill for disposal. For concrete, the same  
9 rubbilization, heavy equipment, and transportation activities would be conducted under the  
10 EPA/State-Regulated Disposal Alternative as under the No Action, Unrestricted Release, and  
11 Limited Dispositions Alternatives, and the air emissions per ton of concrete processed are  
12 assumed to be identical. Under the EPA/State-Regulated Disposal Alternative, the rubbilized  
13 concrete would be transported in trucks an average of 58 miles (93.3 kilometers) to an  
14 EPA/State-regulated disposal facility rather than transported an average of 198 miles (318.6  
15 kilometers) to a recycling location. Fugitive particulate emissions from disposal of concrete  
16 rubble in a EPA/State-regulated landfill would be negligible (see assumptions in Appendix K).  
17

18 For ferrous metal the overall emissions would be lower under the EPA/State-Regulated Disposal  
19 Alternative and the Limited Dispositions Alternative than under the No Action and Unrestricted  
20 Release Alternatives, as under the EPA/State-Regulated Disposal Alternative and Limited  
21 Dispositions Alternative there would be no process emissions from smelting of the ferrous metal.  
22 Air emissions from transportation of ferrous metal to the EPA/State-regulated disposal facility  
23 are assumed to be identical to those estimated for the No Action and Unrestricted Release  
24 Alternatives.  
25

#### 26 Trash

27  
28 Trash released by licensed facilities is assumed to be sent to either EPA/State-regulated landfills  
29 or to EPA/State-regulated solid waste incinerators. Trash will be collected and sorted if  
30 necessary to produce waste piles at the licensed facilities. Heavy equipment will be used to load  
31 that waste into trucks for transport to the landfill or incinerator location. The potential for  
32 fugitive dust emissions during these processes is minimal, since trash will contain a very small  
33 amount of particulate matter that can be dislodged to find its way into the air. The loaded trucks  
34 will generate air emissions during transport. Additional heavy equipment will be used to transfer  
35 the trash to feed stock at the incinerator, or to place the trash in the landfill. The assumptions  
36 used to estimate air emissions from the removal of trash and the resulting emissions estimates are  
37 described.  
38

#### 39 *Heavy Equipment Operation*

40  
41 It is assumed that a bull dozer rated at 100 horsepower can gather 0.5 short tons of released trash  
42 per hour, and that front loaders rated at 100 horsepower can load 0.5 short tons of trash into  
43 trucks per hour. The same assumption is used for unloading at the facility and moving the  
44 material into place as either a feed stock for an incinerator or into position in the landfill. The  
45 emissions estimates for the assumed 66,000 metric tons of trash from power generating reactor

1 units yields an estimate of 67 metric tons of PM<sub>10</sub>, 186 metric tons of NO<sub>x</sub>, and 94 metric tons of  
2 CO.

3  
4 *Transportation*

5  
6 Transportation air emissions for the EPA/State-Regulated Disposal Alternative for trash are the  
7 same as the estimates for the No Action, Limited Dispositions, and Unrestricted Release  
8 Alternatives for trash.

9  
10 *EPA/State-Regulated Landfill Disposal*

11  
12 Typically, operations at EPA/State-regulated landfills are controlled to keep the potential for  
13 fugitive emissions at a minimum. Currently, there are no recommended approaches to estimate  
14 these emissions and it is assumed that any fugitive dust emissions from the landfilling process  
15 are negligible.

16  
17 *EPA/State-Regulated Incineration*

18  
19 Under the EPA/State-Regulated Disposal Alternative, trash could be incinerated. EPA/State-  
20 regulated solid waste incinerators are designed to achieve near complete combustion of the  
21 organic material included in the trash stream. Therefore, a well designed and operated incinerator  
22 typically results in very low emissions of CO. As with all combustion sources some of the  
23 nitrogen in the air supplied to the unit would be oxidized to NO<sub>x</sub> during the combustion process.  
24 The emission rates of VOC and PM from the incinerator would depend on the specific combustor  
25 design and operation, the nature of the trash, and the characteristics of the incinerator air  
26 emission control system. Inorganic materials in the trash could be released as particulate matter  
27 in the incinerator flue gas stream to the incinerator stack, and these emissions would disperse into  
28 the atmosphere and be transported to off site receptors. Some organic materials in the trash may  
29 not achieve complete oxidation and result in formation of products of incomplete combustion,  
30 which would also be emitted in the stack gas. Depending upon the composition of the trash and  
31 the conditions of the incineration process and air emission control system, polycyclic organic  
32 matter and chlorinated dioxins and furans could be formed in the incinerator and emitted in the  
33 stack gas. Incinerators are subject to emissions limitation standards to control the amount of  
34 these hazardous air pollutants and the incremental contribution of the trash released from  
35 licensed facilities is negligible.

36  
37 There are three primary types of combustion technology used in solid waste incinerators: mass  
38 burn, refuse-derived fuel (RDF), and modular combustors. Mass burn units charge the  
39 combustion chamber with waste that has not been separated or processed prior to firing.  
40 Typically, these units operate by moving the waste material through the combustion zone on a  
41 grate and add both underfeed and overfeed air. The excess air facilitates near complete  
42 combustion but can also increase the particulate matter emissions, by causing some of the PM to  
43 entrain into the flue gas stream rather than being collected in the ash pit beneath the traveling  
44 grate.

In RDF combustors the fuel is processed by shredding or by finely dividing the fuel into a dust that is suitable for co-firing with pulverized coal. The waste is typically processed by sorting out all noncombustible materials and shredding the remaining fuel. The use of the shredded fuel increases the heat value of the fuel and facilitates near complete combustion.

Modular combustors also use unprocessed waste as the fuel but include two chambers. In one style of modular combustor the initial chamber is operated in a starved air mode to drive off volatile organic compounds (VOC) and CO. The exhaust is then subject to a second round of combustion with excess air to achieve the near complete combustion result. Another form uses excess air in the initial chamber and refires the exhaust in the second chamber again. The use of these designs is dependent on the nature of the waste stream.

The impacts of trash disposal from licensed facilities is estimated by applying the expected emissions from the use of heavy equipment to collect and transfer the material from the facilities to trucks and then from the trucks to the disposal site. Emissions from the highway transport of the trash are assumed to be negligible in comparison to the overall average annual heavy duty highway diesel vehicle emissions. Similarly, fugitive dust emissions during the process of landfill disposal are assumed to be negligible.

Overall criteria pollutant emissions from heavy equipment operation, transportation, and landfill disposal or incineration of trash released from licensed facilities under the EPA/State-Regulated Disposal Alternative represents a small fraction of the total national emissions associated with solid waste transportation, landfill disposal, and incineration. Emissions impacts from landfill disposal are estimated to be less than for the incineration option since landfill disposal does not include the combustion process. A comparison of total estimated criteria pollutant emissions associated with the EPA/State-Regulated Disposal Alternative and total national emissions is shown in Table I-9. Overall emissions are estimated to be 0.01 percent or less of the national emissions for solid waste disposal.

**Table I-9 EPA/State-Regulated Disposal Alternative – Trash Air Emissions from Trash Landfill Disposal/Incineration**

	PM <sub>10</sub>	NO <sub>x</sub>	CO
Heavy Equipment (metric tons)	67	186	94
Transportation (metric tons)	negligible	0.11	negligible
Landfill Disposal	negligible	negligible	negligible
Incineration (metric tons)	104	151	58
Total Emissions			
Landfill Disposal (metric tons)	67	186	94
Incineration (metric tons)	171	202	152
National Average Emissions (metric tons per year)			
Landfill Disposal	27,880	280,083	207,811
Incineration	29,810	307,415	216,109
Percent of National Average			
Landfill Disposal	<0.01	<0.01	<0.01

**Table I-9 EPA/State-Regulated Disposal Alternative – Trash Air Emissions from Trash Landfill Disposal/Incineration**

Incineration	0.01	<0.01	<0.01
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**3.4 Low-Level Waste Disposal Alternative**

Activities that would generate air emissions for the LLW Disposal Alternative would be similar to those for the EPA/State-Regulated Disposal Alternative, with the exception that trash would not be incinerated under the LLW Disposal Alternative and solid materials may be transported to the LLW disposal facility by railcar in addition to by truck.

For this Alternative all of the potentially clearable materials generated from licensed facilities would be transported to a LLW disposal facility. For the purposes of this analysis all materials are assumed to be taken to the Envirocare disposal facility in Utah. For the LLW Disposal Alternative, all of the processes associated with handling and loading the solid materials would be identical to those discussed above for the No Action, Unrestricted Release, Limited Dispositions, and EPA/State-Regulated Disposal Alternatives. The transportation emissions would be much higher for the LLW Disposal Alternative, however, because the average transportation distance from the licensed facilities to the LLW disposal facility is 1,544 miles (2,482 kilometers) rather than 58 miles (93.3 kilometers) for the EPA/State-Regulated Disposal Alternative. The transportation emissions calculated for the LLW Disposal Alternative are 7 metric tons or 0.15 metric tons per year for SO<sub>2</sub>, 703 metric tons or 15 metric tons per year for NO<sub>x</sub>, and 26 metric tons or 0.6 metric tons per year for PM<sub>10</sub>. These emission totals are insignificant relative to the total annual emissions for heavy duty diesel trucks based on national emissions trends.

**3.5 Limited Dispositions Alternative**

For the Limited Dispositions Alternative, it is assumed that air emissions from reuse of tools and equipment are negligible. Air emissions from recycling of concrete into road bed material under the Limited Dispositions Alternative would be similar to the air emissions for concrete under the No Action and Unrestricted Release Alternatives as discussed in section 3.2. Air emissions from EPA/State-regulated landfill disposal of ferrous metal and trash would be similar to the air emissions for ferrous metal and trash landfill disposal under the EPA/State-Regulated Disposal Alternative as discussed in Section 3.3. Thus, as discussed in Sections 3.2 and 3.3, the impacts to air quality for the Limited Dispositions Alternative would be small.

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**APPENDIX J**  
**COMPARISON OF TYPES OF DISPOSAL FACILITIES**

**1.0 INTRODUCTION**

The Alternatives consider several disposal options for solid materials cleared from Licensed Facilities, including disposal in an EPA/State-regulated Subtitle D Landfill and disposal in an Low Level Waste Disposal Facility. This appendix provides a more detailed comparison of four disposal facility types to the landfill (hereafter referred to as the "SC&A Reference Landfill") used for both the Scenario C and Scenario D analyses in SC&A 2003.

The four disposal facility types analyzed include:

- a) Subtitle D Municipal Solid Waste Landfills,
- b) Subtitle D Industrial Landfills,
- c) Subtitle D Construction and Demolition Landfills, and
- d) Low Level Waste Disposal Facilities

The comparative analysis presented herein identifies specific disposal facility parameters that contribute to the analytical results reported in SC&A 2003, Section 9.2 Exposures Due to Disposal of Cleared Material in a Landfill. The analysis tabulates the parameters for each of the four disposal facility types of interest, as well as for the SC&A Reference Landfill. The SC&A Reference Landfill used in both Scenario C and Scenario D has some characteristics of Subtitle D Municipal Solid Waste Landfills and some characteristics of Subtitle D Industrial Landfills. A sensitivity analysis evaluates the effect of varying the individual parameters.

The Resource Conservation and Recovery Act (RCRA) of 1976 (42 USC 82, Subchapter IV) is a federal statute which deals with the disposal of hazardous and solid wastes. RCRA Subtitle C governs the hazardous waste program. Hazardous waste is defined as a listed waste or a characteristic waste (*40 CFR Part 261*). A listed hazardous waste is waste that is found on specific EPA lists of hazardous wastes. A characteristic hazardous waste is a waste that exhibits any one of four characteristics (i.e. ignitability, reactivity, corrosivity, or toxicity). Hazardous waste excludes household hazardous wastes. RCRA Subtitle D provides the regulation of non-hazardous waste, as well as hazardous waste specifically excluded from RCRA Subtitle C. Subtitle D of RCRA also authorized regulation of State or regional solid waste plans. The promulgated solid waste regulations appear in *40 CFR Part 239 to 282*, with Part 257 Criteria For Classification Of Solid Waste Disposal Facilities And Practices and Part 258 Criteria For Municipal Solid Waste Landfills specifying the siting, design, operational, monitoring, and closure requirements.

This appendix includes three attachments. Attachment 1 provides spreadsheets containing input and output data which support the graphs appearing within this appendix. Attachment 2 provides an analysis of the availability of existing capacity for the various disposal facility types. Attachment 3 provides a detailed regulatory comparison of Subtitle C and Subtitle D landfills.

## 2.0 ANALYTICAL APPROACH

The comparative analysis looks at radionuclide migration from the waste materials to the leachate generated within the disposal facilities and its subsequent release to the environment. We define release as a point of potential leachate contact with a human or ecological receptor. Leachate may be extracted with a leachate collection system, may escape a bottom liner if present, or may pass directly into underlying soils in the absence of a bottom liner. The operation of a leachate collection system is assumed to have no effect on the leaching of activity from the waste. Collected leachate is assumed to be discharged to surface water. No credit for reduction in radioactivity is taken for treatment of the leachate prior to surface water discharge. Leachate which is not collected by a leachate collection system is assumed to eventually enter groundwater. The points of release are the discharge of leachate, the extraction of groundwater from a well, or the discharge of groundwater into a surface water body.

The analytical procedure used in SC&A 2003 is repeated for each of the four disposal facility types to determine the ratio of radionuclide releases from each of the disposal facility types to the radionuclide releases from the SC&A Reference Landfill. The SC&A 2003 analysis used a combination of deterministic and probabilistic input parameters for the SC&A Reference Landfill. In the comparative analysis, mean values reported in SC&A 2003 are substituted for probabilistic input parameters for the SC&A Reference Landfill.

The SC&A 2003 analysis methodology is summarized below. For each equation, we identify parameters which are held constant in the comparative analysis because they are independent of disposal facility type and parameters which may differ because they are dependent on disposal facility type. The SC&A 2003 equations referenced are identified by the equation numbers used in SC&A 2003.

### *SC&A 2003 Equation 9.3*

The release in any subsequent year  $k$  of the  $n^{\text{th}}$  radionuclide due to the disposal of activity  $\alpha_i$  in year  $j$  is calculated by:

$$R_n(j+k) = f_d \alpha_1(j) \beta_n L_n (1 - L_n)^k e^{-\lambda_n k} \quad 0 \leq k \leq 1000 - j \quad (\text{J.1})$$

where landfill independent variables include:

- $f_d$  = fraction of activity disposed of in the landfill (dimensionless), user specified
- $\alpha_i(j)$  = total activity released from the licensee  $i$  during year  $j$  (Ci), calculated by the material pulse model

1            $\beta_n$  = radionuclide n fraction of total activity, user specified

2  
3            $\lambda_n$  = n<sup>th</sup> radionuclide decay constant (yr<sup>-1</sup>)

4  
5 and landfill dependent variables include only:

6  
7            $L_n$  = first-order leach rate constant for the nth radionuclide (yr<sup>-1</sup>)

8  
9 To compare different disposal facility types, Equation J.1 reduces to:

$$R_n(j+k) = [f_d \alpha_1(j) \beta_n] L_n (1-L_n)^k e^{-\lambda_n k} \quad (J.2)$$

$$R_n(j+k) = [C_1] L_n (1-L_n)^k e^{-\lambda_n k} \quad (J.3)$$

11  
12 The sum of all annual releases of radionuclide n equals:

$$\sum_{i=0}^k R_n(j+i) = CL_n \left[ 1 + (1-L_n)^1 e^{-\lambda_n 1} + \dots + (1-L_n)^{(k-1)} e^{-\lambda_n (k-1)} + (1-L_n)^k e^{-\lambda_n k} \right] \quad (J.4)$$

13  
14 Multiplying both sides of Equation J.4 by the annual release decay factor yields:

$$(1-L_n) e^{-\lambda_n} \sum_{i=0}^k R_n(j+i) = CL_n \left[ (1-L_n)^1 e^{-\lambda_n 1} + (1-L_n)^2 e^{-\lambda_n 2} + \dots + (1-L_n)^k e^{-\lambda_n k} + (1-L_n)^{(k+1)} e^{-\lambda_n (k+1)} \right] \quad (J.5)$$

15  
16 Subtracting Equation J.5 from Equation J.4 yields:

$$\left[ 1 - (1-L_n) e^{-\lambda_n} \right] \sum_{i=0}^k R_n(j+i) = CL_n \left[ 1 - (1-L_n)^{(k+1)} e^{-\lambda_n (k+1)} \right] \quad (J.6)$$

$$\sum_{i=0}^k R_n(j+i) = CL_n \frac{1 - (1-L_n)^{(k+1)} e^{-\lambda_n (k+1)}}{1 - (1-L_n) e^{-\lambda_n}} = CL_n \frac{1 - [(1-L_n) e^{-\lambda_n}]^{(k+1)}}{1 - (1-L_n) e^{-\lambda_n}} = Cf(L_n) \quad (J.7)$$

1 Therefore when comparing two disposal facilities with the same inventory, disposal timing, and  
 2 activity levels of disposed radionuclides, the only characteristic which affects the total  
 3 radionuclide activity released is the leach rate constant. The ratio of the total activity released  
 4 from each disposal facility type compared to the total activity released from the SC&A Reference  
 5 Landfill equals:  
 6

$$\sum_{i=0}^k R_n(j+i) = \frac{f(L_n)}{f(L_n)_{REF}} \left[ \sum_{i=0}^k R_n(j+i) \right]_{REF} \quad (J.8)$$

7  
 8 *SC&A 2003 Equation 9.4*  
 9

10 The first-order leach rate constant is defined by RESRAD Equation E.3 (ANL 2001) as the  
 11 following:

$$L_n = \frac{I}{\theta^{cz} T_0 R_{dn}^{cz}} \quad (J.9)$$

12 where each of the following variables are landfill dependent:  
 13

- 14 I = infiltration rate (m/yr)
- 15
- 16  $\theta^{(cz)}$  = volumetric water content<sup>1</sup> of the contaminated zone (dimensionless)
- 17
- 18  $T_0$  = initial thickness of the contaminated zone (m)
- 19
- 20
- 21  $R_{dn}^{(cz)}$  = retardation factor in the contaminated zone for radionuclide n (dimensionless)
- 22

23 *SC&A 2003 Equation 9.5*  
 24

25 In Equation J.9, the retardation factor for radionuclide n,  $R_{dn}$ , is the ratio of the average pore  
 26 water velocity to the radionuclide transport velocity. On the basis of the assumption that the  
 27 adsorption-desorption process can be represented with a linear isotherm (ANL 2001), the  
 28 retardation factor can be calculated with RESRAD, Equation E.8:  
 29

$$R_{dn} = 1 + \frac{\rho_b K_{dn}}{p_t R_s} \quad (J.10)$$

---

<sup>1</sup> Volumetric water content equals the volume of water per unit volume of waste (all phases).

1 where landfill dependent variables include:

- 2
- 3  $\rho_b$  = bulk waste density (g/cm<sup>3</sup>)
- 4
- 5  $K_d$  = distribution coefficient (cm<sup>3</sup>/g)
- 6
- 7  $p_t$  = total porosity (dimensionless)
- 8
- 9  $R_s$  = saturation ratio (dimensionless)
- 10

11 Since the volumetric water content in Equation J.9 is defined as the product of the total porosity  
 12 and the saturation ratio, Equation J.10 can be rewritten as follows:

$$R_{dn} = 1 + \frac{\rho_b K_{dn}}{p_t R_s} = 1 + \frac{\rho_b K_{dn}}{\theta^{cz}} \quad (\text{J.11})$$

13

14 For each disposal facility type, the release of radionuclides is a function of the 5 parameters  
 15 which define the leach rate constants. These 5 parameters are listed below.

- 16
- 17  $I$  = infiltration rate (m/yr)
- 18
- 19  $\theta^{(cz)}$  = volumetric water content of the contaminated zone (dimensionless)
- 20
- 21  $T_0$  = initial thickness of the contaminated zone (m)
- 22
- 23  $\rho_b$  = bulk waste density (g/cm<sup>3</sup>)
- 24
- 25  $K_d$  = distribution coefficient (cm<sup>3</sup>/g)
- 26
- 27

1 **3.0 DESCRIPTION OF LANDFILL TYPES**  
2

3 This section describes the 5 disposal facility types (including the SC&A Reference Landfill) and  
4 determines the value of each of the 5 parameters required to calculate the leach rate constants.  
5 No attempt has been made in this analysis to examine the effect of disposal facility location,  
6 distance from the Licensed Facility generating the material for disposal, area of the disposal  
7 facility, or distance to potential downgradient receptors. The SC&A 2003 analysis used as its  
8 primary source for landfill-specific parameters the Nationwide Database of Landfill Sites  
9 information published in Appendix D of EPA 2003 (EPA 2003i). The EPA database contains  
10 landfill specific data on 790 Subtitle D industrial landfills from a nationwide 1985 survey.  
11

12 Given the broad geographic distribution of the EPA data for Subtitle D Industrial Landfills and  
13 the broad distribution of Subtitle D Municipal Solid Waste Landfills and Subtitle D Construction  
14 and Demolition Landfills throughout the nation, this analysis assumes that any regional  
15 weightings applied in the SC&A 2003 analysis would also apply reasonably well to the other  
16 two landfill types. This leads to the proposition that a comparative analysis of the ratio of total  
17 radionuclide activity released from each landfill type based on nationwide mean landfill  
18 parameters would be equally valid as an analysis based on regionally weighted parameters since  
19 any adjustment for regional weighting would apply equally to all Subtitle D landfill types, within  
20 the limits of the precision of the overall analysis. Since any solid materials within the scope of  
21 the Proposed Action destined for disposal at a LLW disposal facility are assumed to be sent to  
22 the Clive, Utah disposal facility run by Envirocare, the comparative analysis uses site specific  
23 parameters to calculate the LLW disposal facility leach rate constant.  
24

25 **3.1 SC&A Reference Landfill**  
26

27 **3.1.1 Landfill Description**  
28

29 The SC&A Reference Landfill used in SC&A's Scenario C and Scenario D combines  
30 characteristics of both Subtitle D Municipal Solid Waste Landfills and Subtitle D Industrial  
31 Landfills. The SC&A Reference Landfill has a clay cap and a leachate collection system, both of  
32 which are assumed to function for 50 years after emplacement of the waste<sup>2</sup>. After the end of the  
33 50 year period leachate is assumed to enter groundwater. The SC&A Reference Landfill does  
34 not have a bottom liner.  
35

36 Several of the input parameters used in the SC&A 2003 analysis are subject to alternative  
37 interpretation. For the purposes of this comparative analysis, the accuracy of the SC&A 2003  
38 input parameters is in itself not important to the relative ranking of landfill types, but does affect  
39 the accuracy of the results for the SC&A Reference Landfill itself. In the comparative analysis,  
40 the objective is to replicate the SC&A Reference Landfill input parameters to establish a  
41 benchmark value for released activity, albeit with the substitution of deterministic values for  
42 probabilistic distributions. The discussion of each input parameter allows the reader to judge

---

<sup>2</sup> The 50 year time frame is base on the midpoint of the assumed 40 year operating life of the SC&A Reference Landfill (i.e. 20 years) plus a 30 year post-closure period during which the clay cap and leachate collection system would continue to be maintained.

1 each parameter's validity, and the transparency of the analytical method allows the reader to  
2 evaluate the effect of selecting different input parameters.  
3

### 4 **3.1.2 Infiltration**

5  
6 Infiltration in SC&A Equation 9.4 pertains to the rate at which water/leachate percolates into and  
7 through the contaminated zone. SC&A 2003 used landfill leakage values from Table 4.3 in EPA  
8 2003, but these exfiltration values represent the rate at which leachate emanates from the base of  
9 the landfill into the underlying soils, not the rate of infiltration.  
10

11 For the first 50 years following waste emplacement, the SC&A analysis used the reported  
12 exfiltration values for the EPA 2003 Clay Liner case as infiltration values. The EPA 2003 Clay  
13 Liner case modeled flow from a landfill with no leachate collection system and with the  
14 following profile<sup>3,4</sup>, from top to bottom:  
15

- 16 • a 1-ft. (0.30m) layer of loam to support vegetation and drainage
- 17
- 18 • a 1-ft. (0.30m) percolation layer
- 19
- 20 • a 3 ft. (0.91m) clay cover with a hydraulic conductivity of 1.0E-07 cm/sec
- 21
- 22 • a 10-ft. (3.0m) waste layer
- 23
- 24 • a 3-ft. (0.91m) clay liner with a hydraulic conductivity of 1.0E-07 cm/sec
- 25

26 After 50 years, the SC&A 2003 analysis assumes that the clay cap fails, and that the infiltration  
27 rate will be similar to the exfiltration rates reported for the No Liner case in EPA 2003. The  
28 landfill profile in the EPA 2003 No Liner case consists only of a 2 ft. thick final cover of either  
29 a sandy loam, silty loam, or silty clay loam soil randomly selected according to a nationwide  
30 frequency distribution. The thickness of the EPA 2003 No Liner case waste layer is not  
31 indicated. The final cover soils in the EPA 2003 No Liner case have the following properties  
32 shown in Table J-1.  
33  
34

---

<sup>3</sup> EPA 2003 contains discrepancies in the modeled landfill profile. The text in EPA 2003 Section 4.3.1 indicates the presence of a 1 ft. percolation layer above the bottom liner, but the more detailed description in EPA 2003 Appendix A, Section A.1.3 omits this layer and specifically refers to a four layer model. Table A.1 in Appendix A places the 1 ft. percolation layer between the vegetation support layer and the clay cover.

<sup>4</sup> Differences between the EPA 2003 landfill profile and the SC&A Reference Landfill profile do not affect the relative ranking of the disposal facility types, but do affect the accuracy of the results for the SC&A Reference Landfill.

1

**Table J-1 Properties of Final Cover Soil Types**

2	Soil Type	Total Porosity (vol/vol)	Saturated Hydraulic Conductivity (cm/sec)
3	Sandy loam	0.453	0.000720
4	Silt loam	0.501	0.000190
5	Silty clay loam	0.471	0.000042
6	Source: EPA 2003, Table A.6		

7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17

Table J-2 indicates the cumulative frequency distribution of landfill exfiltration for the No Liner and Clay Liner cases from EPA 2003. The data apply to flow through closed landfills. EPA 2003 does not specify the number of annual cycles analyzed for each alternative, nor whether the flow conditions reached steady state. In the absence of a leachate collection system, the steady-state infiltration rate will eventually match the steady-state exfiltration rate, but the time required to reach steady state could be a significant fraction of or could exceed the initial 50 year operating and post-closure period analyzed in SC&A 2003. The length of time required to reach steady-state flow conditions increases with landfill thickness due to internal leachate storage, and increases in more arid climates due to low infiltration rates.

18

**Table J-2 Cumulative Frequency  
Distribution of Landfill Exfiltration Rates**

19

20

21

22

23

24

25

26

27

28

29

30

31

32

33

34

35

per cent	No Liner Exfiltration Rate (m/yr)	Clay Liner Exfiltration Rate (m/yr)
0	0.000010	0.000010
10	0.013500	0.009440
25	0.065800	0.025300
50	0.109000	0.043200
75	0.274000	0.044500
80	0.312000	0.047700
85	0.353000	0.047700
90	0.411000	0.048600
95	0.456000	0.048600
100	1.080000	0.052600

Source: EPA 2003 Table 4.3 (see also SC&A 2003 Table 9.29)

36  
37

1 For the SC&A Reference Landfill, the comparative analysis uses the 50<sup>th</sup> percentile EPA 2003  
 2 Clay Liner exfiltration rate (4.32E-02 m/yr) for the first 50 years and the 50<sup>th</sup> percentile EPA  
 3 2003 No Liner exfiltration rate (1.09E-01 m/yr) for times beyond 50 years.

4  
 5 **3.1.3 Volumetric Water Content**

6  
 7 Volumetric water content equals the product of total porosity times the saturation ratio. To  
 8 calculate the volumetric water content of the contaminated zone, both the total porosity and the  
 9 saturation ratio should correspond to waste material. The SC&A 2003 analysis used total  
 10 porosity data for soil from *Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0*  
 11 *Computer Codes*, NUREG/CR-6697 (ANL 2000) based on a correlation for soil between total  
 12 porosity and soil particle diameter. The mean value of the total porosity distribution for a generic  
 13 soil type in NUREG/CR-6697 equals 0.425.

14  
 15 The SC&A 2003 analysis calculates the probability distribution of saturation ratio as a function  
 16 of the infiltration rate, saturated hydraulic conductivity, and a soil specific exponential parameter,  
 17 as defined by Equation J.12.

$$R_s = \left( \frac{I}{K_s} \right)^{\frac{1}{2b+3}} \quad (\text{J.12})$$

18  
 19 where

- 20  
 21 I = infiltration rate (m/yr)  
 22  $K_s$  = saturated hydraulic conductivity (m/yr)  
 23 b = a soil specific exponential parameter  
 24

25 Although the SC&A 2003 analysis does not explicitly state whether different infiltration rates  
 26 were used to calculate the saturation ratio<sup>5</sup> for the initial 50 year period and later periods, the  
 27 comparative analysis assumes that SC&A 2003 uses probability distributions for the EPA 2003  
 28 Clay Liner exfiltration rate for the initial 50 years after waste placement and for the EPA 2003  
 29 No Liner exfiltration rate thereafter. To compute the saturation ratio for the SC&A Reference  
 30 Landfill, the comparative analysis uses the 50<sup>th</sup> percentile values of these distributions for the  
 31 corresponding time periods.  
 32  
 33

---

<sup>5</sup> SC&A 2003 explicitly indicates the use of different infiltration rates to calculate the leach rate constant, but not to calculate the saturation ratio. The saturation ratio of the waste would not respond instantaneously to changes in infiltration rates. Consistency in infiltration rates in the two calculations may not be necessary or desirable.

1 SC&A 2003 uses the cumulative frequency distribution of saturated hydraulic conductivity  
 2 values reported in EPA 2003, Table 5.21 (SC&A 2003, Table 9.34). The 50<sup>th</sup> percentile value,  
 3 1.89E+03 m/yr will be used in the comparative analysis.

4  
 5 The soil-specific exponential parameter b is lognormally distributed. ANL 2000 reports that the  
 6 mean of the lognormal distribution for a generic soil type is 1.06, so the median of b equals  $e^{1.06}$ ,  
 7 or 2.89.

8  
 9 Table J-3 summarizes the parameters for calculating the volumetric water content for the SC&A  
 10 Reference Landfill in the comparative analysis.

11  
 12 **Table J-3 Parameters for Volumetric Water Content**

13	Parameter	Years ≤ 50	Years > 50
14	Infiltration, m/yr	0.0432	0.109
15	Saturated hydraulic conductivity, m/yr	1890	1890
16	Soil specific exponential parameter b	2.89	2.89
17	Saturation ratio	0.3	0.33
18	Total porosity	0.425	0.425
19	Volumetric water content	0.13	0.14

20  
 21 **3.1.4 Thickness**

22  
 23 The SC&A 2003 analysis used landfill depth data from Table 2.3 in EPA 2003 (SC&A 2003,  
 24 Table 9.31), which is based on the database of 790 industrial landfills. The EPA depth data  
 25 include all landfill layers, not just the waste, so the values reported exceed the actual waste  
 26 thickness.

27  
 28 The comparative analysis uses the 50<sup>th</sup> percentile value of landfill thickness equal to 2.57 meters  
 29 for the SC&A Reference Landfill.

30  
 31 **3.1.5 Bulk waste density**

32  
 33 The SC&A 2003 analysis used bulk density data from EPA 2003 which was derived from an  
 34 analysis of the wet bulk densities of 4 major categories of hazardous waste (solvents, paints,  
 35 petroleum products, and pesticides).

36  
 37 The comparative analysis uses the value 0.89 g/cm<sup>3</sup>, which approximates the 50<sup>th</sup> percentile  
 38 value based on a linear interpolation between the values for the 0<sup>th</sup> and the 53<sup>rd</sup> percentile values.

1 **Table J-4 Industrial Landfill Depth**

2	Probability	Depth (m)
3	0%	0.51
4	10%	0.88
5	25%	1.32
6	50%	2.57
7	75%	4.09
8	80%	4.53
9	85%	5.20
10	90%	6.13
11	95%	7.12
12	100%	10.10

13 Source: EPA 2003, Table 2.3

14  
15 **Table J-5 Waste Bulk Density**

16	Cumulative	Waste Density
17	Probability	(g/cm <sup>3</sup> )
18	0.000	0.7
19	0.530	0.9
20	0.550	1.12
21	0.551	1.13
22	0.553	1.28
23	0.640	1.30
24	0.728	1.33
25	0.815	1.34
26	0.826	1.36
27	0.904	1.46
28	0.905	1.50
29	0.906	1.62
30	0.994	1.63
31	0.995	1.64
32	0.996	1.65
33	0.998	2.1

34  
35

**3.1.6 Distribution Coefficients,  $K_d$**

Table 9.33 in SC&A 2003 presents radionuclide specific distribution coefficients  $K_d$  in two ways. The table presents values of the mean and standard deviation of the natural logarithm of each  $K_d$  probability distribution, providing usable information for a Monte Carlo analysis. The table also presents mean  $K_d$  values for each radionuclide for three specific soil types. Although the explanatory text is not explicit in SC&A 2003, Section 9.2.5.3 implies that the  $K_d$  probability distribution data were used in the SC&A 2003 analysis. Table J-6 lists the radionuclide-specific median values<sup>6</sup> of  $K_d$  from SC&A 2003 Table 9.33.

In a personal communication with SC&A, SC&A said “Equation 9.26 was used to calculate the contaminated zone  $K_d$  values, even in the non-regional data case... Therefore, the only difference between the unsaturated zone  $K_d$ 's and the contaminated zone  $K_d$ 's is the use of Equation 9.26.” The SC&A response to comments further stated “It was always the intent to include a ‘Regional Data’ analysis as part of the analysis. In a regional analysis, landfill parameters would be selected based on the location of the source of the cleared material. Unfortunately, this portion of the analysis was never implemented, and the landfill parameters were selected based on national distributions. Therefore, Section 9.5 (sic)<sup>7</sup> (except for the  $K_d$  adjustment, Section 9.2.5.3) should have been deleted from the report.”

SC&A 2003 adjusted the  $K_d$  values for total organic carbon (TOC) in accordance with Equation J-13 (SC&A 2003, Equation 9.26). Since the SC&A leaching analysis does not rely on site-specific soil type parameters, it appears that the unadjusted  $K_d$  values in the equation correspond to the  $K_d$  probability distribution data in SC&A 2003 Table 9.33.

$$\log K_{dcz} = \log K_d - m \log(TOC(1 - fnc)) \tag{J.13}$$

where

- $K_{dcz}$  = effective distribution coefficient corrected for the organic carbon concentration
- $K_d$  = distribution coefficient for conditions without the presence of organic carbon
- $m$  = slope factor
  - = 0.74 for  $K_d \geq 100$  L/kg
  - = 0.40 for  $K_d < 100$  L/kg

---

<sup>6</sup> The value of  $K_d$  listed equals  $\exp(\mu)$ , where  $\mu$  equals the mean of the lognormal distribution  $Y=\log(K_d)$ . The value  $\exp(\mu)$  equals the median value of  $K_d$ .

<sup>7</sup> Section 9.2.5 (not 9.5) of SC&A 2003 discusses regional data.

1 TOC = total organic carbon (TOC) concentration given in parts per million (ppm),  
 2 which includes all dissolved, suspended, and colloidal organic material

3  
 4  $f_{nc}$  = fraction on non-complexing organic material

5  
 6 Since the  $K_d$  distribution data in SC&A 2003 Table 9.33 define a range of values, it is unclear  
 7 what value of  $K_d$  the SC&A 2003 analysis used to select the slope factor  $m$ . In the comparative  
 8 analysis, we have selected the slope factor  $m$  based on the median value of  $K_d$ . SC&A 2003  
 9 reports a median TOC value of 441 ppm derived from leachate in 8 hazardous waste landfills  
 10 and a median TOC value of 377 ppm derived from leachate in 22 municipal landfills, but does  
 11 not clearly state which value was used in the analysis. Since the values are so close, and since  
 12 the ranges of the underlying data are similar (0 to 3,800 ppm for hazardous landfills and 9.4 to  
 13 3,400 ppm for municipal landfills), the selection of one value over the other has little effect on  
 14 the overall analysis. The comparative analysis uses the municipal landfill value of 377 ppm. The  
 15 fraction of non-complexing material is explicitly set to zero in both the SC&A 2003 analysis and  
 16 in the comparative analysis of the SC&A Reference Landfill.

17  
 18 **Table J-6 Radionuclide-specific Distribution Coefficients for**  
 19 **the SC&A Reference Landfill**

20	Radionuclide	$K_d$ (cm <sup>3</sup> /g)	Slope factor $m$	$K_{dec}$ (cm <sup>3</sup> /g)
21	C-14	11	0.4	1
22	Fe-55	209	0.74	2.6
23	Mn-54	158	0.74	2
24	Co-58	235	0.74	2.9
25	Co-60	235	0.74	2.9
26	Ni-63	424	0.74	5.3
27	Sr-90	32	0.4	3
28	Nb-95	380	0.74	4.7
29	Zr-95	1,380	0.74	17.1
30	Ru-106	1,588	0.74	19.7
31	Ag-110m	217	0.74	2.7
32	Sb-125	380	0.74	4.7
33	I-129	4.6	0.4	0.43
34	Cs-134	446	0.74	5.5
35	Cs-137	446	0.74	5.5
36	Pu-238	953	0.74	11.8
37	Pu-239	953	0.74	11.82
38	Pu-240	953	0.74	11.82

39 Source: SC&A 2003 Table 9.33 ( $K_d$  values only)

1     **3.2     Subtitle D Municipal Solid Waste Landfills**

2  
3     **3.2.1   Landfill Description**

4  
5     The comparative analysis defines a Subtitle D Municipal Solid Waste Landfill consistent with  
6     the requirements of *40 CFR Part 258*, referenced hereinafter as the MSW Reference Landfill.  
7     The MSW Reference Landfill has a leachate collection system, a compacted clay bottom liner,  
8     and a final compacted clay cover to minimize infiltration. It also requires the use of daily cover.  
9     We assume that the landfill is filled in cells during a 40 year operating life, and that the solid  
10    materials from Licensed Facilities are placed, on average, at the midpoint of this operating life.  
11    We further assume that each cell has only daily cover soils for 10 years, an interim cover for the  
12    next 10 years, and a final cover thereafter. The leachate collection system is assumed to function  
13    for 30 years after landfill closure.

14  
15    **3.2.2   Infiltration**

16  
17    The rate of infiltration will vary with the type of cover existing in each phase of the landfill's  
18    operating life. The three phases can be briefly described as daily cover for years 0 to 10 after  
19    waste placement, interim cover for years 10 to 20, intact final cover for years 20 to 50, and failed  
20    final cover for more than 50 years after waste placement.

21  
22    *Daily Cover Phase*

23  
24    For the first 10 years following waste placement, the MSW Reference Landfill has the following  
25    profile, from top to bottom:

- 26  
27    • alternating layers of daily cover and waste consisting of
- 28       - 6-in. (0.15 m.) layers of daily cover material
  - 29       - 5-ft. (1.52 m) waste layers
- 30  
31    • a 1-ft. (0.30 m) leachate collection layer
- 32  
33    • a 2-ft. (0.61 m) clay liner with a hydraulic conductivity of  $1 \times 10^{-7}$  cm/sec
- 34  
35  
36

37    For the first 10 years after waste placement, the surface of the MSW Reference Landfill consists  
38    of alternating sequences of exposed waste and daily cover. The conditions for surface runoff and  
39    evapotranspiration of an operating landfill are closer to those of an uncovered waste pile than to  
40    those of a closed landfill, although the daily cover may provide some reduction in infiltration.  
41    EPA 2003 reports a probability distribution for exfiltration rate from uncovered, unlined waste  
42    piles (see Table J-7). The steady-state exfiltration rate from a waste pile approximates the  
43    infiltration rate into the waste pile. We verified that the reported exfiltration values were valid  
44    for MSW by confirming that the permeability of the waste in the modeled waste pile was similar  
45    to the permeability of MSW. This waste pile exfiltration rate resulted from a HELP model  
46    (Schroeder 1994) analysis with waste consisting of coal bottom ash having a permeability of

1 **Table J-7 Cumulative Frequency**  
 2 **Distribution of Waste Pile Exfiltration**

3	percent	No Liner Exfiltration Rate (m/yr)
4	0	0.0003
5	10	0.0602
6	25	0.1280
7	50	0.2550
8	75	0.3910
9	80	0.4490
10	85	0.4760
11	90	0.5380
12	95	0.6140
13	100	1.82

14 Source: EPA 2003, Table 4.4

15  
 16 4.1E-03 cm/sec<sup>8</sup>. This agrees well with Oweis & Khera 1998 reported values of hydraulic  
 17 conductivity between 3.5E-03 cm/sec and 5.0E-03 cm/sec for municipal solid waste of  
 18 intermediate density (Oweis & Khera 1998). For the comparative analysis, we use the 50<sup>th</sup>  
 19 percentile exfiltration rate for uncovered, unlined waste piles equal to 2.55E-01 m/yr as the  
 20 infiltration rate for the daily cover phase of the MSW Reference Landfill.

21  
 22 *Interim Cover Phase*

23  
 24 When the top of the landfill cell reaches its design elevation, the operator typically places an  
 25 interim cover over the cell. For the period from 10 to 20 years after waste placement, the  
 26 comparative analysis assumes that the landfill has the vertical profile shown below:

- 27
- 28 • a 2-ft. (0.61m) interim cover
- 29
- 30 • alternating layers of daily cover and waste consisting of
- 31
- 32 - 6-in. (0.15 m.) layers of daily cover material
- 33
- 34 - 5-ft. (1.52 m) waste layers
- 35
- 36

---

<sup>8</sup> There is a discrepancy in the reported permeability of coal bottom ash in EPA 2003. Section 4.3.2 refers to coal bottom ash with a moderate permeability of 4.1E-04 cm/sec, but Appendix A says the moderate permeability waste, coal bottom ash, has a permeability of 4.1E-03 cm/sec. Oweis & Khera 1998 reports a hydraulic conductivity range for coal bottom ash between 5.0E-03 cm/sec and 1.0E-01 cm/sec. The 4.1E-03 cm/sec value in EPA 2003 is presumed to be correct.

- 1 • a 1-ft. (0.30 m) leachate collection layer
- 2
- 3 • a 2-ft. (0.61 m) clay liner with a hydraulic conductivity of  $1 \times 10^{-7}$  cm/sec
- 4

5 The interim cover is typically about 2 ft (0.61 m) thick, and is graded to promote runoff from the  
6 landfill. The frequency distribution of interim cover soils types is assumed to be the same as the  
7 distribution for cover soils in the EPA 2003 No Liner case. We assume that the steady-state  
8 exfiltration rates in the EPA 2003 No Liner case approximate the steady-state infiltration rates  
9 into the landfill.

10  
11 For the comparative analysis, we use the 50<sup>th</sup> percentile exfiltration rate for the EPA 2003 No  
12 Liner closed landfill exfiltration rate, 1.09E-01 m/yr (see Table J-2), as the infiltration rate for the  
13 interim cover phase of the MSW Reference Landfill.

#### 14 *Intact Final Cover Phase*

15  
16  
17 For the period from 20 to 50 years after waste placement, the comparative analysis assumes that  
18 the landfill has a final cover, and that the landfill has the vertical profile shown below:

- 19
- 20 • a 6-in. (0.15 m) vegetative support layer
- 21 • an 18-in. (0.46 m) infiltration barrier layer with a hydraulic conductivity of  $1 \times 10^{-7}$  cm/sec
- 22 • alternating layers of daily cover and waste consisting of
- 23 - 6-in. (0.15 m.) layers of daily cover material
- 24 - 5-ft. (1.52 m) waste layers
- 25 • a 1-ft. (0.30 m) leachate collection layer
- 26 • a 2-ft. (0.61 m) clay liner with a hydraulic conductivity of  $1 \times 10^{-7}$  cm/sec
- 27

28 The final cover is assumed to remain intact for the period from 20 to 50 years following waste  
29 placement. Since the EPA 2003 Clay Liner landfill case has no leachate collection system, we  
30 assume that the steady-state exfiltration rates approximate the steady-state infiltration rates into  
31 the landfill. The 18 inch low permeability infiltration barrier layer in the MSW Reference  
32 Landfill is only half as thick as the clay cover in the EPA 2003 Clay Liner case. To account for  
33 the thinner barrier layer, the comparative analysis uses the 75<sup>th</sup> percentile EPA 2003 Clay Liner  
34 closed landfill exfiltration rate, 4.45E-02 m/yr (see Table J-2), as the infiltration rate for the  
35 MSW Reference Landfill with the intact final cover.

#### 36 *Failed Final Cover Phase*

37  
38  
39 After 50 years following waste placement, the final cover is assumed to degrade<sup>9</sup> to the level of  
40 an interim cover and leachate collection system operation is discontinued. The comparative  
41 analysis uses the 50<sup>th</sup> percentile EPA 2003 No Liner closed landfill exfiltration rate, 1.09E-01

---

<sup>9</sup> Degradation of the final cover infiltration barrier is modeled as an instantaneous change at 50 years, but would actually occur gradually, primarily due to settlement. The degradation process could begin before and continue after the 50 year milestone.

1 m/yr (see Table J-2), as the infiltration rate for the MSW Reference Landfill for times beyond 50  
2 years following waste placement.

### 3.2.3 Volumetric Water Content

3  
4  
5  
6 Typical ranges for volumetric water content (Reinhart 2004) values for MSW are 0.036 to 0.205  
7 as placed, 0.3 to 0.4 under free drainage conditions, and 0.5 to 0.6 when saturated (Reinhart  
8 2004). These data imply that the MSW will retain infiltrated water until the water content  
9 approaches the free drainage values.

10  
11 Oweis & Khera 1998 report a range of moisture content for municipal waste between 15 percent  
12 and 40 percent of dry weight, i.e. weight of water divided by weight of dry solids. For well-  
13 compacted refuse with a total unit weight of 40 lb/ft<sup>3</sup> (0.64 t/m<sup>3</sup>), the preceding water contents  
14 yield volumetric water contents between 0.08 and 0.18. Saturated unit weights of MSW may  
15 reach 1.28 t/m<sup>3</sup>, with volumetric water contents up to 75 percent.

16  
17 The volumetric water content can vary during the life of the MSW in the landfill from less than  
18 0.20 when placed to up to 0.75 when saturated. Since the operating leachate collection system  
19 will prevent the development of a leachate mound and therefore prevent saturation of the waste,  
20 in the comparative analysis we use a volumetric water content equal to 0.35, the midpoint of the  
21 range for free drainage values, for all phases of the MSW Reference Landfill. This value may  
22 overstate the volumetric water content in the early life of the landfill, and may understate it after  
23 the leachate collection system is shut down.

### 3.2.4 Thickness

24  
25  
26  
27 The average thickness of municipal solid waste landfills greatly exceeds the 2.57 meter thickness  
28 used in the SC&A Reference Landfill. An analysis of the State of California Solid Waste  
29 Information System database (CA IWMB 2004) yielded the following distribution of municipal  
30 landfill waste thickness (Table J-8). The 176 sites selected for the analysis included all solid  
31 waste landfills or solid waste disposal facilities in the database which accepted municipal waste,  
32 and for which the database has total volume capacity and disposal acreage information.

33  
34 The comparative analysis uses the 50<sup>th</sup> percentile value of landfill thickness equal to 13.4 meters  
35 for the MSW Reference Landfill.

### 3.2.5 Bulk waste density

36  
37  
38  
39 For the MSW Reference Landfill, we use a typical bulk waste density for municipal solid waste,  
40 making the explicit assumptions that the solid materials from Licensed Facilities constitute a  
41 small percentage of the overall volume of materials in the MSW landfill and are widely  
42 distributed throughout the landfill. Oweis & Khera 1998 report total unit weights for MSW  
43 ranging from 18 lb/ft<sup>3</sup> to 89 lb/ft<sup>3</sup> depending primarily on degree of compaction and moisture  
44 content. Measured in situ total unit weights of MSW range from 35 lb/ft<sup>3</sup> to 44 lb/ft<sup>3</sup>, which  
45 agrees well with the range for moderately to well compacted waste, 30 lb/ft<sup>3</sup> to 45 lb/ft<sup>3</sup>. Large  
46 scale field tests conducted by measuring the amount of compacted MSW to fill a known or

1 **Table J-8 Municipal Landfill**  
 2 **Thickness**

3	percent	Thickness in m
4	0	0.0
5	10	2.2
6	20	4.6
7	30	8.1
8	40	11.2
9	50	13.4
10	60	17.7
11	70	21.7
12	80	29.8
13	90	41.5
14	100	80

15 measurable volume also produce typical total unit weights between 35 lb/ft<sup>3</sup> and 45 lb/ft<sup>3</sup>. If the  
 16 range of total unit weights is driven largely by differences in water content, waste with densities  
 17 ranging from 35 lb/ft<sup>3</sup> and 45 lb/ft<sup>3</sup> due to water content changes from 15 percent to 40 percent of  
 18 dry weight would have a dry unit weight of approximately 31 lb/ft<sup>3</sup>.  
 19

20  
 21 For waste compacted to a given volume, there is a relationship between bulk density and  
 22 volumetric water content:

$$\rho_b = \theta\rho_w + \rho_d \tag{J.14}$$

23  
 24 where landfill dependent variables include:

- 25  $\rho_b$  = bulk waste density
- 26  $\theta$  = volumetric water content
- 27  $\rho_w$  = density of water
- 28  $\rho_d$  = dry density

29  
 30  
 31 Using the free drainage volumetric water content value of 0.35 and a dry unit weight of 31 lb/ft<sup>3</sup>,  
 32 the bulk waste density for the MSW Reference Landfill becomes 53 lb/ft<sup>3</sup> (0.85 t/m<sup>3</sup>).  
 33

### 34 3.2.6 Distribution Coefficients, $K_d$

35  
 36 Selection of appropriate  $K_d$  values for waste is supported by few studies and is complicated by  
 37 the number and range of parameters which influence the chemistry of the waste environment.  
 38 ANL 2001a provides a very thorough discussion of the complexities. As the soil-specific data in  
 39 SC&A 2003 Table 9.33 show, mean  $K_d$  values can vary by about 1 order of magnitude depending  
 40 on soil type. Within each soil type,  $K_d$  values can vary by more than 6 orders of magnitude, with  
 41 a 4 order of magnitude range being common (ANL 2001a, Table 4).  
 42

In the comparative analysis, we have selected the median values of  $K_d$  reported in SC&A 2003 Table 9.33, and adjusted<sup>10</sup> them in accordance with Equation J.13. We used the median TOC value of 377 ppm derived from municipal landfill leachate, and explicitly set the fraction of non-complexing material to zero. The radionuclide specific mean values of the distribution coefficients used in the comparative analysis for the MSW Reference Landfill appear in Table J-9 below.

EPA 1999 discusses alternate approaches to estimating  $K_d$  values in waste from soil  $K_d$  data, but none of the approaches are clearly superior to the methodology suggested in SC&A. Values calculated from a regression analysis suggested in EPA 1999 are presented in Table J-10, but are not used in the comparative analysis for the MSW Reference Landfill. Each of these values fall between the raw soil  $K_d$  values and the adjusted  $K_d$  values presented in Table J-9.

**Table J-9 Radionuclide-Specific Distribution Coefficients for the MSW Reference Landfill**

Radionuclide	$K_d$ (cm <sup>3</sup> /g)	Slope factor m	$K_{dcz}$ (cm <sup>3</sup> /g)
C-14	11	0.4	1
Fe-55	209	0.74	2.6
Mn-54	158	0.74	2
Co-58	235	0.74	2.9
Co-60	235	0.74	2.9
Ni-63	424	0.74	5.3
Sr-90	32	0.4	3
Nb-95	380	0.74	4.7
Zr-95	1380	0.74	17.1
Ru-106	1,588	0.74	19.7
Ag-110m	217	0.74	2.7
Sb-125	380	0.74	4.7
I-129	4.6	0.4	0.43
Cs-134	446	0.74	5.5
Cs-137	446	0.74	5.5
Pu-238	953	0.74	11.8
Pu-239	953	0.74	11.82
Pu-240	953	0.74	11.82

Source: SC&A 2003 Table 9.33 ( $K_d$  values only)

<sup>10</sup> The  $K_d$  values in SC&A 2003 Table 9.33 come from ANL 2000, Table 3.9-1, which compiled  $K_d$  values for soil (not MSW) from five separate sources.

**Table J-10 Alternate Estimates of Radionuclide-Specific Distribution Coefficients  $K_d$  for MSW Landfills, ( $\text{cm}^3/\text{g}$ )**

Radionuclide	$K_{d(\text{cz})}$ , Table J-9	EPA 1999 $K_d(\text{waste})$	Serkiz 2001, Table 13				
			DOC = 1 mg C/L pH =5.5	DOC = 10 mg C/L pH =5.25	DOC = 30 mg C/L pH =5.00	DOC = 100 mg C/L pH =4.75	DOC = 1000 mg C/L pH =4.50
C-14	1	7.2	2	2	2	2	2
Fe-55	2.6	56.8					
Mn-54	2	46.7					
Co-58	2.9	61.7					
Co-60	2.9	61.7					
Ni-63	5.3	93.2	400	163	8	3.8	2.2
Sr-90	3	15.3	10	4	0.2	0.1	0.1
Nb-95	4.7	86.3	160	160	160	160	160
Zr-95	17.1	212.9	600	107	17	6	3
Ru-106	19.7	234.9					
Ag-110m	2.7	58.3					
Sb-125	4.7	86.3					
I-129	0.43	3.9	0.6	0.6	0.6	0.6	0.6
Cs-134	5.5	96.6	18	12	5	5	5
Cs-137	5.5	96.6	18	12	5	5	5
Pu-238	11.8	164.3	100	18	3	1	1
Pu-239	11.8	164.3	100	18	3	1	1
Pu-240	11.8	164.3	100	18	3	1	1

Notes:

EPA 1999 values:  $K_d(\text{waste}) = 0.7 \log(K_d(\text{soil})) + 0.3$ ,  $K_d(\text{soil})$  from SC&A 2003 Table 9.33

Since about one third of MSW consists of paper, we also investigated  $K_d$  values in a cellulose-rich environment. Serkiz 2001 investigated the effects of cellulose degradation and recommended  $K_d$  values for 12 of the 18 radionuclides of interest for 5 different values of pH and dissolved organic content (DOC). In Table J-10 we present the  $K_d$  values from Serkiz 2001 for informational purposes, but have not used them in the comparative analysis for the MSW Reference Landfill. The adjusted  $K_d$  values presented in Table J-9 generally agree with the Serkiz 2001 values for DOC levels between 10 and 100 mg C/L.

### 3.3 Subtitle D Industrial Landfills

#### 3.3.1 Landfill Description

The comparative analysis defines a Subtitle D Industrial Waste Landfill consistent with the requirements of *40 CFR Part 257*, referenced hereinafter as the Industrial Reference Landfill. We define the Industrial Reference Landfill as having an equal probability of being unlined or having a compacted clay bottom liner. If it has a clay liner, it also has a compacted clay cover

after closure. If it does not have a clay liner, the landfill has a compacted soil cover after closure. The Industrial Reference Landfill does not have a leachate collection system. These two landfill designs correspond to the EPA 2003 No Liner and Clay Liner cases. We assume that the landfill is filled during a 40 year operating life, and that the solid materials from Licensed Facilities are placed, on average, at the midpoint of this operating life. We further assume that the landfill has no cover for 20 years after waste placement and a final cover thereafter.

### 3.3.2 Infiltration

The rate of infiltration will vary with the surface conditions in each phase of the landfill's operating life. The three phases can be briefly described as no cover for years 0 to 20 after waste placement, intact final cover for years 20 to 50, and failed final cover for more than 50 years after waste placement.

#### *No Cover Phase*

For the first 10 years following waste placement, the Industrial Reference Landfill has the following profile, from top to bottom:

- waste material
- either a 2-ft. (0.61 m) clay liner with a hydraulic conductivity of  $1 \times 10^{-7}$  cm/sec or no bottom liner

For the first 20 years after waste placement, the surface of the Industrial Reference Landfill consists of exposed waste. The conditions for surface runoff and evapotranspiration are similar to those of an uncovered waste pile. HELP modeling reported in Appendix A of EPA 2003 indicated that the permeability of the waste material itself influenced the predicted exfiltration rates. EPA 2003 input values for modeling the low permeability, moderate permeability, and high permeability industrial waste appear in Table J-11.

**Table J-11 Moisture Retention Properties for Waste Pile Materials**

Waste Type	Total Porosity (vol/vol)	Field Capacity (vol/vol)	Saturated Hydraulic Conductivity (cm/sec)
Low Permeability (electric plant fly ash)	0.5410	0.1870	0.0001
Moderate Permeability (electric plant bottom ash)	0.5780	0.0760	0.0041
High Permeability (fine copper slag)	0.3750	0.0550	0.0410

Source: EPA 2003, Table A.7 and Oweis & Khera 1998

Oweis & Khera 1998 report the annual generated quantities of industrial nonhazardous waste shown in Table J-12. The American Coal Ash Association (ACAA 2003) reports that fly ash contributes approximately 80 percent to the total, and bottom ash 20 percent. Low permeability materials including fly ash, cement and lime kiln dust, and probably silica fume make up approximately 55 percent of the total and have a permeability close to the low permeability waste modeled in EPA 2003. The remainder of the materials more closely approximate the modeled high permeability material, and include bottom ash, slags, probably roofing shingles, and probably foundry wastes for a total of 45 percent of the industrial waste. The comparative analysis considers one Industrial Reference Landfill with low permeability waste, and one Industrial Reference Landfill with high permeability waste.

**Table J-12 Quantities and Hydraulic Properties of Industrial Waste**

Waste Type	Land Disposal	Quantity, in million tons/yr	Percentage of Land Disposed Industrial Waste	Permeability, in cm/sec
Coal ash	Yes	72	48%	
- fly ash			38%	.000012 (1)
- bottom ash			10%	.022 (1)
Ferrous and nonferrous slags	Yes	34	23%	> 0.5 (2) .045 (3)
Reclaimed paving materials	No	103	N/A	N/A
Construction and demolition	Yes	31.5	Excluded	N/A
Cement and lime kiln dusts	Yes	24	16%	.000021 (4)
Sulfate	No	18	N/A	N/A
Lime	No	2	N/A	N/A
Roofing shingle	Yes	8	5%	Unknown
Foundry	Yes	10	7%	Unknown
Ceramic	No	3	N/A	N/A
Silica fume	Yes	1	1%	Unknown
Small quantity generator hazardous (<1000 kg/month)	No	0.66	N/A	N/A

Sources: (1) Oweis & Khera 1998, (2) USACE 1984, (3) Ziemkiewicz 1998, (4) EPA 1998

Notes:

Construction and demolition waste has been excluded from consideration in industrial landfills, and will be considered in construction and demolition landfills.

If a source document reported a range of permeability values, the geometric mean is listed in the table.

Under steady-state flow conditions, the exfiltration rate from a waste pile approximates the infiltration rate into the waste pile. EPA 2003 reports exfiltration rates from uncovered, unlined waste piles containing low, moderate, and high permeability waste. We calculated the cumulative frequency distribution of the reported waste pile exfiltration data, and present the results in Table J-13. For a difference in waste permeabilities of nearly 3 orders of magnitude between the low and high permeability waste, the 50<sup>th</sup> percentile exfiltration values differ by only a factor of 3. For the comparative analysis, we use the 50<sup>th</sup> percentile exfiltration rate for uncovered, unlined waste piles with low permeability waste materials equal to 1.13E-01 m/yr as

1 **Table J-13 Cumulative Frequency Distribution of**  
 2 **Waste Pile No Liner Exfiltration Rates (m/yr)**

3	Permeability of Waste Material (cm/sec)			
	4 percent	Low 5.-E-05	Med 4.1E-03	High 4.1E-02
5	0	0.0053	0.0003	0.0097
6	10	0.0056	0.0004	0.0375
7	20	0.0177	0.0374	0.0959
8	30	0.0501	0.1340	0.2010
9	40	0.0845	0.1840	0.2740
10	50	0.1130	0.2480	0.3420
11	60	0.1530	0.2840	0.3890
12	70	0.1800	0.3380	0.4560
13	80	0.2540	0.4510	0.5360
14	90	0.3300	0.5330	0.6380
15	100	1.5400	1.8100	1.8800

16 Source: EPA 2003, Table A.11

17  
 18 the infiltration rate for the no cover phase of the Industrial Reference Landfill with low  
 19 permeability waste. We use the 50<sup>th</sup> percentile exfiltration rate for uncovered, unlined waste  
 20 piles with high permeability waste materials equal to 3.42E-01 m/yr as the infiltration rate for the  
 21 no cover phase of the Industrial Reference Landfill with high permeability waste.

22  
 23 *Intact Final Cover Phase*

24  
 25 For the period from 20 to 50 years after waste placement, the Industrial Reference Landfill has a  
 26 final cover. We assume that it has an equal probability of having either a compacted clay cover  
 27 or a compacted soil cover, and that the landfill has the vertical profile shown below:

- 28
- 29 • a 6-in. (0.15 m) vegetative support layer
- 30
- 31 • an 18-in. (0.46 m) infiltration barrier layer, either compacted clay with a hydraulic  
 32 conductivity of  $1 \times 10^{-7}$  cm/sec or compacted soil
- 33
- 34 • waste material
- 35
- 36 • either a 2-ft. (0.61 m) clay liner with a hydraulic conductivity of  $1 \times 10^{-7}$  cm/sec or no bottom  
 37 liner
- 38

39 The final cover is assumed to remain intact for the period from 20 to 50 years following waste  
 40 placement. Since the EPA 2003 Clay Liner landfill case has no leachate collection system, we  
 41 assume that the steady-state exfiltration rates approximate the steady-state infiltration rates into  
 42 the landfill. The 18 inch low permeability infiltration barrier layer in the Industrial Reference

1 Landfill is only half as thick as the clay cover in the EPA 2003 Clay Liner case. To calculate an  
2 infiltration rate, we used the combined EPA 2003 No Liner and EPA 2003 Clay Liner closed  
3 landfill datasets, which yielded a 50th percentile exfiltration rate equal to 7.61E-02 m/yr (see  
4 Table J-2), for input as the infiltration rate for the Industrial Reference Landfill. For the  
5 Industrial Reference Landfill, we did not make any specific allowance to account for the thinner  
6 barrier layer, relative to the clay cover in the EPA 2003 Clay Liner analysis.

#### 7 8 *Failed Final Cover Phase*

9  
10 After 50 years following waste placement, the final compacted clay cover is assumed to degrade  
11 to the level of the compacted soil cover. The comparative analysis uses the 50<sup>th</sup> percentile EPA  
12 2003 No Liner closed landfill exfiltration rate, 1.09E-01 m/yr (see Table J-2), as the infiltration  
13 rate for the Industrial Reference Landfill for times beyond 50 years following waste placement.

### 14 15 **3.3.3 Volumetric Water Content**

16  
17 Table J-11 lists the moisture retention properties for low, medium, and high permeability  
18 industrial wastes, consisting of electric plant fly ash, electric plant bottom ash, and fine copper  
19 slag, respectively. The table lists the field capacity and the total porosity of each material. The  
20 field capacity is the maximum amount of water the material can hold in a gravitational field and  
21 corresponds to the volumetric water content under free drainage conditions. The total porosity  
22 equals the volumetric water content when the material is fully saturated.

23  
24 We assume that the industrial waste materials are initially placed at a water content near their  
25 field capacity. Over time, infiltration raises the water content to the field capacity and  
26 gravitational leachate flow can develop. Without a leachate collection system, the saturation  
27 ratio of the waste can increase. After placement of the final cover, the volumetric water content  
28 can decrease by drainage (e.g. compacted soil cover and no bottom liner), remain the same (e.g.  
29 equal infiltration and exfiltration rates), or increase (e.g. degraded clay cover over an intact  
30 bottom clay liner).

31  
32 For the comparative analysis for the Industrial Reference Landfill with low permeability waste,  
33 principally fly ash, we use a volumetric water content equal to its field capacity of 0.187 for all  
34 time periods. For the Industrial Reference Landfill with high permeability waste, principally  
35 slag, we use a volumetric water content equal to its field capacity under moderate compaction of  
36 0.055 for years 0 to 10, and equal to 0.125 for all later time periods to account for particle  
37 crushing and consolidation under increased loading.

### 38 39 **3.3.4 Thickness**

40  
41 The comparative analysis uses the 50<sup>th</sup> percentile value of landfill thickness equal to 2.57 meters  
42 derived from the database of 790 industrial landfills and reported in EPA 2003 for the thickness  
43 of the Industrial Reference Landfill.

**3.3.5 Bulk waste density**

For the Industrial Reference Landfill, we use typical bulk waste densities for fly ash and slag for the low permeability and high permeability wastes, respectively, making the explicit assumptions that the solid materials from Licensed Facilities constitute a small percentage of the overall volume of materials in the industrial landfill and are widely distributed throughout the landfill.

Compacted fly ash for embankment fills placed at optimum water content has a typical dry unit weight of 85 lb/ft<sup>3</sup> (1.36 g/cm<sup>3</sup>). With a volumetric water content of 0.187, the bulk density equals 92 lb/ft<sup>3</sup> (1.47 g/cm<sup>3</sup>). This value is used in the comparative analysis for the Industrial Reference Landfill with low permeability waste.

Slag densities vary greatly depending on the production method. Table J-14 lists typical densities for ferrous slag materials. Slag destined for disposal would not be subjected to additional processing such as crushing, so the range of applicable dry densities is 0.56 to 1.36 t/m<sup>3</sup>. For the comparative analysis for the Industrial Reference Landfill with high permeability waste, we selected a dry density of 1.12 t/m<sup>3</sup> which lies at the low end of the air cooled blast furnace slag density range and at the upper end of the expanded blast furnace slag density range. For the comparative analysis, we used a volumetric water content of 0.09 to calculate a bulk density equal to 1.21 t/m<sup>3</sup>.

**Table J-14 Typical Slag Dry Densities**

Type of Slag	Typical Density (t/m <sup>3</sup> )
Air cooled blast furnace slag	1.12 to 1.36
Expanded blast furnace slag, coarse aggregate	0.56 to 0.88
Expanded blast furnace slag, fine aggregate	0.80 to 1.12
Crushed blast furnace slag	2
Crushed steel furnace slag	2.6

Source: Jones 2004

**3.3.6 Distribution Coefficients, K<sub>d</sub>**

An EPA technical document reports that coal fly ash, coal bottom ash, and cement kiln dust have very low concentrations of organic compounds (EPA 1997). Slags contain little to no organic matter. In the comparative analysis, we have selected the median values of K<sub>d</sub> reported in SC&A 2003 Table 9.33, and made no reduction for TOC concentration (see Table J-9).

1     **3.4     Subtitle D Construction and Demolition Landfills**

2  
3     **3.4.1    Landfill Description**

4  
5     The comparative analysis defines a Subtitle D Construction and Demolition (C&D) Landfill  
6     consistent with the definitions and requirements of *40 CFR Part 257*, referenced hereinafter as  
7     the C&D Reference Landfill. A C&D landfill typically receives one or more of the following  
8     types of solid wastes: roadwork material, excavated material, demolition waste, construction/  
9     renovation waste, and site clearance waste. We define the C&D Reference Landfill as having no  
10    bottom liner and no leachate collection system, although in some States these are generally  
11    required. This landfill design corresponds to the EPA 2003 No Liner case. We assume that an  
12    active landfill cell is filled during a 10 year<sup>11</sup> operating life, and that the solid materials from  
13    Licensed Facilities are placed, on average, at the midpoint of this operating life (GA 2003). We  
14    further assume that the landfill has a final compacted soil cover thereafter.

15  
16    **3.4.2    Infiltration**

17  
18    The rate of infiltration will vary with the surface conditions in each phase of the landfill's  
19    operating life. The two phases can be briefly described as no cover for years 0 to 5 after waste  
20    placement, and final cover for all later times.

21  
22    *No Cover Phase*

23  
24    For the first 5 years following waste placement, the C&D Reference Landfill has the following  
25    profile, from top to bottom:

- 26  
27    • waste material  
28    • no bottom liner

29  
30    For the first 5 years after waste placement, the surface of the Industrial Reference Landfill  
31    consists of exposed waste. The conditions for surface runoff and evapotranspiration are similar  
32    to those of an uncovered waste pile. Under steady-state flow conditions, the exfiltration rate  
33    from a waste pile approximates the infiltration rate into the waste pile. HELP modeling reported  
34    in Appendix A of EPA 2003 indicated that the permeability of the waste material itself  
35    influenced the predicted exfiltration rates. The highest permeability value modeled in EPA 2003  
36    equals 4.1E-02 cm/sec (see Table J-11). Construction debris characteristically has large voids,  
37    and will have a permeability comparable to a poorly graded clean gravel which can exceed 10<sup>1</sup>  
38    cm/sec.

39    To account for this higher permeability, for the comparative analysis we use the 80<sup>th</sup> percentile  
40    exfiltration rate for uncovered, unlined waste piles with high permeability waste materials equal  
41    to 5.36E-01 m/yr (see Table J-13) as the infiltration rate for the no cover phase of the C&D  
42    Reference Landfill.

---

<sup>11</sup> The average remaining life of 44 C&D landfills was 13.6 years (GA 2003). Although the average remaining life may be half of the average total life of the landfills, individual landfill cells are typically closed when full to minimize infiltration.

1 *Final Cover Phase*

2  
3 After 50 years following waste placement, the C&D Reference Landfill has a final cover of  
4 compacted soil, giving the landfill the profile shown below:

- 5  
6 • a 6-in. (0.15 m) vegetative support layer  
7 • an 18-in. (0.46 m) infiltration barrier layer of compacted soil  
8 • waste material  
9 • no bottom liner

10  
11 The cover is typically about 2 ft (0.61 m) thick, and is graded to promote runoff from the landfill.  
12 The frequency distribution of cover soils types is assumed to be the same as the distribution for  
13 cover soils in the EPA 2003 No Liner case. We assume that the steady-state exfiltration rates in  
14 the EPA 2003 No Liner case approximate the steady-state infiltration rates into the landfill. For  
15 the comparative analysis, we use the 50<sup>th</sup> percentile exfiltration rate for the EPA 2003 No Liner  
16 closed landfill exfiltration rate, 1.09E-01 m/yr (see Table J-2), as the infiltration rate for the  
17 interim cover phase of the C&D Reference Landfill for all times greater than 5 years after waste  
18 placement.

19  
20 **3.4.3 Volumetric Water Content**

21  
22 For the C&D Reference Landfill, we make the explicit assumptions that the solid materials from  
23 Licensed Facilities constitute the majority of materials in the C&D landfill, at least in the  
24 sections of the landfill receiving them. We assume that the materials are initially placed at a  
25 water content near their field capacity. Concrete rubble is expected to have an effective field  
26 capacity of about 0.03, similar to that of coarse, clean gravel. The effective field capacity  
27 neglects any water absorbed into the concrete particles, as this water would remain relatively  
28 immobile. This absorbed water content can reach about 10 percent by weight. Steel would also  
29 have a similar, low field capacity due to the smooth surfaces and large dimensions of individual  
30 pieces.

31  
32 Without a leachate collection system, the saturation ratio of the waste can increase. After  
33 placement of the final cover, the volumetric water content can decrease by drainage (e.g.  
34 compacted soil cover and no bottom liner), remain the same (e.g. equal infiltration and  
35 exfiltration rates), or increase (e.g. final cover more permeable than underlying soils). For the  
36 comparative analysis for the C&D Reference Landfill, we use a volumetric water content equal  
37 to the field capacity of 0.03 for all time periods.

38  
39 **3.4.4 Thickness**

40  
41 Many C&D landfills are used for a single demolition project and are located onsite. These tend  
42 to be small and have a short operating life. Commercial and public C&D landfills tend to be  
43 larger in area, have a greater waste thickness, and have a longer operating life. An analysis of the  
44 State of California Solid Waste Information System database (CA IWMB 2004) yielded the  
45 following distribution of C&D landfill waste thickness (Table J-15). The 11 sites selected for the  
46 analysis included all disposal facilities in the database which accepted primarily construction and

demolition waste, which did not accept municipal waste, and for which the database has total volume capacity and disposal acreage information. The data set is small and the extreme values are suspect, possibly due to inconsistent interpretation of reporting requirements.

The comparative analysis uses the 50<sup>th</sup> percentile value of landfill thickness equal to 5.3 meters for the MSW Reference Landfill.

**Table J-15 C&D Landfill Thickness**

percent	Thickness in m
0	0.0
10	0.5
20	3.6
30	4.3
40	4.7
50	5.3
60	14.5
70	26.8
80	54.4
90	75.6
100	132.2

**3.4.5 Bulk waste density**

The bulk density of the solid materials in the C&D Reference Landfill will be dominated by the concrete rubble. The comparative analysis uses 2.10 g/cm<sup>3</sup> as the bulk density for the C&D Reference Landfill.

**3.4.6 Distribution Coefficients, K<sub>d</sub>**

Melendez 1996 reports a mean TOC concentration of 307 ppm based on leachate samples from 7 C&D landfills. However, a substantial percentage of the waste in most C&D landfills consists of wood which would probably not be the case for an industrial landfill receiving large quantities of solid materials from Licensed Facilities. Concrete and steel contain no organic matter. In the comparative analysis, we have selected the median values of K<sub>d</sub> reported in SC&A 2003 Table 9.33, and made no reduction for TOC concentration (see Table J-9).

**3.5 Low Level Waste Disposal Facilities**

**3.5.1 Landfill Description**

For the purposes of this comparative analysis, all solid materials generated by licensed facilities within the scope of the Proposed Action that are sent to Low Level Waste Disposal Facilities are

1 assumed to be sent to the disposal facility in Clive, Utah. The Clive, Utah disposal facility run  
2 by Envirocare incorporates waste cells constructed over naturally clayey soils. The Envirocare  
3 facility is located in a remote desert location with an arid to semi-arid climate. The site is over  
4 20 miles from the nearest permanent human habitation.

5  
6 The Envirocare disposal facility has several distinct operable units licensed for the disposal of  
7 different types of waste. Solid materials relevant to the Proposed Action and destined for the  
8 Envirocare facility would most likely be classified as Low Activity Radioactive Waste (LARW)  
9 or as Class A waste. Envirocare does not have current licenses to dispose of Class B or Class C  
10 wastes.

11  
12 The LARW and Class A operable units have similar engineered barriers. Each has a compacted  
13 clay bottom liner, and each cell receives a final cover incorporating a compacted clay layer to  
14 minimize infiltration of precipitation and the release of radon. Neither has a leachate collection  
15 system beneath the waste, but license restrictions require the removal of accumulated stormwater  
16 in the LARW and Class A cells within 24 hours. Stormwater removed is pumped to dedicated  
17 holding ponds and evaporated.

18  
19 Since the engineered components of the LARW and Class A cells are similar, we define a single  
20 LLW Reference Disposal Facility for purposes of the comparative analysis. The Envirocare  
21 LARW and Class A operable units have license restrictions that limit the duration of an open cell  
22 to 6 years. We assume that the solid materials from Licensed Facilities are placed, on average, at  
23 the midpoint of this open cell period. Each cell is required to receive a radon barrier before the  
24 open cell limitation expires. We assume that the cell receives a final cover 2 years after  
25 placement of the radon barrier, i.e. 5 years after waste placement.

### 26 27 **3.5.2 Infiltration**

28  
29 The rate of infiltration will vary with the surface conditions in each phase of the disposal  
30 facility's operating life. The two phases can be briefly described as no cover for years 0 to 3 after  
31 waste placement, radon barrier from 3 to 5 years after waste placement, and final cover for all  
32 later times.

#### 33 34 *No Cover Phase*

35  
36 For the first 3 years following waste placement, the LLW Reference Disposal Facility has the  
37 following profile, from top to bottom:

- 38 • waste material up to 43 ft. (13.1 m)<sup>12</sup>
- 39 • a 2-ft. (0.61 m) clay liner with a hydraulic conductivity of  $1 \times 10^{-6}$  cm/sec

40  
41  
42 For the first 3 years after waste placement, the surface of the Industrial Reference Landfill  
43 consists of exposed waste. Envirocare places waste in 12-inch compacted lifts. Soil is

---

<sup>12</sup> The licenses limit waste thickness to 43 ft. in an LARW cell, and to 54 ft. in a Class A cell. For the analysis, we chose the thinner cell because it produces a higher leach rate constant.

1 compacted around oversize debris to eliminate voids, or else the oversize debris is surrounded  
2 with flowable fill. Because of the compacted surface and attention to void avoidance, the  
3 conditions for surface runoff and evapotranspiration are more similar to those of a landfill cover  
4 than to an uncovered waste pile.

5  
6 For the comparative analysis we used the location specific exfiltration rate for Cedar City<sup>13</sup>, Utah,  
7 for the No Liner closed landfill case as the infiltration rate for the no cover phase of the LLW  
8 Disposal Facility. EPA 2003 Appendix A presents exfiltration rates for 3 different cover soils.  
9 We chose the highest rate equal to 8.0E-04 m/yr, which corresponds to a sandy loam cover soil.

#### 10 *Radon Barrier Phase*

11  
12 After construction of the radon barrier, the LLW Reference Disposal Facility has the following  
13 profile, from top to bottom:

- 14 • a 1-ft. (0.30 m) clay radon barrier with a hydraulic conductivity of  $1 \times 10^{-6}$  cm/sec
- 15 • waste material up to 43 ft. (13.1 m)
- 16 • a 2-ft. (0.61 m) clay liner with a hydraulic conductivity of  $1 \times 10^{-6}$  cm/sec

17  
18 The infiltration rate for the radon barrier phase should be less than the no cover phase. For the  
19 comparative analysis, we used half the EPA 2003 location specific exfiltration rate for Cedar  
20 City, Utah, for the No Liner closed landfill case as the infiltration rate for the radon barrier phase  
21 of the LLW Disposal Facility. The infiltration rate used equals 4.0E-04 m/yr.

#### 22 *Final Cover Phase*

23  
24 Upon cell closure, the LLW Reference Disposal Facility has the following profile, from top to  
25 bottom:

- 26 • a 1.5-ft. (0.46 m) erosion barrier of gravel and rock
- 27 • a 0.5-ft. (0.15 m) sandy gravel layer
- 28 • a 1-ft. (0.30 m) layer of sacrificial soil
- 29 • a 0.5-ft. (0.15 m) sandy gravel layer
- 30 • a 1-ft. (0.30 m) clay infiltration barrier with a hydraulic conductivity of  $1 \times 10^{-8}$  cm/sec
- 31 • a 1-ft. (0.30 m) clay radon barrier with a hydraulic conductivity of  $1 \times 10^{-6}$  cm/sec
- 32 • waste material up to 43 ft. (13.1 m)

---

<sup>13</sup> Even though HELP model results are available for Salt Lake City which is closer to Clive, we used Cedar City because its annual precipitation of 10.6 inches is approximately equal to Clive's.

1 • a 2-ft. (0.61 m) clay liner with a hydraulic conductivity of  $1 \times 10^{-6}$  cm/sec  
2 For the comparative analysis, we used the EPA 2003 location specific exfiltration rate for Cedar  
3 City, Utah, for the Clay Liner closed landfill case as the infiltration rate for the final cover phase  
4 of the LLW Disposal Facility. The infiltration rate used equals  $1.0E-04$  m/yr.  
5

6 The post-closure plan requires maintenance for a minimum of 30 years after cell closure.  
7 Because of the low potential for settlement and the protection against erosion and desiccation, we  
8 assume that the clay infiltration barrier remains intact for 50 years after waste placement. For  
9 the comparative analysis, we used an infiltration rate equal to  $4.0E-04$  m/yr, which corresponds  
10 to the radon barrier phase rate, for all time periods exceeding 50 years after waste placement.  
11

### 12 **3.5.3 Volumetric Water Content**

13 Waste material compacted in 12-inch lifts, or soil surrounding oversized debris, is compacted to  
14 90 percent of its maximum density. To achieve this density, the water content would need to be  
15 within several percent of the material's optimum moisture content. For a sandy soil with some  
16 silt content, typical values of optimum moisture content range from 11 to 16 percent (weight of  
17 water to weight of solids). Given the arid nature of the climate, the facility operator is most  
18 likely to need to raise the water content to facilitate compaction, and would use the least amount  
19 of water necessary. We have assumed a compaction moisture content of 11 percent by weight, a  
20 maximum dry density of  $1.87 \text{ g/cm}^3$ , a compacted dry density of  $1.75 \text{ g/cm}^3$ , and a solid specific  
21 gravity of 2.0. This yields a volumetric water content equal to 0.19, which the comparative  
22 analysis uses for the LLW Reference Disposal Facility for all phases.  
23  
24

### 25 **3.5.4 Thickness**

26  
27 The comparative analysis uses the licensed waste depth of 13.1 meters as the thickness of the  
28 LLW Reference Disposal Facility.  
29

### 30 **3.5.5 Bulk waste density**

31  
32 The bulk density of the solid materials in the LLW Reference Disposal Facility will be a function  
33 of the mix of concrete, steel, and trash (or Dry Active Waste) disposed in the cell. Trash will  
34 undergo better compaction than in a typical MSW landfill, and will therefore have a higher bulk  
35 density than the  $0.85 \text{ g/cm}^3$  used for the MSW Reference Landfill. Concrete rubble will have a  
36 bulk density near  $2.10 \text{ g/cm}^3$ . Steel can raise the bulk density significantly, but will probably be  
37 surrounded with soil compacted to a bulk density of about  $1.94 \text{ g/cm}^3$ . For the comparative  
38 analysis, we used a bulk density equal to  $2.10 \text{ g/cm}^3$ .  
39

### 40 **3.5.6 Distribution Coefficients, $K_d$**

41  
42 The introduction of trash into the LLW Reference Disposal Facility introduces the possibility of  
43 a significant organic component in the leachate. In the comparative analysis, we have selected  
44 the median values of  $K_d$  reported in SC&A 2003 Table 9.33, and adjusted them in accordance  
45 with Equation J.13. We conservatively used the median TOC value of 377 ppm derived from  
46 municipal landfill leachate, and explicitly set the fraction of non-complexing material to zero.

The radionuclide specific mean values of the distribution coefficients used in the comparative analysis for the LLW Reference Disposal Facility equal those used for the MSW Reference Landfill and appear in Table J-9.

#### 4.0 COMPARATIVE ANALYSIS

In the comparative analysis, each disposal facility type receives an amount of each radionuclide representing one unit of activity<sup>14</sup>. For the different disposal facility types, if the inventory, timing, and activity levels of disposed radionuclides is held constant, the ratio of the total activity released from each disposal facility type compared to the total activity released from the SC&A Reference Landfill is a function of the leach rate constant  $L_n$  and equals:

$$\frac{\sum_{i=0}^k R_n(j+i)}{\left[ \sum_{i=0}^k R_n(j+i) \right]_{REF}} = \frac{f(L_n)}{f(L_n)_{REF}} \quad (J.15)$$

$$L_n = \frac{I}{\theta^{cz} T_0 R_{dn}^{cz}} \quad (J.16)$$

$$R_{dn} = 1 + \frac{\rho_b K_{dn}}{\theta^{cz}} \quad (J.17)$$

Combining the Equations J.16 and J.17 yields:

$$L_n = \frac{I}{\theta^{cz} T_0 \left( 1 + \frac{\rho_b K_{dn}}{\theta^{cz}} \right)} \quad (J.18)$$

Table J-16 summarizes the input parameters for the comparative analysis.

It is worth reiterating that the  $K_d$  values can vary by several orders of magnitude. Figure J-1 show the range of  $K_d$  values for each radionuclide reported in the literature. The shaded sections of each horizontal bar represent the  $K_d$  values that correspond to plus or minus one standard deviation (from Table 9.33 in SC&A 2003) of  $\log(K_d)$ , as measured from the median value of  $K_d$  at the boundary between the colored bars. The ends of the white bars represent the minimum and maximum  $K_d$  values. Note that the horizontal scale is logarithmic.

---

<sup>14</sup> This corresponds to  $\beta_1 = \beta_2 = \dots = \beta_n$  in Equation J.1. In practice,  $\beta_1 \neq \beta_2 \neq \dots \neq \beta_n$  and the radionuclide-specific activity released would be recalculated from the unit activity results.

1 The mobilization and movement of radionuclides are dependent on their chemical forms, pH of  
2 the leachate, nature of the organic constituents, presence of other chemical agents, porosity of  
3 the soils and waste mixture, water saturation of the soil and waste mixture, water infiltration  
4 rates, and age of the landfill. As a result, the analysis considered whether coefficient  
5 distributions ( $K_d$ ) of radionuclides contained in a mixture of released materials and other wastes  
6 should be modified, given that such an environment may have different retention or sorption  
7 properties than natural soils. The presence of highly heterogenous wastes with widely different  
8 physical and chemical properties may result in conditions that are less than ideal in maintaining  
9 an efficient ion exchange process between dissimilar materials. For example, coefficient  
10 distributions are reduced when organic materials are kept in solution, i.e., making radionuclides  
11 more mobile in such conditions. Conversely, coefficients increase when organic materials are  
12 bound in solid phase, thereby, making radionuclides less mobile. Given that it is not feasible to  
13 develop landfill-specific  $K_d$  values, a simplified and realistically conservative approach was used  
14 in this analysis. Since  $K_d$  values are normally defined for soils or materials with soil-like  
15 properties, the analysis assumed that coefficient distributions typically developed for soils are  
16 unlikely to apply to a mixture of released materials and landfill wastes containing organic  
17 constituents. An Argonne National Laboratory report was used to make specific adjustments to  
18 radionuclide distribution coefficients originally defined for soils (ANL 2001). The adjustment  
19 considers the presence of organic constituents as total organic carbon (TOC) and a correction  
20 factor based on  $K_d$  values.  
21  
22  
23

**Table J-16: Input Parameters for the Comparative Analysis**

Parameter	Symbol	Type of Disposal Facility					
		SC&A Reference	Municipal Solid Waste	Industrial, low permeability waste	Industrial, high permeability waste	Construction &	NRC LLW
Infiltration rate, years 0-3 (m/yr)	I	0.0432	0.2	0.113	0.342	0.536	0
Infiltration rate, years 3-5 (m/yr)	I	0.0432	0.2	0.113	0.342	0.536	0
Infiltration rate, years 5-10 (m/yr)	I	0.0432	0.2	0.113	0.342	0.109	0
Infiltration rate, years 10-20 (m/yr)	I	0.0432	0.109	0.113	0.342	0.109	0
Infiltration rate, years 20-50 (m/yr)	I	0.0432	0.0445	0.0761	0.0761	0.109	0
Infiltration rate, years > 50 (m/yr)	I	0.109	0.109	0.109	0.109	0.109	0
Volumetric water content of the contaminated zone, years 0-50 (dimensionless)	$\theta^{(cz)}$	0.13	0.35	0.187	0.055	0.03	0.19
Volumetric water content of the contaminated zone, years > 50 (dimensionless)	$\theta^{(cz)}$	0.14	0.35	0.187	0.125	0.03	0.19
Thickness of the contaminated zone (m)	$T_0$	2.57	13.4	2.57	2.57	5.3	13.1
Bulk waste density (g/cm <sup>3</sup> )	$\rho_b$	0.89	0.85	1.47	1.21	2.1	2.1
Distribution coefficient (cm <sup>3</sup> /g)	$K_d$						
C-14		1	1	11	11	11	1
Fe-55		2.6	2.6	209	209	209	2.6
Mn-54		2	2	158	158	158	2
Co-58		2.9	2.9	235	235	235	2.9
Co-60		2.9	2.9	235	235	235	2.9
Ni-63		5.3	5.3	424	424	424	5.3
Sr-90		3	3	32	32	32	3
Nb-95		4.7	4.7	380	380	380	4.7
Zr-95		17.1	17.1	1,380	1,380	1,380	17.1
Ru-106		19.7	19.7	1,588	1,588	1,588	19.7
Ag-110m		2.7	2.7	217	217	217	2.7
Sb-125		4.7	4.7	380	380	380	4.7
I-129		0.43	0.43	4.6	4.6	4.6	0.43
Cs-134		5.5	5.5	446	446	446	5.5
Cs-137		5.5	5.5	446	446	446	5.5
Pu-238		11.8	11.8	953	953	953	11.8
Pu-239		11.8	11.8	953	953	953	11.8
Pu-240		11.8	11.8	953	953	953	11.8

1     **5.0     ANALYTICAL RESULTS**

2  
3     The next 6 graphs present the cumulative leaching of activity from the waste versus time for  
4     each radionuclide as a fraction of the activity placed in the landfill or disposal facility. The  
5     leveling of each curve signifies either that all of the activity from that radionuclide has leached  
6     from the waste to the environment, or that the radionuclide has decayed beyond the point of any  
7     consequential release.

8  
9     Figures J-2 through J-7 indicate the radionuclide-specific release for 6 disposal facilities, which  
10    are respectively:

- 11    • the SC&A Reference Landfill
- 12    • the MSW Reference Landfill
- 13    • the Industrial Reference Landfill with high permeability waste
- 14    • the Industrial Reference Landfill with low permeability waste
- 15    • the C&D Reference Landfill
- 16    • the LLW Reference Disposal Facility

17  
18  
19    Note that the release from the LLW Reference Disposal Facility is much lower than in any of the  
20    other disposal facilities, and that less than 1 percent of the activity of any radionuclide is released  
21    within 1,000 years. In the other 5 graphs, two radionuclides, C-14 and I-129, dominate the early  
22    and sometimes the total release of radioactivity, with between 70 and 100 percent of the activity  
23    of C-14 and I-129 released within 1,000 years. In the SC&A Reference Landfill (Figure J-2) and  
24    the MSW Reference Landfill (Figure J-3), Pu-239 and Pu-240 make important contributions to  
25    the total activity released but at a rate which is approximately 10 percent of the C-14 and I-129  
26    release rates. The differences in the activity amounts for each radionuclide are assumed to be  
27    equal. For example, in Figure J-2, 100 percent of the C-14 activity but only 0.1 percent of the Zr-  
28    95 activity is ultimately released from the SC&A Reference Landfill.

29  
30    In Figures J-8 through J-17, the curves apply only when the activity amounts for each  
31    radionuclide are equal.

32  
33    Figure J-8 shows the total activity released for all radionuclides for each of the disposal facility  
34    types. Each curve equals the sum of the 18 radionuclide-specific curves for the corresponding  
35    disposal facility type. The graph allows a direct comparison of the predicted release history for  
36    each disposal facility, but the position of each curve is dependent on the specific input  
37    parameters selected for the reference landfill. Other combinations of parameters could cause  
38    curves to rise or fall relative to the results for other disposal facility types. For the combination  
39    of parameters and activities analyzed, the SC&A Reference Landfill and the MSW Reference  
40    Landfill allow the greatest release of activity and the LLW Reference Disposal Facility allows the  
41    least. The releases from the Industrial Reference Landfills and the C&D Reference Landfill fall  
42    about midway in between.

43  
44    Figure J-9 compares the cumulative release from each disposal facility up to the indicated time  
45    (i.e. its curve in Figure J-8) to the cumulative release at the same time from the SC&A  
46    Reference Landfill. Note that the relative benefits of the disposal facility types vary over time.

1 The dips generally reflect the influence of reduced infiltration due to the placement of a low  
2 permeability cap, and the subsequent rises reflect eventual deterioration of the cap and  
3 breakthrough of leachate-contaminated groundwater to a well or surface water body.  
4

5 Figure J-10 shows the cumulative release from each disposal facility up to the indicated time  
6 compared to the ultimate cumulative release from the same disposal facility. The curves show  
7 the percentage of the activity that has been released at any point in time compared to the amount  
8 that will ultimately be released. For example, in the first 100 years following disposal, 66 percent  
9 of the ultimately released activity is released from the SC&A Reference Landfill, 38 percent from  
10 the MSW Reference Landfill, and less than 1 percent from the LLW Reference Disposal Facility.  
11

12 A sensitivity analysis was also performed of the effect of each input parameter to the cumulative  
13 release rate. The MSW Reference Landfill was chosen as the control. For each part of the  
14 sensitivity analysis, one input parameter was changed in an unfavorable and in a favorable  
15 direction, and the results graphed against the MSW Reference Landfill control. Figures J-11  
16 through J-16 present the results of the sensitivity analysis for the individual parameter variation.  
17

18 Figure J-11 shows the effect of varying  $K_d$ . Lowering all of the radionuclide-specific  $K_d$  values  
19 by the equivalent of one standard deviation of  $\log(K_d)$  increased and accelerated the release of  
20 radioactivity approximately by a factor of 10. Raising the  $K_d$  values by the same amount reduced  
21 the release to a small fraction of the control. ANL 2001a concludes that “given the fact that the  
22 effective  $K_d$  values of radionuclides in ... disposal units can either increase or decrease as the  
23 result of many factors, ... whenever they are available, actual (measured)  $K_d$  values rather than  
24 modeled values should be used.”  
25

26 Figure J-12 shows the influence of infiltration. Doubling the infiltration increases the release  
27 about the same amount as reducing the infiltration by half decreases the release. This is to be  
28 expected by the proportionality of the leach rate constant and infiltration in Equation J.18. The  
29 infiltration rate depends primarily on the amount of precipitation, the percentage of runoff and  
30 the permeability of the cap or surface waste layer. Disposal facilities with sloping, low  
31 permeability caps in arid climates will have lower infiltration values and release rates than other  
32 facilities, if all other parameters are the same.  
33

34 Figure J-13 shows the relative insensitivity of the cumulative release and the release rate to the  
35 volumetric water content. The range of volumetric water contents chosen, 0.12 to 0.55, represent  
36 all but extreme conditions in MSW landfills.  
37

38 Figure J-14 shows the effect of varying the landfill thickness. Reducing the landfill thickness by  
39 half increases the release about the same amount that doubling the landfill thickness reduces the  
40 release. This is to be expected by the inverse proportionality of the leach rate constant and  
41 thickness in Equation J.18. Thicker landfills increase the retention time of the radionuclides in  
42 the landfill itself, slowing the rate of release. The increased retention time also allows more  
43 complete radioactive decay and lower cumulative releases.  
44

45 Figure J-15 shows the effect of varying the density. The density has an effect because the  $K_d$   
46 values are partitioning ratios between the volume of liquid and mass of solids, and the density

1 input parameter establishes the mass. Varying the MSW bulk density from 0.57 t/m<sup>3</sup> to 1.28  
2 t/m<sup>3</sup>, about the maximum range for MSW landfills, shows moderate variation in the cumulative  
3 release curves.  
4

5 Figure J-16 shows the effect of varying the groundwater travel time from 0 years to 500 years  
6 before it potentially reaches a biological receptor. The additional decay time has a minimal  
7 effect on the cumulative release. Note that the curves only begin to diverge when the leachate  
8 collection system is shut down 50 years after waste placement. Also note that the 0 year curve is  
9 equivalent to a landfill where the leachate collection system functions forever. Shutting down  
10 the leachate collection system reduces the radioactivity released to the environment, but releases  
11 the activity in a less controlled manner.  
12

13 Figure J-17 summarizes the results from Figures J-11 through J-16, and shows only the  
14 unfavorable curves compared to the MSW Reference Landfill control curve. Note that due to the  
15 proportionality of infiltration and the inverse proportionality of thickness to the leach rate  
16 constant, that the 200 percent infiltration and 50 percent thickness curves are exactly the same.  
17 Also note that the curves for volumetric water content, groundwater travel time, and density are  
18 graphed at or near has the most unfavorable possible values. It is important to recognize that  $K_d$   
19 the most pronounced effect, and also has the widest range of potential values.  
20  
21

Appendix J: Comparison of Disposal Facility Types

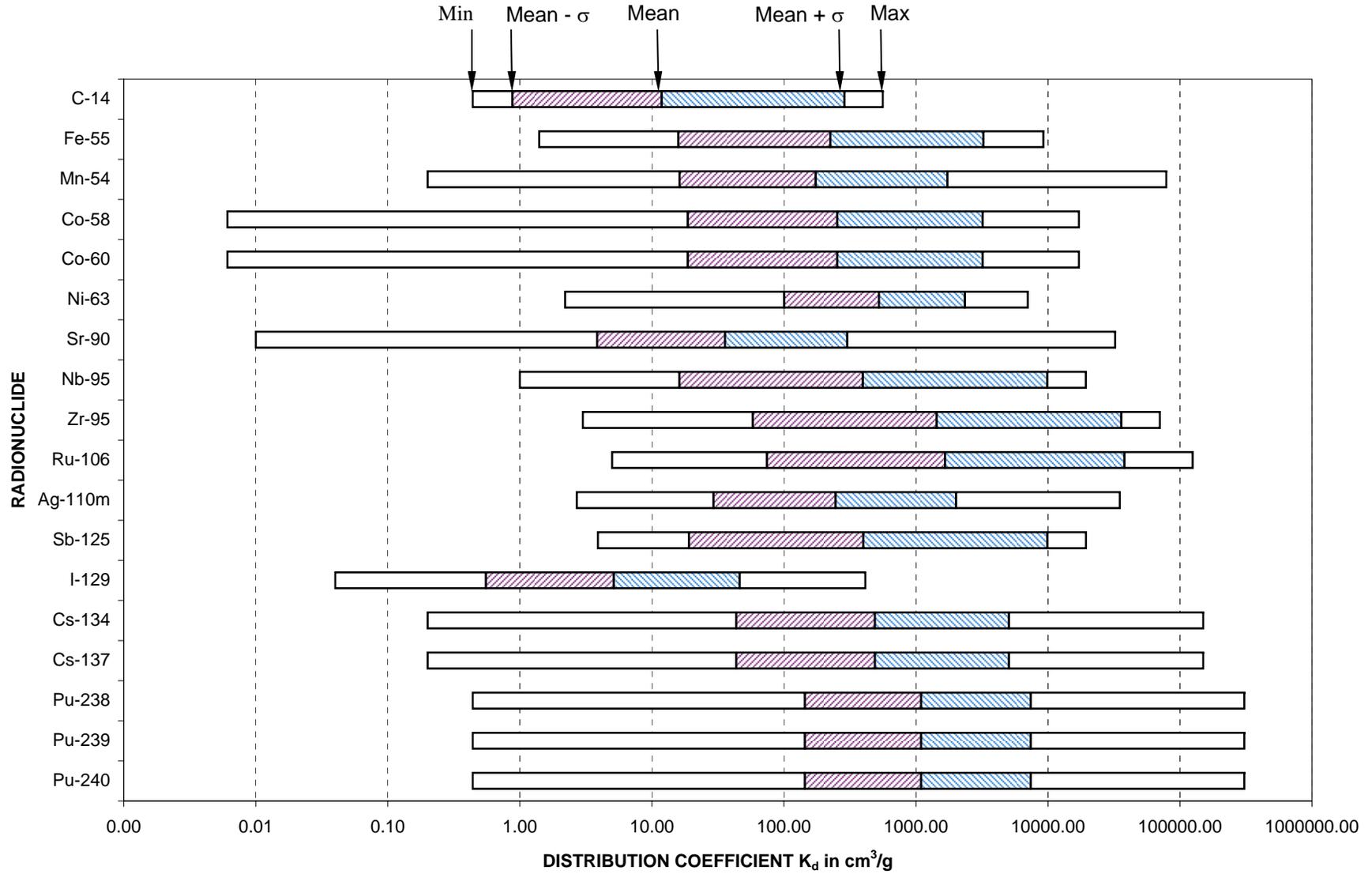


Figure J-1

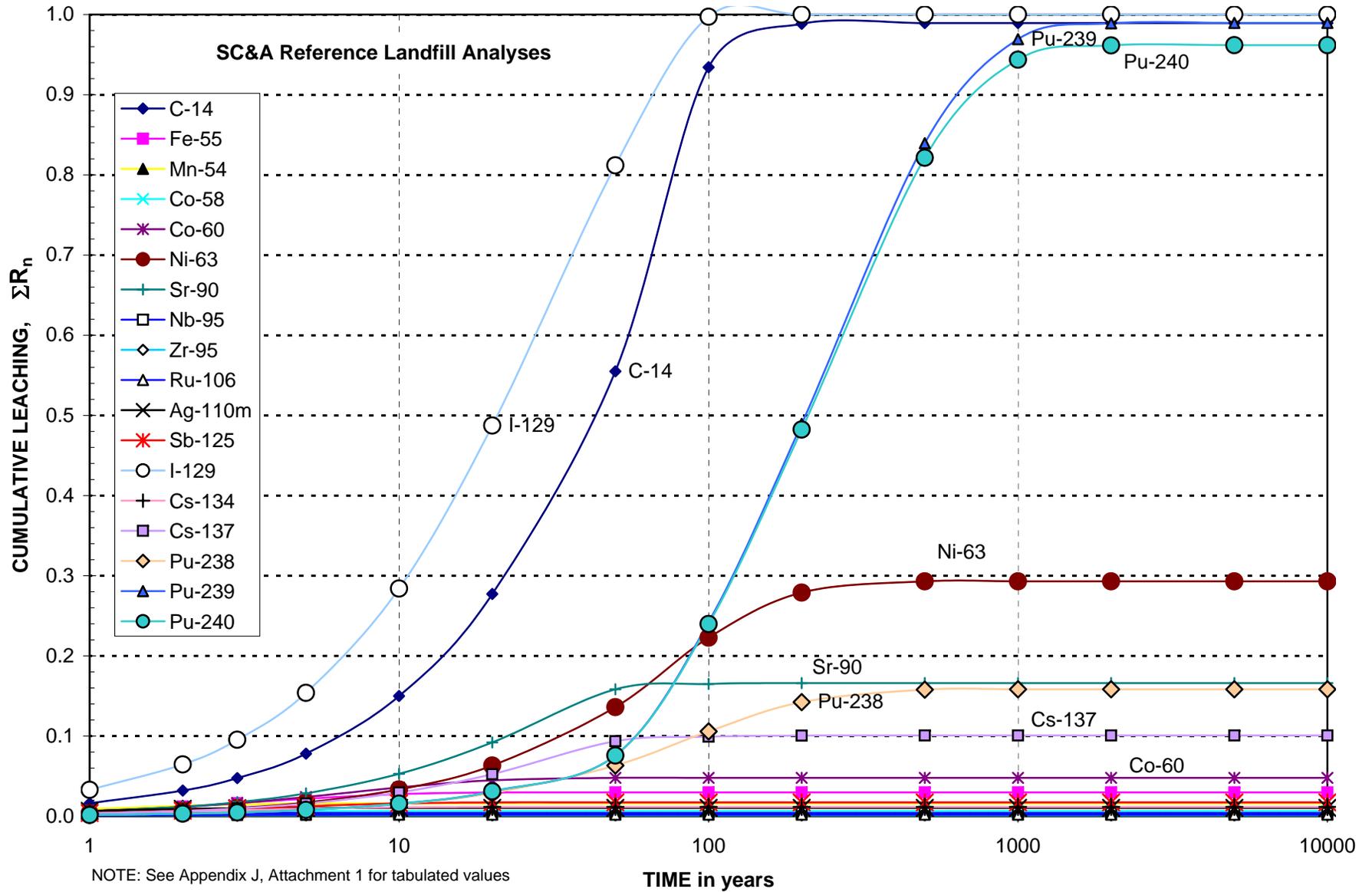


Figure J-2

Appendix J: Comparison of Disposal Facility Types

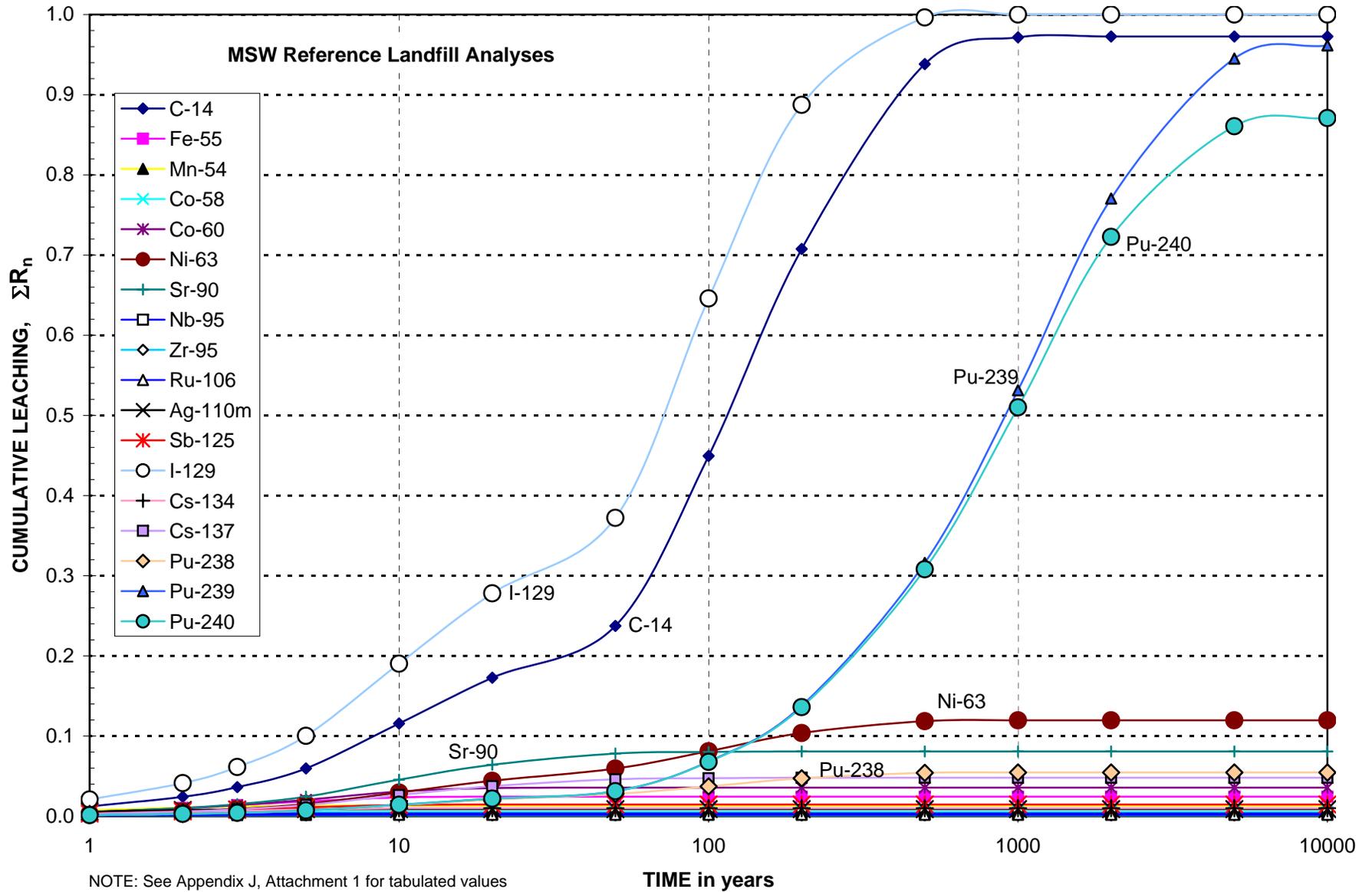


Figure J-3

Appendix J: Comparison of Disposal Facility Types

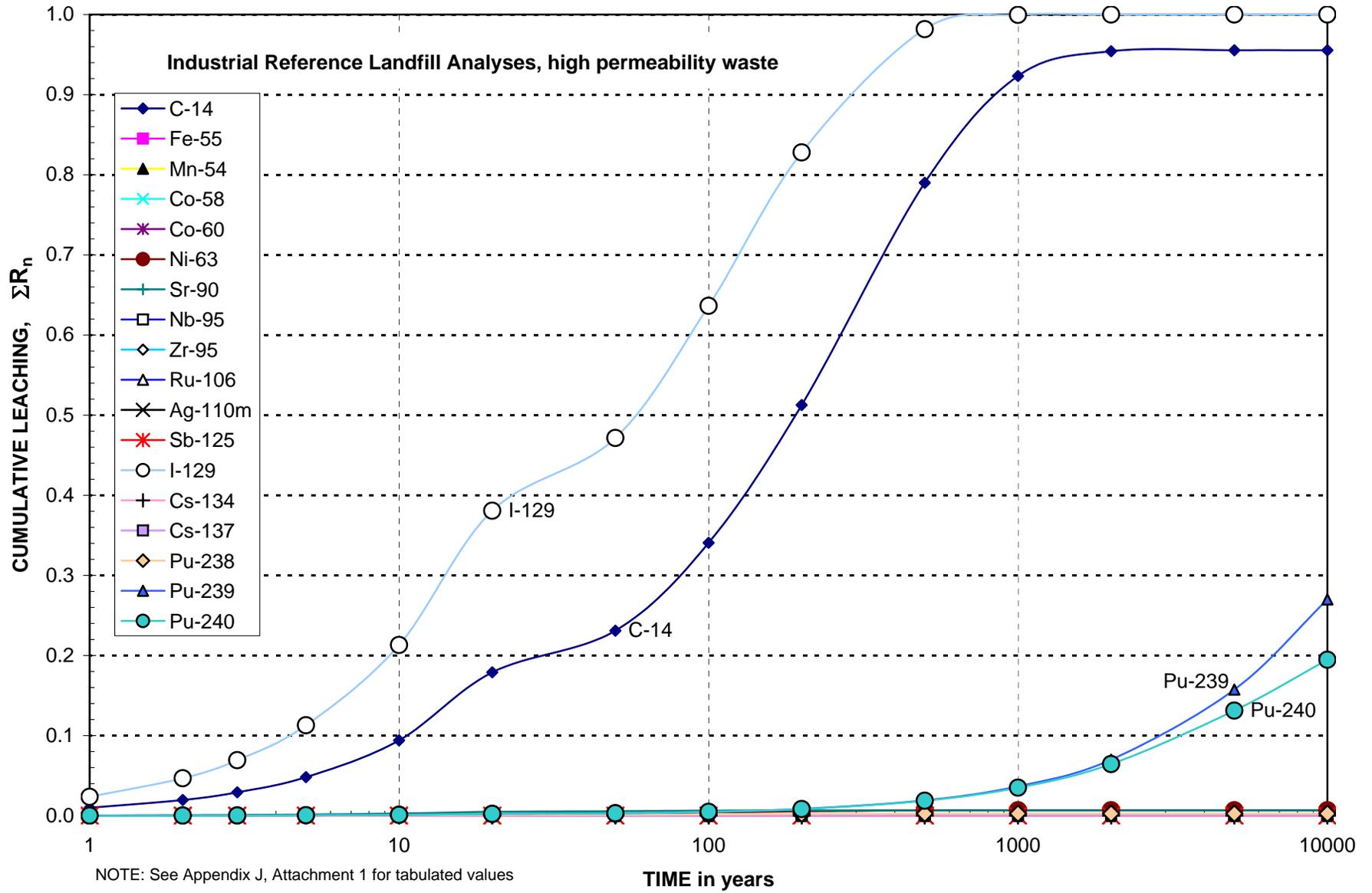


Figure J-4

Appendix J: Comparison of Disposal Facility Types

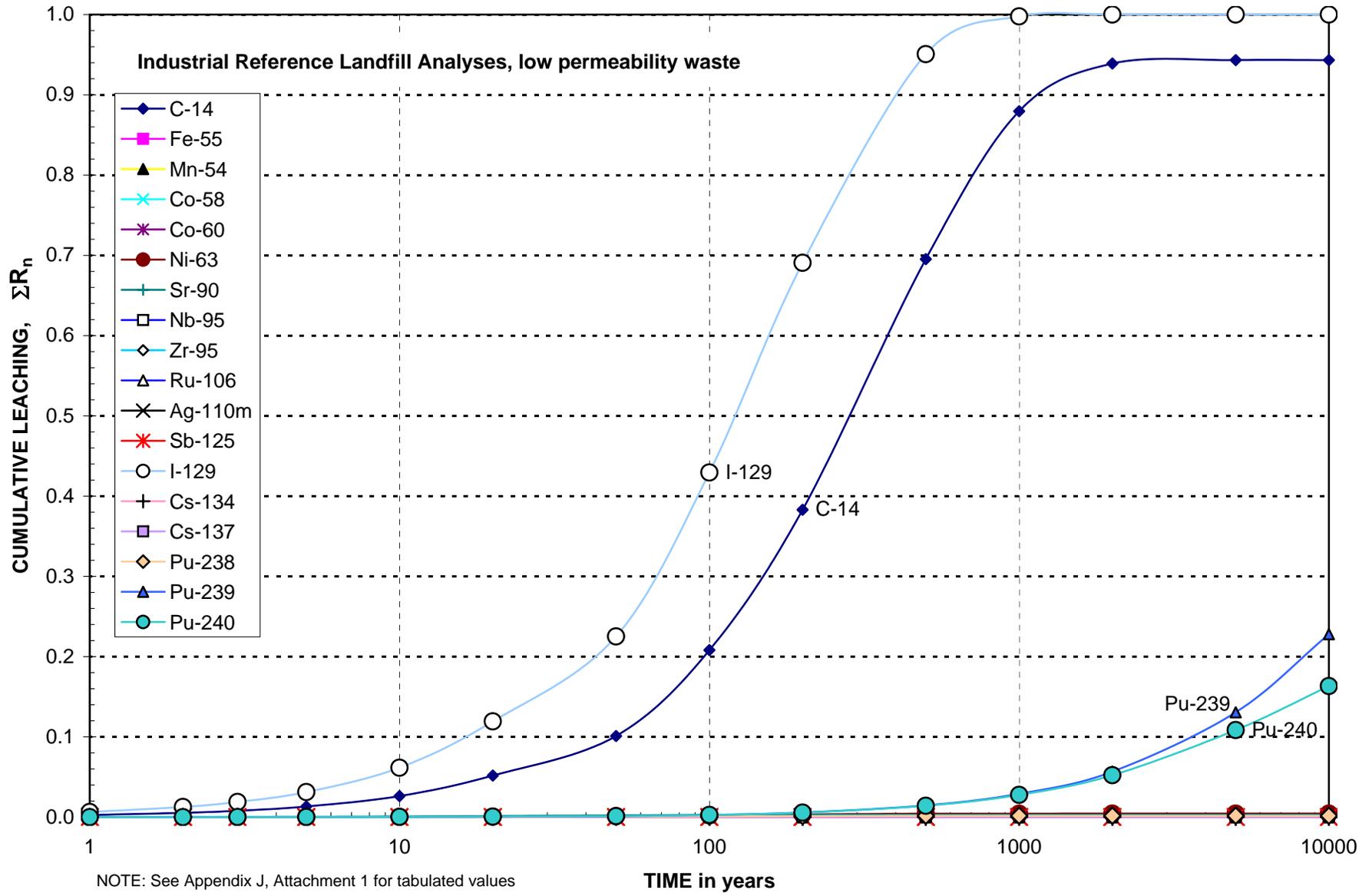


Figure J-5

Appendix J: Comparison of Disposal Facility Types

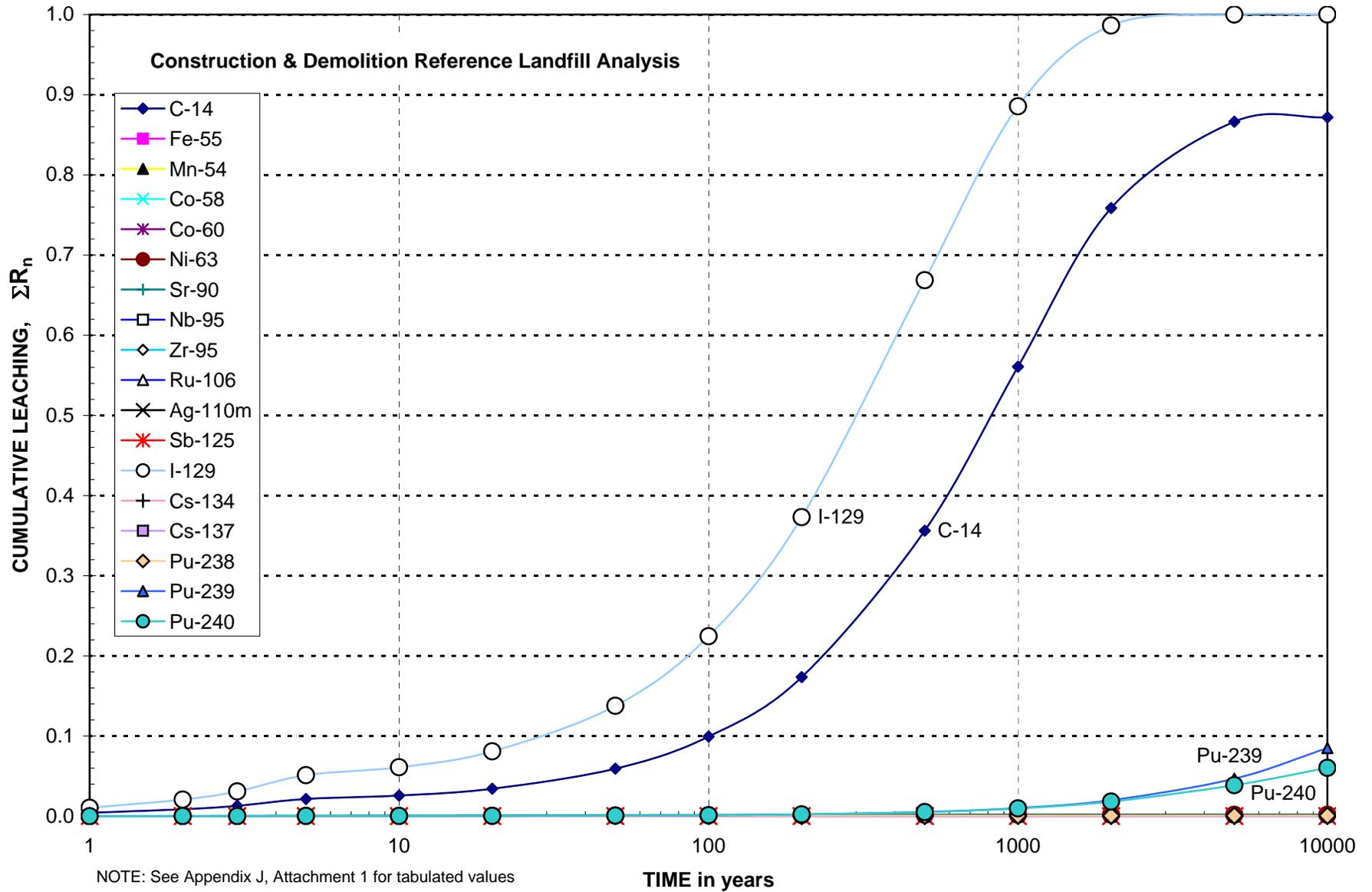


Figure J-6

Appendix J: Comparison of Disposal Facility Types

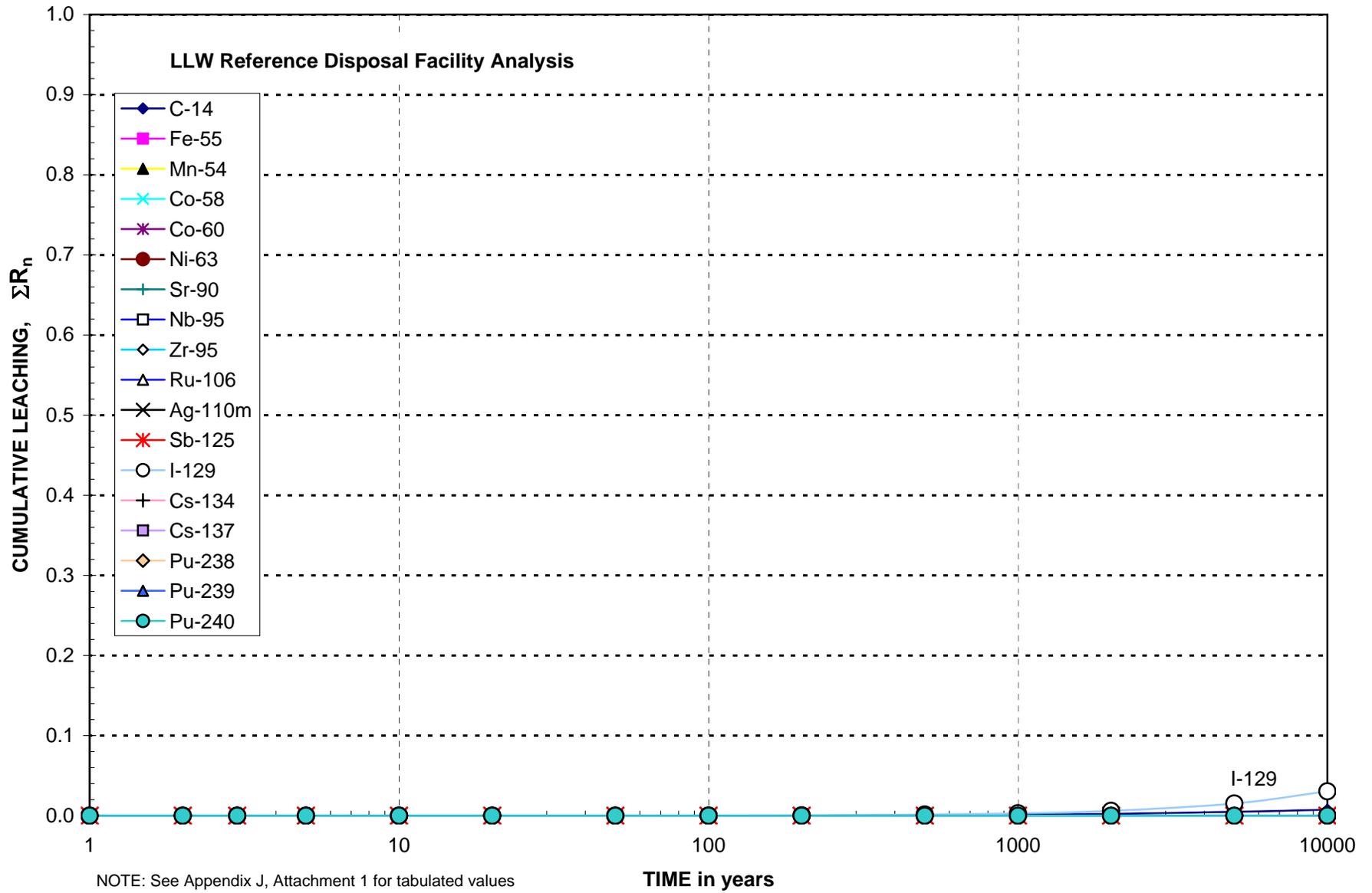


Figure J-7

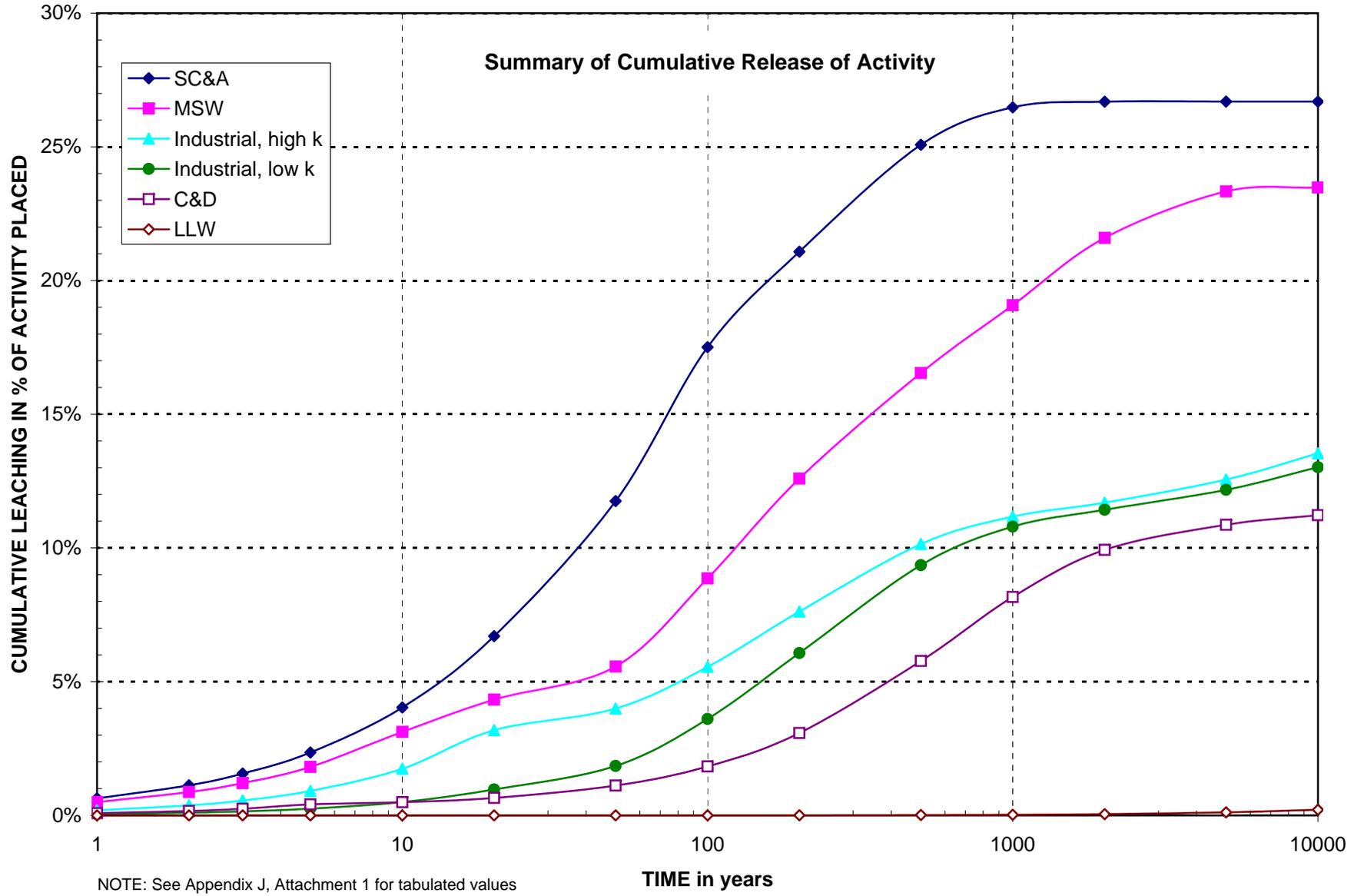


Figure J-8

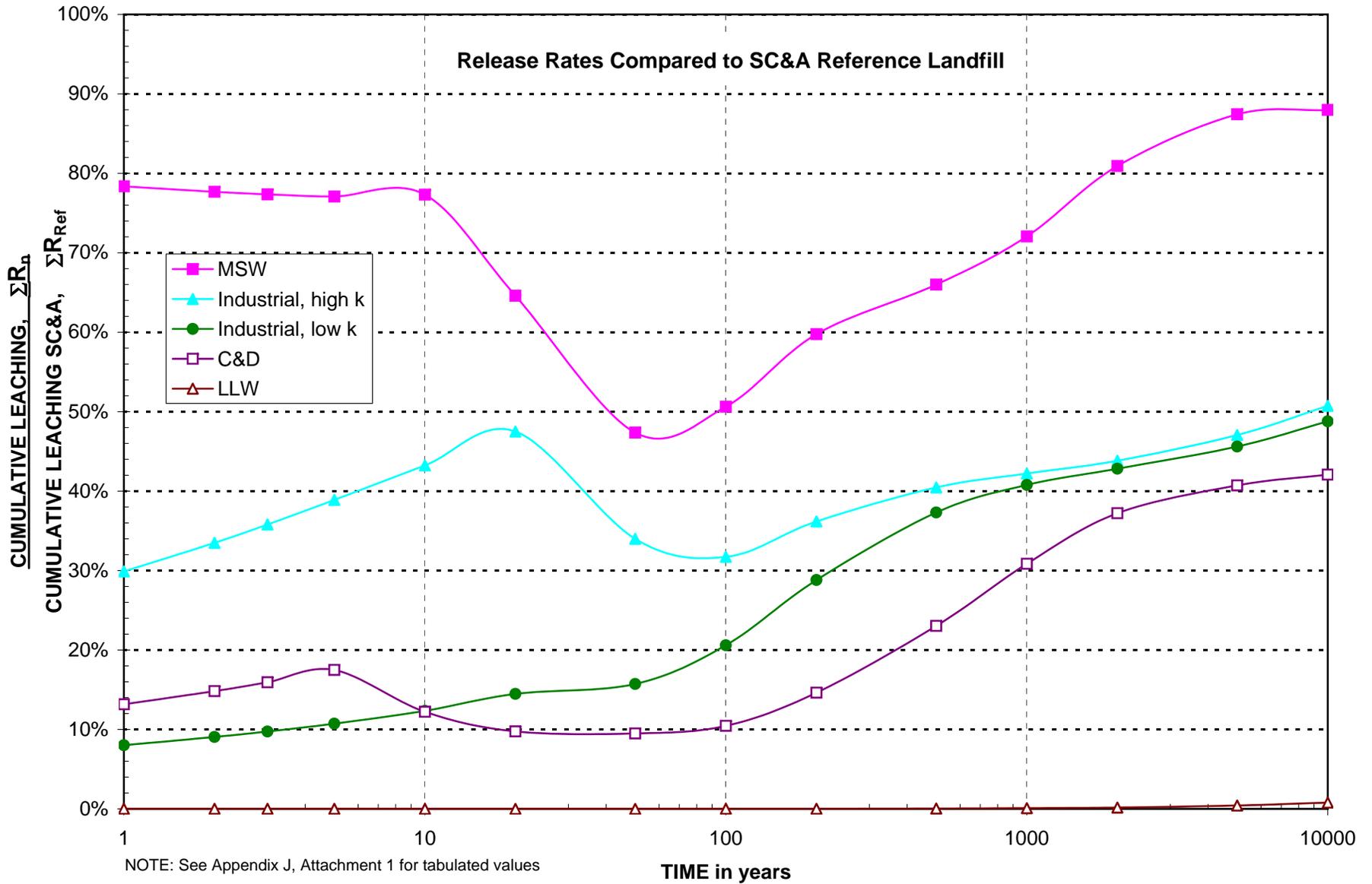


Figure J-9

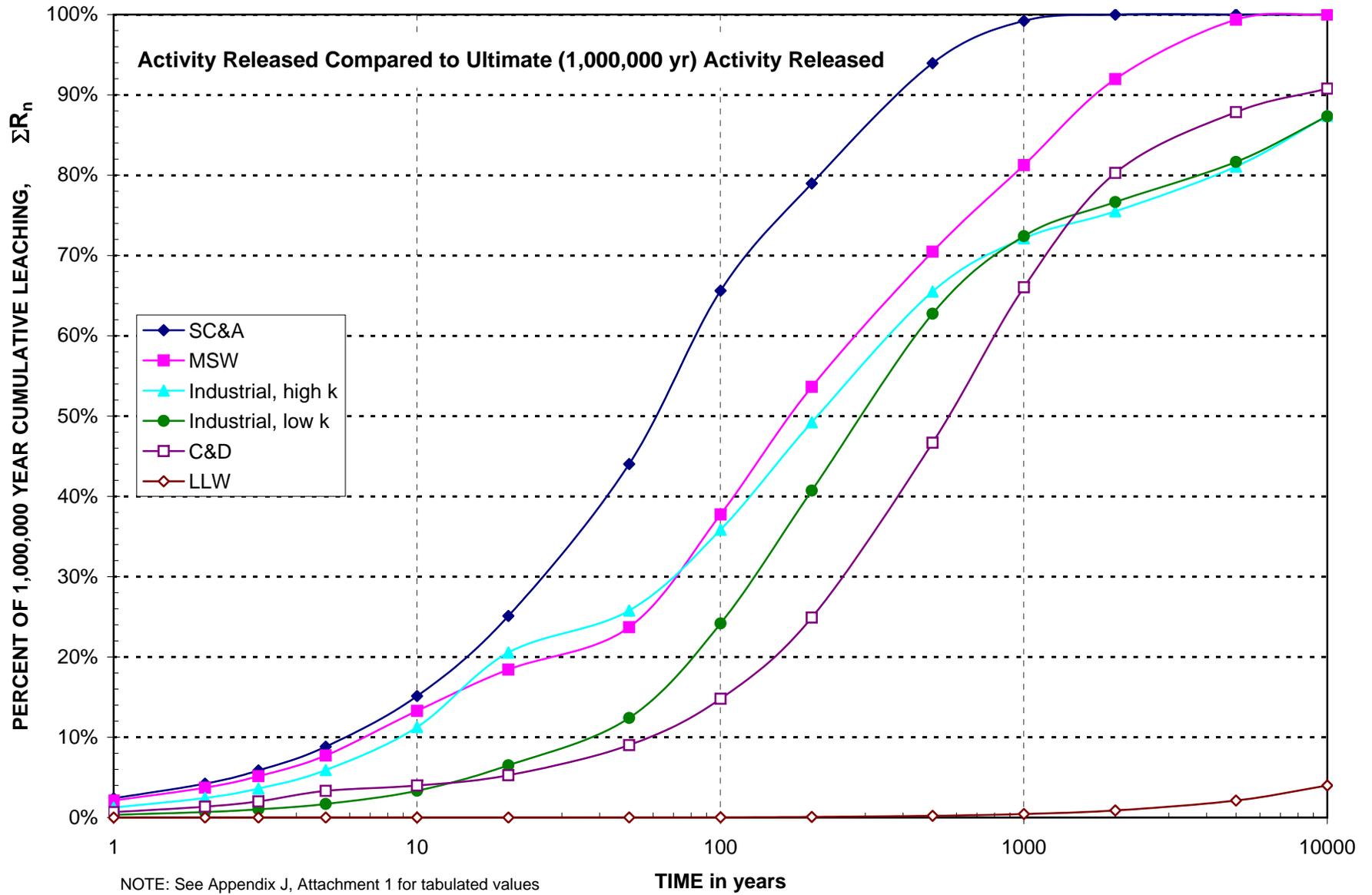


Figure J-10

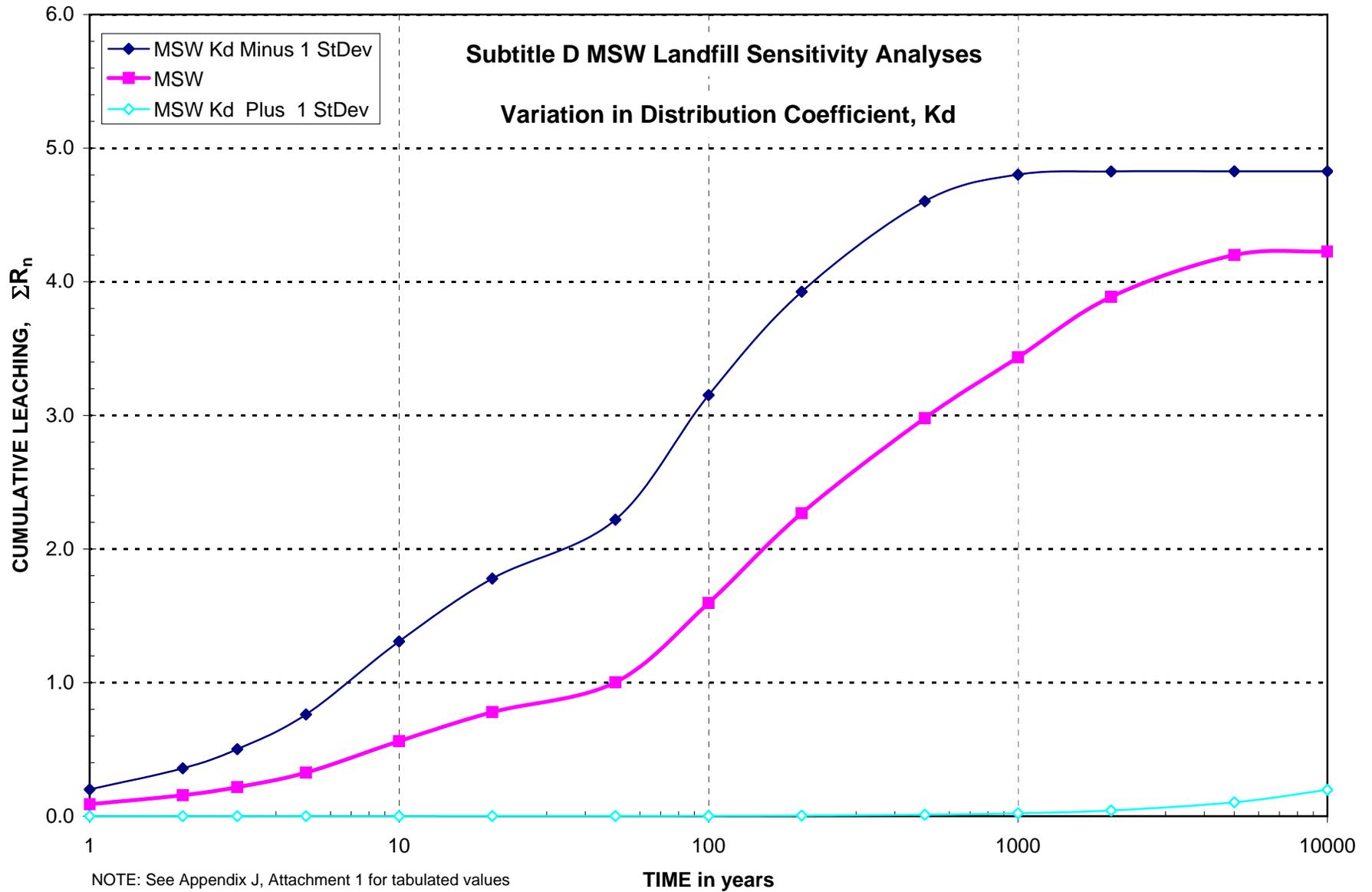


Figure J-11

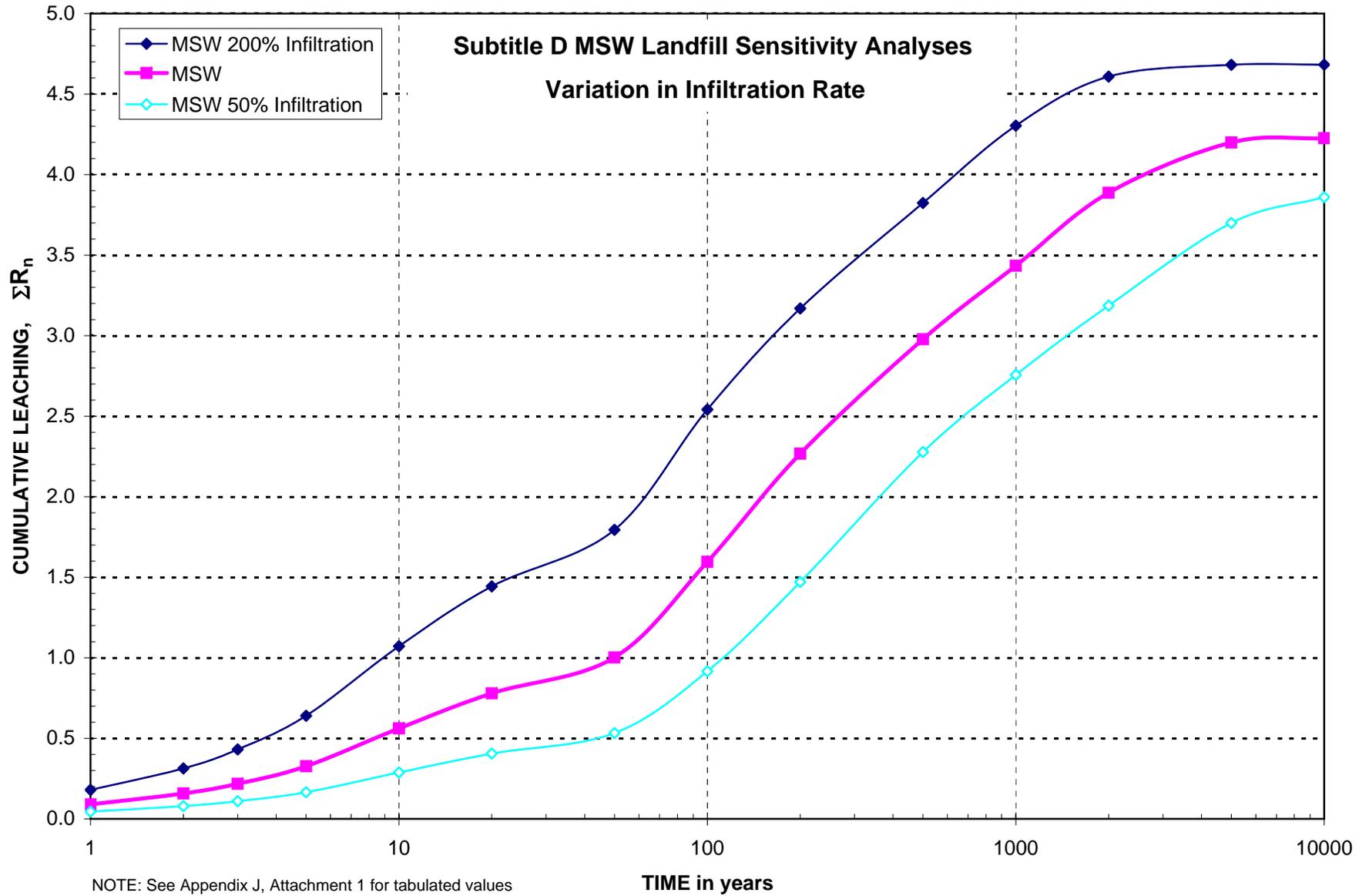


Figure J-12

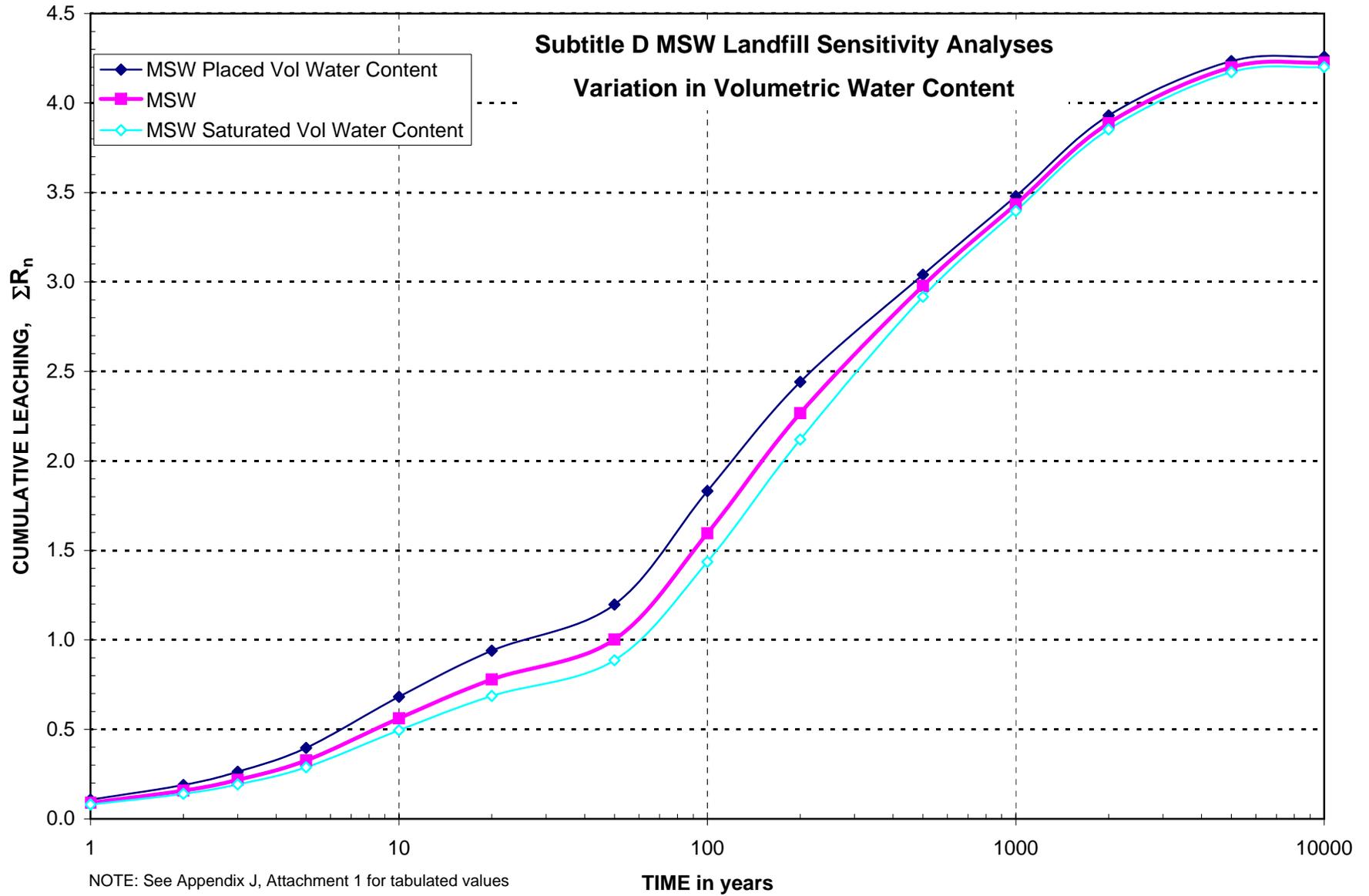


Figure J-13

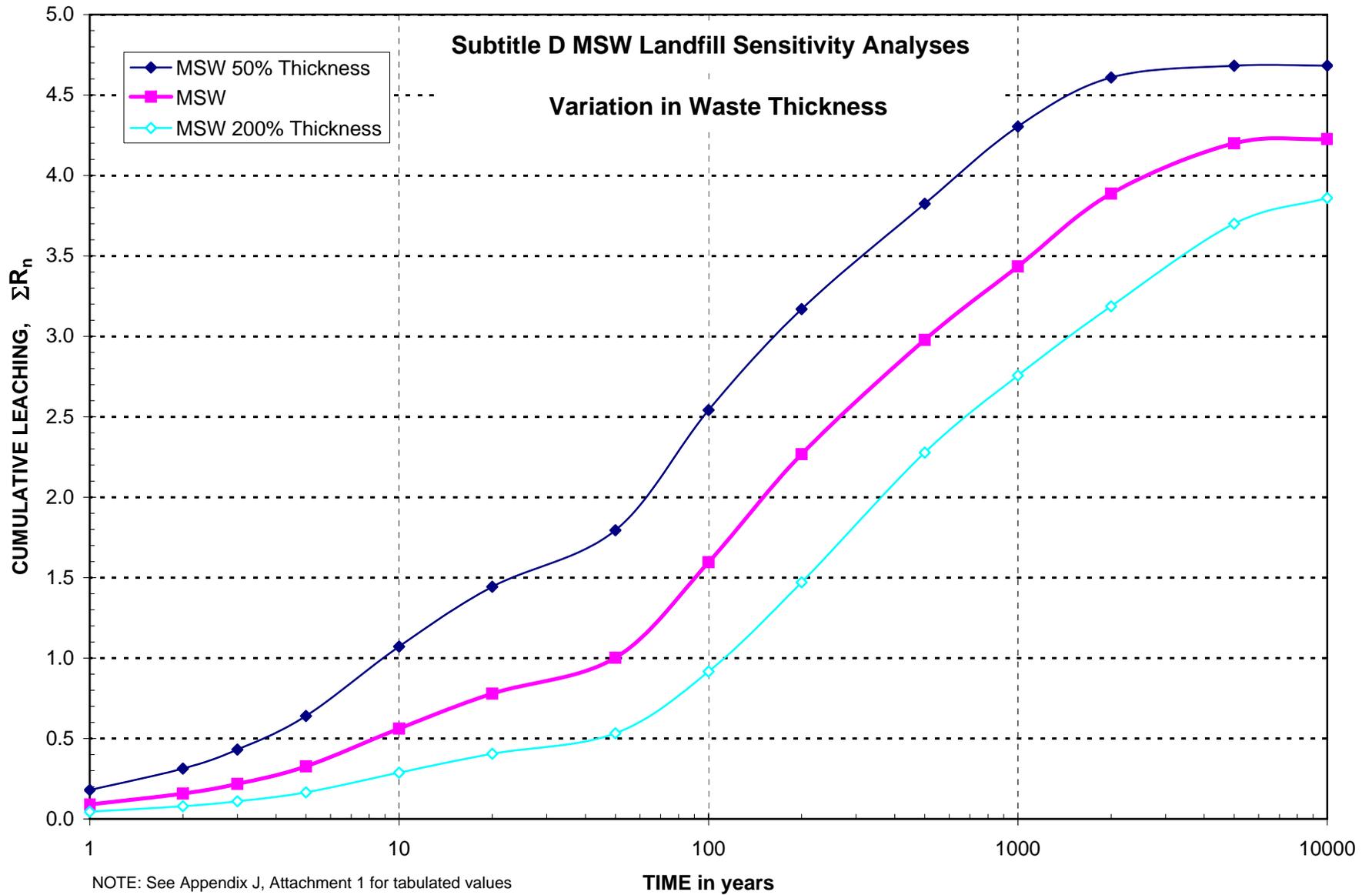


Figure J-14

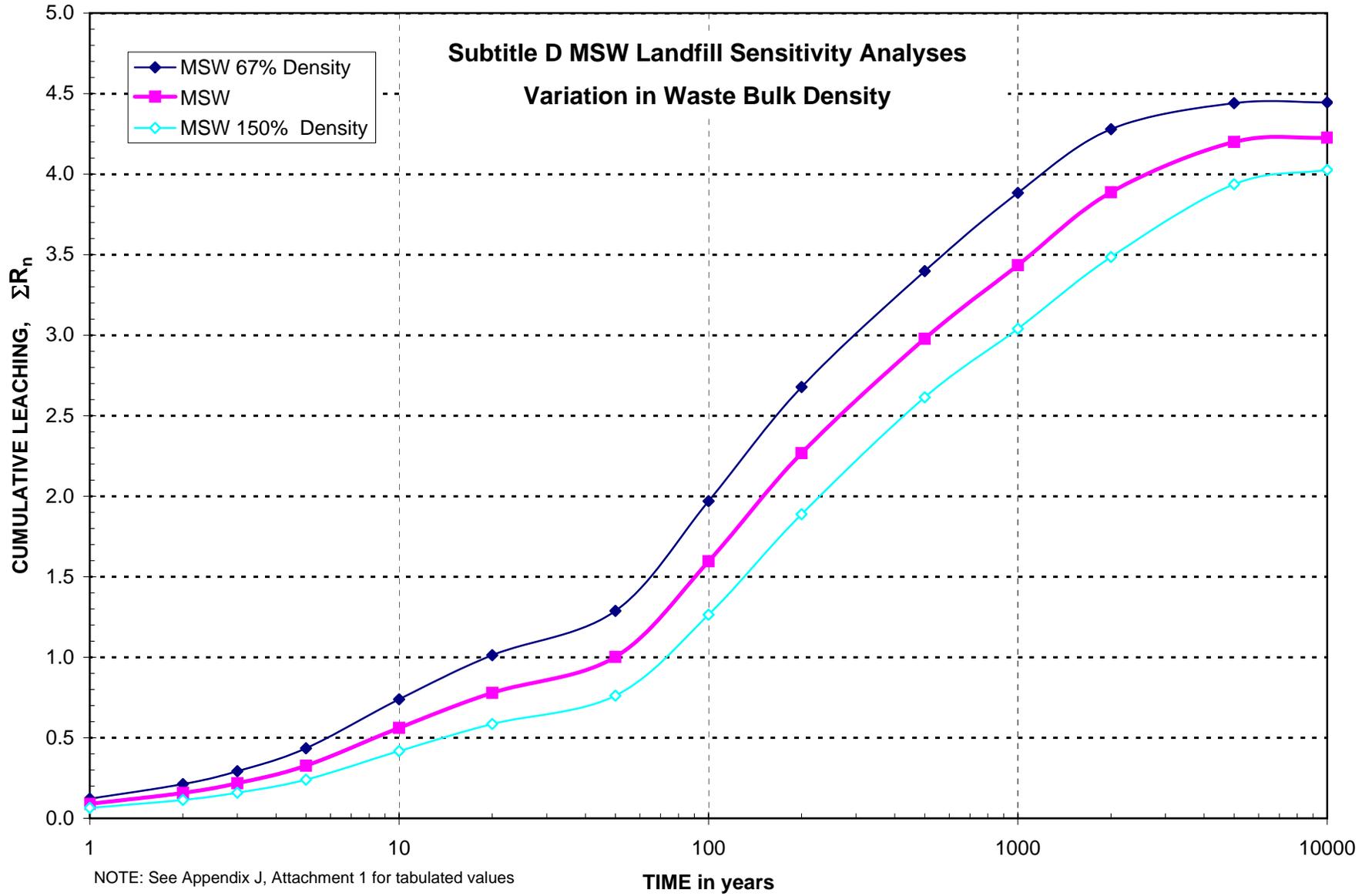


Figure J-15

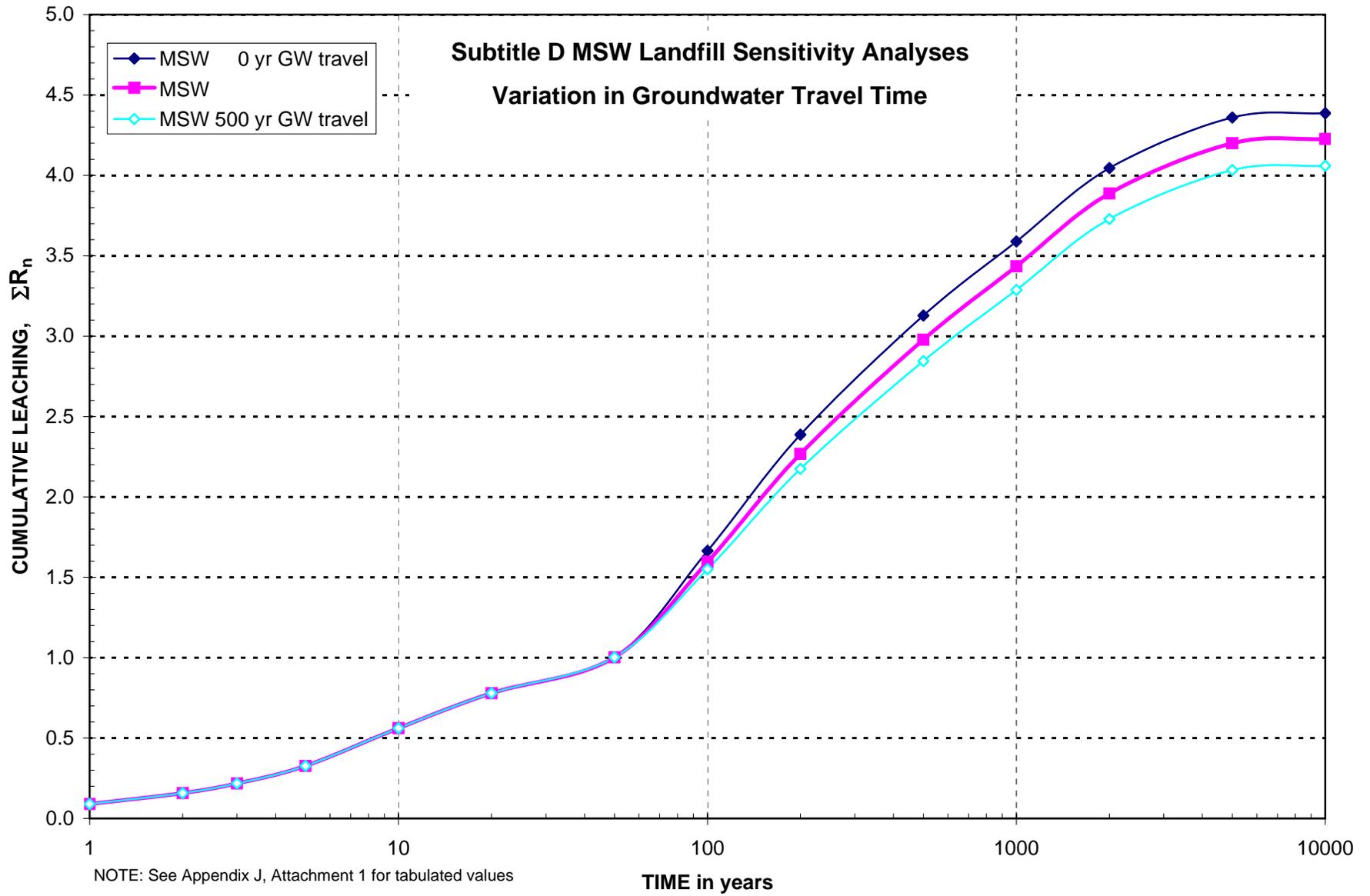


Figure J-16

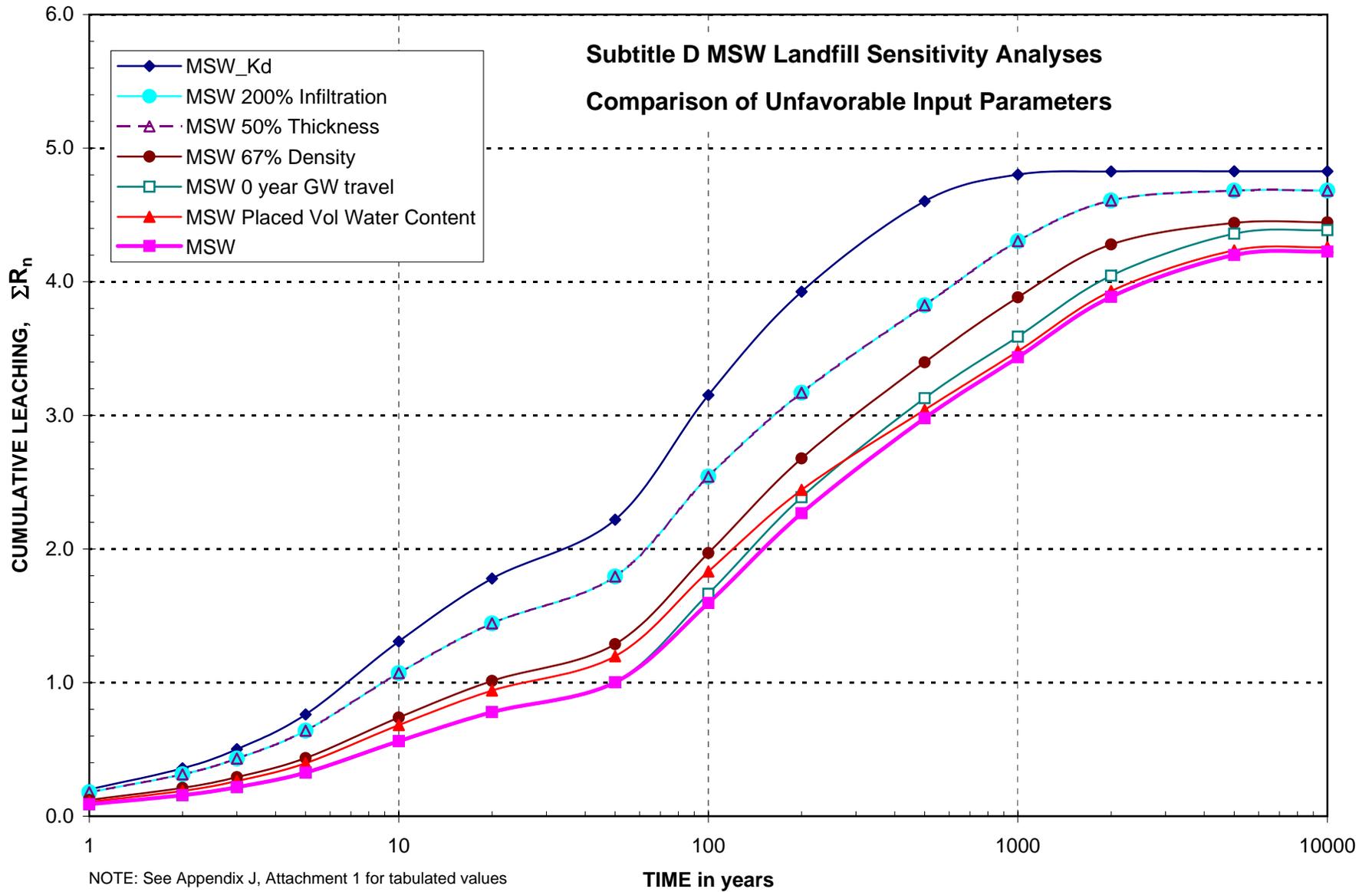


Figure J-17

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**Attachment 1**

**Analytical Support Files for the Comparison of Disposal Facilities**

### SC&A Reference Landfill Analyses

#### Input Parameters and Leach Rate Constants

$$\text{Leach Rate } L = I / (\theta * T_0 * (1 + \rho_b K_d) / \theta)$$

	Start Year	0	3	5	10	20	50
Infiltration rate (m/yr)	I =	0.0432	0.0432	0.0432	0.0432	0.0432	0.1090
Volumetric water content	$\theta$ =	0.13	0.13	0.13	0.13	0.13	0.14
Thickness (m)	$T_0$ =	2.57	2.57	2.57	2.57	2.57	2.57
Bulk density, unsaturated waste (g/cm <sup>3</sup> )	$\rho_b$ =	0.89	0.89	0.89	0.89	0.89	0.89

Radionuclide	Decay Constant $\lambda, \text{yr}^{-1}$		$e^{-\lambda}$	$K_d$	Leach Rate					
					0	3	5	10	20	50
C-14	1.21E-04	1.00E+00	1.00E+00	1.03	1.61E-02	1.61E-02	1.61E-02	1.61E-02	1.61E-02	4.03E-02
Fe-55	2.57E-01	7.73E-01	7.73E-01	2.59	6.90E-03	6.90E-03	6.90E-03	6.90E-03	6.90E-03	1.73E-02
Mn-54	8.10E-01	4.45E-01	4.45E-01	1.96	8.97E-03	8.97E-03	8.97E-03	8.97E-03	8.97E-03	2.25E-02
Co-58	3.58E+00	2.79E-02	2.79E-02	2.91	6.17E-03	6.17E-03	6.17E-03	6.17E-03	6.17E-03	1.55E-02
Co-60	1.32E-01	8.76E-01	8.76E-01	2.91	6.17E-03	6.17E-03	6.17E-03	6.17E-03	6.17E-03	1.55E-02
Ni-63	7.22E-03	9.93E-01	9.93E-01	5.26	3.49E-03	3.49E-03	3.49E-03	3.49E-03	3.49E-03	8.80E-03
Sr-90	2.41E-02	9.76E-01	9.76E-01	2.98	6.04E-03	6.04E-03	6.04E-03	6.04E-03	6.04E-03	1.52E-02
Nb-95	7.24E+00	7.17E-04	7.17E-04	4.71	3.89E-03	3.89E-03	3.89E-03	3.89E-03	3.89E-03	9.78E-03
Zr-95	3.95E+00	1.93E-02	1.93E-02	17.12	1.09E-03	1.09E-03	1.09E-03	1.09E-03	1.09E-03	2.76E-03
Ru-106	6.78E-01	5.08E-01	5.08E-01	19.70	9.52E-04	9.52E-04	9.52E-04	9.52E-04	9.52E-04	2.40E-03
Ag-110m	1.01E+00	3.64E-01	3.64E-01	2.69	6.66E-03	6.66E-03	6.66E-03	6.66E-03	6.66E-03	1.67E-02
Sb-125	2.51E-01	7.78E-01	7.78E-01	4.71	3.89E-03	3.89E-03	3.89E-03	3.89E-03	3.89E-03	9.78E-03
I-129	4.41E-08	1.00E+00	1.00E+00	0.43	3.29E-02	3.29E-02	3.29E-02	3.29E-02	3.29E-02	8.13E-02
Cs-134	3.36E-01	7.15E-01	7.15E-01	5.53	3.33E-03	3.33E-03	3.33E-03	3.33E-03	3.33E-03	8.38E-03
Cs-137	2.31E-02	9.77E-01	9.77E-01	5.53	3.33E-03	3.33E-03	3.33E-03	3.33E-03	3.33E-03	8.38E-03
Pu-238	7.90E-03	9.92E-01	9.92E-01	11.82	1.58E-03	1.58E-03	1.58E-03	1.58E-03	1.58E-03	3.98E-03
Pu-239	2.87E-05	1.00E+00	1.00E+00	11.82	1.58E-03	1.58E-03	1.58E-03	1.58E-03	1.58E-03	3.98E-03
Pu-240	1.06E-04	1.00E+00	1.00E+00	11.82	1.58E-03	1.58E-03	1.58E-03	1.58E-03	1.58E-03	3.98E-03

*Appendix J: Comparison of Disposal Facility Types*  
*Attachment 1: Analytical Support Files for the Comparison of Disposal Facilities*

**SC&A Reference Landfill Analyses**

**Radionuclide Activity Released per Unit Activity Placed in Disposal Facility**

Percent of activity released =	0.6%	1.1%	1.6%	2.4%	4.0%	6.7%	11.8%	17.5%	21.1%	25.1%	26.5%	26.7%	26.7%	26.7%
Cumulative activity released =	0.11458	0.20259	0.28151	0.42357	0.72652	1.20614	2.11537	3.15182	3.79374	4.51355	4.76624	4.80386	4.80452	4.80452
Relative activity released =	2.4%	4.2%	5.9%	8.8%	15.1%	25.1%	44.0%	65.6%	79.0%	93.9%	99.2%	100.0%	100.0%	100.0%
Cum. released/SC&A released =	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

*100 Groundwater travel time (years)*

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.01612	0.03199	0.04759	0.07804	0.14995	0.27724	0.55494	0.93412	0.98846	0.98935	0.98935	0.98935	0.98935	0.98935	0.98935
Fe-55	0.00690	0.01220	0.01626	0.02179	0.02761	0.02958	0.02974	0.02974	0.02974	0.02974	0.02974	0.02974	0.02974	0.02974	0.02974
Mn-54	0.00897	0.01292	0.01467	0.01577	0.01604	0.01604	0.01604	0.01604	0.01604	0.01604	0.01604	0.01604	0.01604	0.01604	0.01604
Co-58	0.00617	0.00634	0.00635	0.00635	0.00635	0.00635	0.00635	0.00635	0.00635	0.00635	0.00635	0.00635	0.00635	0.00635	0.00635
Co-60	0.00617	0.01155	0.01623	0.02385	0.03581	0.04480	0.04776	0.04776	0.04776	0.04776	0.04776	0.04776	0.04776	0.04776	0.04776
Ni-63	0.00349	0.00695	0.01037	0.01710	0.03332	0.06324	0.13598	0.22263	0.27885	0.29285	0.29297	0.29297	0.29297	0.29297	0.29297
Sr-90	0.00604	0.01189	0.01758	0.02844	0.05290	0.09203	0.15822	0.16495	0.16601	0.16604	0.16604	0.16604	0.16604	0.16604	0.16604
Nb-95	0.00389	0.00389	0.00389	0.00389	0.00389	0.00389	0.00389	0.00389	0.00389	0.00389	0.00389	0.00389	0.00389	0.00389	0.00389
Zr-95	0.00109	0.00112	0.00112	0.00112	0.00112	0.00112	0.00112	0.00112	0.00112	0.00112	0.00112	0.00112	0.00112	0.00112	0.00112
Ru-106	0.00095	0.00143	0.00168	0.00187	0.00193	0.00193	0.00193	0.00193	0.00193	0.00193	0.00193	0.00193	0.00193	0.00193	0.00193
Ag-110m	0.00666	0.00906	0.00994	0.01037	0.01043	0.01043	0.01043	0.01043	0.01043	0.01043	0.01043	0.01043	0.01043	0.01043	0.01043
Sb-125	0.00389	0.00690	0.00923	0.01245	0.01593	0.01717	0.01728	0.01728	0.01728	0.01728	0.01728	0.01728	0.01728	0.01728	0.01728
I-129	0.03286	0.06463	0.09537	0.15383	0.28400	0.48735	0.81183	0.99729	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
Cs-134	0.00333	0.00570	0.00738	0.00944	0.01117	0.01155	0.01156	0.01156	0.01156	0.01156	0.01156	0.01156	0.01156	0.01156	0.01156
Cs-137	0.00333	0.00657	0.00972	0.01579	0.02962	0.05236	0.09351	0.09918	0.10060	0.10066	0.10066	0.10066	0.10066	0.10066	0.10066
Pu-238	0.00158	0.00314	0.00469	0.00774	0.01513	0.02889	0.06315	0.10578	0.14229	0.15783	0.15828	0.15829	0.15829	0.15829	0.15829
Pu-239	0.00158	0.00315	0.00473	0.00787	0.01567	0.03109	0.07589	0.24207	0.48923	0.83946	0.96928	0.98905	0.98941	0.98941	0.98941
Pu-240	0.00158	0.00315	0.00473	0.00787	0.01567	0.03107	0.07575	0.23971	0.48221	0.82126	0.94357	0.96142	0.96172	0.96172	0.96172
Cumulative Leaching, ΣR															

### MSW Reference Landfill Analyses

#### Input Parameters and Leach Rate Constants

$$\text{Leach Rate } L = I / (\theta * T_0 * (1 + \rho_b K_d) / \theta)$$

	Start Year	0	3	5	10	20	50
Infiltration rate (m/yr)	I =	0.200	0.200	0.200	0.109	0.045	0.109
Volumetric water content	$\theta$ =	0.35	0.35	0.35	0.35	0.35	0.35
Thickness (m)	$T_0$ =	13.40	13.40	13.40	13.40	13.40	13.40
Bulk density, unsaturated waste (g/cm <sup>3</sup> )	$\rho_b$ =	0.85	0.85	0.85	0.85	0.85	0.85

Radionuclide	Decay Constant $\lambda, \text{yr}^{-1}$		$e^{-\lambda}$	$K_d$	Leach Rate					
					0	3	5	10	20	50
C-14	1.21E-04	1.00E+00	1.00E+00	1.03	1.22E-02	1.22E-02	1.22E-02	6.66E-03	2.72E-03	6.66E-03
Fe-55	2.57E-01	7.73E-01	7.73E-01	2.59	5.85E-03	5.85E-03	5.85E-03	3.19E-03	1.30E-03	3.19E-03
Mn-54	8.10E-01	4.45E-01	4.45E-01	1.96	7.40E-03	7.40E-03	7.40E-03	4.04E-03	1.65E-03	4.04E-03
Co-58	3.58E+00	2.79E-02	2.79E-02	2.91	5.28E-03	5.28E-03	5.28E-03	2.88E-03	1.17E-03	2.88E-03
Co-60	1.32E-01	8.76E-01	8.76E-01	2.91	5.28E-03	5.28E-03	5.28E-03	2.88E-03	1.17E-03	2.88E-03
Ni-63	7.22E-03	9.93E-01	9.93E-01	5.26	3.10E-03	3.10E-03	3.10E-03	1.69E-03	6.89E-04	1.69E-03
Sr-90	2.41E-02	9.76E-01	9.76E-01	2.98	5.17E-03	5.17E-03	5.17E-03	2.82E-03	1.15E-03	2.82E-03
Nb-95	7.24E+00	7.17E-04	7.17E-04	4.71	3.43E-03	3.43E-03	3.43E-03	1.87E-03	7.62E-04	1.87E-03
Zr-95	3.95E+00	1.93E-02	1.93E-02	17.12	1.00E-03	1.00E-03	1.00E-03	5.46E-04	2.23E-04	5.46E-04
Ru-106	6.78E-01	5.08E-01	5.08E-01	19.70	8.73E-04	8.73E-04	8.73E-04	4.76E-04	1.94E-04	4.76E-04
Ag-110m	1.01E+00	3.64E-01	3.64E-01	2.69	5.66E-03	5.66E-03	5.66E-03	3.08E-03	1.26E-03	3.08E-03
Sb-125	2.51E-01	7.78E-01	7.78E-01	4.71	3.43E-03	3.43E-03	3.43E-03	1.87E-03	7.62E-04	1.87E-03
I-129	4.41E-08	1.00E+00	1.00E+00	0.43	2.09E-02	2.09E-02	2.09E-02	1.14E-02	4.65E-03	1.14E-02
Cs-134	3.36E-01	7.15E-01	7.15E-01	5.53	2.95E-03	2.95E-03	2.95E-03	1.61E-03	6.57E-04	1.61E-03
Cs-137	2.31E-02	9.77E-01	9.77E-01	5.53	2.95E-03	2.95E-03	2.95E-03	1.61E-03	6.57E-04	1.61E-03
Pu-238	7.90E-03	9.92E-01	9.92E-01	11.82	1.44E-03	1.44E-03	1.44E-03	7.82E-04	3.19E-04	7.82E-04
Pu-239	2.87E-05	1.00E+00	1.00E+00	11.82	1.44E-03	1.44E-03	1.44E-03	7.82E-04	3.19E-04	7.82E-04
Pu-240	1.06E-04	1.00E+00	1.00E+00	11.82	1.44E-03	1.44E-03	1.44E-03	7.82E-04	3.19E-04	7.82E-04

*Appendix J: Comparison of Disposal Facility Types*  
*Attachment 1: Analytical Support Files for the Comparison of Disposal Facilities*

**MSW Reference Landfill Analyses**

**Radionuclide Activity Released per Unit Activity Placed in Disposal Facility**

Percent of activity released =	0.5%	0.9%	1.2%	1.8%	3.1%	4.3%	5.6%	8.9%	12.6%	16.5%	19.1%	21.6%	23.3%	23.5%	23.5%
Cumulative activity released =	0.08979	0.15736	0.21773	0.32650	0.56161	0.77892	1.00192	1.59543	2.26704	2.97828	3.43415	3.88711	4.19969	4.22636	4.22677
Relative activity released =	2.1%	3.7%	5.2%	7.7%	13.3%	18.4%	23.7%	37.7%	53.6%	70.5%	81.2%	92.0%	99.4%	100.0%	100.0%
Cum. released/SC&A released =	78.4%	77.7%	77.3%	77.1%	77.3%	64.6%	47.4%	50.6%	59.8%	66.0%	72.1%	80.9%	87.4%	88.0%	88.0%

*100 Groundwater travel time (years)*

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.01222	0.02429	0.03621	0.05960	0.11562	0.17268	0.23728	0.44928	0.70754	0.93815	0.97144	0.97259	0.97259	0.97259	0.97259
Fe-55	0.00585	0.01034	0.01380	0.01849	0.02346	0.02439	0.02442	0.02442	0.02442	0.02442	0.02442	0.02442	0.02442	0.02442	0.02442
Mn-54	0.00740	0.01067	0.01212	0.01304	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326
Co-58	0.00528	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543
Co-60	0.00528	0.00988	0.01389	0.02044	0.03072	0.03500	0.03561	0.03561	0.03561	0.03561	0.03561	0.03561	0.03561	0.03561	0.03561
Ni-63	0.00310	0.00616	0.00919	0.01517	0.02957	0.04420	0.05944	0.08107	0.10379	0.11851	0.11959	0.11960	0.11960	0.11960	0.11960
Sr-90	0.00517	0.01020	0.01508	0.02441	0.04550	0.06419	0.07817	0.08005	0.08067	0.08072	0.08072	0.08072	0.08072	0.08072	0.08072
Nb-95	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343
Zr-95	0.00100	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102
Ru-106	0.00087	0.00132	0.00154	0.00171	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177
Ag-110m	0.00566	0.00771	0.00845	0.00882	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887
Sb-125	0.00343	0.00608	0.00814	0.01098	0.01405	0.01466	0.01468	0.01468	0.01468	0.01468	0.01468	0.01468	0.01468	0.01468	0.01468
I-129	0.02089	0.04134	0.06137	0.10018	0.19032	0.27793	0.37211	0.64581	0.88729	0.99636	0.99998	0.99999	0.99999	0.99999	0.99999
Cs-134	0.00295	0.00506	0.00656	0.00839	0.00993	0.01011	0.01012	0.01012	0.01012	0.01012	0.01012	0.01012	0.01012	0.01012	0.01012
Cs-137	0.00295	0.00583	0.00864	0.01403	0.02635	0.03748	0.04607	0.04744	0.04795	0.04800	0.04800	0.04800	0.04800	0.04800	0.04800
Pu-238	0.00144	0.00286	0.00427	0.00705	0.01377	0.02063	0.02775	0.03719	0.04726	0.05401	0.05455	0.05455	0.05455	0.05455	0.05455
Pu-239	0.00144	0.00287	0.00430	0.00716	0.01426	0.02194	0.03126	0.06826	0.13789	0.31589	0.53127	0.77050	0.94496	0.96143	0.96172
Pu-240	0.00144	0.00287	0.00430	0.00716	0.01426	0.02193	0.03123	0.06772	0.13603	0.30803	0.51000	0.72256	0.86067	0.87087	0.87099
Cumulative Leaching, ΣR															

**Industrial Reference Landfill Analyses, high permeability waste**

**Input Parameters and Leach Rate Constants**

$$\text{Leach Rate } L = I / (\theta * T_0 * (1 + \rho_b K_d) / \theta)$$

	Start Year	0	3	5	10	20	50
Infiltration rate (m/yr)	I =	0.3420	0.3420	0.3420	0.3420	0.0761	0.1090
Volumetric water content	$\theta$ =	0.055	0.055	0.055	0.055	0.055	0.125
Thickness (m)	$T_0$ =	2.57	2.57	2.57	2.57	2.57	2.57
Bulk density, unsaturated waste (g/cm <sup>3</sup> )	$\rho_b$ =	1.21	1.21	1.21	1.21	1.21	1.21

Radionuclide	Decay Constant		$K_d$	Leach Rate					
	$\lambda, \text{yr}^{-1}$	$e^{-\lambda}$		0	3	5	10	20	50
C-14	1.21E-04	1.00E+00	11.00	9.96E-03	9.96E-03	9.96E-03	9.96E-03	2.22E-03	3.16E-03
Fe-55	2.57E-01	7.73E-01	209.00	5.26E-04	5.26E-04	5.26E-04	5.26E-04	1.17E-04	1.68E-04
Mn-54	8.10E-01	4.45E-01	158.00	6.96E-04	6.96E-04	6.96E-04	6.96E-04	1.55E-04	2.22E-04
Co-58	3.58E+00	2.79E-02	235.00	4.68E-04	4.68E-04	4.68E-04	4.68E-04	1.04E-04	1.49E-04
Co-60	1.32E-01	8.76E-01	235.00	4.68E-04	4.68E-04	4.68E-04	4.68E-04	1.04E-04	1.49E-04
Ni-63	7.22E-03	9.93E-01	424.00	2.59E-04	2.59E-04	2.59E-04	2.59E-04	5.77E-05	8.26E-05
Sr-90	2.41E-02	9.76E-01	32.00	3.43E-03	3.43E-03	3.43E-03	3.43E-03	7.64E-04	1.09E-03
Nb-95	7.24E+00	7.17E-04	380.00	2.89E-04	2.89E-04	2.89E-04	2.89E-04	6.44E-05	9.22E-05
Zr-95	3.95E+00	1.93E-02	1,380.00	7.97E-05	7.97E-05	7.97E-05	7.97E-05	1.77E-05	2.54E-05
Ru-106	6.78E-01	5.08E-01	1,588.00	6.93E-05	6.93E-05	6.93E-05	6.93E-05	1.54E-05	2.21E-05
Ag-110m	1.01E+00	3.64E-01	217.00	5.07E-04	5.07E-04	5.07E-04	5.07E-04	1.13E-04	1.61E-04
Sb-125	2.51E-01	7.78E-01	380.00	2.89E-04	2.89E-04	2.89E-04	2.89E-04	6.44E-05	9.22E-05
I-129	4.41E-08	1.00E+00	4.60	2.37E-02	2.37E-02	2.37E-02	2.37E-02	5.27E-03	7.45E-03
Cs-134	3.36E-01	7.15E-01	446.00	2.47E-04	2.47E-04	2.47E-04	2.47E-04	5.49E-05	7.86E-05
Cs-137	2.31E-02	9.77E-01	446.00	2.47E-04	2.47E-04	2.47E-04	2.47E-04	5.49E-05	7.86E-05
Pu-238	7.90E-03	9.92E-01	953.00	1.15E-04	1.15E-04	1.15E-04	1.15E-04	2.57E-05	3.68E-05
Pu-239	2.87E-05	1.00E+00	953.00	1.15E-04	1.15E-04	1.15E-04	1.15E-04	2.57E-05	3.68E-05
Pu-240	1.06E-04	1.00E+00	953.00	1.15E-04	1.15E-04	1.15E-04	1.15E-04	2.57E-05	3.68E-05

*Appendix J: Comparison of Disposal Facility Types*  
*Attachment 1: Analytical Support Files for the Comparison of Disposal Facilities*

**Industrial Reference Landfill Analyses, high permeability waste**

**Radionuclide Activity Released per Unit Activity Placed in Disposal Facility**

Percent of activity released =	0.2%	0.4%	0.6%	0.9%	1.7%	3.2%	4.0%	5.6%	7.6%	10.1%	11.2%	11.7%	12.6%	13.5%	15.5%
Cumulative activity released =	0.03425	0.06783	0.10076	0.16470	0.31405	0.57281	0.71877	0.99946	1.37242	1.82632	2.01141	2.10524	2.26062	2.43681	2.78850
Relative activity released =	1.2%	2.4%	3.6%	5.9%	11.3%	20.5%	25.8%	35.8%	49.2%	65.5%	72.1%	75.5%	81.1%	87.4%	100.0%
Cum. released/SC&A released =	29.9%	33.5%	35.8%	38.9%	43.2%	47.5%	34.0%	31.7%	36.2%	40.5%	42.2%	43.8%	47.1%	50.7%	58.0%

Radionuclide	100 Groundwater travel time (years)														
	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.00984	0.01958	0.02922	0.04820	0.09403	0.17900	0.23085	0.34052	0.51256	0.78995	0.92328	0.95411	0.95532	0.95532	0.95532
Fe-55	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Mn-54	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Co-58	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Co-60	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ni-63	0.00013	0.00025	0.00038	0.00062	0.00122	0.00235	0.00300	0.00417	0.00554	0.00668	0.00682	0.00682	0.00682	0.00682	0.00682
Sr-90	0.00031	0.00061	0.00090	0.00146	0.00273	0.00481	0.00565	0.00642	0.00671	0.00673	0.00673	0.00673	0.00673	0.00673	0.00673
Nb-95	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Zr-95	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ru-106	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ag-110m	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Sb-125	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
I-129	0.02367	0.04679	0.06935	0.11290	0.21305	0.38071	0.47146	0.63638	0.82790	0.98175	0.99956	0.99999	0.99999	0.99999	0.99999
Cs-134	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Cs-137	0.00002	0.00005	0.00007	0.00012	0.00022	0.00040	0.00047	0.00054	0.00057	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058
Pu-238	0.00005	0.00010	0.00016	0.00026	0.00051	0.00097	0.00124	0.00170	0.00222	0.00262	0.00266	0.00266	0.00266	0.00266	0.00266
Pu-239	0.00012	0.00023	0.00035	0.00058	0.00115	0.00230	0.00306	0.00489	0.00851	0.01925	0.03669	0.06989	0.15741	0.26998	0.56062
Pu-240	0.00011	0.00023	0.00034	0.00057	0.00114	0.00228	0.00304	0.00483	0.00839	0.01876	0.03510	0.06446	0.13112	0.19473	0.25579
Cumulative Leaching, ΣR															

**Industrial Reference Landfill Analyses, low permeability waste**

**Input Parameters and Leach Rate Constants**

$$\text{Leach Rate } L = I/(\theta \cdot T_0 \cdot (1 + \rho_b K_d) / \theta)$$

	Start Year	0	3	5	10	20	50
Infiltration rate (m/yr)	I =	0.1130	0.1130	0.1130	0.1130	0.0761	0.1090
Volumetric water content	$\theta$ =	0.187	0.187	0.187	0.187	0.187	0.187
Thickness (m)	$T_0$ =	2.57	2.57	2.57	2.57	2.57	2.57
Bulk density, unsaturated waste (g/cm <sup>3</sup> )	$\rho_b$ =	1.47	1.47	1.47	1.47	1.47	1.47

Radionuclide	Decay Constant $\lambda, \text{yr}^{-1}$		$e^{-\lambda}$	$K_d$	Leach Rate					
					0	3	5	10	20	50
C-14	1.21E-04	1.00E+00	11.00	2.69E-03	2.69E-03	2.69E-03	2.69E-03	1.81E-03	2.59E-03	
Fe-55	2.57E-01	7.73E-01	209.00	1.43E-04	1.43E-04	1.43E-04	1.43E-04	9.63E-05	1.38E-04	
Mn-54	8.10E-01	4.45E-01	158.00	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.27E-04	1.82E-04	
Co-58	3.58E+00	2.79E-02	235.00	1.27E-04	1.27E-04	1.27E-04	1.27E-04	8.57E-05	1.23E-04	
Co-60	1.32E-01	8.76E-01	235.00	1.27E-04	1.27E-04	1.27E-04	1.27E-04	8.57E-05	1.23E-04	
Ni-63	7.22E-03	9.93E-01	424.00	7.05E-05	7.05E-05	7.05E-05	7.05E-05	4.75E-05	6.80E-05	
Sr-90	2.41E-02	9.76E-01	32.00	9.31E-04	9.31E-04	9.31E-04	9.31E-04	6.27E-04	8.98E-04	
Nb-95	7.24E+00	7.17E-04	380.00	7.87E-05	7.87E-05	7.87E-05	7.87E-05	5.30E-05	7.59E-05	
Zr-95	3.95E+00	1.93E-02	1,380.00	2.17E-05	2.17E-05	2.17E-05	2.17E-05	1.46E-05	2.09E-05	
Ru-106	6.78E-01	5.08E-01	1,588.00	1.88E-05	1.88E-05	1.88E-05	1.88E-05	1.27E-05	1.82E-05	
Ag-110m	1.01E+00	3.64E-01	217.00	1.38E-04	1.38E-04	1.38E-04	1.38E-04	9.28E-05	1.33E-04	
Sb-125	2.51E-01	7.78E-01	380.00	7.87E-05	7.87E-05	7.87E-05	7.87E-05	5.30E-05	7.59E-05	
I-129	4.41E-08	1.00E+00	4.60	6.33E-03	6.33E-03	6.33E-03	6.33E-03	4.26E-03	6.10E-03	
Cs-134	3.36E-01	7.15E-01	446.00	6.70E-05	6.70E-05	6.70E-05	6.70E-05	4.52E-05	6.47E-05	
Cs-137	2.31E-02	9.77E-01	446.00	6.70E-05	6.70E-05	6.70E-05	6.70E-05	4.52E-05	6.47E-05	
Pu-238	7.90E-03	9.92E-01	953.00	3.14E-05	3.14E-05	3.14E-05	3.14E-05	2.11E-05	3.03E-05	
Pu-239	2.87E-05	1.00E+00	953.00	3.14E-05	3.14E-05	3.14E-05	3.14E-05	2.11E-05	3.03E-05	
Pu-240	1.06E-04	1.00E+00	953.00	3.14E-05	3.14E-05	3.14E-05	3.14E-05	2.11E-05	3.03E-05	

*Appendix J: Comparison of Disposal Facility Types*  
*Attachment I: Analytical Support Files for the Comparison of Disposal Facilities*

**Industrial Reference Landfill Analyses, low permeability waste**

**Radionuclide Activity Released per Unit Activity Placed in Disposal Facility**

Percent of activity released =	0.1%	0.1%	0.2%	0.3%	0.5%	1.0%	1.8%	3.6%	6.1%	9.4%	10.8%	11.4%	12.2%	13.0%	14.9%
Cumulative activity released =	0.00918	0.01832	0.02740	0.04542	0.08963	0.17453	0.33257	0.64895	1.09285	1.68390	1.94321	2.05711	2.19129	2.34360	2.68377
Relative activity released =	0.3%	0.7%	1.0%	1.7%	3.3%	6.5%	12.4%	24.2%	40.7%	62.7%	72.4%	76.7%	81.6%	87.3%	100.0%
Cum. released/SC&A released =	8.0%	9.0%	9.7%	10.7%	12.3%	14.5%	15.7%	20.6%	28.8%	37.3%	40.8%	42.8%	45.6%	48.8%	55.9%

100 Groundwater travel time (years)

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.00266	0.00530	0.00794	0.01320	0.02622	0.05172	0.10105	0.20803	0.38295	0.69524	0.87945	0.93896	0.94317	0.94317	0.94317
Fe-55	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Mn-54	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Co-58	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Co-60	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ni-63	0.00003	0.00007	0.00010	0.00017	0.00033	0.00064	0.00118	0.00215	0.00328	0.00422	0.00434	0.00434	0.00434	0.00434	0.00434
Sr-90	0.00008	0.00017	0.00024	0.00040	0.00075	0.00133	0.00206	0.00274	0.00299	0.00301	0.00301	0.00301	0.00301	0.00301	0.00301
Nb-95	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Zr-95	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ru-106	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ag-110m	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Sb-125	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
I-129	0.00633	0.01261	0.01886	0.03124	0.06150	0.11922	0.22513	0.42945	0.69067	0.95070	0.99768	0.99998	0.99999	0.99999	0.99999
Cs-134	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Cs-137	0.00001	0.00001	0.00002	0.00003	0.00006	0.00011	0.00017	0.00023	0.00025	0.00026	0.00026	0.00026	0.00026	0.00026	0.00026
Pu-238	0.00001	0.00003	0.00004	0.00007	0.00014	0.00026	0.00048	0.00087	0.00130	0.00162	0.00165	0.00165	0.00165	0.00165	0.00165
Pu-239	0.00003	0.00006	0.00009	0.00016	0.00031	0.00063	0.00126	0.00276	0.00575	0.01462	0.02907	0.05671	0.13049	0.22785	0.51174
Pu-240	0.00003	0.00006	0.00009	0.00016	0.00031	0.00062	0.00124	0.00273	0.00566	0.01423	0.02776	0.05220	0.10838	0.16334	0.21962
Cumulative Leaching, ΣR															

### Construction & Demolition Reference Landfill Analysis

#### Input Parameters and Leach Rate Constants

$$\text{Leach Rate } L = I / (\theta * T_0 * (1 + \rho_b K_d) / \theta)$$

	Start Year	0	3	5	10	20	50
Infiltration rate (m/yr)	I =	0.5360	0.5360	0.1090	0.1090	0.1090	0.1090
Volumetric water content	$\theta$ =	0.03	0.03	0.03	0.03	0.03	0.03
Thickness (m)	$T_0$ =	5.30	5.30	5.30	5.30	5.30	5.30
Bulk density, unsaturated waste (g/cm <sup>3</sup> )	$\rho_b$ =	2.10	2.10	2.10	2.10	2.10	2.10

Radionuclide	Decay Constant $\lambda, \text{yr}^{-1}$		$e^{-\lambda}$	$K_d$	Leach Rate					
					0	3	5	10	20	50
C-14	1.21E-04	1.00E+00	11.00	4.37E-03	4.37E-03	8.89E-04	8.89E-04	8.89E-04	8.89E-04	
Fe-55	2.57E-01	7.73E-01	209.00	2.30E-04	2.30E-04	4.69E-05	4.69E-05	4.69E-05	4.69E-05	
Mn-54	8.10E-01	4.45E-01	158.00	3.05E-04	3.05E-04	6.20E-05	6.20E-05	6.20E-05	6.20E-05	
Co-58	3.58E+00	2.79E-02	235.00	2.05E-04	2.05E-04	4.17E-05	4.17E-05	4.17E-05	4.17E-05	
Co-60	1.32E-01	8.76E-01	235.00	2.05E-04	2.05E-04	4.17E-05	4.17E-05	4.17E-05	4.17E-05	
Ni-63	7.22E-03	9.93E-01	424.00	1.14E-04	1.14E-04	2.31E-05	2.31E-05	2.31E-05	2.31E-05	
Sr-90	2.41E-02	9.76E-01	32.00	1.50E-03	1.50E-03	3.06E-04	3.06E-04	3.06E-04	3.06E-04	
Nb-95	7.24E+00	7.17E-04	380.00	1.27E-04	1.27E-04	2.58E-05	2.58E-05	2.58E-05	2.58E-05	
Zr-95	3.95E+00	1.93E-02	1,380.00	3.49E-05	3.49E-05	7.10E-06	7.10E-06	7.10E-06	7.10E-06	
Ru-106	6.78E-01	5.08E-01	1,588.00	3.03E-05	3.03E-05	6.17E-06	6.17E-06	6.17E-06	6.17E-06	
Ag-110m	1.01E+00	3.64E-01	217.00	2.22E-04	2.22E-04	4.51E-05	4.51E-05	4.51E-05	4.51E-05	
Sb-125	2.51E-01	7.78E-01	380.00	1.27E-04	1.27E-04	2.58E-05	2.58E-05	2.58E-05	2.58E-05	
I-129	4.41E-08	1.00E+00	4.60	1.04E-02	1.04E-02	2.12E-03	2.12E-03	2.12E-03	2.12E-03	
Cs-134	3.36E-01	7.15E-01	446.00	1.08E-04	1.08E-04	2.20E-05	2.20E-05	2.20E-05	2.20E-05	
Cs-137	2.31E-02	9.77E-01	446.00	1.08E-04	1.08E-04	2.20E-05	2.20E-05	2.20E-05	2.20E-05	
Pu-238	7.90E-03	9.92E-01	953.00	5.05E-05	5.05E-05	1.03E-05	1.03E-05	1.03E-05	1.03E-05	
Pu-239	2.87E-05	1.00E+00	953.00	5.05E-05	5.05E-05	1.03E-05	1.03E-05	1.03E-05	1.03E-05	
Pu-240	1.06E-04	1.00E+00	953.00	5.05E-05	5.05E-05	1.03E-05	1.03E-05	1.03E-05	1.03E-05	

*Appendix J: Comparison of Disposal Facility Types*  
*Attachment 1: Analytical Support Files for the Comparison of Disposal Facilities*

**Construction & Demolition Reference Landfill Analysis**

**Radionuclide Activity Released per Unit Activity Placed in Disposal Facility**

Percent of activity released =	0.1%	0.2%	0.2%	0.4%	0.5%	0.7%	1.1%	1.8%	3.1%	5.8%	8.2%	9.9%	10.9%	11.2%	12.4%
Cumulative activity released =	0.01508	0.03003	0.04485	0.07409	0.08871	0.11750	0.20064	0.32932	0.55466	1.03921	1.47033	1.78729	1.95598	2.02129	2.22666
Relative activity released =	0.7%	1.3%	2.0%	3.3%	4.0%	5.3%	9.0%	14.8%	24.9%	46.7%	66.0%	80.3%	87.8%	90.8%	100.0%
Cum. released/SC&A released =	13.2%	14.8%	15.9%	17.5%	12.2%	9.7%	9.5%	10.4%	14.6%	23.0%	30.8%	37.2%	40.7%	42.1%	46.3%

*100 Groundwater travel time (years)*

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.00432	0.00862	0.01290	0.02141	0.02569	0.03420	0.05921	0.09925	0.17350	0.35611	0.56065	0.75852	0.86631	0.87174	0.87177
Fe-55	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Mn-54	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Co-58	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Co-60	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ni-63	0.00006	0.00011	0.00016	0.00027	0.00033	0.00043	0.00069	0.00102	0.00141	0.00173	0.00177	0.00177	0.00177	0.00177	0.00177
Sr-90	0.00014	0.00027	0.00040	0.00064	0.00076	0.00095	0.00131	0.00155	0.00164	0.00164	0.00164	0.00164	0.00164	0.00164	0.00164
Nb-95	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Zr-95	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ru-106	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ag-110m	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Sb-125	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
I-129	0.01044	0.02076	0.03098	0.05111	0.06113	0.08087	0.13763	0.22454	0.37297	0.66850	0.88540	0.98629	0.99995	0.99998	0.99998
Cs-134	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Cs-137	0.00001	0.00002	0.00003	0.00005	0.00006	0.00008	0.00011	0.00013	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014
Pu-238	0.00002	0.00005	0.00007	0.00011	0.00013	0.00018	0.00028	0.00041	0.00056	0.00067	0.00068	0.00068	0.00068	0.00068	0.00068
Pu-239	0.00005	0.00010	0.00015	0.00025	0.00030	0.00041	0.00071	0.00122	0.00224	0.00527	0.01025	0.01991	0.04674	0.08504	0.26305
Pu-240	0.00005	0.00010	0.00015	0.00025	0.00030	0.00040	0.00071	0.00121	0.00221	0.00514	0.00980	0.01834	0.03875	0.06030	0.08763
Cumulative Leaching, ΣR															

### LLW Reference Disposal Facility Analysis

#### Input Parameters and Leach Rate Constants

$$\text{Leach Rate } L = I/(\theta * T_0 * (1 + \rho_b K_d) / \theta)$$

	Start Year	0	3	5	10	20	50
Infiltration rate (m/yr)	I =	0.0008	0.0004	0.0001	0.0001	0.0001	0.0004
Volumetric water content	$\theta$ =	0.19	0.19	0.19	0.19	0.19	0.19
Thickness (m)	$T_0$ =	13.10	13.10	13.10	13.10	13.10	13.10
Bulk density, unsaturated waste (g/cm <sup>3</sup> )	$\rho_b$ =	2.10	2.10	2.10	2.10	2.10	2.10

Radionuclide	Decay Constant $\lambda, \text{yr}^{-1}$		$e^{-\lambda}$	$K_d$	Leach Rate					
					0	3	5	10	20	50
C-14	1.21E-04	1.00E+00	11.00	2.62E-06	1.31E-06	3.28E-07	3.28E-07	3.28E-07	1.31E-06	
Fe-55	2.57E-01	7.73E-01	209.00	1.39E-07	6.95E-08	1.74E-08	1.74E-08	1.74E-08	6.95E-08	
Mn-54	8.10E-01	4.45E-01	158.00	1.84E-07	9.20E-08	2.30E-08	2.30E-08	2.30E-08	9.20E-08	
Co-58	3.58E+00	2.79E-02	235.00	1.24E-07	6.18E-08	1.55E-08	1.55E-08	1.55E-08	6.18E-08	
Co-60	1.32E-01	8.76E-01	235.00	1.24E-07	6.18E-08	1.55E-08	1.55E-08	1.55E-08	6.18E-08	
Ni-63	7.22E-03	9.93E-01	424.00	6.86E-08	3.43E-08	8.57E-09	8.57E-09	8.57E-09	3.43E-08	
Sr-90	2.41E-02	9.76E-01	32.00	9.06E-07	4.53E-07	1.13E-07	1.13E-07	1.13E-07	4.53E-07	
Nb-95	7.24E+00	7.17E-04	380.00	7.65E-08	3.83E-08	9.56E-09	9.56E-09	9.56E-09	3.83E-08	
Zr-95	3.95E+00	1.93E-02	1,380.00	2.11E-08	1.05E-08	2.63E-09	2.63E-09	2.63E-09	1.05E-08	
Ru-106	6.78E-01	5.08E-01	1,588.00	1.83E-08	9.16E-09	2.29E-09	2.29E-09	2.29E-09	9.16E-09	
Ag-110m	1.01E+00	3.64E-01	217.00	1.34E-07	6.70E-08	1.67E-08	1.67E-08	1.67E-08	6.70E-08	
Sb-125	2.51E-01	7.78E-01	380.00	7.65E-08	3.83E-08	9.56E-09	9.56E-09	9.56E-09	3.83E-08	
I-129	4.41E-08	1.00E+00	4.60	6.20E-06	3.10E-06	7.75E-07	7.75E-07	7.75E-07	3.10E-06	
Cs-134	3.36E-01	7.15E-01	446.00	6.52E-08	3.26E-08	8.15E-09	8.15E-09	8.15E-09	3.26E-08	
Cs-137	2.31E-02	9.77E-01	446.00	6.52E-08	3.26E-08	8.15E-09	8.15E-09	8.15E-09	3.26E-08	
Pu-238	7.90E-03	9.92E-01	953.00	3.05E-08	1.53E-08	3.81E-09	3.81E-09	3.81E-09	1.53E-08	
Pu-239	2.87E-05	1.00E+00	953.00	3.05E-08	1.53E-08	3.81E-09	3.81E-09	3.81E-09	1.53E-08	
Pu-240	1.06E-04	1.00E+00	953.00	3.05E-08	1.53E-08	3.81E-09	3.81E-09	3.81E-09	1.53E-08	

*Appendix J: Comparison of Disposal Facility Types*  
*Attachment 1: Analytical Support Files for the Comparison of Disposal Facilities*

**LLW Reference Disposal Facility Analysis**

**Radionuclide Activity Released per Unit Activity Placed in Disposal Facility**

Percent of activity released =	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	5.3%
Cumulative activity released =	0.00001	0.00002	0.00003	0.00004	0.00004	0.00005	0.00009	0.00031	0.00075	0.00206	0.00421	0.00840	0.02022	0.03809	0.95469
Relative activity released =	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%	0.9%	2.1%	4.0%	100.0%
Cum. released/SC&A released =	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%	0.8%	19.9%

100 Groundwater travel time (years)

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.00000	0.00001	0.00001	0.00001	0.00001	0.00002	0.00002	0.00009	0.00022	0.00059	0.00118	0.00226	0.00481	0.00743	0.01055
Fe-55	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Mn-54	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Co-58	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Co-60	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ni-63	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Sr-90	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Nb-95	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Zr-95	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ru-106	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ag-110m	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Sb-125	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
I-129	0.00001	0.00001	0.00002	0.00002	0.00003	0.00004	0.00006	0.00021	0.00052	0.00145	0.00300	0.00609	0.01528	0.03042	0.94346
Cs-134	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Cs-137	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Pu-238	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Pu-239	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00003	0.00007	0.00013	0.00053
Pu-240	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00003	0.00006	0.00009	0.00014
Cumulative Leaching, ΣR															

**Subtitle D MSW Landfill Sensitivity Analyses**  
**Variation in Distribution Coefficient,  $K_d$**   
**Input Parameters and Leach Rate Constants**

$$\text{Leach Rate } L = I/(\theta \cdot T_0 \cdot (1 + \rho_b K_d) / \theta)$$

	Start Year	0	3	5	10	20	50
Infiltration rate (m/yr)	I =	0.200	0.200	0.200	0.109	0.045	0.109
Volumetric water content	$\theta$ =	0.35	0.35	0.35	0.35	0.35	0.35
Thickness (m)	$T_0$ =	13.40	13.40	13.40	13.40	13.40	13.40
Bulk density, unsaturated waste (g/cm <sup>3</sup> )	$\rho_b$ =	0.85	0.85	0.85	0.85	0.85	0.85

Radionuclide	Decay		$K_d$	Leach Rate					
	Constant $\lambda$ , yr <sup>-1</sup>	$e^{-\lambda}$		0	3	5	10	20	50
C-14	1.21E-04	1.00E+00	4.10E-02	3.88E-02	3.88E-02	3.88E-02	2.11E-02	8.63E-03	2.11E-02
Fe-55	2.57E-01	7.73E-01	1.35E+00	9.97E-03	9.97E-03	9.97E-03	5.43E-03	2.22E-03	5.43E-03
Mn-54	8.10E-01	4.45E-01	1.49E+00	9.23E-03	9.23E-03	9.23E-03	5.03E-03	2.05E-03	5.03E-03
Co-58	3.58E+00	2.79E-02	1.74E+00	8.14E-03	8.14E-03	8.14E-03	4.44E-03	1.81E-03	4.44E-03
Co-60	1.32E-01	8.76E-01	1.74E+00	8.14E-03	8.14E-03	8.14E-03	4.44E-03	1.81E-03	4.44E-03
Ni-63	7.22E-03	9.93E-01	9.18E+00	1.83E-03	1.83E-03	1.83E-03	9.98E-04	4.07E-04	9.98E-04
Sr-90	2.41E-02	9.76E-01	3.58E-01	2.28E-02	2.28E-02	2.28E-02	1.24E-02	5.08E-03	1.24E-02
Nb-95	7.24E+00	7.17E-04	1.42E+00	9.61E-03	9.61E-03	9.61E-03	5.24E-03	2.14E-03	5.24E-03
Zr-95	3.95E+00	1.93E-02	5.14E+00	3.16E-03	3.16E-03	3.16E-03	1.72E-03	7.04E-04	1.72E-03
Ru-106	6.78E-01	5.08E-01	6.47E+00	2.55E-03	2.55E-03	2.55E-03	1.39E-03	5.68E-04	1.39E-03
Ag-110m	1.01E+00	3.64E-01	2.48E+00	6.08E-03	6.08E-03	6.08E-03	3.31E-03	1.35E-03	3.31E-03
Sb-125	2.51E-01	7.78E-01	1.42E+00	9.61E-03	9.61E-03	9.61E-03	5.24E-03	2.14E-03	5.24E-03
I-129	4.41E-08	1.00E+00	4.80E-02	3.82E-02	3.82E-02	3.82E-02	2.08E-02	8.50E-03	2.08E-02
Cs-134	3.36E-01	7.15E-01	4.04E+00	3.94E-03	3.94E-03	3.94E-03	2.15E-03	8.77E-04	2.15E-03
Cs-137	2.31E-02	9.77E-01	4.04E+00	3.94E-03	3.94E-03	3.94E-03	2.15E-03	8.77E-04	2.15E-03
Pu-238	7.90E-03	9.92E-01	1.79E+00	7.99E-03	7.99E-03	7.99E-03	4.36E-03	1.78E-03	4.36E-03
Pu-239	2.87E-05	1.00E+00	1.79E+00	7.99E-03	7.99E-03	7.99E-03	4.36E-03	1.78E-03	4.36E-03
Pu-240	1.06E-04	1.00E+00	1.79E+00	7.99E-03	7.99E-03	7.99E-03	4.36E-03	1.78E-03	4.36E-03

Radionuclide	Decay		$K_d$	Leach Rate					
	Constant $\lambda$ , yr <sup>-1</sup>	$e^{-\lambda}$		0	3	5	10	20	50
C-14	1.21E-04	1.00E+00	2.22E+04	7.91E-07	7.91E-07	7.91E-07	4.31E-07	1.76E-07	4.31E-07
Fe-55	2.57E-01	7.73E-01	2.43E+05	7.22E-08	7.22E-08	7.22E-08	3.93E-08	1.61E-08	3.93E-08
Mn-54	8.10E-01	4.45E-01	1.26E+05	1.40E-07	1.40E-07	1.40E-07	7.61E-08	3.11E-08	7.61E-08
Co-58	3.58E+00	2.79E-02	2.38E+05	7.38E-08	7.38E-08	7.38E-08	4.02E-08	1.64E-08	4.02E-08
Co-60	1.32E-01	8.76E-01	2.38E+05	7.38E-08	7.38E-08	7.38E-08	4.02E-08	1.64E-08	4.02E-08
Ni-63	7.22E-03	9.93E-01	1.47E+05	1.19E-07	1.19E-07	1.19E-07	6.50E-08	2.65E-08	6.50E-08
Sr-90	2.41E-02	9.76E-01	2.15E+04	8.17E-07	8.17E-07	8.17E-07	4.45E-07	1.82E-07	4.45E-07
Nb-95	7.24E+00	7.17E-04	7.67E+05	2.29E-08	2.29E-08	2.29E-08	1.25E-08	5.09E-09	1.25E-08
Zr-95	3.95E+00	1.93E-02	2.78E+06	6.31E-09	6.31E-09	6.31E-09	3.44E-09	1.40E-09	3.44E-09
Ru-106	6.78E-01	5.08E-01	2.93E+06	6.00E-09	6.00E-09	6.00E-09	3.27E-09	1.33E-09	3.27E-09
Ag-110m	1.01E+00	3.64E-01	1.43E+05	1.23E-07	1.23E-07	1.23E-07	6.70E-08	2.73E-08	6.70E-08
Sb-125	2.51E-01	7.78E-01	7.67E+05	2.29E-08	2.29E-08	2.29E-08	1.25E-08	5.09E-09	1.25E-08
I-129	4.41E-08	1.00E+00	4.41E+02	3.98E-05	3.98E-05	3.98E-05	2.17E-05	8.85E-06	2.17E-05
Cs-134	3.36E-01	7.15E-01	3.70E+05	4.75E-08	4.75E-08	4.75E-08	2.59E-08	1.06E-08	2.59E-08
Cs-137	2.31E-02	9.77E-01	3.70E+05	4.75E-08	4.75E-08	4.75E-08	2.59E-08	1.06E-08	2.59E-08
Pu-238	7.90E-03	9.92E-01	5.09E+05	3.45E-08	3.45E-08	3.45E-08	1.88E-08	7.68E-09	1.88E-08
Pu-239	2.87E-05	1.00E+00	5.09E+05	3.45E-08	3.45E-08	3.45E-08	1.88E-08	7.68E-09	1.88E-08
Pu-240	1.06E-04	1.00E+00	5.09E+05	3.45E-08	3.45E-08	3.45E-08	1.88E-08	7.68E-09	1.88E-08

**Subtitle D MSW Landfill Sensitivity Analyses  
 Variation in Distribution Coefficient, Kd  
 Radionuclide Activity Released per Unit Activity Placed in Disposal Facility**

Percent of activity released =	1.1%	2.0%	2.8%	4.2%	7.3%	9.9%	12.3%	17.5%	21.8%	25.6%	26.7%	26.8%	26.8%	26.8%	26.8%
Cumulative activity released =	0.19997	0.35788	0.50174	0.76167	1.30739	1.77843	2.21917	3.15165	3.92527	4.60232	4.80183	4.82582	4.82611	4.82611	4.82611
Relative activity released =	4.1%	7.4%	10.4%	15.8%	27.1%	36.9%	46.0%	65.3%	81.3%	95.4%	99.5%	100.0%	100.0%	100.0%	100.0%

100 Groundwater travel time (years)

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	100000
C-14	0.03879	0.07606	0.11189	0.17941	0.32654	0.45584	0.57983	0.84943	0.97295	0.98924	0.98927	0.98927	0.98927	0.98927	0.98927
Fe-55	0.00997	0.01761	0.02345	0.03136	0.03961	0.04112	0.04117	0.04117	0.04117	0.04117	0.04117	0.04117	0.04117	0.04117	0.04117
Mn-54	0.00923	0.01329	0.01509	0.01622	0.01649	0.01650	0.01650	0.01650	0.01650	0.01650	0.01650	0.01650	0.01650	0.01650	0.01650
Co-58	0.00814	0.00837	0.00837	0.00837	0.00837	0.00837	0.00837	0.00837	0.00837	0.00837	0.00837	0.00837	0.00837	0.00837	0.00837
Co-60	0.00814	0.01522	0.02137	0.03136	0.04693	0.05330	0.05420	0.05420	0.05420	0.05420	0.05420	0.05420	0.05420	0.05420	0.05420
Ni-63	0.00183	0.00365	0.00544	0.00899	0.01759	0.02637	0.03560	0.04896	0.06368	0.07426	0.07522	0.07524	0.07524	0.07524	0.07524
Sr-90	0.02281	0.04457	0.06533	0.10402	0.18617	0.25232	0.29685	0.30155	0.30243	0.30245	0.30245	0.30245	0.30245	0.30245	0.30245
Nb-95	0.00961	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962	0.00962
Zr-95	0.00316	0.00322	0.00323	0.00323	0.00323	0.00323	0.00323	0.00323	0.00323	0.00323	0.00323	0.00323	0.00323	0.00323	0.00323
Ru-106	0.00255	0.00384	0.00450	0.00500	0.00516	0.00517	0.00517	0.00517	0.00517	0.00517	0.00517	0.00517	0.00517	0.00517	0.00517
Ag-110m	0.00608	0.00828	0.00908	0.00947	0.00953	0.00953	0.00953	0.00953	0.00953	0.00953	0.00953	0.00953	0.00953	0.00953	0.00953
Sb-125	0.00961	0.01702	0.02272	0.03051	0.03880	0.04037	0.04043	0.04043	0.04043	0.04043	0.04043	0.04043	0.04043	0.04043	0.04043
I-129	0.03819	0.07493	0.11026	0.17692	0.32255	0.45106	0.57505	0.85155	0.98188	0.99996	1.00000	1.00000	1.00000	1.00000	1.00000
Cs-134	0.00394	0.00674	0.00874	0.01117	0.01322	0.01346	0.01346	0.01346	0.01346	0.01346	0.01346	0.01346	0.01346	0.01346	0.01346
Cs-137	0.00394	0.00778	0.01151	0.01868	0.03499	0.04965	0.06090	0.06267	0.06332	0.06337	0.06337	0.06337	0.06337	0.06337	0.06337
Pu-238	0.00799	0.01586	0.02360	0.03871	0.07446	0.10963	0.14472	0.18666	0.22168	0.23585	0.23621	0.23621	0.23621	0.23621	0.23621
Pu-239	0.00799	0.01592	0.02378	0.03932	0.07709	0.11649	0.16237	0.32577	0.56224	0.87616	0.97814	0.99074	0.99089	0.99089	0.99089
Pu-240	0.00799	0.01592	0.02378	0.03931	0.07706	0.11642	0.16218	0.32340	0.55542	0.85937	0.95551	0.96689	0.96702	0.96702	0.96702
Cumulative Leaching, ΣR															

Percent of activity leached =	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.6%	1.1%	5.6%
Cumulative activity leached =	0.00004	0.00008	0.00013	0.00021	0.00042	0.00064	0.00092	0.00202	0.00423	0.01082	0.02170	0.04309	0.10432	0.19748	1.00232
Relative activity leached =	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%	0.9%	2.2%	4.1%	20.8%

100 Groundwater travel time (years)

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	100000
C-14	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00002	0.00004	0.00008	0.00020	0.00040	0.00075	0.00159	0.00246	0.00350
Fe-55	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Mn-54	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Co-58	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Co-60	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ni-63	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Sr-90	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Nb-95	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Zr-95	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ru-106	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ag-110m	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Sb-125	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
I-129	0.00004	0.00008	0.00012	0.00020	0.00040	0.00061	0.00088	0.00196	0.00412	0.01058	0.02125	0.04224	0.10255	0.19472	0.99797
Cs-134	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Cs-137	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Pu-238	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Pu-239	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00002	0.00004	0.00009	0.00016	0.00065
Pu-240	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00002	0.00003	0.00007	0.00011	0.00018
Cumulative Leaching, ΣR															

**Subtitle D MSW Landfill Sensitivity Analyses  
 Variation in Infiltration Rate  
 Input Parameters and Leach Rate Constants**

$$\text{Leach Rate } L = I / (\theta * T_0 * (1 + \rho_b K_d) / \theta)$$

		Start Year	0	3	5	10	20	50
Infiltration rate (m/yr)	I =		0.200	0.200	0.200	0.109	0.045	0.109
Volumetric water content	$\theta =$		0.35	0.35	0.35	0.35	0.35	0.35
Thickness (m)	$T_0 =$		13.40	13.40	13.40	13.40	13.40	13.40
Bulk density, unsaturated waste (g/cm <sup>3</sup> )	$\rho_b =$		0.85	0.85	0.85	0.85	0.85	0.85
I =	200%		0.400	0.400	0.400	0.218	0.089	0.218

		Leach Rate							
Radionuclide	Decay Constant $\lambda$ , yr <sup>-1</sup>	$e^{-\lambda}$	$K_d$	0	3	5	10	20	50
C-14	1.21E-04	1.00E+00	1.03	2.44E-02	2.44E-02	2.44E-02	1.33E-02	5.44E-03	1.33E-02
Fe-55	2.57E-01	7.73E-01	2.59	1.17E-02	1.17E-02	1.17E-02	6.37E-03	2.60E-03	6.37E-03
Mn-54	8.10E-01	4.45E-01	1.96	1.48E-02	1.48E-02	1.48E-02	8.07E-03	3.30E-03	8.07E-03
Co-58	3.58E+00	2.79E-02	2.91	1.06E-02	1.06E-02	1.06E-02	5.75E-03	2.35E-03	5.75E-03
Co-60	1.32E-01	8.76E-01	2.91	1.06E-02	1.06E-02	1.06E-02	5.75E-03	2.35E-03	5.75E-03
Ni-63	7.22E-03	9.93E-01	5.26	6.19E-03	6.19E-03	6.19E-03	3.38E-03	1.38E-03	3.38E-03
Sr-90	2.41E-02	9.76E-01	2.98	1.03E-02	1.03E-02	1.03E-02	5.64E-03	2.30E-03	5.64E-03
Nb-95	7.24E+00	7.17E-04	4.71	6.85E-03	6.85E-03	6.85E-03	3.73E-03	1.52E-03	3.73E-03
Zr-95	3.95E+00	1.93E-02	17.12	2.00E-03	2.00E-03	2.00E-03	1.09E-03	4.46E-04	1.09E-03
Ru-106	6.78E-01	5.08E-01	19.70	1.75E-03	1.75E-03	1.75E-03	9.52E-04	3.89E-04	9.52E-04
Ag-110m	1.01E+00	3.64E-01	2.69	1.13E-02	1.13E-02	1.13E-02	6.17E-03	2.52E-03	6.17E-03
Sb-125	2.51E-01	7.78E-01	4.71	6.85E-03	6.85E-03	6.85E-03	3.73E-03	1.52E-03	3.73E-03
I-129	4.41E-08	1.00E+00	0.43	4.18E-02	4.18E-02	4.18E-02	2.28E-02	9.30E-03	2.28E-02
Cs-134	3.36E-01	7.15E-01	5.53	5.91E-03	5.91E-03	5.91E-03	3.22E-03	1.31E-03	3.22E-03
Cs-137	2.31E-02	9.77E-01	5.53	5.91E-03	5.91E-03	5.91E-03	3.22E-03	1.31E-03	3.22E-03
Pu-238	7.90E-03	9.92E-01	11.82	2.87E-03	2.87E-03	2.87E-03	1.56E-03	6.39E-04	1.56E-03
Pu-239	2.87E-05	1.00E+00	11.82	2.87E-03	2.87E-03	2.87E-03	1.56E-03	6.39E-04	1.56E-03
Pu-240	1.06E-04	1.00E+00	11.82	2.87E-03	2.87E-03	2.87E-03	1.56E-03	6.39E-04	1.56E-03

		I =	50%	0.100	0.100	0.100	0.055	0.022	0.055
		Leach Rate							
Radionuclide	Decay Constant $\lambda$ , yr <sup>-1</sup>	$e^{-\lambda}$	$K_d$	0	3	5	10	20	50
C-14	1.21E-04	1.00E+00	1.03	6.11E-03	6.11E-03	6.11E-03	3.33E-03	1.36E-03	3.33E-03
Fe-55	2.57E-01	7.73E-01	2.59	2.92E-03	2.92E-03	2.92E-03	1.59E-03	6.50E-04	1.59E-03
Mn-54	8.10E-01	4.45E-01	1.96	3.70E-03	3.70E-03	3.70E-03	2.02E-03	8.24E-04	2.02E-03
Co-58	3.58E+00	2.79E-02	2.91	2.64E-03	2.64E-03	2.64E-03	1.44E-03	5.87E-04	1.44E-03
Co-60	1.32E-01	8.76E-01	2.91	2.64E-03	2.64E-03	2.64E-03	1.44E-03	5.87E-04	1.44E-03
Ni-63	7.22E-03	9.93E-01	5.26	1.55E-03	1.55E-03	1.55E-03	8.44E-04	3.45E-04	8.44E-04
Sr-90	2.41E-02	9.76E-01	2.98	2.59E-03	2.59E-03	2.59E-03	1.41E-03	5.75E-04	1.41E-03
Nb-95	7.24E+00	7.17E-04	4.71	1.71E-03	1.71E-03	1.71E-03	9.34E-04	3.81E-04	9.34E-04
Zr-95	3.95E+00	1.93E-02	17.12	5.01E-04	5.01E-04	5.01E-04	2.73E-04	1.11E-04	2.73E-04
Ru-106	6.78E-01	5.08E-01	19.70	4.37E-04	4.37E-04	4.37E-04	2.38E-04	9.72E-05	2.38E-04
Ag-110m	1.01E+00	3.64E-01	2.69	2.83E-03	2.83E-03	2.83E-03	1.54E-03	6.30E-04	1.54E-03
Sb-125	2.51E-01	7.78E-01	4.71	1.71E-03	1.71E-03	1.71E-03	9.34E-04	3.81E-04	9.34E-04
I-129	4.41E-08	1.00E+00	0.43	1.04E-02	1.04E-02	1.04E-02	5.69E-03	2.32E-03	5.69E-03
Cs-134	3.36E-01	7.15E-01	5.53	1.48E-03	1.48E-03	1.48E-03	8.05E-04	3.29E-04	8.05E-04
Cs-137	2.31E-02	9.77E-01	5.53	1.48E-03	1.48E-03	1.48E-03	8.05E-04	3.29E-04	8.05E-04
Pu-238	7.90E-03	9.92E-01	11.82	7.18E-04	7.18E-04	7.18E-04	3.91E-04	1.60E-04	3.91E-04
Pu-239	2.87E-05	1.00E+00	11.82	7.18E-04	7.18E-04	7.18E-04	3.91E-04	1.60E-04	3.91E-04
Pu-240	1.06E-04	1.00E+00	11.82	7.18E-04	7.18E-04	7.18E-04	3.91E-04	1.60E-04	3.91E-04

**Subtitle D MSW Landfill Sensitivity Analyses  
Variation in Infiltration Rate  
Radionuclide Activity Released per Unit Activity Placed in Disposal Facility**

Percent of activity released =	1.0%	1.7%	2.4%	3.6%	6.0%	8.0%	10.0%	14.1%	17.6%	21.2%	23.9%	25.6%	26.0%	26.0%	26.0%
Cumulative activity released =	0.17958	0.31323	0.43124	0.63990	1.07141	1.44308	1.79414	2.54163	3.16945	3.82432	4.30403	4.60829	4.68186	4.68242	4.68242
Relative activity released =	3.8%	6.7%	9.2%	13.7%	22.9%	30.8%	38.3%	54.3%	67.7%	81.7%	91.9%	98.4%	100.0%	100.0%	100.0%

100 Groundwater travel time (years)

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.02444	0.04827	0.07153	0.11633	0.21907	0.31687	0.41948	0.69689	0.90964	0.98252	0.98380	0.98380	0.98380	0.98380	0.98380
Fe-55	0.01169	0.02063	0.02746	0.03667	0.04623	0.04797	0.04803	0.04803	0.04803	0.04803	0.04803	0.04803	0.04803	0.04803	0.04803
Mn-54	0.01481	0.02130	0.02414	0.02594	0.02636	0.02636	0.02636	0.02636	0.02636	0.02636	0.02636	0.02636	0.02636	0.02636	0.02636
Co-58	0.01056	0.01085	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086
Co-60	0.01056	0.01971	0.02765	0.04050	0.06035	0.06838	0.06950	0.06950	0.06950	0.06950	0.06950	0.06950	0.06950	0.06950	0.06950
Ni-63	0.00619	0.01230	0.01833	0.03015	0.05834	0.08649	0.11527	0.15414	0.19048	0.20894	0.20974	0.20974	0.20974	0.20974	0.20974
Sr-90	0.01035	0.02034	0.03000	0.04834	0.08902	0.12407	0.14949	0.15268	0.15356	0.15361	0.15361	0.15361	0.15361	0.15361	0.15361
Nb-95	0.00685	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686
Zr-95	0.00200	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204
Ru-106	0.00175	0.00263	0.00308	0.00342	0.00354	0.00354	0.00354	0.00354	0.00354	0.00354	0.00354	0.00354	0.00354	0.00354	0.00354
Ag-110m	0.01132	0.01539	0.01686	0.01758	0.01769	0.01769	0.01769	0.01769	0.01769	0.01769	0.01769	0.01769	0.01769	0.01769	0.01769
Sb-125	0.00685	0.01215	0.01624	0.02184	0.02786	0.02902	0.02906	0.02906	0.02906	0.02906	0.02906	0.02906	0.02906	0.02906	0.02906
I-129	0.04178	0.08182	0.12018	0.19216	0.34740	0.48166	0.60833	0.87619	0.98763	0.99998	1.00000	1.00000	1.00000	1.00000	1.00000
Cs-134	0.00591	0.01011	0.01309	0.01671	0.01974	0.02009	0.02010	0.02010	0.02010	0.02010	0.02010	0.02010	0.02010	0.02010	0.02010
Cs-137	0.00591	0.01165	0.01722	0.02790	0.05203	0.07350	0.08977	0.09226	0.09310	0.09317	0.09317	0.09317	0.09317	0.09317	0.09317
Pu-238	0.00287	0.00571	0.00852	0.01405	0.02737	0.04083	0.05470	0.07267	0.09084	0.10168	0.10235	0.10236	0.10236	0.10236	0.10236
Pu-239	0.00287	0.00573	0.00859	0.01427	0.02834	0.04343	0.06158	0.13190	0.25679	0.53145	0.77745	0.93820	0.97880	0.97914	0.97914
Pu-240	0.00287	0.00573	0.00859	0.01427	0.02833	0.04341	0.06150	0.13088	0.25340	0.51894	0.74990	0.89339	0.92637	0.92659	0.92659
Cumulative Leaching, ΣR															

Percent of activity leached =	0.2%	0.4%	0.6%	0.9%	1.6%	2.3%	3.0%	5.1%	8.2%	12.7%	15.3%	17.7%	20.6%	21.4%	21.6%
Cumulative activity leached =	0.04489	0.07886	0.10940	0.16493	0.28773	0.40556	0.53208	0.91604	1.47031	2.27716	2.75666	3.18655	3.69993	3.85976	3.87915
Relative activity leached =	1.0%	1.7%	2.3%	3.5%	6.1%	8.7%	11.4%	19.6%	31.4%	48.6%	58.9%	68.1%	79.0%	82.4%	82.8%

100 Groundwater travel time (years)

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.00611	0.01218	0.01821	0.03017	0.05941	0.09021	0.12643	0.25778	0.46125	0.77934	0.92304	0.95310	0.95408	0.95408	0.95408
Fe-55	0.00292	0.00518	0.00691	0.00929	0.01182	0.01230	0.01232	0.01232	0.01232	0.01232	0.01232	0.01232	0.01232	0.01232	0.01232
Mn-54	0.00370	0.00534	0.00607	0.00654	0.00665	0.00665	0.00665	0.00665	0.00665	0.00665	0.00665	0.00665	0.00665	0.00665	0.00665
Co-58	0.00264	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271
Co-60	0.00264	0.00495	0.00696	0.01027	0.01550	0.01771	0.01803	0.01803	0.01803	0.01803	0.01803	0.01803	0.01803	0.01803	0.01803
Ni-63	0.00155	0.00308	0.00460	0.00761	0.01489	0.02235	0.03019	0.04159	0.05431	0.06365	0.06455	0.06456	0.06456	0.06456	0.06456
Sr-90	0.00259	0.00510	0.00756	0.01227	0.02300	0.03265	0.03998	0.04101	0.04137	0.04140	0.04140	0.04140	0.04140	0.04140	0.04140
Nb-95	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171
Zr-95	0.00050	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051
Ru-106	0.00044	0.00066	0.00077	0.00086	0.00089	0.00089	0.00089	0.00089	0.00089	0.00089	0.00089	0.00089	0.00089	0.00089	0.00089
Ag-110m	0.00283	0.00386	0.00423	0.00441	0.00444	0.00444	0.00444	0.00444	0.00444	0.00444	0.00444	0.00444	0.00444	0.00444	0.00444
Sb-125	0.00171	0.00304	0.00408	0.00550	0.00706	0.00737	0.00738	0.00738	0.00738	0.00738	0.00738	0.00738	0.00738	0.00738	0.00738
I-129	0.01045	0.02078	0.03101	0.05115	0.09968	0.14964	0.20697	0.40390	0.66319	0.93924	0.99649	0.99998	0.99999	0.99999	0.99999
Cs-134	0.00148	0.00253	0.00328	0.00420	0.00498	0.00507	0.00508	0.00508	0.00508	0.00508	0.00508	0.00508	0.00508	0.00508	0.00508
Cs-137	0.00148	0.00292	0.00433	0.00704	0.01326	0.01893	0.02334	0.02406	0.02434	0.02437	0.02437	0.02437	0.02437	0.02437	0.02437
Pu-238	0.00072	0.00143	0.00213	0.00353	0.00691	0.01037	0.01397	0.01881	0.02412	0.02789	0.02823	0.02823	0.02823	0.02823	0.02823
Pu-239	0.00072	0.00144	0.00215	0.00358	0.00715	0.01103	0.01575	0.03473	0.07150	0.17299	0.31614	0.52625	0.81461	0.91482	0.92881
Pu-240	0.00072	0.00144	0.00215	0.00358	0.00715	0.01102	0.01573	0.03445	0.07052	0.16857	0.30273	0.48895	0.71297	0.77259	0.77800
Cumulative Leaching, ΣR															

**Subtitle D MSW Landfill Sensitivity Analyses  
 Variation in Volumetric Water Content  
 Input Parameters and Leach Rate Constants**

$$\text{Leach Rate } L = I/(\theta \cdot T_0 \cdot (1 + \rho_b K_d) / \theta)$$

				Start Year	0	3	5	10	20	50
Infiltration rate (m/yr)				I =	0.200	0.200	0.200	0.109	0.045	0.109
Volumetric water content				$\theta$ =	0.35	0.35	0.35	0.35	0.35	0.35
Thickness (m)				$T_0$ =	13.40	13.40	13.40	13.40	13.40	13.40
Bulk density, unsaturated waste (g/cm <sup>3</sup> )				$\rho_b$ =	0.85	0.85	0.85	0.85	0.85	0.85
$\theta$ =				Placed	0.12	0.12	0.12	0.12	0.12	0.12
				Leach Rate						
Radionuclide	Decay Constant $\lambda$ , yr <sup>-1</sup>	$e^{-\lambda}$	$K_d$	0	3	5	10	20	50	
C-14	1.21E-04	1.00E+00	1.03	1.51E-02	1.51E-02	1.51E-02	8.20E-03	3.35E-03	8.20E-03	
Fe-55	2.57E-01	7.73E-01	2.59	6.42E-03	6.42E-03	6.42E-03	3.50E-03	1.43E-03	3.50E-03	
Mn-54	8.10E-01	4.45E-01	1.96	8.36E-03	8.36E-03	8.36E-03	4.56E-03	1.86E-03	4.56E-03	
Co-58	3.58E+00	2.79E-02	2.91	5.75E-03	5.75E-03	5.75E-03	3.13E-03	1.28E-03	3.13E-03	
Co-60	1.32E-01	8.76E-01	2.91	5.75E-03	5.75E-03	5.75E-03	3.13E-03	1.28E-03	3.13E-03	
Ni-63	7.22E-03	9.93E-01	5.26	3.25E-03	3.25E-03	3.25E-03	1.77E-03	7.24E-04	1.77E-03	
Sr-90	2.41E-02	9.76E-01	2.98	5.62E-03	5.62E-03	5.62E-03	3.06E-03	1.25E-03	3.06E-03	
Nb-95	7.24E+00	7.17E-04	4.71	3.62E-03	3.62E-03	3.62E-03	1.97E-03	8.05E-04	1.97E-03	
Zr-95	3.95E+00	1.93E-02	17.12	1.02E-03	1.02E-03	1.02E-03	5.55E-04	2.26E-04	5.55E-04	
Ru-106	6.78E-01	5.08E-01	19.70	8.85E-04	8.85E-04	8.85E-04	4.82E-04	1.97E-04	4.82E-04	
Ag-110m	1.01E+00	3.64E-01	2.69	6.20E-03	6.20E-03	6.20E-03	3.38E-03	1.38E-03	3.38E-03	
Sb-125	2.51E-01	7.78E-01	4.71	3.62E-03	3.62E-03	3.62E-03	1.97E-03	8.05E-04	1.97E-03	
I-129	4.41E-08	1.00E+00	0.43	3.08E-02	3.08E-02	3.08E-02	1.68E-02	6.85E-03	1.68E-02	
Cs-134	3.36E-01	7.15E-01	5.53	3.10E-03	3.10E-03	3.10E-03	1.69E-03	6.89E-04	1.69E-03	
Cs-137	2.31E-02	9.77E-01	5.53	3.10E-03	3.10E-03	3.10E-03	1.69E-03	6.89E-04	1.69E-03	
Pu-238	7.90E-03	9.92E-01	11.82	1.47E-03	1.47E-03	1.47E-03	8.00E-04	3.27E-04	8.00E-04	
Pu-239	2.87E-05	1.00E+00	11.82	1.47E-03	1.47E-03	1.47E-03	8.00E-04	3.27E-04	8.00E-04	
Pu-240	1.06E-04	1.00E+00	11.82	1.47E-03	1.47E-03	1.47E-03	8.00E-04	3.27E-04	8.00E-04	

				Saturated	0.55	0.55	0.55	0.55	0.55	0.55
				Leach Rate						
Radionuclide	Decay Constant $\lambda$ , yr <sup>-1</sup>	$e^{-\lambda}$	$K_d$	0	3	5	10	20	50	
C-14	1.21E-04	1.00E+00	1.03	1.05E-02	1.05E-02	1.05E-02	5.72E-03	2.34E-03	5.72E-03	
Fe-55	2.57E-01	7.73E-01	2.59	5.42E-03	5.42E-03	5.42E-03	2.95E-03	1.21E-03	2.95E-03	
Mn-54	8.10E-01	4.45E-01	1.96	6.74E-03	6.74E-03	6.74E-03	3.67E-03	1.50E-03	3.67E-03	
Co-58	3.58E+00	2.79E-02	2.91	4.93E-03	4.93E-03	4.93E-03	2.69E-03	1.10E-03	2.69E-03	
Co-60	1.32E-01	8.76E-01	2.91	4.93E-03	4.93E-03	4.93E-03	2.69E-03	1.10E-03	2.69E-03	
Ni-63	7.22E-03	9.93E-01	5.26	2.97E-03	2.97E-03	2.97E-03	1.62E-03	6.62E-04	1.62E-03	
Sr-90	2.41E-02	9.76E-01	2.98	4.84E-03	4.84E-03	4.84E-03	2.64E-03	1.08E-03	2.64E-03	
Nb-95	7.24E+00	7.17E-04	4.71	3.28E-03	3.28E-03	3.28E-03	1.79E-03	7.29E-04	1.79E-03	
Zr-95	3.95E+00	1.93E-02	17.12	9.89E-04	9.89E-04	9.89E-04	5.39E-04	2.20E-04	5.39E-04	
Ru-106	6.78E-01	5.08E-01	19.70	8.63E-04	8.63E-04	8.63E-04	4.70E-04	1.92E-04	4.70E-04	
Ag-110m	1.01E+00	3.64E-01	2.69	5.26E-03	5.26E-03	5.26E-03	2.87E-03	1.17E-03	2.87E-03	
Sb-125	2.51E-01	7.78E-01	4.71	3.28E-03	3.28E-03	3.28E-03	1.79E-03	7.29E-04	1.79E-03	
I-129	4.41E-08	1.00E+00	0.43	1.63E-02	1.63E-02	1.63E-02	8.90E-03	3.63E-03	8.90E-03	
Cs-134	3.36E-01	7.15E-01	5.53	2.84E-03	2.84E-03	2.84E-03	1.55E-03	6.32E-04	1.55E-03	
Cs-137	2.31E-02	9.77E-01	5.53	2.84E-03	2.84E-03	2.84E-03	1.55E-03	6.32E-04	1.55E-03	
Pu-238	7.90E-03	9.92E-01	11.82	1.41E-03	1.41E-03	1.41E-03	7.68E-04	3.13E-04	7.68E-04	
Pu-239	2.87E-05	1.00E+00	11.82	1.41E-03	1.41E-03	1.41E-03	7.68E-04	3.13E-04	7.68E-04	
Pu-240	1.06E-04	1.00E+00	11.82	1.41E-03	1.41E-03	1.41E-03	7.68E-04	3.13E-04	7.68E-04	

**Subtitle D MSW Landfill Sensitivity Analyses  
Variation in Volumetric Water Content  
Radionuclide Activity Released per Unit Activity Placed in Disposal Facility**

Percent of activity released =	0.6%	1.1%	1.5%	2.2%	3.8%	5.2%	6.7%	10.2%	13.6%	16.9%	19.3%	21.8%	23.5%	23.7%	23.7%
Cumulative activity released =	0.10694	0.18922	0.26311	0.39640	0.68197	0.94007	1.19765	1.83184	2.44171	3.04050	3.47958	3.93038	4.23396	4.25845	4.25879
Relative activity released =	2.5%	4.4%	6.2%	9.3%	16.0%	22.1%	28.1%	43.0%	57.3%	71.4%	81.7%	92.3%	99.4%	100.0%	100.0%

100 Groundwater travel time (years)

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.01505	0.02988	0.04448	0.07302	0.14066	0.20849	0.28394	0.52052	0.77883	0.96039	0.97625	0.97649	0.97649	0.97649	0.97649
Fe-55	0.00642	0.01136	0.01515	0.02031	0.02575	0.02676	0.02680	0.02680	0.02680	0.02680	0.02680	0.02680	0.02680	0.02680	0.02680
Mn-54	0.00836	0.01205	0.01367	0.01471	0.01495	0.01495	0.01495	0.01495	0.01495	0.01495	0.01495	0.01495	0.01495	0.01495	0.01495
Co-58	0.00575	0.00591	0.00591	0.00591	0.00591	0.00591	0.00591	0.00591	0.00591	0.00591	0.00591	0.00591	0.00591	0.00591	0.00591
Co-60	0.00575	0.01075	0.01512	0.02223	0.03339	0.03802	0.03868	0.03868	0.03868	0.03868	0.03868	0.03868	0.03868	0.03868	0.03868
Ni-63	0.00325	0.00647	0.00965	0.01592	0.03103	0.04637	0.06233	0.08491	0.10851	0.12360	0.12467	0.12469	0.12469	0.12469	0.12469
Sr-90	0.00562	0.01108	0.01637	0.02651	0.04935	0.06955	0.08461	0.08663	0.08728	0.08732	0.08732	0.08732	0.08732	0.08732	0.08732
Nb-95	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362	0.00362
Zr-95	0.00102	0.00104	0.00104	0.00104	0.00104	0.00104	0.00104	0.00104	0.00104	0.00104	0.00104	0.00104	0.00104	0.00104	0.00104
Ru-106	0.00089	0.00133	0.00156	0.00174	0.00179	0.00180	0.00180	0.00180	0.00180	0.00180	0.00180	0.00180	0.00180	0.00180	0.00180
Ag-110m	0.00620	0.00844	0.00926	0.00966	0.00972	0.00972	0.00972	0.00972	0.00972	0.00972	0.00972	0.00972	0.00972	0.00972	0.00972
Sb-125	0.00362	0.00642	0.00860	0.01159	0.01483	0.01547	0.01549	0.01549	0.01549	0.01549	0.01549	0.01549	0.01549	0.01549	0.01549
I-129	0.03081	0.06067	0.08961	0.14484	0.26870	0.38262	0.49773	0.78460	0.96038	0.99975	1.00000	1.00000	1.00000	1.00000	1.00000
Cs-134	0.00310	0.00530	0.00687	0.00879	0.01040	0.01059	0.01060	0.01060	0.01060	0.01060	0.01060	0.01060	0.01060	0.01060	0.01060
Cs-137	0.00310	0.00611	0.00905	0.01470	0.02759	0.03923	0.04821	0.04964	0.05017	0.05022	0.05022	0.05022	0.05022	0.05022	0.05022
Pu-238	0.00147	0.00292	0.00436	0.00720	0.01408	0.02109	0.02837	0.03801	0.04829	0.05516	0.05570	0.05570	0.05570	0.05570	0.05570
Pu-239	0.00147	0.00293	0.00440	0.00732	0.01458	0.02244	0.03196	0.06975	0.14078	0.32173	0.53918	0.77774	0.94712	0.96223	0.96248
Pu-240	0.00147	0.00293	0.00440	0.00732	0.01458	0.02242	0.03192	0.06920	0.13888	0.31374	0.51765	0.72963	0.86383	0.87320	0.87330
	Cumulative Leaching, ΣR														

Percent of activity leached =	0.4%	0.8%	1.1%	1.6%	2.7%	3.8%	4.9%	8.0%	11.8%	16.2%	18.9%	21.4%	23.2%	23.3%	23.3%
Cumulative activity leached =	0.08022	0.13980	0.19284	0.28820	0.49466	0.68704	0.88657	1.43605	2.11955	2.91716	3.39659	3.85232	4.17252	4.20117	4.20164
Relative activity leached =	1.9%	3.3%	4.5%	6.8%	11.6%	16.1%	20.8%	33.7%	49.8%	68.5%	79.8%	90.5%	98.0%	98.6%	98.7%

100 Groundwater travel time (years)

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.01050	0.02089	0.03117	0.05139	0.10012	0.15022	0.20755	0.40102	0.65304	0.91482	0.96645	0.96935	0.96936	0.96936	0.96936
Fe-55	0.00542	0.00959	0.01280	0.01716	0.02178	0.02265	0.02268	0.02268	0.02268	0.02268	0.02268	0.02268	0.02268	0.02268	0.02268
Mn-54	0.00674	0.00971	0.01103	0.01187	0.01207	0.01207	0.01207	0.01207	0.01207	0.01207	0.01207	0.01207	0.01207	0.01207	0.01207
Co-58	0.00493	0.00507	0.00507	0.00507	0.00507	0.00507	0.00507	0.00507	0.00507	0.00507	0.00507	0.00507	0.00507	0.00507	0.00507
Co-60	0.00493	0.00923	0.01298	0.01910	0.02873	0.03274	0.03331	0.03331	0.03331	0.03331	0.03331	0.03331	0.03331	0.03331	0.03331
Ni-63	0.00297	0.00592	0.00883	0.01457	0.02841	0.04248	0.05715	0.07800	0.10001	0.11441	0.11549	0.11550	0.11550	0.11550	0.11550
Sr-90	0.00484	0.00954	0.01410	0.02285	0.04261	0.06017	0.07332	0.07510	0.07569	0.07573	0.07573	0.07573	0.07573	0.07573	0.07573
Nb-95	0.00328	0.00328	0.00328	0.00328	0.00328	0.00328	0.00328	0.00328	0.00328	0.00328	0.00328	0.00328	0.00328	0.00328	0.00328
Zr-95	0.00099	0.00101	0.00101	0.00101	0.00101	0.00101	0.00101	0.00101	0.00101	0.00101	0.00101	0.00101	0.00101	0.00101	0.00101
Ru-106	0.00086	0.00130	0.00152	0.00169	0.00175	0.00175	0.00175	0.00175	0.00175	0.00175	0.00175	0.00175	0.00175	0.00175	0.00175
Ag-110m	0.00526	0.00717	0.00786	0.00820	0.00825	0.00825	0.00825	0.00825	0.00825	0.00825	0.00825	0.00825	0.00825	0.00825	0.00825
Sb-125	0.00328	0.00582	0.00779	0.01050	0.01344	0.01402	0.01404	0.01404	0.01404	0.01404	0.01404	0.01404	0.01404	0.01404	0.01404
I-129	0.01632	0.03238	0.04817	0.07899	0.15174	0.22424	0.30445	0.55506	0.81792	0.98752	0.99985	0.99999	0.99999	0.99999	0.99999
Cs-134	0.00284	0.00487	0.00631	0.00807	0.00955	0.00973	0.00973	0.00973	0.00973	0.00973	0.00973	0.00973	0.00973	0.00973	0.00973
Cs-137	0.00284	0.00561	0.00831	0.01350	0.02536	0.03608	0.04436	0.04568	0.04618	0.04623	0.04623	0.04623	0.04623	0.04623	0.04623
Pu-238	0.00141	0.00280	0.00419	0.00691	0.01351	0.02024	0.02723	0.03650	0.04641	0.05306	0.05358	0.05359	0.05359	0.05359	0.05359
Pu-239	0.00141	0.00281	0.00422	0.00702	0.01399	0.02153	0.03068	0.06701	0.13547	0.31097	0.52456	0.76427	0.94303	0.96073	0.96106
Pu-240	0.00141	0.00281	0.00422	0.00702	0.01399	0.02152	0.03064	0.06649	0.13364	0.30323	0.50352	0.71647	0.85791	0.86885	0.86899
	Cumulative Leaching, ΣR														

**Subtitle D MSW Landfill Sensitivity Analyses  
 Variation in Waste Thickness  
 Input Parameters and Leach Rate Constants**

$$\text{Leach Rate } L = I / (\theta * T_0 * (1 + \rho_b K_d) / \theta)$$

				Start Year	0	3	5	10	20	50
Infiltration rate (m/yr)				I =	0.200	0.200	0.200	0.109	0.045	0.109
Volumetric water content				$\theta$ =	0.35	0.35	0.35	0.35	0.35	0.35
Thickness (m)				$T_0$ =	13.40	13.40	13.40	13.40	13.40	13.40
Bulk density, unsaturated waste (g/cm <sup>3</sup> )				$\rho_b$ =	0.85	0.85	0.85	0.85	0.85	0.85
$T_0$ =				50%	6.70	6.70	6.70	6.70	6.70	6.70
				Leach Rate						
Radionuclide	Decay Constant $\lambda$ , yr <sup>-1</sup>	$e^{-\lambda}$	$K_d$	0	3	5	10	20	50	
C-14	1.21E-04	1.00E+00	1.03	2.44E-02	2.44E-02	2.44E-02	1.33E-02	5.44E-03	1.33E-02	
Fe-55	2.57E-01	7.73E-01	2.59	1.17E-02	1.17E-02	1.17E-02	6.37E-03	2.60E-03	6.37E-03	
Mn-54	8.10E-01	4.45E-01	1.96	1.48E-02	1.48E-02	1.48E-02	8.07E-03	3.30E-03	8.07E-03	
Co-58	3.58E+00	2.79E-02	2.91	1.06E-02	1.06E-02	1.06E-02	5.75E-03	2.35E-03	5.75E-03	
Co-60	1.32E-01	8.76E-01	2.91	1.06E-02	1.06E-02	1.06E-02	5.75E-03	2.35E-03	5.75E-03	
Ni-63	7.22E-03	9.93E-01	5.26	6.19E-03	6.19E-03	6.19E-03	3.38E-03	1.38E-03	3.38E-03	
Sr-90	2.41E-02	9.76E-01	2.98	1.03E-02	1.03E-02	1.03E-02	5.64E-03	2.30E-03	5.64E-03	
Nb-95	7.24E+00	7.17E-04	4.71	6.85E-03	6.85E-03	6.85E-03	3.73E-03	1.52E-03	3.73E-03	
Zr-95	3.95E+00	1.93E-02	17.12	2.00E-03	2.00E-03	2.00E-03	1.09E-03	4.46E-04	1.09E-03	
Ru-106	6.78E-01	5.08E-01	19.70	1.75E-03	1.75E-03	1.75E-03	9.52E-04	3.89E-04	9.52E-04	
Ag-110m	1.01E+00	3.64E-01	2.69	1.13E-02	1.13E-02	1.13E-02	6.17E-03	2.52E-03	6.17E-03	
Sb-125	2.51E-01	7.78E-01	4.71	6.85E-03	6.85E-03	6.85E-03	3.73E-03	1.52E-03	3.73E-03	
I-129	4.41E-08	1.00E+00	0.43	4.18E-02	4.18E-02	4.18E-02	2.28E-02	9.30E-03	2.28E-02	
Cs-134	3.36E-01	7.15E-01	5.53	5.91E-03	5.91E-03	5.91E-03	3.22E-03	1.31E-03	3.22E-03	
Cs-137	2.31E-02	9.77E-01	5.53	5.91E-03	5.91E-03	5.91E-03	3.22E-03	1.31E-03	3.22E-03	
Pu-238	7.90E-03	9.92E-01	11.82	2.87E-03	2.87E-03	2.87E-03	1.56E-03	6.39E-04	1.56E-03	
Pu-239	2.87E-05	1.00E+00	11.82	2.87E-03	2.87E-03	2.87E-03	1.56E-03	6.39E-04	1.56E-03	
Pu-240	1.06E-04	1.00E+00	11.82	2.87E-03	2.87E-03	2.87E-03	1.56E-03	6.39E-04	1.56E-03	

				$T_0$ =	200%	26.80	26.80	26.80	26.80	26.80	26.80
				Leach Rate							
Radionuclide	Decay Constant $\lambda$ , yr <sup>-1</sup>	$e^{-\lambda}$	$K_d$	0	3	5	10	20	50		
C-14	1.21E-04	1.00E+00	1.03	6.11E-03	6.11E-03	6.11E-03	3.33E-03	1.36E-03	3.33E-03		
Fe-55	2.57E-01	7.73E-01	2.59	2.92E-03	2.92E-03	2.92E-03	1.59E-03	6.50E-04	1.59E-03		
Mn-54	8.10E-01	4.45E-01	1.96	3.70E-03	3.70E-03	3.70E-03	2.02E-03	8.24E-04	2.02E-03		
Co-58	3.58E+00	2.79E-02	2.91	2.64E-03	2.64E-03	2.64E-03	1.44E-03	5.87E-04	1.44E-03		
Co-60	1.32E-01	8.76E-01	2.91	2.64E-03	2.64E-03	2.64E-03	1.44E-03	5.87E-04	1.44E-03		
Ni-63	7.22E-03	9.93E-01	5.26	1.55E-03	1.55E-03	1.55E-03	8.44E-04	3.45E-04	8.44E-04		
Sr-90	2.41E-02	9.76E-01	2.98	2.59E-03	2.59E-03	2.59E-03	1.41E-03	5.75E-04	1.41E-03		
Nb-95	7.24E+00	7.17E-04	4.71	1.71E-03	1.71E-03	1.71E-03	9.34E-04	3.81E-04	9.34E-04		
Zr-95	3.95E+00	1.93E-02	17.12	5.01E-04	5.01E-04	5.01E-04	2.73E-04	1.11E-04	2.73E-04		
Ru-106	6.78E-01	5.08E-01	19.70	4.37E-04	4.37E-04	4.37E-04	2.38E-04	9.72E-05	2.38E-04		
Ag-110m	1.01E+00	3.64E-01	2.69	2.83E-03	2.83E-03	2.83E-03	1.54E-03	6.30E-04	1.54E-03		
Sb-125	2.51E-01	7.78E-01	4.71	1.71E-03	1.71E-03	1.71E-03	9.34E-04	3.81E-04	9.34E-04		
I-129	4.41E-08	1.00E+00	0.43	1.04E-02	1.04E-02	1.04E-02	5.69E-03	2.32E-03	5.69E-03		
Cs-134	3.36E-01	7.15E-01	5.53	1.48E-03	1.48E-03	1.48E-03	8.05E-04	3.29E-04	8.05E-04		
Cs-137	2.31E-02	9.77E-01	5.53	1.48E-03	1.48E-03	1.48E-03	8.05E-04	3.29E-04	8.05E-04		
Pu-238	7.90E-03	9.92E-01	11.82	7.18E-04	7.18E-04	7.18E-04	3.91E-04	1.60E-04	3.91E-04		
Pu-239	2.87E-05	1.00E+00	11.82	7.18E-04	7.18E-04	7.18E-04	3.91E-04	1.60E-04	3.91E-04		
Pu-240	1.06E-04	1.00E+00	11.82	7.18E-04	7.18E-04	7.18E-04	3.91E-04	1.60E-04	3.91E-04		

**Subtitle D MSW Landfill Sensitivity Analyses  
Variation in Waste Thickness  
Radionuclide Activity Released per Unit Activity Placed in Disposal Facility**

Percent of activity released =	1.0%	1.7%	2.4%	3.6%	6.0%	8.0%	10.0%	14.1%	17.6%	21.2%	23.9%	25.6%	26.0%	26.0%	26.0%
Cumulative activity released =	0.17958	0.31323	0.43124	0.63990	1.07141	1.44308	1.79414	2.54163	3.16945	3.82432	4.30403	4.60829	4.68186	4.68242	4.68242
Relative activity released =	3.8%	6.7%	9.2%	13.7%	22.9%	30.8%	38.3%	54.3%	67.7%	81.7%	91.9%	98.4%	100.0%	100.0%	100.0%

100 Groundwater travel time (years)

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.02444	0.04827	0.07153	0.11633	0.21907	0.31687	0.41948	0.69689	0.90964	0.98252	0.98380	0.98380	0.98380	0.98380	0.98380
Fe-55	0.01169	0.02063	0.02746	0.03667	0.04623	0.04797	0.04803	0.04803	0.04803	0.04803	0.04803	0.04803	0.04803	0.04803	0.04803
Mn-54	0.01481	0.02130	0.02414	0.02594	0.02636	0.02636	0.02636	0.02636	0.02636	0.02636	0.02636	0.02636	0.02636	0.02636	0.02636
Co-58	0.01056	0.01085	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086	0.01086
Co-60	0.01056	0.01971	0.02765	0.04050	0.06035	0.06838	0.06950	0.06950	0.06950	0.06950	0.06950	0.06950	0.06950	0.06950	0.06950
Ni-63	0.00619	0.01230	0.01833	0.03015	0.05834	0.08649	0.11527	0.15414	0.19048	0.20894	0.20974	0.20974	0.20974	0.20974	0.20974
Sr-90	0.01035	0.02034	0.03000	0.04834	0.08902	0.12407	0.14949	0.15268	0.15356	0.15361	0.15361	0.15361	0.15361	0.15361	0.15361
Nb-95	0.00685	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686	0.00686
Zr-95	0.00200	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204	0.00204
Ru-106	0.00175	0.00263	0.00308	0.00342	0.00354	0.00354	0.00354	0.00354	0.00354	0.00354	0.00354	0.00354	0.00354	0.00354	0.00354
Ag-110m	0.01132	0.01539	0.01686	0.01758	0.01769	0.01769	0.01769	0.01769	0.01769	0.01769	0.01769	0.01769	0.01769	0.01769	0.01769
Sb-125	0.00685	0.01215	0.01624	0.02184	0.02786	0.02902	0.02906	0.02906	0.02906	0.02906	0.02906	0.02906	0.02906	0.02906	0.02906
I-129	0.04178	0.08182	0.12018	0.19216	0.34740	0.48166	0.60833	0.87619	0.98763	0.99998	1.00000	1.00000	1.00000	1.00000	1.00000
Cs-134	0.00591	0.01011	0.01309	0.01671	0.01974	0.02009	0.02010	0.02010	0.02010	0.02010	0.02010	0.02010	0.02010	0.02010	0.02010
Cs-137	0.00591	0.01165	0.01722	0.02790	0.05203	0.07350	0.08977	0.09226	0.09310	0.09317	0.09317	0.09317	0.09317	0.09317	0.09317
Pu-238	0.00287	0.00571	0.00852	0.01405	0.02737	0.04083	0.05470	0.07267	0.09084	0.10168	0.10235	0.10236	0.10236	0.10236	0.10236
Pu-239	0.00287	0.00573	0.00859	0.01427	0.02834	0.04343	0.06158	0.13190	0.25679	0.53145	0.77745	0.93820	0.97880	0.97914	0.97914
Pu-240	0.00287	0.00573	0.00859	0.01427	0.02833	0.04341	0.06150	0.13088	0.25340	0.51894	0.74990	0.89339	0.92637	0.92659	0.92659
Cumulative Leaching, ΣR															

Percent of activity leached =	0.2%	0.4%	0.6%	0.9%	1.6%	2.3%	3.0%	5.1%	8.2%	12.7%	15.3%	17.7%	20.6%	21.4%	21.6%
Cumulative activity leached =	0.04489	0.07886	0.10940	0.16493	0.28773	0.40556	0.53208	0.91604	1.47031	2.27716	2.75666	3.18655	3.69993	3.85976	3.87915
Relative activity leached =	1.0%	1.7%	2.3%	3.5%	6.1%	8.7%	11.4%	19.6%	31.4%	48.6%	58.9%	68.1%	79.0%	82.4%	82.8%

100 Groundwater travel time (years)

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.00611	0.01218	0.01821	0.03017	0.05941	0.09021	0.12643	0.25778	0.46125	0.77934	0.92304	0.95310	0.95408	0.95408	0.95408
Fe-55	0.00292	0.00518	0.00691	0.00929	0.01182	0.01230	0.01232	0.01232	0.01232	0.01232	0.01232	0.01232	0.01232	0.01232	0.01232
Mn-54	0.00370	0.00534	0.00607	0.00654	0.00665	0.00665	0.00665	0.00665	0.00665	0.00665	0.00665	0.00665	0.00665	0.00665	0.00665
Co-58	0.00264	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271	0.00271
Co-60	0.00264	0.00495	0.00696	0.01027	0.01550	0.01771	0.01803	0.01803	0.01803	0.01803	0.01803	0.01803	0.01803	0.01803	0.01803
Ni-63	0.00155	0.00308	0.00460	0.00761	0.01489	0.02235	0.03019	0.04159	0.05431	0.06365	0.06455	0.06456	0.06456	0.06456	0.06456
Sr-90	0.00259	0.00510	0.00756	0.01227	0.02300	0.03265	0.03998	0.04101	0.04137	0.04140	0.04140	0.04140	0.04140	0.04140	0.04140
Nb-95	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171	0.00171
Zr-95	0.00050	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051	0.00051
Ru-106	0.00044	0.00066	0.00077	0.00086	0.00089	0.00089	0.00089	0.00089	0.00089	0.00089	0.00089	0.00089	0.00089	0.00089	0.00089
Ag-110m	0.00283	0.00386	0.00423	0.00441	0.00444	0.00444	0.00444	0.00444	0.00444	0.00444	0.00444	0.00444	0.00444	0.00444	0.00444
Sb-125	0.00171	0.00304	0.00408	0.00550	0.00706	0.00737	0.00738	0.00738	0.00738	0.00738	0.00738	0.00738	0.00738	0.00738	0.00738
I-129	0.01045	0.02078	0.03101	0.05115	0.09968	0.14964	0.20697	0.40390	0.66319	0.93924	0.99649	0.99998	0.99999	0.99999	0.99999
Cs-134	0.00148	0.00253	0.00328	0.00420	0.00498	0.00507	0.00508	0.00508	0.00508	0.00508	0.00508	0.00508	0.00508	0.00508	0.00508
Cs-137	0.00148	0.00292	0.00433	0.00704	0.01326	0.01893	0.02334	0.02406	0.02434	0.02437	0.02437	0.02437	0.02437	0.02437	0.02437
Pu-238	0.00072	0.00143	0.00213	0.00353	0.00691	0.01037	0.01397	0.01881	0.02412	0.02789	0.02823	0.02823	0.02823	0.02823	0.02823
Pu-239	0.00072	0.00144	0.00215	0.00358	0.00715	0.01103	0.01575	0.03473	0.07150	0.17299	0.31614	0.52625	0.81461	0.91482	0.92881
Pu-240	0.00072	0.00144	0.00215	0.00358	0.00715	0.01102	0.01573	0.03445	0.07052	0.16857	0.30273	0.48895	0.71297	0.77259	0.77800
Cumulative Leaching, ΣR															

**Subtitle D MSW Landfill Sensitivity Analyses  
 Variation in Waste Bulk Density  
 Input Parameters and Leach Rate Constants**

$$\text{Leach Rate } L = I/(\theta * T_0 * (1 + \rho_b K_d) / \theta)$$

				Start Year	0	3	5	10	20	50
Infiltration rate (m/yr)				I =	0.200	0.200	0.200	0.109	0.045	0.109
Volumetric water content				$\theta$ =	0.35	0.35	0.35	0.35	0.35	0.35
Thickness (m)				$T_0$ =	13.40	13.40	13.40	13.40	13.40	13.40
Bulk density, unsaturated waste (g/cm <sup>3</sup> )				$\rho_b$ =	0.85	0.85	0.85	0.85	0.85	0.85
$\rho_b$ =				67%	0.57	0.57	0.57	0.57	0.57	0.57
				Leach Rate						
Radionuclide	Decay Constant $\lambda$ , yr <sup>-1</sup>	$e^{-\lambda}$	$K_d$	0	3	5	10	20	50	
C-14	1.21E-04	1.00E+00	1.03	1.60E-02	1.60E-02	1.60E-02	8.74E-03	3.57E-03	8.74E-03	
Fe-55	2.57E-01	7.73E-01	2.59	8.21E-03	8.21E-03	8.21E-03	4.47E-03	1.83E-03	4.47E-03	
Mn-54	8.10E-01	4.45E-01	1.96	1.02E-02	1.02E-02	1.02E-02	5.57E-03	2.27E-03	5.57E-03	
Co-58	3.58E+00	2.79E-02	2.91	7.46E-03	7.46E-03	7.46E-03	4.06E-03	1.66E-03	4.06E-03	
Co-60	1.32E-01	8.76E-01	2.91	7.46E-03	7.46E-03	7.46E-03	4.06E-03	1.66E-03	4.06E-03	
Ni-63	7.22E-03	9.93E-01	5.26	4.48E-03	4.48E-03	4.48E-03	2.44E-03	9.97E-04	2.44E-03	
Sr-90	2.41E-02	9.76E-01	2.98	7.32E-03	7.32E-03	7.32E-03	3.99E-03	1.63E-03	3.99E-03	
Nb-95	7.24E+00	7.17E-04	4.71	4.94E-03	4.94E-03	4.94E-03	2.69E-03	1.10E-03	2.69E-03	
Zr-95	3.95E+00	1.93E-02	17.12	1.49E-03	1.49E-03	1.49E-03	8.09E-04	3.30E-04	8.09E-04	
Ru-106	6.78E-01	5.08E-01	19.70	1.30E-03	1.30E-03	1.30E-03	7.07E-04	2.89E-04	7.07E-04	
Ag-110m	1.01E+00	3.64E-01	2.69	7.96E-03	7.96E-03	7.96E-03	4.34E-03	1.77E-03	4.34E-03	
Sb-125	2.51E-01	7.78E-01	4.71	4.94E-03	4.94E-03	4.94E-03	2.69E-03	1.10E-03	2.69E-03	
I-129	4.41E-08	1.00E+00	0.43	2.52E-02	2.52E-02	2.52E-02	1.37E-02	5.60E-03	1.37E-02	
Cs-134	3.36E-01	7.15E-01	5.53	4.28E-03	4.28E-03	4.28E-03	2.33E-03	9.53E-04	2.33E-03	
Cs-137	2.31E-02	9.77E-01	5.53	4.28E-03	4.28E-03	4.28E-03	2.33E-03	9.53E-04	2.33E-03	
Pu-238	7.90E-03	9.92E-01	11.82	2.12E-03	2.12E-03	2.12E-03	1.15E-03	4.71E-04	1.15E-03	
Pu-239	2.87E-05	1.00E+00	11.82	2.12E-03	2.12E-03	2.12E-03	1.15E-03	4.71E-04	1.15E-03	
Pu-240	1.06E-04	1.00E+00	11.82	2.12E-03	2.12E-03	2.12E-03	1.15E-03	4.71E-04	1.15E-03	

$\rho_b$ =				150%	1.28	1.28	1.28	1.28	1.28	1.28
				Leach Rate						
Radionuclide	Decay Constant $\lambda$ , yr <sup>-1</sup>	$e^{-\lambda}$	$K_d$	0	3	5	10	20	50	
C-14	1.21E-04	1.00E+00	1.03	9.01E-03	9.01E-03	9.01E-03	4.91E-03	2.00E-03	4.91E-03	
Fe-55	2.57E-01	7.73E-01	2.59	4.08E-03	4.08E-03	4.08E-03	2.23E-03	9.09E-04	2.23E-03	
Mn-54	8.10E-01	4.45E-01	1.96	5.24E-03	5.24E-03	5.24E-03	2.86E-03	1.17E-03	2.86E-03	
Co-58	3.58E+00	2.79E-02	2.91	3.67E-03	3.67E-03	3.67E-03	2.00E-03	8.17E-04	2.00E-03	
Co-60	1.32E-01	8.76E-01	2.91	3.67E-03	3.67E-03	3.67E-03	2.00E-03	8.17E-04	2.00E-03	
Ni-63	7.22E-03	9.93E-01	5.26	2.12E-03	2.12E-03	2.12E-03	1.15E-03	4.71E-04	1.15E-03	
Sr-90	2.41E-02	9.76E-01	2.98	3.59E-03	3.59E-03	3.59E-03	1.96E-03	8.00E-04	1.96E-03	
Nb-95	7.24E+00	7.17E-04	4.71	2.35E-03	2.35E-03	2.35E-03	1.28E-03	5.22E-04	1.28E-03	
Zr-95	3.95E+00	1.93E-02	17.12	6.73E-04	6.73E-04	6.73E-04	3.67E-04	1.50E-04	3.67E-04	
Ru-106	6.78E-01	5.08E-01	19.70	5.86E-04	5.86E-04	5.86E-04	3.19E-04	1.30E-04	3.19E-04	
Ag-110m	1.01E+00	3.64E-01	2.69	3.95E-03	3.95E-03	3.95E-03	2.15E-03	8.78E-04	2.15E-03	
Sb-125	2.51E-01	7.78E-01	4.71	2.35E-03	2.35E-03	2.35E-03	1.28E-03	5.22E-04	1.28E-03	
I-129	4.41E-08	1.00E+00	0.43	1.66E-02	1.66E-02	1.66E-02	9.07E-03	3.70E-03	9.07E-03	
Cs-134	3.36E-01	7.15E-01	5.53	2.02E-03	2.02E-03	2.02E-03	1.10E-03	4.49E-04	1.10E-03	
Cs-137	2.31E-02	9.77E-01	5.53	2.02E-03	2.02E-03	2.02E-03	1.10E-03	4.49E-04	1.10E-03	
Pu-238	7.90E-03	9.92E-01	11.82	9.68E-04	9.68E-04	9.68E-04	5.28E-04	2.15E-04	5.28E-04	
Pu-239	2.87E-05	1.00E+00	11.82	9.68E-04	9.68E-04	9.68E-04	5.28E-04	2.15E-04	5.28E-04	
Pu-240	1.06E-04	1.00E+00	11.82	9.68E-04	9.68E-04	9.68E-04	5.28E-04	2.15E-04	5.28E-04	

**Subtitle D MSW Landfill Sensitivity Analyses  
Variation in Waste Bulk Density  
Radionuclide Activity Released per Unit Activity Placed in Disposal Facility**

Percent of activity released =	0.7%	1.2%	1.6%	2.4%	4.1%	5.6%	7.2%	10.9%	14.9%	18.9%	21.6%	23.8%	24.7%	24.7%	24.7%
Cumulative activity released =	0.12188	0.21213	0.29212	0.43490	0.73850	1.01302	1.28762	1.96923	2.67794	3.39738	3.88357	4.27876	4.44024	4.44456	4.44457
Relative activity released =	2.7%	4.8%	6.6%	9.8%	16.6%	22.8%	29.0%	44.3%	60.3%	76.4%	87.4%	96.3%	99.9%	100.0%	100.0%

100 Groundwater travel time (years)

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.01603	0.03180	0.04732	0.07761	0.14915	0.22050	0.29939	0.54290	0.79901	0.96519	0.97742	0.97757	0.97757	0.97757	0.97757
Fe-55	0.00821	0.01450	0.01933	0.02587	0.03274	0.03401	0.03405	0.03405	0.03405	0.03405	0.03405	0.03405	0.03405	0.03405	0.03405
Mn-54	0.01022	0.01472	0.01670	0.01796	0.01825	0.01826	0.01826	0.01826	0.01826	0.01826	0.01826	0.01826	0.01826	0.01826	0.01826
Co-58	0.00746	0.00766	0.00767	0.00767	0.00767	0.00767	0.00767	0.00767	0.00767	0.00767	0.00767	0.00767	0.00767	0.00767	0.00767
Co-60	0.00746	0.01394	0.01958	0.02876	0.04308	0.04896	0.04979	0.04979	0.04979	0.04979	0.04979	0.04979	0.04979	0.04979	0.04979
Ni-63	0.00448	0.00891	0.01329	0.02190	0.04255	0.06336	0.08486	0.11469	0.14445	0.16171	0.16270	0.16271	0.16271	0.16271	0.16271
Sr-90	0.00732	0.01440	0.02127	0.03438	0.06376	0.08950	0.10851	0.11099	0.11175	0.11180	0.11180	0.11180	0.11180	0.11180	0.11180
Nb-95	0.00494	0.00494	0.00494	0.00494	0.00494	0.00494	0.00494	0.00494	0.00494	0.00494	0.00494	0.00494	0.00494	0.00494	0.00494
Zr-95	0.00149	0.00151	0.00151	0.00151	0.00151	0.00151	0.00151	0.00151	0.00151	0.00151	0.00151	0.00151	0.00151	0.00151	0.00151
Ru-106	0.00130	0.00195	0.00229	0.00254	0.00263	0.00263	0.00263	0.00263	0.00263	0.00263	0.00263	0.00263	0.00263	0.00263	0.00263
Ag-110m	0.00796	0.01084	0.01188	0.01239	0.01246	0.01246	0.01246	0.01246	0.01246	0.01246	0.01246	0.01246	0.01246	0.01246	0.01246
Sb-125	0.00494	0.00877	0.01173	0.01580	0.02019	0.02104	0.02107	0.02107	0.02107	0.02107	0.02107	0.02107	0.02107	0.02107	0.02107
I-129	0.02517	0.04971	0.07363	0.11967	0.22503	0.32501	0.42967	0.71412	0.92817	0.99885	0.99999	0.99999	0.99999	0.99999	0.99999
Cs-134	0.00428	0.00733	0.00950	0.01214	0.01436	0.01462	0.01462	0.01462	0.01462	0.01462	0.01462	0.01462	0.01462	0.01462	0.01462
Cs-137	0.00428	0.00845	0.01251	0.02029	0.03798	0.05386	0.06601	0.06791	0.06860	0.06865	0.06865	0.06865	0.06865	0.06865	0.06865
Pu-238	0.00212	0.00421	0.00629	0.01038	0.02025	0.03028	0.04065	0.05425	0.06840	0.07737	0.07800	0.07801	0.07801	0.07801	0.07801
Pu-239	0.00212	0.00423	0.00634	0.01054	0.02097	0.03221	0.04578	0.09905	0.19659	0.42859	0.67169	0.88064	0.97021	0.97285	0.97285
Pu-240	0.00212	0.00423	0.00634	0.01054	0.02097	0.03219	0.04573	0.09829	0.19396	0.41820	0.64629	0.83237	0.90429	0.90596	0.90596
Cumulative Leaching, ΣR															

Percent of activity leached =	0.4%	0.6%	0.9%	1.3%	2.3%	3.3%	4.2%	7.0%	10.5%	14.5%	16.9%	19.4%	21.9%	22.4%	22.4%
Cumulative activity leached =	0.06486	0.11438	0.15895	0.23995	0.41770	0.58547	0.76190	1.26395	1.88823	2.61372	3.03969	3.48506	3.93694	4.02553	4.03064
Relative activity leached =	1.5%	2.6%	3.6%	5.4%	9.4%	13.2%	17.1%	28.4%	42.5%	58.8%	68.4%	78.4%	88.6%	90.6%	90.7%

100 Groundwater travel time (years)

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.00901	0.01793	0.02677	0.04422	0.08645	0.13023	0.18081	0.35569	0.59723	0.88449	0.95916	0.96564	0.96569	0.96569	0.96569
Fe-55	0.00408	0.00723	0.00965	0.01295	0.01647	0.01713	0.01715	0.01715	0.01715	0.01715	0.01715	0.01715	0.01715	0.01715	0.01715
Mn-54	0.00524	0.00756	0.00858	0.00924	0.00940	0.00940	0.00940	0.00940	0.00940	0.00940	0.00940	0.00940	0.00940	0.00940	0.00940
Co-58	0.00367	0.00377	0.00378	0.00378	0.00378	0.00378	0.00378	0.00378	0.00378	0.00378	0.00378	0.00378	0.00378	0.00378	0.00378
Co-60	0.00367	0.00688	0.00967	0.01425	0.02148	0.02451	0.02495	0.02495	0.02495	0.02495	0.02495	0.02495	0.02495	0.02495	0.02495
Ni-63	0.00212	0.00421	0.00629	0.01038	0.02029	0.03041	0.04101	0.05630	0.07297	0.08466	0.08567	0.08569	0.08569	0.08569	0.08569
Sr-90	0.00359	0.00709	0.01049	0.01701	0.03183	0.04507	0.05506	0.05644	0.05692	0.05696	0.05696	0.05696	0.05696	0.05696	0.05696
Nb-95	0.00235	0.00235	0.00235	0.00235	0.00235	0.00235	0.00235	0.00235	0.00235	0.00235	0.00235	0.00235	0.00235	0.00235	0.00235
Zr-95	0.00067	0.00069	0.00069	0.00069	0.00069	0.00069	0.00069	0.00069	0.00069	0.00069	0.00069	0.00069	0.00069	0.00069	0.00069
Ru-106	0.00059	0.00088	0.00103	0.00115	0.00119	0.00119	0.00119	0.00119	0.00119	0.00119	0.00119	0.00119	0.00119	0.00119	0.00119
Ag-110m	0.00395	0.00538	0.00590	0.00616	0.00619	0.00619	0.00619	0.00619	0.00619	0.00619	0.00619	0.00619	0.00619	0.00619	0.00619
Sb-125	0.00235	0.00417	0.00558	0.00753	0.00965	0.01007	0.01009	0.01009	0.01009	0.01009	0.01009	0.01009	0.01009	0.01009	0.01009
I-129	0.01665	0.03301	0.04911	0.08050	0.15452	0.22816	0.30947	0.56218	0.82399	0.98856	0.99987	0.99999	0.99999	0.99999	0.99999
Cs-134	0.00202	0.00345	0.00448	0.00573	0.00679	0.00692	0.00692	0.00692	0.00692	0.00692	0.00692	0.00692	0.00692	0.00692	0.00692
Cs-137	0.00202	0.00398	0.00590	0.00959	0.01805	0.02574	0.03170	0.03267	0.03304	0.03308	0.03308	0.03308	0.03308	0.03308	0.03308
Pu-238	0.00097	0.00193	0.00288	0.00475	0.00930	0.01395	0.01880	0.02526	0.03229	0.03718	0.03760	0.03761	0.03761	0.03761	0.03761
Pu-239	0.00097	0.00193	0.00290	0.00483	0.00964	0.01485	0.02118	0.04654	0.09519	0.22591	0.40066	0.63316	0.88667	0.94188	0.94552
Pu-240	0.00097	0.00193	0.00290	0.00483	0.00963	0.01484	0.02116	0.04618	0.09390	0.22020	0.38400	0.59024	0.78857	0.82195	0.82341
Cumulative Leaching, ΣR															

**Subtitle D MSW Landfill Sensitivity Analyses  
 Variation in Groundwater Travel Time  
 Input Parameters and Leach Rate Constants**

$$\text{Leach Rate } L = I/(\theta * T_0 * (1 + \rho_b K_d) / \theta)$$

Start Year	0	3	5	10	20	50
Infiltration rate (m/yr) I =	0.200	0.200	0.200	0.109	0.045	0.109
Volumetric water content $\theta$ =	0.35	0.35	0.35	0.35	0.35	0.35
Thickness (m) $T_0$ =	13.40	13.40	13.40	13.40	13.40	13.40
Bulk density, unsaturated waste (g/cm <sup>3</sup> ) $\rho_b$ =	0.85	0.85	0.85	0.85	0.85	0.85

Radionuclide	Decay		$K_d$	Leach Rate					
	Constant $\lambda$ , yr <sup>-1</sup>	$e^{-\lambda}$		0	3	5	10	20	50
C-14	1.21E-04	1.00E+00	1.03	1.22E-02	1.22E-02	1.22E-02	6.66E-03	2.72E-03	6.66E-03
Fe-55	2.57E-01	7.73E-01	2.59	5.85E-03	5.85E-03	5.85E-03	3.19E-03	1.30E-03	3.19E-03
Mn-54	8.10E-01	4.45E-01	1.96	7.40E-03	7.40E-03	7.40E-03	4.04E-03	1.65E-03	4.04E-03
Co-58	3.58E+00	2.79E-02	2.91	5.28E-03	5.28E-03	5.28E-03	2.88E-03	1.17E-03	2.88E-03
Co-60	1.32E-01	8.76E-01	2.91	5.28E-03	5.28E-03	5.28E-03	2.88E-03	1.17E-03	2.88E-03
Ni-63	7.22E-03	9.93E-01	5.26	3.10E-03	3.10E-03	3.10E-03	1.69E-03	6.89E-04	1.69E-03
Sr-90	2.41E-02	9.76E-01	2.98	5.17E-03	5.17E-03	5.17E-03	2.82E-03	1.15E-03	2.82E-03
Nb-95	7.24E+00	7.17E-04	4.71	3.43E-03	3.43E-03	3.43E-03	1.87E-03	7.62E-04	1.87E-03
Zr-95	3.95E+00	1.93E-02	17.12	1.00E-03	1.00E-03	1.00E-03	5.46E-04	2.23E-04	5.46E-04
Ru-106	6.78E-01	5.08E-01	19.70	8.73E-04	8.73E-04	8.73E-04	4.76E-04	1.94E-04	4.76E-04
Ag-110m	1.01E+00	3.64E-01	2.69	5.66E-03	5.66E-03	5.66E-03	3.08E-03	1.26E-03	3.08E-03
Sb-125	2.51E-01	7.78E-01	4.71	3.43E-03	3.43E-03	3.43E-03	1.87E-03	7.62E-04	1.87E-03
I-129	4.41E-08	1.00E+00	0.43	2.09E-02	2.09E-02	2.09E-02	1.14E-02	4.65E-03	1.14E-02
Cs-134	3.36E-01	7.15E-01	5.53	2.95E-03	2.95E-03	2.95E-03	1.61E-03	6.57E-04	1.61E-03
Cs-137	2.31E-02	9.77E-01	5.53	2.95E-03	2.95E-03	2.95E-03	1.61E-03	6.57E-04	1.61E-03
Pu-238	7.90E-03	9.92E-01	11.82	1.44E-03	1.44E-03	1.44E-03	7.82E-04	3.19E-04	7.82E-04
Pu-239	2.87E-05	1.00E+00	11.82	1.44E-03	1.44E-03	1.44E-03	7.82E-04	3.19E-04	7.82E-04
Pu-240	1.06E-04	1.00E+00	11.82	1.44E-03	1.44E-03	1.44E-03	7.82E-04	3.19E-04	7.82E-04

Radionuclide	Decay		$K_d$	Leach Rate					
	Constant $\lambda$ , yr <sup>-1</sup>	$e^{-\lambda}$		0	3	5	10	20	50
C-14	1.21E-04	1.00E+00	1.03	1.22E-02	1.22E-02	1.22E-02	6.66E-03	2.72E-03	6.66E-03
Fe-55	2.57E-01	7.73E-01	2.59	5.85E-03	5.85E-03	5.85E-03	3.19E-03	1.30E-03	3.19E-03
Mn-54	8.10E-01	4.45E-01	1.96	7.40E-03	7.40E-03	7.40E-03	4.04E-03	1.65E-03	4.04E-03
Co-58	3.58E+00	2.79E-02	2.91	5.28E-03	5.28E-03	5.28E-03	2.88E-03	1.17E-03	2.88E-03
Co-60	1.32E-01	8.76E-01	2.91	5.28E-03	5.28E-03	5.28E-03	2.88E-03	1.17E-03	2.88E-03
Ni-63	7.22E-03	9.93E-01	5.26	3.10E-03	3.10E-03	3.10E-03	1.69E-03	6.89E-04	1.69E-03
Sr-90	2.41E-02	9.76E-01	2.98	5.17E-03	5.17E-03	5.17E-03	2.82E-03	1.15E-03	2.82E-03
Nb-95	7.24E+00	7.17E-04	4.71	3.43E-03	3.43E-03	3.43E-03	1.87E-03	7.62E-04	1.87E-03
Zr-95	3.95E+00	1.93E-02	17.12	1.00E-03	1.00E-03	1.00E-03	5.46E-04	2.23E-04	5.46E-04
Ru-106	6.78E-01	5.08E-01	19.70	8.73E-04	8.73E-04	8.73E-04	4.76E-04	1.94E-04	4.76E-04
Ag-110m	1.01E+00	3.64E-01	2.69	5.66E-03	5.66E-03	5.66E-03	3.08E-03	1.26E-03	3.08E-03
Sb-125	2.51E-01	7.78E-01	4.71	3.43E-03	3.43E-03	3.43E-03	1.87E-03	7.62E-04	1.87E-03
I-129	4.41E-08	1.00E+00	0.43	2.09E-02	2.09E-02	2.09E-02	1.14E-02	4.65E-03	1.14E-02
Cs-134	3.36E-01	7.15E-01	5.53	2.95E-03	2.95E-03	2.95E-03	1.61E-03	6.57E-04	1.61E-03
Cs-137	2.31E-02	9.77E-01	5.53	2.95E-03	2.95E-03	2.95E-03	1.61E-03	6.57E-04	1.61E-03
Pu-238	7.90E-03	9.92E-01	11.82	1.44E-03	1.44E-03	1.44E-03	7.82E-04	3.19E-04	7.82E-04
Pu-239	2.87E-05	1.00E+00	11.82	1.44E-03	1.44E-03	1.44E-03	7.82E-04	3.19E-04	7.82E-04
Pu-240	1.06E-04	1.00E+00	11.82	1.44E-03	1.44E-03	1.44E-03	7.82E-04	3.19E-04	7.82E-04

**Subtitle D MSW Landfill Sensitivity Analyses  
Variation in Groundwater Travel Time  
Radionuclide Activity Released per Unit Activity Placed in Disposal Facility**

Percent of activity released =	0.5%	0.9%	1.2%	1.8%	3.1%	4.3%	5.6%	9.2%	13.3%	17.4%	19.9%	22.5%	24.2%	24.4%	24.4%
Cumulative activity released =	0.08979	0.15736	0.21773	0.32650	0.56161	0.77892	1.00192	1.66432	2.38711	3.12809	3.58891	4.04487	4.35941	4.38624	4.38666
Relative activity released =	2.0%	3.6%	5.0%	7.4%	12.8%	17.8%	22.8%	37.9%	54.4%	71.3%	81.8%	92.2%	99.4%	100.0%	100.0%

0 Groundwater travel time (years)

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.01222	0.02429	0.03621	0.05960	0.11562	0.17268	0.23728	0.45186	0.71326	0.94668	0.98038	0.98154	0.98154	0.98154	0.98154
Fe-55	0.00585	0.01034	0.01380	0.01849	0.02346	0.02439	0.02442	0.02442	0.02442	0.02442	0.02442	0.02442	0.02442	0.02442	0.02442
Mn-54	0.00740	0.01067	0.01212	0.01304	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326
Co-58	0.00528	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543
Co-60	0.00528	0.00988	0.01389	0.02044	0.03072	0.03500	0.03561	0.03564	0.03564	0.03564	0.03564	0.03564	0.03564	0.03564	0.03564
Ni-63	0.00310	0.00616	0.00919	0.01517	0.02957	0.04420	0.05944	0.10396	0.15073	0.18103	0.18325	0.18327	0.18327	0.18327	0.18327
Sr-90	0.00517	0.01020	0.01508	0.02441	0.04550	0.06419	0.07817	0.09915	0.10603	0.10653	0.10653	0.10653	0.10653	0.10653	0.10653
Nb-95	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343
Zr-95	0.00100	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102
Ru-106	0.00087	0.00132	0.00154	0.00171	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177
Ag-110m	0.00566	0.00771	0.00845	0.00882	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887
Sb-125	0.00343	0.00608	0.00814	0.01098	0.01405	0.01466	0.01468	0.01468	0.01468	0.01468	0.01468	0.01468	0.01468	0.01468	0.01468
I-129	0.02089	0.04134	0.06137	0.10018	0.19032	0.27793	0.37211	0.64581	0.88730	0.99636	0.99998	1.00000	1.00000	1.00000	1.00000
Cs-134	0.00295	0.00506	0.00656	0.00839	0.00993	0.01011	0.01012	0.01012	0.01012	0.01012	0.01012	0.01012	0.01012	0.01012	0.01012
Cs-137	0.00295	0.00583	0.00864	0.01403	0.02635	0.03748	0.04607	0.05988	0.06506	0.06554	0.06554	0.06554	0.06554	0.06554	0.06554
Pu-238	0.00144	0.00286	0.00427	0.00705	0.01377	0.02063	0.02775	0.04855	0.07075	0.08562	0.08679	0.08681	0.08681	0.08681	0.08681
Pu-239	0.00144	0.00287	0.00430	0.00716	0.01426	0.02194	0.03126	0.06836	0.13820	0.31671	0.53271	0.77262	0.94758	0.96410	0.96439
Pu-240	0.00144	0.00287	0.00430	0.00716	0.01426	0.02193	0.03123	0.06811	0.13715	0.31098	0.51510	0.72992	0.86951	0.87982	0.87994
Cumulative Leaching, ΣR															

Percent of activity leached =	0.5%	0.9%	1.2%	1.8%	3.1%	4.3%	5.6%	8.6%	12.1%	15.8%	18.3%	20.7%	22.4%	22.6%	22.6%
Cumulative activity leached =	0.08979	0.15736	0.21773	0.32650	0.56161	0.77892	1.00192	1.55076	2.17429	2.84501	3.28693	3.72827	4.03312	4.05918	4.05958
Relative activity leached =	2.0%	3.6%	5.0%	7.4%	12.8%	17.8%	22.8%	35.4%	49.6%	64.9%	74.9%	85.0%	91.9%	92.5%	92.5%

500 Groundwater travel time (years)

Radionuclide	No. of Years														
	1	2	3	5	10	20	50	100	200	500	1000	2000	5000	10000	1000000
C-14	0.01222	0.02429	0.03621	0.05960	0.11562	0.17268	0.23728	0.43926	0.68532	0.90504	0.93675	0.93785	0.93785	0.93785	0.93785
Fe-55	0.00585	0.01034	0.01380	0.01849	0.02346	0.02439	0.02442	0.02442	0.02442	0.02442	0.02442	0.02442	0.02442	0.02442	0.02442
Mn-54	0.00740	0.01067	0.01212	0.01304	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326	0.01326
Co-58	0.00528	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543	0.00543
Co-60	0.00528	0.00988	0.01389	0.02044	0.03072	0.03500	0.03561	0.03561	0.03561	0.03561	0.03561	0.03561	0.03561	0.03561	0.03561
Ni-63	0.00310	0.00616	0.00919	0.01517	0.02957	0.04420	0.05944	0.06065	0.06191	0.06273	0.06279	0.06279	0.06279	0.06279	0.06279
Sr-90	0.00517	0.01020	0.01508	0.02441	0.04550	0.06419	0.07817	0.07817	0.07817	0.07817	0.07817	0.07817	0.07817	0.07817	0.07817
Nb-95	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343	0.00343
Zr-95	0.00100	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102	0.00102
Ru-106	0.00087	0.00132	0.00154	0.00171	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177	0.00177
Ag-110m	0.00566	0.00771	0.00845	0.00882	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887	0.00887
Sb-125	0.00343	0.00608	0.00814	0.01098	0.01405	0.01466	0.01468	0.01468	0.01468	0.01468	0.01468	0.01468	0.01468	0.01468	0.01468
I-129	0.02089	0.04134	0.06137	0.10018	0.19032	0.27793	0.37211	0.64581	0.88728	0.99635	0.99997	0.99998	0.99998	0.99998	0.99998
Cs-134	0.00295	0.00506	0.00656	0.00839	0.00993	0.01011	0.01012	0.01012	0.01012	0.01012	0.01012	0.01012	0.01012	0.01012	0.01012
Cs-137	0.00295	0.00583	0.00864	0.01403	0.02635	0.03748	0.04607	0.04607	0.04607	0.04607	0.04607	0.04607	0.04607	0.04607	0.04607
Pu-238	0.00144	0.00286	0.00427	0.00705	0.01377	0.02063	0.02775	0.02815	0.02858	0.02886	0.02888	0.02888	0.02888	0.02888	0.02888
Pu-239	0.00144	0.00287	0.00430	0.00716	0.01426	0.02194	0.03126	0.06784	0.13667	0.31264	0.52556	0.76206	0.93453	0.95081	0.95110
Pu-240	0.00144	0.00287	0.00430	0.00716	0.01426	0.02193	0.03123	0.06621	0.13168	0.29654	0.49013	0.69386	0.82624	0.83601	0.83613
Cumulative Leaching, ΣR															



**Table J-1 Remaining Disposal Capacity for Subtitle D Landfills, by Year\***

BioCycle Study Year	Landfill Capacity Tons Remaining
1998	4,292,505,695
1999	5,016,256,036
2000	6,985,681,722
2001	6,584,885,975

\* “Year” corresponds to the year in which the BioCycle State of Garbage Report was conducted.

**Table J-2 Remaining Disposal Capacity for Subtitle D Landfills, 2001**

Remaining Capacity in Tons (2001)	Cubic Yards per Ton	Cubic Yards of Remaining Capacity
6,584,885,975	1.66	10,970,420,034
6,584,885,975	4.33	28,512,556,272
6,584,885,975	7	46,094,201,825

The conversion of remaining Subtitle D landfill capacity from tons to cubic yards is dependent on the assumed density of waste and how tightly it is compacted. A wide range of solid waste density conversion factors are used by landfill operators to estimate remaining capacity<sup>16</sup>. Using low, middle, and high end conversion factors produces a wide range of the total volume capacity remaining in Subtitle D landfills as of 2001 (Table J-2).

Subtitle D landfill capacity is not evenly distributed throughout the country, nor is the proportion of landfill space per region to the amount of waste generated per region equal across the country. Table J-3 shows the remaining capacity for each region. The Mountain region has much more capacity than it needs to dispose of waste generated in that region, while the New England and Mid Atlantic regions have a lower amount of disposal capacity. The New England and Mid Atlantic regions export solid waste to other regions for disposal.

<sup>16</sup> Online searches and interviews with randomly chosen landfill operators were used to find standard “tons to cubic yards” conversions. Conversions used in Delaware, Virginia, California, Mississippi, North Carolina, and Colorado ranged from 1.66 cubic yards per ton to 7 cubic yards per ton, depending on the compaction rate for regular solid waste and density of waste. While only two sources cited conversion factors between 4 and 7 cubic yards per ton, the majority cited factors between 1.66 and 3.33 cubic yards per ton. Soil and construction and demolition materials are sometimes deposited in Subtitle D landfills and are more dense than household materials, filling .75 cubic yards to 1 cubic yard per ton.

**Table J-3 Remaining Subtitle D Disposal Capacity, by Region**

Region	Capacity Remaining (Tons)	Waste Produced in 2000 (Tons)	Years of Capacity Remaining for Waste Generated by the Region*
Great Plains	151,566,300	7,874,000	19.2
Mid Atlantic	579,273,144	72,914,000	7.9
Midwest	1,056,426,519	86,071,000	12.3
Mountain	1,388,043,477	8,946,000	155.2
New England	26,029,658	16,278,000	1.6
South	1,744,757,227	119,647,000	14.6
West	1,605,671,450	94,729,000	17

\* Years remaining if waste continued to be generated at 2000 levels, and was landfilled in its region of origin.

**Great Plains:** Kansas, North Dakota, Oklahoma, South Dakota

**Mid Atlantic:** Delaware, D.C, Maryland, Pennsylvania, Virginia, West Virginia, New Jersey, New York

**Midwest:** Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Nebraska, Ohio, Wisconsin

**Mountain:** Wyoming, Idaho, Montana, Colorado

**New England:** Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont

**South:** Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas

**West:** Arizona, Arkansas, California, Nevada, New Mexico, Oregon, Utah, Washington

Because information was not available for 2003 landfill capacity, total national Subtitle D landfill capacity was estimated for four years using the most recent available “The State of Garbage in America” reports. Trends in the data were used to estimate the data missing from the 2001 report and to estimate current remaining capacity. In 2001, three States reported their Subtitle D landfill capacities in tons, which was used for QA/QC. California’s capacity estimated using the methods described in the section above, is 665,280,000 tons, while the State reported its capacity is 677 million tons. Massachusetts’ estimated capacity is 1,883,320 tons and its reported capacity is 1,808,669. New York’s estimated capacity is 64,074,500 tons and its reported capacity is 68 million tons.

**Solid Waste Incinerator Capacity**

As reported in BioCycle 2004, there were 106 waste-to-energy plants or MSW incinerators (hereinafter referred to collectively as incinerators) in the continental United States<sup>17</sup> in 2002. The incinerators are distributed throughout the country, but are much more prevalent east of the Mississippi River. The regional distribution as of 2002 appears in Table J-4.

<sup>17</sup> No data was reported for Alabama.

**Table J-4 Existing MSW Incinerators by Region, 2002**

Region	Facility Location(s)	Number of MSW Incinerators
New England	CT, MA, NH, ME	19
Mid-Atlantic	NY, NJ, PA, MD	24
South	VA, KY, TN, NC, SC, GA, FL	26
Great Lakes	MN, WI, IN, MI	22
Mid-west	IA, OK, AR, TX	6
Rocky Mountain	UT	1
West	CA, OR, WA	8

For solid waste incinerator capacity, States reported daily capacity. Per *Biocycle's* methodology, incinerator capacity (tons per day) was multiplied by 300 operating days per year for total capacity (tons per year)<sup>18</sup>. This capacity, shown in Table J-5, only applies to trash, not to the other materials, which would not be incinerated under any of the Alternatives.

**Table J-5 Existing Solid Waste Incineration Capacity, by Year**

BioCycle Study Year	Incinerator Capacity (tons/year)
1998	29,982,296
1999	34,282,200
2000	35,322,058
2001	33,791,899

As shown, the existing solid waste incineration capacity increased between 1998 and 2000, as State and local governments have developed additional facilities or expanded the capacity of existing facilities. However, for the purposes of the capacity analysis in Section 3.7, NRC has assumed that the incineration capacity would remain equal to the capacity reported in "The State of Garbage in America" in 2001.

To make sure the estimated solid waste incinerator capacities were reasonable, the estimated capacity was compared to percent of solid waste incinerated each year. As reported in BioCycle Data from the 1998 report, incinerators were running at around 100 percent capacity. Data from the 1999 report showed that incinerators were running at 82 percent capacity, which reflects a decline in the percent of waste incinerated nationally in those years from 9 percent to 7.5 percent. The data from the 2000 and 2001 reports show incinerators operating at 75 percent and 84 percent capacity, respectively. In those years, the percent of waste incinerated remained steady at 7 percent, while the total waste stream increased. The drop from incinerators operating at 82 percent to 75 percent capacity, derived from the 1999 and 2000 reports, also corresponds to a drop in percent of waste incinerated from 7.5 percent to 7 percent.

<sup>18</sup> Where daily capacity was not given, the national average daily capacity per incinerator for that year was multiplied by the number of incinerators maintained by the State.

**Low level Radioactive Waste (LLW) Disposal Facility Capacity**

Three facilities in the country are currently licensed by States to accept LLW for disposal. Their total remaining capacity is roughly 10.4 million cubic yards, as summarized in Table J-6.

**Table J-6 LLW Disposal Facility Capacity, 2002**

Facility	Remaining Volume (million cubic yards)	Notes
Envirocare - Clive, UT	2.7	Remaining capacity as of 12/02.
Barnwell Disposal Facility - Barnwell, SC	0.008	Reported as 230,000 cubic feet. This only accounts for non-regional* waste. Barnwell will stop accepting non-regional waste in 2008.
Hanford Off-Site LLW Disposal Facility - Hanford, WA	7.7	Excluding facilities for wastes generated at the Hanford Site.
<b>Total</b>	<b>10.4</b>	<b>Not including Barnwell.</b>

\* Non-regional waste is anything generated outside the Atlantic Compact, which includes South Carolina, New Jersey, and Connecticut.

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**Attachment 3**

**Regulatory Comparison of EPA Regulated Disposal Facilities**



**Selected State Regulations for Construction: Demolition Waste Landfills**

New York	California *	Ohio
<p>• <b>Wastes received:</b> Construction and demolition wastes only, meaning uncontaminated solid waste resulting from the construction, remodeling, repair and demolition of utilities, structures and roads; and uncontaminated solid waste resulting from land clearing. Wastes received vary slightly according to the categories below:</p> <ol style="list-style-type: none"> <li>1. C&amp;D debris landfills three acres or less: C&amp;D debris landfills three acres or less in area may receive C&amp;D debris, other than pulverized C&amp;D debris, provided no more than 200 tons of C&amp;D debris is received per week. All other C&amp;D debris landfills not specifically exempt or registered under this category must comply with the requirements of “C&amp;D debris landfills greater than three acres” (section 360-7.4 NYCRR), described below.</li> <li>2. <b>C&amp;D debris landfills greater than three acres:</b> C&amp;D debris landfills greater than three acres in area, C&amp;D debris landfills that accept any pulverized C&amp;D debris from a permitted C&amp;D debris processing facility, or C&amp;D debris landfills that receive more than 200 tons of C&amp;D debris per week.</li> </ol>	<p>• <b>Wastes received:</b> Construction and demolition wastes and inert debris only, meaning the waste building materials, packaging and rubble resulting from construction, remodeling, repair and demolition operations on pavements, houses, commercial buildings and other structures. Construction, demolition and inert (CDI) waste includes the following that meet the above criteria:</p> <ol style="list-style-type: none"> <li>2. Components of the building or structure that is the subject of the construction work including, (e.g., lumber, gypsum, glass, metal, roofing material, brick, slag, ceramics, plaster, clay and clay products, tile, carpeting, fully cured asphalt, HVAC systems, lighting fixtures, appliances, and furnishings)</li> <li>3. Tools and building materials consumed or partially consumed in the course of the construction work (may include blueprints, plans, etc.);</li> <li>4. Packaging derived from materials installed in the structure or from tools and equipment used in the course of the construction work;</li> <li>5. Plant materials resulting from construction work when commingled with dirt, rock, inert debris or C&amp;D debris; and</li> </ol>	<p>• <b>Wastes received:</b> Construction and demolition wastes as defined by 3745-400-01 of the Administrative Code, and some types of solid waste as specified below:</p> <ol style="list-style-type: none"> <li>1. Packaging which results from the use of construction materials incidental to the load;</li> <li>2. Tree stumps, trunks and clean (i.e., without leaves and smaller branches attached) branches exceeding 4 inches (25 cm) in diameter; and</li> <li>3. Asbestos materials subject to NESHAP, 40 CFR Part 61, Subpart M, may be disposed of only if the necessary air pollution control permits have been issued.</li> </ol>

**Selected State Regulations for Construction: Demolition Waste Landfills**

New York	California *	Ohio
	<p>6. Solid waste that is specifically determined to be inert by the applicable Regional Water Quality Control Board, such as treated industrial wastes and de-watered bentonite-based drilling mud.</p>	
<ul style="list-style-type: none"> <li>• <b>Waste restrictions:</b> Solid waste (including what otherwise would be construction and demolition debris) resulting from any processing technique, other than that employed at a department-approved C&amp;D debris processing facility, that renders individual waste components unrecognizable, such as pulverizing or shredding.</li> <li>• Non-commercial facilities which accept only recognizable, uncontaminated<sup>(a)</sup> concrete and concrete products (including steel or fiberglass reinforcing rods that are embedded in the concrete), asphalt pavement, brick, glass, soil and rock, or landfills for the disposal of trees, stumps, yard waste and wood chips generated from these materials when origin and disposal of such waste occur on properties under the same ownership or control are exempt from the provisions listed below.</li> <li>• <sup>(a)</sup> Uncontaminated means C&amp;D debris that is not mixed or commingled with other solid waste at the point of generation, processing or disposal, and that is not contaminated with spills of a petroleum product, hazardous waste or industrial waste. Contamination from spills of a petroleum</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Waste restrictions:</b> C&amp;D debris excludes commingled office recyclables and, except as provided above, commingled commercial solid waste, and commingled industrial solid waste as they are defined in Title 27, CCR section 20164.</li> <li>• It also excludes wastes not separated for reuse solid waste, recyclable materials that are not hazardous, and may not contain more than 1% putrescible wastes by volume.</li> <li>• It must not contain soluble pollutants at concentrations in excess of applicable water quality objectives, and may not contain significant quantities of decomposable waste.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Waste restrictions:</b> C&amp;D waste may not have been pulverized, shredded, or otherwise rendered to the extent that the debris is not readily identifiable. Facilities may not accept any hazardous wastes, infectious wastes, or containerized or bulk liquids.</li> </ul>

**Selected State Regulations for Construction: Demolition Waste Landfills**

New York	California *	Ohio
<p>product does not include asphalt or concrete pavement that has come into contact with petroleum products through normal vehicle use of the roadway.</p>		
<ul style="list-style-type: none"> <li>• <b>Location restrictions:</b> Restrictions exist for siting on, over, or near agricultural land; floodplains; regulated wetlands; critical habitat for threatened or endangered species; areas located hydraulically upgradient from reservoirs, reservoir stems or controlled lakes, or located in watersheds which are managed pursuant to the Safe Water Drinking Act; primary water supply and principal aquifers; airports; unstable areas; areas with geological characteristics subject to rapid or unpredictable groundwater flow; or unmonitorable or unremediable areas.</li> <li>• <b>C&amp;D debris landfills three acres or less</b> must meet adhere to all these restrictions with the exception that these landfills may be sited over principal aquifers, but may not be sited over primary water supply aquifers or within public water supply stabilized cone of depression areas.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Location restrictions:</b> Facilities within 10,000 feet of any airport runway end used by turbojet aircraft or within 5,000 feet of any airport runway end used by only piston-type aircraft must be designed and operated so that the facility does not pose a bird hazard to aircraft.</li> <li>• Facilities located within a five-mile radius of any airport runway end used by turbojet or piston-type aircraft must notify the affected airport and the FAA.</li> <li>• Facilities must be sited where soil characteristics, distance from waste to ground water, and of water beneath or adjacent to the landfill will ensure no impairment of beneficial uses of surface water or of ground.</li> <li>• Facilities shall not be located on a known Holocene fault and are subject to floodplain restrictions.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Location restrictions:</b> Facilities located within five hundred feet of an occupied building which is not owned by the owner or operator shall establish a barrier to minimize visibility of the facility operations. Also, facilities may not be located within the boundaries of the one-hundred-year flood plain of a watercourse unless the owner or operator has obtained an exemption from the licensing authority in accordance with paragraph (C)(2) of rule 3745-400-15 of the Administrative Code, or within the boundaries of a sole source aquifer designated by the Administrator of the United States Environmental Protection Agency under the "Safe Drinking Water Act," 88 Stat. 1660 , 42 U.S.C.A. 300F, as amended.</li> </ul>

**Selected State Regulations for Construction: Demolition Waste Landfills**

New York	California *	Ohio
<p>• <b>Operating and design criteria:</b></p> <p>1. <u>Base or liner system</u>  <b>For C&amp;D debris landfills three acres or less:</b> A base system of at least two feet of soils having a coefficient of permeability of <math>1 \times 10^{-5}</math> centimeters per second or less is required.  <b>For C&amp;D debris landfills greater than three acres:</b> A minimum liner system of a single composite liner and a leachate collection system where the composite liner must consist of geomembrane having a minimum thickness of 60 mils that directly overlays a soil layer is required. A secondary composite liner where the soil component of the secondary composite liner must be at least 24 inches in compacted thickness and must have a maximum remolded coefficient of permeability of <math>1 \times 10^{-7}</math> centimeters per second throughout its thickness and must be directly overlain by and in contact with a geomembrane is also required. The soil material particles must be able to pass a one inch screen. Geomembrane liners used to control fluid migration from landfills are also required. (360-2.13 (j)(k) except (j)(1)(i).)</p> <p>2. <u>Leachate collection system</u>  <b>For C&amp;D debris landfills three acres or less:</b> No leachate collection system is required.  <b>For C&amp;D debris landfills greater than three acres:</b> A leachate collection and removal system</p>	<p>• <b>Operating and design criteria:</b></p> <p><b>Regulations are as or more stringent than 40 CFR Part 258. Some criteria include:</b></p> <p>Facilities are required to have containment structures which are capable of preventing degradation of waters of the State as a result of waste discharges to the landfills. Liners must be installed to cover all natural geologic materials that are likely to be in contact with waste (including landfill gas or leachate).</p> <p>1. <u>Liners</u> shall be designed and constructed to contain fluid, including landfill gas, waste, and leachate. Clay liners, if used, must be a minimum of 1 foot thick and be installed at a relative compaction of at least 90 percent.</p> <p>2. A <u>leachate collection system</u> may need to be installed directly above underlying containment features for landfills and waste piles, and installed between the liners for surface impoundments (20340. [C15: Section 2543 // T14: Section 17781(b)(2) (d)(1)]).</p> <ul style="list-style-type: none"> <li>• It must be installed immediately above the liner (except in the case of a surface impoundment), and between the inner and outer liner of a double liner system, and be designed, constructed, maintained, and operated to collect and remove twice the maximum anticipated daily volume of leachate from the Unit.</li> </ul>	<p>• <b>Operating and design criteria</b></p> <p>1. Recompacted <u>soil liner</u> is required except for facilities where the conditions in paragraph (A) of rule 3745-400-09 of the Administrative Code are met; where the facility was filled with debris as of September 30, 1996; or where the facility was filled with debris prior to an approved modification to enlarge the facility.</p> <p>2. A <u>leachate collection system</u> is required that</p> <ul style="list-style-type: none"> <li>• Can collect leachate within the limits of debris placement</li> <li>• Is capable of maintaining less than a one foot depth of leachate over the in situ and/or added geologic material or constructed liner, excluding the leachate sump collection point(s).</li> <li>• Is constructed on a prepared smooth surface that shall include the following: <ul style="list-style-type: none"> <li>(a) Have a minimum slope of two per cent.</li> <li>(b) Be able to bear the weight of the facility and its construction and operations without causing or allowing a failure of the leachate collection system to occur through settling.</li> <li>(c) Be free of debris, foreign material, deleterious material; and</li> </ul> </li> <li>• Is constructed of a drainage medium that shall provide a permeability no less than <math>1 \times 10^{-3}</math> cm/sec. The medium may consist of suitable select debris or other suitable</li> </ul>

**Selected State Regulations for Construction: Demolition Waste Landfills**

New York	California *	Ohio
<p>above the liner system must be designed, constructed, maintained and operated to collect and remove leachate from the landfill and ensure that the leachate head on the liner system does not exceed one foot at the expected flow, except during storm events. The leachate collection and removal system must be designed and constructed to operate without clogging throughout the effective facility life and post-closure maintenance period. The leachate collection and removal pipe network must be designed to be accessible for routine cleaning and maintenance (360-2.13(h), (l), (m) except 360-2.13(l)(2)(ii).)</p> <p>3. <u>Final cover system</u>  <b>For C&amp;D debris landfills three acres or less:</b>                      Final landfill slopes must not be less than 4 percent, or greater than 25 percent and must be stable when subjected to the peak discharge from a rainfall intensity of a 24-hour duration, 25-year storm. A surface water drainage system may be necessary to provide such protection. The final cover system must consist of:</p> <ul style="list-style-type: none"> <li>• A barrier soil cover is a soil layer of low permeability constructed to minimize precipitation migration into the landfill.</li> <li>• A protection layer of soil not less than 24 inches thick must be installed on top of the barrier soil cover. Material specifications,</li> </ul>	<ul style="list-style-type: none"> <li>• It should be designed and operated to function without clogging through the scheduled closure of the Unit and during the post closure maintenance period.</li> <li>• It should consist of a permeable subdrain layer which covers the bottom of the Unit and extends as far up the sides as possible.</li> </ul> <p>3. A <u>final cover</u> must function with minimum maintenance and provide waste containment to protect public health and safety by controlling at a minimum, vectors, fire, odor, litter and landfill gas migration. The final cover shall also be compatible with postclosure land use. Thickness, quality, and type of final cover may depend on the following: a need to control landfill gas emissions and fires; the future reuse of the site; and provide access to all areas of the site as needed for inspection of monitoring and control facilities, etc.</p>	<p>waste materials and shall be at least one foot thick.</p> <ul style="list-style-type: none"> <li>• Is designed to prevent crushing of, or damage to, any of its components.</li> <li>• Is designed to function without clogging.</li> <li>• If a pipe network is proposed, is designed with access for cleaning and inspection devices and with pipe lengths not exceeding the capabilities of the cleaning and inspection devices.</li> <li>• Is designed to provide access for obtaining leachate samples for testing of leachate quality and for determining the leachate head.</li> <li>• Is designed to be capable of conveying leachate outside the limits of debris placement for treatment and discharge in accordance with Chapter 6111. (water pollution control) of the Revised Code.</li> <li>• If storage of leachate outside of the limits of debris placement is proposed, include a storage containment designed to be no less protective of the environment than the facility.</li> <li>• Is constructed and certified in phases, if necessary, so as to stay immediately ahead of the working face.</li> </ul> <p>This is true except for areas containing debris as of September 30, 1996, or areas</p>

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<p>installation methods and compaction specifications must be adequate to protect the barrier soil cover from desiccation cracking, frost action, and root penetration, promote stability and resist erosion at the final design slopes of the landfill.</p> <ul style="list-style-type: none"> <li>• A topsoil layer or alternative soil material of not less than six inches thick in-place must be installed on top of the protection layer. The topsoil or alternative soil material must be sufficient to maintain vegetative growth.</li> <li>• Gas venting system. A gas venting system below the barrier soil layer may be required by the department.</li> </ul> <p><b>For C&amp;D debris landfills greater than three acres:</b> The final cover system must also consist of a layered system (gas venting layer, barrier soil or geomembrane layer, barrier protection layer and top soil layer – see above and 360-2.15(d)). Final landfill slopes must not be less than 4 percent, nor greater than 33 percent and must be stable when subjected to the peak discharge from a rainfall intensity of a 24-hour, 25-year storm event. A surface water drainage system may be necessary to provide such protection. Landfill gas control systems must be designed to prevent the migration of concentrated amounts of landfill gases off-site. (360-2.15(e).)</p>		<p>containing debris placed without a recompacted soil liner prior to January 1, 1999.</p> <p>3. The facility shall use a <u>standard cap system</u> over any area of a facility that receives debris after September 30, 1996 that meets the construction and performance specifications of a standard cap system as follows:</p> <ul style="list-style-type: none"> <li>• First, a soil layer of well compacted, cohesive soil with a minimum recompacted thickness of eighteen inches. The soil shall meet the following criteria:             <ol style="list-style-type: none"> <li>(a) The maximum soil particle size shall be six inches.</li> <li>(b) At least ninety five percent of the soil particles, by volume, shall pass the three inch sieve.</li> <li>(c) At least seventy five percent of the soil particles, by volume, shall pass the number four sieve.</li> <li>(d) At least fifty percent of the soil particles, by weight, shall pass the number two hundred sieve.</li> <li>(e) The soil shall meet either of the following specifications:                 <ol style="list-style-type: none"> <li>(i) Possess plasticity properties lying above the A-line in the “Unified Soil Classification System” described in ASTM D 2487.</li> <li>(ii) Consist of 0.002 inch or finer clay particles</li> </ol> </li> </ol> </li> </ul>

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New York	California *	Ohio
<p>4. <u>Access</u>  <b>For both types of C&amp;D debris landfills:</b> An attendant must be on duty during all operating hours of the landfill. The landfill must only be operated between the hours of sunrise and sunset.</p> <p>5. <u>Specific waste placement requirements</u>  <b>For both types of C&amp;D debris landfills:</b></p> <ul style="list-style-type: none"> <li>▪ C&amp;D debris must be spread in layers not exceeding five feet in uncompacted thickness.</li> <li>▪ The first layer of waste placed in contact with any leachate management structures must be at least five feet in compacted thickness, of a select nature and placed in a manner that will not impact or impede the operation of these structures.</li> <li>▪ No slope may be greater than 33 percent.</li> </ul>		<p>as determined in ASTM D 422 such that these clay particles shall comprise at least fifteen percent of the total soil dry mass.</p> <p>(f) The soil may be an alternative soil type acceptable to the licensing authority.</p> <p>(g) The soil shall not be comprised of solid waste or construction and demolition debris.</p> <p>(h) The soil shall be compacted using loose lifts twelve inches thick or less and meet a compaction standard described in paragraph (C)(5) of rule 3745-400-08 of the Administrative Code.</p> <ul style="list-style-type: none"> <li>• Second, a soil layer with minimum thickness of six inches and of sufficient fertility to support dense vegetation.</li> <li>• Third, a complete and dense perennial vegetative cover of healthy grasses or other vegetation shall be established and maintained on all exposed final cover.</li> <li>• The standard cap system shall have a minimum slope of three per cent and a maximum slope of twenty-five per cent and shall be graded to eliminate ponding, promote drainage, and minimize erosion.</li> <li>• Comparable materials and/or thicknesses for the standard cap system may be utilized by the owner or operator if the final cap system specified in this rule is not compatible with the end use.</li> </ul>

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New York	California *	Ohio
		<p>4. The facility shall construct a <u>vegetative cap system</u> where an area of an existing facility is filled with debris to final grade as of September 30, 1996, and where no dense vegetation has been established in the area and the area remains an inactive licensed disposal area for the remaining life of the facility as follows.</p> <p>(a) Consist of a soil layer with a thickness of six inches and of sufficient fertility to support dense vegetation.</p> <p>(b) Consist of a complete and dense perennial vegetative cover of healthy grasses or other vegetation shall be established and maintained on all exposed final cap.</p> <p>(c) Be graded to eliminate ponding, promote drainage, and minimize erosion.</p> <p>(d) Utilize comparable materials and/or thicknesses for the vegetative cap system if the final cap system specified in this rule is not compatible with the end use.</p> <p>The facility shall not be required to construct any cap system where an area of an existing facility is filled with debris to final grade but where dense vegetation has been established in the area as of September 30, 1996, and the area remains an inactive licensed disposal area for the remaining life of the facility.</p> <p>5. <u>Access</u> will</p>

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New York	California *	Ohio
		<ul style="list-style-type: none"> <li>• Be limited to authorized personnel only, except when operating personnel are present during operating hours.</li> <li>• Exclude live domestic and live farm animals from the facility except those used for security or vector control.</li> <li>• Not be denied to the licensing authority and its authorized representatives, who upon proper identification, may enter the facility at reasonable times to determine compliance with Chapter 3714 of the Revised Code and rules adopted thereunder.</li> <li>• Owner/Operators (O/O) must maintain access roads to allow passage of loaded vehicles with minimum dust generation or erosion during inclement weather.</li> <li>• O/Os must employ measures necessary to minimize the incidence of mud, dirt, and dust on public roads before vehicles leave the facility.</li> <li>• O/Os must post clear instructions for using the facility at the entrance. Instructions shall include a listing of wastes the disposal of which is prohibited as outlined in paragraph (F) of this rule and of telephone numbers of emergency personnel including the local fire department, the board of health, and the appropriate district office of Ohio EPA. The instructions shall be readable from vehicles</li> </ul>

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New York	California *	Ohio
<ul style="list-style-type: none"> <li>• <b>Recordkeeping and reporting:</b> The landfill operator must have in his possession during all hours of operation, a copy of the permit issued pursuant to this Part, including conditions, a copy of the operation and maintenance manual and the most recent annual report for both types of C&amp;D debris landfills.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Recordkeeping and reporting:</b> Regulations are as or more stringent than 40 CFR Part 258.</li> </ul>	<p>arriving to deposit debris.</p> <ul style="list-style-type: none"> <li>• <b>Recordkeeping and reporting:</b> O/Os must keep a daily log of operations of the facility that contains all the information specified on forms prescribed by the director. O/Os must keep records of all material prohibited for disposal that was accepted by the facility, including material removed from the working face in accordance with paragraph (F)(3) of 3745-400-11. For prohibited materials removed by the owner or operator, dated records of volumes and destinations for proper disposal shall be kept. For prohibited materials removed by others or for rejected loads, the O/Os must list the responsible entity, including companies maintaining transfer containers at the facility for the purpose of collecting prohibited materials.</li> <li>• O/Os must obtain an approved and valid license as required by Chapter 3745-37 of Administrative Code. The owner or operator shall retain at the facility during operational hours, the license application which contains the facility's construction and monitoring plans.</li> <li>• O/Os must maintain all applicable permits and authorizations required by Chapters 3704. (air pollution control) and 6111. (water pollution</li> </ul>

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New York	California *	Ohio
<p>• <b>Groundwater monitoring:</b>  <b>For both C&amp;D debris landfills:</b> A minimum separation of five-feet must be maintained between the base system and the seasonal high groundwater table. The nature of the materials making up this separation, whether natural or backfilled, shall be subject to department approval. A minimum of ten-feet separation must be maintained between the base system and bedrock. The nature of the materials making up this separation, whether natural or backfilled, shall be subject to department approval.                      The groundwater monitoring system must be comprised of monitoring wells and piezometers able to define the three-dimensional groundwater flow system. Monitoring wells must be capable of detecting landfill-derived groundwater contamination within the critical stratigraphic section. Horizontal well spacing and well screen placement as well as the rest of the groundwater monitoring system must comply with 360-2.11.</p>	<p>• <b>Groundwater monitoring:</b>                      Regulations are as or more stringent than 40 CFR Part 258.</p>	<p>control) of the Revised Code.</p> <ul style="list-style-type: none"> <li>• <b>Groundwater monitoring:</b> O/Os of any facility disposing of debris on or after September 30, 1996, shall have a ground water monitoring well system unless the limits of debris placement meet the criteria in paragraph (B) of rule 3745-400-09 of the Administrative Code. The monitoring well system is not required to be capable of determining the impact of the facility on the quality of the ground water beneath the facility.</li> <li>• The ground water monitoring well system shall include a sufficient number of background and downgradient monitoring wells that yield ground water samples from the first continuous significant zone of saturation underlying the facility.</li> <li>• All monitoring wells must allow the collection of ground water samples that are representative of ground water quality in the geologic unit being monitored and at a minimum include the following:                             <ol style="list-style-type: none"> <li>(1) Monitoring wells shall be cased in a manner that maintains the integrity of the monitoring well boreholes.</li> <li>(2) The annular space, i.e., the space between the borehole and the well casing, above the sampling depth shall be sealed to prevent the contamination of the samples and the ground water.</li> </ol> </li> </ul>

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New York	California *	Ohio
		<p>(3) The casing shall be screened or perforated and surrounded by sand or gravel in such a way that allows for the minimization of the passage of formation materials into the well.</p> <ul style="list-style-type: none"> <li>• Upon the installation of ground water monitoring wells, a construction certification report shall be submitted in accordance with rule 3745-400-08 of the Administrative Code.</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Detection monitoring</b> <b>For both C&amp;D debris landfills:</b> Operational water quality monitoring must be conducted during the operation, closure, and post-closure periods of the facility. The operational water quality monitoring plan must be able to distinguish landfill-derived contamination from the existing water quality at the site. The plan must also describe trigger mechanisms for initiating contingency water quality monitoring. The minimum requirements for operational water quality monitoring include: <ul style="list-style-type: none"> <li>• Sampling and analysis must be performed at least quarterly, once for baseline parameters and three times for routine parameters.</li> <li>• Operational water quality analysis must include at least those parameters specified in the Water Quality Analysis Tables for routine and baseline parameters.</li> <li>• Within 90 days of completing the quarterly field sampling activities, the facility O/O must determine whether or not there is a</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• <b>Detection monitoring:</b> Regulations are as or more stringent than 40 CFR Part 258.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Detection monitoring:</b> O/Os must determine the concentration or value of the parameters listed in the appendix of 3745-400-10 in ground water and leachate in accordance with the following schedule: <ol style="list-style-type: none"> <li>(1) The owner or operator shall, whenever ground water samples are drawn from a monitoring well, field analyze the samples for parameters 1, 2, and 3 listed in the appendix .</li> <li>(2) During the initial year of ground water monitoring, O/Os must: <ul style="list-style-type: none"> <li>• At least quarterly, determine the initial background concentration or value in ground water samples from all monitoring wells for parameters 1 to 19 listed in the appendix of this rule.</li> <li>• During the first quarterly analysis of ground water quality, also determine the concentration or value for parameters 20 to 64 listed in the appendix of this rule.</li> <li>• At least once, determine the</li> </ul> </li> </ol> </li> </ul>

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New York	California *	Ohio
<p>significant increase from existing water quality levels established for each parameter.</p>		<p>concentrations or values in the leachate for parameters 1 to 19 listed in the appendix of this rule.</p> <ul style="list-style-type: none"> <li>• After the initial year, O/Os must at least annually sample all monitoring wells and the leachate collection system and analyze the samples for the parameters 1 to 19 listed in the appendix.</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Compliance/assessment monitoring For both C&amp;D debris landfills:</b> The O/O must compare the groundwater quality of each parameter at each monitoring well to the existing water quality value of that parameter. A significant increase has occurred if: <ul style="list-style-type: none"> <li>• the groundwater quality for any parameter at any monitoring well exceeds the existing water quality value for that parameter (360-2.11(c)(5)(i)(c)), by three standard deviations; or</li> <li>• the groundwater quality for any parameter at any monitoring well exceeds the existing water quality value for that parameter (360-2.11(c)(5)(i)(c)) and exceeds the water quality standards for that parameter as specified in Part 701, 702, or 703 of this Title.</li> </ul> </li> <li>• If the O/O determines that there is a significant increase from existing water quality levels for one or more of the parameters for the routine</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Compliance/assessment monitoring:</b> Regulations are as or more stringent than 40 CFR Part 258.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Compliance/assessment monitoring:</b> The licensing authority or director may order the O/O to conduct a ground water assessment to determine the concentration of possible contaminants, and their extent and rate of migration within the ground water if the licensing authority or director determines that the facility may be affecting ground water quality. Such a determination may be supported by leachate quality reports and the following: <ol style="list-style-type: none"> <li>(1) The ground water quality reports from a qualified ground water scientist.</li> <li>(2) Water quality data from documented leachate releases to seeps, springs, streams or other receptors. <ul style="list-style-type: none"> <li>• Sampling and analysis will include the following: <ol style="list-style-type: none"> <li>(1) Sampling of the affected well(s) and background well(s) and analysis of those samples for all leachate or leachate-derived constituents</li> </ol> </li> </ul> </li> </ol> </li> </ul>

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New York	California *	Ohio
<p>parameters at any monitoring well, the O/O</p> <ul style="list-style-type: none"> <li>• must, within 14 days of this finding, notify the department indicating which parameters have shown significant increases from existing water quality levels; and</li> <li>• must sample and analyze all monitoring points for the baseline parameters during the next quarterly sampling event. Subsequent sampling and analysis for baseline parameters must be conducted at least semiannually until the significant increase is determined not to be landfill-derived.</li> <li>• A system must be in place that includes a plan for contingency water quality monitoring, which must be conducted when a significant increase over existing water quality has been detected.</li> </ul>		<p>including those constituents listed in the appendix. (2) Within ninety days of sampling the affected well(s) and background well(s) as required by this paragraph, sampling of all other monitoring wells and analysis of those samples for those leachate or leachate-derived constituents found to be above background levels in the affected monitoring wells. (3) Sampling at least annually all monitoring wells included in the ground water assessment and analysis of those samples for all the parameters listed in the appendix. A monitoring well shall be considered part of the ground water assessment if it is needed to determine the concentration of any contaminants, and their extent and rate of migration within the ground water.</p>
<ul style="list-style-type: none"> <li>• <b>Closure activities and post-closure requirements</b></li> </ul> <p><b>For both C&amp;D debris landfills:</b> In addition to the final cover system described in “operating and design criteria” above, O/Os must determine if remedial work in addition to final cover is necessary. A closure investigation must be conducted and must include the following:</p> <ul style="list-style-type: none"> <li>• A hydrogeologic investigation must be performed (360-7.3(a)(4) and 360-7.4(a)(4)).</li> <li>• A surface leachate investigation</li> <li>• A vector investigation.</li> <li>• An explosive gas survey.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Closure activities and post-closure requirements:</b></li> </ul> <p>Regulations are as or more stringent than 40 CFR Part 258.</p>	<ul style="list-style-type: none"> <li>• <b>Closure activities and post-closure requirements:</b> Within seven days of closure, the O/O must provide written notification to the licensing authority of the date the facility ceased to accept debris, and block, by locked gates, fencing, or other sturdy obstacles, all entrances and access roads to the facility to prevent unauthorized access during the final closure period.</li> <li>• Within thirty days of closure, the O/O must post signs, easily visible from all access roads leading onto the facility, stating in letters a least three inches high that the construction</li> </ul>

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<ul style="list-style-type: none"> <li>• Maintenance is required of the following: soil cover integrity; slopes; cover vegetation; drainage structures; environmental and facility monitoring points (and sampled during the post-closure period for a minimum of 30 years); and any leachate removal systems (required to ensure the systems remain operational over the 30-year monitoring and maintenance period).</li> <li>• A post-closure monitoring and maintenance manual (360-7.4(a)(6)(xi)) must be submitted as part of the operation and maintenance manual (360-7.4(a)(6)). This document must provide personnel with instructions for assuring monitoring, including, leachate management, environmental sampling and analysis, reporting and proper maintenance of all facility components in order to maintain the facility in accordance with the provisions of the manual as approved by the department for a minimum period of 30 years after landfill closure.</li> <li>• Upon transfer of ownership of a C&amp;D debris landfill, a provision must be included in the property deed indicating the period of time during which the property has been used as a landfill, a description of the wastes contained within and the fact that the records for the facility</li> </ul>		<p>and demolition debris facility is closed and no longer accepts construction and demolition debris. The signs shall be maintained in legible condition for at least two years after the facility ceases to accept debris.</p> <ul style="list-style-type: none"> <li>• Within sixty days of closure, the O/O must cover all uncapped disposal areas with at least six inches of recompact soil and grade this soil to prevent ponding of water. This soil layer may be considered a part of the cap system described in the operating requirement section above.</li> <li>• Within one year of closure, the O/O must complete construction of a cap system over all areas of debris placement not previously certified in accordance with rule 3745-400-08 of the Administrative Code. After completion of construction of the cap system, the O/O must plug and abandon all ground water monitor wells. If any wells are constructed or used as a part of a ground water quality assessment program, and the licensing authority has ordered o/o to monitor any ground water monitor wells, the O/O must continue to conduct ground water monitoring in accordance with those orders.</li> <li>• The O/O must file with the appropriate County Recorder a plat of the facility and information describing the acreage, exact location, depth,</li> </ul>

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<p>have been filed with the department. It must also reference a map filed with the county clerk, showing the limits of the landfilled areas within the property.</p> <ul style="list-style-type: none"> <li>• The O/O of a closing facility must also establish a long-term monitoring well network in the uppermost aquifer.</li> </ul>		<p>volume, and nature of the placed debris.</p> <ul style="list-style-type: none"> <li>• The O/O must record a notation on the deed to the facility that the land has been used as a construction and demolition debris facility and include the same information given to the County Recorder (see above).</li> </ul>

1 \* California CDI waste disposal facilities must obtain full solid waste facility permits and comply with all regulations set forth for municipal solid waste  
2 landfills. The regulations presented are therefore the same as those for MSW facilities in California and are as stringent or are more stringent than the regulations  
3 in 40 CFR Part 258.

**Federal Regulations for Hazardous and Solid Waste Landfills**

<p><b>Subtitle C Hazardous Waste Landfills 40 CFR Part 264/265 Subpart N</b></p>	<p><b>Subtitle D Municipal Solid Waste Landfills (MSWLFs) 40 CFR Part 258</b></p>	<p><b>Solid Waste Disposal Facilities and Practices* (40 CFR Part 257)</b></p>
<p>♦ <b>Wastes received:</b> Listed or characteristic hazardous wastes.</p>	<p>♦ <b>Wastes received:</b> Household wastes, non-hazardous wastes such as commercial solid waste, nonhazardous sludge, conditionally exempt small quantity generator waste, and industrial solid waste.</p>	<p>♦ <b>Wastes Received:</b> Non-hazardous commercial and industrial solid wastes, construction and demolition wastes, and, in some cases, conditionally exempt small quantity generators (CESQG) hazardous wastes.</p>
<p>♦ <b>Waste Restrictions (264.312-264.317):</b> Restrictions and prohibitions on receipt of ignitable and reactive wastes, incompatible wastes, bulk and non-containerized wastes, and containers; and special requirements for lab packs and certain listed acutely hazardous wastes (F020-F023, F026 and F027).</p>	<p>♦ <b>Liquids Restrictions (258.28):</b> Prohibition on disposal of bulk and non-containerized liquid waste, unless it is household waste (other than septic) or leachate or gas condensate derived from the MSWLF unit. Prohibition on disposal of non-household waste containers holding liquids, unless the container is small and normally used to hold liquids for purposes other than storage.</p>	<p>♦ <b>Waste Restrictions:</b> Facilities not meeting the requirements of Part 257 Subpart B cannot accept hazardous wastes from CESQGs.</p>
<p><b>Location Standards (264.18):</b></p> <p>♦ Seismic and floodplain considerations; prohibition on use of underground mines, caves, and salt dome/salt bed formations.</p>	<p>♦ <b>Location Restrictions (258.10-258.15):</b> Restrictions for siting MSWLFs in or near airports (due to bird hazards), floodplains, wetlands, fault areas, seismic impact zones, and unstable areas.</p>	<p>♦ <b>Location Restrictions (257.3-1):</b> Facilities or practices in floodplains shall not restrict the flow of the base flood; reduce the temporary water storage capacity of the floodplain; or result in washout of solid waste from the facility.</p> <p>♦ <b>Solid waste units receiving CESQG waste.</b> 257.8 (floodplains) and 257.9 (wetlands restrictions).</p>

\* This includes Subtitle D industrial landfills and Construction and Demolition (C&D) landfills.

**Federal Regulations for Hazardous and Solid Waste Landfills**

<p><b>Subtitle C Hazardous Waste Landfills 40 CFR Part 264/265 Subpart N</b></p>	<p><b>Subtitle D Municipal Solid Waste Landfills (MSWLFs) 40 CFR Part 258</b></p>	<p><b>Solid Waste Disposal Facilities and Practices* (40 CFR Part 257)</b></p>
<p><b>Design and Operating Criteria</b></p> <p><b>Design and Operating Requirements (264.301):</b></p> <ul style="list-style-type: none"> <li>♦ <u>Existing landfills</u> (pre-1992): Liner and leachate collection &amp; removal system required.</li> <li>♦ <u>New landfills</u> (constructed after 1992): Two or more liners with a leachate collection &amp; removal system above and between such liners.</li> <li>♦ <u>All liners</u>: Constructed of materials appropriate to prevent failure due to pressure gradients (static head), physical contact with the waste, climatic conditions, and the stress of daily operations.</li> <li>♦ <u>Double liner system</u>: top liner (e.g., geomembrane) and a composite bottom liner.</li> </ul>	<p><b>Design and Operating Criteria</b></p> <p><b>Design Criteria – New MSWLFs (258.40):</b></p> <ul style="list-style-type: none"> <li>♦ Performance standards:                             <ul style="list-style-type: none"> <li>➢ Designed to ensure that the concentration values of the chemicals listed in Table 1 of 40 CFR 258.40 will not be exceeded in the uppermost aquifer at the relevant point of compliance.</li> <li>➢ With a composite liner and leachate collection system designed and constructed to maintain less than a 30-cm depth of leachate over the liner.</li> </ul> </li> </ul>	<p><b>Design and Operating Criteria</b></p> <p>No Design Criteria in Part 257.</p> <p><b>Operating Criteria</b></p> <p><b>Endangered Species (257.3-2):</b> Facilities or practices shall not cause or contribute to the taking of any endangered or threatened species of plant, fish or wildlife nor result in the destruction or adverse modification of the critical habitat of any such species.</p> <p><b>Surface Water (257.3-3):</b> Facilities or practices shall not cause a discharge of pollutants or dredged or fill material into surface waters or any non-point source pollution that violates any requirement of the Clean Water Act.</p> <p><b>Ground Water (257.3-4):</b> A facility or practice shall not contaminate an underground drinking water source beyond the solid waste boundary.</p>
<ul style="list-style-type: none"> <li>♦ <u>Composite bottom liner</u>: Upper layer must prevent migration of wastes into this component during the landfill's active life. Lower component: at least 3 feet (91 cm) of compacted soil with a hydraulic conductivity of <math>1 \times 10^{-7}</math> cm/sec.</li> <li>♦ Leachate collection &amp; removal systems (LCRS) performance standard: maintain leachate depth</li> </ul>	<ul style="list-style-type: none"> <li>♦ <u>Composite liner requirements</u>: Upper component must be a minimum 30-mil flexible membrane liner (FML) and lower component must consist of at least two-foot layer of compacted soil with maximum hydraulic conductivity of <math>1 \times 10^{-7}</math> cm/sec.</li> <li>♦ FML components made of HDPE shall be at least 60-mil thick. The FML component must be</li> </ul>	<p><b>Operating Requirements</b></p> <p><b>Disease Vector Control (257.3-6):</b> Facilities or practices shall not exist or occur unless on-site populations of disease vectors are minimized through periodic application of cover material or other appropriate techniques.</p>

**Federal Regulations for Hazardous and Solid Waste Landfills**

<p><b>Subtitle C Hazardous Waste Landfills 40 CFR Part 264/265 Subpart N</b></p>	<p><b>Subtitle D Municipal Solid Waste Landfills (MSWLFs) 40 CFR Part 258</b></p>	<p><b>Solid Waste Disposal Facilities and Practices* (40 CFR Part 257)</b></p>
<p>over the liner not to exceed 30 cm (one foot).</p> <ul style="list-style-type: none"> <li>♦ LCRS and Leak Detection System Minimum Requirements:                             <ul style="list-style-type: none"> <li>➤ Constructed with a bottom slope of one percent or more;</li> <li>➤ Made of granular drainage materials with hydraulic conductivity of <math>1 \times 10^{-2}</math> cm/sec or more and a thickness of 12 inches (30.5 cm) or more (or constructed of synthetic or geonet materials with a minimum transmissivity of <math>3 \times 10^{-5}</math> m<sup>2</sup>/sec);</li> <li>➤ Constructed of materials chemically resistant to materials being managed and leachate expected to be generated;</li> <li>➤ Of sufficient strength to prevent collapse under pressure from overlying wastes;</li> <li>➤ Designed and operated to function without clogging through life of landfill; and</li> <li>➤ Constructed with sumps and liquid removal methods of sufficient size to collect and remove liquids and prevent liquids from backing up into drainage layer.</li> </ul> </li> </ul>	<p>installed in direct and uniform contact with the compacted soil component.</p> <p><b>Operating Criteria – All MSWLFs:</b></p> <ul style="list-style-type: none"> <li>♦ <b>Procedures for excluding hazardous wastes (258.20):</b> O/O must implement a program to detect and prevent disposal of regulated hazardous wastes and PCB wastes, to include:                             <ul style="list-style-type: none"> <li>➤ Random inspections of incoming loads;</li> <li>➤ Records of any inspections;</li> <li>➤ Training of facility personnel to recognize regulated hazardous wastes and PCB wastes;</li> </ul> </li> </ul> <p>Notification of State Director if regulated haz or PCB wastes discovered.</p>	<p><b>Air Criteria (257.3-7):</b> A facility or practice shall not engage in open burning of residential, commercial, institutional, or industrial solid waste. This prohibition does not apply to the infrequent burning of agricultural, silvicultural, (forest) or land-clearing wastes, or debris from emergency clean-up operations.</p> <p><b>Safety Criteria (257.3-8):</b>  <b>Explosive gases.</b> The concentration of explosive gases at a facility or practice shall not exceed:                             <ul style="list-style-type: none"> <li>▪ 25% of the lower explosive limit (LEL) for the gases in facility structures; and</li> <li>▪ The LEL for the gases at the property boundary.</li> </ul> </p> <p><b>Fires.</b> A facility or practice must employ appropriate techniques to avoid the hazard of fires.</p>
<ul style="list-style-type: none"> <li>♦ <b>Action Leakage Rate (ALR) (264.302):</b> Maximum design flow rate that the leak detection system (LDS) can remove without the fluid head on the bottom liner exceeding one foot. To determine if the ALR has been exceeded, the O/O must convert the weekly or monthly flow rate from the monitoring data collected under 264.303 to an</li> </ul>	<p><b>Operating Requirements:</b></p> <ul style="list-style-type: none"> <li>♦ <b>Cover material requirements (258.21):</b> At the end of each operating day (or more frequently if necessary), disposed material must be covered with six inches of earthen material to control disease vectors, fires, odor, blowing litter and scavenging.</li> <li>♦ <b>Disease vector control (258.22):</b> O/Os must</li> </ul>	<p><b>Access requirements.</b> A facility or practice shall not allow uncontrolled public access to the site.</p> <p><b>Bird hazards to aircraft.</b> A facility disposing of putrescible waste that may attract birds and which occurs within 10,000 feet of any airport</p>

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<p><b>Subtitle C Hazardous Waste Landfills 40 CFR Part 264/265 Subpart N</b></p>	<p><b>Subtitle D Municipal Solid Waste Landfills (MSWLFs) 40 CFR Part 258</b></p>	<p><b>Solid Waste Disposal Facilities and Practices* (40 CFR Part 257)</b></p>
<p>average daily flow rate for each sump.</p> <ul style="list-style-type: none"> <li>♦ <b>Monitoring and Inspections (264.303):</b> During and immediately following construction and installation, liners and covers must be inspected for uniformity, damage and imperfections.                             <ul style="list-style-type: none"> <li>➤ During active life, a landfill must be inspected weekly and after storms to detect the following: Deterioration, malfunction or improper operation of run-on and run-off control systems;</li> <li>➤ Proper functioning of wind dispersal control systems, where present; and</li> <li>➤ The presence of leachate in and proper functioning of LCRS.</li> </ul> </li> <li>♦ For LDS, O/O must keep records of amount of liquid removed from each sump at least weekly during the active life and closure period.</li> </ul>	<p>prevent or control on-site populations of disease vectors using techniques appropriate for protection of human health and the environment.</p> <ul style="list-style-type: none"> <li>♦ Explosive gases control (258.23):                             <ul style="list-style-type: none"> <li>➤ The concentration of methane gas generated by the landfill must not exceed 25 % of the lower explosive limit for methane in facility structures; and</li> <li>➤ The concentration of methane gas must not exceed the lower explosive limit (LEL) for methane at the facility property boundary.</li> </ul> </li> <li>♦ O/O must implement a methane-monitoring program, monitoring on at least a quarterly basis. If exceedances are detected, immediately notify the State Director and take steps to ensure protection of human health and the environment (HHE). Within 7 days of detection, document in operating record the gas levels found and steps taken to protect human health.</li> </ul>	<p>runway used by turbojet aircraft (or within 5,000 feet of any runway used by piston-type aircraft) must take measures to eliminate bird hazards.</p>
<ul style="list-style-type: none"> <li>➤ Run-on control systems capable of preventing flow onto active portion of landfill during peak discharge from a 25-year storm. A run-off control system to collect and control at least the water volume resulting from a 24-hour, 25-year storm.</li> <li>➤ Wind dispersal control system consisting of a cover or other means to control wind dispersal.</li> </ul>	<ul style="list-style-type: none"> <li>♦ Within 60 days, implement a remediation plan, place it in the operating record and notify the Director that plan has been implemented.</li> <li>♦ <b>Air criteria (258.24):</b> MSWLF units must not violate any applicable requirements developed under a State Implementation Plan (SIP) approved under the Clean Air Act. Open burning of solid waste, other than wood waste or land-clearing debris, is prohibited at MSWLFs</li> </ul>	

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	<ul style="list-style-type: none"> <li>♦ <b>Access requirements (258.25):</b> O/Os must control public access and prevent unauthorized vehicular traffic and illegal dumping of wastes by using artificial or natural barriers.</li> <li>♦ <b>Run-on/run-off control systems (258.26):</b> Run-on control systems capable of preventing flow onto active portion of landfill during peak discharge from a 25-year storm. A run-off control system to collect and control at least the water volume resulting from a 24-hour, 25-year storm.</li> <li>♦ <b>Surface water requirements (258.27):</b> MSWLFs shall not cause a discharge of pollutants into surface waters or any non-point source discharge that violates any requirement of the Clean Water Act.</li> </ul>	
<p><b>Recordkeeping and Reporting:</b></p> <ul style="list-style-type: none"> <li>♦ O/O must maintain operating record (264.73).</li> <li>♦ O/O must submit biennial report (264.75).</li> <li>♦ <b>Response Action Plan (264.304):</b> Must have approved response action plan before receipt of waste that specified actions to be taken if action leakage rate is exceeded. If the flow rate into the LDS exceeds the ALR for any sump, the O/O must:               <ul style="list-style-type: none"> <li>➤ Notify the Regional Administrator (RA) of the exceedance, in writing, within 7 days of the determination;</li> <li>➤ Submit preliminary assessment within 14 days detailing the amount of liquid, possible cause and location of leak; and short-term actions;</li> </ul> </li> </ul>	<p><b>Recordkeeping requirements (258.29):</b> O/Os must record and retain the following information:</p> <ul style="list-style-type: none"> <li>➤ Any location restriction demonstration;</li> <li>➤ Inspection records, training procedures and notification procedures required in 258.20;</li> <li>➤ Gas monitoring results and any remediation plans required under 258.23;</li> <li>➤ Any MSWLF design documentation for placement of leachate or gas condensate in a MSWLF unit, as required in 258.28;</li> <li>➤ Any demonstration, certification, finding, monitoring, testing or analytical data required by the groundwater-monitoring program;</li> <li>➤ Closure and post-closure care plans and any</li> </ul>	<p><b>Recordkeeping requirements (257.30):</b> The O/O of a non-municipal, non-hazardous waste disposal unit must record and retain near the facility in an operating record, the following information as it becomes available:</p> <ul style="list-style-type: none"> <li>▪ Any location restriction demonstration required under 257.7-257.12; and</li> </ul> <p>Any demonstration, certification, monitoring, testing or analytical data required under 257.21–257.28</p>

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<ul style="list-style-type: none"> <li>➤ Submit, within 30 days, results of analyses undertaken to determine extent of damage and whether waste receipt should cease, etc.; and</li> <li>➤ Monthly thereafter, as long as the flow rate exceeds ALR, submit a report to the RA summarizing the results of any remedial actions taken or planned.</li> </ul>	<p>monitoring, testing or analytical data required in 258.60 and 258.61;</p> <ul style="list-style-type: none"> <li>➤ Any cost estimates and financial assurance documentation; and</li> <li>➤ Any documentation supporting a landfill exemption.</li> </ul>	
<p><b>Groundwater-Monitoring Program (Part 264, Subpart F)</b></p> <ul style="list-style-type: none"> <li>♦ Groundwater monitoring system must consist of a sufficient number of wells, installed at appropriate locations and depths, to yield groundwater samples from the uppermost aquifer that represent the background quality of groundwater that has not been affected by leakage from a regulated unit.</li> <li>♦ Install a groundwater monitoring system at the point(s) of compliance and maintain background wells at other locations. Data on each hazardous constituent specified in facility permit must be collected from both background and compliance wells and maintained in operating record. Also must determine the groundwater surface elevation each time groundwater is sampled. The number and type of samples collected to establish background must be appropriate for the form of statistical test employed.</li> </ul>	<p><b>Groundwater-Monitoring and Corrective Action Program:</b></p> <ul style="list-style-type: none"> <li>♦ With the exception of certain small, remote landfills or landfills in certain arid regions, a groundwater monitoring system must be installed that consists of a sufficient number of wells, at appropriate locations and depths, to yield groundwater samples from the uppermost aquifer that: <ul style="list-style-type: none"> <li>➤ Represent the quality of background groundwater that has not been affected by leakage from a unit;</li> <li>➤ Represent the quality of ground water passing the relevant point of compliance specified by the State Director. The downgradient monitoring system must be installed at the relevant point of compliance or at the waste management unit boundary to ensure detection of groundwater contamination in the uppermost aquifer.</li> </ul> </li> </ul>	<p><b>Groundwater-Monitoring and Corrective Action Program for Non-Municipal, Non-Hazardous Waste Disposal Units Receiving CESQG Hazardous Wastes (40 CFR Part 257, Subpart B):</b></p> <p>Groundwater-monitoring and corrective action requirements are the same as for MSWLFs under Part 258 – see requirements summarized in column to the left.</p>

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<p><b>Subtitle C Hazardous Waste Landfills 40 CFR Part 264/265 Subpart N</b></p>	<p><b>Subtitle D Municipal Solid Waste Landfills (MSWLFs) 40 CFR Part 258</b></p>	<p><b>Solid Waste Disposal Facilities and Practices* (40 CFR Part 257)</b></p>
	<p>♦ <u>Sampling and analysis requirements.</u> The groundwater-monitoring program must include consistent sampling and analysis procedures that are designed to ensure monitoring results that provide an accurate representation of groundwater quality at the background and downgradient wells. Procedures must cover:</p> <ul style="list-style-type: none"> <li>➤ Sample collection;</li> <li>➤ Sample preservation and shipment;</li> <li>➤ Analytical procedures;</li> <li>➤ Chain of custody control; and</li> <li>➤ Quality assurance and quality control.</li> </ul>	
<p>♦ <b>Detection Monitoring Program (40 CFR 264.98)</b> to monitor for the parameters and hazardous constituents specified in the facility permit.</p> <p>♦ A sequence of at least four samples must be collected from each well (background and compliance wells) at least quarterly. If O/O finds statistically significant evidence of contamination for any parameter or constituent specified in permit, O/O must:</p> <ul style="list-style-type: none"> <li>➤ Notify implementing agency in writing within seven days, indicating which parameters or constituents have shown evidence of contamination;</li> <li>➤ Immediately sample the groundwater in all monitoring wells to determine whether the constituents in Appendix IX to 40 CFR Part 264 are present and, if so, in what concentrations.</li> </ul>	<p>♦ <b>Detection Monitoring Program (258.54):</b> Detection monitoring is required at all monitoring wells. At a minimum, detection monitoring must include the constituents listed in Appendix I to Part 258. Monitoring frequency must be at least semi-annual and a minimum of four independent samples from each well must be collected and analyzed for the Appendix I constituents.</p> <p>♦ If detection monitoring yields a statistically significant increase (SSI) over background for one or more constituents, the owner must, within 14 days, record in the operating record the constituents showing SSIs over background and, within 90 days, establish an assessment-monitoring program.</p>	<p><b>Detection Monitoring Program (257.24):</b> See Part 258 requirements to left.</p>

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<p>These constituents will form the basis for compliance monitoring;</p> <ul style="list-style-type: none"> <li>➤ Submit, within 90 days, an application for a permit modification to establish a compliance-monitoring program under 40 CFR 264.99; and</li> <li>➤ Submit, within 180 days, an engineering feasibility plan for a corrective action program under 40 CFR 264.100, unless seeking an alternate concentration limit for every Appendix IX constituent found; or all Appendix IX constituents are listed in Table 1 of 40 CFR 264.94 and their concentrations do not exceed the respective values given in that Table.</li> </ul> <p>♦ If any concentration limits have been exceeded at any monitoring wells at the point of compliance (i.e., if the groundwater protection standard has been exceeded), O/O must:</p> <ul style="list-style-type: none"> <li>➤ Notify implementing agency in writing within seven days, indicating which concentration limits have been exceeded;</li> <li>➤ Submit, within 180 days, an application for a permit modification to establish a corrective action program under 40 CFR 264.100. At a minimum, the application must include the following: <ul style="list-style-type: none"> <li>○ A detailed description of corrective actions that will achieve compliance with the groundwater protection standard specified in the permit; and</li> </ul> </li> </ul>		

**Federal Regulations for Hazardous and Solid Waste Landfills**

<p><b>Subtitle C Hazardous Waste Landfills 40 CFR Part 264/265 Subpart N</b></p>	<p><b>Subtitle D Municipal Solid Waste Landfills (MSWLFs) 40 CFR Part 258</b></p>	<p><b>Solid Waste Disposal Facilities and Practices* (40 CFR Part 257)</b></p>
<ul style="list-style-type: none"> <li>o A plan for a groundwater-monitoring program that will demonstrate the effectiveness of the corrective action program.</li> </ul>		
<ul style="list-style-type: none"> <li>♦ <b>Compliance Monitoring Program (264.99):</b> O/O must monitor the groundwater to determine compliance with the groundwater protection standard specified in the facility permit. A sequence of at least four samples must be collected from each well at the facility (background and compliance wells) at least quarterly during compliance monitoring. Based on these samples, O/O must determine whether there is statistically significant evidence of increased contamination for any parameter or constituent specified in the permit at each monitoring well at the point of compliance.</li> <li>♦ In addition, O/O must analyze samples from the point of compliance in all wells for the constituents contained in Appendix IX to 40 CFR Part 264. This sampling must be conducted at least annually to determine whether additional hazardous constituents are present in the uppermost aquifer. If this sampling indicates new Appendix IX constituents not already identified in the permit (and the presence of these constituents is confirmed by resampling a month later), O/O must report to the implementing agency the concentrations of these additional constituents within seven days and add them to the list of monitoring constituents in</li> </ul>	<ul style="list-style-type: none"> <li>♦ <b>Assessment Monitoring Program (258.55):</b> At inception of the assessment-monitoring program and annually thereafter, the O/O must sample and analyze the groundwater for all constituents in Appendix II to Part 258. A minimum of one sample from each downgradient well must be collected and analyzed during each sampling event.</li> <li>♦ For each Appendix II constituent detected in the groundwater, the O/O must establish a groundwater protection standard (GWPS). The GWPS shall be the MCL, if one exists, or the background concentration of the constituent established under 258.51.</li> <li>♦ Within 90 days of finding that any Appendix II constituents have been detected at a SSI over the GWPS, the O/O must initiate an assessment of corrective measures. Based on the results of this assessment, the O/O must select a remedy that meets the following minimum standards:                         <ul style="list-style-type: none"> <li>➤ Is protective of human health and the environment;</li> <li>➤ Attains the GWPS; and</li> <li>➤ Controls the source(s) of releases of constituents so as to reduce or eliminate such releases.</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>♦ <b>Assessment Monitoring Program (257.25):</b> See Part 258 requirements to left.</li> </ul>

**Federal Regulations for Hazardous and Solid Waste Landfills**

<p><b>Subtitle C Hazardous Waste Landfills 40 CFR Part 264/265 Subpart N</b></p>	<p><b>Subtitle D Municipal Solid Waste Landfills (MSWLFs) 40 CFR Part 258</b></p>	<p><b>Solid Waste Disposal Facilities and Practices* (40 CFR Part 257)</b></p>
<p>the permit.</p> <ul style="list-style-type: none"> <li>♦ <b>Closure and post-closure care (264.310):</b> Final cover must:                             <ul style="list-style-type: none"> <li>➢ Provide long-term minimization of migration of liquids through closed landfill;</li> <li>➢ Function with minimal maintenance;</li> <li>➢ Promote drainage and minimize erosion or abrasion of the cover;</li> <li>➢ Accommodate settling and subsidence so as to maintain cover integrity;</li> <li>➢ Have a permeability less than or equal to that of any bottom liner or natural subsoils present.</li> </ul> </li> <li>♦ Throughout closure period, O/O must comply with all post-closure requirements; maintain integrity of the final cover; continue to operate and monitor the LDS, LCRS, groundwater monitoring system, and run-on and run-off control systems, as needed.</li> </ul>	<ul style="list-style-type: none"> <li>♦ <b>Closure criteria (258.60):</b> The O/O must prepare a written closure plan and must install a final cover system designed to minimize infiltration and erosion. The final cover must:                             <ul style="list-style-type: none"> <li>➢ Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than 1x10-5 cm/sec, whichever is less;</li> <li>➢ Minimize infiltration through the closed MSWLF with an infiltration layer that contains a minimum of 18 inches of earthen material; and</li> <li>➢ Minimize erosion of the final cover by the use of an erosion layer that contains a minimum of 6 inches of earthen material capable of sustaining native plant growth.</li> </ul> </li> <li>♦ <b>Post-closure care requirements (258.61):</b> The O/O must develop a written post-closure plan and conduct post-closure care for 30 years, to include maintaining the integrity of the final cover and, if applicable, maintaining and operating the leachate collection system (LCS); monitoring the groundwater; and maintaining and operating the gas monitoring system.</li> <li>♦ O/Os must demonstrate financial assurance for closure, post-closure care, and for conducting corrective action at a MSWLF unit (258.71-258.74).</li> </ul>	<p><b>Post-closure care period.</b> Under 257.24, the monitoring frequency for constituents under detection monitoring must be at least semiannual, throughout the active life of the unit plus 30 years.</p>

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<b>Subtitle C Hazardous Waste Landfills 40 CFR Part 264/265 Subpart N</b>	<b>Subtitle D Municipal Solid Waste Landfills (MSWLFs) 40 CFR Part 258</b>	<b>Solid Waste Disposal Facilities and Practices* (40 CFR Part 257)</b>
<b>Waste Manifests 40 CFR Part 264 Subpart E</b>  All shipments of hazardous waste to a Subtitle C landfill must be accompanied by a manifest, which includes waste codes, volumes, etc. so that shipments received can be verified.	<b>Waste Manifests</b>  No waste manifesting requirements.	<b>Waste Manifests</b>  No waste manifesting requirements.

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**APPENDIX K  
COST-BENEFIT ANALYSIS METHODOLOGY AND RESULTS**

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## 1. Introduction

This Appendix presents the methodology used in preparing the cost-benefit analysis that is summarized in Chapter 4. According to NUREG/BR-0184 (NRC 1997b) a cost-benefit analysis should examine the costs and benefits of a proposed action. These costs and benefits are divided into 18 categories, described as attributes. Each attribute might contribute to costs or benefits or both. This analysis attempts to quantify both the costs and the benefits of the affected attributes. The costs and benefits within each attribute are driven by factors such as the different types of licensees, the different types of materials, and the life cycle of materials generated for release. The net benefit for each alternative is the difference between the sum of the benefits of all attributes and the sum of the costs of all attributes.

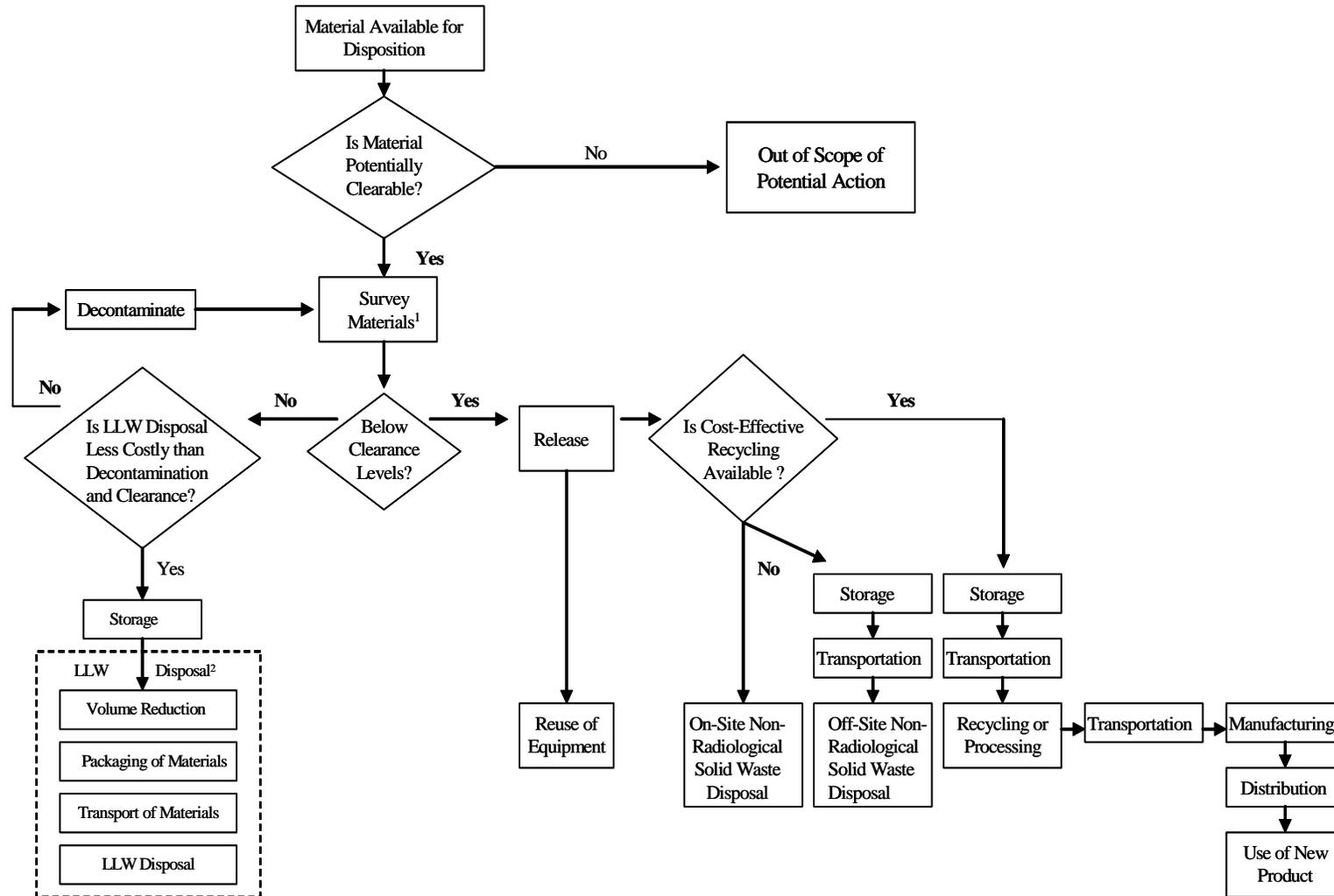
The analysis measures the incremental impacts of each alternative relative to a baseline, which is how things would be if the alternative were not imposed (i.e., the No Action Alternative). The baseline used in this analysis assumes full licensee compliance with existing NRC requirements, including current regulations. This is consistent with the *Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission*, which state that "...in evaluating a new requirement for existing plants, the staff should assume that all existing NRC and Agreement State requirements have been implemented."(NRC 2000c).

Exhibit 1 depicts the life cycle of materials generated for disposal or release for the Unrestricted Release Alternative. In the other alternatives, one or more of the pathways may not be allowed. The analysis is driven by how materials flow through the different paths of the life cycle. The main decision points in the life cycle flow path determination are (1) whether the material potentially has residual radioactivity; (2) whether the material is below the clearance level; (3) whether disposal as low-level waste is less costly than decontamination and release; and (4) whether cost-effective recycling is available for the material. Exhibit 1 also shows the four possible endpoints for radioactively contaminated materials that have been released: reuse of equipment, on-site disposal, off-site disposal, and recycling for use in new products.<sup>1</sup> For each of the alternatives and each of the materials, the analysis assumed that released materials will be recycled, reused, or sent to a municipal solid waste (MSW) landfill or incinerator, and that materials not meeting clearance levels will be sent to a low-level waste (LLW) facility for disposal. Table K-1 identifies the assumptions made for each alternative/material combination.

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<sup>1</sup> On-site disposal is not considered in this analysis. Disposal in an on-site landfill is unlikely because (1) it would hurt the resale value of the property and (2) doses from the on-site landfill would have to be included in the dose analysis conducted in the licensee's decommissioning analysis. Reuse of equipment is only considered qualitatively because data on the amount of equipment that would be available for reuse were not available.

Exhibit 1: Generalized Material Life Cycle for Potentially Cleared Material



1 Survey may include knowledge of where material was located and/or measurement of radioactivity levels.

2 Material can be disposed of under other NRC regulations, such as 10 CFR Subpart K § 20.2002.

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**Table K-1 Disposition of Material under the Baseline and Alternatives**

Alternative	Concrete	Ferrous metal	Trash
Baseline/No Action	Recycled	Recycled	MSW Landfill
Unrestricted Release	Recycled	Recycled	MSW Landfill
EPA-Regulated Landfill Disposal	MSW Landfill	MSW Landfill	MSW Landfill
LLW Disposal	LLW	LLW	LLW
Limited Dispositions	Recycled	MSW Landfill	MSW Landfill

MSW = municipal solid waste; LLW = low-level waste

\* Because it is more expensive to transport material to, and dispose of material in, an MSW incinerator than in an MSW landfill, the analysis assumes that facilities will not choose to send their trash to an MSW incinerator, even if allowed to do so, but instead will dispose of their trash in a MSW landfill. Consequently, the costs and benefits of EPA-regulated trash incineration are the same as the RCRA Subtitle D Landfill Alternative.

Section 2 of this appendix describes the analytic approach used to evaluate each of the 18 “attributes” as defined in NUREG/BR-0184 (NRC 1997b). An in-house model was developed which draws upon input data including quantities and dose from SC&A 2003, survey costs from NRC 2004a, and various unit cost factors described in this appendix. SC&A 2003 presented data broken out by year. Consequently, the model calculates the costs in each year in which material is assumed to be released and then calculates the net present value for each alternative considered in 2003 dollars. For each attribute, Section 2 presents a description of the attribute and the equations used to quantify the associated costs and benefits. Section 2 also describes how costs are discounted to net present value. Section 3 provides the incremental results for each alternative (and dose option) considered, as well as a summary of these results.

## 2. Estimation of the Costs and Benefits by Attribute

This section describes how costs and benefits are estimated for each of the 18 attributes that must be considered in the cost-benefit analyses under NUREG/BR-0184. Of these 18 attributes, 11 are expected to be affected by the proposed action:<sup>2</sup>

- Environmental Considerations,
- Industry Operation,
- Public Health (Routine),
- Occupational Health (Routine),
- Public Health (Accident),
- Industry Implementation,
- NRC Implementation,
- NRC Operation,
- Other Government,
- Regulatory Efficiency, and
- Other Considerations.

These 11 attributes are discussed in Sections 2.1 through 2.11. Each section describes the attribute and presents the equations used to analyze the attribute. The section addressing environmental considerations has a more detailed discussion because the analysis of this attribute draws on different factors. Some of the attributes are partitioned into “sub-attributes” where more detailed analysis is required.

The equations present the cost or benefit in a given year for a material being cleared from light water reactors. As described in Chapter 4, although other types of facilities are affected by this rule, sufficient information was not available to calculate quantitative costs or benefits for these other types of facilities. The costs and benefits are calculated for each year in 2004 dollars in the analysis time horizon (2003-2049), converted to present value, and summed to calculate the net present value, as described in Section 2.12.

To determine the incremental benefit or cost relative to the baseline, the analysis subtracts the baseline benefits or costs from each alternative’s benefits or cost. Negative results indicate net costs, while positive results indicate net benefits. The incremental costs associated with the No Action Alternative would be zero (because there is no change relative to the baseline). All unit costs are presented as negative numbers in the tables and assumptions following the equations, under the description where the numerical value of the cost is presented. The unit costs for the analysis are given in the format of a negative number so that the result of the equations, when calculated using numbers, yield the appropriate value indicating whether the alternative results in a net benefit or cost for that attribute.

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<sup>2</sup> The following seven attributes are not expected to be affected by the proposed action: occupational health (accidental), offsite property, onsite property, other costs to general public (such as increased cleaning costs, property value losses, or inconveniences), improvements in knowledge, antitrust considerations, and safeguards and security considerations.

## 2.1 Attribute - Environmental Considerations

1  
2  
3 This section discusses the methodology for calculating the environmental benefits of the rule  
4 under each alternative. Most of the incremental environmental benefits are expected to result  
5 from air emissions avoided as a result of changes in transportation destinations and increases in  
6 recycling (i.e., reductions in manufacturing using virgin materials) due to clearance of additional  
7 materials. This section provides a detailed analysis of these benefits for structural ferrous metal,  
8 concrete, and trash. Due to data limitations and the small total volume of materials, the analysis  
9 presents discussions of the benefits associated with the reuse of aluminum and copper products  
10 in aggregate terms without the level of detail for the other materials.

11  
12 The environmental benefits due to changes in transportation needs, which cause changes in air  
13 emissions, are calculated for the relevant solid materials by multiplying the changes in net miles  
14 (i.e., miles traveled under a specific alternative minus miles traveled under the baseline) by the  
15 appropriate emission factors for different pollutants and different transportation modes. These  
16 air emission changes are then monetized by multiplying by the price per ton for each pollutant.  
17 Aggregate environmental benefit estimates are then derived by summing over four pollutants  
18 (Sulfur Dioxide (SO<sub>2</sub>), Nitrogen Oxides (NO<sub>x</sub>), Particulate Matter (PM), and Carbon Dioxide  
19 (CO<sub>2</sub>)).

20  
21 Similarly, environmental benefits caused by changes in manufacturing needs for the relevant  
22 materials are calculated by multiplying the changes in the amount of recyclable material that are  
23 estimated to be released under this rule by the appropriate emission factors for relevant  
24 pollutants. Again, to monetize these benefits, total emission changes are multiplied by the price  
25 per ton for each pollutant. Finally, aggregate environmental benefits are derived by summing  
26 over the four pollutants.

27  
28 Note that the overall methodology described above, while appropriate, has not been applied for  
29 all the different materials released under this rule. For example, environmental benefits due to  
30 recycling of released concrete are not expected to be significant and therefore, have been left out  
31 of the analysis. Sections 2.1.1 through 2.1.5 discuss the estimation of environmental benefits in  
32 detail for each material.

33  
34 The quantities of materials released under this rule are not expected to be large enough to have a  
35 disruptive effect on the current market conditions, in terms of its impact on the recycling rates or  
36 the current demand/supply conditions. For example, the ferrous metal industry is likely to have  
37 the largest potential impact from recycling scrap ferrous metal as a result of this proposed rule.  
38 The net amount of scrap ferrous metal salvaged under the rulemaking alternatives (i.e., the  
39 amount salvaged relative to the No Action Alternative) would range between a maximum  
40 increase of 0.03 million tons and a maximum decrease of 0.13 million tons annually. According  
41 to the most recent data, annual U.S. production of ferrous metal is approximately 100 million  
42 tons. This means that the changes in ferrous metal scrap due to this rule would be approximately  
43 a tenth of a percent of the total U.S. ferrous metal market and therefore not expected to have any  
44 significant disruptions. Section 2.1.6 presents a brief discussion of the market share analysis for  
45 ferrous metal.

### 2.1.1 Ferrous Metal

Under the Unrestricted Release Alternative, the most significant environmental benefit is the recycling of ferrous metal released under this rule, which means less virgin ferrous metal is produced.<sup>3</sup> Virgin ferrous metal is produced in integrated ferrous metal mills using a three-step process that involves cokemaking, ironmaking, and Basic Oxygen Furnace (BOF) technology. Cokemaking and ironmaking processes have the greatest impact on the environment because large quantities of SO<sub>2</sub>, NO<sub>x</sub>, PM, and CO<sub>2</sub> are emitted. Electric Arc Furnace (EAF) facilities, often referred to as minimills, use up to 100 percent of scrap metal to produce ferrous metal. EAF technology does not require cokemaking and ironmaking processes. As a result, minimills emit less SO<sub>2</sub>, NO<sub>x</sub>, PM, and CO<sub>2</sub> per unit of output relative to integrated mills.

Under the EPA-Regulated Disposal Alternative, which prohibits recycling, environmental benefits result primarily from a reduction in the amount of fuel burned compared to the LLW Disposal Alternative. Less fuel is used because fewer vehicle miles are traveled (MSW landfills are located closer to NRC-licensed facilities than LLW facilities).

The following two sections explain the methodology for estimating environmental benefits in transportation and ferrous metal manufacturing sectors.

#### *Benefits Due to Transportation Changes*

The analysis calculates the change in air emissions by multiplying the net miles traveled by the corresponding emission factors for different pollutants. The following section explains how the emission factors are derived.

Based on the geographic location of NRC-licensed facilities relative to rail and highway infrastructure, the analysis assumes that ferrous metal scrap is transported by trucks. Depending on the alternative, one-way haul distances range from approximately 60 miles to over 1,500 miles. Given the range of haul distances, the analysis assumes that both short- and long-haul trucks transport ferrous metal scrap from NRC-licensed facilities. For the purpose of this analysis, long-haul trucks are characterized as: (1) class 8b heavy-duty diesel trucks; (2) trucks traveling long distances (greater than 200 miles from their home base); and (3) trucks traveling at higher speeds over longer distances. Short-haul trucks are characterized as: (1) class 8b heavy-duty diesel trucks; (2) trucks traveling less than 200 miles from their home base; and (3) trucks operating mostly in urban areas.

The air emissions standards for short- and long-haul trucks are expected to change over the period covered by this analysis. Therefore, the study models emission factors assuming that, on average, every five years a new standard for on-road vehicle emissions would be established. Thus, the standard established in 2003 would stay in effect until 2009 and a new standard would

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<sup>3</sup> The ferrous metal industry has stated that it will not reprocess radiation-contaminated scrap ferrous metal. If true, this would substantially reduce the rule's environmental benefits. This analysis, however, assumes that recyclable ferrous metal will be recycled because it is not clear from available information how the steel industry views released steel. It is possible that it is currently being released and disposed, rather than released and recycled.

1 be established in 2010. This new standard would be applicable in 2010 and would stay in effect  
 2 until 2014. The emission factors are not modeled past 2030 to avoid excessive speculation.  
 3 Therefore, the standard established in 2030 is assumed to stay in effect until 2049. Fleet age and  
 4 replacement also influence these factors, accounting for the increases seen in the CO<sub>2</sub> emission  
 5 factors. The emission factors by pollutant for long-haul and short-haul trucks are presented in  
 6 Tables K-2 and K-3, respectively.

7  
 8 **Table K-2 Emission Factors (in grams/mile) for Long-Haul Trucks**

9

10	Year	SO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>	CO <sub>2</sub>
11	2003	0.3440	27.919	0.3096	1615.2
12	2010	0.0110	9.720	0.1471	1611.6
13	2015	0.0110	2.612	0.0910	1613.0
14	2020	0.0110	1.235	0.0779	1613.4
15	2025	0.0110	0.997	0.0770	1613.5
16	2030	0.0110	0.960	0.0767	1613.5

17  
 18 **Table K-3 Emission Factors (in grams/mile) for Short-Haul Trucks**

19

20	Year	SO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>	CO <sub>2</sub>
21	2003	0.3557	25.779	0.6184	1665.2
22	2010	0.0111	13.765	0.2599	1617.6
23	2015	0.0110	6.394	0.1591	1612.1
24	2020	0.0110	2.737	0.0989	1612.6
25	2025	0.0110	1.143	0.0836	1613.2
26	2030	0.0110	0.702	0.0781	1613.4

27 Source: ICF Analyses using EPA MOBILE 6.2 emissions factor model and 1997 Vehicle Inventory and Use  
 28 Survey (VIUS).

29  
 30 ***Benefits Due to Manufacturing Changes***

31  
 32 Although this analysis assumes no significant disruptions to the ferrous metal market as a result  
 33 of the rule (see market share analysis presented below), the slight change in the market price of  
 34 ferrous metal is important to the analysis of virgin ferrous metal displacement. The ferrous  
 35 metal market consists of ferrous metal products made from iron ore (i.e., using BOF technology)  
 36 and those made from scrap (i.e., using EAF technology). Under the Unrestricted Release  
 37 Alternative, the supply of ferrous metal products made from scrap would increase. The increase  
 38 in the supply of ferrous metal made from scrap would ultimately lead to an overall increase in  
 39 the supply of all ferrous metal. Based on the economic principles of supply and demand, this  
 40 would cause the price of ferrous metal to decrease slightly.<sup>4</sup> The slight drop in the price of  
 41 ferrous metal is expected to lead to a slight increase in quantity demanded for ferrous metal. In  
 42 addition, the quantity supplied of virgin ferrous metal is expected to decrease slightly as a result  
 43 of the decrease in the market price of ferrous metal.

---

<sup>4</sup> Assuming that the demand for ferrous metal is downward sloping and the supply of ferrous metal is upward sloping, the magnitude of the price change would depend on the elasticities of the supply and demand of ferrous metal. Although the price change estimation is beyond the scope of this analysis, the change in price is not expected to be significant as the increase in supply is relatively small.

1 The general approach used in this analysis is to estimate the quantity of ferrous metal scrap that  
2 would be recycled under each regulatory alternative relative to the baseline, determine the  
3 quantity of domestic virgin ferrous metal that would be displaced, derive emission factors for  
4 each pollutant emitted in the production of virgin ferrous metal, and then multiply emission  
5 factors by quantity of virgin ferrous metal displaced.  
6

7 The industry data indicate that minimills use, on average, 1.07 kilograms of scrap to produce 1  
8 kilogram of ferrous metal (IISI 2002). The study uses this ratio of scrap to ferrous metal to  
9 estimate the amount of ferrous metal that would be produced from licensees' scrap. As  
10 previously explained, the increase in the supply of ferrous metal made from NRC scrap would  
11 cause a slight decrease in the price of ferrous metal and, in turn, increase the quantity of ferrous  
12 metal demanded. In order to estimate how much of the ferrous metal would be replaced by the  
13 ferrous metal made from scrap generated by this rule, the study makes a simplifying assumption  
14 that the elasticities of supply and demand are equal. Under this assumption, an increase of one  
15 million ton in the supply of ferrous metal products made from ferrous metal scrap (released by  
16 licensees) generated by this rule would result in 0.5 million ton increase in quantity demanded of  
17 ferrous metal, and 0.5 million ton decrease in the quantity supplied of ferrous metal (both virgin  
18 ferrous metal and ferrous metal made from scrap). The assumed decreased supply of scrap metal  
19 would not be limited to material not generated by this rule. It is assumed that the decrease in  
20 supply could be from scrap generated by this rule or scrap not generated by this rule. This  
21 assumption is based on the idea that once the scrap metal enters the market, it becomes part of  
22 the total scrap market and no differentiation is made as to whether it was generated as a result of  
23 the rule or not.  
24

25 The quantity of virgin ferrous metal consumed domestically is supplied by both domestic and  
26 foreign producers. The analysis, however, focuses only on air emissions avoided through the  
27 displacement of domestic virgin ferrous metal. In reality, CO<sub>2</sub> does have trans-boundary  
28 implications. Estimating the increase in ambient concentration of CO<sub>2</sub> in the US resulting from  
29 foreign production of virgin ferrous metal is, however, beyond the scope of this analysis.  
30

31 To understand how much of domestic virgin ferrous metal can be replaced with the scrap  
32 generated by this rule under various alternatives, the study first estimates the share of virgin  
33 ferrous metal in the total domestic consumption of ferrous metal, and then calculates the share of  
34 US virgin ferrous metal consumed domestically.  
35

36 The average annual US production of ferrous metal is 98 million tons (for the period 1997-  
37 2001), with 53 million tons of ferrous metal products produced using iron ore (i.e, virgin ferrous  
38 metal using BOF technology). In order to account properly for air emissions in manufacturing  
39 of virgin ferrous metal, the study assumes that all of the U.S. virgin ferrous metal is consumed  
40 domestically. Therefore, for the purpose of this analysis, the U.S. consumption of virgin ferrous  
41 metal is equal to the U.S. production of virgin ferrous metal plus the U.S. imports of virgin  
42 ferrous metal. Based on the estimated amount of foreign virgin ferrous metal imported annually,  
43 the estimated total amount of virgin ferrous metal available for domestic consumption is 77  
44 million tons per year.<sup>5</sup>

---

<sup>5</sup> Using the USGS data for 1997-2001, the study estimates that approximately 75 percent of the  
(continued...)

The next step in the analysis is to estimate the share of domestic virgin ferrous metal in the U.S. consumption of ferrous metal. The U.S. Geological Survey (USGS) data for 1997-2001 (USGS 2004e; USGS 2004f) indicate that the average annual U.S. consumption of ferrous metal is approximately 117 million tons. Based on the study estimates presented above, virgin ferrous metal products account for 66 percent of the total ferrous metal consumption in the U.S. (77 million tons / 117 million tons = 66 percent). Out of 77 million tons of virgin ferrous metal products consumed domestically, 53 million tons, or 69 percent, is produced domestically. Therefore, to derive the amount of domestic virgin ferrous metal displaced, the study first multiplies the total quantity of ferrous metal displaced by 0.66 to derive the amount of virgin ferrous metal displaced in the domestic consumption, and then by 0.69 to calculate the amount of domestic virgin ferrous metal displaced.

As stated previously, virgin ferrous metal production includes cokemaking and ironmaking processes. These two processes are not required when using EAF technology (i.e., when making ferrous metal products from ferrous metal scrap). The industry data indicate that the production of ferrous metal by BOF technology requires about 0.7 tons of pig iron and between 0.35 and 0.65 tons of coke (DOE 2000; IISI 2002). The study uses these factors to estimate the amount of pig iron and coke required to produce the amount of domestic virgin ferrous metal that would be displaced by the NRC ferrous metal scrap.<sup>6</sup>

The next step in the analysis is to estimate the total amount of emissions avoided through the displacement of domestic virgin ferrous metal. The analysis uses the emission factors for the iron and ferrous metal industry derived by DOE (DOE 2000). The emission factors are presented in Table K-4.

**Table K-4 Emission Factors for Criteria Pollutants by Ferrous Metalmaking Process**

Process	Units	SO <sub>2</sub>	NO <sub>x</sub>	PM	CO <sub>2</sub>
Integrated Mills					
<b>Cokemaking</b>	lbs/ton of coke	4.1	0.98	1.374	389.17
<b>Ironmaking</b>	lbs/ton of ferrous metal	26.47	10.27	7.624	2,000.0

Source: DOE.

To estimate the total amount of emissions avoided, the study multiplies the emission factors by the amount of coke and pig iron saved through recycling of NRC ferrous metal scrap.

<sup>5</sup> (...continued)

world production of ferrous metal is produced from virgin ferrous metal (i.e., using BOF technology). The study then assumes that 75 percent of the ferrous metal products imported by the U.S. are made from virgin ferrous metal. The analysis estimates that out of 32 million tons of ferrous metal imported annually, approximately 24 million tons are virgin ferrous metal products (32 million tons \* 75 percent = 24 million tons). Based on the estimated amount of imported virgin ferrous metal, the total amount of virgin ferrous metal available for domestic consumption is 77 million tons per year (53 million tons + 24 million tons = 77 million tons).

<sup>6</sup> Using the mid point of the 0.36-0.65 range yields an average ratio of coke to ferrous metal of 0.5.

**Data on Pollutant Prices**

The study estimates the monetary value of environmental benefits by multiplying the estimated net emissions by the estimated allowance price for each pollutant. Under competitive market conditions, allowance prices are expected to provide the estimated monetary value for reducing a unit of the relevant pollutant. For SO<sub>2</sub> and NO<sub>x</sub>, allowance prices used are based on EPA’s projections for 2006 to 2020 for the proposed multi-pollutant scenario, known as the Clear Skies Act found in ICF Consulting's Integrated Planning Model (an analytical model designed to evaluate various aspects of electric power production, including air pollution). Allowance prices for SO<sub>2</sub> and NO<sub>x</sub> used in this analysis are as shown in Table K-5.

**Table K-5 Allowance Prices for SO<sub>2</sub> and NO<sub>x</sub>**

Year	SO <sub>2</sub> (\$/ton)	NO <sub>x</sub> (\$/ton)
2006	493	1844
2010	605	1,063
2015	785	1,081
2020	1,018	1,402

Note that the prices were not estimated past 2020 to avoid speculation. For the years past 2020, the estimated allowance price for 2020 is used.

For particulate matter and CO<sub>2</sub>, this study uses the 1990 Pace University Study (Ottinger et al. 1990)<sup>7</sup> estimate of \$3,516 per ton of particulate matter and \$20 per ton of CO<sub>2</sub>. The Pace study, prepared for the New York State Energy Research and Development Authority and DOE examines the environmental costs associated with a variety of energy sources and environmental effects (e.g., air pollution, global warming, land use).

**2.1.2 Concrete**

**Benefits Due to Transportation Changes**

Most of the incremental environmental benefits would be provided through reduction in fuel burned by decreasing haul distances. The study used the same methodology for estimating environmental benefits from the change in air emissions as presented above for ferrous metal.

**Benefits Due to Manufacturing Changes**

Recycled concrete is used in place of virgin aggregate primarily as road base material. The analysis assumes that concrete cleared from NRC-licensed facilities would be used in the same capacity. The available publications on concrete recycling, however, do not indicate that there are considerable environmental benefits in terms of emissions avoided from using recycled

<sup>7</sup> Reproduced from U.S. Congress, Office of Technology Assessment, Studies of the Environmental Costs of Electricity, OTA-ETI-134 (Washington, DC: U.S. Government Printing Office, September 1994, page 24).

1 concrete, instead of virgin aggregate, in road construction (DOT 2003). Therefore, the study  
2 does not estimate environmental benefits from recycling of concrete.

### 3 4 **2.1.3 Trash**

#### 5 6 ***Benefits Due to Transportation Changes***

7  
8 Under both the Unrestricted Release and EPA-Regulated Disposal Alternatives, trash from NRC-  
9 licensed facilities would be disposed in MSW landfills or low-level waste facilities. Trash  
10 would not be recycled or used for any purpose that would yield environmental benefits. The  
11 type and location of permitted landfills, however, would vary depending on the alternative.  
12 Thus, some environmental benefits would be provided through reduction in fuel burned by  
13 decreasing the distances that material is hauled. The study uses the same methodology for  
14 estimating environmental benefits from the change in air emissions as presented above for  
15 ferrous metal. For the EPA-Regulated Disposal Alternative, no incineration of trash is expected  
16 because it is less expensive to send material to an MSW landfill for disposal.

### 17 18 **2.1.4 Copper**

19  
20 This analysis presents a brief discussion of the environmental benefits from recycling copper.  
21 The analysis is constrained by the lack of detailed data on the quantity of copper expected to be  
22 recycled due to this rule. SC&A 2003 estimates there are about 6,584 tons of potentially  
23 clearable copper; this is about one-quarter percent of the total mass of ferrous metals (which is  
24 about 2.4 million tons). Also, lack of detailed annual estimates of potentially clearable copper  
25 for different alternatives precludes estimating incremental environmental benefits due to this rule  
26 (i.e., benefits over a No Action “baseline”). However, copper is a valuable material and any  
27 quantity generated by this rule can be expected to be recycled with tangible environmental  
28 benefits, since recycling copper is generally considered less energy-intensive than producing  
29 copper from ore.<sup>8</sup> Given the limitations of the data, this analysis does not quantify this  
30 environmental benefit but notes that the estimated 6,584 tons of potentially clearable copper will  
31 provide finite environmental benefits.

### 32 33 **2.1.5 Aluminum**

34  
35 SC&A 2003 estimates there are about 212 tons of potentially clearable aluminum from  
36 decommissioning all licensed facilities; this is about a tenth of a percent of the total mass of  
37 ferrous metals.<sup>9</sup> Again, because of data limitations, this analysis does not attempt to quantify the  
38 incremental environmental benefits from this amount, but notes that the environmental benefit  
39 from this small amount of aluminum can be expected to be finite but less than that for copper.  
40

---

<sup>8</sup> See for example, “The Life Cycle of Copper, its Co-Products and By-Products,” International Institute for Environment and Development (IIED), 2002.

<sup>9</sup> *Ibid.*

## 2.1.6 Market Share Analysis

This section provides a market share analysis for ferrous metal, copper, and aluminum. The analysis provides a description of the effects that the proposed action could have on the market for these metals, if any.

### *Ferrous metal*

In the period 1997-2001, U.S. production of ferrous metal was, on average, almost 100 million metric tons. Approximately 54 percent of ferrous metal products were produced from virgin materials such as iron ore and coal using BOF technology. The remainder, 46 percent, was produced from ferrous metal scrap in EAF facilities. These data show that the U.S. ferrous metal industry already has a high recycling rate. The rate is expected to increase under the Unrestricted Release Alternative. Although most of the U.S. demand is satisfied through domestic production, ferrous metal imports account for 25 to 30 percent of annual consumption of ferrous metal. The summary statistics for the U.S. iron and ferrous metal industry are presented in Table K-6 (USGS 2004e; USGS 2004f).

**Table K-6 U.S. Iron and Ferrous Metal Industry Summary Statistics from USGS  
(in million metric tons of metal)**

	1997	1998	1999	2000	2001 <sup>1</sup>
Pig Iron Production	49.6	48.2	46.3	47.9	44.2
Ferrous Metal Production	98.5	98.6	97.4	102	92.9
Basic Oxygen Furnaces	55.4	54.1	52.3	54.1	49.4
Electric Arc Furnaces	43.1	44.5	45.1	47.9	43.5
Imports of Ferrous Metal Mill Products	28.3	37.7	32.4	34.4	26.2
Exports of Ferrous Metal Mill Products	5.5	5.0	4.9	5.9	5.6
Apparent Ferrous Metal Consumption <sup>2</sup>	114	118	116	119	118

<sup>1</sup> Estimated values.

<sup>2</sup> Apparent consumption = production + imports – exports + adjustment for industry stock changes + adjustment for imports of semi-finished ferrous metal products.

Source: USGS, 2004e, USGS 2004f

The net amount of scrap salvaged under the alternatives (i.e., the amount salvaged relative to the base case) would range between a maximum increase of 0.03 million tons to a maximum decrease of 0.13 million tons annually, or between 0.03 percent and 0.13 percent of the annual consumption, respectively. These quantities are relatively small compared to the total amount of ferrous metal products consumed annually. Therefore, the rule is not expected to cause any significant disruptions to the U.S. market for ferrous metal.

### *Copper*

In the period 1997-2001, average annual U.S. production of copper was almost 3 million metric tons. Approximately 63 percent of copper products were produced from virgin materials such as ore, concentrate, or precipitate. The remaining 37 percent was produced from old scrap

(secondary production), new scrap, or refinery scrap. Old scrap refers to obsolete or discarded end-use items that are recycled. New scrap represents the copper that is recovered from scrap generated during manufacturing (e.g., stampings, defective parts, etc.), and returned to smelters, refineries, or mills for reprocessing. Refinery scrap may have been processed through smelting and electrolytic refining or directly processed at a fire refinery. Although most of the U.S. demand is satisfied through domestic production, copper imports account for around 30 percent of annual consumption of copper. The summary statistics for the U.S. copper industry are presented in Table K-7 (USGS 2004c).

**Table K-7 U.S. Copper Industry Summary Statistics from USGS  
(in million metric tons of metal)**

	1997	1998	1999	2000	2001
Primary Production	2.07	2.14	1.89	1.59	1.63
Secondary Production	0.498	0.466	0.381	0.357	0.316
New Scrap	0.967	0.956	0.949	0.955	0.833
Refinery Scrap	0.396	0.349	0.23	0.208	0.172
Imports	0.632	0.683	0.837	1.06	0.991
Exports	0.0929	0.0862	0.0252	0.0936	0.0225
Apparent Copper Consumption <sup>1</sup>	2.94	3.03	3.13	3.13	2.5

<sup>1</sup> Apparent consumption = primary production + secondary production + imports – exports ± adjustment for industry stock changes.

Source: USGS, 2003a.

The net amount of scrap salvaged under the rulemaking alternatives (i.e., the amount salvaged relative to the base case) would total 6,584 tons. This quantity is relatively small compared to the total amount of copper consumed annually. Even if all of this copper was generated in the same year, it would only represent 0.22 percent of the average U.S. annual copper consumption. Therefore, the rule is not expected to cause any significant disruptions to the U.S. market for copper.

### *Aluminum*

In the period 1996-2000, average annual U.S. production of aluminum was just over 7 million metric tons. Approximately 51 percent of aluminum products were produced from virgin materials. The remaining 49 percent was produced from secondary sources. Secondary production includes metal recovered from post-consumer aluminum scrap and fabrication aluminum scrap. Although the majority of the U.S. demand is satisfied through domestic production, aluminum imports account for about 48 percent of annual consumption of aluminum. The summary statistics for the U.S. aluminum industry are presented in Table K-8 (USGS 2004d).

The net amount of scrap salvaged under the rulemaking alternatives (i.e., the amount salvaged relative to the base case) would total 212 tons. This quantity is relatively small compared to the total amount of aluminum consumed annually. Even if all of this aluminum was generated in the

1 same year, this amount would only represent 0.003 percent of the average U.S. annual aluminum  
 2 consumption. Therefore, the rule is not expected to cause any significant disruptions to the U.S.  
 3 market for aluminum.  
 4

5 **Table K-8 U.S. Aluminum Industry Summary Statistics from USGS**  
 6 **(in million metric tons of metal)**

	1996	1997	1998	1999	2000
9 Primary Production	3.577	3.603	3.713	3.779	3.668
10 Secondary Production	3.31	3.55	3.44	3.69	3.45
11 Imports	2.81	3.08	3.55	4	3.91
12 Exports	1.5	1.57	1.59	1.64	1.76
13 Apparent Aluminum Consumption <sup>1</sup>	6.61	6.72	7.09	7.77	7.53

14 <sup>1</sup> Apparent consumption = primary production + secondary production + imports – exports ± adjustment for  
 15 industry stock changes.

16 Source: USGS, 2002a

## 18 2.2 Attribute – Industry Operation

### 19 2.2.1 Attribute Definition and Identification of Driving Factors

20 Industry Operation measures yearly net incremental cost and benefits (e.g., relevant capital,  
 21 operating, and maintenance costs) due to changes in industry operations, including incremental  
 22 costs and savings for each of the following four sub-attributes:<sup>10</sup> (1) ongoing decision  
 23 making/paperwork, (2) survey of materials, (3) solid waste disposal, recycling, or reuse, and  
 24 (4) transportation.  
 25

- 26 1. *Sub-Attribute - Decision Making/Paperwork.* This sub-attribute captures the costs  
 27 associated with preparing any required documents for the clearance of materials.  
 28
- 29 2. *Sub-Attribute - Survey of Materials.* Unit cost estimates for surveying materials  
 30 reflect variations in the type of material to be surveyed, the physical shape of the  
 31 material, contamination potential of the material, dose option that must be met, the  
 32 initial activity level of the material, and whether materials are surveyed on or off site.  
 33
- 34 3. *Sub-Attribute - Solid Waste Disposal or Recycling.* This sub-attribute includes cost  
 35 or revenue information for the following three elements: (1) Low-Level Waste  
 36 Disposal, (2) Off-Site Solid Waste Disposal, and (3) Recycling. Unit costs include  
 37 tipping fees and revenue from recycling materials.  
 38  
 39  
 40  
 41

---

<sup>10</sup> If decontamination were conducted, it also would be counted as a cost under industry operation. However, this analysis assumes that it is not cost-effective to decontaminate and re-survey materials in order to clear them.

4. *Sub-Attribute - Transportation.* Unit cost estimates for transportation reflect: (1) the average distances between licensees and the nearest LLW disposal facilities, EPA-regulated landfills, recycling facilities, or reuse facilities; (2) the average capacity of trucks used, and (3) the cost per ton-mile to ship cleared material versus controlled material.

The quantities of materials (ferrous metal, concrete, and trash) that are released in the baseline and for each alternative are taken from the collective dose assessment report, as described in Table K-9. For the alternatives with dose options (Unrestricted Release and EPA-Regulated Disposal), quantity information was provided for the 0.03 mrem/yr, 0.1 mrem/yr, 1 mrem/yr, and 10 mrem/yr options. For the IAEA Safety Guide No. RS-G-1.7 dose option, the quantities were assumed to be equal to the 1 mrem/yr dose option.

**Table K-9 Quantity Sources in SC&A 2003**

Description in Cost-Benefit Analysis	Description in SC&A 2003
Baseline/No Action	No Action (Case A) <sup>11</sup>
Unrestricted Release: Material-Specific Limits	Case A
Unrestricted Release: Material-Independent Limits	Case B
EPA-Regulated Disposal without Incineration	Case C
EPA-Regulated Disposal with Trash Incineration	Case C2
LLW Disposal	No Action (Case A)
Limited Disposition	Case B (Concrete); Case C (Ferrous metal and Trash)

<sup>11</sup> The collective dose report (SC&A 2003) presents different values for the dose associated with the No Action Alternative. This cost-benefit analysis assumes the most appropriate version of the quantities and dose associated with the No Action Alternative (and hence the baseline) is in fact the No Action Alternative in the collective dose report (SC&A 2003) associated with the Unrestricted Release Alternative.

Table K-10 presents the total quantities of material released under the baseline (No Action Alternative) and each alternative. As can be seen, different amounts of material are released under each alternative and dose option. That is, not only could a different amount of material be released between the 0.03 mrem/yr dose option and the 0.1 mrem/yr dose option, but within the 0.03 mrem dose options, different amounts are released depending on the alternative. In the 0.03 mrem/yr dose option in any alternative, less material clears and is available for release than in the baseline (or No Action Alternative). Positive values in the change in quantity released column indicate that more material meets release levels under the alternative than in the baseline. This “newly releasable” material is assumed to be sent to disposal in a LLW facility in the baseline. Often this change in the quantity that can be released drives the results of the cost modeling. Table K-11 presents the quantities of each type of material (ferrous metals, concrete, and trash) that could be released under each alternative and dose option. The totals in tables K-10 and K-11 are different from those presented in Chapter 3 because Chapter 3 uses an absolute analysis rather than an incremental analysis.

**Table K-10 Material Quantities Released by Alternative**

Alternative	Dose	Baseline Tons Released	Alternative Quantity Released	Change in Quantity Released
No Action	NA	17,954,742	17,954,742	0
Unrestricted Release Material Specific Limits	0.03	17,954,742	15,735,586	(2,219,156)
	0.1	17,954,742	18,768,310	813,568
	1	17,954,742	21,525,814	3,571,072
	10	17,954,742	21,909,149	3,954,407
Unrestricted Release Material Independent Limits	0.03	17,954,742	15,247,765	(2,706,977)
	0.1	17,954,742	18,080,580	125,838
	1	17,954,742	21,044,465	3,089,723
	10	17,954,742	21,709,582	3,754,840
	RS-G-1.7	17,954,742	21,044,465	3,089,723
EPA/State-Regulated Disposal (Landfill)	0.03	17,954,742	16,888,904	(1,065,838)
	0.1	17,954,742	19,570,465	1,615,723
	1	17,954,742	21,790,651	3,835,909
	10	17,954,742	21,928,420	3,973,678
	RS-G-1.7	17,954,742	21,790,651	3,835,909
LLW Disposal/ Prohibition	NA	17,954,742	17,954,742	-
Limited Disposition	RS-G-1.7	17,954,742	21,694,631	3,739,890

Table K-11 Quantities Released Under Baseline and Alternatives by Dose Option and Material

Alternative	Dose	Baseline Tons Released			Alternative Tons Released			Change in Quantity Released		
		Steel	Concrete	Trash	Steel	Concrete	Trash	Steel	Concrete	Trash
No Action	NA	1,803,602	16,130,738	20,402	1,803,602	16,130,738	20,402	0	0	0
Unrestricted Release Material Specific Limits	0.03	1,803,602	16,130,738	20,402	759,254	14,962,692	13,640	(1,044,347)	(1,168,047)	(6,762)
	0.1	1,803,602	16,130,738	20,402	1,256,607	17,490,696	21,007	(546,995)	1,359,958	605
	1	1,803,602	16,130,738	20,402	1,940,589	19,544,245	40,979	136,987	3,413,507	20,577
	10	1,803,602	16,130,738	20,402	2,171,232	19,671,833	66,084	367,630	3,541,094	45,682
Unrestricted Release Material Independent Limits	0.03	1,803,602	16,130,738	20,402	284,888	14,962,692	186	(1,518,714)	(1,168,047)	(20,216)
	0.1	1,803,602	16,130,738	20,402	589,452	17,490,696	432	(1,214,150)	1,359,958	(19,970)
	1	1,803,602	16,130,738	20,402	1,498,424	19,544,245	1,796	(305,178)	3,413,507	(18,606)
	10	1,803,602	16,130,738	20,402	2,031,852	19,671,833	5,897	228,250	3,541,094	(14,505)
	RS-G-1.7	1,803,602	16,130,738	20,402	1,498,424	19,544,245	1,796	(305,178)	3,413,507	(18,606)
EPA/State-Regulated Disposal (Landfill)	0.03	1,803,602	16,130,738	20,402	1,332,548	15,542,717	13,640	(471,054)	(588,021)	(6,762)
	0.1	1,803,602	16,130,738	20,402	1,742,296	17,807,161	21,007	(61,306)	1,676,423	605
	1	1,803,602	16,130,738	20,402	2,109,407	19,640,265	40,979	305,805	3,509,527	20,577
	10	1,803,602	16,130,738	20,402	2,190,503	19,671,833	66,084	386,901	3,541,094	45,682
	RS-G-1.7	1,803,602	16,130,738	20,402	2,109,407	19,640,265	40,979	305,805	3,509,527	20,577
LLW Disposal/ Prohibition	NA	1,803,602	16,130,738	20,402	1,803,602	16,130,738	20,402	-	-	-
Limited Disposition	RS-G-1.7	1,803,602	16,130,738	20,402	2,109,407	19,544,245	40,979	305,805	3,413,507	20,577

2.2.2 Attribute Equations

The following four equations are used to calculate the net change in costs and benefits due to the Industry Operation attribute.

**Equation 1 - Decision Making/Paperwork**

The administrative costs associated with decision making and paperwork of the *Industry Operation* attribute are estimated as follows:

$$Decision\ Making/Paperwork = (HOURS_{Technical} \times WAGE_{Technical})$$

Parameter	Description
HOURS <sub>Technical</sub>	The number of additional hours required for administrative tasks by technical workers (see assumptions below)
WAGE <sub>Technical</sub>	The loaded hourly wage per technical labor (see assumptions below)

*Assumptions*

- The number of administrative hours per licensee undergoing their first year of decommissioning required by technical staff (HOURS<sub>Technical</sub>) is equal to 200 hours.<sup>12</sup>
- The hourly wage rates used throughout the equations in this appendix for each labor category are as follows:<sup>13</sup>
  - Technical labor (WAGE<sub>Technical</sub>) = -\$33.84 per hour per person (OPM, 2004)<sup>14</sup>
  - Managerial labor (WAGE<sub>Managerial</sub>) = -\$48.22 per hour per person (OPM, 2004)<sup>15</sup>
  - Attorney or lawyer labor (WAGE<sub>Legal</sub>) = -\$67.04 per hour per person (OPM, 2004)<sup>16</sup>
  - Clerical labor (WAGE<sub>Clerical</sub>) = -\$20.58 per hour per person (OPM, 2004)<sup>17</sup>

**Equation 2 - Survey costs**

The net survey costs associated with the *Industry Operation* attribute are estimated as follows:

<sup>12</sup> Based on Best Professional Judgement and guidance in NUREG-6477 (NRC 1998).

<sup>13</sup> As discussed in Section 2, the unit costs are presented as negative in order to provide results that correctly identify benefits as positive and costs as negative.

<sup>14</sup> GS-11, Step 1 with a standard overhead factor of 1.6.

<sup>15</sup> GS-13, Step 1 with a standard overhead factor of 1.6.

<sup>16</sup> GS-15, Step 1 with a standard overhead factor of 1.6.

<sup>17</sup> GS-6, Step 1 with a standard overhead factor of 1.6.

$$Survey = [(COST_{ferrous\ metal\ dose\ survey} \times QUANTITY_{ferrous\ metal\ dose}) + (COST_{concrete\ dose\ survey} \times QUANTITY_{concrete\ dose}) + (COST_{trash\ dose\ survey} \times QUANTITY_{trash\ dose})] - [(COST_{ferrous\ metal\ baseline\ survey} \times QUANTITY_{ferrous\ metal\ baseline}) + (COST_{baseline\ concrete\ survey} \times QUANTITY_{concrete\ baseline}) + (COST_{trash\ baseline\ survey} \times QUANTITY_{trash\ baseline})]$$

Parameter	Description
COST <sub>baseline concrete survey</sub>	Baseline survey costs per ton of concrete (see table K-12 below)
COST <sub>ferrous metal baseline survey</sub>	Baseline survey costs per ton of ferrous metal (see table K-12 below)
COST <sub>trash baseline survey</sub>	Baseline survey costs per ton of trash (see table K-12 below)
QUANTITY <sub>concrete baseline</sub>	Baseline total tons of concrete
QUANTITY <sub>ferrous metal baseline</sub>	Baseline total tons of ferrous metal
QUANTITY <sub>trash baseline</sub>	Baseline total tons of trash
COST <sub>concrete dose survey</sub>	Survey costs per ton of concrete under dose option (see table K-12 below)
COST <sub>ferrous metal dose survey</sub>	Survey costs per ton of ferrous metal under dose option (see table K-12 below)
COST <sub>trash dose survey</sub>	Survey costs per ton of trash under dose option (see table K-12 below)
QUANTITY <sub>concrete dose</sub>	Total tons of concrete to be released under dose option
QUANTITY <sub>ferrous metal dose</sub>	Total tons of ferrous metal to be released under dose option
QUANTITY <sub>trash dose</sub>	Total tons of trash to be released under dose option

*Assumptions*

- The available survey costs from the Clearance Survey Cost Report (ORISE 2004) are summarized in Table K-12.
- Because survey costs are dependent on MARSSIM classification, the survey costs were weighted to reflect the relative proportion of MARSSIM Class 2 and Class 3 material. The percentages for ferrous metal were taken from SC&A 2003. Based on data in tables on pages 3-10, 3-20, and the scaling factors from page 3-23, the relative proportion of Class 2 material was 27 percent and Class 3 material was 73 percent. Similar information was not available for concrete and trash in SC&A 2003. Attachment 1 describes the relative proportion of Class 1, 2, and 3 material for ferrous metal, concrete, and trash. Assuming that only Class 2 and Class 3 material would be surveyed to be released, this analysis calculates that 11 percent of concrete would be Class 2 and 89 percent would be Class 3. For trash, 50 percent is assumed to be Class 2 and 50 percent is assumed to be Class 3.

**Table K-12: Survey Costs by Dose Option**

<b>Dose Option Level and MARSSIM Classification</b>	<b>Cost</b>	<b>Units</b>	<b>Source in Feb 2004 Clearance Survey Cost Report</b>
<b>Concrete Rubble</b>			
baseline/no action	-26	\$/ton	p. 7-9
0.03 mrem/yr - Class 2	Not Feasible		
0.1 mrem/yr- Class 2	-314	\$/ton	p. 7-10
1 mrem/yr - Class 2	-84	\$/ton	p. 7-10
10 mrem/yr - Class 2	-84	\$/ton	p. 7-10
IAEA Standard - Class 2	-84	\$/ton	Assumed to be equal to 1 mrem/yr
0.03 mrem/yr - Class 3	Not Feasible		
0.1 mrem/yr- Class 3	-85	\$/ton	p. 7-10
1 mrem/yr - Class 3	-30	\$/ton	p. 7-10
10 mrem/yr - Class 3	-30	\$/ton	p. 7-10
IAEA Standard - Class 3	-30	\$/ton	Assumed to be equal to 1 mrem/yr
<b>Structural Ferrous Metal</b>			
baseline/no action	-176	\$/ton	p. 7-26
0.03 mrem/yr - Class 2	Not Feasible		
0.1 mrem/yr- Class 2	-89	\$/ton	p. 7-28
1 mrem/yr - Class 2	-82	\$/ton	p. 7-28
10 mrem/yr - Class 2	-82	\$/ton	p. 7-28
IAEA Standard - Class 2	-82	\$/ton	Assumed to be equal to 1 mrem/yr
0.03 mrem/yr - Class 3	Not Feasible		
0.1 mrem/yr- Class 3	-30	\$/ton	p. 7-28
1 mrem/yr - Class 3	-27	\$/ton	p. 7-28
10 mrem/yr - Class 3	-27	\$/ton	p. 7-28
IAEA Standard - Class 3	-27	\$/ton	Assumed to be equal to 1 mrem/yr
<b>Trash</b>			
baseline/no action	-50	\$/ton	Assumed to be twice 0.1 mrem/yr (for class 3)
0.03 mrem/yr - Class 2	-246	\$/ton	Assumed to be twice 0.1 mrem/yr
0.1 mrem/yr- Class 2	-123	\$/ton	p. 7-53
1 mrem/yr - Class 2	-123	\$/ton	p. 7-53
10 mrem/yr - Class 2	-123	\$/ton	p. 7-53
IAEA Standard - Class 2	-123	\$/ton	Assumed to be equal to 1 mrem/yr
0.03 mrem/yr - Class 3	-50	\$/ton	Assumed to be twice 0.1 mrem/yr
0.1 mrem/yr- Class 3	-25	\$/ton	p. 7-53
1 mrem/yr - Class 3	-25	\$/ton	p. 7-53
10 mrem/yr - Class 3	-25	\$/ton	p. 7-53
IAEA Standard - Class 3	-25	\$/ton	Assumed to be equal to 1 mrem/yr

- It is not feasible to survey concrete and ferrous metal at the 0.03 mrem/yr dose option level, because the data quality objectives for the survey demand a very large number of samples (ORISE 2004). As a result, in the 0.03 mrem/yr dose options of the Unrestricted Release and EPA-Regulated Disposal Alternatives, ferrous metal and concrete are assumed to be sent for LLW disposal rather than surveyed and released.

**Assumptions**

- Survey costs for LLW disposal are not required by the proposed action. However, disposal facilities will not accept waste that has not been surveyed. Consequently, survey costs were included for all material being sent to LLW disposal. The survey costs for the 10 mrem/yr dose option were used as a proxy for the survey costs for LLW disposal.

**Equation 3 - Disposal and recycling costs**

The net disposal and recycling costs associated with the *Industry Operation* attribute are estimated as follows:

$$\begin{aligned}
 \text{Disposal/Recycling} = & [(COST_{LLW\ Disposal} \times QUANTITY_{LLW\ Dose}) + (COST_{Landfill\ Disposal} \\
 & \times QUANTITY_{Landfill\ Dose}) + (REVENUE_{ferrous\ metal\ recycled} \times QUANTITY_{ferrous\ metal\ recycled} \\
 & dose) + (COST_{concrete\ recycled} \times QUANTITY_{concrete\ recycled\ dose}) + (COST_{LLW\ Disposal} \times \\
 & QUANTITY_{baseline-dose})] - [(COST_{LLW\ Disposal} \times QUANTITY_{LLW\ baseline}) + (COST_{Landfill} \\
 & Disposal \times QUANTITY_{Landfill\ baseline}) + (REVENUE_{ferrous\ metal\ recycled} \times QUANTITY_{ferrous\ metal} \\
 & recycled\ baseline) + (COST_{concrete\ recycled} \times QUANTITY_{concrete\ recycled\ baseline})]
 \end{aligned}$$

Parameter	Description
QUANTITY <sub>LLW baseline</sub>	Baseline total tons of material disposed of offsite as LLW
QUANTITY <sub>Landfill baseline</sub>	Baseline total tons of material disposed of offsite as MSW
QUANTITY <sub>ferrous metal recycled baseline</sub>	Baseline total tons of ferrous metal recycled
QUANTITY <sub>concrete recycled baseline</sub>	Baseline total tons of concrete recycled
QUANTITY <sub>LLW Dose</sub>	Total tons of material disposed of offsite as LLW under dose option
QUANTITY <sub>Landfill Dose</sub>	Total tons of material disposed of offsite as MSW under dose option
QUANTITY <sub>ferrous metal recycled dose</sub>	Total tons of ferrous metal recycled under dose option
QUANTITY <sub>concrete recycled dose</sub>	Total tons of concrete recycled under dose option
QUANTITY <sub>baseline-dose</sub>	Net difference in tons cleared in baseline - tons cleared under dose option
COST <sub>LLW Disposal</sub>	Offsite disposal costs per ton of material at a LLW facility (see assumptions below)
COST <sub>Landfill Disposal</sub>	Offsite disposal costs per ton of material at a solid waste landfill (see assumptions below)
REVENUE <sub>ferrous metal recycled</sub>	Revenue generated from the average market price of recycling scrap ferrous metal (see assumptions below)
COST <sub>concrete recycled</sub>	Recycling cost per ton of concrete (see assumptions below)

Assumptions

- The cost for disposal at a LLW facility (Envirocare) is equal to -\$14.72 per cubic foot (DOE 2002b). This cost reflects disposal of DOE waste, because prices for disposal of non-DOE wastes were not publicly available.
- The cost for disposal at a municipal or industrial solid waste landfill is equal to -\$32.19 per ton (REPA 2001).
- The revenue associated with the average market price of scrap ferrous metal is equal to \$85 per ton (Recycler’s World 2003).<sup>18</sup>
- The cost of recycling concrete is equal to -\$5 per ton.<sup>19</sup>

Equation 4 - Transportation costs

The net transportation cost associated with the *Industry Operation* attribute is estimated as follows:

$$\begin{aligned}
 \text{Transportation} = & \text{COST}_{LLW \text{ transport truck}} \times \text{DISTANCE}_{LLW \text{ facility}} \times (\text{QUANTITY}_{LLW \text{ dose}} + \\
 & \text{QUANTITY}_{\text{baseline-dose}} - \text{QUANTITY}_{LLW \text{ baseline}}) + \text{COST}_{\text{Cleared transport truck}} \\
 & [(\text{DISTANCE}_{MSW \text{ Landfill}} \times (\text{QUANTITY}_{\text{Landfill dose}} - \text{QUANTITY}_{\text{Landfill baseline}})) + \\
 & (\text{DISTANCE}_{\text{Recycling Facility-Ferrous metal}} \times (\text{QUANTITY}_{\text{ferrous metal recycled dose}} - \text{QUANTITY}_{\text{ferrous}} \\
 & \text{metal recycled baseline})) + (\text{DISTANCE}_{\text{Recycling Facility-Concrete}} \times (\text{QUANTITY}_{\text{concrete recycled dose}} - \\
 & \text{QUANTITY}_{\text{concrete recycled baseline}}))]
 \end{aligned}$$

Parameter	Description
QUANTITY <sub>LLW baseline</sub>	Total baseline tons of material transported to a LLW facility
QUANTITY <sub>Landfill baseline</sub>	Total baseline tons of material transported to a municipal landfill
QUANTITY <sub>ferrous metal recycled baseline</sub>	Total baseline tons of ferrous metal transported to a recycling facility
QUANTITY <sub>concrete recycled baseline</sub>	Total baseline tons of concrete transported for recycling
COST <sub>LLW transport truck</sub>	Cost per ton-mile for transport of LLW using a truck (see assumptions below)
COST <sub>Cleared transport truck</sub>	Cost per ton-mile for transport of cleared material using a truck (see assumptions below)
DISTANCE <sub>LLW facility</sub>	Distance to a LLW facility (see assumptions below)
DISTANCE <sub>MSW Landfill</sub>	Distance to a MSW landfill (see assumptions below)
DISTANCE <sub>Recycling Facility-Ferrous metal</sub>	Distance to a ferrous metal recycling facility (see assumptions below)
DISTANCE <sub>Recycling Facility-Concrete</sub>	Distance to a concrete recycling facility (see assumptions below)

<sup>18</sup> Because the industry will pay licensees for the ferrous metal, this is considered a negative cost (actualized benefit).://www.recycle.net/price/metals.html

<sup>19</sup> Agretech. Phone Interview. November 25, 2003.

Parameter	Description
QUANTITY <sub>baseline-dose</sub>	Net difference in tons cleared in baseline minus tons cleared under dose option
QUANTITY <sub>LLW dose</sub>	Total tons of material transported under dose option to a LLW facility
QUANTITY <sub>Landfill dose</sub>	Total tons of material transported under dose option to a MSW landfill
QUANTITY <sub>ferrous metal recycled dose</sub>	Total tons of ferrous metal transported under dose option to a recycling facility
QUANTITY <sub>concrete recycled dose</sub>	Total tons of concrete transported under dose option to a recycling facility

*Assumptions*

The following transportation costs apply:

- LLW material using a truck: -\$0.12/ton-mile (DOE 1999).
- Cleared material using a truck: -\$0.06/ton-mile.<sup>20</sup>
- LLW ferrous metal using rail: -\$0.016/ton-mile (DOE 2002b).
- LLW concrete using rail: -\$0.044/ton-mile.<sup>21</sup>

The following average distances apply:

- LLW facility: 1,544 miles.<sup>22</sup>
- MSW Landfill: 58 miles.<sup>23</sup>
- Ferrous metal recycling facility: 269 miles (SC&A 2003).<sup>24</sup>
- Concrete recycling facility: 198 miles.<sup>25</sup>

Trucks are assumed to be able to transport 25 tons per truckload of ferrous metals, concrete, or mixed materials destined for a LLW disposal facility. Trucks are assumed to transport 10 tons per truckload of trash.

Attachment 2 provides a detailed discussion of this attribute.

<sup>20</sup> Best professional judgement.

<sup>21</sup> *Ibid.*

<sup>22</sup> Estimate based on average distance from existing LWRs to Clive, Utah, derived from GIS analysis.

<sup>23</sup> Best professional judgement.

<sup>24</sup> Table 9.62, page 9-97.

<sup>25</sup> *Ibid.*

**2.3 Attribute - Public Health (Routine)**

**2.3.1 Attribute Definition and Identification of Driving Factors**

Public Health (Routine) measures the yearly incremental cost or benefit due to changes in radiation exposures to the public associated with routine NRC licensee activities. The public is defined as any person not working in the nuclear industry. Exposures may occur from the following activities: material handling activities, storage, transportation, processing or recycling, disposal in solid waste landfills, manufacturing, and distribution and use of new products.

**2.3.2 Attribute Equation**

The following equation can be used to calculate the net change in costs and benefits due to the Public Health (Routine) attribute.

**Equation 5 - Routine radiologic exposure**

The routine radiologic exposure cost associated with the *Public Health (Routine)* attribute is estimated as follows:

$$Radiological\ Exposure = (DOSE_{baseline\ public} - DOSE_{dose\ alternative\ public}) \times COST_{exposure}$$

Parameter	Description
DOSE <sub>baseline public</sub>	The baseline dose to the public due to routine exposures in person rem for clearance of materials
DOSE <sub>dose alternative public</sub>	The dose to the public due to routine exposures in person rem for clearance of materials under the alternative
COST <sub>exposure</sub>	Cost of exposure per person-rem (see assumptions below)

*Assumptions*

- The cost of exposure per person is assumed to be -\$2,000 per person-rem (NRC 2003f).
- The dose to the public was taken from SC&A 2003. Table K-13 describes how the alternatives in this cost-benefit analysis relate to the naming conventions used in SC&A 2003. For the dose-specific alternatives (Unrestricted Release and EPA-Regulated Disposal), dose information was provided for the 0.03, 0.1, 1, and 10 mrem/yr options. For the IAEA Safety Guide No. RS-G-1.7 dose option, the quantities were assumed to be twice the dose associated with the 1 mrem/yr dose option based on NUREG-1640 (Appendix D).
- SC&A 2003 presents the collective dose to workers, such as truck drivers and recyclers, as well as members of the general public. Dose to members of the public and workers at non-licensed facilities normally would be captured in the attribute public health-routine, and dose to workers at licensed facilities normally would be captured in the attribute occupational health-routine. Because this analysis could not separate the collective doses into these two

categories on a year-by-year basis for each alternative and dose-option considered, the public health-routine and occupational health routine attributes are combined in a single attribute described as public and occupational health-routine.

- The dose associated with equipment reuse was taken from Appendix D, Section 12.

**Table K-13 Description of Alternatives and Naming Conventions**

Description in Cost-Benefit Analysis	Description in SC&A 2003
Baseline	No Action (Case A) <sup>26</sup>
Unrestricted Release: Material-Specific Limits	Case A
Unrestricted Release: Material-Independent Limits	Case B
EPA-Regulated Disposal without Incineration	Case C
EPA-Regulated Disposal with Trash Incineration	Case C2
Limited Disposition	Case B (concrete), Case C (ferrous metal and trash)
LLW Disposal	Not provided in Report. Assumed to be 0 person-rem.

## 2.4 Attribute - Occupational Health (Routine)

### 2.4.1 Attribute Definition and Identification of Driving Factors

Occupational Health (Routine) measures the yearly incremental cost or benefit due to changes in radiation exposures to occupational workers at licensed facilities associated with routine activities. Exposures may occur from the following material handling activities: storage, surveying, decontamination, volume reduction, packaging for disposal or recycling, and disposal.

### 2.4.2 Attribute Equation

The following equation can be used to calculate the net change in costs and benefits due to the Occupational Health (Routine) attribute.

#### *Equation 6 - Routine occupational radiologic exposures*

The routine radiological exposure cost associated with the *Occupational Health (Routine)* attribute is estimated as follows:

$$\text{Radiologic Exposure} = (\text{DOSE}_{\text{baseline worker}} - \text{DOSE}_{\text{dose alternative worker}}) \times \text{COST}_{\text{exposure}}$$

Parameter	Description
-----------	-------------

<sup>26</sup> SC&A 2003 presents different values for the dose associated with the No Action Alternative. This cost-benefit analysis assumes the most appropriate version of the quantities and dose associated with the No Action Alternative (and hence the baseline) is in fact the No Action Alternative in SC&A 2003 associated with the Unrestricted Release Alternative.

DOSE <sub>baseline worker</sub>	The baseline dose to occupational workers due to exposure in person-rem for clearance of materials.
DOSE <sub>dose alternative worker</sub>	The dose to occupational workers due to exposure in person-rem for clearance of materials, under the alternative.
COST <sub>exposure</sub>	Cost of exposure per person-rem (see assumptions below)

*Assumptions*

- The cost of exposure per person is assumed to be -\$2,000 per person-rem (NRC 2003f).
- SC&A 2003 presents the collective dose to workers, such as truck drivers and recyclers, as well as members of the general public. Dose to members of the public and workers at non-licensed facilities normally would be captured in the attribute public health-routine, and dose to workers at licensed facilities normally would be captured in the attribute occupational health-routine. Because this analysis could not separate the collective doses into these two categories on a year-by-year basis for each alternative and dose-option considered, the public health-routine and occupational health routine attributes are combined in a single attribute described as public and occupational health-routine.

**2.5 Attribute - Public Health (Accident)**

**2.5.1 Attribute Definition and Identification of Driving Factors**

Public Health (Accident) measures the yearly net incremental cost or benefit due to changes in radiation exposures to occupational workers in non-licensed facilities and the general public associated with accidents. While exposures may occur from accidents related to storage, transportation, surveying, decontamination, volume reduction, packaging of materials, and random acts, such as fires, no such exposures are quantified in this analysis because the amount of radiation in any given quantity of material being considered for clearance would not result in a significant dose in the event of these types of accidents (Section 3.3).

Another dimension of the Public Health (Accident) attribute is yearly net incremental cost or benefit due to changes in non-radiologically induced deaths and disabilities related to transportation, decontamination, volume reduction, and packaging of materials.

**2.5.2 Attribute Equation**

The following equation can be used to calculate the net change in costs and benefits due to the Public Health (Accident) attribute. For this analysis, accidents are due to truck transport.

**Equation 7 - Deaths and disabilities due to accidents**

The cost of accidental deaths and disabilities associated with the *Public Health (Accident)* attribute is estimated as follows:

$$Accidental\ Deaths\ and\ Disabilities = [(DISTANCE_{alternative\ total} - DISTANCE_{baseline\ total}) \times NUM_{accident\ deaths} \times COST_{lost\ life}] + [(DISTANCE_{alternative\ total} - DISTANCE_{baseline\ total}) \times NUM_{accident\ disabilities} \times COST_{lifetime\ disability}]$$

Parameter	Description
DISTANCE <sub>baseline total</sub>	Total vehicle miles traveled in baseline
DISTANCE <sub>alternative total</sub>	Total vehicle miles traveled in alternative
NUM <sub>accident deaths</sub>	Number of deaths due to accidents per vehicle mile traveled
COST <sub>lost life</sub>	Average cost of a lost life (see assumptions below)
NUM <sub>accident disabilities</sub>	Number of disabilities due to accidents per vehicle mile traveled
COST <sub>lifetime disability</sub>	Lifetime cost of disability

*Assumptions*

- The average cost of a life is assumed to be -\$3,000,000 (NRC 2003f).
- This analysis does not calculate any lifetime disabilities.
- The number of accidents is based on vehicle miles traveled multiplied by the accident fatality rate. As discussed in Chapter 3 of this Draft GEIS, the fatal accident rate for a truck is 2.409 E-08 per vehicle mile traveled (NRC 1994b). This fatality rate includes both death to members of the public and to drivers.

**2.6 Attribute - Industry Implementation**

**2.6.1 Attribute Definition and Identification of Driving Factors**

Industry Implementation measures the initial incremental cost or benefit to licenses due to changes in industry implementation, including incremental costs and savings of the following: reading regulations and guidance documents; training employees on new procedures; capital outlay for new equipment (e.g., trucks, survey equipment); and researching markets and vendors for cleared material. No capital outlay is expected to be required under this rulemaking. Fees paid to NRC are not included in the analysis as they represent a transfer payment. Thus fees paid are a cost to industry and a benefit to NRC, with a net balance of zero.

**2.6.2 Attribute Equation**

The following equation can be used to calculate the net change in costs and benefits due to the Industry Implementation attribute.

**Equation 8 - Implementation costs**

The implementation costs associated with the *Industry Implementation* attribute are estimated as follows:

$$Implementation = (HOURS_{industry\ implementation\ managers} \times WAGE_{Managerial}) + (HOURS_{industry\ implementation\ legal} \times WAGE_{Legal}) + (HOURS_{industry\ implementation\ clerical} \times WAGE_{Clerical})$$

Parameter	Description
HOURS <sub>industry implementation managers</sub>	The number of additional hours required for administrative implementation tasks by managers (see assumptions below)
WAGE <sub>Managerial</sub>	The loaded hourly wage per managerial labor (see Equation 1 assumptions in Section 2.2.2)
HOURS <sub>industry implementation legal</sub>	The number of additional hours required for administrative implementation tasks by attorneys (see assumptions below)
WAGE <sub>Legal</sub>	The loaded hourly wage per attorney (see Equation 1 assumptions in Section 2.2.2)
HOURS <sub>industry implementation clerical</sub>	The number of additional hours required for administrative implementation tasks by clerical workers (see assumptions below)
WAGE <sub>Clerical</sub>	The loaded hourly wage per clerical labor (see Equation 1 assumptions in Section 2.2.2)

*Assumptions*

The following are the number of hours assumed, using best professional judgement:

- Number of Managerial hours: 60.
- Number of Legal hours: 10.
- Number of Clerical hours: 10.

**2.7 Attribute - NRC Implementation**

**2.7.1 Attribute Definition and Identification of Driving Factors**

NRC Implementation involves, among other considerations, NRC staff time to complete the following implementation tasks:

- Develop guidance, procedures, and aids for use by NRC and Agreement States
- Develop enforcement procedures
- Develop guidance, procedures, and aids for use by licensees

**2.7.2 Attribute Equation**

The following equation calculates the costs and benefits due to NRC Implementation of new control criteria.

**Equation 9 - Develop guidance**

The administrative costs associated with developing guidance under the *NRC Implementation* attribute are estimated as follows:

$$Develop\ Guidance = (HOURS_{NRC\ implementation\ managerial} \times WAGE_{Managerial}) + (HOURS_{NRC\ implementation\ technical} \times WAGE_{Technical}) + (HOURS_{NRC\ implementation\ clerical} \times WAGE_{Clerical})$$

Parameter	Description
HOURS <sub>NRC implementation managerial</sub>	The number of additional hours required for NRC managerial staff (see assumptions below)
HOURS <sub>NRC implementation technical</sub>	The number of additional hours required for NRC technical staff (see assumptions below)
HOURS <sub>NRC implementation clerical</sub>	The number of additional hours required for NRC clerical staff (see assumptions below)
WAGE <sub>Managerial</sub>	The loaded hourly wage per managerial labor (see Equation 1 assumptions in Section 2.2.2)
WAGE <sub>Technical</sub>	The loaded hourly wage per technical labor (see Equation 1 assumptions in Section 2.2.2)
WAGE <sub>Clerical</sub>	The loaded hourly wage per clerical labor (see Equation 1 assumptions in Section 2.2.2)

*Assumptions*

The following are the number of hours necessary to develop guidance for the clearance of material, for the first year only, using best professional judgement:

- Number of Managerial hours: 10.
- Number of Technical hours: 80.
- Number of Clerical hours: 10.

**2.8 Attribute - NRC Operation**

**2.8.1 Attribute Definition and Identification of Driving Factors**

NRC operation involves NRC staff time to conduct the following operational tasks on an annual basis:

- Conduct inspections;

- Conduct evaluations of licensee compliance; and
- Enforcement.

### 2.8.2 Attribute Equations

The following equations calculate the costs due to NRC Operations related to new control criteria.

#### Equation 10 - Paperwork

The administrative costs associated with the paperwork of the *NRC Operations* attribute are estimated as follows:

$$NRC\ Paperwork = (HOURS_{NRC\ Ops\ Managerial} \times WAGE_{Managerial}) + (HOURS_{NRC\ Ops\ Legal} \times WAGE_{Legal}) + (HOURS_{NRC\ Ops\ Technical} \times WAGE_{Technical}) + (HOURS_{NRC\ Ops\ Clerical} \times WAGE_{Clerical})$$

Parameter	Description
HOURS <sub>NRC Ops Managerial</sub>	The number of additional hours required for NRC managerial staff, to review paperwork for the clearance of material
HOURS <sub>NRC Ops Legal</sub>	The number of additional hours required for NRC legal staff, to review paperwork for the clearance of material
HOURS <sub>NRC Ops Technical</sub>	The number of additional hours required for NRC technical staff, to review paperwork for the clearance of material
HOURS <sub>NRC Ops Clerical</sub>	The number of additional hours required for NRC clerical staff, to review paperwork for the clearance of material
WAGE <sub>Managerial</sub>	The loaded hourly wage per managerial labor (see Equation 1 assumptions in Section 2.2.2)
WAGE <sub>Legal</sub>	The loaded hourly wage per attorney (see Equation 1 assumptions in Section 2.2.2)
WAGE <sub>Technical</sub>	The loaded hourly wage per technical labor (see Equation 1 assumptions in Section 2.2.2)
WAGE <sub>Clerical</sub>	The loaded hourly wage per clerical labor (see Equation 1 assumptions in Section 2.2.2)

#### Assumptions

The analysis assumes that no hours will be required for NRC because no additional paperwork will be submitted by licensees, and therefore Equation 10 is equal to zero.

#### Equation 11 - Enforcement activities

The administrative costs associated with enforcement activities of the *NRC Operations* attribute are estimated as follows:

$$NRC\ Enforcement = (HOURS_{Enforcement\ Managerial} \times WAGE_{Managerial}) + (HOURS_{Enforcement\ Legal} \times WAGE_{Legal}) + (HOURS_{Enforcement\ Technical} \times WAGE_{Technical}) + (HOURS_{Enforcement\ Clerical} \times WAGE_{Clerical}) + COST_{Inspection\ Travel}$$

Parameter	Description
$HOURS_{\text{Enforcement Managerial}}$	The number of additional hours required for NRC managerial staff to conduct inspections for the clearance of material
$HOURS_{\text{Enforcement Legal}}$	The number of additional hours required for NRC legal staff to conduct inspections for the clearance of material
$HOURS_{\text{Enforcement Technical}}$	The number of additional hours required for NRC technical staff to conduct inspections for the clearance of material
$HOURS_{\text{Enforcement Clerical}}$	The number of additional hours required for NRC clerical staff to conduct inspections for the clearance of material
$WAGE_{\text{Managerial}}$	The loaded hourly wage per managerial labor (see Equation 1 assumptions in Section 2.2.2)
$WAGE_{\text{Legal}}$	The loaded hourly wage per attorney (see Equation 1 assumptions in Section 2.2.2)
$WAGE_{\text{Technical}}$	The loaded hourly wage per technical labor (see Equation 1 assumptions in Section 2.2.2)
$WAGE_{\text{Clerical}}$	The loaded hourly wage per clerical labor (see Equation 1 assumptions in Section 2.2.2)
$COST_{\text{Inspection Travel}}$	The travel-related costs associated with inspection of cleared material

### Assumptions

The analysis assumes that no hours will be required because no additional enforcement activities will be necessary for NRC; therefore, Equation 11 is equal to zero.

## 2.9 Attribute - Other Government

### 2.9.1 Attribute Definition and Identification of Driving Factors

This analysis estimates Other Government costs, excluding facilities that are assumed to be covered under the attributes Industry Implementation and Industry Operation, such as DOE and Department of Defense (DoD) facilities. Since regulation of LWRs is not delegated to Agreement States, they will not incur costs related to these facilities. The administrative tasks for other government agencies that have been identified are rulemakings in the Agreement States.

### 2.9.2 Attribute Equation

The following equation calculates the Other Government costs due to the implementation of new control criteria.

#### *Equation 12 - Burden to Agreement States*

The administrative costs associated with State agencies under the *Other Government* attribute are estimated as follows:

$$Environmental\ Agencies = \sum(HOURS_{State\ Employees} \times WAGE_x)$$

Parameter	Description
HOURS <sub>State Employees</sub>	The number of additional hours required for State employees for rulemakings
WAGE <sub>x</sub>	The loaded hourly wage per worker type x.

*Assumptions*

- 33 Agreement States will need to adapt their regulations to this rulemaking.
- 25 of these States are assumed to require 520 hours of managerial labor (NRC 2003e).
- 8 of these States are assumed to require 208 hours of managerial labor (NRC 2003e).

**2.10 Attribute - Regulatory Efficiency**

This attribute is considered qualitatively in Section 3, regarding the significant benefits associated with the streamlining of clearance procedures in the post regulatory environment compared with baseline clearance procedures.

**2.11 Attribute - Other Considerations**

This attribute is considered qualitatively in Section 3, regarding public confidence in NRC.

**2.12 Calculating Net Present Value**

Present value is a future cash flow, or stream of cash flows, recalculated as an equivalent current amount of money. Net Present Value (NPV) is the present value of all cash flows, *positive and negative*, connected to a project. To calculate NPV, the amount and timing of the cash flows must be determined. Additionally, a discount rate must be used to find the present value. Solving for the present value of a future cash flow is also known as discounting. The following formula shows how NPV is calculated by summing the discounted cash flows that occur in each year:

$$Net\ Present\ Value = \sum_{t=1}^n \left[ \frac{CF_t}{(1+r)^t} \right]$$

Parameter	Description
CF	cash flow in year t
t	year in which the cash flow takes place
n	life span (years) of the project
r	discount rate in year t

*Assumptions*

- 1 • For this analysis, the discount rate used is 7 percent, in accordance with NUREG/BR-0184,  
2 *Regulatory Analysis Technical Evaluation Handbook* (NRC 1997b).
- 3
- 4 • As a sensitivity analysis, the results also are calculated using a 3 percent discount rate.
- 5

### 3. Results

This section presents the results of the cost-benefit analysis. Table K-14 presents a summary of the net incremental benefits for each attribute by alternative and dose-option and the total net benefit. Tables K-15 through K-30 present the undiscounted annual incremental costs associated with each attribute for each alternative-dose option under consideration, with the exception of the No Action alternative. Note that costs appear in some years and not in others; this is a result of the distribution of plants shutting down in different years. For the periods where there are no net costs or benefits for Industry Implementation, these are years during which no active D&D is occurring at any decommissioning plant. The cost summary tables follow the information contained in SC&A 2003, Chapter 3. The following general conclusions can be drawn from these results:

- By definition, there are no benefits or costs associated with the No Action Alternative.
- The Unrestricted Release Alternative is expected to result in net incremental benefits under the 1 mem/yr, 10 mrem/yr, and IAEA Safety Guide No. RS-G-1.7 dose options. As shown in Table K-14, most of the benefits result from changes in industry operations (i.e., costs and benefits associated with survey, transportation, and recycling or disposal of material). Public health benefits arise as there are fewer vehicular accidents. Environmental benefits arise as there are fewer air emissions due to a decrease in vehicle miles traveled and as a result of favorable manufacturing tradeoffs as recycled ferrous metal replaces virgin ferrous metal. Sometimes these benefits are slightly offset by a cost resulting from a slight increase in dose to the public.
- Conversely, under the Unrestricted Release Alternative, at the 0.1 mrem/yr or 0.03 mrem/yr dose option levels, the analysis projects net costs, because more material fails to clear and, therefore, must be transported across the country for disposal as low-level waste.
- The EPA/State-Regulated Disposal Alternative, while less beneficial than the Unrestricted Release Alternative also is expected to result in substantial net incremental benefits at the 1 mrem/yr, 10 mrem/yr, and IAEA Safety Guide No. RS-G-1.7 dose options. In this alternative, benefits result from changes in industry operation. A small additional benefit results from changes in public health (routine) because the dose to the public is less than in the baseline. However, some benefit is offset by environmental costs related to a decrease in recycling.
- The LLW Disposal Alternative is projected to result in a net cost of approximately \$1.4 billion. Most of this cost results from changes in industry operation, including transportation and disposal of materials as LLW. Other substantial costs result from change in public health - accidental, as a result of more deaths from the increased transportation distances. A lower collective dose to the public is the only benefit of this alternative. All of the other quantifiable attributes contribute to a net cost.
- The Limited Disposition Alternative is expected to result in a net incremental benefit of about \$260 million. Most of the benefits result from changes in industry operations (i.e.,

1 benefits associated with survey, transportation, and recycling or disposal of material). Public  
2 health benefits arise from both lower radiological doses and fewer vehicular accidents.  
3 There is a slight environmental cost associated with the loss of otherwise recyclable ferrous  
4 metals being disposed in landfills. Because this material is not recycled, recycled ferrous  
5 metal cannot replace virgin ferrous metal production.  
6

- 7 • For the 0.03 mrem/yr dose options (regardless of the Alternative) it is economically  
8 infeasible to survey concrete and ferrous metal. Consequently, these materials are sent to  
9 LLW disposal, resulting in costs similar to the LLW disposal alternative. Because trash can  
10 still be surveyed at this dose level, some trash is sent to EPA landfills, resulting in a slightly  
11 lower cost than the LLW disposal alternative.  
12
- 13 • Note that OMB considers a rule “economically significant” under Executive Order 12866 if  
14 annual effects are greater than \$100 million; by this criterion, the 47-year 7 percent  
15 discounted net cost for the LLW Disposal Alternative, and the 0.03 dose options of the  
16 Unrestricted Release and EPA-Regulated Disposal Alternatives would qualify as  
17 “economically significant.”  
18

### 19 **Qualitative Results**

- 20 • Regulatory Efficiency - By developing standardized procedures to clear material, there will  
21 be increased regulatory efficiency for both NRC and for facilities that are undergoing  
22 decommissioning (except under the No Action Alternative). Currently, material may be  
23 released under Regulatory Guide 1.86 on a case-by-case basis. By having clearly defined  
24 procedures for clearing materials, facilities will be more certain of the options open to them  
25 at decommissioning. At the same time, NRC will have procedures in place that address how  
26 material can be released.  
27
- 28 • Other Considerations - Public confidence in NRC likely will be affected by this action,  
29 regardless of which one of the alternatives NRC adopts. Early public comment indicated that  
30 the public is concerned about the safety issues related to radioactive materials in consumer  
31 products. NRC will need to consider public confidence as it proceeds in the decision making  
32 process.  
33  
34

*Appendix K: Cost-Benefit Analysis Methodology and Results*

**Table K-14 Net Incremental Benefit (Cost) Associated with Attributes by Alternative and Dose Level  
(2003\$)**

Alternative	Dose Option	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations	Total
No Action	NA	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Unrestricted Release Material Specific Limits	0.03	\$1,174,216	(\$13,514,350)	(\$219,720)	(\$1,376,897,891)	(\$3,395)	\$0	(\$451,377)	(\$12,878,667)	(\$1,402,791,183)
	0.1	\$960,746	\$0	(\$219,720)	(\$226,113,873)	(\$3,395)	\$0	(\$451,377)	(\$618,308)	(\$226,445,926)
	1	(\$787,022)	\$0	(\$219,720)	\$293,675,372	(\$3,395)	\$0	(\$451,377)	\$2,125,995	\$294,339,854
	10	(\$8,167,397)	\$0	(\$219,720)	\$329,263,365	(\$3,395)	\$0	(\$451,377)	\$2,801,081	\$323,222,558
Unrestricted Release Material Independent Limits	0.03	\$1,233,593	(\$13,514,350)	(\$219,720)	(\$1,378,418,237)	(\$3,395)	\$0	(\$451,377)	(\$12,902,162)	(\$1,404,275,647)
	0.1	\$1,205,052	\$0	(\$219,720)	(\$291,974,108)	(\$3,395)	\$0	(\$451,377)	(\$2,278,274)	(\$293,721,822)
	1	\$713,415	\$0	(\$219,720)	\$246,021,542	(\$3,395)	\$0	(\$451,377)	\$987,754	\$247,048,219
	10	(\$1,851,424)	\$0	(\$219,720)	\$306,935,439	(\$3,395)	\$0	(\$451,377)	\$2,352,109	\$306,761,633
	RS-G-1.7	\$186,142	\$0	(\$219,720)	\$246,021,542	(\$3,395)	\$0	(\$451,377)	\$987,754	\$246,520,945
EPA/State-Regulated Disposal (Landfill)	0.03	\$1,240,634	(\$13,514,350)	(\$219,720)	(\$1,376,897,891)	(\$3,395)	\$0	(\$451,377)	(\$12,878,667)	(\$1,402,724,765)
	0.1	\$1,240,530	\$0	(\$219,720)	(\$281,093,000)	(\$3,395)	\$0	(\$451,377)	(\$2,259,193)	(\$282,786,154)
	1	\$1,239,881	\$0	(\$219,720)	\$181,462,308	(\$3,395)	\$0	(\$451,377)	(\$1,033,674)	\$180,994,024
	10	\$1,237,267	\$0	(\$219,720)	\$193,637,557	(\$3,395)	\$0	(\$451,377)	(\$922,985)	\$193,277,348
	RS-G-1.7	\$1,239,074	\$0	(\$219,720)	\$181,462,308	(\$3,395)	\$0	(\$451,377)	(\$1,033,674)	\$180,993,217
LLW Disposal/ Prohibition	NA	\$1,240,689	(\$13,514,350)	\$0	(\$1,378,439,254)	(\$3,395)	\$0	(\$451,377)	(\$12,902,486)	(\$1,404,070,173)
Limited Dispositions	RS-G-1.7	\$1,227,219	\$0	(\$219,720)	\$258,149,485	(\$3,395)	\$0	(\$451,377)	(\$1,500,316)	\$257,201,896

**Table K-15 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Specific Limits - 0.03 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$14,362	\$0	(\$18,848)	(\$73,792,689)	(\$3,395)	\$0	(\$451,377)	(\$1,348,379)
2004	\$20,530	\$0	(\$11,309)	(\$40,532,801)	\$0	\$0	\$0	(\$745,860)
2005	\$19,384	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2006	\$18,192	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2007	\$17,212	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2008	\$16,348	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2009	\$15,600	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2010	\$14,928	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2011	\$14,352	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2012	\$13,854	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2013	\$13,392	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2014	\$13,236	\$0	(\$3,770)	(\$3,662,425)	\$0	\$0	\$0	(\$57,614)
2015	\$24,478	\$0	(\$18,848)	(\$110,212,760)	\$0	\$0	\$0	(\$868,326)
2016	\$43,140	(\$3,000,000)	(\$26,387)	(\$166,548,785)	\$0	\$0	\$0	(\$1,342,084)
2017	\$54,720	\$0	(\$18,848)	(\$113,032,649)	\$0	\$0	\$0	(\$952,889)
2018	\$75,220	(\$3,000,000)	(\$33,926)	(\$221,381,781)	\$0	\$0	\$0	(\$1,765,758)
2019	\$116,760	(\$3,000,000)	(\$60,314)	(\$370,432,493)	\$0	\$0	\$0	(\$3,044,680)
2020	\$165,600	(\$6,000,000)	(\$67,853)	(\$476,413,898)	\$0	\$0	\$0	(\$3,882,032)
2021	\$185,960	(\$3,000,000)	(\$41,466)	(\$316,584,440)	\$0	\$0	\$0	(\$2,556,884)
2022	\$195,360	(\$3,000,000)	(\$30,157)	(\$203,730,363)	\$0	\$0	\$0	(\$1,775,903)
2023	\$208,580	(\$3,000,000)	(\$37,696)	(\$230,909,345)	\$0	\$0	\$0	(\$2,016,965)
2024	\$204,720	\$0	(\$22,618)	(\$111,286,568)	\$0	\$0	\$0	(\$1,047,434)
2025	\$189,280	\$0	(\$15,078)	(\$53,367,953)	\$0	\$0	\$0	(\$506,990)
2026	\$181,220	\$0	(\$18,848)	(\$81,613,878)	\$0	\$0	\$0	(\$769,510)
2027	\$191,200	(\$3,000,000)	(\$30,157)	(\$168,001,997)	\$0	\$0	\$0	(\$1,572,635)
2028	\$208,280	(\$3,000,000)	(\$37,696)	(\$253,776,649)	\$0	\$0	\$0	(\$2,204,502)
2029	\$221,580	(\$3,000,000)	(\$37,696)	(\$301,038,895)	\$0	\$0	\$0	(\$2,457,628)
2030	\$253,960	(\$6,000,000)	(\$52,774)	(\$423,645,204)	\$0	\$0	\$0	(\$3,506,365)
2031	\$290,020	(\$6,000,000)	(\$56,544)	(\$454,470,162)	\$0	\$0	\$0	(\$3,841,311)
2032	\$320,440	(\$6,000,000)	(\$56,544)	(\$465,170,953)	\$0	\$0	\$0	(\$3,869,190)
2033	\$343,160	(\$6,000,000)	(\$52,774)	(\$409,017,991)	\$0	\$0	\$0	(\$3,494,670)
2034	\$327,820	(\$3,000,000)	(\$22,618)	(\$146,593,443)	\$0	\$0	\$0	(\$1,375,334)
2035	\$303,260	\$0	(\$11,309)	(\$95,796,042)	\$0	\$0	\$0	(\$811,410)
2036	\$278,580	\$0	(\$11,309)	(\$94,261,732)	\$0	\$0	\$0	(\$797,075)
2037	\$248,200	\$0	(\$3,770)	(\$24,769,000)	\$0	\$0	\$0	(\$234,464)
2038	\$219,860	\$0	(\$3,770)	(\$5,746,314)	\$0	\$0	\$0	(\$45,140)
2039	\$204,620	\$0	(\$15,078)	(\$70,650,437)	\$0	\$0	\$0	(\$651,218)
2040	\$208,460	(\$3,000,000)	(\$26,387)	(\$160,753,698)	\$0	\$0	\$0	(\$1,434,603)
2041	\$202,760	\$0	(\$18,848)	(\$119,968,404)	\$0	\$0	\$0	(\$1,053,780)
2042	\$185,840	\$0	(\$7,539)	(\$44,134,092)	\$0	\$0	\$0	(\$413,940)
2043	\$166,880	\$0	(\$3,770)	(\$19,968,177)	\$0	\$0	\$0	(\$187,148)
2044	\$149,680	\$0	(\$3,770)	(\$35,919,945)	\$0	\$0	\$0	(\$265,184)
2045	\$134,540	\$0	(\$3,770)	(\$35,919,945)	\$0	\$0	\$0	(\$265,184)
2046	\$117,860	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$107,620	\$0	(\$3,770)	(\$22,049,890)	\$0	\$0	\$0	(\$207,017)
2048	\$103,040	\$0	(\$7,539)	(\$44,154,494)	\$0	\$0	\$0	(\$414,420)
2049	\$97,780	\$0	(\$7,539)	(\$51,774,275)	\$0	\$0	\$0	(\$426,393)

**Table K-16 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Specific Limits - 0.1 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$11,560	\$0	(\$18,848)	(\$11,184,825)	(\$3,395)	\$0	(\$451,377)	(\$19,826)
2004	\$16,520	\$0	(\$11,309)	(\$6,068,223)	\$0	\$0	\$0	(\$11,345)
2005	\$15,660	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$3,104)
2006	\$14,720	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$3,104)
2007	\$13,960	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$3,104)
2008	\$13,300	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$3,104)
2009	\$12,720	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$3,104)
2010	\$12,180	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$2,467)
2011	\$11,740	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$2,467)
2012	\$11,360	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$2,467)
2013	\$11,000	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$2,467)
2014	\$10,880	\$0	(\$3,770)	(\$112,632)	\$0	\$0	\$0	(\$2,468)
2015	\$20,220	\$0	(\$18,848)	(\$19,148,387)	\$0	\$0	\$0	(\$24,671)
2016	\$35,700	\$0	(\$26,387)	(\$28,569,167)	\$0	\$0	\$0	(\$48,994)
2017	\$45,240	\$0	(\$18,848)	(\$18,794,514)	\$0	\$0	\$0	(\$44,321)
2018	\$62,200	\$0	(\$33,926)	(\$38,362,185)	\$0	\$0	\$0	(\$62,318)
2019	\$96,200	\$0	(\$60,314)	(\$62,893,590)	\$0	\$0	\$0	(\$135,006)
2020	\$136,200	\$0	(\$67,853)	(\$82,557,664)	\$0	\$0	\$0	(\$197,561)
2021	\$153,200	\$0	(\$41,466)	(\$55,393,885)	\$0	\$0	\$0	(\$125,416)
2022	\$160,600	\$0	(\$30,157)	(\$32,965,874)	\$0	\$0	\$0	(\$110,930)
2023	\$171,200	\$0	(\$37,696)	(\$37,258,254)	\$0	\$0	\$0	(\$126,882)
2024	\$168,000	\$0	(\$22,618)	(\$16,869,877)	\$0	\$0	\$0	(\$81,219)
2025	\$155,200	\$0	(\$15,078)	(\$7,943,692)	\$0	\$0	\$0	(\$38,385)
2026	\$148,200	\$0	(\$18,848)	(\$12,629,780)	\$0	\$0	\$0	(\$61,374)
2027	\$156,200	\$0	(\$30,157)	(\$26,127,824)	\$0	\$0	\$0	(\$126,524)
2028	\$170,000	\$0	(\$37,696)	(\$41,668,898)	\$0	\$0	\$0	(\$142,292)
2029	\$180,800	\$0	(\$37,696)	(\$51,534,325)	\$0	\$0	\$0	(\$121,991)
2030	\$207,600	\$0	(\$52,774)	(\$72,180,246)	\$0	\$0	\$0	(\$188,050)
2031	\$237,000	\$0	(\$56,544)	(\$76,405,003)	\$0	\$0	\$0	(\$227,927)
2032	\$262,000	\$0	(\$56,544)	(\$78,791,904)	\$0	\$0	\$0	(\$214,203)
2033	\$280,400	\$0	(\$52,774)	(\$68,172,897)	\$0	\$0	\$0	(\$216,099)
2034	\$267,600	\$0	(\$22,618)	(\$23,032,927)	\$0	\$0	\$0	(\$115,351)
2035	\$247,800	\$0	(\$11,309)	(\$16,117,932)	\$0	\$0	\$0	(\$49,027)
2036	\$227,400	\$0	(\$11,309)	(\$15,806,209)	\$0	\$0	\$0	(\$47,115)
2037	\$202,400	\$0	(\$3,770)	(\$3,839,024)	\$0	\$0	\$0	(\$19,525)
2038	\$179,600	\$0	(\$3,770)	(\$1,006,356)	\$0	\$0	\$0	(\$1,323)
2039	\$166,800	\$0	(\$15,078)	(\$11,101,342)	\$0	\$0	\$0	(\$50,654)
2040	\$170,000	\$0	(\$26,387)	(\$25,732,687)	\$0	\$0	\$0	(\$101,016)
2041	\$165,200	\$0	(\$18,848)	(\$19,426,231)	\$0	\$0	\$0	(\$70,901)
2042	\$151,400	\$0	(\$7,539)	(\$6,812,504)	\$0	\$0	\$0	(\$34,285)
2043	\$136,000	\$0	(\$3,770)	(\$3,035,259)	\$0	\$0	\$0	(\$14,935)
2044	\$122,000	\$0	(\$3,770)	(\$6,546,047)	\$0	\$0	\$0	(\$6,713)
2045	\$109,800	\$0	(\$3,770)	(\$6,546,047)	\$0	\$0	\$0	(\$6,713)
2046	\$96,000	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$87,600	\$0	(\$3,770)	(\$3,438,472)	\$0	\$0	\$0	(\$17,603)
2048	\$83,800	\$0	(\$7,539)	(\$6,904,404)	\$0	\$0	\$0	(\$35,381)
2049	\$79,600	\$0	(\$7,539)	(\$8,857,740)	\$0	\$0	\$0	(\$23,068)

**Table K-17 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Specific Limits - 1 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	(\$10,560)	\$0	(\$18,848)	\$16,743,605	(\$3,395)	\$0	(\$451,377)	\$237,554
2004	(\$15,000)	\$0	(\$11,309)	\$9,249,725	\$0	\$0	\$0	\$129,903
2005	(\$14,200)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$5,136
2006	(\$13,640)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$5,136
2007	(\$13,060)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$5,136
2008	(\$12,760)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$5,136
2009	(\$12,340)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$5,136
2010	(\$12,040)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$2,859
2011	(\$11,640)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$2,859
2012	(\$11,360)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$2,859
2013	(\$11,240)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$2,859
2014	(\$11,200)	\$0	(\$3,770)	\$1,214,413	\$0	\$0	\$0	\$6,848
2015	(\$17,800)	\$0	(\$18,848)	\$22,359,758	\$0	\$0	\$0	\$149,095
2016	(\$28,800)	\$0	(\$26,387)	\$34,175,733	\$0	\$0	\$0	\$227,935
2017	(\$36,800)	\$0	(\$18,848)	\$23,776,945	\$0	\$0	\$0	\$156,869
2018	(\$50,000)	\$0	(\$33,926)	\$45,149,318	\$0	\$0	\$0	\$301,877
2019	(\$76,800)	\$0	(\$60,314)	\$76,800,837	\$0	\$0	\$0	\$512,193
2020	(\$105,400)	\$0	(\$67,853)	\$97,322,953	\$0	\$0	\$0	\$644,834
2021	(\$116,000)	\$0	(\$41,466)	\$64,387,344	\$0	\$0	\$0	\$426,412
2022	(\$124,000)	\$0	(\$30,157)	\$44,310,196	\$0	\$0	\$0	\$289,831
2023	(\$134,000)	\$0	(\$37,696)	\$50,279,371	\$0	\$0	\$0	\$328,589
2024	(\$132,000)	\$0	(\$22,618)	\$25,376,779	\$0	\$0	\$0	\$163,806
2025	(\$124,200)	\$0	(\$15,078)	\$12,220,040	\$0	\$0	\$0	\$78,488
2026	(\$120,600)	\$0	(\$18,848)	\$18,356,316	\$0	\$0	\$0	\$119,223
2027	(\$130,000)	\$0	(\$30,157)	\$37,756,101	\$0	\$0	\$0	\$246,062
2028	(\$138,000)	\$0	(\$37,696)	\$54,101,628	\$0	\$0	\$0	\$354,459
2029	(\$148,000)	\$0	(\$37,696)	\$61,800,707	\$0	\$0	\$0	\$408,465
2030	(\$166,000)	\$0	(\$52,774)	\$87,201,747	\$0	\$0	\$0	\$577,084
2031	(\$190,000)	\$0	(\$56,544)	\$94,607,147	\$0	\$0	\$0	\$622,616
2032	(\$208,000)	\$0	(\$56,544)	\$96,936,105	\$0	\$0	\$0	\$638,232
2033	(\$224,000)	\$0	(\$52,774)	\$86,923,790	\$0	\$0	\$0	\$571,652
2034	(\$218,000)	\$0	(\$22,618)	\$32,928,364	\$0	\$0	\$0	\$214,516
2035	(\$200,000)	\$0	(\$11,309)	\$19,796,783	\$0	\$0	\$0	\$130,304
2036	(\$186,000)	\$0	(\$11,309)	\$19,555,954	\$0	\$0	\$0	\$128,407
2037	(\$166,000)	\$0	(\$3,770)	\$5,595,958	\$0	\$0	\$0	\$36,004
2038	(\$144,000)	\$0	(\$3,770)	\$1,148,336	\$0	\$0	\$0	\$7,604
2039	(\$138,000)	\$0	(\$15,078)	\$15,594,693	\$0	\$0	\$0	\$101,832
2040	(\$138,000)	\$0	(\$26,387)	\$34,848,628	\$0	\$0	\$0	\$228,383
2041	(\$134,000)	\$0	(\$18,848)	\$25,840,903	\$0	\$0	\$0	\$169,283
2042	(\$125,800)	\$0	(\$7,539)	\$10,001,286	\$0	\$0	\$0	\$65,004
2043	(\$111,800)	\$0	(\$3,770)	\$4,533,931	\$0	\$0	\$0	\$29,785
2044	(\$100,000)	\$0	(\$3,770)	\$6,893,933	\$0	\$0	\$0	\$46,325
2045	(\$90,000)	\$0	(\$3,770)	\$6,893,933	\$0	\$0	\$0	\$46,325
2046	(\$79,600)	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	(\$72,400)	\$0	(\$3,770)	\$4,991,783	\$0	\$0	\$0	\$31,973
2048	(\$70,000)	\$0	(\$7,539)	\$9,923,992	\$0	\$0	\$0	\$63,460
2049	(\$66,200)	\$0	(\$7,539)	\$10,478,626	\$0	\$0	\$0	\$68,865

**Table K-18 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Specific Limits - 10 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	(\$105,560)	\$0	(\$18,848)	\$18,975,651	(\$3,395)	\$0	(\$451,377)	\$295,470
2004	(\$155,200)	\$0	(\$11,309)	\$10,624,203	\$0	\$0	\$0	\$164,154
2005	(\$156,200)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$13,061
2006	(\$157,440)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$13,061
2007	(\$158,460)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$13,061
2008	(\$159,360)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$13,061
2009	(\$160,140)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$13,061
2010	(\$160,840)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$7,646
2011	(\$161,440)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$7,646
2012	(\$161,960)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$7,646
2013	(\$162,440)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$7,646
2014	(\$164,000)	\$0	(\$3,770)	\$1,659,095	\$0	\$0	\$0	\$12,429
2015	(\$238,000)	\$0	(\$18,848)	\$24,946,800	\$0	\$0	\$0	\$188,170
2016	(\$352,400)	\$0	(\$26,387)	\$38,036,241	\$0	\$0	\$0	\$290,582
2017	(\$420,200)	\$0	(\$18,848)	\$26,618,558	\$0	\$0	\$0	\$205,058
2018	(\$550,600)	\$0	(\$33,926)	\$50,134,101	\$0	\$0	\$0	\$382,867
2019	(\$810,800)	\$0	(\$60,314)	\$85,221,386	\$0	\$0	\$0	\$658,094
2020	(\$1,105,400)	\$0	(\$67,853)	\$107,887,663	\$0	\$0	\$0	\$836,424
2021	(\$1,228,000)	\$0	(\$41,466)	\$71,376,167	\$0	\$0	\$0	\$550,662
2022	(\$1,290,000)	\$0	(\$30,157)	\$49,315,056	\$0	\$0	\$0	\$386,193
2023	(\$1,374,000)	\$0	(\$37,696)	\$55,979,397	\$0	\$0	\$0	\$439,957
2024	(\$1,342,000)	\$0	(\$22,618)	\$28,445,874	\$0	\$0	\$0	\$227,831
2025	(\$1,246,200)	\$0	(\$15,078)	\$13,791,563	\$0	\$0	\$0	\$109,745
2026	(\$1,208,600)	\$0	(\$18,848)	\$20,622,590	\$0	\$0	\$0	\$165,456
2027	(\$1,276,000)	\$0	(\$30,157)	\$42,196,128	\$0	\$0	\$0	\$339,505
2028	(\$1,374,000)	\$0	(\$37,696)	\$60,225,271	\$0	\$0	\$0	\$474,312
2029	(\$1,458,000)	\$0	(\$37,696)	\$68,575,749	\$0	\$0	\$0	\$531,340
2030	(\$1,644,000)	\$0	(\$52,774)	\$96,815,447	\$0	\$0	\$0	\$756,609
2031	(\$1,854,000)	\$0	(\$56,544)	\$105,165,132	\$0	\$0	\$0	\$825,706
2032	(\$2,042,000)	\$0	(\$56,544)	\$107,453,319	\$0	\$0	\$0	\$837,002
2033	(\$2,178,000)	\$0	(\$52,774)	\$96,443,459	\$0	\$0	\$0	\$757,652
2034	(\$2,114,000)	\$0	(\$22,618)	\$36,721,286	\$0	\$0	\$0	\$296,432
2035	(\$1,940,000)	\$0	(\$11,309)	\$22,012,568	\$0	\$0	\$0	\$172,593
2036	(\$1,786,000)	\$0	(\$11,309)	\$21,746,406	\$0	\$0	\$0	\$170,186
2037	(\$1,596,000)	\$0	(\$3,770)	\$6,275,605	\$0	\$0	\$0	\$50,322
2038	(\$1,404,000)	\$0	(\$3,770)	\$1,289,270	\$0	\$0	\$0	\$9,665
2039	(\$1,322,000)	\$0	(\$15,078)	\$17,414,991	\$0	\$0	\$0	\$140,288
2040	(\$1,340,000)	\$0	(\$26,387)	\$38,764,819	\$0	\$0	\$0	\$308,980
2041	(\$1,302,000)	\$0	(\$18,848)	\$28,682,859	\$0	\$0	\$0	\$226,773
2042	(\$1,195,800)	\$0	(\$7,539)	\$11,123,450	\$0	\$0	\$0	\$89,203
2043	(\$1,071,800)	\$0	(\$3,770)	\$5,037,197	\$0	\$0	\$0	\$40,533
2044	(\$960,000)	\$0	(\$3,770)	\$7,611,559	\$0	\$0	\$0	\$57,429
2045	(\$862,000)	\$0	(\$3,770)	\$7,611,559	\$0	\$0	\$0	\$57,429
2046	(\$755,600)	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	(\$688,400)	\$0	(\$3,770)	\$5,556,406	\$0	\$0	\$0	\$44,270
2048	(\$655,200)	\$0	(\$7,539)	\$11,065,139	\$0	\$0	\$0	\$88,317
2049	(\$618,800)	\$0	(\$7,539)	\$11,659,353	\$0	\$0	\$0	\$90,704

**Table K-19 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Independent - 0.03 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,145	\$0	(\$18,848)	(\$73,918,704)	(\$3,395)	\$0	(\$451,377)	(\$1,351,148)
2004	\$21,659	\$0	(\$11,309)	(\$40,656,978)	\$0	\$0	\$0	(\$748,588)
2005	\$20,457	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$48,760)
2006	\$19,216	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$48,760)
2007	\$18,194	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$48,760)
2008	\$17,293	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$48,760)
2009	\$16,511	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$48,760)
2010	\$15,810	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$37,086)
2011	\$15,209	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$37,086)
2012	\$14,689	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$37,086)
2013	\$14,208	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$37,086)
2014	\$14,046	\$0	(\$3,770)	(\$3,784,630)	\$0	\$0	\$0	(\$58,955)
2015	\$25,790	\$0	(\$18,848)	(\$110,334,964)	\$0	\$0	\$0	(\$869,427)
2016	\$45,298	(\$3,000,000)	(\$26,387)	(\$166,670,917)	\$0	\$0	\$0	(\$1,343,184)
2017	\$57,442	\$0	(\$18,848)	(\$113,151,384)	\$0	\$0	\$0	(\$953,959)
2018	\$78,932	(\$3,000,000)	(\$33,926)	(\$221,498,041)	\$0	\$0	\$0	(\$1,766,805)
2019	\$122,504	(\$3,000,000)	(\$60,314)	(\$370,546,753)	\$0	\$0	\$0	(\$3,045,709)
2020	\$173,658	(\$6,000,000)	(\$67,853)	(\$476,522,308)	\$0	\$0	\$0	(\$3,882,983)
2021	\$194,958	(\$3,000,000)	(\$41,466)	(\$316,683,843)	\$0	\$0	\$0	(\$2,557,756)
2022	\$204,904	(\$3,000,000)	(\$30,157)	(\$203,820,426)	\$0	\$0	\$0	(\$1,776,693)
2023	\$218,834	(\$3,000,000)	(\$37,696)	(\$230,997,130)	\$0	\$0	\$0	(\$2,017,735)
2024	\$214,848	\$0	(\$22,618)	(\$111,367,514)	\$0	\$0	\$0	(\$1,048,144)
2025	\$198,718	\$0	(\$15,078)	(\$53,445,682)	\$0	\$0	\$0	(\$507,669)
2026	\$190,354	\$0	(\$18,848)	(\$81,689,214)	\$0	\$0	\$0	(\$770,169)
2027	\$200,896	(\$3,000,000)	(\$30,157)	(\$168,076,981)	\$0	\$0	\$0	(\$1,573,291)
2028	\$218,814	(\$3,000,000)	(\$37,696)	(\$253,847,702)	\$0	\$0	\$0	(\$2,205,122)
2029	\$232,756	(\$3,000,000)	(\$37,696)	(\$301,105,132)	\$0	\$0	\$0	(\$2,458,206)
2030	\$266,602	(\$6,000,000)	(\$52,774)	(\$423,706,158)	\$0	\$0	\$0	(\$3,506,898)
2031	\$304,404	(\$6,000,000)	(\$56,544)	(\$454,525,519)	\$0	\$0	\$0	(\$3,841,795)
2032	\$336,242	(\$6,000,000)	(\$56,544)	(\$465,214,150)	\$0	\$0	\$0	(\$3,869,568)
2033	\$360,124	(\$6,000,000)	(\$52,774)	(\$409,053,376)	\$0	\$0	\$0	(\$3,494,979)
2034	\$344,194	(\$3,000,000)	(\$22,618)	(\$146,617,220)	\$0	\$0	\$0	(\$1,375,542)
2035	\$318,342	\$0	(\$11,309)	(\$95,813,031)	\$0	\$0	\$0	(\$811,558)
2036	\$292,474	\$0	(\$11,309)	(\$94,277,207)	\$0	\$0	\$0	(\$797,210)
2037	\$260,634	\$0	(\$3,770)	(\$24,781,927)	\$0	\$0	\$0	(\$234,577)
2038	\$230,794	\$0	(\$3,770)	(\$5,758,047)	\$0	\$0	\$0	(\$45,242)
2039	\$214,872	\$0	(\$15,078)	(\$70,662,169)	\$0	\$0	\$0	(\$651,321)
2040	\$218,862	(\$3,000,000)	(\$26,387)	(\$160,765,263)	\$0	\$0	\$0	(\$1,434,704)
2041	\$212,890	\$0	(\$18,848)	(\$119,976,328)	\$0	\$0	\$0	(\$1,053,850)
2042	\$195,172	\$0	(\$7,539)	(\$44,137,577)	\$0	\$0	\$0	(\$413,970)
2043	\$175,272	\$0	(\$3,770)	(\$19,970,346)	\$0	\$0	\$0	(\$187,167)
2044	\$157,168	\$0	(\$3,770)	(\$35,920,962)	\$0	\$0	\$0	(\$265,193)
2045	\$141,252	\$0	(\$3,770)	(\$35,920,962)	\$0	\$0	\$0	(\$265,193)
2046	\$123,740	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$112,996	\$0	(\$3,770)	(\$22,051,117)	\$0	\$0	\$0	(\$207,028)
2048	\$108,222	\$0	(\$7,539)	(\$44,156,969)	\$0	\$0	\$0	(\$414,442)
2049	\$102,658	\$0	(\$7,539)	(\$51,776,375)	\$0	\$0	\$0	(\$426,412)

**Table K-20 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Independent - 0.1 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$14,754	\$0	(\$18,848)	(\$15,859,375)	(\$3,395)	\$0	(\$451,377)	(\$159,941)
2004	\$21,092	\$0	(\$11,309)	(\$8,699,774)	\$0	\$0	\$0	(\$88,736)
2005	\$19,916	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$13,569)
2006	\$18,694	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$13,569)
2007	\$17,690	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$13,569)
2008	\$16,804	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$13,569)
2009	\$16,038	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$13,569)
2010	\$15,348	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$9,505)
2011	\$14,758	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$9,505)
2012	\$14,248	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$9,505)
2013	\$13,774	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$9,505)
2014	\$13,616	\$0	(\$3,770)	(\$631,696)	\$0	\$0	\$0	(\$11,129)
2015	\$25,124	\$0	(\$18,848)	(\$23,006,590)	\$0	\$0	\$0	(\$113,097)
2016	\$44,226	\$0	(\$26,387)	(\$35,019,321)	\$0	\$0	\$0	(\$199,643)
2017	\$56,104	\$0	(\$18,848)	(\$23,964,935)	\$0	\$0	\$0	(\$164,367)
2018	\$77,140	\$0	(\$33,926)	(\$46,636,165)	\$0	\$0	\$0	(\$256,952)
2019	\$119,700	\$0	(\$60,314)	(\$78,452,965)	\$0	\$0	\$0	(\$504,598)
2020	\$169,740	\$0	(\$67,853)	(\$101,477,497)	\$0	\$0	\$0	(\$678,976)
2021	\$190,600	\$0	(\$41,466)	(\$67,533,324)	\$0	\$0	\$0	(\$433,171)
2022	\$200,300	\$0	(\$30,157)	(\$43,072,339)	\$0	\$0	\$0	(\$366,869)
2023	\$213,880	\$0	(\$37,696)	(\$48,789,185)	\$0	\$0	\$0	(\$419,463)
2024	\$209,940	\$0	(\$22,618)	(\$23,703,776)	\$0	\$0	\$0	(\$253,521)
2025	\$194,120	\$0	(\$15,078)	(\$11,274,456)	\$0	\$0	\$0	(\$120,761)
2026	\$185,900	\$0	(\$18,848)	(\$17,705,374)	\$0	\$0	\$0	(\$188,539)
2027	\$196,160	\$0	(\$30,157)	(\$36,418,806)	\$0	\$0	\$0	(\$387,304)
2028	\$213,660	\$0	(\$37,696)	(\$54,228,478)	\$0	\$0	\$0	(\$461,336)
2029	\$227,300	\$0	(\$37,696)	(\$63,730,261)	\$0	\$0	\$0	(\$431,902)
2030	\$260,440	\$0	(\$52,774)	(\$90,168,567)	\$0	\$0	\$0	(\$646,417)
2031	\$297,360	\$0	(\$56,544)	(\$97,011,487)	\$0	\$0	\$0	(\$753,557)
2032	\$328,520	\$0	(\$56,544)	(\$98,759,123)	\$0	\$0	\$0	(\$723,923)
2033	\$351,860	\$0	(\$52,774)	(\$87,405,235)	\$0	\$0	\$0	(\$707,295)
2034	\$336,220	\$0	(\$22,618)	(\$32,064,015)	\$0	\$0	\$0	(\$345,735)
2035	\$311,020	\$0	(\$11,309)	(\$20,466,917)	\$0	\$0	\$0	(\$159,760)
2036	\$285,720	\$0	(\$11,309)	(\$20,084,861)	\$0	\$0	\$0	(\$156,104)
2037	\$254,580	\$0	(\$3,770)	(\$5,401,096)	\$0	\$0	\$0	(\$59,040)
2038	\$225,460	\$0	(\$3,770)	(\$1,199,716)	\$0	\$0	\$0	(\$5,831)
2039	\$209,860	\$0	(\$15,078)	(\$15,263,308)	\$0	\$0	\$0	(\$156,797)
2040	\$213,780	\$0	(\$26,387)	(\$34,387,521)	\$0	\$0	\$0	(\$322,227)
2041	\$207,920	\$0	(\$18,848)	(\$25,570,643)	\$0	\$0	\$0	(\$227,958)
2042	\$190,600	\$0	(\$7,539)	(\$9,514,335)	\$0	\$0	\$0	(\$103,346)
2043	\$171,160	\$0	(\$3,770)	(\$4,260,362)	\$0	\$0	\$0	(\$46,228)
2044	\$153,500	\$0	(\$3,770)	(\$7,499,693)	\$0	\$0	\$0	(\$31,096)
2045	\$137,960	\$0	(\$3,770)	(\$7,499,693)	\$0	\$0	\$0	(\$31,096)
2046	\$120,840	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$110,340	\$0	(\$3,770)	(\$4,793,703)	\$0	\$0	\$0	(\$52,264)
2048	\$105,660	\$0	(\$7,539)	(\$9,610,936)	\$0	\$0	\$0	(\$104,602)
2049	\$100,260	\$0	(\$7,539)	(\$11,006,085)	\$0	\$0	\$0	(\$78,007)

**Table K-21 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Independent - 1 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$8,340	\$0	(\$18,848)	\$13,418,392	(\$3,395)	\$0	(\$451,377)	\$142,936
2004	\$12,020	\$0	(\$11,309)	\$7,255,578	\$0	\$0	\$0	\$75,691
2005	\$11,480	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2006	\$10,820	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2007	\$10,300	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2008	\$9,860	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2009	\$9,460	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2010	\$9,100	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2011	\$8,800	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2012	\$8,540	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2013	\$8,300	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2014	\$8,240	\$0	(\$3,770)	\$600,554	\$0	\$0	\$0	(\$581)
2015	\$15,460	\$0	(\$18,848)	\$19,380,272	\$0	\$0	\$0	\$86,144
2016	\$27,260	\$0	(\$26,387)	\$29,461,816	\$0	\$0	\$0	\$123,749
2017	\$34,200	\$0	(\$18,848)	\$20,039,265	\$0	\$0	\$0	\$75,669
2018	\$47,000	\$0	(\$33,926)	\$39,178,995	\$0	\$0	\$0	\$167,442
2019	\$72,200	\$0	(\$60,314)	\$65,971,458	\$0	\$0	\$0	\$262,120
2020	\$102,800	\$0	(\$67,853)	\$84,066,938	\$0	\$0	\$0	\$315,696
2021	\$115,800	\$0	(\$41,466)	\$55,758,237	\$0	\$0	\$0	\$214,214
2022	\$120,800	\$0	(\$30,157)	\$37,375,753	\$0	\$0	\$0	\$120,028
2023	\$128,200	\$0	(\$37,696)	\$42,389,042	\$0	\$0	\$0	\$134,332
2024	\$125,400	\$0	(\$22,618)	\$20,717,459	\$0	\$0	\$0	\$51,169
2025	\$115,200	\$0	(\$15,078)	\$9,852,682	\$0	\$0	\$0	\$23,970
2026	\$109,600	\$0	(\$18,848)	\$14,885,463	\$0	\$0	\$0	\$36,542
2027	\$114,800	\$0	(\$30,157)	\$30,890,787	\$0	\$0	\$0	\$77,247
2028	\$125,200	\$0	(\$37,696)	\$45,583,568	\$0	\$0	\$0	\$143,438
2029	\$133,600	\$0	(\$37,696)	\$53,336,462	\$0	\$0	\$0	\$198,469
2030	\$153,800	\$0	(\$52,774)	\$74,869,268	\$0	\$0	\$0	\$268,667
2031	\$175,400	\$0	(\$56,544)	\$80,592,498	\$0	\$0	\$0	\$271,138
2032	\$194,200	\$0	(\$56,544)	\$83,268,822	\$0	\$0	\$0	\$294,697
2033	\$207,800	\$0	(\$52,774)	\$73,956,030	\$0	\$0	\$0	\$245,300
2034	\$196,800	\$0	(\$22,618)	\$26,997,098	\$0	\$0	\$0	\$65,784
2035	\$182,600	\$0	(\$11,309)	\$16,820,600	\$0	\$0	\$0	\$56,034
2036	\$167,400	\$0	(\$11,309)	\$16,642,459	\$0	\$0	\$0	\$55,620
2037	\$148,800	\$0	(\$3,770)	\$4,554,848	\$0	\$0	\$0	\$10,519
2038	\$132,400	\$0	(\$3,770)	\$983,419	\$0	\$0	\$0	\$4,256
2039	\$122,400	\$0	(\$15,078)	\$12,851,053	\$0	\$0	\$0	\$33,086
2040	\$124,800	\$0	(\$26,387)	\$29,130,525	\$0	\$0	\$0	\$84,190
2041	\$121,400	\$0	(\$18,848)	\$21,756,129	\$0	\$0	\$0	\$66,255
2042	\$110,600	\$0	(\$7,539)	\$8,231,138	\$0	\$0	\$0	\$20,360
2043	\$99,200	\$0	(\$3,770)	\$3,732,438	\$0	\$0	\$0	\$9,614
2044	\$89,200	\$0	(\$3,770)	\$6,187,055	\$0	\$0	\$0	\$28,472
2045	\$80,400	\$0	(\$3,770)	\$6,187,055	\$0	\$0	\$0	\$28,472
2046	\$70,400	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$64,200	\$0	(\$3,770)	\$4,107,966	\$0	\$0	\$0	\$9,645
2048	\$61,200	\$0	(\$7,539)	\$8,153,607	\$0	\$0	\$0	\$18,737
2049	\$58,200	\$0	(\$7,539)	\$9,008,663	\$0	\$0	\$0	\$31,735

**Table K-22 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Independent - 10 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	(\$24,560)	\$0	(\$18,848)	\$17,313,589	(\$3,395)	\$0	(\$451,377)	\$254,977
2004	(\$35,000)	\$0	(\$11,309)	\$9,381,712	\$0	\$0	\$0	\$136,282
2005	(\$33,800)	\$0	\$0	\$343,833	\$0	\$0	\$0	(\$999)
2006	(\$32,840)	\$0	\$0	\$343,833	\$0	\$0	\$0	(\$999)
2007	(\$31,860)	\$0	\$0	\$343,833	\$0	\$0	\$0	(\$999)
2008	(\$31,160)	\$0	\$0	\$343,833	\$0	\$0	\$0	(\$999)
2009	(\$30,340)	\$0	\$0	\$343,833	\$0	\$0	\$0	(\$999)
2010	(\$29,840)	\$0	\$0	\$343,833	\$0	\$0	\$0	\$42
2011	(\$29,240)	\$0	\$0	\$343,833	\$0	\$0	\$0	\$42
2012	(\$28,760)	\$0	\$0	\$343,833	\$0	\$0	\$0	\$42
2013	(\$28,440)	\$0	\$0	\$343,833	\$0	\$0	\$0	\$42
2014	(\$28,400)	\$0	(\$3,770)	\$860,222	\$0	\$0	\$0	\$4,459
2015	(\$44,800)	\$0	(\$18,848)	\$23,411,217	\$0	\$0	\$0	\$163,770
2016	(\$71,200)	\$0	(\$26,387)	\$35,976,200	\$0	\$0	\$0	\$253,707
2017	(\$87,400)	\$0	(\$18,848)	\$24,891,088	\$0	\$0	\$0	\$175,747
2018	(\$117,200)	\$0	(\$33,926)	\$47,724,349	\$0	\$0	\$0	\$337,092
2019	(\$180,800)	\$0	(\$60,314)	\$81,344,324	\$0	\$0	\$0	\$577,239
2020	(\$249,400)	\$0	(\$67,853)	\$103,249,196	\$0	\$0	\$0	\$730,426
2021	(\$278,000)	\$0	(\$41,466)	\$68,184,587	\$0	\$0	\$0	\$480,447
2022	(\$294,000)	\$0	(\$30,157)	\$46,701,157	\$0	\$0	\$0	\$329,620
2023	(\$314,000)	\$0	(\$37,696)	\$53,072,560	\$0	\$0	\$0	\$375,694
2024	(\$310,000)	\$0	(\$22,618)	\$26,602,875	\$0	\$0	\$0	\$189,853
2025	(\$288,200)	\$0	(\$15,078)	\$12,681,057	\$0	\$0	\$0	\$90,074
2026	(\$280,600)	\$0	(\$18,848)	\$19,181,885	\$0	\$0	\$0	\$137,149
2027	(\$300,000)	\$0	(\$30,157)	\$39,744,030	\$0	\$0	\$0	\$285,504
2028	(\$326,000)	\$0	(\$37,696)	\$57,265,437	\$0	\$0	\$0	\$407,005
2029	(\$346,000)	\$0	(\$37,696)	\$65,602,724	\$0	\$0	\$0	\$463,177
2030	(\$388,000)	\$0	(\$52,774)	\$92,688,108	\$0	\$0	\$0	\$658,608
2031	(\$442,000)	\$0	(\$56,544)	\$100,544,873	\$0	\$0	\$0	\$714,586
2032	(\$486,000)	\$0	(\$56,544)	\$102,944,105	\$0	\$0	\$0	\$727,365
2033	(\$522,000)	\$0	(\$52,774)	\$92,221,838	\$0	\$0	\$0	\$654,454
2034	(\$506,000)	\$0	(\$22,618)	\$34,777,896	\$0	\$0	\$0	\$249,735
2035	(\$462,000)	\$0	(\$11,309)	\$20,992,713	\$0	\$0	\$0	\$148,582
2036	(\$428,000)	\$0	(\$11,309)	\$20,751,891	\$0	\$0	\$0	\$146,653
2037	(\$384,000)	\$0	(\$3,770)	\$5,881,302	\$0	\$0	\$0	\$41,730
2038	(\$336,000)	\$0	(\$3,770)	\$1,180,040	\$0	\$0	\$0	\$8,174
2039	(\$318,000)	\$0	(\$15,078)	\$16,499,508	\$0	\$0	\$0	\$118,350
2040	(\$322,000)	\$0	(\$26,387)	\$36,925,771	\$0	\$0	\$0	\$263,602
2041	(\$314,000)	\$0	(\$18,848)	\$27,384,292	\$0	\$0	\$0	\$194,707
2042	(\$289,800)	\$0	(\$7,539)	\$10,569,439	\$0	\$0	\$0	\$75,535
2043	(\$259,800)	\$0	(\$3,770)	\$4,779,947	\$0	\$0	\$0	\$34,248
2044	(\$232,000)	\$0	(\$3,770)	\$7,385,450	\$0	\$0	\$0	\$51,809
2045	(\$208,000)	\$0	(\$3,770)	\$7,385,450	\$0	\$0	\$0	\$51,809
2046	(\$181,600)	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	(\$166,400)	\$0	(\$3,770)	\$5,274,950	\$0	\$0	\$0	\$37,265
2048	(\$159,200)	\$0	(\$7,539)	\$10,498,179	\$0	\$0	\$0	\$74,207
2049	(\$148,800)	\$0	(\$7,539)	\$11,189,626	\$0	\$0	\$0	\$79,022

**Table K-23 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Independent - RS-G-1.7 (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$1,440	\$0	(\$18,848)	\$13,418,392	(\$3,395)	\$0	(\$451,377)	\$142,936
2004	\$2,240	\$0	(\$11,309)	\$7,255,578	\$0	\$0	\$0	\$75,691
2005	\$2,360	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2006	\$2,280	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2007	\$2,260	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2008	\$2,280	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2009	\$2,260	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2010	\$2,240	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2011	\$2,240	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2012	\$2,240	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2013	\$2,240	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2014	\$2,280	\$0	(\$3,770)	\$600,554	\$0	\$0	\$0	(\$581)
2015	\$4,920	\$0	(\$18,848)	\$19,380,272	\$0	\$0	\$0	\$86,144
2016	\$8,920	\$0	(\$26,387)	\$29,461,816	\$0	\$0	\$0	\$123,749
2017	\$10,600	\$0	(\$18,848)	\$20,039,265	\$0	\$0	\$0	\$75,669
2018	\$14,600	\$0	(\$33,926)	\$39,178,995	\$0	\$0	\$0	\$167,442
2019	\$21,200	\$0	(\$60,314)	\$65,971,458	\$0	\$0	\$0	\$262,120
2020	\$31,000	\$0	(\$67,853)	\$84,066,938	\$0	\$0	\$0	\$315,696
2021	\$35,600	\$0	(\$41,466)	\$55,758,237	\$0	\$0	\$0	\$214,214
2022	\$35,600	\$0	(\$30,157)	\$37,375,753	\$0	\$0	\$0	\$120,028
2023	\$36,400	\$0	(\$37,696)	\$42,389,042	\$0	\$0	\$0	\$134,332
2024	\$34,800	\$0	(\$22,618)	\$20,717,459	\$0	\$0	\$0	\$51,169
2025	\$30,600	\$0	(\$15,078)	\$9,852,682	\$0	\$0	\$0	\$23,970
2026	\$27,800	\$0	(\$18,848)	\$14,885,463	\$0	\$0	\$0	\$36,542
2027	\$27,600	\$0	(\$30,157)	\$30,890,787	\$0	\$0	\$0	\$77,247
2028	\$30,400	\$0	(\$37,696)	\$45,583,568	\$0	\$0	\$0	\$143,438
2029	\$33,200	\$0	(\$37,696)	\$53,336,462	\$0	\$0	\$0	\$198,469
2030	\$39,600	\$0	(\$52,774)	\$74,869,268	\$0	\$0	\$0	\$268,667
2031	\$44,800	\$0	(\$56,544)	\$80,592,498	\$0	\$0	\$0	\$271,138
2032	\$50,400	\$0	(\$56,544)	\$83,268,822	\$0	\$0	\$0	\$294,697
2033	\$53,600	\$0	(\$52,774)	\$73,956,030	\$0	\$0	\$0	\$245,300
2034	\$47,600	\$0	(\$22,618)	\$26,997,098	\$0	\$0	\$0	\$65,784
2035	\$45,200	\$0	(\$11,309)	\$16,820,600	\$0	\$0	\$0	\$56,034
2036	\$40,800	\$0	(\$11,309)	\$16,642,459	\$0	\$0	\$0	\$55,620
2037	\$35,600	\$0	(\$3,770)	\$4,554,848	\$0	\$0	\$0	\$10,519
2038	\$32,800	\$0	(\$3,770)	\$983,419	\$0	\$0	\$0	\$4,256
2039	\$28,800	\$0	(\$15,078)	\$12,851,053	\$0	\$0	\$0	\$33,086
2040	\$29,600	\$0	(\$26,387)	\$29,130,525	\$0	\$0	\$0	\$84,190
2041	\$28,800	\$0	(\$18,848)	\$21,756,129	\$0	\$0	\$0	\$66,255
2042	\$25,000	\$0	(\$7,539)	\$8,231,138	\$0	\$0	\$0	\$20,360
2043	\$22,200	\$0	(\$3,770)	\$3,732,438	\$0	\$0	\$0	\$9,614
2044	\$20,400	\$0	(\$3,770)	\$6,187,055	\$0	\$0	\$0	\$28,472
2045	\$18,800	\$0	(\$3,770)	\$6,187,055	\$0	\$0	\$0	\$28,472
2046	\$16,400	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$14,800	\$0	(\$3,770)	\$4,107,966	\$0	\$0	\$0	\$9,645
2048	\$13,600	\$0	(\$7,539)	\$8,153,607	\$0	\$0	\$0	\$18,737
2049	\$13,200	\$0	(\$7,539)	\$9,008,663	\$0	\$0	\$0	\$31,735

**Table K-24 Net Incremental Benefit (Cost) Associated with Attributes for EPA/State-Regulated Disposal (Landfill) - 0.03 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,236	\$0	(\$18,848)	(\$73,792,689)	(\$3,395)	\$0	(\$451,377)	(\$1,348,379)
2004	\$21,798	\$0	(\$11,309)	(\$40,532,801)	\$0	\$0	\$0	(\$745,860)
2005	\$20,600	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2006	\$19,360	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2007	\$18,340	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2008	\$17,440	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2009	\$16,660	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2010	\$15,960	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2011	\$15,360	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2012	\$14,840	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2013	\$14,360	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2014	\$14,200	\$0	(\$3,770)	(\$3,662,425)	\$0	\$0	\$0	(\$57,614)
2015	\$25,997	\$0	(\$18,848)	(\$110,212,760)	\$0	\$0	\$0	(\$868,326)
2016	\$45,595	(\$3,000,000)	(\$26,387)	(\$166,548,785)	\$0	\$0	\$0	(\$1,342,084)
2017	\$57,796	\$0	(\$18,848)	(\$113,032,649)	\$0	\$0	\$0	(\$952,889)
2018	\$79,393	(\$3,000,000)	(\$33,926)	(\$221,381,781)	\$0	\$0	\$0	(\$1,765,758)
2019	\$123,187	(\$3,000,000)	(\$60,314)	(\$370,432,493)	\$0	\$0	\$0	(\$3,044,680)
2020	\$174,584	(\$6,000,000)	(\$67,853)	(\$476,413,898)	\$0	\$0	\$0	(\$3,882,032)
2021	\$195,990	(\$3,000,000)	(\$41,466)	(\$316,584,440)	\$0	\$0	\$0	(\$2,556,884)
2022	\$205,991	(\$3,000,000)	(\$30,157)	(\$203,730,363)	\$0	\$0	\$0	(\$1,775,903)
2023	\$219,990	(\$3,000,000)	(\$37,696)	(\$230,909,345)	\$0	\$0	\$0	(\$2,016,965)
2024	\$215,994	\$0	(\$22,618)	(\$111,286,568)	\$0	\$0	\$0	(\$1,047,434)
2025	\$199,797	\$0	(\$15,078)	(\$53,367,953)	\$0	\$0	\$0	(\$506,990)
2026	\$191,396	\$0	(\$18,848)	(\$81,613,878)	\$0	\$0	\$0	(\$769,510)
2027	\$201,992	(\$3,000,000)	(\$30,157)	(\$168,001,997)	\$0	\$0	\$0	(\$1,572,635)
2028	\$219,990	(\$3,000,000)	(\$37,696)	(\$253,776,649)	\$0	\$0	\$0	(\$2,204,502)
2029	\$233,990	(\$3,000,000)	(\$37,696)	(\$301,038,895)	\$0	\$0	\$0	(\$2,457,628)
2030	\$267,985	(\$6,000,000)	(\$52,774)	(\$423,645,204)	\$0	\$0	\$0	(\$3,506,365)
2031	\$305,983	(\$6,000,000)	(\$56,544)	(\$454,470,162)	\$0	\$0	\$0	(\$3,841,311)
2032	\$337,983	(\$6,000,000)	(\$56,544)	(\$465,170,953)	\$0	\$0	\$0	(\$3,869,190)
2033	\$361,984	(\$6,000,000)	(\$52,774)	(\$409,017,991)	\$0	\$0	\$0	(\$3,494,670)
2034	\$345,992	(\$3,000,000)	(\$22,618)	(\$146,593,443)	\$0	\$0	\$0	(\$1,375,334)
2035	\$319,996	\$0	(\$11,309)	(\$95,796,042)	\$0	\$0	\$0	(\$811,410)
2036	\$293,996	\$0	(\$11,309)	(\$94,261,732)	\$0	\$0	\$0	(\$797,075)
2037	\$261,999	\$0	(\$3,770)	(\$24,769,000)	\$0	\$0	\$0	(\$234,464)
2038	\$232,000	\$0	(\$3,770)	(\$5,746,314)	\$0	\$0	\$0	(\$45,140)
2039	\$215,997	\$0	(\$15,078)	(\$70,650,437)	\$0	\$0	\$0	(\$651,218)
2040	\$219,993	(\$3,000,000)	(\$26,387)	(\$160,753,698)	\$0	\$0	\$0	(\$1,434,603)
2041	\$213,995	\$0	(\$18,848)	(\$119,968,404)	\$0	\$0	\$0	(\$1,053,780)
2042	\$196,198	\$0	(\$7,539)	(\$44,134,092)	\$0	\$0	\$0	(\$413,940)
2043	\$176,199	\$0	(\$3,770)	(\$19,968,177)	\$0	\$0	\$0	(\$187,148)
2044	\$157,999	\$0	(\$3,770)	(\$35,919,945)	\$0	\$0	\$0	(\$265,184)
2045	\$141,999	\$0	(\$3,770)	(\$35,919,945)	\$0	\$0	\$0	(\$265,184)
2046	\$124,400	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$113,599	\$0	(\$3,770)	(\$22,049,890)	\$0	\$0	\$0	(\$207,017)
2048	\$108,798	\$0	(\$7,539)	(\$44,154,494)	\$0	\$0	\$0	(\$414,420)
2049	\$103,198	\$0	(\$7,539)	(\$51,774,275)	\$0	\$0	\$0	(\$426,393)

**Table K-25 Net Incremental Benefit (Cost) Associated with Attributes for EPA/State-Regulated Disposal (Landfill) - 0.1 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,229	\$0	(\$18,848)	(\$14,151,766)	(\$3,395)	\$0	(\$451,377)	(\$83,417)
2004	\$21,794	\$0	(\$11,309)	(\$7,800,722)	\$0	\$0	\$0	(\$53,266)
2005	\$20,599	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$26,236)
2006	\$19,359	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$26,236)
2007	\$18,339	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$26,236)
2008	\$17,439	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$26,236)
2009	\$16,659	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$26,236)
2010	\$15,959	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$25,837)
2011	\$15,359	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$25,837)
2012	\$14,839	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$25,837)
2013	\$14,359	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$25,837)
2014	\$14,199	\$0	(\$3,770)	(\$482,717)	\$0	\$0	\$0	(\$26,339)
2015	\$25,990	\$0	(\$18,848)	(\$23,629,392)	\$0	\$0	\$0	(\$103,257)
2016	\$45,584	\$0	(\$26,387)	(\$35,182,862)	\$0	\$0	\$0	(\$183,249)
2017	\$57,788	\$0	(\$18,848)	(\$23,309,568)	\$0	\$0	\$0	(\$164,729)
2018	\$79,380	\$0	(\$33,926)	(\$47,062,983)	\$0	\$0	\$0	(\$226,471)
2019	\$123,162	\$0	(\$60,314)	(\$77,247,910)	\$0	\$0	\$0	(\$461,968)
2020	\$174,554	\$0	(\$67,853)	(\$100,888,590)	\$0	\$0	\$0	(\$655,713)
2021	\$195,971	\$0	(\$41,466)	(\$67,627,427)	\$0	\$0	\$0	(\$416,605)
2022	\$205,976	\$0	(\$30,157)	(\$40,823,039)	\$0	\$0	\$0	(\$384,018)
2023	\$219,972	\$0	(\$37,696)	(\$46,142,690)	\$0	\$0	\$0	(\$438,533)
2024	\$215,984	\$0	(\$22,618)	(\$21,165,364)	\$0	\$0	\$0	(\$282,650)
2025	\$199,792	\$0	(\$15,078)	(\$10,090,514)	\$0	\$0	\$0	(\$141,690)
2026	\$191,388	\$0	(\$18,848)	(\$15,775,067)	\$0	\$0	\$0	(\$213,365)
2027	\$201,976	\$0	(\$30,157)	(\$32,462,176)	\$0	\$0	\$0	(\$426,534)
2028	\$219,970	\$0	(\$37,696)	(\$51,366,526)	\$0	\$0	\$0	(\$481,596)
2029	\$233,970	\$0	(\$37,696)	(\$63,153,664)	\$0	\$0	\$0	(\$422,482)
2030	\$267,957	\$0	(\$52,774)	(\$88,410,978)	\$0	\$0	\$0	(\$640,737)
2031	\$305,951	\$0	(\$56,544)	(\$93,741,172)	\$0	\$0	\$0	(\$762,763)
2032	\$337,952	\$0	(\$56,544)	(\$96,557,829)	\$0	\$0	\$0	(\$719,021)
2033	\$361,955	\$0	(\$52,774)	(\$83,659,322)	\$0	\$0	\$0	(\$720,361)
2034	\$345,979	\$0	(\$22,618)	(\$28,443,165)	\$0	\$0	\$0	(\$376,032)
2035	\$319,989	\$0	(\$11,309)	(\$19,791,386)	\$0	\$0	\$0	(\$162,866)
2036	\$293,989	\$0	(\$11,309)	(\$19,417,851)	\$0	\$0	\$0	(\$158,358)
2037	\$261,996	\$0	(\$3,770)	(\$4,768,605)	\$0	\$0	\$0	(\$65,480)
2038	\$231,999	\$0	(\$3,770)	(\$1,250,548)	\$0	\$0	\$0	(\$6,604)
2039	\$215,990	\$0	(\$15,078)	(\$13,748,598)	\$0	\$0	\$0	(\$169,196)
2040	\$219,979	\$0	(\$26,387)	(\$31,792,317)	\$0	\$0	\$0	(\$338,949)
2041	\$213,985	\$0	(\$18,848)	(\$23,963,999)	\$0	\$0	\$0	(\$236,966)
2042	\$196,194	\$0	(\$7,539)	(\$8,453,233)	\$0	\$0	\$0	(\$112,050)
2043	\$176,197	\$0	(\$3,770)	(\$3,784,511)	\$0	\$0	\$0	(\$50,218)
2044	\$157,997	\$0	(\$3,770)	(\$7,951,527)	\$0	\$0	\$0	(\$23,948)
2045	\$141,997	\$0	(\$3,770)	(\$7,951,527)	\$0	\$0	\$0	(\$23,948)
2046	\$124,400	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$113,596	\$0	(\$3,770)	(\$4,249,220)	\$0	\$0	\$0	(\$56,418)
2048	\$108,793	\$0	(\$7,539)	(\$8,530,045)	\$0	\$0	\$0	(\$113,019)
2049	\$103,195	\$0	(\$7,539)	(\$10,845,065)	\$0	\$0	\$0	(\$76,314)

**Table K-26 Net Incremental Benefit (Cost) Associated with Attributes for EPA/State-Regulated Disposal (Landfill) - 1 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,188	\$0	(\$18,848)	\$10,196,041	(\$3,395)	\$0	(\$451,377)	\$60,330
2004	\$21,768	\$0	(\$11,309)	\$5,605,693	\$0	\$0	\$0	\$27,713
2005	\$20,590	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2006	\$19,349	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2007	\$18,329	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2008	\$17,429	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2009	\$16,648	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2010	\$15,948	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2011	\$15,348	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2012	\$14,827	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2013	\$14,347	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2014	\$14,186	\$0	(\$3,770)	\$704,185	\$0	\$0	\$0	(\$21,343)
2015	\$25,948	\$0	(\$18,848)	\$14,031,442	\$0	\$0	\$0	(\$13,996)
2016	\$45,519	\$0	(\$26,387)	\$21,329,573	\$0	\$0	\$0	(\$50,056)
2017	\$57,734	\$0	(\$18,848)	\$14,685,257	\$0	\$0	\$0	(\$74,658)
2018	\$79,298	\$0	(\$33,926)	\$28,249,757	\$0	\$0	\$0	(\$48,958)
2019	\$123,023	\$0	(\$60,314)	\$47,735,563	\$0	\$0	\$0	(\$168,625)
2020	\$174,384	\$0	(\$67,853)	\$60,430,917	\$0	\$0	\$0	(\$285,375)
2021	\$195,858	\$0	(\$41,466)	\$40,043,951	\$0	\$0	\$0	(\$167,667)
2022	\$205,883	\$0	(\$30,157)	\$27,557,562	\$0	\$0	\$0	(\$226,453)
2023	\$219,869	\$0	(\$37,696)	\$31,280,028	\$0	\$0	\$0	(\$260,469)
2024	\$215,921	\$0	(\$22,618)	\$15,593,721	\$0	\$0	\$0	(\$197,501)
2025	\$199,756	\$0	(\$15,078)	\$7,477,842	\$0	\$0	\$0	(\$101,084)
2026	\$191,339	\$0	(\$18,848)	\$11,161,184	\$0	\$0	\$0	(\$150,512)
2027	\$201,886	\$0	(\$30,157)	\$23,030,455	\$0	\$0	\$0	(\$297,893)
2028	\$219,862	\$0	(\$37,696)	\$33,322,099	\$0	\$0	\$0	(\$288,630)
2029	\$233,862	\$0	(\$37,696)	\$38,458,390	\$0	\$0	\$0	(\$192,053)
2030	\$267,800	\$0	(\$52,774)	\$54,026,834	\$0	\$0	\$0	(\$317,955)
2031	\$305,772	\$0	(\$56,544)	\$58,382,683	\$0	\$0	\$0	(\$418,052)
2032	\$337,778	\$0	(\$56,544)	\$60,276,909	\$0	\$0	\$0	(\$361,832)
2033	\$361,790	\$0	(\$52,774)	\$53,919,204	\$0	\$0	\$0	(\$404,564)
2034	\$345,899	\$0	(\$22,618)	\$20,073,968	\$0	\$0	\$0	(\$262,852)
2035	\$319,946	\$0	(\$11,309)	\$12,144,670	\$0	\$0	\$0	(\$90,924)
2036	\$293,950	\$0	(\$11,309)	\$12,044,746	\$0	\$0	\$0	(\$87,495)
2037	\$261,980	\$0	(\$3,770)	\$3,418,544	\$0	\$0	\$0	(\$46,335)
2038	\$231,993	\$0	(\$3,770)	\$713,046	\$0	\$0	\$0	(\$2,047)
2039	\$215,950	\$0	(\$15,078)	\$9,522,377	\$0	\$0	\$0	(\$116,076)
2040	\$219,904	\$0	(\$26,387)	\$21,385,944	\$0	\$0	\$0	(\$218,816)
2041	\$213,932	\$0	(\$18,848)	\$15,911,160	\$0	\$0	\$0	(\$146,779)
2042	\$196,168	\$0	(\$7,539)	\$6,125,910	\$0	\$0	\$0	(\$78,454)
2043	\$176,184	\$0	(\$3,770)	\$2,777,188	\$0	\$0	\$0	(\$35,324)
2044	\$157,985	\$0	(\$3,770)	\$4,351,403	\$0	\$0	\$0	\$3,632
2045	\$141,985	\$0	(\$3,770)	\$4,351,403	\$0	\$0	\$0	\$3,632
2046	\$124,397	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$113,585	\$0	(\$3,770)	\$3,059,277	\$0	\$0	\$0	(\$39,412)
2048	\$108,769	\$0	(\$7,539)	\$6,066,406	\$0	\$0	\$0	(\$79,193)
2049	\$103,172	\$0	(\$7,539)	\$6,464,498	\$0	\$0	\$0	(\$37,645)

**Table K-27 Net Incremental Benefit (Cost) Associated with Attributes for EPA/State-Regulated Disposal (Landfill) - 10 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,032	\$0	(\$18,848)	\$10,947,420	(\$3,395)	\$0	(\$451,377)	\$72,939
2004	\$21,643	\$0	(\$11,309)	\$6,186,051	\$0	\$0	\$0	\$37,452
2005	\$20,497	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$14,872)
2006	\$19,252	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$14,872)
2007	\$18,227	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$14,872)
2008	\$17,323	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$14,872)
2009	\$16,539	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$14,872)
2010	\$15,835	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$20,162)
2011	\$15,233	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$20,162)
2012	\$14,710	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$20,162)
2013	\$14,228	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$20,162)
2014	\$14,063	\$0	(\$3,770)	\$1,082,335	\$0	\$0	\$0	(\$18,174)
2015	\$25,750	\$0	(\$18,848)	\$15,056,026	\$0	\$0	\$0	(\$6,949)
2016	\$45,274	\$0	(\$26,387)	\$22,662,750	\$0	\$0	\$0	(\$40,886)
2017	\$57,522	\$0	(\$18,848)	\$15,670,225	\$0	\$0	\$0	(\$67,883)
2018	\$79,014	\$0	(\$33,926)	\$29,901,486	\$0	\$0	\$0	(\$37,597)
2019	\$122,602	\$0	(\$60,314)	\$50,164,318	\$0	\$0	\$0	(\$151,919)
2020	\$173,900	\$0	(\$67,853)	\$63,497,935	\$0	\$0	\$0	(\$264,826)
2021	\$195,506	\$0	(\$41,466)	\$42,171,597	\$0	\$0	\$0	(\$153,412)
2022	\$205,584	\$0	(\$30,157)	\$28,946,326	\$0	\$0	\$0	(\$217,148)
2023	\$219,546	\$0	(\$37,696)	\$32,822,650	\$0	\$0	\$0	(\$250,133)
2024	\$215,704	\$0	(\$22,618)	\$16,411,646	\$0	\$0	\$0	(\$192,021)
2025	\$199,603	\$0	(\$15,078)	\$7,982,041	\$0	\$0	\$0	(\$97,719)
2026	\$191,150	\$0	(\$18,848)	\$11,792,948	\$0	\$0	\$0	(\$146,296)
2027	\$201,608	\$0	(\$30,157)	\$24,093,204	\$0	\$0	\$0	(\$290,801)
2028	\$219,542	\$0	(\$37,696)	\$34,919,551	\$0	\$0	\$0	(\$277,969)
2029	\$233,534	\$0	(\$37,696)	\$40,410,416	\$0	\$0	\$0	(\$179,025)
2030	\$267,366	\$0	(\$52,774)	\$56,618,999	\$0	\$0	\$0	(\$300,652)
2031	\$305,304	\$0	(\$56,544)	\$61,112,951	\$0	\$0	\$0	(\$399,827)
2032	\$337,316	\$0	(\$56,544)	\$63,061,762	\$0	\$0	\$0	(\$343,242)
2033	\$361,352	\$0	(\$52,774)	\$56,283,908	\$0	\$0	\$0	(\$388,779)
2034	\$345,678	\$0	(\$22,618)	\$20,877,457	\$0	\$0	\$0	(\$257,489)
2035	\$319,811	\$0	(\$11,309)	\$12,728,683	\$0	\$0	\$0	(\$87,025)
2036	\$293,817	\$0	(\$11,309)	\$12,620,983	\$0	\$0	\$0	(\$83,648)
2037	\$261,906	\$0	(\$3,770)	\$3,582,327	\$0	\$0	\$0	(\$45,242)
2038	\$231,947	\$0	(\$3,770)	\$780,242	\$0	\$0	\$0	(\$1,598)
2039	\$215,833	\$0	(\$15,078)	\$9,920,166	\$0	\$0	\$0	(\$113,421)
2040	\$219,702	\$0	(\$26,387)	\$22,266,518	\$0	\$0	\$0	(\$212,938)
2041	\$213,782	\$0	(\$18,848)	\$16,571,919	\$0	\$0	\$0	(\$142,368)
2042	\$196,094	\$0	(\$7,539)	\$6,352,559	\$0	\$0	\$0	(\$76,941)
2043	\$176,139	\$0	(\$3,770)	\$2,878,845	\$0	\$0	\$0	(\$34,645)
2044	\$157,940	\$0	(\$3,770)	\$4,583,305	\$0	\$0	\$0	\$5,180
2045	\$141,942	\$0	(\$3,770)	\$4,583,305	\$0	\$0	\$0	\$5,180
2046	\$124,379	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$113,545	\$0	(\$3,770)	\$3,174,033	\$0	\$0	\$0	(\$38,646)
2048	\$108,708	\$0	(\$7,539)	\$6,299,100	\$0	\$0	\$0	(\$77,640)
2049	\$103,117	\$0	(\$7,539)	\$6,781,883	\$0	\$0	\$0	(\$35,526)

**Table K-28 Net Incremental Benefit (Cost) Associated with Attributes for EPA/State-Regulated Disposal (Landfill) - RS-G-1.7**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,136	\$0	(\$18,848)	\$10,196,041	(\$3,395)	\$0	(\$451,377)	\$60,330
2004	\$21,737	\$0	(\$11,309)	\$5,605,693	\$0	\$0	\$0	\$27,713
2005	\$20,579	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2006	\$19,339	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2007	\$18,318	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2008	\$17,417	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2009	\$16,636	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2010	\$15,936	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2011	\$15,335	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2012	\$14,815	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2013	\$14,334	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2014	\$14,173	\$0	(\$3,770)	\$704,185	\$0	\$0	\$0	(\$21,343)
2015	\$25,896	\$0	(\$18,848)	\$14,031,442	\$0	\$0	\$0	(\$13,996)
2016	\$45,439	\$0	(\$26,387)	\$21,329,573	\$0	\$0	\$0	(\$50,056)
2017	\$57,668	\$0	(\$18,848)	\$14,685,257	\$0	\$0	\$0	(\$74,658)
2018	\$79,197	\$0	(\$33,926)	\$28,249,757	\$0	\$0	\$0	(\$48,958)
2019	\$122,845	\$0	(\$60,314)	\$47,735,563	\$0	\$0	\$0	(\$168,625)
2020	\$174,168	\$0	(\$67,853)	\$60,430,917	\$0	\$0	\$0	(\$285,375)
2021	\$195,716	\$0	(\$41,466)	\$40,043,951	\$0	\$0	\$0	(\$167,667)
2022	\$205,765	\$0	(\$30,157)	\$27,557,562	\$0	\$0	\$0	(\$226,453)
2023	\$219,737	\$0	(\$37,696)	\$31,280,028	\$0	\$0	\$0	(\$260,469)
2024	\$215,842	\$0	(\$22,618)	\$15,593,721	\$0	\$0	\$0	(\$197,501)
2025	\$199,712	\$0	(\$15,078)	\$7,477,842	\$0	\$0	\$0	(\$101,084)
2026	\$191,278	\$0	(\$18,848)	\$11,161,184	\$0	\$0	\$0	(\$150,512)
2027	\$201,772	\$0	(\$30,157)	\$23,030,455	\$0	\$0	\$0	(\$297,893)
2028	\$219,724	\$0	(\$37,696)	\$33,322,099	\$0	\$0	\$0	(\$288,630)
2029	\$233,724	\$0	(\$37,696)	\$38,458,390	\$0	\$0	\$0	(\$192,053)
2030	\$267,600	\$0	(\$52,774)	\$54,026,834	\$0	\$0	\$0	(\$317,955)
2031	\$305,544	\$0	(\$56,544)	\$58,382,683	\$0	\$0	\$0	(\$418,052)
2032	\$337,556	\$0	(\$56,544)	\$60,276,909	\$0	\$0	\$0	(\$361,832)
2033	\$361,580	\$0	(\$52,774)	\$53,919,204	\$0	\$0	\$0	(\$404,564)
2034	\$345,798	\$0	(\$22,618)	\$20,073,968	\$0	\$0	\$0	(\$262,852)
2035	\$319,892	\$0	(\$11,309)	\$12,144,670	\$0	\$0	\$0	(\$90,924)
2036	\$293,899	\$0	(\$11,309)	\$12,044,746	\$0	\$0	\$0	(\$87,495)
2037	\$261,960	\$0	(\$3,770)	\$3,418,544	\$0	\$0	\$0	(\$46,335)
2038	\$231,986	\$0	(\$3,770)	\$713,046	\$0	\$0	\$0	(\$2,047)
2039	\$215,901	\$0	(\$15,078)	\$9,522,377	\$0	\$0	\$0	(\$116,076)
2040	\$219,809	\$0	(\$26,387)	\$21,385,944	\$0	\$0	\$0	(\$218,816)
2041	\$213,864	\$0	(\$18,848)	\$15,911,160	\$0	\$0	\$0	(\$146,779)
2042	\$196,136	\$0	(\$7,539)	\$6,125,910	\$0	\$0	\$0	(\$78,454)
2043	\$176,168	\$0	(\$3,770)	\$2,777,188	\$0	\$0	\$0	(\$35,324)
2044	\$157,970	\$0	(\$3,770)	\$4,351,403	\$0	\$0	\$0	\$3,632
2045	\$141,971	\$0	(\$3,770)	\$4,351,403	\$0	\$0	\$0	\$3,632
2046	\$124,395	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$113,569	\$0	(\$3,770)	\$3,059,277	\$0	\$0	\$0	(\$39,412)
2048	\$108,738	\$0	(\$7,539)	\$6,066,406	\$0	\$0	\$0	(\$79,193)
2049	\$103,144	\$0	(\$7,539)	\$6,464,498	\$0	\$0	\$0	(\$37,645)

**Table K-29 Net Incremental Benefit (Cost) Associated with Attributes for LLW Disposal/Prohibition (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,240	\$0	\$0	(\$73,920,446)	(\$3,395)	\$0	(\$451,377)	(\$1,351,186)
2004	\$21,800	\$0	\$0	(\$40,658,693)	\$0	\$0	\$0	(\$748,626)
2005	\$20,600	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$48,797)
2006	\$19,360	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$48,797)
2007	\$18,340	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$48,797)
2008	\$17,440	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$48,797)
2009	\$16,660	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$48,797)
2010	\$15,960	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$37,104)
2011	\$15,360	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$37,104)
2012	\$14,840	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$37,104)
2013	\$14,360	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$37,104)
2014	\$14,200	\$0	\$0	(\$3,786,318)	\$0	\$0	\$0	(\$58,973)
2015	\$26,000	\$0	\$0	(\$110,336,652)	\$0	\$0	\$0	(\$869,442)
2016	\$45,600	(\$3,000,000)	\$0	(\$166,672,604)	\$0	\$0	\$0	(\$1,343,199)
2017	\$57,800	\$0	\$0	(\$113,153,026)	\$0	\$0	\$0	(\$953,974)
2018	\$79,400	(\$3,000,000)	\$0	(\$221,499,649)	\$0	\$0	\$0	(\$1,766,820)
2019	\$123,200	(\$3,000,000)	\$0	(\$370,548,333)	\$0	\$0	\$0	(\$3,045,724)
2020	\$174,600	(\$6,000,000)	\$0	(\$476,523,809)	\$0	\$0	\$0	(\$3,882,996)
2021	\$196,000	(\$3,000,000)	\$0	(\$316,685,220)	\$0	\$0	\$0	(\$2,557,769)
2022	\$206,000	(\$3,000,000)	\$0	(\$203,821,677)	\$0	\$0	\$0	(\$1,776,704)
2023	\$220,000	(\$3,000,000)	\$0	(\$230,998,348)	\$0	\$0	\$0	(\$2,017,746)
2024	\$216,000	\$0	\$0	(\$111,368,638)	\$0	\$0	\$0	(\$1,048,154)
2025	\$199,800	\$0	\$0	(\$53,446,760)	\$0	\$0	\$0	(\$507,678)
2026	\$191,400	\$0	\$0	(\$81,690,258)	\$0	\$0	\$0	(\$770,178)
2027	\$202,000	(\$3,000,000)	\$0	(\$168,078,021)	\$0	\$0	\$0	(\$1,573,300)
2028	\$220,000	(\$3,000,000)	\$0	(\$253,848,686)	\$0	\$0	\$0	(\$2,205,131)
2029	\$234,000	(\$3,000,000)	\$0	(\$301,106,048)	\$0	\$0	\$0	(\$2,458,214)
2030	\$268,000	(\$6,000,000)	\$0	(\$423,707,002)	\$0	\$0	\$0	(\$3,506,905)
2031	\$306,000	(\$6,000,000)	\$0	(\$454,526,287)	\$0	\$0	\$0	(\$3,841,802)
2032	\$338,000	(\$6,000,000)	\$0	(\$465,214,749)	\$0	\$0	\$0	(\$3,869,573)
2033	\$362,000	(\$6,000,000)	\$0	(\$409,053,868)	\$0	\$0	\$0	(\$3,494,984)
2034	\$346,000	(\$3,000,000)	\$0	(\$146,617,553)	\$0	\$0	\$0	(\$1,375,545)
2035	\$320,000	\$0	\$0	(\$95,813,268)	\$0	\$0	\$0	(\$811,560)
2036	\$294,000	\$0	\$0	(\$94,277,422)	\$0	\$0	\$0	(\$797,212)
2037	\$262,000	\$0	\$0	(\$24,782,108)	\$0	\$0	\$0	(\$234,579)
2038	\$232,000	\$0	\$0	(\$5,758,210)	\$0	\$0	\$0	(\$45,244)
2039	\$216,000	\$0	\$0	(\$70,662,333)	\$0	\$0	\$0	(\$651,322)
2040	\$220,000	(\$3,000,000)	\$0	(\$160,765,424)	\$0	\$0	\$0	(\$1,434,706)
2041	\$214,000	\$0	\$0	(\$119,976,438)	\$0	\$0	\$0	(\$1,053,851)
2042	\$196,200	\$0	\$0	(\$44,137,625)	\$0	\$0	\$0	(\$413,971)
2043	\$176,200	\$0	\$0	(\$19,970,375)	\$0	\$0	\$0	(\$187,167)
2044	\$158,000	\$0	\$0	(\$35,920,975)	\$0	\$0	\$0	(\$265,193)
2045	\$142,000	\$0	\$0	(\$35,920,975)	\$0	\$0	\$0	(\$265,193)
2046	\$124,400	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$113,600	\$0	\$0	(\$22,051,134)	\$0	\$0	\$0	(\$207,028)
2048	\$108,800	\$0	\$0	(\$44,157,004)	\$0	\$0	\$0	(\$414,442)
2049	\$103,200	\$0	\$0	(\$51,776,404)	\$0	\$0	\$0	(\$426,412)

**Table K-30 Net Incremental Benefit (Cost) Associated with Attributes for Limited Dispositions Alternative (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,018	\$0	(\$18,848)	\$14,197,311	(\$3,395)	\$0	(\$451,377)	\$9,867
2004	\$21,561	\$0	(\$11,309)	\$7,782,076	\$0	\$0	\$0	\$197
2005	\$20,420	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2006	\$19,197	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2007	\$18,192	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2008	\$17,305	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2009	\$16,536	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2010	\$15,845	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2011	\$15,254	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2012	\$14,742	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2013	\$14,268	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2014	\$14,109	\$0	(\$3,770)	\$849,614	\$0	\$0	\$0	(\$22,412)
2015	\$25,692	\$0	(\$18,848)	\$20,294,026	\$0	\$0	\$0	(\$51,928)
2016	\$45,061	\$0	(\$26,387)	\$30,757,208	\$0	\$0	\$0	(\$106,862)
2017	\$57,250	\$0	(\$18,848)	\$21,009,910	\$0	\$0	\$0	(\$112,490)
2018	\$78,422	\$0	(\$33,926)	\$40,815,886	\$0	\$0	\$0	(\$124,802)
2019	\$121,496	\$0	(\$60,314)	\$68,608,128	\$0	\$0	\$0	(\$294,188)
2020	\$172,373	\$0	(\$67,853)	\$87,381,423	\$0	\$0	\$0	(\$434,816)
2021	\$193,702	\$0	(\$41,466)	\$57,994,670	\$0	\$0	\$0	(\$267,221)
2022	\$203,688	\$0	(\$30,157)	\$38,925,140	\$0	\$0	\$0	(\$289,311)
2023	\$217,635	\$0	(\$37,696)	\$44,177,926	\$0	\$0	\$0	(\$331,556)
2024	\$213,780	\$0	(\$22,618)	\$21,717,759	\$0	\$0	\$0	(\$230,606)
2025	\$197,731	\$0	(\$15,078)	\$10,393,612	\$0	\$0	\$0	(\$115,989)
2026	\$189,368	\$0	(\$18,848)	\$15,610,281	\$0	\$0	\$0	(\$173,396)
2027	\$199,810	\$0	(\$30,157)	\$32,237,495	\$0	\$0	\$0	(\$345,142)
2028	\$217,742	\$0	(\$37,696)	\$47,458,259	\$0	\$0	\$0	(\$362,202)
2029	\$231,732	\$0	(\$37,696)	\$55,452,885	\$0	\$0	\$0	(\$281,346)
2030	\$265,320	\$0	(\$52,774)	\$77,845,672	\$0	\$0	\$0	(\$440,936)
2031	\$302,587	\$0	(\$56,544)	\$83,836,251	\$0	\$0	\$0	(\$548,861)
2032	\$334,024	\$0	(\$56,544)	\$86,511,515	\$0	\$0	\$0	(\$496,572)
2033	\$357,912	\$0	(\$52,774)	\$76,840,506	\$0	\$0	\$0	(\$522,109)
2034	\$342,330	\$0	(\$22,618)	\$28,115,088	\$0	\$0	\$0	(\$303,341)
2035	\$316,753	\$0	(\$11,309)	\$17,495,562	\$0	\$0	\$0	(\$118,441)
2036	\$291,053	\$0	(\$11,309)	\$17,314,591	\$0	\$0	\$0	(\$114,640)
2037	\$259,388	\$0	(\$3,770)	\$4,767,711	\$0	\$0	\$0	(\$53,191)
2038	\$229,664	\$0	(\$3,770)	\$1,039,773	\$0	\$0	\$0	(\$3,727)
2039	\$213,803	\$0	(\$15,078)	\$13,394,872	\$0	\$0	\$0	(\$135,806)
2040	\$217,751	\$0	(\$26,387)	\$30,288,586	\$0	\$0	\$0	(\$264,217)
2041	\$211,768	\$0	(\$18,848)	\$22,595,140	\$0	\$0	\$0	(\$180,834)
2042	\$194,122	\$0	(\$7,539)	\$8,546,877	\$0	\$0	\$0	(\$90,711)
2043	\$174,291	\$0	(\$3,770)	\$3,869,445	\$0	\$0	\$0	(\$40,888)
2044	\$156,223	\$0	(\$3,770)	\$6,409,222	\$0	\$0	\$0	(\$7,249)
2045	\$140,340	\$0	(\$3,770)	\$6,409,222	\$0	\$0	\$0	(\$7,249)
2046	\$122,899	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$112,196	\$0	(\$3,770)	\$4,273,399	\$0	\$0	\$0	(\$45,512)
2048	\$107,476	\$0	(\$7,539)	\$8,492,696	\$0	\$0	\$0	(\$91,404)
2049	\$101,981	\$0	(\$7,539)	\$9,366,489	\$0	\$0	\$0	(\$52,720)

**Attachment 1 to Appendix K**

**Distribution of “MARSSIM” Survey Unit Classes  
Associated with  
Controlling the Disposition of Solid Materials**

In assessing the conduct of release surveys, there is a need to determine how materials might be distributed among the three survey classes of “MARSSIM.” The survey classification system includes Class 1, 2, and 3. Under Class 1, contamination levels are expected to be above the release criteria over some portion of the material. For Class 2, materials are expected to have contamination levels near but not exceed the release criteria anywhere on the material. Under Class 3, the material are expected to have contamination levels well below release criteria anywhere on the material. Also, the determination of the appropriate classification is fundamentally premised on the specific value of the release criterion for a given radionuclide. That is, it appears reasonable to expect that 70 percent of some material coming from an area within a reactor building to be Class 3 if the release criterion were 10 mrem/yr; however, it is unlikely that a Class 3 designation would be 70 percent if the release criterion were 0.1 mrem/yr instead. This connection of a release criterion to classification distributions is an important consideration which can only be addressed with facility and material specific information. NUREG-1761 on survey methodology for solid materials and the ORISE report on survey costs provide further discussions on these topics (NRC 2004, ORISE 2004).

The types of contaminants and contamination levels are expected to reflect the operational history of such materials in impacted areas, i.e., radiologically controlled areas. For example, steel reinforcement bars used in structures are expected to be mostly free of contamination given that they were encapsulated in concrete during the operating life of a plant, excluding neutron activated materials (i.e., rebars and concrete in bioshields). On the other hand, some process systems may be both externally and internally contaminated. Internal contamination may be associated with process fluids that contained radioactivity, while external contamination may be due to spills and leaks from nearby components. Another consideration addresses how materials were processed and removed out of controlled areas. For example, if precautions were taken in the handling and removal process, external surface contamination levels might be kept to levels that may not warrant a Class 1 designation. Accordingly, such considerations would be addressed as part of an initial assessment, including the use of current operational survey results and by conduct scoping and characterization surveys to supplement that information.

Given the objective of the GEIS, the assignment of survey unit classification focuses on the major types of materials. This discussion does not consider materials that would be shipped as low-level radioactive waste. It is assumed that the provisions of a release rule would only apply to materials considered to be relatively free of both internal and external surface or volumetric contamination, with levels that straddle release criteria. In other words, the provisions of the release rule is not expected to change the practice in identifying and segregating materials with contamination levels that warrant disposal as low-level radioactive waste. Moreover, it is assumed that if decontamination were considered as a precursor to releasing materials, the initial contamination levels would be such that release criteria could be readily achieved given the selection of a proper decontamination method. This recognizes that if contamination levels were too high or the decontamination factor were too low, it would be a futile exercise to spend any time and resources on decontamination. Finally, these considerations are assumed to apply as well to the reuse of equipment and tools in their original form or intended applications.

1 The discussions that follow address metals, concrete, trash, and equipment reuse with results  
2 summarized in Table 1.

3  
4 **1. Metals**

5  
6 Metals include ferrous and non-ferrous metals, such as aluminum and copper. In the context of  
7 the release rule, metals can be grouped into three categories by origins, (i) metals that were  
8 completely encapsulated, (ii) metals that were contained in enclosures or isolated with some  
9 degree of protection, and (iii) metals that were exposed to ambient conditions or were part of  
10 some systems or components. The best example of metals that were completely encapsulated is  
11 structural rebars used in concrete structures. Such metals are expected to be essentially all Class  
12 3. Metals that were contained in enclosures or isolated with some degree of protection may be  
13 found in utility chases, pipe penetrations, overhead spaces, or contained in electrical panels or  
14 conduits. This category also includes some structural steel and pipe hangers. Most of this  
15 material is expected to be Class 2. Metals that were exposed to ambient conditions are assumed  
16 to be characterized by contamination levels that would be at or above release criteria. Such  
17 metals would originate from radiologically controlled areas, be part of systems and components,  
18 pipe hangers, and include some structural steel. Most of this type of metal would be Class 1.

19  
20 A review of material inventories compiled in the SC&A report (SC&A 2003) indicates that  
21 rebars from a BWR plant comprise about 60 to 85 percent of the metals inventory that is  
22 potentially releasable, also assumed to be representative of PWRs as well. The balance consists  
23 of structural steel, pipe hangers, and other miscellaneous ferrous metals. A Class 3 designation  
24 is assigned to the inventory of rebars, assuming that 70 percent of metals are rebars. For the  
25 balance, it is assumed that 20 percent is Class 2 and 10 percent is Class 1, given the discussion  
26 above on the grouping of metals by origins. Finally, metals that would be subject to  
27 decontamination are assumed to have an equal distribution among Class 1, 2, and 3, lacking  
28 specific information.

29  
30 **2. Concrete**

31  
32 Essentially all of the concrete present in facilities is associated with structures and building  
33 foundations. However, some concrete is used as equipment pedestals and perimeter curbing  
34 around floor and equipment drains. Accordingly, contamination profiles of concrete are  
35 expected to be primarily surficial in nature for most areas, and volumetric in areas where the  
36 contamination is associated with liquid spills and leaks from components. In addition, some  
37 volumetric contamination is expected around embedded piping servicing floor and equipment  
38 drains, and at wall-to-floor joints and floor-to-floor joints. Generally, the decontamination of  
39 concrete is undertaken when the contamination is present within the near surface (few inches)  
40 and its distribution is well known. For areas where contamination levels are present at depths or  
41 is due to neutron activation, the practice is to remove the entire layer and dispose of it as low-  
42 level waste. The methods rely on aggressive techniques, e.g., scabblers or jack hammers, with the  
43 removal of a layer that overshoots the original depth of the contamination. This approach is used  
44 to remove the contamination on the first pass, as it is costly to repeat such procedures in serial  
45 steps involving more decontamination and surveys. Given such aggressive methods, it is  
46 expected that most of the contamination would be removed, thereby, leaving exposed concrete  
47 surfaces that would most likely be below cleanup criteria.

1 A review of the material inventories presented in the SC&A report (SC&A 2003) indicates that  
2 nearly all concrete from BWR and BWR plants are expected to be below or near release criteria.  
3 The balance is expected to come from areas that were decontaminated and, as a result, would  
4 reflect a classification initially assigned to the area before decontamination. Lacking specific  
5 information, a Class 3 designation is assigned to 80 percent of the total inventory of releasable  
6 concrete. For the balance, it is assumed that 10 percent is Class 2 and 10 percent is Class 1.  
7

### 8 **3. Trash**

9  
10 Trash is expected to be generated routinely out of radiologically controlled areas. Various types  
11 of materials fall in the designation of trash. Trash generally consists of paper, wood, plastic,  
12 glass, cloth, filters, rubber, cardboard, small metallic objects, among others. Other types of  
13 materials may be included in trash when quantities are too small and do not warrant segregation  
14 for disposal via other means. Such additional materials may include concrete rubble, bricks,  
15 asphalt, metal scraps, and discarded tools and equipment. Given that trash is being generated  
16 frequently, licensees are routinely surveying and segregating trash, with some items being  
17 disposed of as LLW depending on radioactivity levels. For expediency and cost considerations,  
18 this segregation process tends to err on the side of safety by labeling some items as being  
19 contaminated while more detailed surveys might reveal otherwise. As a result, this process tends  
20 to generate trash that might have a greater number of items with Class 2 and 3 distributions than  
21 Class 1.  
22

23 Trash can be grouped into three categories by origins, (i) items that have introduced in a  
24 radiologically controlled area with little potential of being contaminated, (ii) items that have  
25 been introduced in a radiologically controlled area and have become contaminated at levels at or  
26 above release criteria, and (iii) items that have been in a radiologically controlled area and have  
27 become contaminated at significant levels. In illustrating the first example, a pallet used to  
28 deliver some equipment would fall in this category. The pallet might be protected with some  
29 covering. Once the equipment is removed, the pallet would be taken out of the controlled area as  
30 part of that same operation. In the second category, the pallet might become contaminated and  
31 contamination levels would dictate whether it can be released or should be disposed of as  
32 radioactive waste, assuming that decontamination is not feasible. For the third category, an  
33 example might include the use of a disposable covering (e.g., plastic sheeting) to protect some  
34 equipment during some maintenance evolution. Once the work is completed, the covering  
35 would be removed and surveyed to determine whether it can be released or needs to be disposed  
36 of as radioactive waste, assuming that decontamination is not feasible. Given the relative  
37 protection afforded by plastic wrappings or any other forms of encapsulation methods, it cannot  
38 be assumed that this level of protection would be totally effective against contamination, as a  
39 result a lesser survey classification than Class 1 could not be justified. Given the variability of  
40 the radiological properties of trash that might be potentially released, trash is assumed to have an  
41 equal distribution among Class 1, 2, and 3 considering the potential heterogeneous distributions  
42 of contaminants.  
43

### 44 **4. Equipment, Tools, and Vehicles**

45  
46 As with materials described above, it is known that different types of equipment and tools are  
47 used in radiologically controlled areas and later taken out. The types of equipment that could be  
48 potentially released from nuclear facilities for reuse in an environment free of radiological  
49 controls ranges from small items, such as hand tools, to very large ones, such as mechanized

1 equipment and industrial vehicles. The following are examples of potentially reusable  
2 equipment, tools, and miscellaneous items:

- 3
- 4 • small hand tools (wrenches, screw drivers, etc.) and power tools (drills, saws,  
5 etc.)
- 6 • electrical equipment, such as control panels, motors, pumps, and generators
- 7 • office furniture (desks, chairs, filing cabinets, etc.) and office equipment (copiers,  
8 computers, printers, fax machines, etc.)
- 9 • construction equipment, such as scaffolding, noise or dust-control barriers,  
10 wheelbarrows, etc.
- 11 • mechanized equipment, such as backhoes, bulldozers, cranes, drill rigs, etc.
- 12
- 13 • vehicles, such as dump trucks, flat-bed trucks, pickup trucks, vans, etc.
- 14
- 15 • materials and supplies for use in their original forms, but taken out as excess,  
16 such as piping, tubing, electrical wiring, floor covering, ductwork, sheet metal,  
17 pipe hangers, light fixtures, wall board, and sheet glass.
- 18

19 It should be noted that these examples are assumed to characterize the profile of equipment,  
20 tools, and miscellaneous items that may be released by various types of licensees.

21

22 It is recognized that the release of equipment is an extremely dynamic process involving  
23 different types of facilities and activities, such as routine operations, research and development,  
24 major and minor power plant outages, refurbishment, decommissioning, etc. In addition, this  
25 process is taking place simultaneously at thousands of facilities across the nation and conducted  
26 every hour of the day and every day of the week. As a result, it is not readily possible to define  
27 what types of objects and how many are routinely used in radiologically controlled areas, and  
28 what fraction is surveyed and released for reuse *versus* those that are discarded as LLW.

29

30 In practice, equipment and tools are surveyed before being taken out of radiologically controlled  
31 areas. The survey consists of conducting a scan with a portable radiation survey meter and  
32 taking wipes to assess the presence of removable surface activity. The presence of radioactivity  
33 on wipes is evaluated using separate instrumentation. Some survey methods involve the  
34 introduction of the item into an instrument (e.g., gamma tool monitor) that measures  
35 radioactivity *in toto* from all external and internal surfaces. Depending on the results of surveys,  
36 the items are either cleaned to meet release criteria, not taken out of the controlled area and set  
37 aside for later use in any controlled area, or simply discarded as LLW.

38

39 Given that equipment, tools, and vehicles have a productive life cycle, it is assumed that the  
40 impetus will be keep on using equipment to their maximum useful lives. The productive cycle  
41 of equipment is driven by operational conditions and economic considerations, taking into  
42 account replacement costs *vs.* cost of repairs, amortization rates, and cost of money. These  
43 factors are expected to be different among facilities. Accordingly, it is expected that licensees  
44 will take all appropriate measures to protect equipment, tools, vehicles, etc.

45

46 Together, these practices are expected to mitigate the presence of residual radioactivity on  
47 potentially releasable equipment and should result in residual levels that are below release

criteria for most items. As a result, it is expected that most of the equipment will be Class 2 and 3, with a smaller fraction being Class 1. Given the paucity of information and potential for heterogeneous distributions of contaminants, it is assumed that 50 percent of the potentially release equipment is Class 3, 30 percent is Class 2, and 20 percent is Class 1.

Table 1 Assignment of Survey Classification to Potentially Releasable Materials and Equipment

Material	Percent of Material		
	Class 1	Class 2	Class 3
Metals - no decon	10	20	70
Metals - with decon	33	33	33
Concrete	10	10	80
Trash	33	33	33
Equipment, tools, vehicles, etc.	20	30	50

**Note:** The assumed distributions of survey classifications for concrete and steel do not consider the presence of neutron activation products. The presence of radionuclides associated with neutron activation is too complex of an issue to be addressed generically and should be dealt with on a case-by-case basis.

**References**

ORISE 2004 Oak Ridge Institute for Science and Education, "Clearance Survey Costs - Technical Bases for Developing Survey Costs," Oak Ridge, TN, prepared for the NRC under contract, draft report, February 2004.

SC&A 2003 S. Cohen & Associates, Inc., Collective Doses Associated with Clearance of Material from NRC/Agreement State-Licensed Facilities, 2<sup>nd</sup> draft, Dec. 2003, McLean, VA.

NRC 2004 U.S. Nuclear Regulatory Commission, Radiological Surveys for Controlling Release of Solid Materials, NUREG-1761, Washington, DC, June 2004.

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**Attachment 2 to Appendix K**

**Description of Industry Operation Attribute**

This attachment provides a detailed description of how the benefits and costs were calculated for one of the attributes - Industry Operation - which is by far the most significant of the cost-benefit attributes shown in Tables 4-3 and K-14. The Industry Operation attribute includes four sub-attributes, but two in particular -- transportation and disposal -- are the significant drivers in the analysis. The information provided here is intended to help the reader understand how the cost-benefit analysis is performed and also to provide the values of the assumed parameters necessary to duplicate the Industry Operation portion of the analysis in the year 2020 for three Alternatives compared to No Action. (The sample year 2020 was chosen because it is a year with a higher volume of potentially clearable solid material.) This will be helpful in understanding the extent to which transportation and disposal activities influence the overall analysis.

**1. Description of the Model's Calculations**

The cost-benefit model is based on a set of linked calculations (via spreadsheets). The spreadsheets contain information on potentially clearable solid materials (steel, concrete and trash in units of tons) for each of the Alternatives and for each dose option. The spreadsheets also contain parameters used to model costs, for example truck transportation in units of \$/ton-mile and concrete rubble surveys in units of \$/ton.

The cost-benefit model considered inventories of potentially clearable solid materials that may accumulate during the dismantlement of commercial nuclear power reactors. The dismantlement of these facilities is the major source of potentially clearable materials. The inventories are developed as a function of time based on the scheduled shutdown dates of the existing nuclear power plants. Dismantlement of a facility is assumed to be completed in 7 years, with 5 years for post-shutdown activities and 2 years for dismantlement.

Table K-31 shows a summary of the total inventory of clearable solid materials over the study period. The solid materials shown below are either "released" or they are disposed in a LLW facility. Two examples of release destinations are (1) an EPA/State-Regulated landfill used for trash, concrete and/or ferrous metals, or (2) a recycling facility used to process released concrete only for use as roadbed material. For the comparison of Alternatives in this attachment, the Unrestricted Release and EPA/State-Regulated Disposal Alternatives all have a dose option of 1 mrem/yr based on NUREG-1640. The Limited Dispositions Alternative is based on IAEA Safety Guide No. RS-G-1.7, which is derived from a dose of 1 mrem/yr.

The Unrestricted Release inventory is for material-independent values. Note that in Table K-31 the amount of tons of concrete released under the Unrestricted Release Alternative is larger than the inventory of concrete released under the No Action Alternative. However, for steel the situation is reversed. This is because the material-independent values are based on the most limiting scenario, which is concrete, and thus inventory values for steel are normalized to a lower value. The concept of material-independent values is explained on page 3-20 and in Appendix D of this GEIS.

The cost-benefit results are generated by multiplying material amounts by unit costs, on an annual basis for each of the Alternatives and dose options. Using the convention described earlier in this Appendix, negative numbers represent either costs or decreases in benefits, while positive numbers represent either benefits or decreases in costs. The costs and benefits associated with the No Action Alternative are subtracted from the costs and benefits associated with each Alternative, to estimate the incremental cost of the rule. After the annual incremental total costs are calculated in current year dollars, these dollars are discounted to present value 2003\$ on an annual basis. Summing over all years provides the total discounted cost or benefit for an attribute (e.g., Industry Operation, Environmental Considerations) for each Alternative (e.g., Unrestricted Release, Limited Disposition) and dose option (e.g., 1 mrem/yr). A final sum over all of the attributes provides the Total Net Incremental Benefit or Cost (2003\$) for the Alternative and dose option compared to the No Action Alternative. Table 4-3 presents these results.

**Table K-31: Total Inventory of Clearable Solid Materials - All Alternatives Except No Action are for a 1 mrem/yr Dose Option (Thousand Tons)**

	No Action	Unrestricted Release	EPA/State-Regulated Disposal	Limited Dispositions
<b>Material Recycled</b>				
Steel	1,800	1,500	NA	NA
Concrete	16,000	20,000	NA	20,000
Trash	NA	NA	NA	NA
<b>Material Disposed at EPA/State-Regulated Landfills</b>				
Steel	0	0	2,100	2,100
Concrete	0	0	20,000	0
Trash	20	1.8	41	41

Source: SC&A 2003 Tables 4.6, 4.7, 10.3 and 10.7. For steel, the decontaminated quantity was not included in the release volumes because of the high cost of steel decontamination.

The overall analysis covers the years 2003 through 2049, but this discussion presents results only for a single sample year, 2020. It is important to keep in mind that the amount of solid material normally varies from year to year, and some years have very little material generated from decommissioning. The sample year 2020 represents a high volume year. The annual tonnage of potentially clearable solid material is based on three items in the analysis methodology:

- dismantlement activity in that year,
- the method by which the materials are managed for the Alternative (recycled or disposed), and
- the dose at which materials are allowed to be released.

With the amount of potentially clearable solid material changing each year, the dollar impacts – either cost or benefit – also change each year. These changes are seen in the stream of current year dollars (both benefits and costs compared to No Action) in Table K-23 for Unrestricted

1 Release, Table K-28 for EPA/State-Regulated Disposal, and Table K-30 for Limited  
 2 Dispositions. All three tables show major annual benefits under the Industry Operation attribute,  
 3 and to a lesser extent under the Public and Occupational Health Routine attribute. These tables  
 4 also show major annual costs under the Environmental Considerations and Industry  
 5 Implementation attributes.  
 6

7 Table K-32 shows the quantity of potentially clearable solid materials in the sample year 2020,  
 8 and how the specific quantities are managed for each material. These quantities are shown for  
 9 the No Action, Unrestricted Release, EPA/State-Regulated Disposal, and Limited Dispositions  
 10 Alternatives. The amounts of material (in metric tons) in the year 2020 serve as a starting point  
 11 to describe how the analysis is performed for the Industry Operation attribute.  
 12

13 **Table K-32: Inventory of Clearable Solid Materials**  
 14 **for the Industry Operation Attribute in the Year 2020 -**  
 15 **All Alternatives Except No Action are for a 1 mrem/yr Dose Option**  
 16 **(Thousand Tons)**  
 17

		<b>No Action</b>	<b>Unrestricted Release</b>	<b>EPA/State-Regulated Disposal</b>	<b>Limited Dispositions</b>
<b>Material Recycled</b>					
Steel		120	99	NA	NA
Concrete		1,293	1,564	NA	1,564
Trash		0	0	NA	NA
<b>Material Disposed at EPA/State-Regulated Landfills</b>					
Steel		0	0	141	141
Concrete		0	0	1,572	0
Trash		1	< 1	1	1
<b>Material Disposed at LLW Facility</b>					
Steel	Unrestricted	0	22	0	0
	EPA/State	21			
	Limited Disp	21			
Concrete	Unrestricted	271	0	0	0
	EPA/State	279			
	Limited Disp	271			
Trash	Unrestricted	0	1	0	0
	EPA/State	1			
	Limited Disp	1			

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 41 Because different amounts of each material clear in each Alternative, the No Action Alternative  
 42 is divided into three baselines, one corresponding to each of the other Alternatives (Unrestricted  
 43 Release, EPA/State-Regulated Disposal, and Limited Dispositions). The unaccounted for  
 44 material (for example, the 271,000 ton difference in the amount of concrete released in the No  
 45 Action and Unrestricted Release Alternatives) is added back to the No Action – Unrestricted  
 46 Release baseline, so like quantities are compared. Because any material that does not clear

1 would need to be sent to a LLW disposal facility, this change in quantity is assumed to be  
2 disposed of at a LLW disposal facility.

3  
4 As noted above, the Industry Operation attribute has four “sub-attributes,” or cost components.  
5 These sub-attributes are (in their order of cost significance):

- 6  
7 • transportation;  
8 • disposal and recycling;  
9 • survey; and  
10 • paperwork.

11  
12 The next sections explain how the costs and benefits are calculated for the year 2020. Assumed  
13 parameters are discussed to provide transparency on how costs and benefits are calculated.  
14 These sections illustrate the large beneficial impacts due to transportation and disposal activities  
15 associated with each of the three 1 mrem/yr Alternatives.

16  
17 When the impacts from the four sub-attributes are summed for each Alternative at the end of this  
18 section, the resulting total net benefits for the Industry Operation attribute (compared to No  
19 Action) will match the following values with some allowance for rounding:

- 20  
21 • \$84,066,938 for Unrestricted Release shown in Table K-23  
22 • \$60,430,917 for EPA/State-Regulated Disposal shown in Table K-28  
23 • \$87,381,423 for Limited Dispositions shown in Table K-30.

## 24 25 **2. Transportation Sub-Attribute**

26  
27 The annual net benefits or costs attributed to transportation are calculated for each year of the  
28 analysis, 2003-2049, by subtracting the estimated transportation costs of the No Action approach  
29 (or “baseline”) from the estimated transportation costs of the Alternative under consideration.  
30 Lower costs for the Alternative produce positive values, or net “benefits.” Higher costs for the  
31 Alternative produce negative values, or net “costs.” These annual values are calculated first in  
32 current year dollars and then discounted to 2003\$ for present value comparison.

33  
34 Transportation costs are estimated by multiplying the quantity (tons) of each material released in  
35 a year by (1) the number of miles traveled to the appropriate destination, and (2) the \$ per ton-  
36 mile rate for transporting the material by truck.

37  
38 Table K-33 shows the assumed unit costs used to calculate transportation costs.

39  
40 Table K-34 shows net transportation costs and benefits in sample year 2020 for the Alternatives  
41 in 2020\$.

42  
43 The released solid material is either transported to a recycling facility (steel and concrete only)  
44 or to an EPA/State-Regulated landfill. Solid material also is transported to a LLW facility.  
45 Multiplying the tons released (Table K-32) by the unit cost assumptions provides the  
46 transportation costs for each Alternative compared to No Action.

Table K-33  
Assumed Parameters for Transportation Cost Calculations

Transportation Cost Component	Cost or Mileage
Cost per ton-mile for non-LLW (truck)	-\$0.06
Cost per ton-mile for LLW (truck)	-\$0.12
Number of miles to an MSW Landfill	58 miles
Number of miles to a steel recycling facility	269 miles
Number of miles to a concrete recycling facility	198 miles
Number of miles to a LLW facility	1,544 miles

Transportation of concrete to a LLW facility under the No Action baseline is the most significant influence in the transportation costs. The Alternatives that use the 1 mrem/yr dose option release more concrete compared to the No Action baseline, and their costs for these releases are much less than the baseline assumption of sending the material to a LLW facility. The Unrestricted Release Alternative has the added cost of transporting steel a greater distance to a recycling facility compared to transporting steel to a mixed solid waste (MSW) landfill for the EPA/State-Regulated Disposal and Limited Dispositions Alternatives.

In summary, there are three differences associated with the Unrestricted Release, EPA/State-Regulated Disposal, and Limited Dispositions Alternatives compared to the No Action Alternative in the year 2020:

- more tons of concrete are released for the 1 mrem/yr dose option,
- each ton of concrete released and transported to a landfill is about 3.5 times closer (58 miles compared to 198 miles) than the concrete sent to a recycling facility, and
- the Unrestricted Release Alternative has an additional \$4 million cost in year 2020 for transporting steel to LLW compared to the EPA/State-Regulated Disposal and Limited Dispositions Alternatives.

### 3. Disposal and Recycling Sub-Attribute

The annual net benefits or costs attributed to disposal and recycling activities are calculated for each year of the analysis, 2003-2049. The estimated costs of the No Action approach (or “baseline”) are subtracted from the estimated costs of the other Alternative under consideration. These annual values are calculated first in current year dollars and then discounted to 2003\$ for present value comparison.

Disposal and recycling costs are estimated by multiplying the quantity (tons) of each material released in a year by the \$ per ton unit cost for disposal and recycling activities.

Table K-35 shows the assumed unit costs used to calculate disposal and recycling costs. Note that there is a cost to recycle concrete but a benefit to recycle steel.

Table K-34  
 Calculation of Transportation Benefits and Costs (Year 2020)  
 (Millions 2020\$)

	No Action Baseline	Unrestricted Release	EPA/State- Regulated Disposal	Limited Dispositions
<b>Material Recycled</b>				
Assumptions: 269 miles to steel recycling facility				
198 miles to concrete recycling facility				
\$0.06 cost per ton-mile for truck transport				
Steel	-1.9	-1.6	0	0
Concrete	-15.4	-18.6	0	-18.6
Trash	0	0	0	0
<b>Material Disposed at EPA/State-Regulated Landfills</b>				
Assumptions: 58 miles to a MSW landfill				
\$0.06 cost per ton-mile for truck transport				
Steel	0	0	-0.5	-0.5
Concrete	0	0	-5.5	0
Trash	< 0.1	< 0.1	< 0.1	< 0.1
<b>Material Disposed at LLW Facility</b>				
Assumptions: 1,544 miles to LLW facility				
\$0.12 cost per ton-mile for truck transport				
Steel	Unrestricted	0	-4.0	
	EPA/State	-3.8		0
	Limited Disp	-3.8		0
Concrete	Unrestricted	-50.3	0	
	EPA/State	-51.7		0
	Limited Disp	-50.3		0
Trash	Unrestricted	0	-0.1	
	EPA/State	-0.1		0
	Limited Disp	-0.1		0
Alternative Total \$	Unrestricted	-67.6	-24.3	
	EPA/State	-72.9		-6.0
	Limited Disp	-71.5		-19.1
Net Benefit (Cost) compared to No Action		+43.3	+66.9	+52.4

Table K-35  
Assumed Parameters for Disposal and Recycling Cost Calculations

<b>Disposal, Recycling and Reuse Cost Component</b>	<b>Cost (\$/ton)</b>
Steel, concrete and trash disposal in a landfill	-32.19
Concrete recycling	-5.00
Steel recycling revenue	+85.00
Steel, concrete and trash disposal in a LLW facility	-164.00

Table K-36 shows net disposal and recycling costs and benefits in sample year 2020 for the Alternatives in 2020\$.

The released solid material is either disposed at a recycling facility (steel and concrete only) or at an EPA/State-Regulated landfill. Solid material also is disposed at a LLW facility. Multiplying the tons released (Table K-32) by the disposal unit cost assumptions provides the disposal costs and recycling revenue for each Alternative compared to No Action.

As shown in Table K-36, both Unrestricted Release and Limited Disposition Alternatives have significant benefits compared to No Action, while the EPA/State-Regulated Disposal Alternative is more costly than No Action. The No Action baseline is about the same for all three Alternatives (i.e., \$40-\$45 million). The EPA/State-Regulated Disposal Alternative has a \$50 million expense in disposing of concrete in a landfill at \$32.19 per ton. The Unrestricted Release Alternative obtains a benefit of about \$8 million in 2020 from the sale of steel to a recycling facility, but not as much steel is recycled as that for the No Action Alternative (\$10 million). The significant benefit for the Unrestricted Release and Limited Dispositions Alternatives compared to No Action is in the disposal of concrete at a recycling facility at \$5.00 per ton compared to disposal at a LLW facility at \$164.00 per ton.

In summary, there are three differences associated with the Unrestricted Release, EPA/State-Regulated Disposal, and Limited Dispositions Alternatives compared to the No Action Alternative in the year 2020:

- the amount of concrete disposed in a landfill compared to the amount released for recycling,
- the cost of disposing of concrete in a landfill is more than 6 times the cost (\$32.19/ton compared to \$5/ton) of releasing concrete to a recycling facility, and
- the amount of concrete sent to a LLW facility.

#### 4. Survey Costs Sub-Attribute

The annual net benefits or costs attributed to survey activities are calculated for each year of the analysis, 2003-2049. The estimated costs of the No Action approach (or “baseline”) are subtracted from the estimated costs of the Alternative under consideration. These annual values are calculated first in current year dollars and then discounted to 2003\$ for present value comparison.

Survey costs are estimated by multiplying the quantity (tons) of each material released in a year by the \$ per ton survey cost.

Table K-36  
 Calculation of Disposal and Recycle Benefits and Costs (Year 2020)  
 (Millions 2020\$)

	No Action Baseline	Unrestricted Release	EPA/State- Regulated Disposal	Limited Dispositions
<b>Material Recycled</b>				
Assumptions: \$85.00 revenue per ton for steel \$ 5.00 cost per ton for concrete				
Steel	+10.2	+8.4	0	0
Concrete	-6.5	-7.8	0	-7.8
Trash	0	0	0	0
<b>Material Disposed at EPA/State-Regulated Landfills</b>				
Assumptions: \$32.19 cost per ton for steel, concrete, and trash				
Steel	0	0	-4.5	-4.5
Concrete	0	0	-50.6	0
Trash	< -0.1	< -0.1	< -0.1	< -0.1
<b>Material Disposed at LLW Facility</b>				
Assumption: \$164.00 cost per ton for steel, concrete and trash				
Steel	Unrestricted	0	-3.5	
	EPA/State	-3.4	0	
	Limited Disp	-3.4		0
Concrete	Unrestricted	-44.4	0	
	EPA/State	-45.7	0	
	Limited Disp	-44.4		0
Trash	Unrestricted	0	-0.1	
	EPA/State	-0.1	0	
	Limited Disp	-0.1		0
Alternative Total \$				
	Unrestricted	-40.7	-3.0	
	EPA/State	-45.5		-55.1
	Limited Disp	-44.2		-12.3
Net Benefit (Cost) compared to No Action		+37.7	-9.6	+31.9

Table K-37 shows the assumed unit costs used to calculate survey costs.

Table K-37  
Assumed Parameters for Survey Cost Calculations

Survey Cost Components	Cost (\$/ton)
Trash survey for baseline	-50.00
Steel survey for baseline	-176.00
Concrete survey for baseline	-26.00
Trash survey for 1 mrem/yr dose option	-74.00
Steel survey for 1 mrem/yr dose option	-41.85
Concrete survey for 1 mrem/yr dose option	-35.94

Table K-38 show net survey costs and benefits in sample year 2020 for the Alternatives in 2020\$.

Note that for survey activities, the net benefit of each Alternative compared to No Action is exactly the same, \$3.3 million. This equality seems counter intuitive, as the number of tons surveyed under each Alternative in the year 2020 is different. The incremental net benefit of one Alternative compared to another Alternative is the same (relative to No Action) because the unit costs for surveying material going to a landfill are the same as those going to a LLW facility. The extra material released for the Limited Dispositions Alternative compared to the Unrestricted Release Alternative in 2020 is also assumed for the Limited Disposition No Action baseline compared to the Unrestricted Release No Action baseline. Thus, incremental amounts among Alternatives cancel each other out because the same increment is in both the Alternative and the baseline for that Alternative.

Limited Disposition survey costs are about \$1 million more costly than Unrestricted Release survey costs in 2020 (\$62.2 million compared to \$61.2 million) due to more steel surveyed prior to release to a landfill. This added cost is offset by a lesser amount of steel going to a LLW facility in the baseline (\$64.5 million compared to \$65.5 million).

In summary, there are two conclusions from the survey cost sub-attribute:

- an approximate \$3.3 million benefit in 2020 is obtained for each of the three Alternatives compared to No Action, and
- the benefit is due to the cost difference in surveying steel for the Alternatives, \$41.85 per ton compared to \$176.00 per ton for No Action, and to the quantity of concrete surveyed prior to LLW disposal for No Action compared to no tons for the Alternatives.

Table K-38  
 Calculation of Survey Costs (Year 2020)  
 (Millions 2020\$)

		No Action Baseline	Unrestricted Release	EPA/State- Regulated Disposal	Limited Dispositions
<b>Material Recycled</b>					
Assumptions: \$ 35.94 cost per ton for concrete survey for 1 mrem/yr dose option					
\$ 26.00 cost per ton for concrete No Action baseline survey					
\$ 41.85 cost per ton for steel survey for 1 mrem/yr dose option					
\$176.00 cost per ton for steel No Action baseline survey					
Steel		-21.2	-4.1	0	0
Concrete		-33.6	-56.2	0	-56.2
Trash		0	0	0	0
<b>Material Disposed at EPA/State-Regulated Landfills</b>					
Assumptions: \$41.85 cost per ton for steel survey for 1 mrem/yr dose option					
\$35.94 cost per ton for concrete survey for 1 mrem/yr dose option					
\$74.00 cost per ton for trash survey for 1 mrem/yr dose option					
\$50.00 cost per ton for trash No Action baseline survey					
Steel		0	0	-5.9	-5.9
Concrete		0	0	-56.4	0
Trash		< -0.1	< -0.1	-0.1	-0.1
<b>Material Disposed at LLW Facility</b>					
Assumptions: \$41.85 cost per ton for steel survey					
\$35.94 cost per ton for concrete survey					
\$74.00 cost per ton for trash survey					
Steel	Unrestricted	0	-0.9		
	EPA/State	-0.9		0	
	Limited Disp	-0.9			0
Concrete	Unrestricted	-9.7	0		
	EPA/State	-10.0		0	
	Limited Disp	-9.7			0
Trash	Unrestricted	0	< -0.1		
	EPA/State	0		0	
	Limited Disp	< -0.1			0
Alternative Total \$					
	Unrestricted	-64.5	-61.2		
	EPA/State	-65.7		-62.4	
	Limited Disp	-65.5			-62.2
Net Benefit (Cost) compared to No Action			+3.3	+3.3	+3.3

1  
2 **5. Paperwork Sub-Attribute**  
3

4 The Paperwork sub-attribute is exactly the same value each year for each of the three  
5 Alternatives. This sub-attribute cost is associated with the administrative technical labor hours  
6 required of the licensees in their preparation and submittal of information supporting the release  
7 of solid material from their facilities.  
8

9 Eighteen facilities are involved in decommissioning activities in the year 2020.

10  
11 As described in Section 2.2.2 of Appendix K, the number of administrative technical labor hours  
12 for each licensee per facility is assumed to be 200, and the labor rate cost is assumed to be  
13 \$33.84 per hour.  
14

15 Thus, the value of -\$121,824 is assigned to each Alternative (Unrestricted Release, EPA/State-  
16 Regulated Disposal and Limited Dispositions) as a cost in 2020 compared to the No Action  
17 Alternative. Thus, as with the survey sub-attribute, the paperwork sub-attribute has no  
18 differentiation value in ranking the Alternatives compared to No Action.  
19

20 **6. Summary of Industry Operation Benefits and Costs**  
21

22 Table 4-3 in this draft GEIS shows the Industry Operation attribute is by far the most significant  
23 of the eight cost attributes quantified in the cost-benefit analysis of the Alternatives compared to  
24 No Action. Table 4-3 is in units of present value 2003\$, with the analysis having been  
25 performed over the years 2003 through 2049.  
26

27 This attachment provided a discussion of the assumed parameters used for calculations and the  
28 results of those calculations for the Industry Operation cost-benefit analysis in the year 2020.  
29 The dollar values in this attachment are in current year dollars (2020\$). The cost-benefit is for  
30 the Unrestricted Release, EPA/State-Regulated Disposal, and Limited Dispositions Alternatives  
31 compared to No Action.  
32

33 The methodology evaluates four cost sub-attributes within the Industry Operation attribute. Two  
34 of these -- transportation and disposal -- are the significant drivers in the analysis. Table K-39  
35 summarizes the results for the Industry Operation attribute in the year 2020 for the three  
36 Alternatives compared to No Action.  
37

38 The transportation of about 270,000 tons of concrete by truck to a LLW facility (1,544 miles  
39 distant) under the No Action baseline is the most significant influence in the transportation costs.  
40 (More tonnage is released under the 1 mrem/yr Alternatives than under the No Action dose  
41 option.) For the three other Alternatives, this volume of concrete is assumed to be transported  
42 either to a concrete recycling facility (198 miles distant) or to a landfill (58 miles distant). For  
43 the Unrestricted Release Alternative, there is a larger cost of transporting steel a greater distance  
44 to a recycling facility (269 miles) compared to a landfill (58 miles) used in the EPA/State-  
45 Regulated Disposal and Limited Disposition Alternatives. As with concrete, the landfill is only  
46 58 miles away, whereas the LLW facility is 1,544 miles. Also, the truck unit cost to the LLW  
47 facility is about double, at \$0.12 per ton-mile, compared to \$0.06 per ton-mile to the landfill.  
48  
49

Table K-39  
 Summary of Industry Operation Sub-Attribute Benefits and (Costs)  
 Year 2020 Compared to No Action  
 (Millions 2020\$)

	<b>No Action Baseline</b>	<b>Unrestricted Release</b>	<b>EPA/State- Regulated Disposal</b>	<b>Limited Dispositions</b>
Transportation	0	+43.3	+66.9	+52.4
Disposal and recycle	0	+37.7	-9.6	+31.9
Survey	0	+3.3	+3.3	+3.3
Paperwork	0	-0.1	-0.1	-0.1
Net Benefit (Cost) compared to No Action		+84.2	+60.5	+87.5

For the disposal costs, both the Unrestricted Release and Limited Disposition Alternatives have significant benefits compared to No Action, but the EPA/State-Regulated Disposal Alternative is more costly than No Action. This is due to the EPA/State-Regulated Disposal Alternative having an additional \$50 million expense in disposing of concrete in a landfill at \$32.19 per ton compared to \$5.00 per ton disposal cost at a concrete recycling facility for the other Alternatives. The disposal of steel by selling it as recycled scrap in the Unrestricted Release Alternative provides a benefit of about \$8 million in 2020 compared to the other two Alternatives.

This section provided a discussion using year 2020 data. Since the unit costs remain constant and the volume of cleared material changes each year in the analysis, all other years in the analysis would provide similar results as the year 2020 relative to the number of facilities entering their dismantlement activities in that year. The number of facilities starting dismantlement is the basis of the tonnage of solid material available for clearance in 2020 and other years. Eighteen facilities are involved in decommissioning in 2020. In the years 2003 through 2049, the number of facilities entering dismantlement each year ranges from none to 18.

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## APPENDIX L GLOSSARY

### **Activation**

The process of making a radioisotope by bombarding a stable element with neutrons or protons.

### **Agreement State**

A state that has signed an agreement with the Nuclear Regulatory Commission under which the state regulates the use of by-product, source and small quantities of special nuclear material within that state.

### **Air sampling**

The collection of samples of air to measure the radioactivity or to detect the presence of radioactive material, particulate matter, or chemical pollutants in the air.

### **ALARA**

Acronym for "As Low As Reasonably Achievable," means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest (see 10 CFR 20.1003).

### **Alpha particle**

A positively charged particle ejected spontaneously from the nuclei of some radioactive elements. It is identical to a helium nucleus that has a mass number of 4 and an electrostatic charge of +2. It has low penetrating power and a short range (a few centimeters in air). The most energetic alpha particle will generally fail to penetrate the dead layers of cells covering the skin and can be easily stopped by a sheet of paper. Alpha particles are hazardous when an alpha-emitting isotope is inside the body.

### **Anion**

A negatively charged ion.

### **Atom**

The smallest particle of an element that cannot be divided or broken up by chemical means. It consists of a central core of protons and neutrons, called the nucleus. Electrons revolve in orbits in the region surrounding the nucleus.

### **Atomic energy**

Energy released in nuclear reactions. Of particular interest is the energy released when a neutron initiates the breaking up or fissioning of an atom's nucleus into smaller pieces (fission), or when two nuclei are joined together under millions of degrees of heat (fusion). It is more correctly called nuclear energy.

1       **Attenuation**

2       The process by which the number of particles or photons entering a body of matter is reduced by  
3       absorption and scattered radiation.

4  
5       **Background radiation**

6       Radiation from cosmic sources; naturally occurring radioactive materials, including radon  
7       (except as a decay product of source or special nuclear material) and global fallout as it exists in  
8       the environment from the testing of nuclear explosive devices. It does not include radiation from  
9       source, byproduct, or special nuclear materials regulated by the Nuclear Regulatory Commission.  
10      The typically quoted average individual exposure from background radiation is 360 millirem per  
11      year.

12  
13      **Becquerel (Bq)**

14      The unit of radioactive decay equal to 1 disintegration per second. 37 billion (3.7E+10)  
15      becquerels = 1 curie (Ci).

16  
17      **Beta particle**

18      A charged particle emitted from a nucleus during radioactive decay, with a mass equal to 1/1837  
19      that of a proton. A negatively charged beta particle is identical to an electron. A positively  
20      charged beta particle is called a positron. Large amounts of beta radiation may cause skin burns,  
21      and beta emitters are harmful if they enter the body. Beta particles may be stopped by thin sheets  
22      of metal or plastic.

23  
24      **Bioassay**

25      The determination of kinds, quantities or concentrations, and in some cases, the locations, of  
26      radioactive material in the human body, whether by direct measurement (in vivo counting) or by  
27      analysis and evaluation of materials excreted or removed (in vitro) from the human body.

28  
29      **Biological half-life**

30      The time required for a biological system, such as that of a human, to eliminate, by natural  
31      processes, half of the amount of a substance (such as a radioactive material) that has entered it.

32  
33      **Biological shield**

34      A mass of absorbing material placed around a reactor or radioactive source to reduce the  
35      radiation to a level safe for humans.

36  
37      **Boiling water reactor (BWR)**

38      A reactor in which water, used as both coolant and moderator, is allowed to boil in the core. The  
39      resulting steam can be used directly to drive a turbine and electrical generator, thereby producing  
40      electricity.

41  
42      **British Thermal Unit (Btu)**

43      A British thermal unit. The amount of heat required to change the temperature of one pound of  
44      water one degree Fahrenheit at sea level.

1 **Byproduct**

2 Byproduct is (1) any radioactive material (except special nuclear material) yielded in, or made  
3 radioactive by, exposure to the radiation incident to the process of producing or using special  
4 nuclear material (as in a reactor); and (2) the tailings or wastes produced by the extraction or  
5 concentration of uranium or thorium from ore (see 10 CFR 20.1003).  
6

7 **Calibration**

8 The adjustment, as necessary, of a measuring device such that it responds within the required  
9 range and accuracy to known values of input.  
10

11 **Cask**

12 A heavily shielded container used to store and/or ship radioactive materials. Lead and steel are  
13 common materials used in the manufacture of casks.  
14

15 **Cation**

16 A positively charged ion.  
17

18 **Charged particle**

19 An ion. An elementary particle carrying a positive or negative electric charge.  
20

21 **Cladding**

22 The thin-walled metal tube that forms the outer jacket of a nuclear fuel rod. It prevents corrosion  
23 of the fuel by the coolant and the release of fission products into the coolant. Aluminum,  
24 stainless steel, and zirconium alloys are common cladding materials.  
25

26 **Clearance**

27 Removal of material that meets certain release criteria from regulatory control.  
28

29 **Collective dose**

30 The sum of the individual doses received on a given period of time by a specified population  
31 from exposure to a specified source of radiation.  
32

33 **Committed dose equivalent**

34 This is the dose to some specific organ or tissue that is received from an intake of radioactive  
35 material by an individual during the 50-year period following the intake (see 10 CFR 20.1003).  
36

37 **Committed effective dose equivalent**

38 The committed dose equivalent for a given organ multiplied by a weighting factor (see 10 CFR  
39 20.1003).  
40

41 **Compact**

42 A group of two or more States formed to dispose of low-level radioactive waste on a regional  
43 basis. Forty-two States have formed nine compacts.  
44

1 **Condenser**

2 A large heat exchanger designed to cool exhaust steam from a turbine below the boiling point so  
3 that it can be returned to the heat source as water. In a pressurized water reactor, the water is  
4 returned to the steam generator. In a boiling water reactor, it returns to the reactor core. The heat  
5 removed from the steam by the condenser is transferred to a circulating water system and is  
6 exhausted to the environment, either through a cooling tower or directly into a body of water.  
7

8 **Containment structure**

9 A gaslight shell or other enclosure around a nuclear reactor to confine fission products that  
10 otherwise might be released to the atmosphere in the event of an accident.  
11

12 **Control room**

13 The area in a nuclear power plant from which most of the plant power production and emergency  
14 safety equipment can be operated by remote control.  
15

16 **Controlled area**

17 At a nuclear facility, an area outside of a restricted area but within the site boundary, access to  
18 which can be limited by the licensee for any reason.  
19

20 **Cooling tower**

21 A heat exchanger designed to aid in the cooling of water that was used to cool exhaust steam  
22 exiting the turbines of a power plant. Cooling towers transfer exhaust heat into the air instead of  
23 into a body of water.  
24

25 **Core**

26 The central portion of a nuclear reactor containing the fuel elements, moderator, neutron poisons,  
27 and support structures.  
28

29 **Cosmic radiation**

30 Penetrating ionizing radiation, both particulate and electromagnetic, originating in outer space.  
31 Secondary cosmic rays, formed by interactions in the earth's atmosphere, account for about 45 to  
32 50 millirem of the 360 millirem background radiation that an average individual receives in a  
33 year.  
34

35 **Counter**

36 A general designation applied to radiation detection instruments or survey meters that detect and  
37 measure radiation. The signal that announces an ionization event is called a count.  
38

39 **Crud**

40 A colloquial term for corrosion and wear products (rust particles, etc.) that become radioactive  
41 (i.e., activated) when exposed to radiation. Because the activated deposits were first discovered  
42 at Chalk River, a Canadian nuclear plant, "crud" has been used as shorthand for Chalk River  
43 Unidentified Deposits.  
44

1 **Cumulative dose**

2 The total dose resulting from repeated exposures of ionizing radiation to an occupationally  
3 exposed worker to the same portion of the body, or to the whole body, over a period of time (see  
4 10 CFR 20.1003).

5  
6 **Curie (Ci)**

7 The basic unit used to describe the intensity of radioactivity in a sample of material. The curie is  
8 equal to 37 billion (3.7E+10) disintegrations per second, which is approximately the activity of 1  
9 gram of radium. A curie is also a quantity of any radionuclide that decays at a rate of 37 billion  
10 disintegrations per second. It is named for Marie and Pierre Curie, who discovered radium in  
11 1898.

12  
13 **Daughter products**

14 Isotopes that are formed by the radioactive decay of some other isotope. In the case of  
15 radium-226, for example, there are 10 successive daughter products, ending in the stable isotope,  
16 lead-206.

17  
18 **Decay, radioactive**

19 The decrease in the amount of any radioactive material with the passage of time due to the  
20 spontaneous emission from the atomic nuclei of either alpha or beta particles, often accompanied  
21 by gamma radiation.

22  
23 **Decommission**

24 The process of closing down a facility followed by reducing residual radioactivity to a level that  
25 permits the release of the property for unrestricted use (see 10 CFR 20.1003).

26  
27 **Decon**

28 A method of decommissioning in which the equipment, structures, and portions of a facility and  
29 site containing radioactive contaminants are removed and safely buried in a low-level radioactive  
30 waste landfill or decontaminated to a level that permits the property to be released for  
31 unrestricted use shortly after cessation of operations.

32  
33 **Decontamination**

34 The reduction or removal of contaminating radioactive material from a structure, area, object, or  
35 person. Decontamination may be accomplished by: (1) treating the surface to remove or decrease  
36 the contamination, (2) letting the material stand so that the radioactivity is decreased as a result  
37 of natural radioactive decay, or (3) covering the contamination to shield or attenuate the radiation  
38 emitted (see 10 CFR 20.1003 and §20.1402).

39  
40 **Derived air concentration (DAC)**

41 The concentration of radioactive material in air and the time of exposure to that radionuclide, in  
42 hours. An NRC licensee may take 2,000 hours to represent one ALI, equivalent to a committed  
43 effective dose equivalent of 5 rem (0.05 sievert).

1 **Detector**

2 A material or device that is sensitive to radiation and can produce a response signal suitable for  
3 measurement or analysis. A radiation detection instrument.

4  
5 **Deterministic effect**

6 The health effects, the severity of which varies with the dose and for which a threshold is  
7 believed to exist. Radiation-induced cataract formation is an example of a deterministic effect  
8 (also called a non-stochastic effect) (see 10 CFR 20.1003).

9  
10 **Dose**

11 The absorbed dose, given in rads (or the international system of units, grays), that represents the  
12 energy absorbed from the radiation in a gram of any material. Furthermore, the biological dose or  
13 dose equivalent, given in rems or sieverts, is a measure of the biological damage to living tissue  
14 from the radiation exposure.

15  
16 **Dose equivalent**

17 The product of absorbed dose in tissue multiplied by a quality factor, and then sometimes  
18 multiplied by other necessary modifying factors at the location of interest. It is expressed  
19 numerically in rems or sieverts (see 10 CFR 20.1003).

20  
21 **Dose factor**

22 Multiplier used to convert radionuclide concentrations to dose.

23  
24 **Dose rate**

25 The ionizing radiation dose delivered per unit time. For example, rem or sieverts per hour.

26  
27 **Dose, absorbed**

28 The amount of energy deposited in any substance by ionizing radiation per unit mass of the  
29 substance. It is expressed numerically in rads or grays.

30  
31 **Dosimeter**

32 A small portable instrument (such as a film badge, thermoluminescent or pocket dosimeter) for  
33 measuring and recording the total accumulated personnel dose of ionizing radiation.

34  
35 **Dosimetry**

36 The theory and application of the principles and techniques involved in the measurement and  
37 recording of ionizing radiation doses.

38  
39 **Effective dose**

40 The quantity obtained by multiplying the equivalent dose to various tissues and organs by a  
41 weighting factor appropriate to each and summing the products.

42  
43 **Effective half-life**

44 The time required for the amount of a radioactive element deposited in a living organism to be  
45 diminished 50% as a result of the combined action of radioactive decay and biological  
46 elimination.

1 **Electromagnetic radiation**

2 A traveling wave motion resulting from changing electric or magnetic fields. Familiar  
3 electromagnetic radiation range from x-rays (and gamma rays) of short wavelength, through the  
4 ultraviolet, visible, and infrared regions, to radar and radio waves of relatively long wave length.  
5

6 **Electron**

7 An elementary particle with a negative charge and a mass 1/1837 that of the proton. Electrons  
8 surround the positively charged nucleus and determine the chemical properties of the atom.  
9

10 **Entomb**

11 A method of decommissioning in which radioactive contaminants are encased in a structurally  
12 long-lived material, such as concrete. The entombment structure is appropriately maintained, and  
13 continued surveillance is carried out until the radioactivity decays to a level permitting  
14 decommissioning and ultimate unrestricted release of the property.  
15

16 **Exclusion area**

17 That area surrounding the reactor, in which the reactor licensee has the authority to determine all  
18 activities, including exclusion or removal of personnel and property from the area.  
19

20 **Exposure**

21 Being exposed to ionizing radiation or to radioactive material.  
22

23 **External radiation**

24 Exposure to ionizing radiation when the radiation source is located outside the body.  
25

26 **Fiscal Year**

27 The 12-month period, from October 1 through September 30, used by the Federal Government in  
28 budget formulation and execution. The fiscal year is designated by the calendar year in which it  
29 ends.  
30

31 **Fissile material**

32 Although sometimes used as a synonym for fissionable material, this term has acquired a more  
33 restricted meaning. Namely, any material fissionable by thermal (slow) neutrons. The three  
34 primary fissile materials are uranium-233, uranium-235, and plutonium-239.  
35

36 **Fission (fissioning)**

37 The splitting of a nucleus into at least two other nuclei and the release of a relatively large  
38 amount of energy. Two or three neutrons are usually released during this type of transformation.  
39

40 **Fuel assembly**

41 A cluster of fuel rods (or plates). Also called a fuel element. Many fuel assemblies make up a  
42 reactor core.  
43

44 **Fuel cycle**

45 The series of steps involved in supplying fuel for nuclear power reactors. It can include mining,  
46 milling, isotopic enrichment, fabrication of fuel elements, use in a reactor, chemical reprocessing

1 to recover the fissionable material remaining in the spent fuel, re-enrichment of the fuel material,  
2 refabrication into new fuel elements, and waste disposal.

3  
4 **Fuel reprocessing**

5 The processing of reactor fuel to separate the unused fissionable material from waste material.

6  
7 **Fuel rod**

8 A long, slender tube that holds fissionable material (fuel) for nuclear reactor use. Fuel rods are  
9 assembled into bundles called fuel elements or fuel assemblies, which are loaded individually  
10 into the reactor core.

11  
12 **Full-time equivalent**

13 A measurement equal to one staff person working a full-time work schedule for 1 year.

14  
15 **Gamma radiation**

16 High-energy, short wavelength, electromagnetic radiation emitted from the nucleus. Gamma  
17 radiation frequently accompanies alpha and beta emissions and always accompanies fission.  
18 Gamma rays are very penetrating and are best stopped or shielded by dense materials, such as  
19 lead or depleted uranium. Gamma rays are similar to x-rays.

20  
21 **Gas Centrifuge**

22 A uranium enrichment process that uses a large number of rotating cylinders in a series. These  
23 series of centrifuge machines, called trains, are interconnected to form cascades. In this process,  
24 UF<sub>6</sub> gas is placed in a rotating drum or cylinder and rotated at high speed. This rotation creates  
25 a strong gravitational field so that the heavier gas molecules (containing U-238) move toward the  
26 outside of the cylinder and the lighter gas molecules (containing U-235) collect closer to the  
27 center. The stream that is slightly enriched in U-235 is withdrawn and fed into the next higher  
28 stage, while the slightly depleted stream is recycled back into the next lower stage. Significantly  
29 more U-235 enrichment can be obtained from a single unit gas centrifuge than from a single unit  
30 gaseous diffusion barrier.

31  
32 **Gaseous Diffusion Plant**

33 A facility where uranium hexafluoride gas is filtered, uranium-235 is separated from  
34 uranium-238, increasing the percentage of uranium-235 from 1 to about 3 percent. The process  
35 requires enormous amounts of electric power.

36  
37 **Geiger-Mueller counter**

38 A radiation detection and measuring instrument. It consists of a gas-filled tube containing  
39 electrodes, between which there is an electrical voltage, but no current flowing. When ionizing  
40 radiation passes through the tube, a short, intense pulse of current passes from the negative  
41 electrode to the positive electrode and is measured or counted. The number of pulses per second  
42 measures the intensity of the radiation field. It was named for Hans Geiger and W. Mueller, who  
43 invented it in the 1920s. It is sometimes called simply a Geiger counter or a G-M counter, and is  
44 the most commonly used portable radiation instrument.

1 **Gigawatt**

2 One billion watts.

3  
4 **Gigawatthour**

5 One billion watt-hours.

6  
7 **Graphite**

8 A form of carbon, similar to the lead used in pencils, used as a moderator in some nuclear  
9 reactors.

10  
11 **Gray (Gy)**

12 The international system (SI) unit of absorbed dose. One gray is equal to an absorbed dose of 1  
13 Joule/kilogram (one gray equals 100 rads) (see 20.1004).

14  
15 **Half-life**

16 The time in which one half of the atoms of a particular radioactive substance disintegrates into  
17 another nuclear form. Measured half-lives vary from millionths of a second to billions of years.  
18 Also called physical or radiological half-life

19  
20 **Half-life, biological**

21 The time required for the body to eliminate one half of the material taken in by natural biological  
22 means.

23  
24 **Half-life, effective**

25 The time required for a radionuclide contained in a biological system, such as a human or an  
26 animal, to reduce its activity by one-half as a combined result of radioactive decay and biological  
27 elimination.

28  
29 **Head, reactor vessel**

30 The removable top section of a reactor pressure vessel. It is bolted in place during power  
31 operation and removed during refueling to permit access of fuel handling equipment to the core.

32  
33 **Health physics**

34 The science concerned with the recognition, evaluation, and control of hazards to health and the  
35 environment that may arise from the use and application of ionizing radiation.

36  
37 **Heat exchanger**

38 Any device that transfers heat from one fluid (liquid or gas) to another fluid or to the  
39 environment.

40  
41 **Hot**

42 A colloquial term meaning highly radioactive.

43  
44 **Hot spot**

45 The region in a radiation/contamination area in which the level of radiation/contamination is  
46 significantly greater than in neighboring regions in the area.

1 **Impacted Area**

2 An area with some reasonable potential for residual radioactivity in excess of natural background  
3 or fallout levels.  
4

5 **Ion-exchange**

6 A common method for concentrating uranium from a solution. The uranium solution is passed  
7 through a resin bed where the uranium-carbonate complex ions are transferred to the resin by  
8 exchange with a negative ion like chloride. After build-up of the uranium complex on the resin,  
9 the uranium is eluted with a salt solution and the uranium is precipitated in another process.  
10

11 **Isotope**

12 Any two or more forms of an element having identical or very closely related chemical properties  
13 and the same atomic number but different atomic weights or mass numbers.  
14

15 **Kilovolt**

16 The unit of electrical potential equal to 1,000 volts.  
17

18 **Leachate**

19 An often toxic liquid that forms as water seeps down through waste in a landfill and collects  
20 contaminates from the waste.  
21

22 **Light water**

23 Ordinary water as distinguished from heavy water.  
24

25 **Light water reactor**

26 A term used to describe reactors using ordinary water as coolant, including boiling water reactors  
27 (BWRs) and pressurized water reactors (PWRs), the most common types used in the United  
28 States.  
29

30 **Loop**

31 In a pressurized water reactor, the coolant flow path through piping from the reactor pressure  
32 vessel to the steam generator, to the reactor coolant pump, and back to the reactor pressure  
33 vessel. Large PWRs may have as many as four separate loops.  
34

35 **Low-level waste**

36 A general term for a wide range of wastes having low levels of radioactivity. Industries,  
37 hospitals and medical, educational, or research institutions; private or government laboratories;  
38 and nuclear fuel cycle facilities (e.g., nuclear power reactors and fuel fabrication plants) that use  
39 radioactive materials generate low-level wastes as part of their normal operations. These wastes  
40 are generated in many physical and chemical forms and levels of contamination (see 10 CFR  
41 61.2). Low-level radioactive wastes containing source, special nuclear, or byproduct material are  
42 acceptable for disposal in a land disposal facility. For the purposes of this definition, low-level  
43 waste has the same meaning as in the Low-level Waste Policy Act, that is, radioactive waste not  
44 classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or byproduct  
45 material as defined in section 11e.(2) of the Atomic Energy Act (uranium or thorium tailings and  
46 waste). See also High-level waste.

1 **Material-independent dose factors**

2 Dose factors that consider the most conservative dose factor for each radionuclide, regardless of  
3 the material.

4  
5 **Material-specific dose factors**

6 Dose factors based on the most limiting scenario.

7  
8 **Megacurie**

9 One million curies.

10  
11 **Megawatt (MW)**

12 One million watts.

13  
14 **Megawatt hour (MWh)**

15 One million watt-hours.

16  
17 **Metric ton**

18 Approximately 2,200 pounds in the English system of measurements (Note: in the international  
19 system of measurements, 1 metric ton = 1000 kg.)

20  
21 **Microcurie**

22 One millionth of a curie. That amount of radioactive material that disintegrates (decays) at the  
23 rate of 37 thousand atoms per second.

24  
25 **Mill tailings**

26 Naturally radioactive residue from the processing of uranium ore into yellowcake in a mill.  
27 Although the milling process recovers about 93 percent of the uranium, the residues, or tailings,  
28 contain several naturally-occurring radioactive elements, including uranium, thorium, radium,  
29 polonium, and radon.

30  
31 **Millirem**

32 One thousandth of a rem (0.001 rem).

33  
34 **Mixed oxide fuel**

35 A mixture of uranium oxide and plutonium oxide used to fuel a reactor. Mixed oxide fuel is often  
36 abbreviated as "MOX." Conventional nuclear fuel is made of pure uranium oxide.

37  
38 **Monitoring of Radiation**

39 Periodic or continuous determination of the amount of ionizing radiation or radioactive  
40 contamination present in a region, as a safety measure, for the purpose of health or environmental  
41 protection. Monitoring is done for air, surface, & ground water, soil & sediment, equipment  
42 surfaces, and personnel (for example, bioassay or alpha scans).

43  
44 **Nanocurie**

45 One billionth (10<sup>-9</sup>) of a curie.

46

1 **Natural uranium**

2 Uranium as found in nature. It contains 0.7 percent uranium-235, 99.3 percent uranium-238, and  
3 a trace of uranium-234 by weight. In terms of the amount of radioactivity, it contains  
4 approximately 2.2 percent uranium-235, 48.6 percent uranium-238, and 49.2 percent  
5 uranium-234.

6  
7 **Neutron**

8 An uncharged elementary particle with a mass slightly greater than that of the proton, and found  
9 in the nucleus of every atom heavier than hydrogen.

10  
11 **Nonpower reactor**

12 Reactors used for research, training, and test purposes, and for the production of radioisotopes for  
13 medical and industrial uses.

14  
15 **Nuclear energy**

16 The energy liberated by a nuclear reaction (fission or fusion) or by radioactive decay.

17  
18 **Nuclear power plant**

19 An electrical generating facility using a nuclear reactor as its heat source to provide steam to a  
20 turbine generator.

21  
22 **Nuclear waste**

23 A particular type of radioactive waste, that is produced as part of the nuclear fuel cycle, i.e.,  
24 those activities needed to produce nuclear fission, or splitting of the atom. These include  
25 extraction of uranium from ore, concentration of uranium, processing into nuclear fuel, and  
26 disposal of byproducts. Radioactive waste is a broader terms that includes all waste that contains  
27 radioactivity. Residues from water treatment, contaminated equipment from oil drilling, and  
28 tailings from the processing of metals such as vanadium and copper, also contain radioactivity  
29 but are not "nuclear waste" because they are produced outside of the nuclear fuel cycle. NRC  
30 generally regulates only those wastes produced in the nuclear fuel cycle (uranium mill tailings,  
31 depleted uranium, spent fuel rods, etc).

32  
33 **Nucleon**

34 Common name for a constituent particle of the atomic nucleus. At present, applied to protons and  
35 neutrons, but may include any other particles found to exist in the nucleus.

36  
37 **Nucleus**

38 The small, central, positively charged region of an atom. Except for the nucleus of ordinary  
39 hydrogen, which has only a proton, all atomic nuclei contain both protons and neutrons. The  
40 number of protons determines the total positive charge or atomic number. This number is the  
41 same for all the atomic nuclei of a given chemical element. The total number of neutrons and  
42 protons is called the mass number.

43  
44 **Nuclide**

45 A general term referring to all known isotopes, both stable (279) and unstable (about 2,700), of  
46 the chemical elements.

1 **Parent**

2 A radionuclide that upon radioactive decay or disintegration yields a specific nuclide (the  
3 daughter).  
4

5 **Parts per million (ppm)**

6 Parts (molecules) of a substance contained in a million parts of another substance (or water).  
7

8 **Personnel monitoring**

9 The use of portable survey meters to determine the amount of radioactive contamination on an  
10 individual, or the use of dosimetry to determine an individual's occupational radiation dose.  
11

12 **Photon**

13 A quantum (or packet) of energy emitted in the form of electromagnetic radiation. Gamma rays  
14 and x-rays are examples of photons.  
15

16 **Picocurie**

17 One trillionth (10<sup>-12</sup>) of a curie.  
18

19 **Pig**

20 A colloquial term describing a container (usually lead or depleted uranium) used to ship or store  
21 radioactive materials. The thick walls of this shielding device protect the person handling the  
22 container from radiation. Large containers used for spent fuel storage are commonly called casks.  
23

24 **Point source**

25 Any discernible, confined, and discrete conveyance, including but not limited to, any pipe, ditch,  
26 channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal  
27 feeding operation, landfill leachate collection system, vessel or other floating craft from which  
28 pollutants are or may be discharged. This term does not include return flows from irrigated  
29 agriculture or agricultural storm water runoff. (See 40 CFR 122.3).  
30

31 **Potentially Clearable Material**

32 Solid materials that originate in restricted or impacted areas of NRC/Agreement State-licensed  
33 facilities, and have no, or very small amounts of, radioactivity resulting from licensed operations.  
34

35 **Power reactor**

36 A reactor designed to produce heat for electric generation, as distinguished from reactors used for  
37 research, for producing radiation or fissionable materials, or for reactor component testing.  
38

39 **Pressure vessel**

40 A strong-walled container housing the core of most types of power reactors. It usually also  
41 contains the moderator, neutron reflector, thermal shield, and control rods.  
42

43 **Pressurized water reactor (PWR)**

44 A power reactor in which heat is transferred from the core to an exchanger by high temperature  
45 water kept under high pressure in the primary system. Steam is generated in a secondary circuit.  
46 Many reactors producing electric power are pressurized water reactors.

1 **Proton**

2 An elementary nuclear particle with a positive electric charge located in the nucleus of an atom.

3  
4 **Quality Factor**

5 Factor by which the absorbed dose (rad or gray) is to be multiplied to obtain a quantity that  
6 expresses, on a common scale for all ionizing radiation, the biological damage (rem or sievert) to  
7 an exposed individual. It is used because some types of radiation, such as alpha particles, are  
8 more biologically damaging internally than other types.

9  
10 **Rad**

11 The special unit for radiation absorbed dose, which is the amount of energy from any type of  
12 ionizing radiation (e.g., alpha, beta, gamma, neutrons, etc.) deposited in any medium (e.g., water,  
13 tissue, air). A dose of one rad means the absorption of 100 ergs (a small but measurable amount  
14 of energy) per gram of absorbing tissue (100 rad = 1 gray).

15  
16 **Radiation (ionizing radiation)**

17 Alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed  
18 protons, and other particles capable of producing ions. Radiation, as used in 10 CFR Part 20,  
19 does not include non-ionizing radiation, such as radio- or microwaves, or visible, infrared, or  
20 ultraviolet light (see also 10 CFR 20.1003).

21  
22 **Radiation area**

23 Any area with radiation levels greater than 5 millirem (0.05 millisievert) in one hour at 30  
24 centimeters from the source or from any surface through which the radiation penetrates.

25  
26 **Radiation source**

27 Usually a sealed source of radiation used in teletherapy and industrial radiography, as a power  
28 source for batteries (as in use in space craft), or in various types of industrial gauges. Machines,  
29 such as accelerators and radioisotope generators, and natural radionuclides may be considered  
30 sources.

31  
32 **Radiation standards**

33 Exposure standards, permissible concentrations, rules for safe handling, regulations for  
34 transportation, regulations for industrial control of radiation, and control of radioactive material  
35 by legislative means.

36  
37 **Radiation Survey**

38 In the context of the GEIS, "radiation survey" is used to define various types of surveys  
39 conducted to assess levels of residual radioactivity in or on material and equipment. Such  
40 surveys include the use of conventional radiation detection instrumentation, and sample  
41 collection and sample analysis using appropriate types of analytical equipment and procedures.  
42 The use of any one method or combination of methods are mandated by the type of material,  
43 radionuclide distributions and their relative mix, and detection limits in comparison to allowable  
44 dose criteria.

1 **Radiation, nuclear**

2 Particles (alpha, beta, neutrons) or photons(gamma) emitted from the nucleus of unstable  
3 radioactive atoms as a result of radioactive decay.

4  
5 **Radioactive decay**

6 Large unstable atoms can become more stable by emitting radiation. This process is called  
7 radioactive decay. This radiation can be emitted in the form of a positively charged ALPHA  
8 particle, a negatively charged BETA particle, or GAMMA RAYS or X-RAYS.

9  
10 **Radioactivity**

11 The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by  
12 gamma rays, from the nucleus of an unstable isotope. Also, the rate at which radioactive material  
13 emits radiation. Measured in units of becquerels or disintegrations per second.

14  
15 **Radioisotope**

16 An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation.  
17 Approximately 5,000 natural and artificial radioisotopes have been identified.

18  
19 **Radionuclide**

20 A radioisotope.

21  
22 **Reaction**

23 Any process involving a chemical or nuclear change.

24  
25 **Reactivity**

26 A term expressing the departure of a reactor system from criticality. A positive reactivity  
27 addition indicates a move toward supercriticality (power increase). A negative reactivity addition  
28 indicates a move toward subcriticality (power decrease).

29  
30 **Reactor coolant system**

31 The system used to remove energy from the reactor core and transfer that energy either directly or  
32 indirectly to the steam turbine.

33  
34 **Reactor, nuclear**

35 A device in which nuclear fission may be sustained and controlled in a self-supporting nuclear  
36 reaction. The varieties are many, but all incorporate certain features, including fissionable  
37 material or fuel, a moderating material (unless the reactor is operated on fast neutrons), a  
38 reflector to conserve escaping neutrons, provisions of removal of heat, measuring and controlling  
39 instruments, and protective devices. The reactor is the heart of a nuclear power plant.

40  
41 **Reference man**

42 A person with the anatomical and physiological characteristics of an average individual which is  
43 used in calculations assessing internal dose (also may be called "Standard Man").

1 **REM**

2 The acronym for Roentgen Equivalent Man is a standard unit that measures the effects of  
3 ionizing radiation on humans. The dose equivalent in rems is equal to the absorbed dose in rads  
4 multiplied by the quality factor of the type of radiation (see 10 CFR 20.1004).  
5

6 **Restricted area**

7 Any area to which access is controlled for the protection of individuals from exposure to  
8 radiation and radioactive materials.  
9

10 **Risk-informed regulation**

11 Incorporating an assessment of safety significance or relative risk in NRC regulatory actions.  
12 Making sure that the regulatory burden imposed by individual regulations or processes is  
13 commensurate with the importance of that regulation or process to protecting public health and  
14 safety and the environment.  
15

16 **Rubblization**

17 A decommissioning technique involving demolition and burial of formerly operating nuclear  
18 facilities. All equipment from buildings is removed and the surfaces are decontaminated.  
19 Above-grade structures are demolished into rubble and buried in the structure's foundation below  
20 ground. The site surface is then covered, regraded and landscaped for unrestricted use.  
21

22 **Runoff**

23 Water from precipitation or irrigation that flows over the ground and does not infiltrate the  
24 ground surface. It may collect pollutants from the land and carry them into receiving water  
25 bodies.  
26

27 **Sealed source**

28 Any radioactive material or byproduct encased in a capsule designed to prevent leakage or escape  
29 of the material.  
30

31 **Secondary radiation**

32 Radiation originating as the result of absorption of other radiation in matter. It may be either  
33 electromagnetic or particulate in nature.  
34

35 **Sievert (Sv)**

36 The new international system (SI) unit for dose equivalent equal to 1 Joule/kilogram. 1 sievert =  
37 100 rem.  
38

39 **Somatic effects of radiation**

40 Effects of radiation limited to the exposed individual, as distinguished from genetic effects,  
41 which may also affect subsequent unexposed generations.  
42

43 **Source material**

44 Uranium or thorium, or any combination thereof, in any physical or chemical form or ores that  
45 contain by weight one-twentieth of one percent (0.05%) or more of (1) uranium, (2) thorium, or  
46 (3) any combination thereof. Source material does not include special nuclear material.

1 **Special nuclear material**

2 Plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235.

3  
4 **Spent (or depleted) nuclear fuel**

5 Fuel that has been removed from a nuclear reactor because it can no longer sustain power  
6 production for economic or other reasons.

7  
8 **Steel slag**

9 A solid made of the silicate and oxide components found in iron, which are considered  
10 undesirable in steel. It is a by-product formed during the removal of excess quantities of carbon  
11 and silicon from iron in the production of steel.

12  
13 **Stochastic effects**

14 Effects that occur by chance, generally occurring without a threshold level of dose, whose  
15 probability is proportional to the dose and whose severity is independent of the dose. In the  
16 context of radiation protection, the main stochastic effects are cancer and genetic effects.

17  
18 **Storm water discharge associated with industrial activity**

19 Discharge from any conveyance that is used for collecting and conveying storm water and that is  
20 directly related to manufacturing, processing or raw materials storage areas at an industrial plant  
21 (see 40 CFR 122.26(b)14).

22  
23 **Survey meter**

24 Any portable radiation detection instrument especially adapted for inspecting an area or  
25 individual to establish the existence and amount of radioactive material present.

26  
27 **Terrestrial radiation**

28 The portion of the natural background radiation that is emitted by naturally occurring radioactive  
29 materials, such as uranium, thorium, and radon in the earth.

30  
31 **Thermal neutron**

32 Neutrons that have been slowed to the degree that they have the same average thermal energy as  
33 the atoms or molecules through which they are passing. The average energy of neutrons at  
34 ordinary temperatures is about 0.025 eV, corresponding to an average velocity of  
35  $2.2 \times 10^3$  m s<sup>-1</sup>.

36  
37 **Thermal power**

38 The total core heat transfer rate to the reactor coolant.

39  
40 **Thermal reactor**

41 A reactor in which the fission chain reaction is sustained primarily by thermal neutrons. Most  
42 current reactors are thermal reactors.

43  
44 **Transuranic Element**

45 An artificially made, radioactive element that has an atomic number higher than uranium in the  
46 Periodic Table of Elements such as neptunium, plutonium, americium, and others.

1 **Transuranic Waste**

2 Waste containing more than 100 nCi/g of alpha-emitting transuranic isotopes per gram of waste,  
3 with half-lives greater than 20 years.

4  
5 **Turbine**

6 A rotary engine made with a series of curved vanes on a rotating shaft, usually turned by water or  
7 steam. Turbines are considered the most economical means to turn large electrical generators.

8  
9 **Turbine generator (TG)**

10 A steam (or water) turbine directly coupled to an electrical generator. The two devices are often  
11 referred to as one unit.

12  
13 **Unrestricted area**

14 The area outside the owner-controlled portion of a nuclear facility (usually the site boundary). An  
15 area in which a person could not be exposed to radiation levels in excess of 2 millirem in any one  
16 hour from external sources (see 10 CFR 20.1003).

17  
18 **Uranium fuel fabrication facility**

19 A facility that (1) manufactures reactor fuel containing uranium for any of the following (I)  
20 preparation of fuel materials; (ii) formation of fuel materials into desired shapes; (iii) application  
21 of protective cladding; (iv) recovery of scrap material; and (v) storage associated with such  
22 operations; or (2) conducts research and development activities.

23  
24 **Uranium hexafluoride production facility**

25 A facility that receives natural uranium in the form of ore concentrate; processes the concentrate  
26 and converts it into uranium hexafluoride (UF<sub>6</sub>).

27  
28 **Waste, radioactive**

29 Radioactive materials at the end of a useful life cycle or in a product that is no longer useful and  
30 should be properly disposed of.

31  
32 **Watt**

33 An electrical unit of power. 1 watt = 1 Joule/second. It is equal to the power in a circuit in which  
34 a current of one ampere flows across a potential difference of one volt.

35  
36 **Watt-hour**

37 An electrical energy unit of measure equal to 1 watt of power supplied to, or taken from, an  
38 electrical circuit steadily for 1 hour.

39  
40 **Whole-body counter**

41 A device used to identify and measure the radioactive material in the body of human beings and  
42 animals. It uses heavy shielding to keep out naturally existing background radiation and  
43 ultrasensitive radiation detectors and electronic counting equipment.

1 **Whole-body exposure**

2 For purposes of whole body exposure includes at least the external exposure, head, trunk, arms  
3 above the elbow, or legs above the knee. Where a radioisotope is uniformly distributed  
4 throughout the body tissues, rather than being concentrated in certain parts, the irradiation can be  
5 considered as whole-body exposure (see also 10 CFR 20.1003).  
6

7 **Wipe sample**

8 A sample made for the purpose of determining the presence of removable radioactive  
9 contamination on a surface. It is done by wiping, with slight pressure, a piece of soft filter paper  
10 over a representative type of surface area. It is also known as a "swipe or smear" sample.  
11

12 **X-rays**

13 Penetrating electromagnetic radiation (photon) having a wavelength that is much shorter than  
14 that of visible light.  
15

1  
2  
3  
4

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Draft Regulatory Analysis

Amendments to 10 CFR Part 20 on

Radiological Criteria for Controlling the Disposition of Solid Materials

March 2005

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## 1.0 Introduction

The Proposed Rule being considered in this Draft Regulatory Analysis (RA) is a Nuclear Regulatory Commission (NRC) regulation to control the disposition of solid materials. These solid materials originate in restricted or impacted areas<sup>1</sup> of NRC-licensed facilities, and have no, or very small amounts of, radioactivity resulting from licensed operations (collectively referred to in this RA as “solid materials”). The Proposed Rule would provide a clear and consistent regulatory basis for determining the disposition of solid materials. In conducting this rulemaking, the NRC is guided by the goals in its Strategic Plan (NRC 2004b) of which the primary goal is ensuring the protection of public health and safety and the environment. The NRC is also seeking to avoid unnecessary regulatory burden associated with disposal of solid materials when they are no longer needed or useful at licensed facilities.

The purpose of this RA is to evaluate the benefits and costs associated with the Proposed Rule. This document presents background material, describes the objectives of the rule, outlines the alternatives considered, and evaluates the benefits and costs of the alternatives for the Proposed Rule.

### 1.1 Background

NRC initially considered a proposed rulemaking in 1999. As part of the scoping process, NRC published an Issues Paper on the Release of Solid Materials from Licensed Facilities in June 1999 in the Federal Register (64 FR 35090) (NRC 1999) and requested public comments. NRC indicated that it was examining alternatives for controlling the disposition of solid materials. NRC held four public meetings during the fall of 1999 as part of the scoping process to receive comments. Over 800 public comment letters were received during the public comment period in 1999. Comments were diverse in the views expressed, and provided a number of alternatives for controlling the disposition of solid materials.

On March 23, 2000, the NRC staff provided the Commission with a paper (SECY-00-0070) on the diversity of views expressed in public comments received on the Issues Paper. Attachment 2 of SECY-00-0070 (NRC 2000a) provides a summary of views and comments received; summaries of the comments can also be viewed in NUREG/CR-6682, “Summary and Categorization of Public Comments on the Control of Solid Materials” (September 2000) (NRC 2000b). To solicit additional input, the Commission held a public meeting on May 9, 2000, at which stakeholder groups presented their views and discussed alternatives for controlling the disposition of solid materials.

On August 18, 2000, the Commission decided to defer a final decision on whether to proceed with a rulemaking and directed the staff to request that the National Academies conduct a study of alternatives for controlling the disposition of solid materials. The Commission also directed

---

<sup>1</sup> A restricted area is any area to which access is controlled for the protection of individuals from exposure to radiation and radioactive materials. An impacted area is an area with some reasonable potential for residual radioactivity in excess of natural background or fallout levels.

the staff to continue to develop technical information and to stay informed of international and U.S. agency activities in this area.

The National Academies study of alternatives for controlling the disposition of solid materials was initiated in August 2000. As part of the study, the National Academies held three information gathering meetings in January, March, and June of 2001, at which it obtained input from various stakeholder groups. The input received was similar to that presented to the NRC earlier. Based on these meetings, and on its deliberations on this topic, the National Academies submitted a report to the NRC in March 2002 titled *The Disposition Dilemma - Controlling the Release of Solid Materials from Nuclear Regulatory Commission-Licensed Facilities* (National Research Council, 2002). The report contains findings and nine recommendations related to the decision-making process, potential approaches for controlling the disposition of solid materials, and additional technical information needs. An important finding in the National Academies report was that NRC's current approach for controlling the disposition of solid materials protects public health and does not need immediate revamping. However, the National Academies report also states that NRC's current approach is incomplete and inconsistent and concludes that NRC should therefore undertake a process to evaluate a broad range of alternatives to provide clear risk-informed direction on controlling the disposition of solid materials. The report notes that broad stakeholder involvement and participation in the NRC's decision-making process on the alternatives is critical as the process moves forward. The report also recommends that an individual dose standard of 1 mrem/yr provides a reasonable starting point for the process of considering alternatives for a dose-based standard. A link to the National Academies report is contained in the Background section of the NRC's web page on controlling the disposition of solid materials.<sup>2</sup>

Following completion of the National Academies report, the NRC staff submitted a paper to the Commission on July 15, 2002 (SECY-02-0133) (NRC 2002) which contained a set of options for proceeding with a regulatory process for examining alternatives for controlling the disposition of solid materials. Based on its review of the National Academies report and of SECY-02-0133, the Commission, **in a Staff Requirements Memorandum** dated October 25, 2002, directed the staff to proceed with an enhanced participatory rulemaking to develop specific requirements for controlling the disposition of solid materials.

On February 28, 2003, NRC published a notice in the Federal Register (68 FR 9595) (NRC 2003a) requesting comments on the scope of the proposed rulemaking and announcing its intention to prepare a GEIS to analyze alternatives for establishing requirements for controlling the disposition of solid materials. On April 18, 2003, NRC published another notice in the Federal Register (68 FR 19232) (NRC 2003b) announcing the dates and location of a public workshop to discuss the proposed rulemaking and the scoping process.

---

<sup>2</sup> <http://www.nrc.gov/materials.html>. Click on "Controlling the Disposition of Solid Materials" under "Key Issues."

## **1.2 Objectives of the Proposed Rule (Purpose and Need)**

The purpose of the Proposed Rule is to provide efficiency in regulation of the disposition of solid materials and to continue to provide control in a manner that protects public health and safety and the environment. To this end, the Commission's Proposed Rule should not impose unnecessary regulatory burdens beyond what is necessary and sufficient for providing reasonable assurance that public health and safety is protected.

The Proposed Rule is focused on controlling the disposition of solid materials from restricted or impacted areas in NRC-licensed facilities. Despite their location in these restricted or impacted areas, much of this solid material has no, or very small amounts of, radioactivity resulting from licensed operations either because the material was exposed to radioactivity in the facility to only a limited extent or because it has been cleaned. These solid materials can include furniture and ventilation ducts in buildings; metal equipment and pipes; wood, paper, and glass; laboratory materials (gloves, beakers, etc); routine trash; site fences; concrete; or soil.

Currently, radiation surveys are conducted on solid materials before they leave restricted or impacted areas of a site. Solid materials can currently be released for any unrestricted use using a set of existing guidelines that are based primarily on survey instrument capabilities. However, these levels are in NRC guidance and 10 CFR Part 20 does not currently specify the level below which the material can be released. The NRC agrees with the findings in the National Academies report regarding the need to consider modifying its current approach to provide specific direction on controlling the disposition of solid materials.

## **2.0 Identification and Analysis of Alternative Approaches**

NRC has identified a number of alternatives for controlling the disposition of solid materials. A set of preliminary alternatives for controlling the disposition of solid materials was first described in an NRC Issues Paper published for public comment in the Federal Register on June 30, 1999 (64 FR 35090) (NRC 1999). This set of preliminary alternatives was narrowed down and finalized based on input from a public scoping process.

### **2.1 Comparison of Alternatives**

NRC is studying five alternatives in detail for controlling the disposition of solid materials.

1. No Action: Retain current approach of allowing unrestricted use using measurement-based guidelines.
2. Unrestricted Release: Permit release of materials for unrestricted use if the potential dose to the public from the materials are less than a specified dose-based criterion determined during the rulemaking process.
3. EPA/State-Regulated Disposal: Dispose of all solid materials in EPA/State-regulated landfills.
4. Low-Level Waste (LLW) Disposal/Prohibition: Dispose of all solid materials in restricted or impacted areas in LLW disposal facilities. Prohibit solid material from general commerce or EPA/State-regulated landfill disposal.
5. Limited Dispositions: Permit release of materials from licensed control if the potential dose to the public from the material is less than a specified dose-based criterion determined during the rulemaking process. However, NRC would allow only certain authorized dispositions to limit the potential for public exposure.

### **2.2 No Action**

NRC requires the analysis of a No Action Alternative to provide the decisionmaker with a basis for comparison to a Proposed Rule and other reasonable alternatives. In this case, under the No Action Alternative, NRC would continue to apply its current approach to determining the eligibility of solid material for unrestricted release in general commerce or disposal. The NRC's current approach is one that employs measurement-based guidelines to determine if solid materials can be released for any use or disposal. In implementation, the provisions of license conditions and facility-specific procedures require that solid materials that have been used in restricted areas be surveyed for the presence of radioactivity before being taken out of radiologically controlled areas. Solid materials can currently be released for any unrestricted use or disposal using a set of existing NRC guidelines that are based primarily on survey instrument capabilities. Although NRC does not track release quantities if the materials meet the criteria, NRC inspectors routinely inspect a licensee's radiation protection programs and implementing procedures, which includes survey records for compliance with Part 20 and license conditions.

However, 10 CFR Part 20 does not currently specify a numerical level (e.g. dose limit) below which the material can be released. Decisions on disposition of solid materials are currently made using levels contained in a set of existing guidelines that are based primarily on the ability of survey techniques to measure the radioactivity level on, or in, the solid material. Solid material releases have been evaluated at many sites during decommissioning. Under the current case-by-case approach, NRC considers the volumes of material, exposure pathways, doses to individuals, environmental impacts, stakeholder concerns, and ALARA<sup>3</sup> issues in evaluating licensee requests.

Under the No Action Alternative, solid material released for unrestricted use may be recycled and reused in a variety of end products, or it may be sent for disposal. Disposal may take place in an EPA/State-regulated landfill or LLW disposal facility. The potential exposures and the groups of individuals subject to exposures from released materials are dependent on their final dispositions.

Disadvantages of the current case-by-case approach are (1) the lack of a consistent criteria for controlling solid materials can result in inconsistent release levels, (2) there is no guidance for volumetrically contaminated materials, (3) there have been problems when new detectors with greater sensitivity are used and low levels of radioactivity are detected in previously released material, and (4) additional time and resources are required to evaluate and implement an approach that can vary with each case.

### **2.3 Unrestricted Release**

The Unrestricted Release Alternative would allow solid materials to be released for any use in general commerce (recycling and/or reuse into consumer products and industrial and construction uses) or for disposal, if they are below a dose-based criterion. Under the Unrestricted Release Alternative, all materials to be released would undergo a radiation survey and the measured level of radiation would be compared against the criterion for unrestricted release.<sup>4</sup> Solid materials with measured radiation levels below the established criterion would be released from regulatory control for unrestricted release, while solid materials with radiation levels above the criterion would be sent to a LLW disposal site. The proposed rulemaking would include a table of radionuclide concentrations (clearance levels) corresponding to the selected dose-based criterion. In implementation, survey results would be compared to the clearance level of each radionuclide or mixture of radionuclides in demonstrating compliance with the rule. Compliance is demonstrated when the survey results are less than the applicable clearance levels. A supporting NRC document (NRC 2005a) presents the methodology by which licensees would demonstrate compliance.

Under the Unrestricted Release Alternative, solid material released for unrestricted use may follow any disposition path – it may be recycled and reused in a variety of end products, or it may be sent for disposal. Disposal may take place in an EPA/State-regulated landfill or LLW disposal

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<sup>3</sup> As Low As Reasonably Achievable.

<sup>4</sup> The term clearance is used by various organizations and in various documents to mean removal from regulatory control of material that meets certain release criteria.

facility. The potential radionuclide exposures and the groups of individuals subject to exposures from released materials are dependent on their final dispositions.

This RA considers a range of potential options for allowable dose levels for allowing the release of solid materials. The allowable dose level that NRC selects would directly impact the amount of solid material released for use in general commerce, with the amount of material released decreasing as the allowable dose criterion decreases. These dose options are:

- 0.03 mrem/yr (A zero above background dose option was modeled at 0.03 mrem/yr.)
- 0.1 mrem/yr
- 1 mrem/yr
- 10 mrem/yr
- International Atomic Energy Agency (IAEA) Safety Guide No. RS-G-1.7, “Application of the Concepts of Exclusion, Exemption, and Clearance” (IAEA, 2004); based on 1 mrem/yr.

For the first four dose options, NRC has independently assessed potential doses to individuals that could result from release of solid materials (NUREG-1640 (NRC 2003c)). For the fifth dose option, IAEA Safety Guide No. RS-G-1.7 (IAEA, 2004) was assessed. Using RS-G-1.7 for clearance levels would provide more consistency with international numeric standards. An additional international standard is the European Commission’s clearance levels. RS-G-1.7 was considered as part of this alternative because it was more recently adopted.

Under each dose option, solid materials to be released would have their level of radioactivity measured on-site by licensed facility workers (survey workers) prior to release. Those materials whose level of activity are found to be below the applicable clearance levels would be cleared for unrestricted release, including disposal in a landfill. Materials that do not meet clearance levels would be disposed of in a licensed LLW facility.

## **2.4 EPA/State-Regulated Disposal**

Under this alternative, all solid material would be sent to EPA/State-regulated landfills and would be prohibited from general commerce (recycling into consumer products and industrial and construction uses). A base case and one variation of this alternative are being considered, specifically:

1. EPA/State-Regulated Landfill (base case) – All released solid materials would be disposed of in EPA/State-regulated Resource Conservation and Recovery Act (RCRA) Subtitle D landfills. Solid materials above the dose-based criterion would be sent to a LLW disposal facility.
2. EPA/State-Regulated Trash Incineration (variation) – Trash would be incinerated at EPA/State-regulated incinerators and the ash disposed of in EPA/State-Regulated landfills. All non-trash solid materials (concrete, ferrous metal, etc.) would not be incinerated, but would be disposed of in EPA/State-regulated landfills. Solid materials above the dose-based criterion would be sent to a LLW disposal facility.

Under both the base case and the incinerator variations of this alternative, the following five dose options are being considered.

- 0.03 mrem/yr
- 0.1 mrem/yr
- 1 mrem/yr
- 10 mrem/yr
- IAEA Safety Guide No. RS-G-1.7 (1 mrem/yr)

For the first four dose options, which are based on NRC's independent analysis in NUREG-1640 (NRC 2003c), a greater amount of activity could be released to landfills than the amount that would be released to general commerce under the Unrestricted Release Alternative.

EPA regulates municipal and industrial solid waste under RCRA. Under RCRA Subtitle D, the solid waste program encourages States to develop comprehensive plans for managing non-hazardous industrial solid waste and municipal solid waste and also sets criteria for municipal solid waste landfills and other solid waste disposal facilities.

Under RCRA Subtitle C, the hazardous waste program establishes a system for controlling chemically-hazardous waste from the time it is generated until its disposal. Because NRC's current rulemaking effort focuses on materials which are at a risk level well below the chemical hazard of materials typically disposed of in Subtitle C facilities, this alternative considers only RCRA Subtitle D facilities. However, it is useful to discuss the status of EPA efforts on RCRA Subtitle C facilities. EPA is considering a rulemaking that could permit disposal of certain NRC-regulated material in a RCRA Subtitle C facility subject to, if necessary, an appropriate NRC approval process (e.g., a site-specific or general license, or exemption). EPA published an Advanced Notice of Proposed Rulemaking in the Federal Register (68 FR 65119, November 18, 2003) (EPA 2003) to solicit stakeholder input on a potential regulatory framework to permit disposal of low-activity radioactive waste, including mixed waste and other low-level waste, in RCRA Subtitle C disposal facilities. EPA is considering a wide range of allowable dose limits for materials being disposed, most of which are higher than a 1 mrem/yr dose limit. EPA is coordinating with NRC on the ANPR effort. If EPA decides to move forward with a rulemaking for Subtitle C facilities, NRC would need to take conforming regulatory action in a separate rulemaking. That effort would be different from the Proposed Rule discussed in this RA and would take place at a later time once EPA decides if it is moving forward with a rulemaking.

## **2.5 LLW Disposal/Prohibition**

Under the alternatives described in Sections 2.2-2.4, solid materials in excess of the release criteria would be sent to licensed LLW disposal facilities. However, under this alternative, also known as Prohibition, all potentially clearable solid material would be prohibited from general commerce and EPA/State-regulated landfill disposal. All solid material in restricted or impacted areas would be classified as LLW and required to be disposed of under NRC's existing regulations (10 CFR Part 61). The requirements of 10 CFR Part 61 address the siting, operation, and closure of LLW disposal facilities. Requirements in Appendix G to 10 CFR Part 20 focus on

licensees (as waste generators) and provide procedures to ship LLW wastes to such disposal sites.

There are currently three LLW disposal sites operating in the country that could accept solid material under this alternative. These facilities are:

- Envirocare - Clive, UT
- Barnwell Disposal Facility - Barnwell, SC
- Hanford Off-Site LLW Disposal Facility - Hanford, WA

The Barnwell Disposal Facility will only accept non-regional waste until 2008, at which time it will accept waste only from the Atlantic Compact States of South Carolina, New Jersey, and Connecticut, which is a relatively small subset of the total population of licensed facilities. The Hanford Off-Site LLW Disposal Facility accepts waste only from the Northwest and Rocky Mountain Compact States, which are: Washington, Oregon, Idaho, Montana, Utah, Wyoming, Nevada, Colorado, New Mexico, Alaska, and Hawaii. Because it is assumed that very little of the solid material would be eligible for disposal at the Barnwell and Hanford facilities, this alternative assumes that in the future all solid material would be sent to the Envirocare site for disposal.

## **2.6 Limited Dispositions**

In this alternative, solid material would be released from further licensed control, but NRC would allow only certain authorized dispositions to limit the potential for public exposure. All materials to be released would undergo a radiation survey and the measured level of radiation would be compared against the dose criterion for release for limited dispositions. Solid materials with measured radiation levels below the established criterion would be released for pre-approved limited dispositions, while solid materials with radiation levels above the radionuclide levels associated with a dose-based criterion would be sent to a LLW disposal facility. NRC regulations in 10 CFR Part 20 would be amended to add a dose-based regulation on limited dispositions. Any requests to release material for other than these limited end uses or at higher radionuclide concentrations than those of the Proposed Rule would require case-specific approval from NRC.

For the pre-approved dispositions, the radionuclide criterion was chosen to be a dose limit of 1 mrem/yr using the IAEA Safety Guide No. RS-G-1.7 (IAEA, 2004). A dose limit of 1 mrem/yr was chosen based on various factors, including that it is a small fraction of the public dose limit established to ensure adequate protection of public health and safety. It is also consistent with dose criteria in Federal standards for other media and is consistent with the NCRP and the National Academies recommendations. The table of radionuclide concentrations accompanying the IAEA Safety Guide are based on unrestricted release. The materials that could be released under the IAEA standard are concrete, metal and trash. It is difficult to develop a generic set of radionuclide concentrations for soil, so disposition of soil would be considered under the case-specific element of the proposed rule.

Solid material could be released if its further use would be restricted to only certain uses with limited potential for public exposure, such as use in a controlled environment. Examples include industrial uses such as metals in bridges or sewer lines, concrete use in road fill, and reuse of tools and equipment for its original purpose. Based on public comments during the scoping period, some of the possible recycling uses were not considered as pre-approved dispositions. Also, the marketplace is likely to limit the range of end-uses for the disposition of solid materials. For example, the recycling industry indicated it would be difficult to find scrap metal brokers and steels mills willing to accept and process the released materials. Although recycling of scrap metal was not considered as a pre-approved disposition, metal recycling could be considered as a case-specific application.

Based on public comments during the scoping period and on NRC's analyses of the Unrestricted Release and EPA/State-Regulated Disposal Alternatives, the only limited dispositions considered under this alternative are disposal in a RCRA Subtitle D landfill, concrete use in roadbeds, and reuse of tools and equipment for their original purpose. Licensees would need to demonstrate that doses for limited dispositions would be consistent with the dose criterion. Any requests to release material for other than these limited end uses would require case-specific approval (including the disposition of soils).

To help assure that the material releases are occurring to the pre-approved dispositions, there will be licensee recordkeeping and these activities would be evaluated periodically during routine staff inspections at licensed facilities. Also, enforcement action would be taken if necessary according to NRC regulations in 10 CFR Part 2.

The following are the components of this alternative.

**Landfills.** For landfill disposal under this alternative, the released solid materials (concrete, metal or trash) at or below the 1 mrem/yr criterion using the RS-G-1.7 standard could be disposed of in RCRA Subtitle D landfills. At this risk level, the controls associated with disposal of solid materials at RCRA Subtitle D landfills are sufficient to provide reasonable assurance of that the dose criterion of the Proposed Rule is maintained. Solid materials above the 1 mrem/yr criterion would be sent to a LLW disposal facility. As explained in Section 2.4.3 (EPA/State-Regulated Disposal Alternative), this proposed rulemaking considers only RCRA Subtitle D facilities because EPA is currently evaluating the possibility of higher dose limits at RCRA Subtitle C facilities.

Although NRC would authorize by rule disposal in a RCRA Subtitle D facility, the regulator of each RCRA facility would determine if an actual transfer to that facility will be allowed. If a specific RCRA facility is permitted by the EPA or a State agency to receive material at a projected dose greater than that in the proposed rule, disposition of such material could be considered under existing provisions of 10 CFR 20.2002.

**Concrete in Roadbeds.** Released concrete at or below the 1 mrem/yr criterion using the RS-G-1.7 standard could be recycled into roadbed material. Licensees who could demonstrate that concrete would be recycled into roadbed material could proceed with that release of material

without an initial approval of the NRC, but subject to NRC inspections in demonstrating compliance with the provisions of the rule.

**Reuse of Tools and Equipment for their Original Purpose.** A separate provision of the rule would address the reuse of tools and equipment for their original use. Tools and equipment that meet the 1 mrem/yr dose criterion using the IAEA standard could be reused. Equipment at a licensed facility includes scaffolds, cranes, trucks and office furniture. Smaller pieces of equipment and tools are used by workers and may be transported in and out of restricted/impacted areas as part of the routine conduct of work in those areas.

**Case-specific approvals.** Any request to release solid material for other than these limited dispositions or releases at higher radionuclide concentrations would require case-specific approval from NRC. For these requests, NRC would codify the process and the criteria for licensees to seek case-specific approvals under a license amendment request. The licensee would also be required to submit environmental information for the proposed action. The Proposed Rule would identify the requirements that licensees need to observe in preparing and submitting such requests. It is expected that such applications would address limited end-uses for types and amounts of materials. For example, some types of structural steel may be reused for the construction of a framework for warehouses. For soils, materials may be used as backfill or as bedding in pipe trenches. For soil-like materials with cementitious properties, materials may be used as an additive to concrete in industrial settings, such as building footings and foundations or equipment pedestals. A licensee seeking release of solid material for some limited end use would be required to request approval based on pathways, worker protection, future uses, etc. A licensee would have to provide reasonable assurance that such materials are kept out of disposition paths that are not allowed and would have to submit a dose assessment to NRC for a case-specific disposition application.

**Recordkeeping.** As part of its Proposed Rule, the NRC would include a requirement for records maintenance. These records would aid in allowing verification that the dose criterion has been met and provide reasonable assurance that the material was delivered to one of the allowed destinations. Licensees would be required to maintain records indicating the nature of the material released (i.e., type and quantity of solid material, and nuclides present and their concentrations) and its destination (i.e., the landfill or specific end use shipped to, etc.). For tools and equipment released from restricted/impacted areas as part of the routine conduct of business, records would be kept of the specific tool or equipment removed from the restricted/impacted area and the nuclide level of the item.

In summary, the limited dispositions for each material are as follows:

- Concrete could be disposed of in a RCRA Subtitle D landfill or recycled into roadbed material.
- Metals could be disposed of in a RCRA Subtitle D landfill.
- Tools and equipment could be disposed of in a RCRA Subtitle D landfill or could be reused.

- Trash could be disposed in a RCRA Subtitle D landfill.
- Disposition of soils would be case-specific.
- Any other disposition of these materials or disposition in landfills at higher radionuclide concentrations would require case-specific approval by NRC.

### 3.0 Analysis of Values and Impacts

This chapter examines the values (benefits) and impacts (costs) expected to result from NRC's Proposed Rule and its alternatives. The cost-benefit analysis sets forth the various economic benefits and costs of the alternatives under consideration, including environmental benefits. Benefits and costs are assessed at the national level. Section 3.1 presents the affected attributes. Section 3.2 presents the methodology for calculating the benefits and costs associated with each attribute, and Section 3.3 presents the results.

#### 3.1 Identification of Affected Attributes

This section identifies the factors within the public and private sectors that the alternatives are expected to affect. These factors are classified as "attributes" using the list of potential attributes provided by NRC in Chapter 5 of its *Regulatory Analysis Technical Evaluation Handbook* (NRC 1997).

- ***Environmental Considerations.*** For each alternative, air emissions could be affected by the number of vehicle miles traveled and/or the relative production of new versus recycled materials (i.e., ferrous metal, copper, aluminum).
- ***Industry Operation.*** Industry may incur operational costs or savings related to surveys, transportation of either LLW or released material, disposal as either LLW or released material, and recycling fees or revenues for released material.
- ***Public Health (Routine).*** The dose to the public associated with release levels or released materials may increase or decrease as a result of the alternatives. The dose is monetized using a value of \$2,000 per person rem.
- ***Occupational Health (Routine).*** The dose to workers associated with release levels or released materials may increase or decrease as a result of the alternatives. The dose is monetized using a value of \$2,000 per person rem.
- ***Public Health (Accidental).*** The number of driver fatalities associated with accidents may be affected by changes in the number of vehicle miles traveled. Fatalities are monetized using a value of \$3 million per fatality.
- ***Industry Implementation.*** One-time costs or savings may result from incremental activities such as reading the regulations and guidance documents; training employees on new procedures; capital outlays for equipment; increased recordkeeping if required; and researching markets and vendors for released material.
- ***NRC Implementation.*** The NRC may incur an incremental staff burden to conduct the following implementation tasks: develop guidance, procedures, and aids for use by NRC; develop enforcement procedures; and develop guidance, procedures, and aids for use by licensees.

- ***NRC Operation.*** The NRC may incur an annual incremental staff burden to conduct inspections, evaluate licensee compliance, and enforcement activities.
- ***Other Government.*** Other government costs could include costs related to rulemakings in Agreement States. (This excludes facilities that are assumed to be covered under the industry operation and industry implementation attributes, such as DOE and DoD facilities.)
- ***Regulatory Efficiency.*** The alternatives will result in benefits associated with the streamlining of procedures compared with baseline (current) procedures.
- ***Other Considerations.*** Public confidence in NRC may be affected by the outcome of this action.

The following attributes are not expected to be affected:

- Occupational Health (Accidental),
- Offsite Property,
- Onsite Property,
- General Public,
- Improvements in Knowledge,
- Antitrust Considerations, and
- Safeguards and Security Considerations.

### **3.2 Analytical Methodology**

This section presents the methodology for calculating the values (benefits) and impacts (costs) associated with each of the affected attributes. An in-house model was developed which draws upon input data including inventory quantities and dose estimates from SC&A 2003, survey costs from NRC 2004a, and various unit cost factors described in this appendix. SC&A 2003 presented data broken out by year. Consequently, the model calculates the costs in each year in which material is assumed to be released and then calculates the net present value for each alternative considered in 2003 dollars.

For a given alternative, the costs and benefits within each attribute are driven by the quantities of materials generated for release, the different types of licensees, the different types of materials, and the assumed life cycle of materials generated for release. The benefits include any desirable changes in affected attributes (e.g., improved safety, monetary savings) while the costs include any undesirable changes in affected attributes (e.g., increased radiological exposures, monetary costs). The net benefit for each alternative is the difference between the sum of the benefits of all attributes and the sum of the costs of all attributes.

With two exceptions (i.e., regulatory efficiency and other considerations), this analysis evaluates all attributes quantitatively.<sup>5</sup> Quantitative analysis requires a baseline characterization of factors such as the number of affected facilities, the quantities of material generated, the rate and time over which the materials are generated, cost information, and a range of other factors.

### 3.2.1 Scope of the Cost-Benefit Analysis

Ideally, the cost-benefit analysis should analyze each of the following:

- The five rule alternatives under consideration:
  1. No Action
  2. Unrestricted Release
    - < Material-specific limits
    - < Material-independent limits
  3. EPA/State-Regulated Disposal
    - < RCRA Subtitle D Landfill Disposal without Incineration
    - < Disposal with Trash Incineration
  4. LLW Disposal
  5. Limited Dispositions
  
- The five dose options (for the dose-specific alternatives):
  - 0.03 mrem/yr;
  - 0.1 mrem/yr;
  - 1.0 mrem/yr;
  - 10.0 mrem/yr; and
  - IAEA Safety Guide No. RS-G-1.7.
  
- All facility types:
  - Light water reactors (LWRs);
  - Independent spent fuel storage installations (ISFSIs);
  - Research reactors;
  - Facilities included in the site decommissioning management plan (SDMP);
  - Fuel cycle facilities; and
  - Other materials licensees including, but not limited to medical, academic, industrial, source, and special nuclear licensees.
  
- All affected materials:
  - Ferrous Metal;

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<sup>5</sup> A third attribute, environmental considerations, is evaluated partly quantitatively and partly qualitatively.

- Concrete;
- Copper;
- Aluminum;
- Equipment, and
- Trash.

Due to the broad scope of this Draft RA and limited data availability, not all facility types and materials could be evaluated for all rule alternatives. Nevertheless, the analysis captures a substantial majority of material (i.e., items) and activity (i.e., radioactivity) that could be released, as well as the resulting dose.

### **Alternatives/Dose Options Considered**

The cost-benefit analysis addresses all of the alternatives under consideration. For the dose-specific alternatives (i.e., Unrestricted Release and EPA/State-Regulated Disposal), all five dose options are evaluated.

### **Materials/Facilities Covered**

This analysis quantitatively addresses LWRs for ferrous metals, concrete, and trash. Inventory information on other metals, besides ferrous metal, indicated these were primarily copper or aluminum, and there is a small amount of these materials generated as compared to ferrous metal. The results of a screening analysis indicated that collective doses for copper and aluminum are about one to two orders of magnitude lower than that of ferrous metals. Consequently, these materials were not included in the cost-benefit analysis. Since data on the type and quantity of tools and equipment available for reuse and the frequency at which they are being released were not available, equipment reuse was not included in the cost-benefit analysis, but a scoping assessment of collective doses is presented in Appendix D, Section 12 of the Draft GEIS (NRC 2005b).

### **3.2.2 Data and Assumptions**

This analysis draws on data regarding material quantities, doses, and survey costs that were developed in the *Collective Dose Assessment* (SC&A, 2003) and the *Clearance Survey Cost Report* (NRC 2004a), prepared under technical basis contracts for NRC. Some additional information was collected during the development of this RA.

The analysis measures the incremental impacts of each alternative relative to a baseline, which is how things would be if the alternative were not imposed (i.e., the No Action Alternative). The baseline used in this analysis assumes full licensee compliance with existing NRC requirements, including current regulations. This is consistent with the *Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission* which states that, "...in evaluating a new requirement for existing plants, the staff should assume that all existing NRC and Agreement State requirements have been implemented" (NRC 2000c). Unless otherwise noted, all costs and savings estimates reflect this baseline.

Exhibit 1 depicts the life cycle of materials generated for disposal or release for the Unrestricted Release Alternative. In the other alternatives, one or more of the pathways may not be allowed. The analysis is driven by how materials flow through the different paths of the life cycle. The main decision points in the life cycle flow path determination are (1) whether the material potentially contains residual radioactivity; (2) whether the material is below the release level; (3) whether disposal is less costly than decontamination and release; and (4) whether cost effective recycling is available for the material. Exhibit 1 also shows the four possible endpoints for materials that have residual radioactivity that have been released: reuse of equipment, on-site disposal, off-site disposal, and recycling for use in new products.<sup>6</sup>

For each of the alternatives and each of the materials, the analysis assumed that released materials will be recycled, reused, or sent to a municipal solid waste (MSW) landfill or incinerator, and that materials not meeting the clearance levels will be sent to a LLW facility for disposal. This analysis assumes economic rationality (i.e., least cost behavior) on the part of all entities affected by the rule. For example, under the Unrestricted Release Alternative, in which ferrous metal could be recycled, this analysis assumes that ferrous metal will only be recycled if it is more profitable (or less costly) to recycle ferrous metal than to dispose of it. Similarly, the costs associated with a MSW incinerator are greater than those associated with an MSW landfill due to transport and disposal costs. Therefore, this analysis assumes that facilities will not choose to send their trash to an MSW incinerator, even if allowed to do so, and instead will dispose of their trash in a MSW landfill. Consequently, the costs and benefits of EPA/State-regulated trash incineration are the same as the RCRA Subtitle D Landfill Alternative. Table 3-1 summarizes the assumptions made about how materials are managed in the baseline and in each alternative under consideration.

**Table 3-1: Assumed Disposition of Material under Baseline and Alternatives**

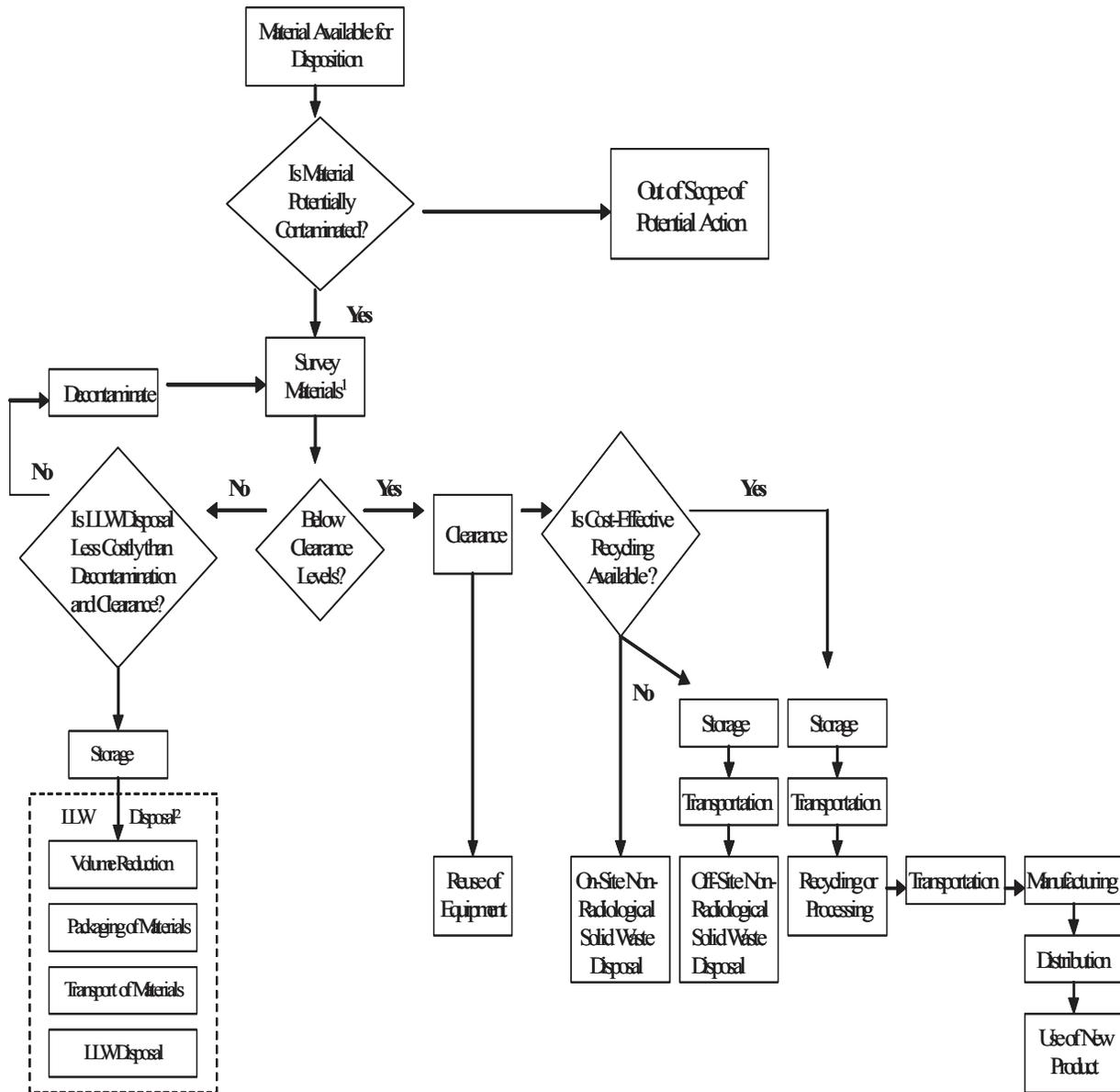
<b>Alternative</b>	<b>Concrete</b>	<b>Ferrous metal</b>	<b>Trash</b>
Baseline/ No Action	Recycled	Recycled	MSW Landfill
Unrestricted Release	Recycled	Recycled	MSW Landfill
EPA/State-Regulated Landfill Disposal	MSW Landfill	MSW Landfill	MSW Landfill
LLW Disposal	LLW	LLW	LLW
Limited Dispositions	Recycled*	MSW Landfill	MSW Landfill

MSW = municipal solid waste; LLW = low-level waste

\* Concrete would be released at or below the 1 mrem/yr criterion and could be recycled into roadbed material.

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<sup>6</sup> On-site disposal is not considered here. Doses from the on-site landfill would be included in the dose analysis conducted in a licensee's decommissioning analysis. Reuse of equipment is considered qualitatively because data on amount of equipment that would be available for reuse were not available.



1 Survey may include knowledge of where material was located and/or measurement of radioactivity levels.

2 Material can be disposed of under other NRC regulations, such as 10 CFR Subpart K §20.2002.

### Exhibit 1: Generalized Material Life Cycle for Potentially Cleared Materials

The analysis also assumes it will not be cost effective to decontaminate and resurvey any material that is not clearable based on the initial survey. Such material is assumed to be sent for disposal at a LLW facility. Additionally, recycling fees and/or revenues from recycling only are calculated for the first recipient of the material (e.g., a scrap yard) because after that point, the material has been “released.”<sup>7</sup>

<sup>7</sup> In contrast, dose is calculated through end users.

The time frame for which costs are estimated differs based on the remaining operating life of the relevant LWRs. For the analysis as a whole, however, costs and savings are estimated over approximately 47 years, with each year's costs and savings discounted back to the present at both a seven- and a three-percent discount rate, in accordance with NUREG/BR-0184 (NRC 1997) and OMB Circular A-4. The 47-year period encompasses the planned shutdown dates and subsequent decommissioning of all LWRs. Dose is estimated for 300 years, because the dose will not cease at the end of 47 years. In fact, dose will continue after 300 years, however, after that point, dose becomes negligible in the cost-benefit analysis.

Further, the current and future cost of disposal and other disposal options are assumed to equal the current applicable disposal fee. It is possible that new disposal capacity will be required, or required earlier, as a result of some alternatives of this rule. If new disposal facilities are constructed, it is possible that disposal costs will change as a result. To address the uncertainty of LLW disposal costs, which are a major cost driver, this analysis conducts a sensitivity analysis that considers the effect of a 15 percent increase in disposal costs effective in the year 2020. A second sensitivity analysis was performed to assess the impact of transportation costs on the overall benefits and costs of the alternatives. In the main analysis all material was assumed to be shipped by truck. However, given the long distances that are involved in transporting material to LLW disposal facilities (1,544 miles on average), a sensitivity analysis was run in which all material being shipped to LLW facilities was shipped by rail. Section 3.3.7 presents the results of these sensitivity analyses.

### **3.2.3 Attribute Methodology Introduction**

The methodology for analyzing the cost and benefits of the 11 affected attributes is discussed in the following subsections. Each subsection describes the attribute and presents the equations that were used to analyze the attribute. These subsections also present data on unit costs and major assumptions used in evaluating each attribute. The methodology for calculating the environmental considerations attribute has a detailed discussion because the calculations were complex. For the other attributes, one or more equations are included followed by a table that contains the definition of the equation's parameters. Some of the attributes are partitioned into "sub-attributes" where more detailed analysis is required.

These equations present the cost or benefit in a given year for material being cleared from light water reactors. While other types of facilities are affected by this rule, sufficient information was not available to calculate quantitative costs or benefits for these other types of facilities. The costs and benefits are calculated for each year in the analysis time horizon (2003-2049), converted to present value and summed to calculate the net present value (in \$2003), as described in Section 3.2.15.

To determine the incremental benefit or cost relative to the baseline (No Action), the analysis subtracts the baseline benefits or costs from each alternative's benefits or cost. Negative results indicated net costs, while positive results indicate net benefits. The incremental costs associated with the No Action Alternative would be zero (because there is no change relative to the baseline). All unit costs are presented as negative numbers in the tables and assumptions following the equations, under the description where the numerical value of the cost is presented.

The unit costs for the analysis are given in the format of a negative number so that the result of the equations, when calculated using numbers, yield the appropriate value indicating whether the alternative results in a net benefit or cost for that attribute.

### **3.2.4 Attribute - Environmental Considerations**

This section discusses the methodology for calculating the environmental benefits of the rule under each alternative. Most of the incremental environmental benefits are expected to result from air emissions avoided as a result of changes in transportation destinations and increases in recycling (i.e., reductions in manufacturing using virgin materials) due to clearance of additional materials. This section provides a detailed analysis of these benefits for structural ferrous metal, concrete, and trash. Due to data limitations and the small total volume of materials, the analysis presents discussions of the benefits associated with the reuse of aluminum and copper products in aggregate terms without the level of detail for the other materials.

The environmental benefits due to changes in transportation needs, which cause changes in air emissions, are calculated for the relevant solid materials by multiplying the changes in net miles (i.e., miles traveled under a specific alternative minus miles traveled under the baseline) by the appropriate emission factors for different pollutants and different transportation modes. These air emission changes are then monetized by multiplying by the price per ton for each pollutant. Aggregate environmental benefit estimates are then derived by summing over four pollutants (Sulfur Dioxide (SO<sub>2</sub>), Nitrogen Oxides (NO<sub>x</sub>), Particulate Matter (PM), and Carbon Dioxide (CO<sub>2</sub>)).

Similarly, environmental benefits caused by changes in manufacturing needs for the relevant materials are calculated by multiplying the changes in the amount of recyclable material that are estimated to be released under this rule by the appropriate emission factors for relevant pollutants. Again, to monetize these benefits, total emission changes are multiplied by the price per ton for each pollutant. Finally, aggregate environmental benefits are derived by summing over the four pollutants.

Note that the overall methodology described above, while appropriate, has not been applied for all the different materials released under this rule. For example, environmental benefits due to recycling of released concrete are not expected to be significant and therefore, have been left out of the analysis. Sections 3.2.4.1 through 3.2.4.5 discuss the estimation of environmental benefits in detail for each material.

The quantities of materials released under this rule are not expected to be large enough to have a disruptive effect on the current market conditions, in terms of its impact on the recycling rates or the current demand/supply conditions. For example, the ferrous metal industry is likely to have the largest potential impact from recycling scrap ferrous metal as a result of this proposed rule. The net amount of scrap ferrous metal salvaged under the rulemaking alternatives (i.e., the amount salvaged relative to the No Action Alternative) would range between a maximum increase of 0.03 million tons and a maximum decrease of 0.13 million tons annually. According to the most recent data, annual U.S. production of ferrous metal is approximately 100 million tons. This means that the changes in ferrous metal scrap due to this rule would be approximately a tenth of a percent of the total U.S. ferrous metal market and therefore not expected to have any

significant disruptions. Section 3.2.4.1 presents a brief discussion of the market share analysis for ferrous metal.

### **3.2.4.1 Ferrous Metal**

Under the Unrestricted Release Alternative, the most significant environmental benefit is the recycling of ferrous metal released under this rule, which means less virgin ferrous metal is produced.<sup>8</sup> Virgin ferrous metal is produced in integrated ferrous metal mills using a three-step process that involves cokemaking, ironmaking, and Basic Oxygen Furnace (BOF) technology. Cokemaking and ironmaking processes have the greatest impact on the environment because large quantities of SO<sub>2</sub>, NO<sub>x</sub>, PM, and CO<sub>2</sub> are emitted. Electric Arc Furnace (EAF) facilities, often referred to as minimills, use up to 100 percent of scrap metal to produce ferrous metal. EAF technology does not require cokemaking and ironmaking processes. As a result, minimills emit less SO<sub>2</sub>, NO<sub>x</sub>, PM, and CO<sub>2</sub> per unit of output relative to integrated mills.

Under the EPA-Regulated Disposal Alternative, which prohibits recycling, environmental benefits result primarily from a reduction in the amount of fuel burned compared to the LLW Disposal Alternative. Less fuel is used because fewer vehicle miles are traveled (MSW landfills are located closer to NRC-licensed facilities than LLW facilities).

The following two sections explain the methodology for estimating environmental benefits in transportation and ferrous metal manufacturing sectors.

#### ***Benefits Due to Transportation Changes***

The analysis calculates the change in air emissions by multiplying the net miles traveled by the corresponding emission factors for different pollutants. The following section explains how the emission factors are derived.

Based on the geographic location of NRC-licensed facilities relative to rail and highway infrastructure, the analysis assumes that ferrous metal scrap is transported by trucks. Depending on the alternative, one-way haul distances range from approximately 60 miles to over 1,500 miles. Given the range of haul distances, the analysis assumes that both short- and long-haul trucks transport ferrous metal scrap from NRC-licensed facilities. For the purpose of this analysis, long-haul trucks are characterized as: (1) class 8b heavy-duty diesel trucks; (2) trucks traveling long distances (greater than 200 miles from their home base); and (3) trucks traveling at higher speeds over longer distances. Short-haul trucks are characterized as: (1) class 8b heavy-duty diesel trucks; (2) trucks traveling less than 200 miles from their home base; and (3) trucks operating mostly in urban areas.

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<sup>8</sup> The ferrous metal industry has stated that it will not reprocess scrap ferrous metal with residual radioactivity. If true, this would substantially reduce the rule's environmental benefits. This analysis, however, assumes that recyclable ferrous metal will be recycled because it is not clear from available information how the steel industry views released steel. It is possible that it is currently being released and disposed, rather than released and recycled.

The air emissions standards for short- and long-haul trucks are expected to change over the period covered by this analysis. Therefore, the study models emission factors assuming that, on average, every five years a new standard for on-road vehicle emissions would be established. Thus, the standard established in 2003 would stay in effect until 2009 and a new standard would be established in 2010. This new standard would be applicable in 2010 and would stay in effect until 2014. The emission factors are not modeled past 2030 to avoid excessive speculation. Therefore, the standard established in 2030 is assumed to stay in effect until 2049. Fleet age and replacement also influence these factors, accounting for the increases seen in the CO<sub>2</sub> emission factors. The emission factors by pollutant for long-haul and short-haul trucks are presented in Tables 3-2 and 3-3, respectively.

**Table 3-2 Emission Factors (in grams/mile) for Long-Haul Trucks**

Year	SO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>	CO <sub>2</sub>
2003	0.3440	27.919	0.3096	1615.2
2010	0.0110	9.720	0.1471	1611.6
2015	0.0110	2.612	0.0910	1613.0
2020	0.0110	1.235	0.0779	1613.4
2025	0.0110	0.997	0.0770	1613.5
2030	0.0110	0.960	0.0767	1613.5

**Table 3-3 Emission Factors (in grams/mile) for Short-Haul Trucks**

Year	SO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>	CO <sub>2</sub>
2003	0.3557	25.779	0.6184	1665.2
2010	0.0111	13.765	0.2599	1617.6
2015	0.0110	6.394	0.1591	1612.1
2020	0.0110	2.737	0.0989	1612.6
2025	0.0110	1.143	0.0836	1613.2
2030	0.0110	0.702	0.0781	1613.4

Source: ICF Analyses using EPA MOBILE 6.2 emissions factor model and 1997 Vehicle Inventory and Use Survey (VIUS).

### ***Benefits Due to Manufacturing Changes***

Although this analysis assumes no significant disruptions to the ferrous metal market as a result of the rule (see market share analysis presented below), the slight change in the market price of ferrous metal is important to the analysis of virgin ferrous metal displacement. The ferrous metal market consists of ferrous metal products made from iron ore (i.e., using BOF technology) and those made from scrap (i.e., using EAF technology). Under the Unrestricted Release Alternative, the supply of ferrous metal products made from scrap would increase. The increase in the supply of ferrous metal made from scrap would ultimately lead to an overall increase in the supply of all ferrous metal. Based on the economic principles of supply and demand, this would cause the price of ferrous metal to decrease slightly.<sup>9</sup> The slight drop in the price of ferrous metal is

<sup>9</sup> Assuming that the demand for ferrous metal is downward sloping and the supply of ferrous metal is upward sloping, the magnitude of the price change would depend on the elasticities of the supply and

expected to lead to a slight increase in quantity demanded for ferrous metal. In addition, the quantity supplied of virgin ferrous metal is expected to decrease slightly as a result of the decrease in the market price of ferrous metal.

The general approach used in this analysis is to estimate the quantity of ferrous metal scrap that would be recycled under each regulatory alternative relative to the baseline, determine the quantity of domestic virgin ferrous metal that would be displaced, derive emission factors for each pollutant emitted in the production of virgin ferrous metal, and then multiply emission factors by quantity of virgin ferrous metal displaced.

The industry data indicate that minimills use, on average, 1.07 kilograms of scrap to produce 1 kilogram of ferrous metal (IISI 2002). The study uses this ratio of scrap to ferrous metal to estimate the amount of ferrous metal that would be produced from licensees' scrap. As previously explained, the increase in the supply of ferrous metal made from NRC scrap would cause a slight decrease in the price of ferrous metal and, in turn, increase the quantity of ferrous metal demanded. In order to estimate how much of the ferrous metal would be replaced by the ferrous metal made from scrap generated by this rule, the study makes a simplifying assumption that the elasticities of supply and demand are equal. Under this assumption, an increase of one million ton in the supply of ferrous metal products made from ferrous metal scrap (released by licensees) generated by this rule would result in 0.5 million ton increase in quantity demanded of ferrous metal, and 0.5 million ton decrease in the quantity supplied of ferrous metal (both virgin ferrous metal and ferrous metal made from scrap). The assumed decreased supply of scrap metal would not be limited to material not generated by this rule. It is assumed that the decrease in supply could be from scrap generated by this rule or scrap not generated by this rule. This assumption is based on the idea that once the scrap metal enters the market, it becomes part of the total scrap market and no differentiation is made as to whether it was generated as a result of the rule or not.

The quantity of virgin ferrous metal consumed domestically is supplied by both domestic and foreign producers. The analysis, however, focuses only on air emissions avoided through the displacement of domestic virgin ferrous metal. In reality, CO<sub>2</sub> does have trans-boundary implications. Estimating the increase in ambient concentration of CO<sub>2</sub> in the US resulting from foreign production of virgin ferrous metal is, however, beyond the scope of this analysis.

To understand how much of domestic virgin ferrous metal can be replaced with the scrap generated by this rule under various alternatives, the study first estimates the share of virgin ferrous metal in the total domestic consumption of ferrous metal, and then calculates the share of US virgin ferrous metal consumed domestically.

The average annual US production of ferrous metal is 98 million tons (for the period 1997-2001), with 53 million tons of ferrous metal products produced using iron ore (i.e, virgin ferrous metal using BOF technology). In order to account properly for air emissions in manufacturing of virgin ferrous metal, the study assumes that all of the U.S. virgin ferrous metal is consumed

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demand of ferrous metal. Although the price change estimation is beyond the scope of this analysis, the change in price is not expected to be significant as the increase in supply is relatively small.

domestically. Therefore, for the purpose of this analysis, the U.S. consumption of virgin ferrous metal is equal to the U.S. production of virgin ferrous metal plus the U.S. imports of virgin ferrous metal. Based on the estimated amount of foreign virgin ferrous metal imported annually, the estimated total amount of virgin ferrous metal available for domestic consumption is 77 million tons per year.<sup>10</sup>

The next step in the analysis is to estimate the share of domestic virgin ferrous metal in the U.S. consumption of ferrous metal. The U.S. Geological Survey (USGS) data for 1997-2001 (USGS 2004c; USGS 2004d) indicate that the average annual U.S. consumption of ferrous metal is approximately 117 million tons. Based on the study estimates presented above, virgin ferrous metal products account for 66 percent of the total ferrous metal consumption in the U.S. (77 million tons / 117 million tons = 66 percent). Out of 77 million tons of virgin ferrous metal products consumed domestically, 53 million tons, or 69 percent, is produced domestically. Therefore, to derive the amount of domestic virgin ferrous metal displaced, the study first multiplies the total quantity of ferrous metal displaced by 0.66 to derive the amount of virgin ferrous metal displaced in the domestic consumption, and then by 0.69 to calculate the amount of domestic virgin ferrous metal displaced.

As stated previously, virgin ferrous metal production includes cokemaking and ironmaking processes. These two processes are not required when using EAF technology (i.e., when making ferrous metal products from ferrous metal scrap). The industry data indicate that the production of ferrous metal by BOF technology requires about 0.7 tons of pig iron and between 0.35 and 0.65 tons of coke (DOE 2000; IISI 2002). The study uses these factors to estimate the amount of pig iron and coke required to produce the amount of domestic virgin ferrous metal that would be displaced by the NRC ferrous metal scrap.<sup>11</sup>

The next step in the analysis is to estimate the total amount of emissions avoided through the displacement of domestic virgin ferrous metal. The analysis uses the emission factors for the iron and ferrous metal industry derived by DOE (DOE 2000). The emission factors are presented in Table 3-4.

To estimate the total amount of emissions avoided, the study multiplies the emission factors by the amount of coke and pig iron saved through recycling of NRC ferrous metal scrap.

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<sup>10</sup> Using the USGS data for 1997-2001, the study estimates that approximately 75 percent of the world production of ferrous metal is produced from virgin ferrous metal (i.e., using BOF technology). The study then assumes that 75 percent of the ferrous metal products imported by the U.S. are made from virgin ferrous metal. The analysis estimates that out of 32 million tons of ferrous metal imported annually, approximately 24 million tons are virgin ferrous metal products (32 million tons \* 75 percent = 24 million tons). Based on the estimated amount of imported virgin ferrous metal, the total amount of virgin ferrous metal available for domestic consumption is 77 million tons per year (53 million tons + 24 million tons = 77 million tons).

<sup>11</sup> Using the mid point of the 0.36-0.65 range yields an average ratio of coke to ferrous metal of 0.5.

**Table 3-4 Emission Factors for Criteria Pollutants by Ferrous Metallmaking Process**

Process	Units	SO <sub>2</sub>	NO <sub>x</sub>	PM	CO <sub>2</sub>
Integrated Mills					
<b>Cokemaking</b>	lbs/ton of coke	4.1	0.98	1.374	389.17
<b>Ironmaking</b>	lbs/ton of ferrous metal	26.47	10.27	7.624	2,000.0

Source: DOE.

### *Data on Pollutant Prices*

The study estimates the monetary value of environmental benefits by multiplying the estimated net emissions by the estimated allowance price for each pollutant. Under competitive market conditions, allowance prices are expected to provide the estimated monetary value for reducing a unit of the relevant pollutant. For SO<sub>2</sub> and NO<sub>x</sub>, allowance prices used are based on EPA's projections for 2006 to 2020 for the proposed multi-pollutant scenario, known as the Clear Skies Act found in ICF Consulting's Integrated Planning Model (an analytical model designed to evaluate various aspects of electric power production, including air pollution). Allowance prices for SO<sub>2</sub> and NO<sub>x</sub> used in this analysis are as shown in Table 3-5.

**Table 3-5 Allowance Prices for SO<sub>2</sub> and NO<sub>x</sub>**

Year	SO <sub>2</sub> (\$/ton)	NO <sub>x</sub> (\$/ton)
<b>2006</b>	493	1844
<b>2010</b>	605	1,063
<b>2015</b>	785	1,081
<b>2020</b>	1,018	1,402

Note that the prices were not estimated past 2020 to avoid speculation. For the years past 2020, the estimated allowance price for 2020 is used.

For particulate matter and CO<sub>2</sub>, this study uses the 1990 Pace University Study (Ottinger et al. 1990)<sup>12</sup> estimate of \$3,516 per ton of particulate matter and \$20 per ton of CO<sub>2</sub>. The Pace study, prepared for the New York State Energy Research and Development Authority and DOE examines the environmental costs associated with a variety of energy sources and environmental effects (e.g., air pollution, global warming, land use).

<sup>12</sup> Reproduced from U.S. Congress, Office of Technology Assessment, Studies of the Environmental Costs of Electricity, OTA-ETI-134 (Washington, DC: U.S. Government Printing Office, September 1994, page 24).

### **3.2.4.2 Concrete**

#### ***Benefits Due to Transportation Changes***

Most of the incremental environmental benefits would be provided through reduction in fuel burned by decreasing haul distances. The study used the same methodology for estimating environmental benefits from the change in air emissions as presented above for ferrous metal.

#### ***Benefits Due to Manufacturing Changes***

Recycled concrete is used in place of virgin aggregate primarily as road base material. The analysis assumes that concrete cleared from NRC-licensed facilities would be used in the same capacity. The available publications on concrete recycling, however, do not indicate that there are considerable environmental benefits in terms of emissions avoided from using recycled concrete, instead of virgin aggregate, in road construction (DOT 2003). Therefore, the study does not estimate environmental benefits from recycling of concrete.

### **3.2.4.3 Trash**

#### ***Benefits Due to Transportation Changes***

Under both the Unrestricted Release and EPA-Regulated Disposal Alternatives, trash from NRC-licensed facilities would be disposed in MSW landfills or low-level waste facilities. Trash would not be recycled or used for any purpose that would yield environmental benefits. The type and location of permitted landfills, however, would vary depending on the alternative. Thus, some environmental benefits would be provided through reduction in fuel burned by decreasing the distances that material is hauled. The study uses the same methodology for estimating environmental benefits from the change in air emissions as presented above for ferrous metal. For the EPA-Regulated Disposal Alternative, no incineration of trash is expected because it is less expensive to send material to an MSW landfill for disposal.

### **3.2.4.4 Copper**

This analysis presents a brief discussion of the environmental benefits from recycling copper. The analysis is constrained by the lack of detailed data on the quantity of copper expected to be recycled due to this rule. SC&A 2003 estimates there are about 6,584 tons of potentially clearable copper; this is about one-quarter percent of the total mass of ferrous metals (which is about 2.4 million tons). Also, lack of detailed annual estimates of potentially clearable copper for different alternatives precludes estimating incremental environmental benefits due to this rule (i.e., benefits over a No Action “baseline”). However, copper is a valuable material and any quantity generated by this rule can be expected to be recycled with tangible environmental benefits, since recycling copper is generally considered less energy-intensive than producing

copper from ore.<sup>13</sup> Given the limitations of the data, this analysis does not quantify this environmental benefit.

### **3.2.4.5 Aluminum**

SC&A 2003 estimates there are about 212 tons of potentially clearable aluminum from decommissioning all licensed facilities; this is about a tenth of a percent of the total mass of ferrous metals.<sup>14</sup> Again, because of data limitations, this analysis does not attempt to quantify the incremental environmental benefits from this amount, but notes that the environmental benefit from this small amount of aluminum can be expected to be finite but less than that for copper.

### **3.2.4.6 Market Share Analysis**

This section provides a market share analysis for ferrous metal, copper, and aluminum. The analysis provides a description of the effects that the proposed action could have on the market for these metals, if any.

#### *Ferrous metal*

In the period 1997-2001, U.S. production of ferrous metal was, on average, almost 100 million metric tons. Approximately 54 percent of ferrous metal products were produced from virgin materials such as iron ore and coal using BOF technology. The remainder, 46 percent, was produced from ferrous metal scrap in EAF facilities. These data show that the U.S. ferrous metal industry already has a high recycling rate. The rate is expected to increase under the Unrestricted Release Alternative. Although most of the U.S. demand is satisfied through domestic production, ferrous metal imports account for 25 to 30 percent of annual consumption of ferrous metal. The summary statistics for the U.S. iron and ferrous metal industry are presented in Table 3-6 (USGS 2004c; USGS 2004d).

The net amount of scrap salvaged under the alternatives (i.e., the amount salvaged relative to the base case) would range between a maximum increase of 0.03 million tons to a maximum decrease of 0.13 million tons annually, or between 0.03 percent and 0.13 percent of the annual consumption, respectively. These quantities are relatively small compared to the total amount of ferrous metal products consumed annually. Therefore, the rule is not expected to cause any significant disruptions to the U.S. market for ferrous metal.

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<sup>13</sup> See for example, “The Life Cycle of Copper, its Co-Products and By-Products,” International Institute for Environment and Development (IIED), 2002.

<sup>14</sup> *Ibid.*

**Table 3-6 U.S. Iron and Ferrous Metal Industry Summary Statistics from USGS  
(in million metric tons of metal)**

	1997	1998	1999	2000	2001 <sup>1</sup>
Pig Iron Production	49.6	48.2	46.3	47.9	44.2
Ferrous Metal Production	98.5	98.6	97.4	102	92.9
Basic Oxygen Furnaces	55.4	54.1	52.3	54.1	49.4
Electric Arc Furnaces	43.1	44.5	45.1	47.9	43.5
Imports of Ferrous Metal Mill Products	28.3	37.7	32.4	34.4	26.2
Exports of Ferrous Metal Mill Products	5.5	5.0	4.9	5.9	5.6
Apparent Ferrous Metal Consumption <sup>2</sup>	114	118	116	119	118

<sup>1</sup> Estimated values.

<sup>2</sup> Apparent consumption = production + imports – exports + adjustment for industry stock changes + adjustment for imports of semi-finished ferrous metal products.

Source: USGS 2004c, USGS 2004d

### *Copper*

In the period 1997-2001, average annual U.S. production of copper was almost 3 million metric tons. Approximately 63 percent of copper products were produced from virgin materials such as ore, concentrate, or precipitate. The remaining 37 percent was produced from old scrap (secondary production), new scrap, or refinery scrap. Old scrap refers to obsolete or discarded end-use items that are recycled. New scrap represents the copper that is recovered from scrap generated during manufacturing (e.g., stampings, defective parts, etc.), and returned to smelters, refineries, or mills for reprocessing. Refinery scrap may have been processed through smelting and electrolytic refining or directly processed at a fire refinery. Although most of the U.S. demand is satisfied through domestic production, copper imports account for around 30 percent of annual consumption of copper. The summary statistics for the U.S. copper industry are presented in Table 3-7 (USGS 2004a).

The net amount of scrap salvaged under the rulemaking alternatives (i.e., the amount salvaged relative to the base case) would total 6,584 tons. This quantity is relatively small compared to the total amount of copper consumed annually. Even if all of this copper was generated in the same year, it would only represent 0.22 percent of the average U.S. annual copper consumption. Therefore, the rule is not expected to cause any significant disruptions to the U.S. market for copper.

**Table 3-7 U.S. Copper Industry Summary Statistics from USGS  
(in million metric tons of metal)**

	1997	1998	1999	2000	2001
Primary Production	2.07	2.14	1.89	1.59	1.63
Secondary Production	0.498	0.466	0.381	0.357	0.316
New Scrap	0.967	0.956	0.949	0.955	0.833
Refinery Scrap	0.396	0.349	0.23	0.208	0.172
Imports	0.632	0.683	0.837	1.06	0.991
Exports	0.0929	0.0862	0.0252	0.0936	0.0225
Apparent Copper Consumption <sup>1</sup>	2.94	3.03	3.13	3.13	2.5

<sup>1</sup> Apparent consumption = primary production + secondary production + imports – exports ± adjustment for industry stock changes.

Source: USGS 2004a.

### *Aluminum*

In the period 1996-2000, average annual U.S. production of aluminum was just over 7 million metric tons. Approximately 51 percent of aluminum products were produced from virgin materials. The remaining 49 percent was produced from secondary sources. Secondary production includes metal recovered from post-consumer aluminum scrap and fabrication aluminum scrap. Although the majority of the U.S. demand is satisfied through domestic production, aluminum imports account for about 48 percent of annual consumption of aluminum. The summary statistics for the U.S. aluminum industry are presented in Table 3-8 (USGS 2004b).

The net amount of scrap salvaged under the rulemaking alternatives (i.e., the amount salvaged relative to the base case) would total 212 tons. This quantity is relatively small compared to the total amount of aluminum consumed annually. Even if all of this aluminum was generated in the same year, this amount would only represent 0.003 percent of the average U.S. annual aluminum consumption. Therefore, the rule is not expected to cause any significant disruptions to the U.S. market for aluminum.

**Table 3-8 U.S. Aluminum Industry Summary Statistics from USGS  
(in million metric tons of metal)**

	1996	1997	1998	1999	2000
Primary Production	3.577	3.603	3.713	3.779	3.668
Secondary Production	3.31	3.55	3.44	3.69	3.45
Imports	2.81	3.08	3.55	4	3.91
Exports	1.5	1.57	1.59	1.64	1.76
Apparent Aluminum Consumption <sup>1</sup>	6.61	6.72	7.09	7.77	7.53

<sup>1</sup> Apparent consumption = primary production + secondary production + imports – exports ± adjustment for industry stock changes.

Source: USGS 2004b

### 3.2.5 Attribute – Industry Operation

#### Attribute Definition and Identification of Driving Factors

Industry Operation measures yearly net incremental cost and benefits (e.g., relevant capital, operating, and maintenance costs) due to changes in industry operations, including incremental costs and savings for each of the following four sub-attributes:<sup>15</sup> (1) ongoing decision making/paperwork, (2) survey of materials, (3) solid waste disposal, recycling, or reuse, and (4) transportation.

1. *Sub-Attribute - Decision Making/Paperwork.* This sub-attribute captures the costs associated with preparing any required documents for the clearance of materials.
2. *Sub-Attribute - Survey of Materials.* Unit cost estimates for surveying materials reflect variations in the type of material to be surveyed, the physical shape of the material, contamination potential of the material, dose option that must be met, the initial activity level of the material, and whether materials are surveyed on or off site.
3. *Sub-Attribute - Solid Waste Disposal or Recycling.* This sub-attribute includes cost or revenue information for the following three elements: (1) Low-Level Waste Disposal, (2) Off-Site Solid Waste Disposal, and (3) Recycling. Unit costs include tipping fees and revenue from recycling materials.
4. *Sub-Attribute - Transportation.* Unit cost estimates for transportation reflect: (1) the average distances between licensees and the nearest LLW disposal facilities, EPA-regulated landfills, recycling facilities, or reuse facilities; (2) the average

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<sup>15</sup> If decontamination were conducted, it also would be counted as a cost under industry operation. However, this analysis assumes that it is not cost-effective to decontaminate and re-survey materials in order to clear them.

capacity of trucks used, and (3) the cost per ton-mile to ship cleared material versus controlled material.

The quantities of materials (ferrous metal, concrete, and trash) that are released in the baseline and for each alternative are taken from the collective dose assessment report, as described in Table 3-9. For the alternatives with dose options (Unrestricted Release and EPA-Regulated Disposal), quantity information was provided for the 0.03 mrem/yr, 0.1 mrem/yr, 1 mrem/yr, and 10 mrem/yr options. For the IAEA Safety Guide No. RS-G-1.7 dose option, the quantities were assumed to be equal to the 1 mrem/yr dose option.

**Table 3-9 Quantity Sources in SC&A 2003**

<b>Description in Cost-Benefit Analysis</b>	<b>Description in SC&amp;A 2003</b>
Baseline/No Action	No Action (Case A) <sup>16</sup>
Unrestricted Release: Material-Specific Limits	Case A
Unrestricted Release: Material-Independent Limits	Case B
EPA-Regulated Disposal without Incineration	Case C
EPA-Regulated Disposal with Trash Incineration	Case C2
LLW Disposal	No Action (Case A)
Limited Disposition	Case B (Concrete); Case C (Ferrous metal and Trash)

Table 3-10 presents the total quantities of material released under the baseline (No Action Alternative) and each alternative. As can be seen, different amounts of material are released under each alternative and dose option. That is, not only could a different amount of material be released between the 0.03 mrem/yr dose option and the 0.1 mrem/yr dose option, but within the 0.03 mrem dose options, different amounts are released depending on the alternative. In the 0.03 mrem/yr dose option in any alternative, less material clears and is available for release than in the baseline (or No Action Alternative). Positive values in the change in quantity released column indicate that more material meets release levels under the alternative than in the baseline. This “newly releasable” material is assumed to be sent to disposal in a LLW facility in the baseline. Often this change in the quantity that can be released drives the results of the cost modeling. Table 3-11 presents the quantities of each type of material (ferrous metals, concrete, and trash) that could be released under each alternative and dose option.

<sup>16</sup> The collective dose report (SC&A 2003) presents different values for the dose associated with the No Action Alternative. This cost-benefit analysis assumes the most appropriate version of the quantities and dose associated with the No Action Alternative (and hence the baseline) is in fact the No Action Alternative in the collective dose report (SC&A 2003) associated with the Unrestricted Release Alternative.

**Table 3-10 Material Quantities Released by Alternative**

<b>Alternative</b>	<b>Dose</b>	<b>Baseline Tons Released</b>	<b>Alternative Quantity Released</b>	<b>Change in Quantity Released</b>
No Action	NA	17,954,742	17,954,742	0
Unrestricted Release Material Specific Limits	0.03	17,954,742	15,735,586	(2,219,156)
	0.1	17,954,742	18,768,310	813,568
	1	17,954,742	21,525,814	3,571,072
	10	17,954,742	21,909,149	3,954,407
Unrestricted Release Material Independent Limits	0.03	17,954,742	15,247,765	(2,706,977)
	0.1	17,954,742	18,080,580	125,838
	1	17,954,742	21,044,465	3,089,723
	10	17,954,742	21,709,582	3,754,840
	RS-G-1.7	17,954,742	21,044,465	3,089,723
EPA/State-Regulated Disposal (Landfill)	0.03	17,954,742	16,888,904	(1,065,838)
	0.1	17,954,742	19,570,465	1,615,723
	1	17,954,742	21,790,651	3,835,909
	10	17,954,742	21,928,420	3,973,678
	RS-G-1.7	17,954,742	21,790,651	3,835,909
LLW Disposal/ Prohibition	NA	17,954,742	17,954,742	-
Limited Disposition	RS-G-1.7	17,954,742	21,694,631	3,739,890

**Table 3-11 Quantities Released Under Baseline and Alternatives by Dose Option and Material**

Alternative	Dose	Baseline Tons Released			Alternative Tons Released			Change in Quantity Released		
		Ferrous metal	Concrete	Trash	Ferrous metal	Concrete	Trash	Ferrous metal	Concrete	Trash
No Action	NA	1,803,602	16,130,738	20,402	1,803,602	16,130,738	20,402	0	0	0
Unrestricted Release Material Specific Limits	0.03	1,803,602	16,130,738	20,402	759,254	14,962,692	13,640	(1,044,347)	(1,168,047)	(6,762)
	0.1	1,803,602	16,130,738	20,402	1,256,607	17,490,696	21,007	(546,995)	1,359,958	605
	1	1,803,602	16,130,738	20,402	1,940,589	19,544,245	40,979	136,987	3,413,507	20,577
	10	1,803,602	16,130,738	20,402	2,171,232	19,671,833	66,084	367,630	3,541,094	45,682
Unrestricted Release Material Independent Limits	0.03	1,803,602	16,130,738	20,402	284,888	14,962,692	186	(1,518,714)	(1,168,047)	(20,216)
	0.1	1,803,602	16,130,738	20,402	589,452	17,490,696	432	(1,214,150)	1359958	(19,970)
	1	1,803,602	16,130,738	20,402	1,498,424	19,544,245	1,796	(305,178)	3,413,507	(18,606)
	10	1,803,602	16,130,738	20,402	2,031,852	19,671,833	5,897	228,250	3541094	(14,505)
	RS-G-1.7	1,803,602	16,130,738	20,402	1,498,424	19,544,245	1,796	(305,178)	3,413,507	(18,606)
EPA/State-Regulated Disposal (Landfill)	0.03	1,803,602	16,130,738	20,402	1,332,548	15,542,717	13,640	(471,054)	(588,021)	(6,762)
	0.1	1,803,602	16,130,738	20,402	1,742,296	17,807,161	21,007	(61,306)	1,676,423	605
	1	1,803,602	16,130,738	20,402	2,109,407	19,640,265	40,979	305,805	3,509,527	20,577
	10	1,803,602	16,130,738	20,402	2,190,503	19,671,833	66,084	386,901	3,541,094	45,682
	RS-G-1.7	1,803,602	16,130,738	20,402	2,109,407	19,640,265	40,979	305,805	3,509,527	20,577
LLW Disposal/ Prohibition	NA	1,803,602	16,130,738	20,402	1,803,602	16,130,738	20,402	-	-	-
Limited Disposition	RS-G-1.7	1,803,602	16,130,738	20,402	2,109,407	19,544,245	40,979	305,805	3,413,507	20,577

## Attribute Equations

The following four equations are used to calculate the net change in costs and benefits due to the Industry Operation attribute.

### *Equation 1 - Decision Making/Paperwork*

The administrative costs associated with decision making and paperwork of the *Industry Operation* attribute are estimated as follows:

$$\text{Decision Making/Paperwork} = (\text{HOURS}_{\text{Technical}} \times \text{WAGE}_{\text{Technical}})$$

Parameter	Description
$\text{HOURS}_{\text{Technical}}$	The number of additional hours required for administrative tasks by technical workers (see assumptions below)
$\text{WAGE}_{\text{Technical}}$	The loaded hourly wage per technical labor (see assumptions below)

### *Assumptions*

- The number of administrative hours per licensee undergoing their first year of decommissioning required by technical staff ( $\text{HOURS}_{\text{Technical}}$ ) is equal to 200 hours.<sup>17</sup>
- The hourly wage rates used throughout the equations in this appendix for each labor category are as follows:<sup>18</sup>
  - Technical labor ( $\text{WAGE}_{\text{Technical}}$ ) = -\$33.84 per hour per person (OPM, 2004)<sup>19</sup>
  - Managerial labor ( $\text{WAGE}_{\text{Managerial}}$ ) = -\$48.22 per hour per person (OPM, 2004)<sup>20</sup>
  - Attorney or lawyer labor ( $\text{WAGE}_{\text{Legal}}$ ) = -\$67.04 per hour per person (OPM, 2004)<sup>21</sup>
  - Clerical labor ( $\text{WAGE}_{\text{Clerical}}$ ) = -\$20.58 per hour per person (OPM, 2004)<sup>22</sup>

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<sup>17</sup> Based on Best Professional Judgment and guidance in NUREG-6477 (NRC 1998).

<sup>18</sup> As discussed in Section 3.2.3, the unit costs are presented as negative in order to provide results that correctly identify benefits as positive and costs as negative.

<sup>19</sup> GS-11, Step 1 with a standard overhead factor of 1.6.

<sup>20</sup> GS-13, Step 1 with a standard overhead factor of 1.6.

<sup>21</sup> GS-15, Step 1 with a standard overhead factor of 1.6.

<sup>22</sup> GS-6, Step 1 with a standard overhead factor of 1.6.

**Equation 2 - Survey costs**

The net survey costs associated with the *Industry Operation* attribute are estimated as follows:

$$Survey = [(COST_{ferrous\ metal\ dose\ survey} \times QUANTITY_{ferrous\ metal\ dose}) + (COST_{concrete\ dose\ survey} \times QUANTITY_{concrete\ dose}) + (COST_{trash\ dose\ survey} \times QUANTITY_{trash\ dose})] - [(COST_{ferrous\ metal\ baseline\ survey} \times QUANTITY_{ferrous\ metal\ baseline}) + (COST_{concrete\ baseline\ survey} \times QUANTITY_{concrete\ baseline}) + (COST_{trash\ baseline\ survey} \times QUANTITY_{trash\ baseline})]$$

Parameter	Description
COST <sub>baseline concrete survey</sub>	Baseline survey costs per ton of concrete (see table 3-12 below)
COST <sub>ferrous metal baseline survey</sub>	Baseline survey costs per ton of ferrous metal (see table 3-12 below)
COST <sub>trash baseline survey</sub>	Baseline survey costs per ton of trash (see table 3-12 below)
QUANTITY <sub>concrete baseline</sub>	Baseline total tons of concrete
QUANTITY <sub>ferrous metal baseline</sub>	Baseline total tons of ferrous metal
QUANTITY <sub>trash baseline</sub>	Baseline total tons of trash
COST <sub>concrete dose survey</sub>	Survey costs per ton of concrete under dose option (see table 3-12 below)
COST <sub>ferrous metal dose survey</sub>	Survey costs per ton of ferrous metal under dose option (see table 3-12 below)
COST <sub>trash dose survey</sub>	Survey costs per ton of trash under dose option (see table 3-12 below)
QUANTITY <sub>concrete dose</sub>	Total tons of concrete to be released under dose option
QUANTITY <sub>ferrous metal dose</sub>	Total tons of ferrous metal to be released under dose option
QUANTITY <sub>trash dose</sub>	Total tons of trash to be released under dose option

*Assumptions*

- The available survey costs from the Clearance Survey Cost Report (NRC 2004a) are summarized in Table 3-12.
- Because survey costs are dependent on MARSSIM classification (NRC 2001), the survey costs were weighted to reflect the relative proportion of MARSSIM Class 2 and Class 3 material. The percentages for ferrous metal were taken from SC&A 2003. Based on data in tables on pages 3-10, 3-20, and the scaling factors from page 3-23, the relative proportion of Class 2 material was 27 percent and Class 3 material was 73 percent. Similar information was not available for concrete and trash in SC&A 2003. Attachment 1 of Appendix K of the draft GEIS (NRC 2005b) describes the relative proportion of Class 1, 2, and 3 material for ferrous metal, concrete, and trash. Assuming that only Class 2 and Class 3 material would be surveyed to be released, this analysis calculates that 11 percent of concrete would be Class 2 and 89 percent would be Class 3. For trash, 50 percent is assumed to be Class 2 and 50 percent is assumed to be Class 3.

**Table 3-12: Survey Costs by Dose Option**

<b>Dose Option Level and MARSSIM Classification</b>	<b>Cost</b>	<b>Units</b>	<b>Source in Feb 2004 Clearance Survey Cost Report</b>
<b>Concrete Rubble</b>			
baseline/no action	-26	\$/ton	p. 7-9
0.03 mrem/yr - Class 2	Not Feasible		
0.1 mrem/yr- Class 2	-314	\$/ton	p. 7-10
1 mrem/yr - Class 2	-84	\$/ton	p. 7-10
10 mrem/yr - Class 2	-84	\$/ton	p. 7-10
IAEA Standard - Class 2	-84	\$/ton	Assumed to be equal to 1 mrem/yr
0.03 mrem/yr - Class 3	Not Feasible		
0.1 mrem/yr- Class 3	-85	\$/ton	p. 7-10
1 mrem/yr - Class 3	-30	\$/ton	p. 7-10
10 mrem/yr - Class 3	-30	\$/ton	p. 7-10
IAEA Standard - Class 3	-30	\$/ton	Assumed to be equal to 1 mrem/yr
<b>Structural Ferrous Metal</b>			
baseline/no action	-176	\$/ton	p. 7-26
0.03 mrem/yr - Class 2	Not Feasible		
0.1 mrem/yr- Class 2	-89	\$/ton	p. 7-28
1 mrem/yr - Class 2	-82	\$/ton	p. 7-28
10 mrem/yr - Class 2	-82	\$/ton	p. 7-28
IAEA Standard - Class 2	-82	\$/ton	Assumed to be equal to 1 mrem/yr
0.03 mrem/yr - Class 3	Not Feasible		
0.1 mrem/yr- Class 3	-30	\$/ton	p. 7-28
1 mrem/yr - Class 3	-27	\$/ton	p. 7-28
10 mrem/yr - Class 3	-27	\$/ton	p. 7-28
IAEA Standard - Class 3	-27	\$/ton	Assumed to be equal to 1 mrem/yr
<b>Trash</b>			
baseline/no action	-50	\$/ton	Assumed to be twice 0.1 mrem/yr (for class 3)
0.03 mrem/yr - Class 2	-246	\$/ton	Assumed to be twice 0.1 mrem/yr
0.1 mrem/yr- Class 2	-123	\$/ton	p. 7-53
1 mrem/yr - Class 2	-123	\$/ton	p. 7-53
10 mrem/yr - Class 2	-123	\$/ton	p. 7-53
IAEA Standard - Class 2	-123	\$/ton	Assumed to be equal to 1 mrem/yr
0.03 mrem/yr - Class 3	-50	\$/ton	Assumed to be twice 0.1 mrem/yr
0.1 mrem/yr- Class 3	-25	\$/ton	p. 7-53
1 mrem/yr - Class 3	-25	\$/ton	p. 7-53
10 mrem/yr - Class 3	-25	\$/ton	p. 7-53
IAEA Standard - Class 3	-25	\$/ton	Assumed to be equal to 1 mrem/yr

- It is not feasible to survey concrete and ferrous metal at the 0.03 mrem/yr dose option level, because the data quality objectives for the survey demand a very large number of samples (ORISE 2004). As a result, in the 0.03 mrem/yr dose options of the Unrestricted Release and EPA-Regulated Disposal Alternatives, ferrous metal and concrete are assumed to be sent for LLW disposal rather than surveyed and released.

*Assumptions*

- Survey costs for LLW disposal are not required by the proposed action. However, disposal facilities will not accept waste that has not been surveyed. Consequently, survey costs were included for all material being sent to LLW disposal. The survey costs for the 10 mrem/yr dose option were used as a proxy for the survey costs for LLW disposal.

**Equation 3 - Disposal and recycling costs**

The net disposal and recycling costs associated with the *Industry Operation* attribute are estimated as follows:

$$\begin{aligned}
 \text{Disposal/Recycling} = & [(COST_{LLW\ Disposal} \times QUANTITY_{LLW\ Dose}) + (COST_{Landfill\ Disposal} \times \\
 & QUANTITY_{Landfill\ Dose}) + (REVENUE_{ferrous\ metal\ recycled} \times QUANTITY_{ferrous\ metal\ recycled\ dose}) \\
 & + (COST_{concrete\ recycled} \times QUANTITY_{concrete\ recycled\ dose}) + (COST_{LLW\ Disposal} \times \\
 & QUANTITY_{baseline-dose})] - [(COST_{LLW\ Disposal} \times QUANTITY_{LLW\ baseline}) + (COST_{Landfill} \\
 & Disposal \times QUANTITY_{Landfill\ baseline}) + (REVENUE_{ferrous\ metal\ recycled} \times QUANTITY_{ferrous\ metal \\
 & recycled\ baseline}) + (COST_{concrete\ recycled} \times QUANTITY_{concrete\ recycled\ baseline})]
 \end{aligned}$$

Parameter	Description
QUANTITY <sub>LLW baseline</sub>	Baseline total tons of material disposed of offsite as LLW
QUANTITY <sub>Landfill baseline</sub>	Baseline total tons of material disposed of offsite as MSW
QUANTITY <sub>ferrous metal recycled baseline</sub>	Baseline total tons of ferrous metal recycled
QUANTITY <sub>concrete recycled baseline</sub>	Baseline total tons of concrete recycled
QUANTITY <sub>LLW Dose</sub>	Total tons of material disposed of offsite as LLW under dose option
QUANTITY <sub>Landfill Dose</sub>	Total tons of material disposed of offsite as MSW under dose option
QUANTITY <sub>ferrous metal recycled dose</sub>	Total tons of ferrous metal recycled under dose option
QUANTITY <sub>concrete recycled dose</sub>	Total tons of concrete recycled under dose option
QUANTITY <sub>baseline-dose</sub>	Net difference in tons cleared in baseline - tons cleared under dose option
COST <sub>LLW Disposal</sub>	Offsite disposal costs per ton of material at a LLW facility (see assumptions below)
COST <sub>Landfill Disposal</sub>	Offsite disposal costs per ton of material at a solid waste landfill (see assumptions below)
REVENUE <sub>ferrous metal recycled</sub>	Revenue generated from the average market price of recycling scrap ferrous metal (see assumptions below)
COST <sub>concrete recycled</sub>	Recycling cost per ton of concrete (see assumptions below)

*Assumptions*

- The cost for disposal at a LLW facility (Envirocare) is equal to -\$14.72 per cubic foot (DOE 2002). This cost reflects disposal of DOE waste, because prices for disposal of non-DOE wastes were not publicly available.
- The cost for disposal at a municipal or industrial solid waste landfill is equal to -\$32.19 per ton (REPA 2001).
- The revenue associated with the average market price of scrap ferrous metal is equal to \$85 per ton (Recycler’s World 2003).<sup>23</sup>
- The cost of recycling concrete is equal to -\$5 per ton.<sup>24</sup>

**Equation 4 - Transportation costs**

The net transportation cost associated with the *Industry Operation* attribute is estimated as follows:

$$\begin{aligned}
 \text{Transportation} = & \text{COST}_{LLW \text{ transport truck}} \times \text{DISTANCE}_{LLW \text{ facility}} \times (\text{QUANTITY}_{LLW \text{ dose}} + \\
 & \text{QUANTITY}_{\text{baseline-dose}} - \text{QUANTITY}_{LLW \text{ baseline}}) + \text{COST}_{\text{Cleared transport truck}} \\
 & [( \text{DISTANCE}_{MSW \text{ Landfill}} \times (\text{QUANTITY}_{\text{Landfill dose}} - \text{QUANTITY}_{\text{Landfill baseline}}) ) + \\
 & ( \text{DISTANCE}_{\text{Recycling Facility-Ferrous metal}} \times (\text{QUANTITY}_{\text{ferrous metal recycled dose}} - \\
 & \text{QUANTITY}_{\text{ferrous metal recycled baseline}}) ) + ( \text{DISTANCE}_{\text{Recycling Facility-Concrete}} \times \\
 & (\text{QUANTITY}_{\text{concrete recycled dose}} - \text{QUANTITY}_{\text{concrete recycled baseline}}) ) ]
 \end{aligned}$$

Parameter	Description
QUANTITY <sub>LLW baseline</sub>	Total baseline tons of material transported to a LLW facility
QUANTITY <sub>Landfill baseline</sub>	Total baseline tons of material transported to a municipal landfill
QUANTITY <sub>ferrous metal recycled baseline</sub>	Total baseline tons of ferrous metal transported to a recycling facility
QUANTITY <sub>concrete recycled baseline</sub>	Total baseline tons of concrete transported for recycling
COST <sub>LLW transport truck</sub>	Cost per ton-mile for transport of LLW using a truck (see assumptions below)
COST <sub>Cleared transport truck</sub>	Cost per ton-mile for transport of cleared material using a truck (see assumptions below)
DISTANCE <sub>LLW facility</sub>	Distance to a LLW facility (see assumptions below)
DISTANCE <sub>MSW Landfill</sub>	Distance to a MSW landfill (see assumptions below)
DISTANCE <sub>Recycling Facility-Ferrous metal</sub>	Distance to a ferrous metal recycling facility (see assumptions below)
DISTANCE <sub>Recycling Facility-Concrete</sub>	Distance to a concrete recycling facility (see assumptions below)

<sup>23</sup> Because the industry will pay licensees for the ferrous metal, this is considered a negative cost (actualized benefit).://www.recycle.net/price/metals.html

<sup>24</sup> Agretech. Phone Interview. November 25, 2003.

Parameter	Description
QUANTITY <sub>baseline-dose</sub>	Net difference in tons cleared in baseline minus tons cleared under dose option
QUANTITY <sub>LLW dose</sub>	Total tons of material transported under dose option to a LLW facility
QUANTITY <sub>Landfill dose</sub>	Total tons of material transported under dose option to a MSW landfill
QUANTITY <sub>ferrous metal recycled dose</sub>	Total tons of ferrous metal transported under dose option to a recycling facility
QUANTITY <sub>concrete recycled dose</sub>	Total tons of concrete transported under dose option to a recycling facility

### Assumptions

The following transportation costs apply:

- LLW material using a truck: -\$0.12/ton-mile (DOE 1999).
- Cleared material using a truck: -\$0.06/ton-mile.<sup>25</sup>
- LLW ferrous metal using rail: -\$0.016/ton-mile (DOE 2002).
- LLW concrete using rail: -\$0.044/ton-mile.<sup>26</sup>

The following average distances apply:

- LLW facility: 1,544 miles.<sup>27</sup>
- MSW Landfill: 58 miles.<sup>28</sup>
- Ferrous metal recycling facility: 269 miles (SC&A 2003).<sup>29</sup>
- Concrete recycling facility: 198 miles.<sup>30</sup>

Trucks are assumed to be able to transport 25 tons per truckload of ferrous metals, concrete, or mixed materials destined for a LLW disposal facility. Trucks are assumed to transport 10 tons per truckload of trash.

### 3.2.6 Attribute - Public Health (Routine)

#### Attribute Definition and Identification of Driving Factors

Public Health (Routine) measures the yearly incremental cost or benefit due to changes in radiation exposures to the public associated with routine NRC licensee activities. The public is defined as any person not working in the nuclear industry. Exposures may occur from the

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<sup>25</sup> Best professional judgment

<sup>26</sup> *Ibid.*

<sup>27</sup> Estimate based on average distance from existing LWRs to Clive, Utah, derived from GIS analysis.

<sup>28</sup> Best professional judgment.

<sup>29</sup> Table 9.62, page 9-97.

<sup>30</sup> *Ibid.*

following activities: material handling activities, storage, transportation, processing or recycling, disposal in solid waste landfills, manufacturing, and distribution and use of new products.

### Attribute Equation

The following equation can be used to calculate the net change in costs and benefits due to the Public Health (Routine) attribute.

#### Equation 5 - Routine radiologic exposure

The routine radiologic exposure cost associated with the *Public Health (Routine)* attribute is estimated as follows:

$$\text{Radiological Exposure} = (\text{DOSE}_{\text{baseline public}} - \text{DOSE}_{\text{dose alternative public}}) \times \text{COST}_{\text{exposure}}$$

Parameter	Description
$\text{DOSE}_{\text{baseline public}}$	The baseline dose to the public due to routine exposures in person rem for clearance of materials
$\text{DOSE}_{\text{dose alternative public}}$	The dose to the public due to routine exposures in person rem for clearance of materials under the alternative
$\text{COST}_{\text{exposure}}$	Cost of exposure per person-rem (see assumptions below)

#### Assumptions

- The cost of exposure per person is assumed to be -\$2,000 per person-rem (NRC 2003e).
- The dose to the public was taken from SC&A 2003. Table 3-13 describes how the alternatives in this cost-benefit analysis relate to the naming conventions used in SC&A 2003. For the dose-specific alternatives (Unrestricted Release and EPA-Regulated Disposal), dose information was provided for the 0.03, 0.1, 1, and 10 mrem/yr options. For the IAEA Safety Guide No. RS-G-1.7 dose option, the quantities were assumed to be twice the dose associated with the 1 mrem/yr dose option based on NUREG-1640 (Appendix D, (NRC 2005b)).
- SC&A 2003 presents the collective dose to workers, such as truck drivers and recyclers, as well as members of the general public. Dose to members of the public and workers at non-licensed facilities normally would be captured in the attribute public health-routine, and dose to workers at licensed facilities normally would be captured in the attribute occupational health-routine. Because this analysis could not separate the collective doses into these two categories on a year-by-year basis for each alternative and dose-option considered, the public health-routine and occupational health routine attributes are combined in a single attribute described as public and occupational health-routine.
- The dose associated with equipment reuse was taken from the Draft GEIS, Appendix D, Section 12 (NRC 2005b).

**Table 3-13 Description of Alternatives and Naming Conventions**

Description in Cost-Benefit Analysis	Description in SC&A 2003
Baseline	No Action (Case A) <sup>31</sup>
Unrestricted Release: Material-Specific Limits	Case A
Unrestricted Release: Material-Independent Limits	Case B
EPA-Regulated Disposal without Incineration	Case C
EPA-Regulated Disposal with Trash Incineration	Case C2
Limited Disposition	Case B (concrete), Case C (ferrous metal and trash)
LLW Disposal	Not provided in Report. Assumed to be 0 person-rem.

### 3.2.7 Attribute - Occupational Health (Routine)

#### Attribute Definition and Identification of Driving Factors

Occupational Health (Routine) measures the yearly incremental cost or benefit due to changes in radiation exposures to occupational workers at licensed facilities associated with routine activities. Exposures may occur from the following material handling activities: storage, surveying, decontamination, volume reduction, packaging for disposal or recycling, and disposal.

#### Attribute Equation

The following equation can be used to calculate the net change in costs and benefits due to the Occupational Health (Routine) attribute.

#### *Equation 6 - Routine occupational radiologic exposures*

The routine radiological exposure cost associated with the *Occupational Health (Routine)* attribute is estimated as follows:

$$\text{Radiologic Exposure} = (\text{DOSE}_{\text{baseline worker}} - \text{DOSE}_{\text{dose alternative worker}}) \times \text{COST}_{\text{exposure}}$$

Parameter	Description
DOSE <sub>baseline worker</sub>	The baseline dose to occupational workers due to exposure in person-rem for clearance of materials.
DOSE <sub>dose alternative worker</sub>	The dose to occupational workers due to exposure in person-rem for clearance of materials, under the alternative.
COST <sub>exposure</sub>	Cost of exposure per person-rem (see assumptions below)

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<sup>31</sup> SC&A 2003 presents different values for the dose associated with the No Action Alternative. This cost-benefit analysis assumes the most appropriate version of the quantities and dose associated with the No Action Alternative (and hence the baseline) is in fact the No Action Alternative in SC&A 2003 associated with the Unrestricted Release Alternative.

## Assumptions

- The cost of exposure per person is assumed to be -\$2,000 per person-rem (NRC 2003e).
- SC&A 2003 presents the collective dose to workers, such as truck drivers and recyclers, as well as members of the general public. Dose to members of the public and workers at non-licensed facilities normally would be captured in the attribute public health-routine, and dose to workers at licensed facilities normally would be captured in the attribute occupational health-routine. Because this analysis could not separate the collective doses into these two categories on a year-by-year basis for each alternative and dose-option considered, the public health-routine and occupational health routine attributes are combined in a single attribute described as public and occupational health-routine.

### 3.2.8 Attribute - Public Health (Accident)

#### Attribute Definition and Identification of Driving Factors

Public Health (Accident) measures the yearly net incremental cost or benefit due to changes in radiation exposures to occupational workers in non-licensed facilities and the general public associated with any sort of accidents involving the potentially clearable material. Exposures may occur from accidents related to storage, transportation, surveying, decontamination, volume reduction, packaging of materials, and random acts, such as fires, however, no such exposures are quantified in this analysis because the amount of radiation in any given quantity of material being considered for clearance would not result in a significant dose in the event of these types of accidents (Section 3.3).

Another dimension of the Public Health (Accident) attribute is yearly net incremental cost or benefit due to changes in non-radiologically induced fatalities and disabilities related to transportation, decontamination, volume reduction, and packaging of materials.

#### Attribute Equation

The following equation can be used to calculate the net change in costs and benefits due to the Public Health (Accident) attribute. For this analysis, accidents are due to truck transport.

#### *Equation 7 - Fatalities and disabilities due to accidents*

The cost of accidental fatalities and disabilities associated with the *Public Health (Accident)* attribute is estimated as follows:

$$\text{Accidental Fatalities and Disabilities} = [(DISTANCE_{\text{alternative total}} - DISTANCE_{\text{baseline total}}) \times NUM_{\text{accident fatalities}} \times COST_{\text{lost life}}] + [(DISTANCE_{\text{alternative total}} - DISTANCE_{\text{baseline total}}) \times NUM_{\text{accident disabilities}} \times COST_{\text{lifetime disability}}]$$

Parameter	Description
DISTANCE <sub>baseline total</sub>	Total vehicle miles traveled in baseline
DISTANCE <sub>alternative total</sub>	Total vehicle miles traveled in alternative
NUM <sub>accident fatalities</sub>	Number of fatalities due to accidents per vehicle mile traveled
COST <sub>lost life</sub>	Average cost of a lost life (see assumptions below)
NUM <sub>accident disabilities</sub>	Number of disabilities due to accidents per vehicle mile traveled
COST <sub>lifetime disability</sub>	Lifetime cost of disability

### Assumptions

- The average cost of a life is assumed to be -\$3,000,000 (NRC 2003e).
- This analysis does not calculate any lifetime disabilities.
- The number of accidents is based on vehicle miles traveled multiplied by the accident fatality rate. As discussed in Chapter 3 of the Draft GEIS (NRC 2005b), the fatal accident rate for a truck is 2.409 E-08 per vehicle mile traveled (NRC 1994). This fatality rate includes both fatalities to members of the public and to drivers.

### 3.2.9 Attribute - Industry Implementation

#### Attribute Definition and Identification of Driving Factors

Industry Implementation measures the initial incremental cost or benefit to licensees due to changes in industry implementation, including incremental costs and savings of the following: reading regulations and guidance documents; training employees on new procedures; capital outlay for new equipment (e.g., trucks, survey equipment); and researching markets and vendors for cleared material. No capital outlay is expected to be required under this rulemaking. Fees paid to NRC are not included in the analysis as they represent a transfer payment. Thus fees paid are a cost to industry and a benefit to NRC, with a net balance of zero.

#### Attribute Equation

The following equation can be used to calculate the net change in costs and benefits due to the Industry Implementation attribute.

#### Equation 8 - Implementation costs

The implementation costs associated with the *Industry Implementation* attribute are estimated as follows:

$$Implementation = (HOURS_{industry\ implementation\ managers} \times WAGE_{Managerial}) + (HOURS_{industry\ implementation\ legal} \times WAGE_{Legal}) + (HOURS_{industry\ implementation\ clerical} \times WAGE_{Clerical})$$

Parameter	Description
$HOURS_{\text{industry implementation managers}}$	The number of additional hours required for administrative implementation tasks by managers (see assumptions below)
$WAGE_{\text{Managerial}}$	The loaded hourly wage per managerial labor (see Equation 1 assumptions in Section 3.2.5)
$HOURS_{\text{industry implementation legal}}$	The number of additional hours required for administrative implementation tasks by attorneys (see assumptions below)
$WAGE_{\text{Legal}}$	The loaded hourly wage per attorney (see Equation 1 assumptions in Section 3.2.5)
$HOURS_{\text{industry implementation clerical}}$	The number of additional hours required for administrative implementation tasks by clerical workers (see assumptions below)
$WAGE_{\text{Clerical}}$	The loaded hourly wage per clerical labor (see Equation 1 assumptions in Section 3.2.5)

### *Assumptions*

The following are the number of hours assumed, using best professional judgment:

- Number of Managerial hours: 60.
- Number of Legal hours: 10.
- Number of Clerical hours: 10.

### **3.2.10 Attribute - NRC Implementation**

#### **Attribute Definition and Identification of Driving Factors**

NRC Implementation involves, among other considerations, NRC staff time to complete the following implementation tasks:

- Develop guidance, procedures, and aids for use by NRC and Agreement States
- Develop enforcement procedures
- Develop guidance, procedures, and aids for use by licensees

#### **Attribute Equation**

The following equation calculates the costs and benefits due to NRC Implementation of new control criteria.

#### ***Equation 9 - Develop guidance***

The administrative costs associated with developing guidance under the *NRC Implementation* attribute are estimated as follows:

$$\text{Develop Guidance} = (HOURS_{\text{NRC implementation managerial}} \times WAGE_{\text{Managerial}}) + (HOURS_{\text{NRC implementation technical}} \times WAGE_{\text{Technical}}) + (HOURS_{\text{NRC implementation clerical}} \times WAGE_{\text{Clerical}})$$

Parameter	Description
$HOURS_{NRC\ implementation\ managerial}$	The number of additional hours required for NRC managerial staff (see assumptions below)
$HOURS_{NRC\ implementation\ technical}$	The number of additional hours required for NRC technical staff (see assumptions below)
$HOURS_{NRC\ implementation\ clerical}$	The number of additional hours required for NRC clerical staff (see assumptions below)
$WAGE_{Managerial}$	The loaded hourly wage per managerial labor (see Equation 1 assumptions in Section 3.2.5)
$WAGE_{Technical}$	The loaded hourly wage per technical labor (see Equation 1 assumptions in Section 3.2.5)
$WAGE_{Clerical}$	The loaded hourly wage per clerical labor (see Equation 1 assumptions in Section 3.2.5)

### *Assumptions*

The following are the number of hours necessary to develop guidance for the clearance of material, for the first year only, using best professional judgment:

- Number of Managerial hours: 10.
- Number of Technical hours: 80.
- Number of Clerical hours: 10.

### **3.2.11 Attribute - NRC Operation**

#### **Attribute Definition and Identification of Driving Factors**

NRC operation involves NRC staff time to conduct the following operational tasks on an annual basis:

- Conduct inspections;
- Conduct evaluations of licensee compliance; and
- Enforcement.

#### **Attribute Equations**

The following equations calculate the costs due to NRC Operations related to new control criteria.

#### ***Equation 10 - Paperwork***

The administrative costs associated with the paperwork of the *NRC Operations* attribute are estimated as follows:

$$NRC\ Paperwork = (HOURS_{NRC\ Ops\ Managerial} \times WAGE_{Managerial}) + (HOURS_{NRC\ Ops\ Legal} \times WAGE_{Legal}) + (HOURS_{NRC\ Ops\ Technical} \times WAGE_{Technical}) + (HOURS_{NRC\ Ops\ Clerical} \times WAGE_{Clerical})$$

Parameter	Description
$HOURS_{NRC\ Ops\ Managerial}$	The number of additional hours required for NRC managerial staff, to review paperwork for the clearance of material
$HOURS_{NRC\ Ops\ Legal}$	The number of additional hours required for NRC legal staff, to review paperwork for the clearance of material
$HOURS_{NRC\ Ops\ Technical}$	The number of additional hours required for NRC technical staff, to review paperwork for the clearance of material
$HOURS_{NRC\ Ops\ Clerical}$	The number of additional hours required for NRC clerical staff, to review paperwork for the clearance of material
$WAGE_{Managerial}$	The loaded hourly wage per managerial labor (see Equation 1 assumptions in Section 3.2.5)
$WAGE_{Legal}$	The loaded hourly wage per attorney (see Equation 1 assumptions in Section 3.2.5)
$WAGE_{Technical}$	The loaded hourly wage per technical labor (see Equation 1 assumptions in Section 3.2.5)
$WAGE_{Clerical}$	The loaded hourly wage per clerical labor (see Equation 1 assumptions in Section 3.2.5)

### Assumptions

The analysis assumes that no hours will be required for NRC because no additional paperwork will be submitted by licensees, and therefore Equation 10 is equal to zero.

### Equation 11 - Enforcement activities

The administrative costs associated with enforcement activities of the *NRC Operations* attribute are estimated as follows:

$$NRC\ Enforcement = (HOURS_{Enforcement\ Managerial} \times WAGE_{Managerial}) + (HOURS_{Enforcement\ Legal} \times WAGE_{Legal}) + (HOURS_{Enforcement\ Technical} \times WAGE_{Technical}) + (HOURS_{Enforcement\ Clerical} \times WAGE_{Clerical}) + COST_{Inspection\ Travel}$$

Parameter	Description
$HOURS_{Enforcement\ Managerial}$	The number of additional hours required for NRC managerial staff to conduct inspections for the clearance of material
$HOURS_{Enforcement\ Legal}$	The number of additional hours required for NRC legal staff to conduct inspections for the clearance of material
$HOURS_{Enforcement\ Technical}$	The number of additional hours required for NRC technical staff to conduct inspections for the clearance of material
$HOURS_{Enforcement\ Clerical}$	The number of additional hours required for NRC clerical staff to conduct inspections for the clearance of material
$WAGE_{Managerial}$	The loaded hourly wage per managerial labor (see Equation 1 assumptions in Section 3.2.5)

Parameter	Description
$WAGE_{Legal}$	The loaded hourly wage per attorney (see Equation 1 assumptions in Section 3.2.5)
$WAGE_{Technical}$	The loaded hourly wage per technical labor (see Equation 1 assumptions in Section 3.2.5)
$WAGE_{Clerical}$	The loaded hourly wage per clerical labor (see Equation 1 assumptions in Section 3.2.5)
$COST_{Inspection Travel}$	The travel-related costs associated with inspection of cleared material

### *Assumptions*

The analysis assumes that no hours will be required because no additional enforcement activities will be necessary for NRC; therefore, Equation 11 is equal to zero.

### **3.2.12 Attribute - Other Government**

#### **Attribute Definition and Identification of Driving Factors**

This analysis estimates Other Government costs, excluding facilities that are assumed to be covered under the attributes Industry Implementation and Industry Operation, such as DOE and Department of Defense (DoD) facilities. Since regulation of LWRs is not delegated to Agreement States, they will not incur costs related to these facilities. The administrative tasks for other government agencies that have been identified are rulemakings in the Agreement States.

#### **Attribute Equation**

The following equation calculates the Other Government costs due to the implementation of new control criteria.

#### ***Equation 12 - Burden to Agreement States***

The administrative costs associated with State environmental agencies under the *Other Government* attribute are estimated as follows:

$$Environmental\ Agencies = 3(HOURS_{State\ Employees} \times WAGE_x)$$

Parameter	Description
$HOURS_{State\ Employees}$	The number of additional hours required for State employees for rulemakings
$WAGE_x$	The loaded hourly wage per worker type x.

### *Assumptions*

- 33 Agreement States will need to adapt their regulations to this rulemaking.
- 25 of these States are assumed to require 520 hours of managerial labor (NRC 2003d).
- 8 of these States are assumed to require 208 hours of managerial labor (NRC 2003d).

### 3.2.13 Attribute - Regulatory Efficiency

This attribute is considered qualitatively in **Section 3.3**, regarding the significant benefits associated with the streamlining of procedures in the post regulatory environment compared with baseline procedures.

### 3.2.14 Attribute - Other Considerations

This attribute is considered qualitatively in Section 3.3, regarding public confidence in NRC.

### 3.2.15 Calculating Net Present Value

Present value is a future cash flow, or stream of cash flows, recalculated as an equivalent current amount of money. Net Present Value (NPV) is the present value of all cash flows, *positive and negative*, connected to a project. To calculate NPV, the amount and timing of the cash flows must be determined. Additionally, a discount rate must be used to find the present value. Solving for the present value of a future cash flow is also known as discounting. The following formula shows how NPV is calculated by summing the discounted cash flows that occur in each year:

$$Net\ Present\ Value = \sum_{t=1}^n \left[ \frac{CF_t}{(1+r)^t} \right]$$

Parameter	Description
CF	cash flow in year t
t	year in which the cash flow takes place
n	life span (years) of the project
r	discount rate in year t

#### *Assumptions*

- For this analysis, discount rates of both seven percent and three percent are used in accordance with NUREG/BR-0184, *Regulatory Analysis Technical Evaluation Handbook* (NRC 1997).

### 3.3 Values and Impacts of Regulatory Alternatives Considered

Table 3-14 presents a summary of the benefits and costs associated with each affected attribute for each alternative (and dose option, if applicable) relative to the No Action Alternative, which

is the baseline. Negative benefits (shown in parentheses) reflect net costs, rather than benefits. These benefits and costs are discussed for each alternative below.

For the 0.03 mrem/yr dose options (regardless of the Alternative) it is economically infeasible to survey concrete and ferrous metal. Consequently, these materials are sent to LLW disposal, resulting in costs similar to the LLW Disposal Alternative. Because trash can still be surveyed at this dose level, some trash is sent to EPA landfills, resulting in a slightly lower cost than the LLW disposal alternative.

Note that OMB considers a rule "economically significant" under Executive Order 12866 if annual effects are greater than \$100 million. The \$1.4 billion cost associated with the LLW Disposal Alternative and the 0.03 dose options of the Unrestricted Release and EPA/State-Regulated Disposal Alternatives are discounted. When these costs are spread over the 47 year time frame of the analysis using a 7 percent discount rate, the annual cost exceeds the \$100 million threshold and thus would qualify as "economically significant."

### **3.3.1 No Action Alternative**

By definition, there are no values or impacts associated with the No Action alternative.

### **3.3.2 Unrestricted Release**

The Unrestricted Release Alternative is expected to result in net incremental benefits under the 1 mem/yr, 10 mrem/yr, and IAEA Safety Guide No. RS-G-1.7 dose options. As shown in Table 3-14, most of the benefits result from changes in industry operations (i.e., costs and benefits associated with survey, transportation, and recycling or disposal of material). Public health benefits arise as there are fewer vehicular accidents. Environmental benefits arise as there are fewer air emissions due to a decrease in vehicle miles traveled and as a result of favorable manufacturing tradeoffs as recycled ferrous metal replaces virgin ferrous metal. Sometimes these benefits are offset slightly by a cost resulting from a slight increase in dose to the public.

Conversely, under the Unrestricted Release Alternative, at the 0.1 mrem/yr or 0.03 mrem/yr dose option levels, the analysis projects net costs, because more material fails to meet clear and, therefore, must be transported across the country for disposal as low-level waste.

Tables A-1 through A-9 in Attachment A provide year by year results for each of the dose options under the Unrestricted Release Alternative by attribute. Note that costs appear in some years and not in others; this is a result of the distribution of plants shutting down in different years. For the periods where there are no net costs or benefits for Industry Implementation, these are years during which no active D&D is occurring at any decommissioning plant. The cost summary tables follow the information contained in SC&A 2003, Chapter 3.

**Table 3-14 Net Incremental Benefit (Cost) Associated with Attributes by Alternative and Dose Level  
(2003\$)**

Alternative	Dose Option	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations	Total
No Action	NA	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Unrestricted Release	0.03	\$1,174,216	(\$13,514,350)	(\$219,720)	(\$1,376,897,891)	(\$3,395)	\$0	(\$451,377)	(\$12,878,667)	(\$1,402,791,183)
Material Specific	0.1	\$960,746	\$0	(\$219,720)	(\$226,113,873)	(\$3,395)	\$0	(\$451,377)	(\$618,308)	(\$226,445,926)
Limits	1	(\$787,022)	\$0	(\$219,720)	\$293,675,372	(\$3,395)	\$0	(\$451,377)	\$2,125,995	\$294,339,854
	10	(\$8,167,397)	\$0	(\$219,720)	\$329,263,365	(\$3,395)	\$0	(\$451,377)	\$2,801,081	\$323,222,558
Unrestricted Release	0.03	\$1,233,593	(\$13,514,350)	(\$219,720)	(\$1,378,418,237)	(\$3,395)	\$0	(\$451,377)	(\$12,902,162)	(\$1,404,275,647)
Material	0.1	\$1,205,052	\$0	(\$219,720)	(\$291,974,108)	(\$3,395)	\$0	(\$451,377)	(\$2,278,274)	(\$293,721,822)
Independent	1	\$713,415	\$0	(\$219,720)	\$246,021,542	(\$3,395)	\$0	(\$451,377)	\$987,754	\$247,048,219
Limits	10	(\$1,851,424)	\$0	(\$219,720)	\$306,935,439	(\$3,395)	\$0	(\$451,377)	\$2,352,109	\$306,761,633
	RS-G-1.7	\$186,142	\$0	(\$219,720)	\$246,021,542	(\$3,395)	\$0	(\$451,377)	\$987,754	\$246,520,945
EPA/State-Regulated	0.03	\$1,240,634	(\$13,514,350)	(\$219,720)	(\$1,376,897,891)	(\$3,395)	\$0	(\$451,377)	(\$12,878,667)	(\$1,402,724,765)
Disposal (Landfill)	0.1	\$1,240,530	\$0	(\$219,720)	(\$281,093,000)	(\$3,395)	\$0	(\$451,377)	(\$2,259,193)	(\$282,786,154)
	1	\$1,239,881	\$0	(\$219,720)	\$181,462,308	(\$3,395)	\$0	(\$451,377)	(\$1,033,674)	\$180,994,024
	10	\$1,237,267	\$0	(\$219,720)	\$193,637,557	(\$3,395)	\$0	(\$451,377)	(\$922,985)	\$193,277,348
	RS-G-1.7	\$1,239,074	\$0	(\$219,720)	\$181,462,308	(\$3,395)	\$0	(\$451,377)	(\$1,033,674)	\$180,993,217
LLW Disposal/Prohibition	NA	\$1,240,689	(\$13,514,350)	\$0	(\$1,378,439,254)	(\$3,395)	\$0	(\$451,377)	(\$12,902,486)	(\$1,404,070,173)
Limited Dispositions	RS-G-1.7	\$1,227,219	\$0	(\$219,720)	\$258,149,485	(\$3,395)	\$0	(\$451,377)	(\$1,500,316)	\$257,201,896

1. Results are present value of all quantitatively analyzed attributes calculated over 47 years and discounted at 7 percent.

2. Excludes attributes described qualitatively in Section 3.3 (**regulatory efficiency** and other considerations).

3. Environmental benefits are limited to those described in Section 3.2.4.

At the 1 mrem/yr dose option, the Unrestricted Release Alternative results in a benefits of \$247 million, which is approximately the same as, but slightly lower than the benefit of \$257 million associated with the Limited Dispositions Alternative for the IAEA RS-G-1.7 dose option. This may appear counter intuitive because in the Limited Dispositions Alternative ferrous metals cannot be recycled, resulting in the loss of a revenue stream and the addition of a disposal fee. However, a larger quantity of material can be released in the Limited Disposition Alternative than in the Unrestricted Release Alternative, resulting in a net benefit that offsets those costs..

### **Qualitative Results**

- Regulatory Efficiency - By developing standardized procedures for disposition of solid materials, there will be increased regulatory efficiency for both NRC and facilities that are undergoing decommissioning. By having clearly defined procedures for disposition of solid materials, facilities will be more certain of the options open to them at decommissioning. At the same time, NRC will have guidance in place that addresses disposition of material.
- Other Considerations. Public confidence in NRC likely will be affected by this action, regardless of which one of the alternatives NRC adopts. Early public comment indicated the public is concerned about the safety issues related to radioactive materials in consumer products. NRC will need to consider public confidence as it proceeds in the decision making process.

### **3.3.3 EPA/State-Regulated Disposal**

The EPA/State-Regulated Disposal Alternative, while less beneficial than the Unrestricted Release Alternative, also is expected to result in net incremental benefits at the 1 mrem/yr, 10 mrem/yr, and IAEA Safety Guide No. RS-G-1.7 dose options. In this alternative, benefits result from changes in industry operation. This net benefit arises because under this Alternative a larger quantity of material can be released than in the No Action Alternative. Thus the avoided transport and disposal costs for LLW create a benefit relative to the No Action Alternative, which is offset slightly by the loss of recycling revenues and the cost of EPA/State-regulated disposal. A small additional benefit results from changes in public health (routine) because the dose to the public is less than in the baseline. Additionally, some benefit is offset by environmental costs related to a decrease in recycling.

Conversely, under the EPA/State-Regulated Disposal Alternative, at the 0.1 mrem/yr or 0.03 mrem/yr dose option levels, the analysis projects net costs, because more material fails to meet clear and, therefore, must be transported across the country for disposal as low-level waste.

Tables A-10 through A-14 in Attachment A provide year by year results for each of the dose options under the EPA/State-Regulated Disposal Alternative by attribute.

### **Qualitative Results**

- Regulatory Efficiency - By developing standardized procedures for disposition of solid materials, there will be increased regulatory efficiency for both NRC and facilities that

are undergoing decommissioning. By having clearly defined procedures for disposition of solid materials, facilities will be more certain of the options open to them at decommissioning. At the same time, NRC will have guidance in place that addresses disposition of solid materials.

- Other Considerations. Public confidence in NRC likely will be affected by this action, regardless of which one of the alternatives NRC adopts. Early public comment indicated the public is concerned about the safety issues related to radioactive materials. NRC will need to consider public confidence as it proceeds in the decision making process.

### **3.3.4 Limited Dispositions**

The Limited Disposition Alternative is expected to result in the highest net incremental benefit of about \$257 million. Most of the benefits result from changes in industry operations (i.e., benefits associated with survey, transportation, and recycling or disposal of material). Public health benefits arise from both lower radiological doses and fewer vehicular accidents. There is a slight environmental cost associated with the loss of otherwise recyclable ferrous metals being disposed in landfills. Because this material is not recycled, recycled ferrous metal cannot replace virgin ferrous metal production.

Table A-15 in Attachment A provides year by year results for the Limited Dispositions Alternative by attribute.

### **Qualitative Results**

- Regulatory Efficiency - By developing standardized procedures for disposition of solid materials, there will be increased regulatory efficiency for both NRC and facilities that are undergoing decommissioning. By having clearly defined procedures for disposition of solid materials, facilities will be more certain of the options open to them at decommissioning. At the same time, NRC will have guidance in place that addresses disposition of solid material.
- Other Considerations. Public confidence in NRC likely will be affected by this action, regardless of which one of the alternatives NRC adopts. Early public comment indicated the public is concerned about the safety issues related to radioactive materials. NRC will need to consider public confidence as it proceeds in the decision making process.

### **3.3.5 LLW Disposal**

The LLW Disposal Alternative is projected to result in a net cost of approximately \$1.4 billion. Most of this cost results from changes in industry operation, including transportation and disposal of materials as LLW. Other substantial costs result from change in public health - accidental, as a result of more fatalities from the increased transportation distances. A lower collective dose to the public is the only benefit of this alternative. All of the other quantifiable attributes contribute to a net cost.

Table A-16 in Attachment A provides year by year results for the LLW Disposal Alternative by attribute.

### Qualitative Results

- Regulatory Efficiency - By developing standardized procedures for disposition of solid materials, there will be increased regulatory efficiency for both NRC and facilities that are undergoing decommissioning. By having clearly defined procedures for disposition of solid materials, facilities will be more certain of the options open to them at decommissioning. At the same time, NRC will have guidance in place that addresses disposition of solid materials.
- Other Considerations. Public confidence in NRC likely will be affected by this action, regardless of which one of the alternatives NRC adopts. Early public comment indicated the public is concerned about the safety issues related to radioactive materials. NRC will need to consider public confidence as it proceeds in the decision making process.

### 3.3.6 Summary of Results

The quantifiable net benefits associated with each of the various alternatives are presented in Table 3-15 using a seven percent discount rate and in Table 3-16 using a three percent discount rate. Negative benefits (shown in parentheses) reflect net impacts, rather than values. Compared to the seven percent discount rate, all net benefits and costs shown in Table 3-16 are roughly twice as high when calculated using the three percent discount rate. This reflects the relatively long timeframe (i.e., about 47 years) in which materials will be affected.

**Table 3-15 Net Incremental Benefit (Cost) Associated with Rule Alternatives by Dose Level using Seven Percent Discount Rate (\$2003)**

Dose	No Action	Unrestricted Release Material Specific Limits	Unrestricted Release Material Independent Limits	EPA Landfill	LLW Disposal/ Prohibition	Limited Dispositions
0.03 mrem/yr		(\$1,402,791,183)	(\$1,404,275,647)	(\$1,402,724,765)		
0.1 mrem/yr		(\$226,445,926)	(\$293,721,822)	(\$282,786,154)		
1 mrem/yr		\$294,339,854	\$247,048,219	\$180,994,024		
10 mrem/yr		\$323,222,558	\$306,761,633	\$193,277,348		
IAEA RS-G-1.7			\$246,520,945	\$180,993,217		\$257,201,896
No Action	-					
LLW Disposal					(\$1,404,070,173)	

Notes: Results are calculated as the present value of all quantitatively analyzed attributes calculated over 50 years and discounted at 7 percent. This excludes attributes described qualitatively in Section 3.3 (regulatory efficiency and other considerations).

**Table 3-16 Net Incremental Benefit (Cost) Associated with Rule Alternatives  
by Dose Level using Three Percent Discount Rate (\$2003)**

Dose	No Action	Unrestricted Release Material Specific Limits	Unrestricted Release Material Independent Limits	EPA Landfill	LLW Disposal/ Prohibition	Limited Dispositions
0.03 mrem/yr		(\$3,096,851,438)	(\$3,098,955,560)	(\$3,096,677,677)		
0.1 mrem/yr		(\$503,025,207)	(\$648,746,117)	(\$625,205,528)		
1 mrem/yr		\$646,271,345	\$546,801,706	\$398,563,623		
10 mrem/yr		\$704,293,966	\$677,063,566	\$422,314,544		
IAEA RS-G-1.7			\$545,402,481	\$398,561,911		\$567,379,193
No Action	-					
LLW Disposal					(\$3,098,503,318)	

Notes: Results are calculated as the present value of all quantitatively analyzed attributes calculated over 50 years and discounted at 3 percent. This excludes attributes described qualitatively in Section 3.3 (regulatory efficiency and other considerations).

### 3.3.7 Discussion of Sensitivity Analysis Results

This analysis utilizes many assumptions to estimate the net costs and benefits of the alternatives. This section presents two sensitivity analyses to determine the impact of several key assumptions.

As described in Section 3.2.2, there is uncertainty about future LLW disposal costs. Table 3-17 presents the results of a sensitivity analysis in which LLW disposal costs increase by 15 percent in 2020 to address increases in cost associated with the need for additional LLW disposal capacity. These results are not significantly different from the results of the main analysis. For example, for the Limited Disposition Alternative, the change in disposal costs results in about a five percent *increase* in the overall benefit. The benefits increase because more material is sent to LLW Disposal in the baseline than in the alternative. In the LLW Disposal alternative, the change results in about a four percent *increase* in overall cost. The costs increase because more material is sent to LLW disposal in this alternative than in the baseline.

**Table 3-17 Sensitivity Analysis in Net Incremental Benefit Assuming a 15 Percent Increase in LLW Disposal Costs in 2020 (\$2003)**

Dose	No Action	Unrestricted Release Material Specific Limits	Unrestricted Release Material Independent Limits	EPA Landfill	LLW Disposal/ Prohibition	Limited Dispositions
0.03 mrem/yr		(\$1,467,655,460)	(\$1,469,165,029)	(\$1,467,589,042)		
0.1 mrem/yr		(\$223,501,643)	(\$293,222,556)	(\$276,935,787)		
1 mrem/yr		\$307,248,543	\$258,283,611	\$194,858,206		
10 mrem/yr		\$337,467,478	\$320,393,318	\$207,587,058		
IAEA RS-G-1.7			\$257,756,338	\$194,857,399		\$270,719,576
No Action	-					
LLW Disposal					(\$1,468,959,903)	

Notes:

1. Results are calculated as the present value of all quantitatively analyzed attributes calculated over 47 years and discounted at 7 percent.
2. LLW disposal costs assumed to increase by 15 percent beginning in 2020.
3. This excludes attributes described qualitatively in Section 3.3 (regulatory efficiency and other considerations).
4. Environmental benefits are limited to those described in Section 3.2.4.

A second sensitivity analysis was performed to assess the impact of transportation costs on the overall benefits and costs of each alternative. In the main analysis all material was assumed to be shipped by truck. However, given the long distances that are involved in transporting material to LLW disposal facilities (1,544 miles on average), a sensitivity analysis was run in which all material being shipped to LLW facilities was shipped by rail. Table 3-18 presents the results of this analysis. Use of rail lowers the cost of this rule by about 40 percent for the LLW Disposal Alternative as well as the 0.03 mrem/yr dose option in the Unrestricted Release and EPA/State-Regulated Disposal Alternatives. The benefit of this rule for the Limited Dispositions Alternative, and the 1 mrem/yr and and 10 mrem/yr dose options for the Unrestricted Release and EPA/State- Regulated Disposal Alternatives is reduced, because the more expensive truck transport of material to LLW disposal is avoided, reducing overall baseline costs.

**Table 3-18 Sensitivity Analysis in Net Incremental Benefit (Cost) Assuming Transport of Material Destined for LLW Disposal by Rail (\$2003)**

Dose	No Action	Unrestricted Release Material Specific Limits	Unrestricted Release Material Independent Limits	EPA Landfill	LLW Disposal/ Prohibition	Limited Dispositions
0.03 mrem/yr		(\$883,613,800)	(\$884,334,260)	(\$883,547,382)		
0.1 mrem/yr		(\$242,967,381)	(\$284,430,964)	(\$325,705,793)		
1 mrem/yr		\$195,798,319	\$166,990,577	\$73,595,507		
10 mrem/yr		\$211,169,015	\$203,341,050	\$80,396,722		
IAEA RS-G-1.7			\$166,463,304	\$73,594,700		\$152,405,179
No Action	-					
LLW Disposal					(\$884,118,225)	

Notes:

1. Results are calculated as the present value of all quantitatively analyzed attributes calculated over 47 years and discounted at 7 percent.
2. All materials sent to LLW disposal assumed to be transported by rail in baseline and all alternatives.
3. This excludes attributes described qualitatively in Section 3.3 (regulatory efficiency and other considerations).
4. Environmental benefits are limited to those described in Section 3.2.4.

### 3.4 Initial Regulatory Flexibility Analysis

As required by the Regulatory Flexibility Act of 1980, 5 U.S.C. 605(b), the NRC has considered the rule's likely impacts on small entities. Based on its initial analysis of this matter, the NRC believes that it would be useful to have additional information on small entities to complete its analysis. Therefore, the NRC has specifically requested public comment on the potential impact of the proposed rule on small entities. to reduce the rule's impacts on small entities as part of this rulemaking.

#### 3.4.1 Reason Action is Being Considered

The principal reason for this rulemaking is to improve efficiency and effectiveness of the NRC regulatory process by establishing criteria for disposition of solid materials in the regulations. Section 1 of this Regulatory Analysis describes in more detail the reason the proposed rule is being considered.

#### 3.4.2 Objective of the Proposed Rule

Section 1 of this Regulatory Analysis describes the objectives of the proposed rule.

#### 3.4.3 Description and Estimate of the Number of Small Entities

There are six major categories of facility types that might be affected by this rule:

- C Light water reactors,
- C Independent spent fuel storage installations,
- C Research reactors

- C Facilities included in the site decommissioning management plan (SDMP);
- C Fuel cycle facilities; and
- C Other material licensees including, but not limited to medical, academic, industrial, source and special nuclear licensees.

Of these facility types, only some SDMP sites and some of the other materials licensees are likely to be owned by entities that meet the definition of small businesses used in the Regulatory Flexibility Act. While there are less than 50 sites on the SDMP list, there are more than 20,000 NRC and Agreement State material licensees. At present, it is unknown how many of these sites would qualify as small businesses, what North American Industry Classification System codes they fall into, or their revenues. Further, not all entities in these categories that qualify as small businesses will be affected by this rule.

#### **3.4.4 Estimating Compliance Requirements**

As part of gathering information for this rulemaking, the NRC has had a continuing effort to obtain stakeholder input on major issues associated with this rulemaking and has interacted with a diversity of stakeholders (including representatives from university laboratories, hospitals, manufacturers, etc.) on alternatives and possible impacts. Based on this input, the NRC has developed this proposed rule which would establish requirements that to a large extent formalize existing practices regarding decisions on disposition of solid material. Furthermore, as part of the rulemaking, the NRC is considering ways to minimize unnecessary impacts; for example, Section IV.C of FRN issuing the proposed rule specifically requests comment on the scope of material that should be covered by this proposed rule, namely whether it is more appropriate for the scope of the proposed rule to include material only from impacted areas, rather than both restricted areas and impacted areas. Limiting the scope to impacted areas only could mean that for smaller licensees like medical facilities, who may define restricted areas broadly based on facility design, the NRC could better focus its disposition and recordkeeping requirements on solid materials from those areas where a reasonable potential for the presence of residual radioactivity exists. Licensees could either designate the entire restricted area as an impacted area or could focus more on those areas they were designating as impacted areas, whichever was more cost-effective.

In addition, it can also be noted that many small entities would have only sealed sources or devices containing sealed sources and hence there would not be significant effort involved in disposition of solid materials.

Based on the above, the NRC believes that this proposed rule would not have a significant impact on small entities.

However, most of the data available for this regulatory analysis is for large entities, which account for the vast majority of materials covered by the proposed rule, and limited data has been available for analysis of small entities. It is unclear how many material licensees or SDMP sites currently release materials NRC's current approach (i.e., the No Action Alternative). Thus, as indicated in Section XIII of the FRN issuing this proposed rule, the NRC is seeking public comment on the potential impact of the proposed rule on small entities.

### **3.4.5 Significant Alternatives Considered**

Because the rule is not expected to have negative or significant impacts on small entities, no other significant alternatives were considered.

### **3.4.6 Duplicative, Overlapping, and Conflicting Rules**

NRC is not aware of any duplicative, overlapping, or conflicting federal rules.



#### **4.0 Backfit Analysis**

The regulatory options examined in this RA do not involve any provisions that would require backfits. Consequently, a backfit analysis is not necessary.

## **5.0 Decision Rationale**

After considering the costs, benefits, and impacts of all the alternatives, NRC has preliminarily concluded that the Limited Dispositions Alternative can provide a risk-informed consistent dose criterion for disposition of solid materials that is at a level well below levels established to provide adequate protection of the public and the environment and can allow for a predictable regulatory process that is efficient and effective in not imposing undue burdens for implementation. The No Action Alternative (NRC's current approach) is sufficient to satisfy NRC's strategic goal of ensuring protection of public health, but there is a need for a risk-informed regulation. While some public commenters supported use of the Unrestricted Release Alternative because its dose criterion was below NRC's public dose limit and consistent with NCRP and ICRP suggestions, others were concerned about this alternative because of the increased potential for solid material being present in general commerce and consumer products. The EPA/State-Regulated Disposal Alternative would limit the potential for radiation dose to the general public, but the radionuclide concentration limits for only landfill disposal are higher than for unrestricted release. For the LLW Disposal Alternative, there are higher estimated transportation accidents, a large impact on LLW disposal capacity, and a large cost. Thus the Limited Dispositions Alternative is the staff's preliminary recommendation.

NRC chose the Limited Dispositions Alternative based on the various reports and other standards relevant to decision making in this area, on stakeholder input, and on the results of the draft GEIS (NRC 2005b). The Limited Dispositions Alternative is comprised of four elements:

1. A set of limited allowed disposition paths for released solid material;
2. A dose criterion set at 1 mrem/yr;
3. Tables of nuclide concentrations associated with the dose criterion of 1 mrem/yr; and
4. A recordkeeping system.

The following sections provide a brief explanation of the rationale that supports each specific element.

### **5.1 Limited Disposition Paths**

The decision to allow material to follow a set of limited disposition paths is consistent with NCRP Report No. 141, the National Academies' report, and a diverse range of stakeholder comments. In order to determine the allowed disposition paths, NRC considered the following: the feasibility of the disposition paths proposed; the ability of the disposition paths to limit where material goes while maintaining exposures below the dose criterion; and the costs of implementing the disposition paths.

### **5.2 Dose Criterion of 1 mrem/yr**

The 1 mrem/yr dose criterion is well below the NRC's public dose limit established to ensure adequate protection of public health and safety. It is also consistent with other NRC and EPA standards for disposition of other media, such as air and liquid effluents and groundwater protection. Further, the 1 mrem/yr dose is consistent with the recommendations received from national and international scientific bodies regarding dose criteria. When compared to the low

doses of radiation from natural and other existing sources, the proposed dose criterion of 1 mrem/yr is a minute fraction (less than 0.003) of the background levels of radiation received from routine activities.

### **5.3 Tables of nuclide concentrations**

The 1 mrem/yr dose criterion is less than 1/300th of what a person is routinely receiving from natural background; therefore, the dose level is difficult to measure directly. Tables of measurable volumetric and surficial nuclide concentrations will facilitate confirmation that the dose criterion has been met (i.e., if a licensee can demonstrate for a solid material being considered for release, that the nuclide concentrations are less than the table values, this will provide assurance that the 1 mrem/yr dose criterion has been met). Use of these tables provides a conservative approach that provides assurance that, despite uncertainties in assumptions or possible scenario modeling, a 1 mrem/yr dose criterion will be met.

### **5.4 Recordkeeping**

Records would indicate the nature of the material released (e.g., type and quantity of solid material, and nuclides present and their concentrations) and its destination (e.g., the landfill or specific end use shipped to, etc.). The records required by the proposed rulemaking will aid in allowing verification that the dose criterion has been met and provide reasonable assurance that the material was delivered to one of the authorized destinations.

## **6.0 Implementation**

A draft regulatory guidance document (draft NUREG-1813) is being prepared to provide implementation approaches for the proposed rule in areas of survey methods, disposition approaches, and records maintenance. Draft NUREG-1813 is being issued for public comment at the same time as the proposed rule. In addition, an information base is being developed for decisions for case-specific situations.

### **6.1 Schedule**

Licensees will need adequate time to implement changes in their radiation protection programs as a result of the proposed rule amendment when it becomes final. At this time, the NRC is not proposing an implementation schedule for when licensee would need to comply with the rule when it becomes final. However, NRC is inviting comments on the time period for implementing these changes, including specific information on timing and economic considerations.

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**ATTACHMENT A**

**Net Incremental Benefit or Cost Associated with  
Attributes for Alternatives Studied**

**Table A-1 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Specific Limits - 0.03 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$14,362	\$0	(\$18,848)	(\$73,792,689)	(\$3,395)	\$0	(\$451,377)	(\$1,348,379)
2004	\$20,530	\$0	(\$11,309)	(\$40,532,801)	\$0	\$0	\$0	(\$745,860)
2005	\$19,384	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2006	\$18,192	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2007	\$17,212	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2008	\$16,348	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2009	\$15,600	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2010	\$14,928	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2011	\$14,352	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2012	\$13,854	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2013	\$13,392	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2014	\$13,236	\$0	(\$3,770)	(\$3,662,425)	\$0	\$0	\$0	(\$57,614)
2015	\$24,478	\$0	(\$18,848)	(\$110,212,760)	\$0	\$0	\$0	(\$868,326)
2016	\$43,140	(\$3,000,000)	(\$26,387)	(\$166,548,785)	\$0	\$0	\$0	(\$1,342,084)
2017	\$54,720	\$0	(\$18,848)	(\$113,032,649)	\$0	\$0	\$0	(\$952,889)
2018	\$75,220	(\$3,000,000)	(\$33,926)	(\$221,381,781)	\$0	\$0	\$0	(\$1,765,758)
2019	\$116,760	(\$3,000,000)	(\$60,314)	(\$370,432,493)	\$0	\$0	\$0	(\$3,044,680)
2020	\$165,600	(\$6,000,000)	(\$67,853)	(\$476,413,898)	\$0	\$0	\$0	(\$3,882,032)
2021	\$185,960	(\$3,000,000)	(\$41,466)	(\$316,584,440)	\$0	\$0	\$0	(\$2,556,884)
2022	\$195,360	(\$3,000,000)	(\$30,157)	(\$203,730,363)	\$0	\$0	\$0	(\$1,775,903)
2023	\$208,580	(\$3,000,000)	(\$37,696)	(\$230,909,345)	\$0	\$0	\$0	(\$2,016,965)
2024	\$204,720	\$0	(\$22,618)	(\$111,286,568)	\$0	\$0	\$0	(\$1,047,434)
2025	\$189,280	\$0	(\$15,078)	(\$53,367,953)	\$0	\$0	\$0	(\$506,990)
2026	\$181,220	\$0	(\$18,848)	(\$81,613,878)	\$0	\$0	\$0	(\$769,510)
2027	\$191,200	(\$3,000,000)	(\$30,157)	(\$168,001,997)	\$0	\$0	\$0	(\$1,572,635)
2028	\$208,280	(\$3,000,000)	(\$37,696)	(\$253,776,649)	\$0	\$0	\$0	(\$2,204,502)
2029	\$221,580	(\$3,000,000)	(\$37,696)	(\$301,038,895)	\$0	\$0	\$0	(\$2,457,628)
2030	\$253,960	(\$6,000,000)	(\$52,774)	(\$423,645,204)	\$0	\$0	\$0	(\$3,506,365)
2031	\$290,020	(\$6,000,000)	(\$56,544)	(\$454,470,162)	\$0	\$0	\$0	(\$3,841,311)
2032	\$320,440	(\$6,000,000)	(\$56,544)	(\$465,170,953)	\$0	\$0	\$0	(\$3,869,190)
2033	\$343,160	(\$6,000,000)	(\$52,774)	(\$409,017,991)	\$0	\$0	\$0	(\$3,494,670)
2034	\$327,820	(\$3,000,000)	(\$22,618)	(\$146,593,443)	\$0	\$0	\$0	(\$1,375,334)
2035	\$303,260	\$0	(\$11,309)	(\$95,796,042)	\$0	\$0	\$0	(\$811,410)
2036	\$278,580	\$0	(\$11,309)	(\$94,261,732)	\$0	\$0	\$0	(\$797,075)
2037	\$248,200	\$0	(\$3,770)	(\$24,769,000)	\$0	\$0	\$0	(\$234,464)
2038	\$219,860	\$0	(\$3,770)	(\$5,746,314)	\$0	\$0	\$0	(\$45,140)
2039	\$204,620	\$0	(\$15,078)	(\$70,650,437)	\$0	\$0	\$0	(\$651,218)
2040	\$208,460	(\$3,000,000)	(\$26,387)	(\$160,753,698)	\$0	\$0	\$0	(\$1,434,603)
2041	\$202,760	\$0	(\$18,848)	(\$119,968,404)	\$0	\$0	\$0	(\$1,053,780)
2042	\$185,840	\$0	(\$7,539)	(\$44,134,092)	\$0	\$0	\$0	(\$413,940)
2043	\$166,880	\$0	(\$3,770)	(\$19,968,177)	\$0	\$0	\$0	(\$187,148)
2044	\$149,680	\$0	(\$3,770)	(\$35,919,945)	\$0	\$0	\$0	(\$265,184)
2045	\$134,540	\$0	(\$3,770)	(\$35,919,945)	\$0	\$0	\$0	(\$265,184)
2046	\$117,860	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$107,620	\$0	(\$3,770)	(\$22,049,890)	\$0	\$0	\$0	(\$207,017)
2048	\$103,040	\$0	(\$7,539)	(\$44,154,494)	\$0	\$0	\$0	(\$414,420)
2049	\$97,780	\$0	(\$7,539)	(\$51,774,275)	\$0	\$0	\$0	(\$426,393)

**Table A-2 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Specific Limits - 0.1 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$11,560	\$0	(\$18,848)	(\$11,184,825)	(\$3,395)	\$0	(\$451,377)	(\$19,826)
2004	\$16,520	\$0	(\$11,309)	(\$6,068,223)	\$0	\$0	\$0	(\$11,345)
2005	\$15,660	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$3,104)
2006	\$14,720	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$3,104)
2007	\$13,960	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$3,104)
2008	\$13,300	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$3,104)
2009	\$12,720	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$3,104)
2010	\$12,180	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$2,467)
2011	\$11,740	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$2,467)
2012	\$11,360	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$2,467)
2013	\$11,000	\$0	\$0	\$341,960	\$0	\$0	\$0	(\$2,467)
2014	\$10,880	\$0	(\$3,770)	(\$112,632)	\$0	\$0	\$0	(\$2,468)
2015	\$20,220	\$0	(\$18,848)	(\$19,148,387)	\$0	\$0	\$0	(\$24,671)
2016	\$35,700	\$0	(\$26,387)	(\$28,569,167)	\$0	\$0	\$0	(\$48,994)
2017	\$45,240	\$0	(\$18,848)	(\$18,794,514)	\$0	\$0	\$0	(\$44,321)
2018	\$62,200	\$0	(\$33,926)	(\$38,362,185)	\$0	\$0	\$0	(\$62,318)
2019	\$96,200	\$0	(\$60,314)	(\$62,893,590)	\$0	\$0	\$0	(\$135,006)
2020	\$136,200	\$0	(\$67,853)	(\$82,557,664)	\$0	\$0	\$0	(\$197,561)
2021	\$153,200	\$0	(\$41,466)	(\$55,393,885)	\$0	\$0	\$0	(\$125,416)
2022	\$160,600	\$0	(\$30,157)	(\$32,965,874)	\$0	\$0	\$0	(\$110,930)
2023	\$171,200	\$0	(\$37,696)	(\$37,258,254)	\$0	\$0	\$0	(\$126,882)
2024	\$168,000	\$0	(\$22,618)	(\$16,869,877)	\$0	\$0	\$0	(\$81,219)
2025	\$155,200	\$0	(\$15,078)	(\$7,943,692)	\$0	\$0	\$0	(\$38,385)
2026	\$148,200	\$0	(\$18,848)	(\$12,629,780)	\$0	\$0	\$0	(\$61,374)
2027	\$156,200	\$0	(\$30,157)	(\$26,127,824)	\$0	\$0	\$0	(\$126,524)
2028	\$170,000	\$0	(\$37,696)	(\$41,668,898)	\$0	\$0	\$0	(\$142,292)
2029	\$180,800	\$0	(\$37,696)	(\$51,534,325)	\$0	\$0	\$0	(\$121,991)
2030	\$207,600	\$0	(\$52,774)	(\$72,180,246)	\$0	\$0	\$0	(\$188,050)
2031	\$237,000	\$0	(\$56,544)	(\$76,405,003)	\$0	\$0	\$0	(\$227,927)
2032	\$262,000	\$0	(\$56,544)	(\$78,791,904)	\$0	\$0	\$0	(\$214,203)
2033	\$280,400	\$0	(\$52,774)	(\$68,172,897)	\$0	\$0	\$0	(\$216,099)
2034	\$267,600	\$0	(\$22,618)	(\$23,032,927)	\$0	\$0	\$0	(\$115,351)
2035	\$247,800	\$0	(\$11,309)	(\$16,117,932)	\$0	\$0	\$0	(\$49,027)
2036	\$227,400	\$0	(\$11,309)	(\$15,806,209)	\$0	\$0	\$0	(\$47,115)
2037	\$202,400	\$0	(\$3,770)	(\$3,839,024)	\$0	\$0	\$0	(\$19,525)
2038	\$179,600	\$0	(\$3,770)	(\$1,006,356)	\$0	\$0	\$0	(\$1,323)
2039	\$166,800	\$0	(\$15,078)	(\$11,101,342)	\$0	\$0	\$0	(\$50,654)
2040	\$170,000	\$0	(\$26,387)	(\$25,732,687)	\$0	\$0	\$0	(\$101,016)
2041	\$165,200	\$0	(\$18,848)	(\$19,426,231)	\$0	\$0	\$0	(\$70,901)
2042	\$151,400	\$0	(\$7,539)	(\$6,812,504)	\$0	\$0	\$0	(\$34,285)
2043	\$136,000	\$0	(\$3,770)	(\$3,035,259)	\$0	\$0	\$0	(\$14,935)
2044	\$122,000	\$0	(\$3,770)	(\$6,546,047)	\$0	\$0	\$0	(\$6,713)
2045	\$109,800	\$0	(\$3,770)	(\$6,546,047)	\$0	\$0	\$0	(\$6,713)
2046	\$96,000	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$87,600	\$0	(\$3,770)	(\$3,438,472)	\$0	\$0	\$0	(\$17,603)
2048	\$83,800	\$0	(\$7,539)	(\$6,904,404)	\$0	\$0	\$0	(\$35,381)
2049	\$79,600	\$0	(\$7,539)	(\$8,857,740)	\$0	\$0	\$0	(\$23,068)

**Table A-3 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Specific Limits - 1 mrem/yr (\$)**

<b>Year</b>	<b>Public and Occupational Health Routine</b>	<b>Public and Occupational Health Accident</b>	<b>Industry Implementation</b>	<b>Industry Operation</b>	<b>NRC Implementation</b>	<b>NRC Operation</b>	<b>Other Government</b>	<b>Environmental Considerations</b>
2003	(\$10,560)	\$0	(\$18,848)	\$16,743,605	(\$3,395)	\$0	(\$451,377)	\$237,554
2004	(\$15,000)	\$0	(\$11,309)	\$9,249,725	\$0	\$0	\$0	\$129,903
2005	(\$14,200)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$5,136
2006	(\$13,640)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$5,136
2007	(\$13,060)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$5,136
2008	(\$12,760)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$5,136
2009	(\$12,340)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$5,136
2010	(\$12,040)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$2,859
2011	(\$11,640)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$2,859
2012	(\$11,360)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$2,859
2013	(\$11,240)	\$0	\$0	\$732,608	\$0	\$0	\$0	\$2,859
2014	(\$11,200)	\$0	(\$3,770)	\$1,214,413	\$0	\$0	\$0	\$6,848
2015	(\$17,800)	\$0	(\$18,848)	\$22,359,758	\$0	\$0	\$0	\$149,095
2016	(\$28,800)	\$0	(\$26,387)	\$34,175,733	\$0	\$0	\$0	\$227,935
2017	(\$36,800)	\$0	(\$18,848)	\$23,776,945	\$0	\$0	\$0	\$156,869
2018	(\$50,000)	\$0	(\$33,926)	\$45,149,318	\$0	\$0	\$0	\$301,877
2019	(\$76,800)	\$0	(\$60,314)	\$76,800,837	\$0	\$0	\$0	\$512,193
2020	(\$105,400)	\$0	(\$67,853)	\$97,322,953	\$0	\$0	\$0	\$644,834
2021	(\$116,000)	\$0	(\$41,466)	\$64,387,344	\$0	\$0	\$0	\$426,412
2022	(\$124,000)	\$0	(\$30,157)	\$44,310,196	\$0	\$0	\$0	\$289,831
2023	(\$134,000)	\$0	(\$37,696)	\$50,279,371	\$0	\$0	\$0	\$328,589
2024	(\$132,000)	\$0	(\$22,618)	\$25,376,779	\$0	\$0	\$0	\$163,806
2025	(\$124,200)	\$0	(\$15,078)	\$12,220,040	\$0	\$0	\$0	\$78,488
2026	(\$120,600)	\$0	(\$18,848)	\$18,356,316	\$0	\$0	\$0	\$119,223
2027	(\$130,000)	\$0	(\$30,157)	\$37,756,101	\$0	\$0	\$0	\$246,062
2028	(\$138,000)	\$0	(\$37,696)	\$54,101,628	\$0	\$0	\$0	\$354,459
2029	(\$148,000)	\$0	(\$37,696)	\$61,800,707	\$0	\$0	\$0	\$408,465
2030	(\$166,000)	\$0	(\$52,774)	\$87,201,747	\$0	\$0	\$0	\$577,084
2031	(\$190,000)	\$0	(\$56,544)	\$94,607,147	\$0	\$0	\$0	\$622,616
2032	(\$208,000)	\$0	(\$56,544)	\$96,936,105	\$0	\$0	\$0	\$638,232
2033	(\$224,000)	\$0	(\$52,774)	\$86,923,790	\$0	\$0	\$0	\$571,652
2034	(\$218,000)	\$0	(\$22,618)	\$32,928,364	\$0	\$0	\$0	\$214,516
2035	(\$200,000)	\$0	(\$11,309)	\$19,796,783	\$0	\$0	\$0	\$130,304
2036	(\$186,000)	\$0	(\$11,309)	\$19,555,954	\$0	\$0	\$0	\$128,407
2037	(\$166,000)	\$0	(\$3,770)	\$5,595,958	\$0	\$0	\$0	\$36,004
2038	(\$144,000)	\$0	(\$3,770)	\$1,148,336	\$0	\$0	\$0	\$7,604
2039	(\$138,000)	\$0	(\$15,078)	\$15,594,693	\$0	\$0	\$0	\$101,832
2040	(\$138,000)	\$0	(\$26,387)	\$34,848,628	\$0	\$0	\$0	\$228,383
2041	(\$134,000)	\$0	(\$18,848)	\$25,840,903	\$0	\$0	\$0	\$169,283
2042	(\$125,800)	\$0	(\$7,539)	\$10,001,286	\$0	\$0	\$0	\$65,004
2043	(\$111,800)	\$0	(\$3,770)	\$4,533,931	\$0	\$0	\$0	\$29,785
2044	(\$100,000)	\$0	(\$3,770)	\$6,893,933	\$0	\$0	\$0	\$46,325
2045	(\$90,000)	\$0	(\$3,770)	\$6,893,933	\$0	\$0	\$0	\$46,325
2046	(\$79,600)	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	(\$72,400)	\$0	(\$3,770)	\$4,991,783	\$0	\$0	\$0	\$31,973
2048	(\$70,000)	\$0	(\$7,539)	\$9,923,992	\$0	\$0	\$0	\$63,460
2049	(\$66,200)	\$0	(\$7,539)	\$10,478,626	\$0	\$0	\$0	\$68,865

**Table A-4 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Specific Limits - 10 mrem/yr (\$)**

<b>Year</b>	<b>Public and Occupational Health Routine</b>	<b>Public and Occupational Health Accident</b>	<b>Industry Implementation</b>	<b>Industry Operation</b>	<b>NRC Implementation</b>	<b>NRC Operation</b>	<b>Other Government</b>	<b>Environmental Considerations</b>
2003	(\$105,560)	\$0	(\$18,848)	\$18,975,651	(\$3,395)	\$0	(\$451,377)	\$295,470
2004	(\$155,200)	\$0	(\$11,309)	\$10,624,203	\$0	\$0	\$0	\$164,154
2005	(\$156,200)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$13,061
2006	(\$157,440)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$13,061
2007	(\$158,460)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$13,061
2008	(\$159,360)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$13,061
2009	(\$160,140)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$13,061
2010	(\$160,840)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$7,646
2011	(\$161,440)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$7,646
2012	(\$161,960)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$7,646
2013	(\$162,440)	\$0	\$0	\$1,127,062	\$0	\$0	\$0	\$7,646
2014	(\$164,000)	\$0	(\$3,770)	\$1,659,095	\$0	\$0	\$0	\$12,429
2015	(\$238,000)	\$0	(\$18,848)	\$24,946,800	\$0	\$0	\$0	\$188,170
2016	(\$352,400)	\$0	(\$26,387)	\$38,036,241	\$0	\$0	\$0	\$290,582
2017	(\$420,200)	\$0	(\$18,848)	\$26,618,558	\$0	\$0	\$0	\$205,058
2018	(\$550,600)	\$0	(\$33,926)	\$50,134,101	\$0	\$0	\$0	\$382,867
2019	(\$810,800)	\$0	(\$60,314)	\$85,221,386	\$0	\$0	\$0	\$658,094
2020	(\$1,105,400)	\$0	(\$67,853)	\$107,887,663	\$0	\$0	\$0	\$836,424
2021	(\$1,228,000)	\$0	(\$41,466)	\$71,376,167	\$0	\$0	\$0	\$550,662
2022	(\$1,290,000)	\$0	(\$30,157)	\$49,315,056	\$0	\$0	\$0	\$386,193
2023	(\$1,374,000)	\$0	(\$37,696)	\$55,979,397	\$0	\$0	\$0	\$439,957
2024	(\$1,342,000)	\$0	(\$22,618)	\$28,445,874	\$0	\$0	\$0	\$227,831
2025	(\$1,246,200)	\$0	(\$15,078)	\$13,791,563	\$0	\$0	\$0	\$109,745
2026	(\$1,208,600)	\$0	(\$18,848)	\$20,622,590	\$0	\$0	\$0	\$165,456
2027	(\$1,276,000)	\$0	(\$30,157)	\$42,196,128	\$0	\$0	\$0	\$339,505
2028	(\$1,374,000)	\$0	(\$37,696)	\$60,225,271	\$0	\$0	\$0	\$474,312
2029	(\$1,458,000)	\$0	(\$37,696)	\$68,575,749	\$0	\$0	\$0	\$531,340
2030	(\$1,644,000)	\$0	(\$52,774)	\$96,815,447	\$0	\$0	\$0	\$756,609
2031	(\$1,854,000)	\$0	(\$56,544)	\$105,165,132	\$0	\$0	\$0	\$825,706
2032	(\$2,042,000)	\$0	(\$56,544)	\$107,453,319	\$0	\$0	\$0	\$837,002
2033	(\$2,178,000)	\$0	(\$52,774)	\$96,443,459	\$0	\$0	\$0	\$757,652
2034	(\$2,114,000)	\$0	(\$22,618)	\$36,721,286	\$0	\$0	\$0	\$296,432
2035	(\$1,940,000)	\$0	(\$11,309)	\$22,012,568	\$0	\$0	\$0	\$172,593
2036	(\$1,786,000)	\$0	(\$11,309)	\$21,746,406	\$0	\$0	\$0	\$170,186
2037	(\$1,596,000)	\$0	(\$3,770)	\$6,275,605	\$0	\$0	\$0	\$50,322
2038	(\$1,404,000)	\$0	(\$3,770)	\$1,289,270	\$0	\$0	\$0	\$9,665
2039	(\$1,322,000)	\$0	(\$15,078)	\$17,414,991	\$0	\$0	\$0	\$140,288
2040	(\$1,340,000)	\$0	(\$26,387)	\$38,764,819	\$0	\$0	\$0	\$308,980
2041	(\$1,302,000)	\$0	(\$18,848)	\$28,682,859	\$0	\$0	\$0	\$226,773
2042	(\$1,195,800)	\$0	(\$7,539)	\$11,123,450	\$0	\$0	\$0	\$89,203
2043	(\$1,071,800)	\$0	(\$3,770)	\$5,037,197	\$0	\$0	\$0	\$40,533
2044	(\$960,000)	\$0	(\$3,770)	\$7,611,559	\$0	\$0	\$0	\$57,429
2045	(\$862,000)	\$0	(\$3,770)	\$7,611,559	\$0	\$0	\$0	\$57,429
2046	(\$755,600)	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	(\$688,400)	\$0	(\$3,770)	\$5,556,406	\$0	\$0	\$0	\$44,270
2048	(\$655,200)	\$0	(\$7,539)	\$11,065,139	\$0	\$0	\$0	\$88,317
2049	(\$618,800)	\$0	(\$7,539)	\$11,659,353	\$0	\$0	\$0	\$90,704

**Table A-5 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Independent - 0.03 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,145	\$0	(\$18,848)	(\$73,918,704)	(\$3,395)	\$0	(\$451,377)	(\$1,351,148)
2004	\$21,659	\$0	(\$11,309)	(\$40,656,978)	\$0	\$0	\$0	(\$748,588)
2005	\$20,457	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$48,760)
2006	\$19,216	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$48,760)
2007	\$18,194	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$48,760)
2008	\$17,293	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$48,760)
2009	\$16,511	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$48,760)
2010	\$15,810	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$37,086)
2011	\$15,209	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$37,086)
2012	\$14,689	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$37,086)
2013	\$14,208	\$0	\$0	(\$1,256,768)	\$0	\$0	\$0	(\$37,086)
2014	\$14,046	\$0	(\$3,770)	(\$3,784,630)	\$0	\$0	\$0	(\$58,955)
2015	\$25,790	\$0	(\$18,848)	(\$110,334,964)	\$0	\$0	\$0	(\$869,427)
2016	\$45,298	(\$3,000,000)	(\$26,387)	(\$166,670,917)	\$0	\$0	\$0	(\$1,343,184)
2017	\$57,442	\$0	(\$18,848)	(\$113,151,384)	\$0	\$0	\$0	(\$953,959)
2018	\$78,932	(\$3,000,000)	(\$33,926)	(\$221,498,041)	\$0	\$0	\$0	(\$1,766,805)
2019	\$122,504	(\$3,000,000)	(\$60,314)	(\$370,546,753)	\$0	\$0	\$0	(\$3,045,709)
2020	\$173,658	(\$6,000,000)	(\$67,853)	(\$476,522,308)	\$0	\$0	\$0	(\$3,882,983)
2021	\$194,958	(\$3,000,000)	(\$41,466)	(\$316,683,843)	\$0	\$0	\$0	(\$2,557,756)
2022	\$204,904	(\$3,000,000)	(\$30,157)	(\$203,820,426)	\$0	\$0	\$0	(\$1,776,693)
2023	\$218,834	(\$3,000,000)	(\$37,696)	(\$230,997,130)	\$0	\$0	\$0	(\$2,017,735)
2024	\$214,848	\$0	(\$22,618)	(\$111,367,514)	\$0	\$0	\$0	(\$1,048,144)
2025	\$198,718	\$0	(\$15,078)	(\$53,445,682)	\$0	\$0	\$0	(\$507,669)
2026	\$190,354	\$0	(\$18,848)	(\$81,689,214)	\$0	\$0	\$0	(\$770,169)
2027	\$200,896	(\$3,000,000)	(\$30,157)	(\$168,076,981)	\$0	\$0	\$0	(\$1,573,291)
2028	\$218,814	(\$3,000,000)	(\$37,696)	(\$253,847,702)	\$0	\$0	\$0	(\$2,205,122)
2029	\$232,756	(\$3,000,000)	(\$37,696)	(\$301,105,132)	\$0	\$0	\$0	(\$2,458,206)
2030	\$266,602	(\$6,000,000)	(\$52,774)	(\$423,706,158)	\$0	\$0	\$0	(\$3,506,898)
2031	\$304,404	(\$6,000,000)	(\$56,544)	(\$454,525,519)	\$0	\$0	\$0	(\$3,841,795)
2032	\$336,242	(\$6,000,000)	(\$56,544)	(\$465,214,150)	\$0	\$0	\$0	(\$3,869,568)
2033	\$360,124	(\$6,000,000)	(\$52,774)	(\$409,053,376)	\$0	\$0	\$0	(\$3,494,979)
2034	\$344,194	(\$3,000,000)	(\$22,618)	(\$146,617,220)	\$0	\$0	\$0	(\$1,375,542)
2035	\$318,342	\$0	(\$11,309)	(\$95,813,031)	\$0	\$0	\$0	(\$811,558)
2036	\$292,474	\$0	(\$11,309)	(\$94,277,207)	\$0	\$0	\$0	(\$797,210)
2037	\$260,634	\$0	(\$3,770)	(\$24,781,927)	\$0	\$0	\$0	(\$234,577)
2038	\$230,794	\$0	(\$3,770)	(\$5,758,047)	\$0	\$0	\$0	(\$45,242)
2039	\$214,872	\$0	(\$15,078)	(\$70,662,169)	\$0	\$0	\$0	(\$651,321)
2040	\$218,862	(\$3,000,000)	(\$26,387)	(\$160,765,263)	\$0	\$0	\$0	(\$1,434,704)
2041	\$212,890	\$0	(\$18,848)	(\$119,976,328)	\$0	\$0	\$0	(\$1,053,850)
2042	\$195,172	\$0	(\$7,539)	(\$44,137,577)	\$0	\$0	\$0	(\$413,970)
2043	\$175,272	\$0	(\$3,770)	(\$19,970,346)	\$0	\$0	\$0	(\$187,167)
2044	\$157,168	\$0	(\$3,770)	(\$35,920,962)	\$0	\$0	\$0	(\$265,193)
2045	\$141,252	\$0	(\$3,770)	(\$35,920,962)	\$0	\$0	\$0	(\$265,193)
2046	\$123,740	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$112,996	\$0	(\$3,770)	(\$22,051,117)	\$0	\$0	\$0	(\$207,028)
2048	\$108,222	\$0	(\$7,539)	(\$44,156,969)	\$0	\$0	\$0	(\$414,442)
2049	\$102,658	\$0	(\$7,539)	(\$51,776,375)	\$0	\$0	\$0	(\$426,412)

**Table A-6 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Independent - 0.1 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$14,754	\$0	(\$18,848)	(\$15,859,375)	(\$3,395)	\$0	(\$451,377)	(\$159,941)
2004	\$21,092	\$0	(\$11,309)	(\$8,699,774)	\$0	\$0	\$0	(\$88,736)
2005	\$19,916	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$13,569)
2006	\$18,694	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$13,569)
2007	\$17,690	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$13,569)
2008	\$16,804	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$13,569)
2009	\$16,038	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$13,569)
2010	\$15,348	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$9,505)
2011	\$14,758	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$9,505)
2012	\$14,248	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$9,505)
2013	\$13,774	\$0	\$0	(\$109,642)	\$0	\$0	\$0	(\$9,505)
2014	\$13,616	\$0	(\$3,770)	(\$631,696)	\$0	\$0	\$0	(\$11,129)
2015	\$25,124	\$0	(\$18,848)	(\$23,006,590)	\$0	\$0	\$0	(\$113,097)
2016	\$44,226	\$0	(\$26,387)	(\$35,019,321)	\$0	\$0	\$0	(\$199,643)
2017	\$56,104	\$0	(\$18,848)	(\$23,964,935)	\$0	\$0	\$0	(\$164,367)
2018	\$77,140	\$0	(\$33,926)	(\$46,636,165)	\$0	\$0	\$0	(\$256,952)
2019	\$119,700	\$0	(\$60,314)	(\$78,452,965)	\$0	\$0	\$0	(\$504,598)
2020	\$169,740	\$0	(\$67,853)	(\$101,477,497)	\$0	\$0	\$0	(\$678,976)
2021	\$190,600	\$0	(\$41,466)	(\$67,533,324)	\$0	\$0	\$0	(\$433,171)
2022	\$200,300	\$0	(\$30,157)	(\$43,072,339)	\$0	\$0	\$0	(\$366,869)
2023	\$213,880	\$0	(\$37,696)	(\$48,789,185)	\$0	\$0	\$0	(\$419,463)
2024	\$209,940	\$0	(\$22,618)	(\$23,703,776)	\$0	\$0	\$0	(\$253,521)
2025	\$194,120	\$0	(\$15,078)	(\$11,274,456)	\$0	\$0	\$0	(\$120,761)
2026	\$185,900	\$0	(\$18,848)	(\$17,705,374)	\$0	\$0	\$0	(\$188,539)
2027	\$196,160	\$0	(\$30,157)	(\$36,418,806)	\$0	\$0	\$0	(\$387,304)
2028	\$213,660	\$0	(\$37,696)	(\$54,228,478)	\$0	\$0	\$0	(\$461,336)
2029	\$227,300	\$0	(\$37,696)	(\$63,730,261)	\$0	\$0	\$0	(\$431,902)
2030	\$260,440	\$0	(\$52,774)	(\$90,168,567)	\$0	\$0	\$0	(\$646,417)
2031	\$297,360	\$0	(\$56,544)	(\$97,011,487)	\$0	\$0	\$0	(\$753,557)
2032	\$328,520	\$0	(\$56,544)	(\$98,759,123)	\$0	\$0	\$0	(\$723,923)
2033	\$351,860	\$0	(\$52,774)	(\$87,405,235)	\$0	\$0	\$0	(\$707,295)
2034	\$336,220	\$0	(\$22,618)	(\$32,064,015)	\$0	\$0	\$0	(\$345,735)
2035	\$311,020	\$0	(\$11,309)	(\$20,466,917)	\$0	\$0	\$0	(\$159,760)
2036	\$285,720	\$0	(\$11,309)	(\$20,084,861)	\$0	\$0	\$0	(\$156,104)
2037	\$254,580	\$0	(\$3,770)	(\$5,401,096)	\$0	\$0	\$0	(\$59,040)
2038	\$225,460	\$0	(\$3,770)	(\$1,199,716)	\$0	\$0	\$0	(\$5,831)
2039	\$209,860	\$0	(\$15,078)	(\$15,263,308)	\$0	\$0	\$0	(\$156,797)
2040	\$213,780	\$0	(\$26,387)	(\$34,387,521)	\$0	\$0	\$0	(\$322,227)
2041	\$207,920	\$0	(\$18,848)	(\$25,570,643)	\$0	\$0	\$0	(\$227,958)
2042	\$190,600	\$0	(\$7,539)	(\$9,514,335)	\$0	\$0	\$0	(\$103,346)
2043	\$171,160	\$0	(\$3,770)	(\$4,260,362)	\$0	\$0	\$0	(\$46,228)
2044	\$153,500	\$0	(\$3,770)	(\$7,499,693)	\$0	\$0	\$0	(\$31,096)
2045	\$137,960	\$0	(\$3,770)	(\$7,499,693)	\$0	\$0	\$0	(\$31,096)
2046	\$120,840	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$110,340	\$0	(\$3,770)	(\$4,793,703)	\$0	\$0	\$0	(\$52,264)
2048	\$105,660	\$0	(\$7,539)	(\$9,610,936)	\$0	\$0	\$0	(\$104,602)
2049	\$100,260	\$0	(\$7,539)	(\$11,006,085)	\$0	\$0	\$0	(\$78,007)

**Table A-7 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Independent - 1 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$8,340	\$0	(\$18,848)	\$13,418,392	(\$3,395)	\$0	(\$451,377)	\$142,936
2004	\$12,020	\$0	(\$11,309)	\$7,255,578	\$0	\$0	\$0	\$75,691
2005	\$11,480	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2006	\$10,820	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2007	\$10,300	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2008	\$9,860	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2009	\$9,460	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2010	\$9,100	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2011	\$8,800	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2012	\$8,540	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2013	\$8,300	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2014	\$8,240	\$0	(\$3,770)	\$600,554	\$0	\$0	\$0	(\$581)
2015	\$15,460	\$0	(\$18,848)	\$19,380,272	\$0	\$0	\$0	\$86,144
2016	\$27,260	\$0	(\$26,387)	\$29,461,816	\$0	\$0	\$0	\$123,749
2017	\$34,200	\$0	(\$18,848)	\$20,039,265	\$0	\$0	\$0	\$75,669
2018	\$47,000	\$0	(\$33,926)	\$39,178,995	\$0	\$0	\$0	\$167,442
2019	\$72,200	\$0	(\$60,314)	\$65,971,458	\$0	\$0	\$0	\$262,120
2020	\$102,800	\$0	(\$67,853)	\$84,066,938	\$0	\$0	\$0	\$315,696
2021	\$115,800	\$0	(\$41,466)	\$55,758,237	\$0	\$0	\$0	\$214,214
2022	\$120,800	\$0	(\$30,157)	\$37,375,753	\$0	\$0	\$0	\$120,028
2023	\$128,200	\$0	(\$37,696)	\$42,389,042	\$0	\$0	\$0	\$134,332
2024	\$125,400	\$0	(\$22,618)	\$20,717,459	\$0	\$0	\$0	\$51,169
2025	\$115,200	\$0	(\$15,078)	\$9,852,682	\$0	\$0	\$0	\$23,970
2026	\$109,600	\$0	(\$18,848)	\$14,885,463	\$0	\$0	\$0	\$36,542
2027	\$114,800	\$0	(\$30,157)	\$30,890,787	\$0	\$0	\$0	\$77,247
2028	\$125,200	\$0	(\$37,696)	\$45,583,568	\$0	\$0	\$0	\$143,438
2029	\$133,600	\$0	(\$37,696)	\$53,336,462	\$0	\$0	\$0	\$198,469
2030	\$153,800	\$0	(\$52,774)	\$74,869,268	\$0	\$0	\$0	\$268,667
2031	\$175,400	\$0	(\$56,544)	\$80,592,498	\$0	\$0	\$0	\$271,138
2032	\$194,200	\$0	(\$56,544)	\$83,268,822	\$0	\$0	\$0	\$294,697
2033	\$207,800	\$0	(\$52,774)	\$73,956,030	\$0	\$0	\$0	\$245,300
2034	\$196,800	\$0	(\$22,618)	\$26,997,098	\$0	\$0	\$0	\$65,784
2035	\$182,600	\$0	(\$11,309)	\$16,820,600	\$0	\$0	\$0	\$56,034
2036	\$167,400	\$0	(\$11,309)	\$16,642,459	\$0	\$0	\$0	\$55,620
2037	\$148,800	\$0	(\$3,770)	\$4,554,848	\$0	\$0	\$0	\$10,519
2038	\$132,400	\$0	(\$3,770)	\$983,419	\$0	\$0	\$0	\$4,256
2039	\$122,400	\$0	(\$15,078)	\$12,851,053	\$0	\$0	\$0	\$33,086
2040	\$124,800	\$0	(\$26,387)	\$29,130,525	\$0	\$0	\$0	\$84,190
2041	\$121,400	\$0	(\$18,848)	\$21,756,129	\$0	\$0	\$0	\$66,255
2042	\$110,600	\$0	(\$7,539)	\$8,231,138	\$0	\$0	\$0	\$20,360
2043	\$99,200	\$0	(\$3,770)	\$3,732,438	\$0	\$0	\$0	\$9,614
2044	\$89,200	\$0	(\$3,770)	\$6,187,055	\$0	\$0	\$0	\$28,472
2045	\$80,400	\$0	(\$3,770)	\$6,187,055	\$0	\$0	\$0	\$28,472
2046	\$70,400	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$64,200	\$0	(\$3,770)	\$4,107,966	\$0	\$0	\$0	\$9,645
2048	\$61,200	\$0	(\$7,539)	\$8,153,607	\$0	\$0	\$0	\$18,737
2049	\$58,200	\$0	(\$7,539)	\$9,008,663	\$0	\$0	\$0	\$31,735

**Table A-8 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Independent - 10 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	(\$24,560)	\$0	(\$18,848)	\$17,313,589	(\$3,395)	\$0	(\$451,377)	\$254,977
2004	(\$35,000)	\$0	(\$11,309)	\$9,381,712	\$0	\$0	\$0	\$136,282
2005	(\$33,800)	\$0	\$0	\$343,833	\$0	\$0	\$0	(\$999)
2006	(\$32,840)	\$0	\$0	\$343,833	\$0	\$0	\$0	(\$999)
2007	(\$31,860)	\$0	\$0	\$343,833	\$0	\$0	\$0	(\$999)
2008	(\$31,160)	\$0	\$0	\$343,833	\$0	\$0	\$0	(\$999)
2009	(\$30,340)	\$0	\$0	\$343,833	\$0	\$0	\$0	(\$999)
2010	(\$29,840)	\$0	\$0	\$343,833	\$0	\$0	\$0	\$42
2011	(\$29,240)	\$0	\$0	\$343,833	\$0	\$0	\$0	\$42
2012	(\$28,760)	\$0	\$0	\$343,833	\$0	\$0	\$0	\$42
2013	(\$28,440)	\$0	\$0	\$343,833	\$0	\$0	\$0	\$42
2014	(\$28,400)	\$0	(\$3,770)	\$860,222	\$0	\$0	\$0	\$4,459
2015	(\$44,800)	\$0	(\$18,848)	\$23,411,217	\$0	\$0	\$0	\$163,770
2016	(\$71,200)	\$0	(\$26,387)	\$35,976,200	\$0	\$0	\$0	\$253,707
2017	(\$87,400)	\$0	(\$18,848)	\$24,891,088	\$0	\$0	\$0	\$175,747
2018	(\$117,200)	\$0	(\$33,926)	\$47,724,349	\$0	\$0	\$0	\$337,092
2019	(\$180,800)	\$0	(\$60,314)	\$81,344,324	\$0	\$0	\$0	\$577,239
2020	(\$249,400)	\$0	(\$67,853)	\$103,249,196	\$0	\$0	\$0	\$730,426
2021	(\$278,000)	\$0	(\$41,466)	\$68,184,587	\$0	\$0	\$0	\$480,447
2022	(\$294,000)	\$0	(\$30,157)	\$46,701,157	\$0	\$0	\$0	\$329,620
2023	(\$314,000)	\$0	(\$37,696)	\$53,072,560	\$0	\$0	\$0	\$375,694
2024	(\$310,000)	\$0	(\$22,618)	\$26,602,875	\$0	\$0	\$0	\$189,853
2025	(\$288,200)	\$0	(\$15,078)	\$12,681,057	\$0	\$0	\$0	\$90,074
2026	(\$280,600)	\$0	(\$18,848)	\$19,181,885	\$0	\$0	\$0	\$137,149
2027	(\$300,000)	\$0	(\$30,157)	\$39,744,030	\$0	\$0	\$0	\$285,504
2028	(\$326,000)	\$0	(\$37,696)	\$57,265,437	\$0	\$0	\$0	\$407,005
2029	(\$346,000)	\$0	(\$37,696)	\$65,602,724	\$0	\$0	\$0	\$463,177
2030	(\$388,000)	\$0	(\$52,774)	\$92,688,108	\$0	\$0	\$0	\$658,608
2031	(\$442,000)	\$0	(\$56,544)	\$100,544,873	\$0	\$0	\$0	\$714,586
2032	(\$486,000)	\$0	(\$56,544)	\$102,944,105	\$0	\$0	\$0	\$727,365
2033	(\$522,000)	\$0	(\$52,774)	\$92,221,838	\$0	\$0	\$0	\$654,454
2034	(\$506,000)	\$0	(\$22,618)	\$34,777,896	\$0	\$0	\$0	\$249,735
2035	(\$462,000)	\$0	(\$11,309)	\$20,992,713	\$0	\$0	\$0	\$148,582
2036	(\$428,000)	\$0	(\$11,309)	\$20,751,891	\$0	\$0	\$0	\$146,653
2037	(\$384,000)	\$0	(\$3,770)	\$5,881,302	\$0	\$0	\$0	\$41,730
2038	(\$336,000)	\$0	(\$3,770)	\$1,180,040	\$0	\$0	\$0	\$8,174
2039	(\$318,000)	\$0	(\$15,078)	\$16,499,508	\$0	\$0	\$0	\$118,350
2040	(\$322,000)	\$0	(\$26,387)	\$36,925,771	\$0	\$0	\$0	\$263,602
2041	(\$314,000)	\$0	(\$18,848)	\$27,384,292	\$0	\$0	\$0	\$194,707
2042	(\$289,800)	\$0	(\$7,539)	\$10,569,439	\$0	\$0	\$0	\$75,535
2043	(\$259,800)	\$0	(\$3,770)	\$4,779,947	\$0	\$0	\$0	\$34,248
2044	(\$232,000)	\$0	(\$3,770)	\$7,385,450	\$0	\$0	\$0	\$51,809
2045	(\$208,000)	\$0	(\$3,770)	\$7,385,450	\$0	\$0	\$0	\$51,809
2046	(\$181,600)	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	(\$166,400)	\$0	(\$3,770)	\$5,274,950	\$0	\$0	\$0	\$37,265
2048	(\$159,200)	\$0	(\$7,539)	\$10,498,179	\$0	\$0	\$0	\$74,207
2049	(\$148,800)	\$0	(\$7,539)	\$11,189,626	\$0	\$0	\$0	\$79,022

**Table A-9 Net Incremental Benefit (Cost) Associated with Attributes for Unrestricted Release - Material Independent - RS-G-1.7 (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$1,440	\$0	(\$18,848)	\$13,418,392	(\$3,395)	\$0	(\$451,377)	\$142,936
2004	\$2,240	\$0	(\$11,309)	\$7,255,578	\$0	\$0	\$0	\$75,691
2005	\$2,360	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2006	\$2,280	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2007	\$2,260	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2008	\$2,280	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2009	\$2,260	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$5,669)
2010	\$2,240	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2011	\$2,240	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2012	\$2,240	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2013	\$2,240	\$0	\$0	\$168,496	\$0	\$0	\$0	(\$3,387)
2014	\$2,280	\$0	(\$3,770)	\$600,554	\$0	\$0	\$0	(\$581)
2015	\$4,920	\$0	(\$18,848)	\$19,380,272	\$0	\$0	\$0	\$86,144
2016	\$8,920	\$0	(\$26,387)	\$29,461,816	\$0	\$0	\$0	\$123,749
2017	\$10,600	\$0	(\$18,848)	\$20,039,265	\$0	\$0	\$0	\$75,669
2018	\$14,600	\$0	(\$33,926)	\$39,178,995	\$0	\$0	\$0	\$167,442
2019	\$21,200	\$0	(\$60,314)	\$65,971,458	\$0	\$0	\$0	\$262,120
2020	\$31,000	\$0	(\$67,853)	\$84,066,938	\$0	\$0	\$0	\$315,696
2021	\$35,600	\$0	(\$41,466)	\$55,758,237	\$0	\$0	\$0	\$214,214
2022	\$35,600	\$0	(\$30,157)	\$37,375,753	\$0	\$0	\$0	\$120,028
2023	\$36,400	\$0	(\$37,696)	\$42,389,042	\$0	\$0	\$0	\$134,332
2024	\$34,800	\$0	(\$22,618)	\$20,717,459	\$0	\$0	\$0	\$51,169
2025	\$30,600	\$0	(\$15,078)	\$9,852,682	\$0	\$0	\$0	\$23,970
2026	\$27,800	\$0	(\$18,848)	\$14,885,463	\$0	\$0	\$0	\$36,542
2027	\$27,600	\$0	(\$30,157)	\$30,890,787	\$0	\$0	\$0	\$77,247
2028	\$30,400	\$0	(\$37,696)	\$45,583,568	\$0	\$0	\$0	\$143,438
2029	\$33,200	\$0	(\$37,696)	\$53,336,462	\$0	\$0	\$0	\$198,469
2030	\$39,600	\$0	(\$52,774)	\$74,869,268	\$0	\$0	\$0	\$268,667
2031	\$44,800	\$0	(\$56,544)	\$80,592,498	\$0	\$0	\$0	\$271,138
2032	\$50,400	\$0	(\$56,544)	\$83,268,822	\$0	\$0	\$0	\$294,697
2033	\$53,600	\$0	(\$52,774)	\$73,956,030	\$0	\$0	\$0	\$245,300
2034	\$47,600	\$0	(\$22,618)	\$26,997,098	\$0	\$0	\$0	\$65,784
2035	\$45,200	\$0	(\$11,309)	\$16,820,600	\$0	\$0	\$0	\$56,034
2036	\$40,800	\$0	(\$11,309)	\$16,642,459	\$0	\$0	\$0	\$55,620
2037	\$35,600	\$0	(\$3,770)	\$4,554,848	\$0	\$0	\$0	\$10,519
2038	\$32,800	\$0	(\$3,770)	\$983,419	\$0	\$0	\$0	\$4,256
2039	\$28,800	\$0	(\$15,078)	\$12,851,053	\$0	\$0	\$0	\$33,086
2040	\$29,600	\$0	(\$26,387)	\$29,130,525	\$0	\$0	\$0	\$84,190
2041	\$28,800	\$0	(\$18,848)	\$21,756,129	\$0	\$0	\$0	\$66,255
2042	\$25,000	\$0	(\$7,539)	\$8,231,138	\$0	\$0	\$0	\$20,360
2043	\$22,200	\$0	(\$3,770)	\$3,732,438	\$0	\$0	\$0	\$9,614
2044	\$20,400	\$0	(\$3,770)	\$6,187,055	\$0	\$0	\$0	\$28,472
2045	\$18,800	\$0	(\$3,770)	\$6,187,055	\$0	\$0	\$0	\$28,472
2046	\$16,400	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$14,800	\$0	(\$3,770)	\$4,107,966	\$0	\$0	\$0	\$9,645
2048	\$13,600	\$0	(\$7,539)	\$8,153,607	\$0	\$0	\$0	\$18,737
2049	\$13,200	\$0	(\$7,539)	\$9,008,663	\$0	\$0	\$0	\$31,735

**Table A-10 Net Incremental Benefit (Cost) Associated with Attributes for EPA/State-Regulated Disposal (Landfill) - 0.03 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,236	\$0	(\$18,848)	(\$73,792,689)	(\$3,395)	\$0	(\$451,377)	(\$1,348,379)
2004	\$21,798	\$0	(\$11,309)	(\$40,532,801)	\$0	\$0	\$0	(\$745,860)
2005	\$20,600	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2006	\$19,360	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2007	\$18,340	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2008	\$17,440	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2009	\$16,660	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$46,077)
2010	\$15,960	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2011	\$15,360	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2012	\$14,840	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2013	\$14,360	\$0	\$0	(\$1,134,637)	\$0	\$0	\$0	(\$35,746)
2014	\$14,200	\$0	(\$3,770)	(\$3,662,425)	\$0	\$0	\$0	(\$57,614)
2015	\$25,997	\$0	(\$18,848)	(\$110,212,760)	\$0	\$0	\$0	(\$868,326)
2016	\$45,595	(\$3,000,000)	(\$26,387)	(\$166,548,785)	\$0	\$0	\$0	(\$1,342,084)
2017	\$57,796	\$0	(\$18,848)	(\$113,032,649)	\$0	\$0	\$0	(\$952,889)
2018	\$79,393	(\$3,000,000)	(\$33,926)	(\$221,381,781)	\$0	\$0	\$0	(\$1,765,758)
2019	\$123,187	(\$3,000,000)	(\$60,314)	(\$370,432,493)	\$0	\$0	\$0	(\$3,044,680)
2020	\$174,584	(\$6,000,000)	(\$67,853)	(\$476,413,898)	\$0	\$0	\$0	(\$3,882,032)
2021	\$195,990	(\$3,000,000)	(\$41,466)	(\$316,584,440)	\$0	\$0	\$0	(\$2,556,884)
2022	\$205,991	(\$3,000,000)	(\$30,157)	(\$203,730,363)	\$0	\$0	\$0	(\$1,775,903)
2023	\$219,990	(\$3,000,000)	(\$37,696)	(\$230,909,345)	\$0	\$0	\$0	(\$2,016,965)
2024	\$215,994	\$0	(\$22,618)	(\$111,286,568)	\$0	\$0	\$0	(\$1,047,434)
2025	\$199,797	\$0	(\$15,078)	(\$53,367,953)	\$0	\$0	\$0	(\$506,990)
2026	\$191,396	\$0	(\$18,848)	(\$81,613,878)	\$0	\$0	\$0	(\$769,510)
2027	\$201,992	(\$3,000,000)	(\$30,157)	(\$168,001,997)	\$0	\$0	\$0	(\$1,572,635)
2028	\$219,990	(\$3,000,000)	(\$37,696)	(\$253,776,649)	\$0	\$0	\$0	(\$2,204,502)
2029	\$233,990	(\$3,000,000)	(\$37,696)	(\$301,038,895)	\$0	\$0	\$0	(\$2,457,628)
2030	\$267,985	(\$6,000,000)	(\$52,774)	(\$423,645,204)	\$0	\$0	\$0	(\$3,506,365)
2031	\$305,983	(\$6,000,000)	(\$56,544)	(\$454,470,162)	\$0	\$0	\$0	(\$3,841,311)
2032	\$337,983	(\$6,000,000)	(\$56,544)	(\$465,170,953)	\$0	\$0	\$0	(\$3,869,190)
2033	\$361,984	(\$6,000,000)	(\$52,774)	(\$409,017,991)	\$0	\$0	\$0	(\$3,494,670)
2034	\$345,992	(\$3,000,000)	(\$22,618)	(\$146,593,443)	\$0	\$0	\$0	(\$1,375,334)
2035	\$319,996	\$0	(\$11,309)	(\$95,796,042)	\$0	\$0	\$0	(\$811,410)
2036	\$293,996	\$0	(\$11,309)	(\$94,261,732)	\$0	\$0	\$0	(\$797,075)
2037	\$261,999	\$0	(\$3,770)	(\$24,769,000)	\$0	\$0	\$0	(\$234,464)
2038	\$232,000	\$0	(\$3,770)	(\$5,746,314)	\$0	\$0	\$0	(\$45,140)
2039	\$215,997	\$0	(\$15,078)	(\$70,650,437)	\$0	\$0	\$0	(\$651,218)
2040	\$219,993	(\$3,000,000)	(\$26,387)	(\$160,753,698)	\$0	\$0	\$0	(\$1,434,603)
2041	\$213,995	\$0	(\$18,848)	(\$119,968,404)	\$0	\$0	\$0	(\$1,053,780)
2042	\$196,198	\$0	(\$7,539)	(\$44,134,092)	\$0	\$0	\$0	(\$413,940)
2043	\$176,199	\$0	(\$3,770)	(\$19,968,177)	\$0	\$0	\$0	(\$187,148)
2044	\$157,999	\$0	(\$3,770)	(\$35,919,945)	\$0	\$0	\$0	(\$265,184)
2045	\$141,999	\$0	(\$3,770)	(\$35,919,945)	\$0	\$0	\$0	(\$265,184)
2046	\$124,400	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$113,599	\$0	(\$3,770)	(\$22,049,890)	\$0	\$0	\$0	(\$207,017)
2048	\$108,798	\$0	(\$7,539)	(\$44,154,494)	\$0	\$0	\$0	(\$414,420)
2049	\$103,198	\$0	(\$7,539)	(\$51,774,275)	\$0	\$0	\$0	(\$426,393)

**Table A-11 Net Incremental Benefit (Cost) Associated with Attributes for EPA/State-Regulated Disposal (Landfill) - 0.1 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,229	\$0	(\$18,848)	(\$14,151,766)	(\$3,395)	\$0	(\$451,377)	(\$83,417)
2004	\$21,794	\$0	(\$11,309)	(\$7,800,722)	\$0	\$0	\$0	(\$53,266)
2005	\$20,599	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$26,236)
2006	\$19,359	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$26,236)
2007	\$18,339	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$26,236)
2008	\$17,439	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$26,236)
2009	\$16,659	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$26,236)
2010	\$15,959	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$25,837)
2011	\$15,359	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$25,837)
2012	\$14,839	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$25,837)
2013	\$14,359	\$0	\$0	\$71,845	\$0	\$0	\$0	(\$25,837)
2014	\$14,199	\$0	(\$3,770)	(\$482,717)	\$0	\$0	\$0	(\$26,339)
2015	\$25,990	\$0	(\$18,848)	(\$23,629,392)	\$0	\$0	\$0	(\$103,257)
2016	\$45,584	\$0	(\$26,387)	(\$35,182,862)	\$0	\$0	\$0	(\$183,249)
2017	\$57,788	\$0	(\$18,848)	(\$23,309,568)	\$0	\$0	\$0	(\$164,729)
2018	\$79,380	\$0	(\$33,926)	(\$47,062,983)	\$0	\$0	\$0	(\$226,471)
2019	\$123,162	\$0	(\$60,314)	(\$77,247,910)	\$0	\$0	\$0	(\$461,968)
2020	\$174,554	\$0	(\$67,853)	(\$100,888,590)	\$0	\$0	\$0	(\$655,713)
2021	\$195,971	\$0	(\$41,466)	(\$67,627,427)	\$0	\$0	\$0	(\$416,605)
2022	\$205,976	\$0	(\$30,157)	(\$40,823,039)	\$0	\$0	\$0	(\$384,018)
2023	\$219,972	\$0	(\$37,696)	(\$46,142,690)	\$0	\$0	\$0	(\$438,533)
2024	\$215,984	\$0	(\$22,618)	(\$21,165,364)	\$0	\$0	\$0	(\$282,650)
2025	\$199,792	\$0	(\$15,078)	(\$10,090,514)	\$0	\$0	\$0	(\$141,690)
2026	\$191,388	\$0	(\$18,848)	(\$15,775,067)	\$0	\$0	\$0	(\$213,365)
2027	\$201,976	\$0	(\$30,157)	(\$32,462,176)	\$0	\$0	\$0	(\$426,534)
2028	\$219,970	\$0	(\$37,696)	(\$51,366,526)	\$0	\$0	\$0	(\$481,596)
2029	\$233,970	\$0	(\$37,696)	(\$63,153,664)	\$0	\$0	\$0	(\$422,482)
2030	\$267,957	\$0	(\$52,774)	(\$88,410,978)	\$0	\$0	\$0	(\$640,737)
2031	\$305,951	\$0	(\$56,544)	(\$93,741,172)	\$0	\$0	\$0	(\$762,763)
2032	\$337,952	\$0	(\$56,544)	(\$96,557,829)	\$0	\$0	\$0	(\$719,021)
2033	\$361,955	\$0	(\$52,774)	(\$83,659,322)	\$0	\$0	\$0	(\$720,361)
2034	\$345,979	\$0	(\$22,618)	(\$28,443,165)	\$0	\$0	\$0	(\$376,032)
2035	\$319,989	\$0	(\$11,309)	(\$19,791,386)	\$0	\$0	\$0	(\$162,866)
2036	\$293,989	\$0	(\$11,309)	(\$19,417,851)	\$0	\$0	\$0	(\$158,358)
2037	\$261,996	\$0	(\$3,770)	(\$4,768,605)	\$0	\$0	\$0	(\$65,480)
2038	\$231,999	\$0	(\$3,770)	(\$1,250,548)	\$0	\$0	\$0	(\$6,604)
2039	\$215,990	\$0	(\$15,078)	(\$13,748,598)	\$0	\$0	\$0	(\$169,196)
2040	\$219,979	\$0	(\$26,387)	(\$31,792,317)	\$0	\$0	\$0	(\$338,949)
2041	\$213,985	\$0	(\$18,848)	(\$23,963,999)	\$0	\$0	\$0	(\$236,966)
2042	\$196,194	\$0	(\$7,539)	(\$8,453,233)	\$0	\$0	\$0	(\$112,050)
2043	\$176,197	\$0	(\$3,770)	(\$3,784,511)	\$0	\$0	\$0	(\$50,218)
2044	\$157,997	\$0	(\$3,770)	(\$7,951,527)	\$0	\$0	\$0	(\$23,948)
2045	\$141,997	\$0	(\$3,770)	(\$7,951,527)	\$0	\$0	\$0	(\$23,948)
2046	\$124,400	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$113,596	\$0	(\$3,770)	(\$4,249,220)	\$0	\$0	\$0	(\$56,418)
2048	\$108,793	\$0	(\$7,539)	(\$8,530,045)	\$0	\$0	\$0	(\$113,019)
2049	\$103,195	\$0	(\$7,539)	(\$10,845,065)	\$0	\$0	\$0	(\$76,314)

**Table A-12 Net Incremental Benefit (Cost) Associated with Attributes for EPA/State-Regulated Disposal (Landfill) - 1 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,188	\$0	(\$18,848)	\$10,196,041	(\$3,395)	\$0	(\$451,377)	\$60,330
2004	\$21,768	\$0	(\$11,309)	\$5,605,693	\$0	\$0	\$0	\$27,713
2005	\$20,590	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2006	\$19,349	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2007	\$18,329	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2008	\$17,429	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2009	\$16,648	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2010	\$15,948	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2011	\$15,348	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2012	\$14,827	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2013	\$14,347	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2014	\$14,186	\$0	(\$3,770)	\$704,185	\$0	\$0	\$0	(\$21,343)
2015	\$25,948	\$0	(\$18,848)	\$14,031,442	\$0	\$0	\$0	(\$13,996)
2016	\$45,519	\$0	(\$26,387)	\$21,329,573	\$0	\$0	\$0	(\$50,056)
2017	\$57,734	\$0	(\$18,848)	\$14,685,257	\$0	\$0	\$0	(\$74,658)
2018	\$79,298	\$0	(\$33,926)	\$28,249,757	\$0	\$0	\$0	(\$48,958)
2019	\$123,023	\$0	(\$60,314)	\$47,735,563	\$0	\$0	\$0	(\$168,625)
2020	\$174,384	\$0	(\$67,853)	\$60,430,917	\$0	\$0	\$0	(\$285,375)
2021	\$195,858	\$0	(\$41,466)	\$40,043,951	\$0	\$0	\$0	(\$167,667)
2022	\$205,883	\$0	(\$30,157)	\$27,557,562	\$0	\$0	\$0	(\$226,453)
2023	\$219,869	\$0	(\$37,696)	\$31,280,028	\$0	\$0	\$0	(\$260,469)
2024	\$215,921	\$0	(\$22,618)	\$15,593,721	\$0	\$0	\$0	(\$197,501)
2025	\$199,756	\$0	(\$15,078)	\$7,477,842	\$0	\$0	\$0	(\$101,084)
2026	\$191,339	\$0	(\$18,848)	\$11,161,184	\$0	\$0	\$0	(\$150,512)
2027	\$201,886	\$0	(\$30,157)	\$23,030,455	\$0	\$0	\$0	(\$297,893)
2028	\$219,862	\$0	(\$37,696)	\$33,322,099	\$0	\$0	\$0	(\$288,630)
2029	\$233,862	\$0	(\$37,696)	\$38,458,390	\$0	\$0	\$0	(\$192,053)
2030	\$267,800	\$0	(\$52,774)	\$54,026,834	\$0	\$0	\$0	(\$317,955)
2031	\$305,772	\$0	(\$56,544)	\$58,382,683	\$0	\$0	\$0	(\$418,052)
2032	\$337,778	\$0	(\$56,544)	\$60,276,909	\$0	\$0	\$0	(\$361,832)
2033	\$361,790	\$0	(\$52,774)	\$53,919,204	\$0	\$0	\$0	(\$404,564)
2034	\$345,899	\$0	(\$22,618)	\$20,073,968	\$0	\$0	\$0	(\$262,852)
2035	\$319,946	\$0	(\$11,309)	\$12,144,670	\$0	\$0	\$0	(\$90,924)
2036	\$293,950	\$0	(\$11,309)	\$12,044,746	\$0	\$0	\$0	(\$87,495)
2037	\$261,980	\$0	(\$3,770)	\$3,418,544	\$0	\$0	\$0	(\$46,335)
2038	\$231,993	\$0	(\$3,770)	\$713,046	\$0	\$0	\$0	(\$2,047)
2039	\$215,950	\$0	(\$15,078)	\$9,522,377	\$0	\$0	\$0	(\$116,076)
2040	\$219,904	\$0	(\$26,387)	\$21,385,944	\$0	\$0	\$0	(\$218,816)
2041	\$213,932	\$0	(\$18,848)	\$15,911,160	\$0	\$0	\$0	(\$146,779)
2042	\$196,168	\$0	(\$7,539)	\$6,125,910	\$0	\$0	\$0	(\$78,454)
2043	\$176,184	\$0	(\$3,770)	\$2,777,188	\$0	\$0	\$0	(\$35,324)
2044	\$157,985	\$0	(\$3,770)	\$4,351,403	\$0	\$0	\$0	\$3,632
2045	\$141,985	\$0	(\$3,770)	\$4,351,403	\$0	\$0	\$0	\$3,632
2046	\$124,397	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$113,585	\$0	(\$3,770)	\$3,059,277	\$0	\$0	\$0	(\$39,412)
2048	\$108,769	\$0	(\$7,539)	\$6,066,406	\$0	\$0	\$0	(\$79,193)
2049	\$103,172	\$0	(\$7,539)	\$6,464,498	\$0	\$0	\$0	(\$37,645)

**Table A-13 Net Incremental Benefit (Cost) Associated with Attributes for EPA/State-Regulated Disposal (Landfill) - 10 mrem/yr (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,032	\$0	(\$18,848)	\$10,947,420	(\$3,395)	\$0	(\$451,377)	\$72,939
2004	\$21,643	\$0	(\$11,309)	\$6,186,051	\$0	\$0	\$0	\$37,452
2005	\$20,497	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$14,872)
2006	\$19,252	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$14,872)
2007	\$18,227	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$14,872)
2008	\$17,323	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$14,872)
2009	\$16,539	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$14,872)
2010	\$15,835	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$20,162)
2011	\$15,233	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$20,162)
2012	\$14,710	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$20,162)
2013	\$14,228	\$0	\$0	\$763,279	\$0	\$0	\$0	(\$20,162)
2014	\$14,063	\$0	(\$3,770)	\$1,082,335	\$0	\$0	\$0	(\$18,174)
2015	\$25,750	\$0	(\$18,848)	\$15,056,026	\$0	\$0	\$0	(\$6,949)
2016	\$45,274	\$0	(\$26,387)	\$22,662,750	\$0	\$0	\$0	(\$40,886)
2017	\$57,522	\$0	(\$18,848)	\$15,670,225	\$0	\$0	\$0	(\$67,883)
2018	\$79,014	\$0	(\$33,926)	\$29,901,486	\$0	\$0	\$0	(\$37,597)
2019	\$122,602	\$0	(\$60,314)	\$50,164,318	\$0	\$0	\$0	(\$151,919)
2020	\$173,900	\$0	(\$67,853)	\$63,497,935	\$0	\$0	\$0	(\$264,826)
2021	\$195,506	\$0	(\$41,466)	\$42,171,597	\$0	\$0	\$0	(\$153,412)
2022	\$205,584	\$0	(\$30,157)	\$28,946,326	\$0	\$0	\$0	(\$217,148)
2023	\$219,546	\$0	(\$37,696)	\$32,822,650	\$0	\$0	\$0	(\$250,133)
2024	\$215,704	\$0	(\$22,618)	\$16,411,646	\$0	\$0	\$0	(\$192,021)
2025	\$199,603	\$0	(\$15,078)	\$7,982,041	\$0	\$0	\$0	(\$97,719)
2026	\$191,150	\$0	(\$18,848)	\$11,792,948	\$0	\$0	\$0	(\$146,296)
2027	\$201,608	\$0	(\$30,157)	\$24,093,204	\$0	\$0	\$0	(\$290,801)
2028	\$219,542	\$0	(\$37,696)	\$34,919,551	\$0	\$0	\$0	(\$277,969)
2029	\$233,534	\$0	(\$37,696)	\$40,410,416	\$0	\$0	\$0	(\$179,025)
2030	\$267,366	\$0	(\$52,774)	\$56,618,999	\$0	\$0	\$0	(\$300,652)
2031	\$305,304	\$0	(\$56,544)	\$61,112,951	\$0	\$0	\$0	(\$399,827)
2032	\$337,316	\$0	(\$56,544)	\$63,061,762	\$0	\$0	\$0	(\$343,242)
2033	\$361,352	\$0	(\$52,774)	\$56,283,908	\$0	\$0	\$0	(\$388,779)
2034	\$345,678	\$0	(\$22,618)	\$20,877,457	\$0	\$0	\$0	(\$257,489)
2035	\$319,811	\$0	(\$11,309)	\$12,728,683	\$0	\$0	\$0	(\$87,025)
2036	\$293,817	\$0	(\$11,309)	\$12,620,983	\$0	\$0	\$0	(\$83,648)
2037	\$261,906	\$0	(\$3,770)	\$3,582,327	\$0	\$0	\$0	(\$45,242)
2038	\$231,947	\$0	(\$3,770)	\$780,242	\$0	\$0	\$0	(\$1,598)
2039	\$215,833	\$0	(\$15,078)	\$9,920,166	\$0	\$0	\$0	(\$113,421)
2040	\$219,702	\$0	(\$26,387)	\$22,266,518	\$0	\$0	\$0	(\$212,938)
2041	\$213,782	\$0	(\$18,848)	\$16,571,919	\$0	\$0	\$0	(\$142,368)
2042	\$196,094	\$0	(\$7,539)	\$6,352,559	\$0	\$0	\$0	(\$76,941)
2043	\$176,139	\$0	(\$3,770)	\$2,878,845	\$0	\$0	\$0	(\$34,645)
2044	\$157,940	\$0	(\$3,770)	\$4,583,305	\$0	\$0	\$0	\$5,180
2045	\$141,942	\$0	(\$3,770)	\$4,583,305	\$0	\$0	\$0	\$5,180
2046	\$124,379	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$113,545	\$0	(\$3,770)	\$3,174,033	\$0	\$0	\$0	(\$38,646)
2048	\$108,708	\$0	(\$7,539)	\$6,299,100	\$0	\$0	\$0	(\$77,640)
2049	\$103,117	\$0	(\$7,539)	\$6,781,883	\$0	\$0	\$0	(\$35,526)

**Table A-14 Net Incremental Benefit (Cost) Associated with Attributes for EPA/State-Regulated Disposal (Landfill) - RS-G-1.7**

<b>Year</b>	<b>Public and Occupational Health Routine</b>	<b>Public and Occupational Health Accident</b>	<b>Industry Implementation</b>	<b>Industry Operation</b>	<b>NRC Implementation</b>	<b>NRC Operation</b>	<b>Other Government</b>	<b>Environmental Considerations</b>
2003	\$15,136	\$0	(\$18,848)	\$10,196,041	(\$3,395)	\$0	(\$451,377)	\$60,330
2004	\$21,737	\$0	(\$11,309)	\$5,605,693	\$0	\$0	\$0	\$27,713
2005	\$20,579	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2006	\$19,339	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2007	\$18,318	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2008	\$17,417	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2009	\$16,636	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2010	\$15,936	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2011	\$15,335	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2012	\$14,815	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2013	\$14,334	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2014	\$14,173	\$0	(\$3,770)	\$704,185	\$0	\$0	\$0	(\$21,343)
2015	\$25,896	\$0	(\$18,848)	\$14,031,442	\$0	\$0	\$0	(\$13,996)
2016	\$45,439	\$0	(\$26,387)	\$21,329,573	\$0	\$0	\$0	(\$50,056)
2017	\$57,668	\$0	(\$18,848)	\$14,685,257	\$0	\$0	\$0	(\$74,658)
2018	\$79,197	\$0	(\$33,926)	\$28,249,757	\$0	\$0	\$0	(\$48,958)
2019	\$122,845	\$0	(\$60,314)	\$47,735,563	\$0	\$0	\$0	(\$168,625)
2020	\$174,168	\$0	(\$67,853)	\$60,430,917	\$0	\$0	\$0	(\$285,375)
2021	\$195,716	\$0	(\$41,466)	\$40,043,951	\$0	\$0	\$0	(\$167,667)
2022	\$205,765	\$0	(\$30,157)	\$27,557,562	\$0	\$0	\$0	(\$226,453)
2023	\$219,737	\$0	(\$37,696)	\$31,280,028	\$0	\$0	\$0	(\$260,469)
2024	\$215,842	\$0	(\$22,618)	\$15,593,721	\$0	\$0	\$0	(\$197,501)
2025	\$199,712	\$0	(\$15,078)	\$7,477,842	\$0	\$0	\$0	(\$101,084)
2026	\$191,278	\$0	(\$18,848)	\$11,161,184	\$0	\$0	\$0	(\$150,512)
2027	\$201,772	\$0	(\$30,157)	\$23,030,455	\$0	\$0	\$0	(\$297,893)
2028	\$219,724	\$0	(\$37,696)	\$33,322,099	\$0	\$0	\$0	(\$288,630)
2029	\$233,724	\$0	(\$37,696)	\$38,458,390	\$0	\$0	\$0	(\$192,053)
2030	\$267,600	\$0	(\$52,774)	\$54,026,834	\$0	\$0	\$0	(\$317,955)
2031	\$305,544	\$0	(\$56,544)	\$58,382,683	\$0	\$0	\$0	(\$418,052)
2032	\$337,556	\$0	(\$56,544)	\$60,276,909	\$0	\$0	\$0	(\$361,832)
2033	\$361,580	\$0	(\$52,774)	\$53,919,204	\$0	\$0	\$0	(\$404,564)
2034	\$345,798	\$0	(\$22,618)	\$20,073,968	\$0	\$0	\$0	(\$262,852)
2035	\$319,892	\$0	(\$11,309)	\$12,144,670	\$0	\$0	\$0	(\$90,924)
2036	\$293,899	\$0	(\$11,309)	\$12,044,746	\$0	\$0	\$0	(\$87,495)
2037	\$261,960	\$0	(\$3,770)	\$3,418,544	\$0	\$0	\$0	(\$46,335)
2038	\$231,986	\$0	(\$3,770)	\$713,046	\$0	\$0	\$0	(\$2,047)
2039	\$215,901	\$0	(\$15,078)	\$9,522,377	\$0	\$0	\$0	(\$116,076)
2040	\$219,809	\$0	(\$26,387)	\$21,385,944	\$0	\$0	\$0	(\$218,816)
2041	\$213,864	\$0	(\$18,848)	\$15,911,160	\$0	\$0	\$0	(\$146,779)
2042	\$196,136	\$0	(\$7,539)	\$6,125,910	\$0	\$0	\$0	(\$78,454)
2043	\$176,168	\$0	(\$3,770)	\$2,777,188	\$0	\$0	\$0	(\$35,324)
2044	\$157,970	\$0	(\$3,770)	\$4,351,403	\$0	\$0	\$0	\$3,632
2045	\$141,971	\$0	(\$3,770)	\$4,351,403	\$0	\$0	\$0	\$3,632
2046	\$124,395	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$113,569	\$0	(\$3,770)	\$3,059,277	\$0	\$0	\$0	(\$39,412)
2048	\$108,738	\$0	(\$7,539)	\$6,066,406	\$0	\$0	\$0	(\$79,193)
2049	\$103,144	\$0	(\$7,539)	\$6,464,498	\$0	\$0	\$0	(\$37,645)

**Table A-15 Net Incremental Benefit (Cost) Associated with Attributes for Limited Dispositions Alternative (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,018	\$0	(\$18,848)	\$14,197,311	(\$3,395)	\$0	(\$451,377)	\$9,867
2004	\$21,561	\$0	(\$11,309)	\$7,782,076	\$0	\$0	\$0	\$197
2005	\$20,420	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2006	\$19,197	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2007	\$18,192	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2008	\$17,305	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2009	\$16,536	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$20,943)
2010	\$15,845	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2011	\$15,254	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2012	\$14,742	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2013	\$14,268	\$0	\$0	\$401,448	\$0	\$0	\$0	(\$23,194)
2014	\$14,109	\$0	(\$3,770)	\$849,614	\$0	\$0	\$0	(\$22,412)
2015	\$25,692	\$0	(\$18,848)	\$20,294,026	\$0	\$0	\$0	(\$51,928)
2016	\$45,061	\$0	(\$26,387)	\$30,757,208	\$0	\$0	\$0	(\$106,862)
2017	\$57,250	\$0	(\$18,848)	\$21,009,910	\$0	\$0	\$0	(\$112,490)
2018	\$78,422	\$0	(\$33,926)	\$40,815,886	\$0	\$0	\$0	(\$124,802)
2019	\$121,496	\$0	(\$60,314)	\$68,608,128	\$0	\$0	\$0	(\$294,188)
2020	\$172,373	\$0	(\$67,853)	\$87,381,423	\$0	\$0	\$0	(\$434,816)
2021	\$193,702	\$0	(\$41,466)	\$57,994,670	\$0	\$0	\$0	(\$267,221)
2022	\$203,688	\$0	(\$30,157)	\$38,925,140	\$0	\$0	\$0	(\$289,311)
2023	\$217,635	\$0	(\$37,696)	\$44,177,926	\$0	\$0	\$0	(\$331,556)
2024	\$213,780	\$0	(\$22,618)	\$21,717,759	\$0	\$0	\$0	(\$230,606)
2025	\$197,731	\$0	(\$15,078)	\$10,393,612	\$0	\$0	\$0	(\$115,989)
2026	\$189,368	\$0	(\$18,848)	\$15,610,281	\$0	\$0	\$0	(\$173,396)
2027	\$199,810	\$0	(\$30,157)	\$32,237,495	\$0	\$0	\$0	(\$345,142)
2028	\$217,742	\$0	(\$37,696)	\$47,458,259	\$0	\$0	\$0	(\$362,202)
2029	\$231,732	\$0	(\$37,696)	\$55,452,885	\$0	\$0	\$0	(\$281,346)
2030	\$265,320	\$0	(\$52,774)	\$77,845,672	\$0	\$0	\$0	(\$440,936)
2031	\$302,587	\$0	(\$56,544)	\$83,836,251	\$0	\$0	\$0	(\$548,861)
2032	\$334,024	\$0	(\$56,544)	\$86,511,515	\$0	\$0	\$0	(\$496,572)
2033	\$357,912	\$0	(\$52,774)	\$76,840,506	\$0	\$0	\$0	(\$522,109)
2034	\$342,330	\$0	(\$22,618)	\$28,115,088	\$0	\$0	\$0	(\$303,341)
2035	\$316,753	\$0	(\$11,309)	\$17,495,562	\$0	\$0	\$0	(\$118,441)
2036	\$291,053	\$0	(\$11,309)	\$17,314,591	\$0	\$0	\$0	(\$114,640)
2037	\$259,388	\$0	(\$3,770)	\$4,767,711	\$0	\$0	\$0	(\$53,191)
2038	\$229,664	\$0	(\$3,770)	\$1,039,773	\$0	\$0	\$0	(\$3,727)
2039	\$213,803	\$0	(\$15,078)	\$13,394,872	\$0	\$0	\$0	(\$135,806)
2040	\$217,751	\$0	(\$26,387)	\$30,288,586	\$0	\$0	\$0	(\$264,217)
2041	\$211,768	\$0	(\$18,848)	\$22,595,140	\$0	\$0	\$0	(\$180,834)
2042	\$194,122	\$0	(\$7,539)	\$8,546,877	\$0	\$0	\$0	(\$90,711)
2043	\$174,291	\$0	(\$3,770)	\$3,869,445	\$0	\$0	\$0	(\$40,888)
2044	\$156,223	\$0	(\$3,770)	\$6,409,222	\$0	\$0	\$0	(\$7,249)
2045	\$140,340	\$0	(\$3,770)	\$6,409,222	\$0	\$0	\$0	(\$7,249)
2046	\$122,899	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$112,196	\$0	(\$3,770)	\$4,273,399	\$0	\$0	\$0	(\$45,512)
2048	\$107,476	\$0	(\$7,539)	\$8,492,696	\$0	\$0	\$0	(\$91,404)
2049	\$101,981	\$0	(\$7,539)	\$9,366,489	\$0	\$0	\$0	(\$52,720)

**Table A-16 Net Incremental Benefit (Cost) Associated with Attributes for LLW  
Disposal/Prohibition (\$)**

Year	Public and Occupational Health Routine	Public and Occupational Health Accident	Industry Implementation	Industry Operation	NRC Implementation	NRC Operation	Other Government	Environmental Considerations
2003	\$15,240	\$0	\$0	(\$73,920,446)	(\$3,395)	\$0	(\$451,377)	(\$1,351,186)
2004	\$21,800	\$0	\$0	(\$40,658,693)	\$0	\$0	\$0	(\$748,626)
2005	\$20,600	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$48,797)
2006	\$19,360	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$48,797)
2007	\$18,340	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$48,797)
2008	\$17,440	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$48,797)
2009	\$16,660	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$48,797)
2010	\$15,960	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$37,104)
2011	\$15,360	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$37,104)
2012	\$14,840	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$37,104)
2013	\$14,360	\$0	\$0	(\$1,258,455)	\$0	\$0	\$0	(\$37,104)
2014	\$14,200	\$0	\$0	(\$3,786,318)	\$0	\$0	\$0	(\$58,973)
2015	\$26,000	\$0	\$0	(\$110,336,652)	\$0	\$0	\$0	(\$869,442)
2016	\$45,600	(\$3,000,000)	\$0	(\$166,672,604)	\$0	\$0	\$0	(\$1,343,199)
2017	\$57,800	\$0	\$0	(\$113,153,026)	\$0	\$0	\$0	(\$953,974)
2018	\$79,400	(\$3,000,000)	\$0	(\$221,499,649)	\$0	\$0	\$0	(\$1,766,820)
2019	\$123,200	(\$3,000,000)	\$0	(\$370,548,333)	\$0	\$0	\$0	(\$3,045,724)
2020	\$174,600	(\$6,000,000)	\$0	(\$476,523,809)	\$0	\$0	\$0	(\$3,882,996)
2021	\$196,000	(\$3,000,000)	\$0	(\$316,685,220)	\$0	\$0	\$0	(\$2,557,769)
2022	\$206,000	(\$3,000,000)	\$0	(\$203,821,677)	\$0	\$0	\$0	(\$1,776,704)
2023	\$220,000	(\$3,000,000)	\$0	(\$230,998,348)	\$0	\$0	\$0	(\$2,017,746)
2024	\$216,000	\$0	\$0	(\$111,368,638)	\$0	\$0	\$0	(\$1,048,154)
2025	\$199,800	\$0	\$0	(\$53,446,760)	\$0	\$0	\$0	(\$507,678)
2026	\$191,400	\$0	\$0	(\$81,690,258)	\$0	\$0	\$0	(\$770,178)
2027	\$202,000	(\$3,000,000)	\$0	(\$168,078,021)	\$0	\$0	\$0	(\$1,573,300)
2028	\$220,000	(\$3,000,000)	\$0	(\$253,848,686)	\$0	\$0	\$0	(\$2,205,131)
2029	\$234,000	(\$3,000,000)	\$0	(\$301,106,048)	\$0	\$0	\$0	(\$2,458,214)
2030	\$268,000	(\$6,000,000)	\$0	(\$423,707,002)	\$0	\$0	\$0	(\$3,506,905)
2031	\$306,000	(\$6,000,000)	\$0	(\$454,526,287)	\$0	\$0	\$0	(\$3,841,802)
2032	\$338,000	(\$6,000,000)	\$0	(\$465,214,749)	\$0	\$0	\$0	(\$3,869,573)
2033	\$362,000	(\$6,000,000)	\$0	(\$409,053,868)	\$0	\$0	\$0	(\$3,494,984)
2034	\$346,000	(\$3,000,000)	\$0	(\$146,617,553)	\$0	\$0	\$0	(\$1,375,545)
2035	\$320,000	\$0	\$0	(\$95,813,268)	\$0	\$0	\$0	(\$811,560)
2036	\$294,000	\$0	\$0	(\$94,277,422)	\$0	\$0	\$0	(\$797,212)
2037	\$262,000	\$0	\$0	(\$24,782,108)	\$0	\$0	\$0	(\$234,579)
2038	\$232,000	\$0	\$0	(\$5,758,210)	\$0	\$0	\$0	(\$45,244)
2039	\$216,000	\$0	\$0	(\$70,662,333)	\$0	\$0	\$0	(\$651,322)
2040	\$220,000	(\$3,000,000)	\$0	(\$160,765,424)	\$0	\$0	\$0	(\$1,434,706)
2041	\$214,000	\$0	\$0	(\$119,976,438)	\$0	\$0	\$0	(\$1,053,851)
2042	\$196,200	\$0	\$0	(\$44,137,625)	\$0	\$0	\$0	(\$413,971)
2043	\$176,200	\$0	\$0	(\$19,970,375)	\$0	\$0	\$0	(\$187,167)
2044	\$158,000	\$0	\$0	(\$35,920,975)	\$0	\$0	\$0	(\$265,193)
2045	\$142,000	\$0	\$0	(\$35,920,975)	\$0	\$0	\$0	(\$265,193)
2046	\$124,400	\$0	\$0	\$0	\$0	\$0	\$0	\$0
2047	\$113,600	\$0	\$0	(\$22,051,134)	\$0	\$0	\$0	(\$207,028)
2048	\$108,800	\$0	\$0	(\$44,157,004)	\$0	\$0	\$0	(\$414,442)
2049	\$103,200	\$0	\$0	(\$51,776,404)	\$0	\$0	\$0	(\$426,412)

**Letters from Cooperating Agencies**



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
WASHINGTON, D.C. 20460

JAN 19 2005

OFFICE OF  
AIR AND RADIATION

Scott C. Flanders, Deputy Director  
Environmental and Performance Assessment Directorate  
Division of Waste Management and Environmental Protection  
Office of Nuclear Materials Safety and Safeguards  
United States Nuclear Regulatory Commission  
Mail Stop T-7-J-9  
11555 Rockville Pike  
Rockville, MD 20555

Dear Mr. Flanders:

The Environmental Protection Agency (EPA) appreciates the opportunity to serve as a cooperating agency in the review of the Draft Generic Environmental Impact Statement (DGEIS) prepared by NRC to support its upcoming rulemaking on controlling the disposition of solid materials. In particular, we appreciate NRC's desire for a review of those areas in which this action may intersect with EPA programs or authorities. Overall, we view our cooperating agency role with respect to the development of the DGEIS as consultative and our comments as advisory, with NRC retaining sole responsibility for selecting the regulatory approach and choosing among regulatory options. Therefore, while we have provided comments on the DGEIS, we are not expressing a preference regarding the alternatives discussed in the DGEIS.

For completeness, we are attaching our comments on various drafts of the DGEIS. We recognize that many of these comments have already been addressed. We may also choose to submit additional comments, both on the GEIS and the proposed rule, following publication of those documents. We would, however, like to highlight several general points:

1. Although NRC has identified a preferred alternative, the basis for this decision is unclear. The reader would be well-served by a detailed compilation of the reasons for preferring this alternative, whether based on technical analyses or NRC policy.
2. The document would benefit from more clarity in the description of the various alternatives, which solid materials are considered under each alternative, how the alternatives would need to be implemented, and particularly how the alternatives may relate to current regulation and practices.
3. The complexity of the technical analyses, with many details embedded in appendices or separate documents (some still in draft stages), will make it

extremely difficult for non-experts to evaluate the assessments underlying the alternatives presented and their relative impacts. Given the level of interest in this topic from the general public, review of the document would be enhanced by a more transparent and simplified presentation of the technical analyses.

4. Many readers are likely to question the impact of the considered alternatives on other NRC policies and regulatory practices, such as those related to decommissioning. It would be useful for the NRC to clearly articulate its views of such issues, which may be appropriate for inclusion in either the GEIS or the Federal Register notice accompanying the regulatory proposal.

5. Readers may also have difficulty in relating some concepts of protectiveness to the alternatives. For example, it may be helpful to provide some perspective on the realistic or conservative nature of assumptions inherent in using collective dose to express the impacts of a standard based on exposures to individuals or applying radionuclide concentrations derived for unrestricted use to specified limited dispositions.

I hope these comments are useful. If you have questions or need further information, please call Adam Klinger at (202) 343-9378.

Sincerely,



Bonnie C. Gitlin, Acting Director  
Radiation Protection Division  
Office of Radiation and Indoor Air

**EPA Comments on Revised Chapter 2**  
**“Proposed Action and Alternatives”**  
**Draft GEIS on Controlling the Disposition of Solid Materials**  
**Draft dated 9/1/04**

Comments on this revised chapter are primarily editorial in nature. The most significant conceptual comments relate to Section 2.4.5, "Dose Based Regulation on Limited Dispositions". As described in the document, this section represents a modification of the "conditional release" option, after the broader approach had been eliminated based on concerns about acceptability and tracking future generations of material uses. However, it seems to take a different approach to release criteria and is more limited in evaluation scope than the other alternatives without clearly explaining why. Further, the overall discussion is confusing and internally contradictory.

Individual comments are discussed by section below.

**Section 2.0**

Footnote 1: Suggest revising to read "...as an area to which *access* is limited...", unless this is a direct quote.

**Section 2.3**

First paragraph, last two sentences: Suggest revising first sentence to read "Materials considered by this rulemaking are described below". In last sentence, make "characterization" singular.

"Concrete": revise last sentence to read "sidewalks or equipment pedestals to building foundations."

"Metals": revise first sentence to read "...ferrous metals *expected to be* predominant."

"Soils": remove "In terms of quantities" from second sentence.

"Tools and Equipment": in last sentence, replace "those" with "items".

**Section 2.4**

Figure 2-1: correct the spelling of "dose" in second box under "Alternatives". Under "Variations" for last box on right, replace "Pre-approved use" with "Concrete in road beds" and "Re-use of tools and equipment" to be consistent with the discussion in the text.

**Section 2.4.3**

In the last sentence before 2.4.4, replace "they are" with "it is".

**Section 2.4.5 Conceptual**

As noted above, this section seems to take a completely different approach to releases for specific destinations, when compared to Section 2.4.3 (the common destination in both sections is landfill disposal). However, the description of release criteria here seems inconsistent from one paragraph to the next.

The fourth paragraph in this section lays out the basic premise: because NRC is unable to account for potential future generation exposures from released material, it is evaluating each "limited disposition" outlet against a 1 mrem/yr limit "as analyzed for the Unrestricted Release Alternative." This suggests that NRC is evaluating the most conservative scenario (unrestricted release) rather than each specific "limited disposition" scenario. This in itself is a departure from the approach used for the "EPA/State Regulated Disposal" alternative, in which the dose is evaluated for that specific management option. Further, by considering only the 1 mrem dose limit, this section departs further from the methodology already established for the other alternatives. Why not evaluate the same dose options considered under the Unrestricted Release and Landfill Disposal Alternatives (i.e., 0.03, 0.1, 10, IAEA standard, in addition to 1 mrem)?

Fifth paragraph: "...scope of the impacts from these material releases is within that which was defined in this GEIS..." This appears to mean that NRC wants to ensure that materials are in fact going only to these limited dispositions, or that unqualified (higher-activity) material is not being released. However, if evaluations are against unrestricted release criteria, there should be no possibility of higher impacts. If NRC is concerned about compliance with a release standard, should this concern also be raised in Section 2.4.3 (Landfill Disposal), where it would probably also be an issue? In this context, "that" needs to be clarified.

"Landfills": the fourth sentence reads "Licensees would need to demonstrate that doses for disposal of material into a RCRA Subtitle D facility are consistent with the individual dose criterion of 1 mrem/yr." This suggests that approval of this "limited disposition" option is not "as analyzed for the Unrestricted Release Alternative," which contradicts the fourth paragraph as cited above. NRC should clarify whether this "limited disposition" is actually the Landfill Disposal Alternative using the 1 mrem/yr dose limit. If so, that should be less restrictive (i.e., would allow higher concentrations) than the Unrestricted Release Alternative, as there will be some period of control, which may be particularly effective for shorter-lived radionuclides.

"Concrete in Road Beds": the second sentence cites scenarios examined under the Unrestricted Release Alternative that could be relevant to this disposition (workers processing concrete, public driving on roads). NRC needs to clarify the purpose of citing these particular scenarios. These are surely not the only scenarios examined, and if the basis of comparison is the Unrestricted Release Alternative, all scenarios have to be considered, not just those relevant to road bed construction. If these are in fact the scenarios that give the highest exposure, a statement to that effect would clarify this point. The next sentence, referring to "doses for recycling of concrete

into roadbed material", raises the same question as the preceding discussion of landfill disposal. Is the basis of comparison the Unrestricted Release Alternative, or is it the specific disposition under consideration?

"Case-specific approvals": the last sentence states that a "licensee could have to provide...a dose assessment for a case-specific disposition application." Again, the question of unrestricted vs. disposition-specific assessments should be clarified. Further, although "[i]t is expected that such applications would address end-uses for limited types and amounts of materials," NRC should consider whether it is creating the kind of open-ended conditional release environment it has attempted to avoid if such applications are not sufficiently "limited". Despite requiring "reasonable assurance that such materials are kept out of disposition paths not allowed", it seems that there would be the same problems with subsequent generation uses that raised concerns with a broader conditional release approach (if not, NRC should explain why there is the presumption of greater control over future uses for the "limited disposition" alternative). NRC should also clarify whether this process is also subject to the 1 mrem/yr limit. It would seem contradictory to exclude some uses from the generic analyses, presumably because they are publicly sensitive, more likely to cause exposures (at higher levels or to more people), or more difficult to control, and then allow case-specific releases for those very same uses when assessed against a higher dose limit.

#### **Section 2.4.5 Editorial:**

"Concrete in Road Beds": first sentence, "...could be recycled *into* roadbed material." Next sentence, replace "we" with "NRC".

#### **Section 2.5.1:**

EPA notes that NRC has been responsive to earlier comments and provided additional discussion of why it does not consider the ANSI standard appropriate for a dose-based clearance regulation. However, EPA also notes that the State of Texas recently issued a draft proposed rule for comment that included a 1 mrem/yr clearance standard based upon use of the ANSI standard. As Texas is an Agreement State, the compatibility of its program with NRC requirements could be affected if it issues a rule based on a standard that NRC expressly rejects. EPA suggests that it may be prudent for NRC to minimize the potential for such compatibility conflicts by taking steps to communicate its concerns over use of the ANSI standard to the Agreement States. In doing so, NRC need not state that it has eliminated the ANSI standard from consideration as a basis for its dose-based regulation.

#### **Section 2.6:**

First paragraph: the last sentence is awkward as well as confusing: "The time period of this analysis is 1,000 years, which is the time when potentially clearable materials from existing licensees would occur." This sounds as though NRC is suggesting that "existing licensees" will still be found in 1,000 years. Further, stating that "materials would...occur" gives the impression that they may appear

spontaneously. Perhaps this should read "when *impacts from* potentially..." Finally, there were references in the previous draft to much shorter times (the "period of proposed action" was on the order of 50 years, and some of the results referenced 250 years). Will all results now cover the 1,000 year period?

**U.S. Environmental Protection Agency  
Office of Radiation and Indoor Air  
Preliminary Comments on Draft Generic Environmental Impact Statement (DGEIS)  
Controlling the Disposition of Solid Materials  
December, 2004 Version**

The Environmental Protection Agency (EPA) appreciates the opportunity to offer the following preliminary comments in preparation for meetings between cooperating agencies and NRC management and staff on January 11-12, 2005.

1. The reliance on RS-G-1.7 raises some issues that appear not to be clearly described in the DGEIS. Of most importance is probably the dose basis for deriving the concentrations in that document. The DGEIS characterizes it as 1 mrem/yr, which is true for artificial radionuclides. However, the concentration for natural radionuclides is based on "the upper end of the worldwide distribution of activity concentrations in soil" and is evaluated against 100 mrem/yr (section 3.3). This results, for example, in radium concentrations more than 5 times EPA's cleanup standard of 5 pCi/g. The DGEIS does not appear to explain this fact.
2. The DGEIS is not clear about the inclusion of soils in the various Alternatives. The impression we have is that soil would be included in the Unrestricted Release and Regulated Disposal Alternatives, but not in the Limited Dispositions Alternative. Again, reference to RS-G-1.7 appears key, as page 2-9 (and ES-5) states that "the IAEA standard does not apply to soils." However, the standard itself makes distinction only between bulk (> 1 tonne) and non-bulk (< 1 tonne) quantities, not to the description of the material involved. Soils in smaller amounts would seem to be covered by the standard. If NRC deems soils to be not covered by RS-G-1.7, is the scope of the analyses under the Unrestricted Release and Regulated Disposal Alternatives different for the RS-G-1.7 option as opposed to the other dose-based options?
3. DOE's comments regarding the description of scenarios and reasons for excluding certain Alternatives are consistent with comments we have made previously. For example, page 3-7 states that only the use of concrete in roadbed was analyzed because that is the end-use of 85% of recycled concrete. Without knowing what uses the other 15% goes to, how can we tell whether roadbed construction is actually the limiting scenario? We also agree with the references to the "case by case" evaluations that are built in to the Limited Dispositions Alternative. As we commented earlier on the revised Chapter 2, it is not clear how this process would improve upon the existing process, which NRC is trying to replace, or whether it would result in approvals for use of higher-activity material in ways not covered by the "limited dispositions". Further, it is not clear why a similar process is not part of the Unrestricted Release Alternative (although for disposal, we recognize that 10 CFR 20.2002 fulfills that purpose).
4. A number of the results in Chapter 3 appear anomalous, particularly those connected with RS-G-1.7. In general, one would expect results for RS-G-1.7 to be comparable to those for the 1 mrem/yr option. However, this does not appear to be the case, and there is not a clear explanation of the differences between the two methods (some of this detail may be in appendices, but there should be clear recognition in the text that the reader will

question the reasons for the apparent discrepancies). For example, in Table 3-5, RS-G-1.7 releases more than twice the radioactivity as the 1 mrem/yr option, yet the dose to LLW disposal facility workers is also doubled. Why should the dose to those workers increase from an option that diverts more material away from those facilities? Further, in comparing Table 3-5 to Table 3-7, one finds that the dose to LLW facility workers when no material is released is only 34 person-rem. This must be the most limiting scenario. How can the RS-G-1.7 option result in higher doses (other options are within rounding errors)? As a final example, in Table 3-14 the RS-G-1.7 collective dose from medical centers is twice all other options shown, including the No Action Alternative.

5. Transportation impacts are based on vehicle miles traveled, regardless of cargo. It would seem that there is sufficient experience to evaluate transportation accident rates for radioactive or hazardous cargo separately from other types of shipments. Our understanding is that transporters of radioactive material must receive additional training and licensing, which may be reflected in lower accident rates. Applying this information (which may be difficult to obtain) would give some idea of the conservatisms involved in the current analysis, although it would necessitate partitioning shipments into released material (say, to a landfill) and material that continues to be regulated (LLW disposal).

6. We second the Massachusetts comment regarding rubblization and standards applicable to license termination or off-site release. NRC should clarify its position regarding leaving material on-site and the potential effects of the disposition effort on its policies.

7. In a related comment, RS-G-1.7 may not be appropriate for material with surface contamination only. For example, there are situations in which licensees break up surficially-contaminated concrete and mix it with "clean" concrete to meet the site's release criteria. How would the standard be applied to such bulk non-homogeneous material? If sufficiently crushed, would the residual be treated like soil?

8. The discussion of cost-benefit analysis raises questions regarding the release of equipment. The text on page 4-7 states that there are no estimates of the quantity of equipment released. If so, how can collective doses be calculated? How can costs and benefits be estimated?

**U.S. Environmental Protection Agency  
Office of Radiation and Indoor Air  
Comments on Draft Generic Environmental Impact Statement (DGEIS)  
Controlling the Disposition of Solid Materials  
February 9, 2004 version**

**GENERAL COMMENTS:**

**1. Discussion of Alternatives:** Recognizing the complexity of the alternatives and analyses involved, we recommend greater clarity to ensure that the reader can follow exactly which alternative is under discussion at any place in the document. For example, in Chapter 3, the discussion of the exposure pathways for the No Action and Unrestricted Use Alternatives are combined. This makes sense, as they are likely to include the same activities, if not the same levels of those activities. In Chapter 4, however, results for alternatives and scenarios are continually mixed in ways that make the discussion less clear.

For example, in Section 4.3.2, the last sentence of the first paragraph states "Radiological impacts for the No Action Alternative and the Unrestricted Use Alternative are discussed in separate sections because of the differences in the collective dose results for the two Alternatives." Section 4.3.2.1 focuses on the No Action Alternative. However, Tables 4-13 through 4-15 provide steel and concrete dose results for both the No Action and Unrestricted Use Alternatives, so that the "differences in the collective dose results" are not apparent. The presentation is further confused by the use of first-year and 30-year collective dose estimates for 1,000 tons of material, without providing the rationale for either, other than as an illustration of the relative doses from various end uses (e.g., why 30 years instead of the period of the Proposed Action (45-50 years), or the 250 years also mentioned in this section as a period for analysis?). The discussion under the heading "Non-Licensed Facility Worker Collective Dose," in which these tables occur, focuses on the fact that the collective dose results from General Public end uses are dominant. The next heading, "General Public Collective Dose," is a single paragraph focusing on steel. The reference is to Table 4-16, which gives the collective dose for all materials released from nuclear reactors for the No Action Alternative. Over what time period are these doses incurred? 1, 30, 50, 250 years?

There also needs to be more explanation/illustration of the concepts of "material specific" and "material independent" analyses in Section 4.1.3. While they are not that complicated, it appears that applying these concepts would have a significant effect on the amount of material that could be released under the various Alternatives. A clearly illustrated example would help the reader keep these concepts straight and understand the differences.

**2. ANSI Standard:** More detailed explanation on the differences between the 1 mrem/yr option and the ANSI standard is needed. Footnote 1 of the draft GEIS Chapter on the Collective Dose Report appears to be the most lengthy discussion. What scenarios and methodologies were used to develop the ANSI standard so that it "does not model 'clearance' dose properly"? Why does it not apply to soils intended for agricultural use? Does it apply to other soils? Most important, what can explain the radical difference in cost-benefit shown in Table 6-3? NRC's 1 mrem level

shows several hundred million dollar benefits, while the ANSI standard shows costs of the same magnitude.

**3. Collective Dose:** The concept of applying an individual dose criterion, but analyzing it using collective dose, is unclear and difficult to grasp. It appears that the "collective dose" begins with the dose to the average member of a critical group and is then propagated somehow to the larger population. Are there estimates of the number of such critical groups? Where are the details of the critical groups described (e.g., size, lifestyle)? This information may be in the Collective Dose Report, but there should be a clear reference in the GEIS (the proposed summary chapter does not address this part of the methodology).

It is likely that released materials will end up outside the system of regulatory control. That is to say, once a solid material has been "released," there can no longer be a reliance on compliance enforcement activities to ensure that anticipated dose limits are not being exceeded. This assurance must then rely on the modeling and measurement activities performed in support of the NRC's rule authorizing such releases. It appears that NRC is using the calculation of collective dose as a means of determining the health consequences to the population from various scenarios. The technical work presented in the Collective Dose Report seems appropriate as a means of estimating population health effects. However, there does not appear to be a method for determining that individual dose limits will not be exceeded.

The problem comes down to the question of attributable risk versus individual risk. EPA generally regulates solid waste so that the risk to a reasonably maximally exposed (RME) individual (hypothetical) is deemed acceptable. In this approach, the size of the population at risk is irrelevant if the risk to any supposed RME receptor is too high. The collective dose approach, on the other hand, appears to rely only on the total population dose (and resulting risk) as a means of determining the acceptability of a practice. For example, suppose ten thousand people live near a Superfund site that is giving them each a  $10 \text{ E-}3$  risk (exceeding the upper bound of EPA's risk range by an order of magnitude). A collective dose approach would say that the impact to this population would be the same as to a similar population of 100,000 people each receiving a  $10 \text{ E-}4$  risk. On the other hand, an individual dose limit approach would say the 10,000 people were unacceptably exposed whereas the 100,000 people might not need to have their doses reduced.

NRC needs to be more explicit about the role of the collective dose analysis and how it relates to its various proposed individual dose standards. NRC also needs to clarify what is meant by this standard as a release standard. Does the release standard represent a level that cannot be exceeded? If the release standard is 1 millirem, is it acceptable that the rare individual gets 3, 5 or even 10 millirem if the population average is consistently well below the product of the release standard (1 millirem in this case) x the total number of people exposed to the released material? If not, what mechanism is there to ensure that individuals are not exposed to levels that would exceed acceptable ranges of dose or risk? NRC needs to make sure that people understand the type of standard it is creating, its basis and how it will be used.

**4. Evaluation of Doses from Alternatives:** Two aspects of the exposure assessment that should

be discussed in more detail are the selection of end uses and the selection of exposure pathways or receptors for each end use. These are most significant for the No Action and Unrestricted Use Alternatives.

Although focusing on the most frequent use of cleared material is a sensible approach to assess potential doses, that approach is always open to criticism if other, less frequent uses, result in higher doses (presumably to smaller numbers of affected individuals or groups). For example, more attention should be given to the uses of concrete for other than road construction. It may not be sufficient to say that the primary use (85%, according to page 3-16) is the only one that should be evaluated. It may be that higher doses could result from one of the other uses cited (e.g., sidewalk construction, roofing materials, landscaping). For example, sidewalks or plazas at a local park could expose people who spend more time there (e.g., eating lunch) than would a driver on an interstate highway.

In the pathway or receptor selection, for the road construction end use, is the potential variation in dose for different types of roads considered? Is there a difference between a local road in a residential subdivision and an interstate highway? What is the significance of different traffic speeds, or sitting in traffic for extended periods of time? In that analysis, some attention should be given to exposures incurred by someone other than the driver, through the pathways outlined in Chapter 3. In the case of a local road, it is not uncommon for children to play in the street. Road erosion over a period of years could also make radionuclides more available to surrounding populations and present potential pathways of exposure through ground or surface waters. Differences in construction practices for local roads and highways may affect their longevity.

As another example, use of contaminated steel in bridges may be the common usage, but is it possible that contaminated steel finding its way into bed frames would give a higher dose to someone sleeping on that bed every night for 20 years? To avoid the criticism about ignoring less frequent uses that give higher doses, the assessments should demonstrate that these uses do not give higher individual doses or provide an explicit rationale for not weighing such uses as heavily as the more common usages in the clearance decision making.

**5. Characterization of Candidate Materials:** Readers of the GEIS are likely to express interest in having the potentially cleared material characterized by radionuclide, in addition to estimates of total activity. We find that members of the general public are often most concerned about certain radionuclides (e.g., Pu). If this material is present in the Collective Dose Report, it should be clearly referenced in the GEIS.

**6. Envirocare as presumed destination for all material destined for LLRW Disposal:** Waste considered for disposal in LLRW facilities are assumed to go to Envirocare because "very little of the solid material would be eligible for disposal at these sites." (Pg. 2-8) But, for example, wouldn't waste from Atlantic Compact States – states with an appreciable number of commercial reactors – be eligible to go to Barnwell after 2008? Is it really a matter of eligibility or are assumptions also being made about the relative economics of these two facilities. If so, such assumptions should be clarified. Not clear, whether the Northwest compact states would have similar issues with respect to the Richland facility.

## **SPECIFIC COMMENTS:**

### **Acronyms, Abbreviations, and Terms:**

DNAPL, LNAPL: give the full term, not a description (definition could go in Glossary).

POTW: Publicly Owned Treatment Works (not Facility)

### **Chapter 1: Purpose and Need**

Editorial (and throughout): use consistent format when citing the Federal Register (underline or italics), when citing reports (italics or quotes), when citing "U.S." or "US" (see Appendix F), "titled" vs. "entitled".

Page 1-3, first full paragraph: ensure that (c) replaces copyright symbol.

Page 1-3, second paragraph: consistency in referring to "no, or very small amounts of" (compare to page 1-4, first paragraph, "very low amounts of, or no")

Page 1-4, second paragraph: "Federal Register Notice" (neither underlined nor italicized)

Page 1-5, first paragraph, sixth sentence: "...although it does not currently..."

Page 1-5, second paragraph, first sentence: "NRC's goal in preparing this Draft..."

Page 1-5, last bullet: should other pollutants be discussed in evaluating transportation as they are for processing, as noted in the bullet on Air Quality on page 1-6 ("other priority air pollutants")? It appears from Appendix F (page F-8 and Tables F-2 and F-3) that some consideration is being given to truck emissions. Both the "Transportation" and "Air Quality" bullets should be clear about including truck emissions. Suggest revising last sentence under "Transportation" to read "credible accident and terrorist scenarios."

Page 1-6, bullet on "Irreversible and Irrecoverable Commitment of Resources", is there consideration of management in energy recovery facilities rather than incineration?

Page 1-6, bullet on "Cost-Benefit Analysis", expand to summarize the scope of the analyses, e.g., "summarizes the environmental and economic costs and benefits of NRC's current approach to solid materials management (baseline), as well as three alternative "nationally consistent" approaches, involving six categories of solid materials (steel, concrete, copper, aluminum, trash, and soil) generated by six types of NRC-licensed industrial facilities."

Page 1-7, third paragraph: although it is in the Glossary, should provide a brief definition for this first use of "Agreement State". Even "see Glossary" would remind the reader that there is a Glossary.

### **Chapter 2: Proposed Action and Alternatives**

Page 2-2, last bullet at top: remove comma before parenthetical

Page 2-2, Alternative 4: perhaps this should read "EPA/State Regulated Landfills", as the Subtitle D program is primarily a State responsibility. Unlike the Subtitle C program, EPA does not delegate Subtitle D authority to the States. This would parallel the term "NRC/AS" in Alternative 5.

Page 2-2, Alternative 5: as this is the first use of the phrase "NRC/AS", should clarify that "AS" means "Agreement State" (now done on page 2-8).

Page 2-3, second paragraph: Spell out and define "EC" and "IAEA".

Page 2-3, section 2.3 heading: Suggest changing to "Four Alternatives Studied in Detail". Note

that it may be somewhat confusing to the reader to see the Alternatives presented in different forms, as on page 6-1, where the “material specific” and “material independent” variations are broken out, as well as the “landfill” and “incineration” variations.

Page 2-4, first paragraph: give title of Appendix I, which does not exist in current draft.

Page 2-4, next to last paragraph, clarify that the dose-based criterion does not vary based on the “specific end use of the materials”; rather, one or more limiting end uses were identified and analyzed, such that exposures for other end uses would be below the reference dose. In the last sentence, spelling of “radionuclide”.

Page 2-4, footnote 4: this is the first use of the term “clearance”. Our understanding is that NRC wants to move away from the use of this term (preferring “disposition” or “control” or even “release” of “solid materials”), yet it is used repeatedly. See for example page 2-6 (three uses).

Page 2-5, paragraph below bullets: should copper be included in the last sentence? Provide a brief discussion of how these materials were selected; in particular, explain why other materials commonly found in demolition debris were not included in the analyses. Such materials include glass, rubber (e.g., floor coverings), wood, asphalt, brick, other metals (e.g., tin), and textiles (e.g., carpeting, roofing/wall felt). See EPA’s website on construction and demolition debris:

<http://www.epa.gov/tribalmw/thirds/recandd.htm> and  
[www.epa.gov/epaoswer/hazwaste/sqg/c&d-rpt.pdf](http://www.epa.gov/epaoswer/hazwaste/sqg/c&d-rpt.pdf).

Page 2-5, last paragraph: “dose level” in second sentence should not be hyphenated.

Page 2-5, footnote 5: ANSI standard is 13.12, not 12.12.

Page 2-6, top paragraph (and throughout): “Unrestricted Use Alternative” should be capitalized consistently. Some later sections refer to “Unrestrictive Use”.

Page 2-7, dose options: list 0.1 before 1.0. Need to explain better why 0.03 is equivalent to zero.

Page 2-7, next to last paragraph, last sentence: prefer listing of EPA ANPR as page 65120 of FR, where the notice actually begins. See also Reference 19.

Page 2-10, next to last paragraph: since the Subtitle C option is dropped, why does there need to be detailed discussion of available volumes and facilities?

Page 2-12, Table 2-1: The explanation on the following pages needs to be more clear. In particular, the impact on LLW facilities for the alternatives should be explained further. At what point does the impact change from “small” to “moderate” to “large”? From page 2-14, 8 to 10 percent of remaining Envirocare capacity is “moderate” and 85 percent is “large”. The definitions on page 2-12 include terms such as “alter noticeably” and “destabilize”. What do these mean in terms of disposal capacity? What is the “resource” that is being “destabilized”?

Page 2-14, bottom line: spelling of “dose”

Section 2.5: this section summarizes various impacts and cost-benefit results, yet up to this point there has been no discussion of the time period over which these impacts are estimated. Are these annual impacts? This feeds into the general comments related to the more detailed presentation of results, in which several time periods are discussed.

Figures 2-1 through 2-12: can these figures be combined in some way to reduce repetition?

### **Chapter 3: Affected Environment**

Page 3-2, first paragraph: next to last sentence is repetitive: “*On site disposal of...could be left on site...*”

Page 3-2, paragraph above 3.1.2, second sentence has two periods.

Page 3-3: second paragraph refers to 360 mrem as average background, fourth paragraph cites 300 mrem in United States. If first reference is global average, it should be stated so.

Page 3-5, first paragraph: second sentence, footnote numbers should appear outside quotes. Next to last sentence, consistency of commas inside or outside quotes.

Page 3-6, bullets: this information might be better presented in a table. In last bullet, spell out "SDMP" (note on page 3-9 refers to change of terminology). Which category includes ISFSIs? They are discussed separately in Section 3.1.3.5.

Page 3-11, last sentence above 3.2 needs a period.

Page 3-16, first paragraph: second sentence needs a period. In the third sentence, suggest moving the last clause to before the colon ("USGS allocated these applications into three general categories for the purposes of developing a material flow analysis:"). Fourth sentence, add a comma before "9 percent is used". Last sentence, remove comma from parenthetical after "landscaping".

Page 3-15, third bullet needs a semicolon

Page 3-17, Tables 3-2 and 3-3: Notes a, b, c are not reflected in the tables. In Table 3-3 (Concrete), note b refers to steel scrap at EAF mills. Should that note be for Table 3-2, or is there a similar one for concrete?

Page 3-22, Table 3-6, note a is not reflected in the table.

Page 3-23, Table 3-8, note a is not reflected in the table.

Page 3-24, last sentence under Trash: spelling of "for" and "...disposal of the all of the..."

Page 3-24, note about truck drivers: if previous analyses have been done, need to ensure that the assumptions are consistent with the GEIS, particularly the assumption that all disposal takes place at Envirocare (length of trip would be significant).

Page 3-25, Section 3.2.5.1: explain why the No Action and Unrestricted Use Alternatives are considered together.

Page 3-25, last paragraph: suggest rearranging this paragraph to eliminate redundancy, e.g., "The only end use of recycled concrete analyzed in this Draft GEIS is its use for road construction. The affected General Public groups for the No Action and Unrestricted Use Alternatives were identified for this end use and potential collective dose based on driving on roads containing recycled material. Road bed construction was selected as the single end use based on research..." (remainder of existing paragraph).

Page 3-26, Table 3-10: does "fraction of material" indicate that 38.5% of the roadbed consists of recycled concrete material?

Page 3-27, Table 3-11: it is not clear what "occupancy" refers to, or what the units are. If it is included as an "exposure duration" parameter, the units should be person-hours per year. Does this mean that a person spends only 1.78 hours per year in the automobile, or 1.78 sleeping in bed? If it is not an "exposure duration" parameter, what are the units? The average number of people in an automobile, or office building, or bed, or ship? Further, explain the "individual" and "integrated" columns. If the "integrated" exposure duration considers the number of "individuals" who would be exposed through the various end uses, why is the "integrated" duration for the slag cement basement end use an order of magnitude smaller than the "individual" duration?

Page 3-29, third paragraph: consistency in use of quotes (single, double, none).

Page 3-30, second paragraph, add a comma in the second sentence between GEIS and NRC.

Page 3-31, Table 3-13: explain the "No Dose" category. Does that include disposal?

Page 3-33, first paragraph, next to last sentence: perhaps “would preclude” is too categorical, and “designed to prevent” might be better.

Page 3-34, next to last paragraph, extra comma in last sentence. In next paragraph, remove “(transportation accidents)” as redundant.

Page 3-37, last paragraph, first sentence needs a period.

Page 3-38, first paragraph, need comma after “e.g.” (three occurrences). POTW is “Works”, not “Facility”.

Page 3-39, paragraph before 3.4.3: explain that “quality factor” translates energy (e.g., rad) into dose (e.g., rem) and why a value of 1 is conservative. The sentence needs a period.

Page 3-39, last paragraph: first sentence has two periods. In second sentence, replace comma with “and” between “discharges” and “industrial”.

Page 3-40, Table 3-14: should Category (iv) be removed, since Subtitle C is not among the Alternatives?

Page 3-41: why are these definitions given in detail here rather than in the Glossary? They could be summarized here. In the definition of “Storm water discharge...”, quoted definitions include the phrase “this section” in three places, referring to the CFR section. In last sentence above (i), add “that” between “facilities” and “are”.

Page 3-42: in (vi), should it read “including but not limited to...”? In (ix), spell out “mgd”. In (x), replace semicolon at end with period.

Page 3-42: first sentence under 3.4.3.2, add comma between “141” and “the”.

Page 3-43, section 3.4.3.3: what does this have to do with CEQ?

Page 3-43, third paragraph: add comma after “i.e.” in last sentence.

Page 3-43, last paragraph, delete second use of “aggregate for” in first sentence.

Page 3-48, second paragraph, spelling of “may” in first sentence.

Page 3-48, third paragraph, remove period after “Arthur”.

Page 3-48, last paragraph: suggest revising this paragraph to clarify the time frame for these projections. What is the significance of 2 million tons? Page 3-47 says 40 million tons are recycled annually, with less than 200,000 tons from commercial nuclear reactor facilities. Is the reference to 2 million tons projecting a decade’s worth of recycling from nuclear facilities? What is the significance of a decade (the use of the phrase “coming decades” is not sufficient to explain this)?

Page 3-49, second paragraph, remove the semicolon after “facility” (see also page 3-55). Does the last sentence conflict with earlier statements about “significant” runoff flows being “precluded by NPDES controls” (see pages 3-45 and 3-47)?

Page 3-49, third paragraph: spell out “BOS”.

Page 3-49, fourth paragraph, fifth sentence: clarify what is meant by “precipitation to hydrate residual lime”. Is this “precipitation” as in rainfall, or “precipitation” as a chemical treatment process?

Page 3-50: TCLP is Toxicity Characteristic Leaching Procedure (not Protocol), so “test” is redundant (later in paragraph as well). Should this be in the list of abbreviations?

Page 3-51, last paragraph, is there a stray period in the third from last sentence?

Page 3-53, Table 3-20, need a space before “enters” in last entry.

Page 3-54, Table 3-21, headings “EAF Dust Secondary Processing” and “Steel residue disposal” need to be underlined (the second also needs consistent capitalization, as does Table 3-20).

Page 3-62, last sentence under “Trash” has two periods.

Page 3-63, first paragraph, add a comma after "i.e."

Page 3-63, last paragraph, should be "pH".

Page 3-65, last paragraph, remove extra space before period in first sentence.

Page 3-66, last paragraph, remove period before parenthetical in last sentence.

Page 3-69, discussion of Non Licensed-Facility Worker Exposure (for the NRC/AS Alternative): what is really considered in this analysis? Page 3-24 states that "[t]here are no Non Licensed-Facility Workers involved in the NRC/AS-Licensed Disposal Facility Alternative other than truck drivers..." Why, then, are "activities associated with the handling of materials at the licensee facility site, and placement and storage of the materials at the licensed disposal facility" addressed here? Further, "water-related potential...exposures are limited to contact with leachate or runoff water." Why are truck drivers expected to have such contact?

Page 3-72, next to last paragraph, first sentence, period should be after parenthetical.

Page 3-72, last paragraph is repetitive, suggest deleting either first or third sentence.

Page 3-76, Table 3-35, FR citation for Subtitle D should just be 2227. The note is numbered, which is inconsistent with previous tables (using letters to designate notes).

Page 3-78, Table 3-36, alignment is inconsistent with previous tables (e.g., Table 3-11).

Page 3-79, Table 3-37, font for notes is inconsistent with previous tables.

Page 3-82, Table 3-38, first column, remove period after "aluminum".

Page 3-94, first paragraph, first sentence is redundant ("EPA regulated landfills Subtitle D landfills").

Page 3-94, second paragraph: since the Subtitle C Alternative "has been removed from consideration", why is it discussed in such detail?

Page 3-94, another reference for Subtitle D management is the "2003 Directory & Atlas of Solid Waste Disposal Facilities" (<http://wasteinfo.com/products/diratlas.htm>).

Page 3-96, Table 3-40, the note (asterisk) is not reflected in table.

Page 3-97, why is section 3.6.1.2 included?

Page 3-98, Table 3-43: if this table is to be included, it should be organized by state or company. Enviro-safe of Ohio is included twice. Should Enviro-care of Utah be mentioned, even though it is not strictly a Subtitle C facility (it has mixed waste capability)? The table needs further updating.

Page 3-99, Table 3-44: using Table 3-43 as the reference, there should be 4 landfills in the South.

Page 3-101, first paragraph, add a colon after "3-46".

#### **Chapter 4: Environmental Consequences**

Page 4-2, first paragraph: suggest stating the activities that would be released for recycling and sent for disposal along with the volumes. Capitalization of "Unrestricted Use Alternative" (and other Alternatives) needs to be consistent throughout the document.

Page 4-2, first sentence under 4.1.2, remove period after "4-1".

Page 4-3, last paragraph: discussion of "material specific" and "material independent" needs to be more clear, possibly with examples. For example, explain why the masses of steel and trash are lower for the material specific scenario (because concrete is the limiting material for radionuclide concentrations). In the last sentence, should "material-specific" be "material-independent"? In that sentence, "approximately 90 percent" should be "greater than 99 percent".

Page 4-4, Table 4-2 (and following tables): what are the units of mass (or activity) for these tables? Units should be consistent to the extent possible. Over what time period are these values

calculated?

Page 4-8, Table 4-6: what is signified by "Fe" and "RCA" in this table?

Page 4-9, Table 4-7: the difference between the 1 mrem/yr option and the ANSI 13.12 option should be explained here, as the results are an order of magnitude different for activity and about a factor of two different for mass. Why are there not similar tables for concrete and steel? Is there no expectation for decommissioning of licensees other than commercial reactors?

Page 4-10: this section begins using the phrase "Non-Licensed Facility Workers", which is inconsistent with previous sections ("Non Licensed-Facility Workers"). The distinction is whether it is the worker or the facility that is licensed.

Page 4-10, last paragraph: capitalize "General" in third sentence and add a space before "mrem/year" in last sentence.

Page 4-11, first paragraph, capitalization of "Facility".

Page 4-11, third paragraph: the last sentence is redundant with footnote 1.

Page 4-12, second paragraph, last sentence, remove extra space before "Disposal".

Page 4-13, first paragraph, first sentence, period should be placed after parenthetical.

Page 4-13, second paragraph, spelling of "Envirocare". Remove stray period in last sentence.

Page 4-14, second paragraph, extra period in first sentence. In last sentence, should be "3-9".

Page 4-14, third paragraph, first sentence, "methodology...is summarized". Last sentence refers to Section 4.2.2.5, which does not exist. There are numerous later references to Sections 4.2.x that are nonexistent. Have sections been renumbered from earlier drafts (perhaps these should be 4.3.x)?

Page 4-14, last paragraph, second sentence should read "Figure 4-1 also..." Insert a comma after "however" in second sentence.

Page 4-15, Figure 4-1, title should be more apparent. It looks like part of the diagram.

Page 4-17, Figure 4-2, spelling of "RR Ballast" (on right side of diagram).

Page 4-20, references to Sections 4.2.2.1 and 4.2.2.2 probably should be 4.3.2.1 and 4.3.2.2.

Page 4-22, last paragraph, first sentence: "estimated by estimating" is redundant. Insert "and" before "subtracting".

Page 4-24, second and third paragraphs: why does this description refer to the No Action and Unrestricted Use Alternatives when page 4-20 says the results are in "separate sections"? Should this heading be "Non-Licensed Facility [Non Licensed-Facility?] Worker and General Public Collective Dose", since it also discusses the General Public? What is the significance of the "first-year collective dose"?

Page 4-25, second sentence, revise to read "The collective dose..."

Page 4-26, Tables 4-14 and 4-15: why are these in units of person-Sv, instead of person-rem, like previous and later tables?

Page 4-27, Table 4-16: for the reader to make the connection between this table and Tables 4-14 and 4-15, there needs to be a clear correlation of the mass and time represented in Table 4-16.

The reader can't easily tell whether the numbers match up. Also, by including both No Action and Unrestricted Use in Tables 4-14 and 4-15, the reader can't tell how the Unrestricted Use Alternative is included in these tables, and at which dose option. Looking at Tables 4-16 and 4-17, it looks as though No Action steel falls between 1 and 10 mrem/yr, while concrete falls between 0.03 and 0.1 mrem/yr.

Page 4-28, second paragraph, first sentence: replace "and" with "in" ("...Workers involved in activities for..."). Remove period at end of parenthetical.

Page 4-33, last paragraph: why use person-Sv here, instead of person-rem?

Page 4-37, first paragraph, fourth sentence: insert "with" before "solid".

Page 4-38, Table 4-21, why are steel and concrete not broken out? Does the "trash from other licensees" mean trash from all the different categories of facilities, or is trash also included in the individual categories (e.g., large medical centers)? Why is there not a table similar to Table 4-1 for these categories (mass and activity)?

Page 4-39, third paragraph, third sentence: revise to simplify explanation ("for each option within each Alternative based on the dose limit for each option under each Alternative"). Insert a comma after "concrete" in the parenthetical.

Page 4-40, first paragraph, next to last sentence states that "[t]he methodology for calculating the mean distances is described in Section 4.2." It is not, and it's not clear where this description can be found.

Page 4-41, first paragraph, last sentence: should the fatal accident rate be 6.12E-08 per mile? It may be easier for the reader to grasp if presented on a per million mile basis (0.0612 fatal accidents per million miles). Railcar accident rates later on this page are given per billion miles traveled.

Page 4-41, second paragraph: clarify that the railcar calculation is provided only for assessment of accidents, since all collective dose estimates assumed transportation by truck.

Page 4-42, last sentence, replace "an" with "are".

Page 4-43, Tables 4-24 through 4-28, should the last column read "Accident Fatalities" to be consistent with title? Why are there separate tables for the Unrestricted Use Alternative dose options and only one for the EPA-Regulated Alternative?

Page 4-46, first sentence, "from for".

Page 4-46, these headings ("Truck Transportation" and "Railcar Transportation") are not clearly distinguishable from the earlier discussion. Perhaps a "Summary" Section 4.4.3 is in order.

Page 4-47, first paragraph, fourth sentence needs a period.

Page 4-47, last paragraph, first sentence, suggest simplifying to read "Each Alternative begins..." Third sentence, delete "under each Alternative".

Page 4-48, second paragraph, revise to read "The following sections..." Radiological impacts are in Section 4.3.

Page 4-48, third paragraph, last sentence, add a comma after "i.e.".

Page 4-49, last paragraph, second sentence: should this be 2.5 million metric tons? Is this annual generation? Clarify that "release" is based on screening.

Page 4-50, Table 4-31, clarify "high pH". Add "pH =" to entries under Steel Scrap Recycling.

Page 4-51, discussion of aluminum and copper: introducing a new phrase "over the period of the Proposed Action". Need to define that period (by the discussion of relative amounts of copper generation and release, the period is 10 years at most, if all copper is released - is that possible?). Simplify the term "temporal scaling factor as for steel" (also on page 4-52). Are these also metric tons?

Page 4-51, last sentence has an extra period.

Page 4-52, second paragraph, third sentence has an extra period. In the last sentence, suggest replacing "exceed" with "are larger than".

Page 4-53, third paragraph refers to Section 4.6. The correct reference appears to be 4.7.

Page 4-54, first paragraph, first partial sentence, "the these materials".

Page 4-54, second paragraph, third sentence refers to total amount of generated material shown in

Table 4-6. Clarify that this table refers only to commercial nuclear reactor facilities, not all "licensed facilities". Next sentence refers again to Section 4.2.

Page 4-54, third paragraph needs a reference to Table 4-7 (other licensed facilities). Next to last sentence needs a period.

Page 4-55, first full paragraph, second sentence needs a period.

Page 4-55, third paragraph suggests that concrete will only come from commercial reactor sites. There should be some statement as to why other licensee sites will not generate significant amounts of steel and concrete when they decommission. See comment on Table 4-7 above.

Page 4-57, last paragraph, first sentence, "break up" should be two words.

Page 4-58, first paragraph, second sentence, remove period from parenthetical.

Page 4-60, first paragraph, second sentence, insert a comma before "an average". This sentence also needs a verb. Fifth sentence, does EPA "recommend" furnace types?

Page 4-60, last paragraph, second sentence, insert a comma before "the incremental".

Page 4-61, third sentence, insert a comma before "the emissions impacts".

Page 4-62, Table 4-38, the number for Tons steel recycled under No Action needs another digit. The Unrestricted Use number for Emissions assuming 2 melts needs another decimal digit. Actual emissions for 1999 needs units.

Page 4-64, first paragraph refers to Table 3-37 as giving emission factors in grams per horsepower-hour. It does not.

Page 4-64, Table 4-40, entries are inconsistent in use of significant digits. CO entry for crushing equipment needs to have the comma moved.

Page 4-64, last paragraph, first sentence, period should be outside parenthetical.

Page 4-65, first paragraph, next to last sentence, insert "than" before "transported 198 miles".

Page 4-65, last paragraph, third sentence, replace "that" with "the".

Page 4-66, last sentence, insert a space before "10 mrem/year".

Page 4-68, Table 4-42, under Activity, insert a space in "10 mrem" and insert "/yr" after "mrem". Capitalization needs to be consistent with 0.03 mrem option.

Page 4-69, first paragraph refers again to Table 3-37. Verify that this is the correct table.

Page 4-69, second paragraph refers to Table 4-42 as emissions from incineration. Should this be Table 4-41? Table 4-42 is for equipment emissions.

Page 4-69, heading for 4.7 should be all caps for consistency.

Page 4-69, last paragraph, fourth and last sentence, why is Subtitle C included here?

Page 4-71, second paragraph, first sentence, capitalize "Subtitle". In the last sentence, suggest simplifying to read "Existing capacity of Subtitle D landfills would be adequate for disposal of all the materials released under this Alternative."

Page 4-71, Section 4.7.1.2 should be removed as it is no longer under consideration.

Page 4-72, last paragraph, capitalize "Agreement State" in the first sentence.

Page 4-73, last paragraph contains two references to "NRC's website" as the source of information. Suggest finding a more specific reference. Further, at one time Barnwell refused waste from North Carolina because of compact issues. Is this still the case? Legal suits against North Carolina are still in process. The sixth sentence needs a period. Suggest citing the number of power reactors in the Atlantic Compact, as is done for the Northwest and Rocky Mountain Compacts.

Page 4-74, last paragraph, first sentence, remove extra comma.

Page 4-75, first sentence, remove period after "8.5".

Page 4-75, first full paragraph, first sentence, remove extra comma.

Page 4-75, last paragraph, second sentence, insert comma before "the existing LLW". Remove stray period before last sentence.

Page 4-76, last paragraph, first sentence, insert comma before "copper".

## **Chapter 6: Cost-Benefit Analysis**

Page 6-1, second paragraph: clarify that costs and benefits are relative to the No Action Alternative. Also clarify time frame for analysis. Next to last sentence refers to "attributes" with no previous use or definition of the term (until page 6-3).

Page 6-1, bullets: first and second bullets, should be "incurs" (not "incur"). Need to be consistent throughout with previous chapters in capitalizing "Alternative" and using the same terms ("Unrestrictive Use" and "LLW Disposal" are not consistent).

Page 6-2, first paragraph after bullets, capitalize "GEIS".

Page 6-3, bullets: simplify first bullet, e.g., "Air emissions could be affected by the number of vehicle miles traveled as well as the relative production of new versus recycled material (e.g., steel, copper, aluminum)." Is air the only environmental consideration? Ground water and surface water are prominent transport pathways for several Alternatives. The next three bullets use the term "cleared" or "clearance" several times (see comment for page 2-4, footnote 4).

Page 6-4, fourth bullet: change "memorandums" to "memoranda" and capitalize "Agreement States". Clarify the parenthetical: Does "this excludes" mean "there are no additional government costs for" government facilities that are generators of waste? If DOE and DoD facilities are included in the analyses (as it seems they must be if they are covered by some of the attributes most applicable to waste generators), where are the tables summarizing the mass and activities of the waste that could be released under the various Alternatives from these facilities?

Page 6-5, there is an extra space at the beginning of the last paragraph and footnote 5 needs a period.

Page 6-6, first paragraph, footnote 6 has already been cited as footnote 1. Spell out "OMB" and provide a reference.

Page 6-6, second paragraph, Unrestricted Use is referred to as "unrestricted release".

Page 6-6, Table 6-2, why are copper and aluminum not listed in this table? It appears to be a generic table of disposition possibilities under the Alternatives.

Page 6-6, last paragraph, clarify that "uncleared" waste is sent for disposal at an LLW facility.

Page 6-7, first paragraph refers to Section 4.6 (should be 4.7).

Page 6-7, next to last paragraph, last sentence, spelling of "dose".

Page 6-7, last paragraph, change "are" to "is".

Page 6-8, Table 6-3, explain the reason for the dramatic differences between the 1 mrem/yr dose option and the ANSI 13.12 option, which is nominally 1 mrem/yr. Note that OMB considers a rule "economically significant" under Executive Order 12866 if annual effects are greater than \$100 million; by this criterion, the 50-year 7% discounted net cost of \$1.583 billion for LLW disposal at the "no dose limit" is equivalent to \$114.7 million in average annualized net cost (using a 50-year 7% annualization multiplier of 0.07246), which would qualify as "economically significant". Suggest also including a table of non-discounted (0%) impacts, in addition to 7% and 3%. A 3% rate is often used to depict impacts <30 years, and 0% is used to depict impacts >30 years. For example, EPA's "Guidelines for Preparing Economic Analyses" (September

2000) recommends using a 2% to 3% discount rate for “intragenerational impacts”, and a 0.5% to 3% rate for “intergenerational impacts”. See

<http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html> for more information.

Page 6-8, last bullet, fifth sentence, should be “benefits arise”. See also page F-29.

Page 6-9, second bullet, add a comma after “unrestrictive use alternative” (Unrestricted Use).

Page 6-9, third bullet, “industry” should be lower case.

Page 6-9, last bullet, after “Other Considerations” replace period with dash.

Page 6-11, Table 6-5, note 1 still refers to a 7 percent discount rate.

## **Chapter 8: References**

General: suggest distinguishing further among references from same source in same year, e.g., EPA 2003, EPA 2003a, etc.

Reference 48, remove extra period.

References 69, 70, 77, insert periods after title and at end of citation.

Reference 75, insert space in “Vol. 2” and add comma before page number.

Reference 86, insert period at end.

## **Appendix A (if this can be edited): Scoping Summary Report**

Page 2, last paragraph, need close quote on document title.

Page 4, second paragraph, second sentence, insert comma after “Others”. Last sentence is repetitive.

Page 7, “Other studies”, under (f), spelling of “bear”. (g) has a stray close parentheses.

Page 28, middle heading, spelling of “disadvantages”.

## **Appendix D: Dose Assessments**

Page D-4, third paragraph, fifth sentence: is there a reference to support this statement (risks are reduced if doses are spread out), particularly if a “great deal” of data exists? Some comments refer to data and studies supporting the idea that low doses are more harmful (i.e., carry higher risks) than previously believed.

Page D-5, second paragraph, does this statement that “cancer risk per unit dose varies [not vary] as a function of...dose rate received...” contradict the statement on D-4 in the previous comment?

Page D-6, Tables 1 and 2, why are these in units of Sv and Bq, instead of Rem and Ci?

Page D-8, reference for “UN 1988” is referred to as “UNSCEAR” in the text.

## **Appendix E: Radiological Assessments for Clearance**

General: spellings of certain words are English (e.g., aluminium, vapour). The appendix uses units of Sv throughout.

Page E-2, first paragraph, second sentence, remove “in”.

Page E-2, last paragraph, fifth sentence, remove “in”.

Page E-3, last paragraph, fifth sentence, remove period after “Figure 1” (and “Figure 2”, “Table 1”, etc.).

Page E-4, Figures 1 and 2, titles need to be more clearly associated with figures. Figure 2 has a "Figure 6" label that should be removed.

## **Appendix F: Cost-Benefit Analysis Methodology and Results**

General: In addition to presenting cost/benefit results on an average annualized basis (see Tables F-11 to F-26), can material quantities be expressed in a similar way (with standardized units such as tons/year)? This would allow an expression of the variation in materials from different types of facilities at different points in their lifetimes (e.g., operating period vs. decommissioning). Such projected variation could also be compared to the annual intake rates for the different Alternatives (e.g., landfill disposal, incineration) to estimate annual percentage increase. In addition, much of this material could be moved to Chapter 6, as it contains fundamental information about the 18 cost/benefit "attribute" categories, as well as discussion of methodology, which may be appropriate for the main body of the report rather than relatively hidden in the appendix.

Page F-3, second paragraph refers to "Exhibit 1" (should be "Figure" to be consistent).

Page F-3, footnote 2, second sentence, add apostrophe to "licensee's".

Page F-4, first sentence, remove "NRC's regulation analysis guidance" and parentheses (NUREG/BR-0184 has already been defined in footnote 1). Third sentence, should be "costs".

Page F-4, footnote 4 is identical to footnote 1.

Page F-6, last paragraph: aren't the "baseline's benefits or costs" considered equal to zero? Using the phrase "benefits or cost" is misleading, since benefits or cost can only be determined relative to the baseline. Further, this explanation that net costs are positive while net benefits are negative is the opposite of the way results are presented in Chapter 6 and could be confusing.

Page F-7, fourth paragraph, last sentence, remove extra "s" from "Sections". The reference to Sections 2.1.1 through 2.1.5 is incorrect (not clear where correct sections are - Chapter 3?).

Page F-8, footnote 5: does the steel industry consider scrap cleared under Reg Guide 1.86 to be radiation-contaminated? The question, then, is how will the dose-based levels compare to RG 1.86.

Page F-10, second paragraph, last sentence needs some clarification. Assuming that the 1 ton increase is from scrap "generated by this rule", it appears the 0.5 ton decrease in steel quantity involves scrap not "generated by this rule", i.e., scrap from other than licensees. Is that correct?

Page F-10, last paragraph, first sentence, suggest inserting "virgin steel" before "using" in parenthetical.

Page F-11, consistency of format between text and footnotes: "US" vs. "U.S."

Page F-12, Table F-5, provide a more detailed reference for the Integrated Planning Model.

Page F-12, second paragraph, explain the 1990 Pace University Study.

Page F-15, footnote 18: it appears that there is some question about the way the Collective Dose report is evaluating the No Action Alternative. There should be no guesswork about how two related pieces of this analyses were developed. See also footnote 33.

Page F-18, footnote 20 uses DOE disposal costs at Envirocare as the reference cost. The possibility that the prices negotiated by DOE are affected by the volumes of waste generated by DOE (relative to industry), and expectations of continued future generation, should be considered.

Page F-28, footnote 51 is identical to footnote 1.

Page F-29, summary of results should explain why certain years have no cost or benefit relative to the baseline, particularly when there is a significant difference from other Alternatives. Some statements have been made earlier, such as the expectation that survey costs at a generator will be similar for all options (except possibly for the LLW Disposal Alternative). For example, why are there net costs under Industry Implementation for two years (2003-2004), no net cost or benefit for 9 years, then net costs again? This pattern seems to hold regardless of Alternative or dose option.

#### **Appendix G: Current NRC Approach**

Page G-1, third paragraph, second sentence, change "their" to "its" and "are" to "is".

Page G-2, second paragraph, first sentence, insert comma before "e.g." in parenthetical.

Page G-4, first paragraph, capitalize "Nuclear" in title. Does the Branch Technical Position have a title? Date?

Page G-4, first bullet needs a period.

#### **Appendix H: Glossary of Terms**

Consider adding terms: "Clearance"; "Effective Dose"; "Quality Factor"; "Thermal Neutron".

Under "Gas Centrifuge", "UR6" should be "UF6".

Combine "Spent (depleted) fuel" and "Spent nuclear fuel".

"Transuranic Waste" - refer to definition of 100 nCi/g.

#### **GEIS Chapter on Collective Dose Report:**

General: Headings and numbering of sections should be made consistent with DGEIS. This appears to be intended as an executive summary for the collective dose report.

Page 1, first paragraph: has ADAMS been previously defined? In the last sentence, the wording is curious if this chapter will in fact be part of the GEIS ("in support of a Draft...").

Page 1, footnote 1 relates to the general comment regarding the need for further explanation of the ANSI standard and how it compares to the 1 mrem/year option under consideration.

Page 2, item 3 should read "Subtitle D". Note that there is a distinction made here that is not accurate (and that does not appear to have been explicitly made in the remainder of the DGEIS).

Both municipal solid waste and industrial solid waste landfills fall under Subtitle D of RCRA.

There are explicit standards that apply to municipal landfills (40 CFR part 258), which may be what is referred to as the "Subpart D regulations" that industrial landfills "are not required to comply with". Regulations in 40 CFR part 257 relate to industrial landfills (and waste). Fifth sentence needs a period. The sixth sentence is confusing because of the different meanings of the term "restrict" (the "restriction" to disposal eliminates some pathways considered for "unrestricted" release, so the release criteria are less "restrictive" - but what can be "less restrictive" than "unrestricted"?). Suggest revising to present the outcome in terms of "greater amounts of material can be released" rather than "less restrictive criteria". The eighth sentence seems to suggest that NUREG-1640 evaluates municipal and industrial landfills differently. Is that correct? If not, what is the distinction in how the radionuclide concentrations were derived? Next to last sentence needs a period.

Page 2, item 4, suggest adding "or Agreement State" before "licensed".

Page 2, last paragraph: this document uses the term "ferrous metal" throughout, while the DGEIS simply refers to "steel" (see also "carbon steel" on page 13). Why is soil not included? Soil is certainly addressed by the DGEIS.

Page 3, top paragraph, delete extra space before period in last sentence.

Page 3, first paragraph below bullets, fifth sentence, insert "a" before "valid" and insert comma before "value". Last sentence, delete "the use of".

Page 3, last paragraph, fifth sentence: this sounds as though people decide whether to use an end-product based on its radioactive content. Suggest clarifying that the term "end-product" refers to a specific item, not a product line (e.g., a car as opposed to the generic category of cars), and that as the concentration in any one product item goes down, the overall activity is distributed among many more product items (hence the use and potential exposure by more individuals).

Page 4, third paragraph, first sentence, delete comma after "emphasized that".

Page 4, fourth paragraph, first sentence, change "different than" to "different from". In the third sentence, remove reference to "we" (last sentence also) and change "the mean of the" to "those mean values of the".

Page 5, fifth paragraph, use of abbreviation "t" for metric tons is not consistent with DGEIS.

Page 5, last paragraph, insert "n" at end of "give". How is the "radionuclide contamination" signified in the curves (activity, dpm, surface, volumetric)?

Page 6, paragraph below bullets suggests that material was characterized generically for content of different radionuclides. Was the potential variation and uncertainty taken into account? How much confidence is there that materials do not vary in such a way as to result in larger doses than expected?

Page 6, third paragraph, what are referred to here as "regulatory alternatives" are "dose options" in the DGEIS. It would be best not to use the word "alternative" in such different ways.

Page 6, last paragraph, suggest inserting "collective dose" before "report". Generally, need to be clear that this is not part of the collective dose report, but of the DGEIS.

Page 6, footnote 4, how were normalized doses derived for trash (again, note the reference to "this report" - the collective dose report?).

Page 7, this discussion of decontamination seems a bit inconsistent with the DGEIS. It makes sense that most of the mass, if not activity, is found in materials that are only slightly contaminated, and that incremental activity should be larger than incremental mass as the reference dose increases. However, there are statements in the DGEIS to the effect that decontamination can be expected to achieve a reduction of a factor of 10, which suggests that there is some subset of material that can be decontaminated to just meet the release criteria (rather than "very little, if any, radioactivity" remaining because "decontamination is a destructive process").

Page 10, second paragraph, why are BWRs not addressed as well? In the second sentence, clarify "incremental radioactivity". Does it refer to total activity or concentration? If the mass is much smaller, but the total activity is 7% larger, the concentration must be significantly larger.

Page 10, fourth paragraph, third sentence, provide examples of "chemically-similar elements".

Page 10, last paragraph, reference to "this report".

Page 11, first paragraph, second and third sentences, suggest combining and removing "was made. This upper-bound estimate".

Page 11, third paragraph, units of kt and Bq are not consistent with the rest of the DGEIS.

Page 11, last paragraph, sixth sentence, should make clear that the relative contributions of all scenarios were increased, not just the ones that don't contribute much.

Page 13, third paragraph, first sentence, add "s" at end of "radionuclide".

Page 15-16, Figures 3-5, explain the notation on the figures. Do the section numbers refer to the collective dose report?

Page 17, second paragraph below equations, last sentence, the reference should be clarified. Is "1995" part of the title of the document?

Page 17, next paragraph, spell out "MCNP". Do section numbers correspond to the collective dose report?

Page 18, top, notation for ingestion dose conversion factor is similar to that for external exposure. Perhaps the notation can be made more distinct.

Page 18, second paragraph, third sentence, change "is" to "are". In the fourth sentence, remove "what was done was".

Page 18, last paragraph, second sentence, change "are" to "is".

Page 19, first paragraph, last sentence, revise reference to "our analysis".

Page 19, last paragraph, revise reference to "the enclosed Excel data files".

Page 20, second paragraph, second sentence has an extra period. Reverse "equivalent" and "the".

Page 20, Table 1.2, terminology under "GEIS" is not consistent with the actual document (Unrestricted Use, EPA-Regulated Disposal, NRC/AS-Licensed LLW Disposal, etc.). Why is Case D not included in the collective dose report terminology?

#### **Exposures From Multiple Sources:**

Page 1, second paragraph, last sentence refers to "iron" and "steel". The main DGEIS refers only to steel.

Page 2, eighth sentence of the paragraph, change "does" to "do". Clarify that restrictive scenarios do not include copper for volumetrically-contaminated materials, since the next sentence states that copper is a restricting material for surface contamination. Remove period from "Table 1" (and throughout after citing tables, figures, or sections).

Page 3, first paragraph, last sentence, delete "actually occurring".

Page 3, second paragraph, first sentence, delete "of".

Page 3, third paragraph, last sentence, insert a space after "e.g.,".

Page 5, last two sentence, remove "s" from end of "millions".

Page 5, footnote 1 needs clarification on the "fractions". Suggest revising third and fourth sentences to read "From NUREG-1640, 50% of iron castings are used for the auto and truck industry, and 20% of all scrap is used for casting." Add a reference to the statement that all scrap cleared would be one-thousandth of total scrap used in a year (there is some discussion in the main body of the DGEIS). Over what period does this consider "all the scrap that could potentially be cleared from the nuclear industry"? Show the calculation to reach the one-ten-thousandth conclusion ( $0.001 \times 0.5 \times 0.2$ ).

**NAVAL REACTORS  
A JOINT NAVY DOE PROGRAM**

21 January 2005

*Luis*  
Dear Mr. Reyes,

Last week the NRC staff held a meeting among representatives of the Agencies cooperating in the NRC's Draft Generic Environmental Impact Statement (GEIS) on Controlling the Disposition of Solid Materials. Enclosed is a copy of the Naval Reactors letter objecting to the proposed alternative in this Draft GEIS which would, with few exceptions, prohibit unrestricted release of any solid material originating in restricted or impacted areas of NRC licensees.

Naval Reactors has worked for decades to maintain a radiologically clean workplace so that people and materials do not become radiologically contaminated. This proposed alternative takes a big step backwards in penalizing NRC licensees that run a similarly clean operation. Furthermore, the Draft GEIS provides no health or safety justification that would warrant selection of this preferred alternative.

The proposed regulation will not prevent introduction of radiologically clean materials meeting stringent international standards from entering commerce. The rest of the world has rational limits, and through world trade, the U.S. will use this material. Also, the Navy under our separate regulatory authority has been safely recycling large quantities of nonradioactive materials from decommissioned nuclear powered ships for decades. We have safely demonstrated that when strict standards and modern analysis techniques are used, what counts is not where a material comes from, but whether or not it is radioactive.

I would encourage you and the Commissioners to reconsider your preferred alternative.

*Tom Beckett*

T. H. Beckett  
Deputy Director  
Naval Nuclear Propulsion Program

Mr. Luis A. Reyes  
Executive Director for Operations  
U.S. Nuclear Regulatory Commission

**NAVAL REACTORS  
A JOINT NAVY DOE PROGRAM**

21 January 2005

Mr. Scott W. Moore  
Chief, Rulemaking and Guidance Branch  
Division of Industrial and Medical Nuclear Safety  
Office of Nuclear Material Safety and Safeguards  
U.S. Nuclear Regulatory Commission

The purpose of this letter is to provide comments from the Naval Nuclear Propulsion Program on the Draft Generic Environmental Impact Statement (GEIS) Controlling the Disposition of Solid Materials. The Naval Nuclear Propulsion Program is a joint Department of Energy/Navy Program that is responsible for the operation and regulation of 103 nuclear reactors, a number equal to the number of power reactors regulated by the NRC. Our personnel participated in the recent review of the Draft GEIS by participating agencies in this GEIS process.

The Naval Nuclear Propulsion Program strongly disagrees with NRC's preliminary selection of the Limited Disposition alternative as the preferred alternative in this GEIS. Under this alternative, with a few relatively minor exceptions, all solid material removed from licensee's restricted areas or impacted areas would require disposal at a landfill even if the material met internationally recognized standards for release for unrestricted use. The lengthy analysis provided in the Draft GEIS demonstrated no significant health or safety benefit resulting from this alternative compared to other alternatives such as allowing unrestricted use or recycling of materials meeting stringent internationally accepted standards. Furthermore, the application of this rule to all solid material leaving restricted areas or impacted areas would include much material that would have been exposed to a gamma radiation field only, which physically cannot induce radioactivity in material.

Under the independent regulatory authority of the Naval Nuclear Propulsion Program, the U.S. Navy has for many decades been releasing for unrestricted use nonradioactive material used in association with Naval Nuclear Propulsion Plants. Our Program has always made great efforts in the design, operation, maintenance, and inactivation of Naval nuclear-powered ships to control radioactivity at the source. Our nuclear fuel and plant

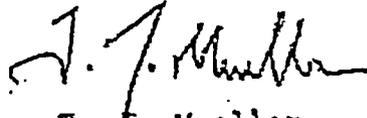
design keeps radioactivity associated with these propulsion plants within limited areas. In our maintenance and operating procedures, we ensure that radioactivity is not spread when we open these systems. This longstanding practice of controlling radioactivity at the source not only results in more capable and effective warships, but it also has the significant benefit of allowing our people and their equipment to routinely come into direct contact with our nuclear propulsion plants without wearing any protective clothing or becoming radioactively contaminated. With appropriate and careful controls, our Program has released such nonradioactive items for unrestricted use.

The most prominent and successful example of this process is the Navy's decommissioned nuclear-powered ship recycling program. This program has been in place since 1986 and was the subject of Environmental Impact Statements in 1984 and 1996. Under this program, defueled reactor compartments and associated radioactive piping are removed from nuclear-powered ships for disposal as radioactive waste. Nearly all of the remainder of the ships is released for unrestricted use and recycling following extensive confirmatory surveys. Due to the Navy's successful efforts at containing radioactivity at the source, these recycled sections of the ship include portions of the nuclear propulsion plant such as the secondary steam piping, propulsion and electricity generating turbines, and condensers. According to the Draft GEIS, analogous components in NRC-licensed nuclear power plants would be in the restricted area and precluded from unrestricted release regardless of whether they were actually radioactive or not.

The Navy's program of recycling decommissioned nuclear-powered ships has become a model for the rest of the world. Over 400,000 tons of recyclable material from 108 nuclear-powered ships have been recycled for productive use. There have been no problems with inappropriate material released for recycling, and this material has been accepted into both the U.S. and international scrap recycling markets. This recycling program is ongoing and will continue into the future for the Navy's current and future nuclear-powered ships.

While the Navy's release of material for unrestricted use both in our ship recycling program and our normal operations has proceeded under our Program's independent authority, it is highly desirable that our activities be carried out under requirements comparable to and in concert with those of the NRC.

This would not be the case if the preferred alternative identified in the Draft GEIS were adopted by NRC. For this reason, the Naval Nuclear Propulsion Program urges NRC to reconsider its preferred alternative.



T. J. Mueller  
Director, Nuclear Technology Division  
Naval Nuclear Propulsion Program

Copy to:

Jack Strosnider, NRC Nuclear Material Safety and Safeguards  
James Dyer, NRC Nuclear Reactor Regulation  
Paul Lohaus, NRC State and Tribal Programs  
Carl Paperiello, NRC Nuclear Regulatory Research



Department of Energy  
Washington, DC 20585

April 5, 2005

Mr. Scott Flanders  
Director  
Environmental and Performance Assessment Directorate  
Division of Waste Management and Environmental Protection  
Office of Nuclear Material Safety and Safeguards  
Nuclear Regulatory Commission, Mailstop T7J-8  
Washington, DC 20555-0001

Dear Mr. Flanders:

Enclosed please find the U.S. Department of Energy (DOE) staff comments on the Nuclear Regulatory Commission's (NRC) Draft Report for Comment, *Generic Environmental Impact Statement: Controlling the Disposition of Solid Materials* (GEIS), NUREG-1812 dated December 2004. We understand that the NRC Draft GEIS is in support of a regulation being considered by the NRC to control the disposition of solid materials that originate in restricted or impacted areas of NRC/Agreement-State licensed facilities, and have no, or very small amounts of, radioactivity resulting from licensed operations.

I am sending this letter, to document for the record, the Department of Energy staff comments previously provided in response to the NRC letter dated December 2, 2004 (Phyllis Sobel, NRC; to Stephen Domotor, DOE) requesting our review of the NRC GEIS. The comments also take into account information presented by NRC staff and management at a meeting of Cooperating Agency representatives you hosted on January 11-12, 2005.

The enclosed comments were developed by my office and include input from staff representing several DOE offices. However, they are not necessarily reflective of all comments that might result from a DOE-complex-wide review. Although the DOE staff comments are provided on the material in the GEIS and the briefing in the context of the draft NRC staff preferred alternative, we emphasize that DOE has not yet indicated a preference for any of the alternatives analyzed in the GEIS.

We look forward to continued coordination with you in DOE's role as a cooperating agency to NRC regarding your considerations in proposing to amend NRC regulations to provide radiological criteria for controlling the disposition of solid materials. Please contact me or Mr. Stephen Domotor of my staff (202-586-0871) with questions concerning these comments and with additional information concerning the NRC's path forward on this initiative.

Sincerely,

A handwritten signature in black ink, appearing to read 'A. Wallo', written in a cursive style.

Andrew Wallo  
Director  
Office of Air, Water and Radiation Protection  
Policy and Guidance

Enclosure

**Draft staff comments on NUREG 1812  
Draft Generic Environmental Impact Statement  
Controlling the Disposition of Solid Materials, December 2004**

The following reflects the position of Department of Energy staff who have reviewed the subject GEIS draft. It based on the GEIS and in part, on information provided to DOE staff during a January 11 and 12, 2005 meeting between NRC staff and representatives of the GEIS cooperating agencies. The summary of DOE staff position was developed by the staff from the DOE Office of Air, Water and Radiation Protection Policy and Guidance.

***DOE Staff Position:***

The Department of Energy has not yet indicated a preference for any of the alternatives in the GEIS. The Department is in the process of completing more thorough reviews of the GEIS dose and cost estimates to support the formulation of a Department position. The following is summarizes current staff views based on an initial review of the draft GEIS.

Department staff is concerned that there is not sufficient risk-based justification for the NRC staff's proposed preferred alternative. Based on its review, DOE staff believes that NRC's analyses does not provide a compelling basis for selecting the "limited disposition" alternative over the base case (No Action) alternative or one or more of the dose-based unrestricted release alternatives.

Additional clarification is also needed in the GEIS that the 1 mrem/y criterion selected is not a bright line between safe and unsafe relative to other dose criteria evaluated in the GEIS and used in other rulemakings, guidance, and recommendations by international scientific organizations. There should be flexibility for consideration of dose criteria other than 1 mrem/y in the case-by-case process described in the staff preferred alternative of the GEIS.

***Rationale for Staff Position on "Preferred Alternative":***

The GEIS indicates that there are no significant health and safety impacts associated with any of the alternatives and, although DOE is still evaluating the cost assessment, the GEIS data indicates no significant differences between the three alternatives. Further, there was insufficient discussion on the impact of the proposed preferred alternative and the "disposal only" alternatives on pollution prevention programs and goals. This attribute could be a significant discriminator between the base-case and unrestricted use alternatives and the limited disposition and two disposal only alternatives.

The GEIS indicated that the NRC is proceeding with the rule making based partly to respond to NAS recommendations for a more transparent and risk-based process and, although the current case-by-case approach (No Action Alternative) was working, to address several disadvantages of the current process including:

- lack of a consistent criteria for controlling solid material
- no guidance for controlling volumetrically contaminated material

- greater sensitivity of new detectors can detect levels lower than detectors previously used for non-detection-based releases
- additional time and resources required to evaluate and implement the various case-by-case approaches.

It is not clear from the GEIS how the preferred alternative is significantly more transparent or risk-based or that it does not have many of the same disadvantages as the current approach given that, under the preferred alternative, a large portion of released material may be and, in many cases, can only be released through a case-by-case process.

***General Concerns:***

Although as noted, we see no compelling reason for selecting the preferred alternative over other options, we also have concerns with the complexity and lack of flexibility in the preferred alternative and the possibility of it being considered a precedent for defining safe or acceptable doses in general. The 1 mrem/y criterion is not a bright line between safe and unsafe and there should be flexibility for case-by-case application of other dose criterion. There is no discussion on how the proposed preferred alternative relates to other similar radiation rules and guidance and how they make up part of an integrated radiation protection system.

For example, the preferred alternative may be compared by some to the 10 CFR Part 20 license termination standards in subpart E which allows 25 mrem/y (after ALARA process). Similarly, the preferred alternative could inappropriately be used as a benchmark for the protective action guides that might be used to control or release property following a radiological emergency. It may not be in the best interest of public welfare to use the SG-R-1.7 values or the 1 mrem/y-based criterion for controlling property during an emergency. Dedicating emergency response resources to controlling property at levels that are on the order of 0.3% of normal background radiation could actually increase risks in other areas. In general, the International Atomic Energy Agency established the SG-R-1.7 levels for unrestricted release (or rather levels that require no radiological control). In the Commission Staff preferred alternative, the values are being made more restrictive and are only being applied for restricted release. The GEIS does not indicate why the Commission staff is choosing to be more restrictive than suggested necessary in SG-R-1.7. Therefore, DOE staff believes the GEIS needs to provide more perspective on the proposed alternative. It should more clearly discuss the limitations and scope explaining why the alternative and its criteria are not appropriate for other applications. It should note that the 1 mrem/y criterion is not a bright line between safe and unsafe but rather the point of departure or screen value or goal for this specific application. The preferred alternative should recognize that other dose criterion may be justified on a case-by-case basis if it meets 10 CFR Part 20 protective requirements and is determined to be as low as is reasonably achievable. Flexibility in the dose criterion should be included in all alternatives whether it be for unrestricted release, limited disposition or disposal only.

As structured, the preferred alternative would restrict recycling of any property taken into or used in a restricted area, whether or not it is radiologically impacted. There should be a process for clearing uncontaminated material for recycling.



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March 7, 2005

Phyllis Sobel, Ph.D.  
Nuclear Regulatory Commission  
TWFN, Mail Stop: 7 J8  
11545 Rockville Pike  
Rockville, Maryland 20852-2738

**RE: Comments on 4<sup>th</sup> Preliminary draft GEIS  
on Controlling the Disposition of Solid  
Materials**

Dear Dr. Sobel:

Clearly, a lot of good work has been done on the draft Generic Environmental Impact Statement (DGEIS). However, as it currently reads, the DGEIS appears premature; inconsistent with other NRC regulations; lacks harmonization with international standards; and are not scientifically justified. Hence, more time is needed to transform the DGEIS to support its Proposed Action or to change the Proposed Action to reflect the data and analysis.

Premature

It is not appropriate to put forward a draft GEIS until all supporting research and reports have been published peer-reviewed accepted by the public, industry, and the Agreement States (AS). Examples of some of the reports that need to be reviewed include:

- A. "Collective Doses Associated with Clearance of Material From NRC/Agreement State-Licensed Facilities" by SC & A, Inc. Last available as a draft in September 2003.
- B. Documents/reports that support IAEA RS-G-1.7, "Application of the Concepts of Exclusion, Exemption and Clearance," August 2004.

At this time it is not possible to review the draft FRN without reviewing the GEIS-dependent document of the SC & A, Inc. and, a determination that documentation publication for IAEA RS-

G 1.7 will be transparent and acceptable. The NRC needs to slow down the DGEIS effort until all reports are publicly available, reviewed and accepted by the public, industry, and the AS.

Inconsistent with other NRC regulations

The Proposed Action will allow solid materials which have no, or very small amounts of, residual radioactivity resulting from licensed operations to be released into the environment and/or public and no longer be under regulatory control - this is a prospective 'how clean is clean' (clean) standard. While it is understood, that prospective 'clean' standard will be more restrictive than the retrospective 'clean' standard (i.e., License Termination (LT), cleanup after a dirty bomb, etc.) whereby the dose criterion are one mrem/yr and 25 mrem/yr respectively, a problem arises when the NRC does not apply these standards evenly.

Currently, licensees wishing to bury waste on-site need to apply to the NRC under 10 CFR 20.2002 and adhere to a 1 mrem/yr standard. But, as soon as the licensee initiates termination and starts decommissioning, the waste can be buried on-site using the retrospective standard of 25 mrem/yr. This unevenly application of these standards does not make sense. Burial of waste on-site and off-site need to be held to the same standard not only when the NRC feels like it. Thus, the scope of the Proposed Action needs to be changed to include both on-site and off-site limited dispositions.

Also, the next owner/tenant may dig up and use the contaminated solid materials as they see fit. This is an unforeseen problem, because license termination was never intended to include on-site disposal of waste (and using the retrospective dose criterion of the LTR). License termination was for whole intact buildings and the land - not rubblized buildings and redistribution of radioactive contaminated on-site landfills.

With regards to the above inconsistent application of the LT rule (LTR) and Limited Disposition Standard (LDS), the NRC needs to:

- A. demonstrate that potential materials (e.g., soil, rubble) that could be removed from a site after license termination will not result in doses greater than 1 mrem/yr,
- B. better define what the LTR includes. It is hard to swallow that intentionally disposing waste material (i.e., rubble) on-site was part of the LTR. The LTR is a retrospective clean up standard while disposal of contaminated waste material is to be held to a prospective clean standard (i.e., intentionally introduced into the environment and/or public), and,
- C. restrict on-site burial of rubblized building, landfills material, etc. to the LDS requirements. [Note that, most NPP sites could never qualify as a RCRA subtitle D landfill because they sit close to rivers, lakes and oceans, whereby the distance to the groundwater is relatively small and the leach rates would be too great because of lack of a liner or equivalent. Hence, site specific dose modeling will be required whereby the dose from waste be held to the prospective standard of 1 mrem/yr of the 25 mrem/yr allowed under LTR.]

Furthermore, it is unclear why the disposition of solid material's dose criterion is proposed to be less than NRC's gaseous ( 5 mrem/yr) and liquid effluent (3 mrem/yr) standards and the EPA's drinking water standard (4 mrem/yr). It appears the justification is that a smaller dose criterion is better, and it is consistent with NCRP, ICRP, IAEA, HPS, etc. define as a negligible dose. If so, then perhaps this is the time to harmonize these prospective release standards all down to one mrem/yr, or it is time to better explain why one mrem/yr for disposition of solid materials is ok while 3 mrem/yr from liquid effluents is equally ok, etc.

Perhaps a logical and compromising solution would be for a Limited Disposition dose criterion of 3 to 5 mrem/yr (per NUREG 1640) and an Unrestricted Releases to be 1 mrem/yr (per IAEA RS-G-1.7 values). Processing requests for disposals using dose criterion of 3 to 5 mrem/yr are already permitted by the NRC under an CFR 20.2002 application and leaves open the 1 mrem/yr dose criterion for unrestricted releases which is consistent with IAEA RS-G-1.7 recommendations. Another justification for the above proposal is the level of certainty of the dose models and their corresponding doses; destination of the solid materials under the Limited Dispositions is better defined and has higher degree of certainty than will solid material under the Unrestricted Releases where the material could end up anywhere

Lacks Harmonization with International Standards & Not Scientifically Justifiable (and other Notes) Per the DGEIS

Page xvii, Alternatives Eliminated from Detailed Study, Line 28, DGEIS

1. States that Conditional Uses, such as, "concrete use in road fill" were eliminated from detailed study, but the preliminary recommendation includes "concrete use in road beds." What's the difference? Is this a misprint? Furthermore, it is unclear why "concrete use in road beds" is included in the preliminary recommendations, because the concrete may ultimately be reused and/or recycled into unforeseen consumer products, which should eliminate it from consideration.
2. Also troubling about this section, is that the entire alternative of Conditional Use was eliminated from detailed study because the material may ultimately be reused and/or recycled into products not authorized under the Conditional Use Alternative (i.e., unforeseen), and the Conditional Use Alternative would allow a greater amount of activity than the Limited Disposition Alternative, which are based on Unrestricted Use Alternative (based on 1 mrem/yr.)

Neither of the above two explanations is acceptable. First, the Conditional Use dose scenarios should take into account the worst thing that could solid material could be reused for and/or recycled into. Logic dictates that whatever this secondary item and/or use will be, it will result in a smaller dose than the original material especially if it is recycled. Secondly, allowing more activity to be released under the Conditional Use Alternative, some would argue, is the desire goal. If more activity available for release is

not desired, then why was the Conditional Use Alternative not assigned the values of the Unrestricted Use Alternative (based on 1 mrem/yr for normalization purposes)?

Hence, it is unclear why a generic process with generic release concentrations could not be formulated. All the factors used to eliminate the Alternative Use Alternative need to be stated in this section as well as section 2.5.

Page xvi, Limited Dispositions, DGEIS

1. The reasons for the use of IAEA RS-G 1.7 concentrations limits for Limited Dispositions supports the use of these values for the other Alternative scenarios, as noted above, such as Conditional Use and the Unrestricted Release Alternatives. Because, as stated on lines 32-35, "these materials could end up in dispositions, including reuse and recycling into other products, given that the licensees [will] have no administrative controls over materials once they leave the site."; this reason is used to disqualify the Conditional Use Alternative and assisted on marginalizing the Unrestricted Use Alternative.

If the use of IAEA RS-G-1.7 values is ok for Limited Dispositions, because the material may end up in consumer products, then these values (or equivalent values of NUREG 1640) are also acceptable for all the Alternatives. In other words, why is 1 mrem/yr from Limited Dispositions treated differently than 1 mrem/yr from Unrestricted Releases or 1 mrem/yr from Conditional Uses? One mrem/yr is one mrem/yr is one mrem/yr, regardless of where it comes from. Or, more to the point, why is the DGEIS selecting an Alternative based upon public perceptions?

Page xxiv, Staff Assessment & Preliminary Recommendations, DGEIS

All the reasons against unrestricted releases (page xxiv, lines 33-36) are not valid. Concerns that risks associated with unrestricted releases are avoidable and involuntary, and potential of doses from multiple sources is true for all the Alternatives. Moreover, section 3.8, on Cumulative Impacts states that "the likelihood of . . . multiple concurrent exposures becomes vanishingly small as the number of potential concurrent scenarios increases." This correctly implies that doses from multiple sources is a very small (especially when compared to the public dose limit of 100 mrem/yr.)

Furthermore, the Unrestricted Release alternative assumes that all the material will be recycled - this does not realistic, in fact, it is overly conservative. Also, the transportation traveled under the Unrestricted Release alternative appears to be greatly exaggerated. Much unrestricted releases will end up at the local transfer station and / or municipal landfills which are much closer in distance than a Subtitle D landfill. Using the above two assumptions appears to be a biased attempt to raise the collective doses to the Unrestricted Release alternative, thus removing it from consideration.

Furthermore, the concern that "any dose increases cancer risk," though valid in the LNT-

sphere of regulation formulation, it is not valid according to the HPS, ICRP, NRCP, IAEA, and this DGEIS; one mrem/yr is negligible. And, again, one mrem/yr from Unrestricted Release is equivalent to Limited Disposition's one mrem/yr, etc.; this DGEIS cannot simultaneously cite that one mrem/yr from one Alternative (e.g., Unrestricted Releases, Conditional Use, etc.) poses more risk (i.e., dose) than another Alternative.

The concern that Unrestricted Releases would not be accurately measured and tracked is moot - tracking could be addressed in the DGEIS and measurements are addressed during inspections. But, the point of the DGEIS is to release solid materials from regulatory control because the risk from the material is negligible; hence, material tracking is not a disposition prerequisite nor is confirmatory measurements out of the question.

Thus, it appears that the DGEIS is not Process Driven, but rather it is public perception driven.

#### Pages xviii & xxiv, Socio-Economic Issues, DGEIS

The steel and concrete industry's concerns appear to be socio-economic issues, which are not addressed, according to the DGEIS (page xviii, line 13). But, then later (page xxiv, lines 37-39), it appears that some socio-economics issues were qualitatively addressed. Thus, it appears that socio-economic issues are not addressed evenly across all the alternatives. Socio-economic issues either need to be analyzed in full (detail) or they leave out the Metal and Concrete industry concerns.

In addition, the above industries already screen-out and do not accept radioactive contaminated materials. It appears this will continue, regardless of this DGEIS and associated rule-making. Thus, it does not make sense that "consumers could choose not to purchase items made from material recycled from licensed facilities," when the industries will not be accepting radioactive contaminated material in the first place. Not accepting the material is an industry business decision which should not affect this DGEIS. These industries are firm on this issue.

The above industries may soften their stance if the NRC worked with the EPA to start an initiative, under Section 6602 (b) of the Pollution Prevention Act of 1990, to purchase and use radioactive contaminated steel (i.e., inadvertent source melt) and concrete in the construction and retrofitting of government buildings. If this never materializes or fails, the material can be sold to another country that will accept it, under IAEA RS-G-1.7.

#### Page xix & xx, Transportation, DGEIS

The average number of miles to the closest Subtitle D landfill is stated as 100 miles. But this assumes that all these facilities will accept the material and that licensee will always choose the closest landfill - these are not good assumptions. It's interesting to note that

the DGEIS takes into account the LLW "foreseeable future actions" landscape - only the Utah will be available - but does not take into account the "foreseeable future actions" of the Subtitle D landfills (i.e., the number and locations of landfills that will accept "solid material.") This analysis needs to be performed and may have a cascading effect on the number of fatalities; the cost/benefit analysis; and, result in the Subtitle D landfills requiring an "Irreversible and Irretrievable Commitment of Resources" analysis (i.e., Subtitle D capacity used up.) In addition, the siting of new Subtitle D landfills may become difficult because finding publically acceptable locations may become burdensome - this needs to be included in the cost / benefit analysis of the Alternatives.

## Analysis, DGEIS

In the comparison of the five Alternatives and their impacts, it appears that the concentrations and quantities used were not the same. Invariable, the Limited Disposition Alternative employs the use of IAEA RS-G-1.7 concentration limit's recommendations while the other Alternative employ scenario specific concentration limits; this does not appear appropriate. A table should be developed to show comparison of the impacts if all the alternatives used IAEA RS-G-1.7.

## Page, xxiv - xxvi, Preliminary Recommendations, DGEIS

The choice of using IAEA RS-G-1.7 values for the Limited Disposition Alternative is not inconsistent with its scope; is unjustified overly conservative; will not result in efficiency for licensees and regulators; and may result in increased costs to businesses in the United States as noted below:

1. Create inconsistency with international guidelines, because the U.S. will use IAEA RS-G-1.7 values for Limited Disposition while the rest of the world will use the values for Unrestricted Release. Thus, imported materials (e.g., steel) inadvertently imported - containing IAEA RS-G-1.7 concentrations - into the U.S. will have to be disposed in Subtitle D landfill, while the rest of the world will be making products (most likely non-consumer products)
2. Nullifies the DGEIS, NRCP, ICRP, HPS, IAEA recommendation that 1 mrem/yr is negligible because burying concentrations of solid materials at IAEA RS-G-1.7 concentrations will result in doses much less than 1 mrem/yr. This sends a bad message to licensees and the public - that 1 mrem/yr is really not ok. The NRC needs to meet this head-on because these types of dispositions have been occurring for decades under current NRC guidelines. Burial of solid materials using IAEA values is a step backwards from what is the NRC has done for years and most licensees will opt for case-by-case basis (See below.)
3. Ensure that licensees will still opt for applying for the time and resource consuming case-by-case application process because these case-by-case applications will invariably result

in larger concentrations and quantities eligible for disposition. Financially, a licensee will spend a little money up front to formulate and submit a 10 CFR 20.2002 application to save a lot of money in the end (i.e., disposal costs). Thus, generic Limited Disposition using IAEA values will not result in a more efficient licensing actions than current method because no licensee will take advantage of it. (Note that the NRC has been doing these for years under 10 CFR 20.2002 and frequently apply a dose criterions greater than 1 mrem/yr.)

4. Increase the cost of doing business internationally. International stakeholder (i.e., compatibility associated problems) cost/benefit analysis needs to be assessed due to their inability to import and make items containing small concentrations of radioactive material.

### Conclusion

The NRC needs to better meeting the public perceptions head-on that radioactive material have been released to public, landfills and for recycling for years under RG 1.86 and NUREG 1556. Many anti-nuclear entities have framed this issue as “de-regulating” radioactive contaminated material, when in fact, this effort is just to generically codify what has been in effect for years. The NRC needs to better frame this issue.

We feel that there should be, in the least, a 1 mrem/yr dose criterion codified in the regulations; hence this effort should be continued. But, more time is needed to allow the supporting reports and documents to be digested and accepted by the public, industry and the Agreement States (AS); to either transform the rulemaking to support the current Proposed Action of the DGEIS or to change the Proposed Action to reflect the data and analysis of the DGEIS; to make the Proposed Actions consistent with current and future NRC regulations; and, be in harmony with international standards.

The latter two points could be solved by allowing the proposed Limited Dispositions alternative to use the gas and liquids dose criterion for NPP of 3 to 5 mrem/yr, based on NUREG 1640, and allow Unrestricted Releases, based on IAEA RS-G-1.7, of solid materials that are not likely to be recycled into consumer products.

Overall, the DGEIS still suffers from the abrupt change in focus from Unrestricted Use to the Limited Disposition Alternative. Also, the staff's preliminary recommendations are not well supported because the DGEIS is missing data and/or analysis, and relies too heavily on public perception.

Respectively Submitted,

Michael Whalen, CHP  
OAS & CRCPD Cooperating Agency

Representative  
Massachusetts Radiation Control Program

cc    CRCPD  
      OAS

**Letters from Agreement States**

# TEXAS DEPARTMENT OF STATE HEALTH SERVICES

EDUARDO J. SANCHEZ, M.D., M.P.H.  
COMMISSIONER

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February 23, 2005

Ms. Kim Karcagi  
Office of State and Tribal Programs  
U.S. Nuclear Regulatory Commission  
Washington, D.C. 20555-0001

Dear Ms. Karcagi:

The agency provides the following comments concerning draft proposed Title 10, Code of Federal Regulations, Part 20, relating to Radiological Criteria for Controlling the Disposition of Solid Materials (STP-05-008).

1. The compatibility level for Agreement States isn't set yet; therefore, we have no comments regarding compatibility at this time.
2. It appears that the 1 mrem/yr standard that NRC is using to release material (to a limited number of disposition options) is well below the level necessary to protect public health and the environment. Early input has shown that "there is no technical reason for this rule" and that it is being written with such a low release standard to appease the steel industry's concern about public perception.
3. The specifics of what the materials become when NRC releases them needs to be addressed. For example, do they become EPA-regulated solid waste? If so, at what point? How will enforcement work (which agency does it; do they regulate the disposal facility or the NRC licensee) if something goes wrong after the material is no longer regulated under AEA?
4. The draft proposed rule doesn't include the ability to survey material for non-detectable activity to be released.
5. The Navy has indicated a strong concern that they'll no longer be able to cut ships up, survey the parts, put them in to a radioactive pile and a non radioactive pile and sell the non radioactive pile for recycle as scrap. They've already decommissioned about 114 vessels this way and have another 100 or so to do. The agency agrees that this could be a potential issue.
6. Early input has shown that using the concentration is easier to comply with the amendment rather than having to do modeling to meet the dose based standards.

Ms. Kim Karcagi  
United States Nuclear Regulatory Commission  
February 23, 2005  
Page 2

7. The DOE has indicated that the amendment would be taking away the option of declaring something clean and then recycling. They felt that it made doing pollution prevention efforts on materials from within a restricted area impossible. In Texas, historically we have allowed licensees to decontaminate to specified limits in order to release for unrestricted use. The agency is concerned that this amendment could eliminate this option. For example, subcontractors wouldn't be able to bring equipment in, do their job, survey and/or decontaminate and then take their equipment to the next job site.
8. Early input has shown that this amendment would encourage folks to stockpile low-contaminated material until license termination at which point the 25 mrem/yr standard would apply.

If you have any questions, please feel free to contact me or Monica Perez at 512-834-6688 or [Cindy.Cardwell@dshs.state.tx.us](mailto:Cindy.Cardwell@dshs.state.tx.us) or [Monica.Perez@dshs.state.tx.us](mailto:Monica.Perez@dshs.state.tx.us).

Sincerely,

Cynthia C. Cardwell, Manager  
Radiation Policy/Standards/Quality Assurance Group  
Department of State Health Services

**WASHINGTON STATE (WDOH) COMMENTS ON NRC PROPOSED RULE:  
RADIOLOGICAL CRITERIA FOR CONTROLLING THE DISPOSITION OF SOLID  
MATERIALS (STP-05-008)**

- The proposed rule pertains to residual radioactivity resulting from licensed operations AND which originate in restricted or impacted areas of NRC (and, as a matter of compatibility, Agreement State) licensed facilities. It does not directly apply to US DOE or DOD facilities although ultimately it will affect them. For example, the Navy recycles thousands of tons of metal from its naval ship decommissioning activities.

The NRC proposal will restrict solid waste disposal to only certain limited disposition paths. The current practice of releasing solid material from licensed facilities based on survey instrument capabilities will not be allowed. There are no provisions for releasing materials that are arguably “not radioactive” yet must be disposed via one of the “limited allowed disposition paths” simply because they were in a restricted area or in the newly defined “impacted area”. This is despite the acknowledgement that NRC’s current approach “is sufficiently protective of public health that it does not need immediate revamping”.

The proposed regulation makes all release criteria for NRC licensee effluents and wastes dose based. The proposed dose criterion is set at 1 mRem/yr, 1/100 of the public doses limit in NRC’s 10CFR20 Part 20. The 1 mRem/yr dose criterion is smaller than standards and design objectives set by NRC, EPA and WDOH for other specific media being released from licensed facilities. The economic consequences of this more restrictive dose criterion are not adequately explained.

Agency	Task	Limit (mRem/yr)	Regulation
NRC	Solid materials	1	10CFR20 (proposed)
NRC	Liquid effluent from power reactors	3	10CFR50 App I
EPA	Drinking Water	4	40CFR141
NRC	Gaseous effluent from power reactors	5	10CFR50 App I
EPA	Clean Air	10	40CFR61
WDOH	Hanford Guide for Radiological Cleanup	15	WDOH-320-015
NRC	License termination of facilities	25	10CFR20.1403
NRC	Liquid, air, sewer effluent release	50	10CFR20TableII
NRC	Public exposure	100	10CFR20

The NRC believes there is ample EPA/State regulated landfill capacity to accept the material that have residual radioactivity that is below the 1mrem/yr criteria. That assume these landfills will accept the material. It is clear that they do not have to. The consequences of not having this space available are not adequately discussed. It is possible that the volume of bulk metal, soil and soil-like material could be substantial and disposal into a landfill may not be feasible.

While the NRC proposes to allow the licensee to petition for alternate disposal under certain conditions, the NRC also notes that recyclers have expressed some doubt about the ability to keep this recycled material separate as required. There is further concern that the case specific approach for soil and soil-like materials would be hampered by the wide variability of soil behavior and general soil uses. Acceptable radionuclide concentrations are not necessarily conservative for the range of possible dispositions of soil.

We believe the following added burdens are not adequately addressed:

1. Licensees who must maintain records for disposition of re-use materials have little or no control over what happens to materials deposited in the landfill or once delivered to a recycler. Our auditing adherence to the new rule will be performance-based as far as the licensee is concerned but will NRC and Agreement State staff be inspecting landfills and recyclers to actually confirm that the rule is met.
2. Licensees, regulators, landfill operators and recyclers will need adequate instrumentation that allows specific radionuclide assessments. While the disposal criteria is dose-based (1 mrem/yr), the disposal really requires pCi/g activity determinations. Landfill operators and recyclers should also have adequately trained staff for protection of the public health and worker safety.
3. Licensees will need some sort of working agreement with landfill operators that the slightly contaminated waste that is disposed within the landfill will not leave the landfill and end up recycled. This should not be a problem for RCRA C landfills but there is some responsibility of the licensee to make sure their waste stays put.
4. Licensees may find that landfill operators refuse to accept waste. There is no obligation that landfills accept waste.
5. Licensees that want to dispose of bulk metal are likewise burdened in that they will have to have some assurance that the metal will not be made into consumer goods.
6. Recyclers will need to make sure that no material with residual contamination finds its way into new consumer products. Recycling streams will have to be kept separate. We believe a recycler of "residually contaminated radioactive material" will need to be licensed.
7. Licensees that want to dispose of soil and soil-like materials need a case specific review if the material is to go anywhere but into a RCRA C landfill. The dose-criterion remains 1 mrem/yr in order for materials to be considered for disposal. The licensee is at the mercy of the dose assessment scenario when applying for alternate disposal. For instance, our Hanford Cleanup guide uses a rural-residential scenario and has an acceptance limit of 15 mrem/yr. For many radionuclides, the concentration of residual radionuclide concentration allowed using the Hanford Guide is more restrictive than the concentration given in the proposed rule when both sets of concentrations are scaled to 1 mrem/yr. This disconnect illustrates the importance of scenario development.

8. Regulators are going to need to make assessments on whether material with residual contamination was appropriately disposed of. There are no mandatory reports. The assessments are performance-based and may require additional monitoring at recyclers and re-use endpoints. Further, regulators are going to have to determine that no treated process materials were disposed under this rule.
9. Regulatory Guide 1.86 criteria (or similar criteria) has been successfully used for decades by industry and regulatory agencies, for unrestricted release of essentially non-radioactive materials presenting minimal or no exposure risk. Both public & licensee confidence in reasonable radiation safety regulations are essential. We must protect health & safety without unnecessary and imbalanced regulatory burden caused by insisting that non-radioactive items be disposed as radioactive waste.
10. The 1 millirem per year dose criteria is unclear; is that 1 mrem total per licensee per year for all wastes, or is it per item (per box, per drum, per truckload, per landfill, per day)?
11. What effect does this proposed rule have on decay-in-storage? This material was most likely from a restricted area. If a survey says the material is indistinguishable from background can it still be considered non-radioactive and disposed as currently done? There may be still more than ~ 0 dpm in the waste container per activity decay calculations.

Bottom line, our concern is that despite all the years that this has been studied by NRC, it appears that there are still significant concerns that have not been fully addressed. We should not rush to implement even a modest regulatory ratcheting when the full extent of the burden is unknown. As previously noted, the current standards and regulations "is sufficiently protective of public health". Above all, we need to keep in mind that "the potential radiological hazards of these materials are so low that their exemption from continued regulation is deemed warranted and because funds unnecessarily spent on controlling trivial risks in one sector are not available for application to the control of 'real' risks elsewhere."



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February 23, 2005

Kim Karcagi  
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**RE: Combined Rulemaking & DGEIS comments**

Dear Kim:

A lot of good work has been done on the draft Generic Environmental Impact Statement (DGEIS) and concurrent Rule-making. Please find attached comments that may be useful in finalizing the DGEIS and rule-making.

As they currently read, the DGEIS and the draft rule-making are premature; inconsistent with other NRC regulations; lacks harmonization with international standards; and are not scientifically justified. Hence, more time is needed to transform the DGEIS and concurrent rule-making to support the current Proposed Action or to change the Proposed Action to reflect the data and analysis.

Premature

It is not appropriate to put forward a rule-making until all the supporting research and reports have been published and peer-reviewed. The entire rule-making may collapse without prior public acceptance many of the supporting documents, such as:

A. "Collective Doses Associated with Clearance of Material From NRC/Agreement State-

Licensed Facilities” by SC & A, Inc. Last available as a draft in September 2003.

- B. NUREG 1812, “Generic Environmental Impact Statement for Controlling the Disposition of Solid Materials” (GEIS). Last available as a draft in February 2005.
- C. Documents/reports that support IAEA RS-G-1.7, “Application of the Concepts of Exclusion, Exemption and Clearance,” August 2004.

At this time it is not possible to review the draft rule-making without the reviewing the GEIS and the recommendations made therein; the GEIS-dependent document of the SC & A, Inc.; and, a determination that documentation publication for IAEA RS-G 1.7 will be transparent and acceptable. Hence, the NRC needs to slow down the Rule Making effort until all their ducks are in a row.

#### Inconsistent with other NRC regulations

The Proposed Action will allow solid materials which have no, or very small amounts of, residual radioactivity resulting from licensed operations - this is a prospective ‘clean’ standard. This prospective standard effort will result in tables of radionuclide concentrations a licensee may use to intentionally release solid materials to the environment and/or public and have the solid material no longer be under regulatory control. Additionally, it is understood that by its very nature, prospective standards are more restrictive than the retrospective ‘clean’ standards (i.e., License Termination (LT), cleanup after a dirty bomb, etc.); hence, the proposed prospective dose criterion is 1 mrem/yr while the LT cleanup standard is 25 mrem/yr.

But, currently, the NRC does not apply these standards evenly.

Currently, licensees wishing to bury waste on-site need to apply to the NRC under 10 CFR 20.2002 and adhere to a 1 mrem/yr standard. But, as soon as the licensee initiates termination and starts decommissioning, waste can be buried on-site using the retrospective standard of 25 mrem/yr. This subtle switch is not congruent

NRC’s unofficial policy of applying the retrospective ‘clean’ standard when allowing on-site burial of contaminated solid materials (e.g., concrete, etc.) needs to be changed. All intentional burial (i.e., dispositions) of radioactive material must be held to the same prospective standard, not only when the NRC feels like it. Thus, the scope of the Proposed Action needs to be changed to include intentional dispositions of solid materials on-site as well as off-site.

Furthermore, because all NPP’s are near body of waters, they should not be allowed to apply the generic disposition limits of IAEA RS-G 1.7 because the scenario used in NUREG 1640 for concrete disposition assumes the EPA input parameters need to cite a subtitle D landfill (i.e., “Input Parameter Values for the Industrial D Tier 1 Tool.”) But, NPP’s do not have liners, are not a Subtitle D facility, and could never be classified as such. Hence, all on-site burials will be needed to be evaluated on a case-by-case basis.

With regards to inconsistency application of the LT rule (LTR) and Limited Disposition Standard (LDS), the NRC needs to:

- A. demonstrate that potential materials (e.g., soil, rubble) that could be removed from a site after license termination will not result in doses greater than 1 mrem/yr,
- B. better define what the LTR includes. We find it hard to swallow that intentionally disposing waste material (i.e., rubble) on-site was part of the LTR. The LTR is a retrospective clean up standard while disposal of contaminated waste material is to be held to a prospective clean standard (i.e., intentionally introduced into the environment and/or public), and,
- C. restrict rubbleization and burial on-site of radioactive contaminated solid materials (especially concrete) to the LDS requirements. Note that, most NPP sites could never qualify as an RCRA subtitle D landfill because they sit close to rivers, lakes and oceans, whereby the distance to the groundwater is relatively small and the leach rates would be too great because of lack of a liner or equivalent. Hence, site specific dose modeling are to be required whereby the dose from waste (i.e., radioactive contaminated rubble) be held to the prospective standard, thus, constitute 1 mrem/yr of the 25 mrem/yr allowed under LTR.

Page 1-7, line 31, of the DGEIS states that "Solid materials remaining on-site at facilities after license termination are subject to existing NRC regulations that would not be changed by the Proposed Actions." What regulations are meant here? After license termination, the next tenant may dig up and use the contaminated solid materials as they see fit. This is an unforeseen problem, because license termination was never intended to include prospectively disposed waste. License termination was for land and structures - intact whole building and landscape (i.e., soils).

It is unclear why the disposition of solid material's dose criterion is proposed to be less than the gaseous and liquid effluent standards of the NRC, and the drinking water standard of the EPA. It appears the justification is that a smaller dose criterion is better. If so, then this is the time to harmonize these prospective release standards all down to one mrem/yr, or time to better explain why one mrem/yr for disposition of solid materials is ok while 3 mrem/yr from liquid effluents is equally ok, etc.

Lacks Harmonization with International Standards &  
Not Scientifically Justifiable (and other Notes) Per the DGEIS

Many of the following comments refer to the DGEIS, but similar statements are in the Rulemaking also. As noted above without an acceptable DGEIS, the rule-making should not occur.

Page xiv, Purpose and Scope, Line 28, DGEIS

It is unclear why the Proposed Action does not include guidance for 'surficially' contaminated materials. Especially, since the NRC current guidance is a surficially contamination guidance (i.e., Reg. Guide 1.86.); and NUREG 1640 has methods for converting volumetrical limits into surficial limits. Furthermore, when surficial limits are shown, they are only guidance (NUREG 1813) while the volumetrical limits are in regulations. It needs to be explained why surficial limits are in guidance while volumetric limits are proposed to be in the regulations.

Page xvii, Alternatives Eliminated from Detailed Study, Line 28, DGEIS

1. States that Conditional Uses, such as, "concrete use in road fill" were eliminated from detailed study, but the preliminary recommendation includes "concrete use in road beds." What's the difference? Is this a misprint? Furthermore, it is unclear why "concrete use in road beds" is included in the preliminary recommendations, because the concrete may ultimately be reused and/or recycled into unforeseen consumer products, which should eliminate it from consideration.
2. Also troubling about this section, is that the entire alternative of Conditional Use was eliminated from detailed study because the material may ultimately be reused and/or recycled into products not authorized under the Conditional Use Alternative (i.e., unforeseen), and the Conditional Use Alternative would allow a greater amount of activity than the Limited Disposition Alternative, which are based on Unrestricted Use Alternative (based on 1 mrem/yr.)

Neither of the above two explanations is acceptable. First, the Conditional Use dose scenarios should take into account the worst thing that could solid material could be re-used for and/or recycled into. Logic dictates that whatever this secondary item and/or use will be, it will result in a smaller dose than the original material especially if it is recycled. Secondly, allowing more activity to be released under the Conditional Use Alternative, some would argue, is a good thing. If more activity available for release is not desired, then why was the Conditional Use Alternative not assigned the values of the Unrestricted Use Alternative (based on 1 mrem/yr for normalization purposes)?

Hence, it is unclear why a generic process with generic release concentrations could not be formulated. All the factors used to eliminate the Alternative Use Alternative need to be stated in this section as well as section 2.5.

Page xvi, Limited Dispositions, DGEIS

1. The reasons for the use of IAEA RS-G 1.7 concentrations limits for Limited Dispositions supports the use of these values for the other Alternative scenarios, as noted above, such as Conditional Use and the Unrestricted Release Alternatives. Because, as stated on lines 32-35, "these materials could end up in dispositions, including reuse and recycling into

other products, given that the licensees [will] have no administrative controls over materials once they leave the site.”; this reason is used to disqualify the Conditional Use Alternative and assisted on marginalizing the Unrestricted Use Alternative.

If the use of IAEA RG-S-1.7 values is ok for Limited Dispositions, because the material may end up in consumer products, then these values (or equivalent values of NUREG 1640) are also acceptable for all the Alternatives. In other words, why is 1 mrem/yr from Limited Dispositions treated differently than 1 mrem/yr from Unrestricted Releases or 1 mrem/yr from Conditional Uses? One mrem/yr is one mrem/yr is one mrem/yr, regardless of where it comes from. Or, more to the point, why is the DGEIS selecting an Alternative based upon public perceptions?

#### Page xxiv, Staff Assessment & Preliminary Recommendations, DGEIS

All the reasons against unrestricted releases (page xxiv, lines 33-36) are not valid. Concerns that risks associated with unrestricted releases are avoidable and involuntary, and potential of doses from multiple sources is true for all the Alternatives. Moreover, section 3.8, on Cumulative Impacts states that “the likelihood of . . . multiple concurrent exposures becomes vanishingly small as the number of potential concurrent scenarios increases.” This correctly implies that doses from multiple sources is a very small (especially when compared to the public dose limit of 100 mrem/yr.)

Furthermore, the concern that “any dose increases cancer risk,” though valid in the LNT-sphere of regulation formulation, it is not valid according to the HPS, ICRP, NRC, IAEA, and this DGEIS; one mrem/yr is negligible. And, again, one mrem/yr from Unrestricted Release is equivalent to Limited Disposition’s one mrem/yr, etc.; this DGEIS cannot simultaneously cite that one mrem/yr from one Alternative (e.g., Unrestricted Releases, Conditional Use, etc.) poses more risk (i.e., dose) than another Alternative.

The concern that Unrestricted Releases would not be accurately measured and tracked is moot - tracking could be addressed in the DGEIS and measurements are addressed during inspections. But, the point of the DGEIS is to release solid materials from regulatory control because the risk from the material is negligible; hence, material tracking is not a disposition prerequisite nor is confirmatory measurements out of the question.

Thus, it appears that the DGEIS is not Process Driven, but rather it is public perception driven.

#### Pages xviii & xxiv, Socio-Economic Issues, DGEIS

The steel and concrete industry’s concerns appear to be socio-economic issues, which are not addressed, according to the DGEIS (page xviii, line 13). But, then later (page xxiv, lines 37-39), it appears that some socio-economics issues were qualitatively addressed.

Thus, it appears that socio-economic issues are not addressed evenly across all the alternatives. Socio-economic issues either need to be analyzed in full (detail) or they leave out the Metal and Concrete industry concerns.

In addition, the above industries already screen-out and do not accept radioactive contaminated materials. It appears this will continue, regardless of this DGEIS and associated rule-making. Thus, it does not make sense that "consumers could choose not to purchase items made from material recycled from licensed facilities," when the industries will not be accepting radioactive contaminated material in the first place. Not accepting the material is an industry business decision which should not affect this DGEIS. These industries are firm on this issue.

The above industries may soften their stance if the NRC worked with the EPA to start an initiative, under Section 6602 (b) of the Pollution Prevention Act of 1990, to purchase and use radioactive contaminated steel (i.e., inadvertent source melt) and concrete in the construction and retrofitting of government buildings. If this never materializes or fails, the material can be sold to another country that will accept it, under IAEA RG-S-1.7.

Page xix & xx, Transportation, DGEIS

The average number of miles to the closest Subtitle D landfill is stated as 100 miles. But this assumes that all these facilities will accept the material and that licensee will always choose the closest landfill - these are not good assumptions. It's interesting to note that the DGEIS takes into account the LLW "foreseeable future actions" landscape - only the Utah will be available - but does not take into account the "foreseeable future actions" of the Subtitle D landfills (i.e., the number and locations of landfills that will accept "solid material.") This analysis needs to be performed and may have a cascading effect on the number of fatalities; the cost/benefit analysis; and, result in the Subtitle D landfills requiring an "Irreversible and Irrecoverable Commitment of Resources" analysis (i.e., Subtitle D capacity used up.) In addition, the siting of new Subtitle D landfills may become difficult because finding publically acceptable locations may become burdensome - this needs to be included in the cost / benefit analysis of the Alternatives.

Analysis, DGEIS

In the comparison of the five Alternatives and their impacts, it appears that the concentrations and quantities used were not the same. Invariable, the Limited Disposition Alternative employs the use of IAEA RG-S-1.7 concentration limit's recommendations while the other Alternative employ scenario specific concentration limits; this does not appear appropriate. A table should be developed to show comparison of the impacts if all the alternatives used IAEA RG-S-1.7.

Page, xxiv - xxvi, Preliminary Recommendations, DGEIS

The chose of using IAEA RG-S-7 values for the Limited Disposition Alternative is not justified, because it will:

1. Create inconsistency with international guidelines, because the U.S. will use IAEA RG-S-1.7 values for Limited Disposition while the rest of the world will use the values for Unrestricted Release. Undoubtably this will cause international trade and transportation issues similar to the days before the U.S. finally adopted the IAEA transportation guidelines.
2. Nullifies the DGEIS, NRCP, ICRP, HPS, IAEA recommendation that 1 mrem/yr is negligible because burying concentrations of solid materials at IAEA RG-S-1.7 concentrations will result in doses much less than 1 mrem/yr. This sends a bad message to licensees and the public.
3. Ensure that licensees will still opt for applying for the time and resource consuming case-specific application process because these applications will result in larger concentrations and quantities to be eligible for disposition.
4. Increase the cost of doing business internationally. International stakeholder (i.e., compatibility associated problems) cost/benefit analysis needs to be assessed.

Overall, the DGEIS (and the draft Rulemaking) still suffer from the abrupt change in focus from Unrestricted Use to the Limited Disposition Alternative. Also, the staff's preliminary recommendations are not well supported because the DGEIS is missing data and/or analysis, and relies too heavily on public perception.

If you have any questions regarding this letter, please call me at (617) 427-2944 x2020.

Sincerely,



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