Review of Processes for the Release of DOE Real and Non-Real Property for Reuse and Recycle
Argonne National Laboratory

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Review of Processes for the Release of DOE Real and Non-Real Property for Reuse and Recycle

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Environmental Assessment Division,
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November 1997

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<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AEA</td>
<td>Atomic Energy Act</td>
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<tr>
<td>AEC</td>
<td>Atomic Energy Commission</td>
</tr>
<tr>
<td>ALARA</td>
<td>as low as reasonably achievable</td>
</tr>
<tr>
<td>ANL</td>
<td>Argonne National Laboratory</td>
</tr>
<tr>
<td>ANL-E</td>
<td>Argonne National Laboratory-East</td>
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<tr>
<td>ANL-W</td>
<td>Argonne National Laboratory-West</td>
</tr>
<tr>
<td>ARAR</td>
<td>applicable or relevant and appropriate requirement</td>
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<tr>
<td>ARCL</td>
<td>allowable residual contamination level</td>
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<td>BRC</td>
<td>below regulatory concern</td>
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<tr>
<td>CAA</td>
<td>Clean Air Act</td>
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<tr>
<td>CEC</td>
<td>Commission of the European Communities</td>
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<td>CERCLA</td>
<td>Comprehensive Environmental Response, Compensation, and Liability Act</td>
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<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
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<tr>
<td>D.C.</td>
<td>District of Columbia</td>
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<tr>
<td>DCGLs</td>
<td>derived concentration guideline levels</td>
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<tr>
<td>D&amp;D</td>
<td>decontamination and decommissioning</td>
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<tr>
<td>DEAR</td>
<td>DOE Acquisition Regulations</td>
</tr>
<tr>
<td>DHS</td>
<td>Department of Health Services (California)</td>
</tr>
<tr>
<td>DOC</td>
<td>decommissioning operations contractor</td>
</tr>
<tr>
<td>DOE</td>
<td>U.S. Department of Energy</td>
</tr>
<tr>
<td>EA</td>
<td>environmental assessment</td>
</tr>
<tr>
<td>EBWR</td>
<td>Experimental Boiling Water Reactor</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>EM</td>
<td>Office of Environmental Management (DOE)</td>
</tr>
<tr>
<td>EPA</td>
<td>U.S. Environmental Protection Agency</td>
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<tr>
<td>FEMP</td>
<td>Fernald Environmental Management Project</td>
</tr>
<tr>
<td>FONSI</td>
<td>Finding of No Significant Impact</td>
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<tr>
<td>FPMR</td>
<td>Federal Property Management Regulations</td>
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<tr>
<td>FR</td>
<td>Federal Register</td>
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<td>FRG</td>
<td>Federal Radiation Protection Guidance</td>
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<tr>
<td>FUSRAP</td>
<td>Formerly Utilized Sites Remedial Action Program</td>
</tr>
<tr>
<td>GAO</td>
<td>U.S. General Accounting Office</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<td>--------------</td>
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<tr>
<td>HWCTR</td>
<td>Heavy Water Components Test Reactor</td>
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<tr>
<td>HSWA</td>
<td>Hazardous and Solid Waste Amendments of 1984</td>
</tr>
<tr>
<td>IAEA</td>
<td>International Atomic Energy Agency</td>
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<td>ICRP</td>
<td>International Commission on Radiological Protection</td>
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<td>INEEL</td>
<td>Idaho National Engineering and Environmental Laboratory</td>
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<tr>
<td>LLRWPAAn</td>
<td>Low-Level Radioactive Waste Policy Amendments Act</td>
</tr>
<tr>
<td>MAVT</td>
<td>multiattribute value theory</td>
</tr>
<tr>
<td>MTCA</td>
<td>Model Toxics Control Act (Washington)</td>
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<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>NCP</td>
<td>National Oil and Hazardous Substances Contingency Plan</td>
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<tr>
<td>NCRP</td>
<td>National Council on Radiation Protection</td>
</tr>
<tr>
<td>NEPA</td>
<td>National Environmental Policy Act</td>
</tr>
<tr>
<td>NESHAPs</td>
<td>National Emission Standards for Hazardous Air Pollutants</td>
</tr>
<tr>
<td>NPL</td>
<td>National Priorities List</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for Economic Cooperation and Development</td>
</tr>
<tr>
<td>OEPA</td>
<td>Ohio Environmental Protection Agency</td>
</tr>
<tr>
<td>ORNL</td>
<td>Oak Ridge National Laboratory</td>
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<tr>
<td>PMR</td>
<td>Property Management Regulations (DOE)</td>
</tr>
<tr>
<td>PNL</td>
<td>Pacific Northwest Laboratory (now Pacific Northwest National Laboratory)</td>
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<tr>
<td>PPL</td>
<td>Personal Property Letter (DOE)</td>
</tr>
<tr>
<td>PPPL</td>
<td>Princeton Plasma Physics Laboratory</td>
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<tr>
<td>RADWG</td>
<td>R&amp;D Laboratory Working Group (DOE)</td>
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<tr>
<td>RCRA</td>
<td>Resource Conservation and Recovery Act</td>
</tr>
<tr>
<td>RCW</td>
<td>Revised Code of Washington</td>
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<tr>
<td>RESRAD</td>
<td>residual radioactive material guidelines computer code</td>
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<tr>
<td>ROD</td>
<td>record of decision</td>
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<tr>
<td>RSM</td>
<td>radioactive scrap metal</td>
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<tr>
<td>SAPS</td>
<td>Shippingport Atomic Power Station</td>
</tr>
<tr>
<td>SDWA</td>
<td>Safe Drinking Water Act</td>
</tr>
<tr>
<td>SEG</td>
<td>Scientific Ecology Group, Inc.</td>
</tr>
<tr>
<td>SFMP</td>
<td>Surplus Facilities Management Program</td>
</tr>
<tr>
<td>SRS</td>
<td>Savannah River Site</td>
</tr>
<tr>
<td>TEDE</td>
<td>total effective dose equivalent</td>
</tr>
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</table>
UMTRA  Uranium Mill Tailings Remedial Action (Program)
UMTRCA  Uranium Mill Tailings Radiation Control Act
U.S.  United States
USA  United States of America
USNRC  U.S. Nuclear Regulatory Commission
WAC  Washington Administrative Code
WL  working level
WM '97  Waste Management '97 Conference
1

REVIEW OF PROCESSES FOR THE RELEASE OF
DOE REAL AND NON-REAL PROPERTY
FOR REUSE AND RECYCLE

by

N.L. Ranek, S. Kamboj, J. Hensley, S.Y. Chen, and D. Blunt

ABSTRACT

This report summarizes the underlying historical and regulatory framework supporting the concept of authorizing release for restricted or unrestricted reuse or recycle of real and non-real U.S. Department of Energy (DOE) properties containing residual radioactive material. Basic radiation protection principles as recommended by the International Commission on Radiological Protection are reviewed, and international initiatives to investigate radiological clearance criteria are reported. Applicable requirements of the U.S. Nuclear Regulatory Commission, the Environmental Protection Agency, DOE, and the State of Washington are discussed. Several processes that have been developed for establishing cleanup and release criteria for real and non-real DOE property containing residual radioactive material are presented. Examples of DOE real property for which radiological cleanup criteria were established to support unrestricted release are provided. Properties discussed include Formerly Utilized Sites Remedial Action Project sites, Uranium Mill Tailings Remedial Action Project sites, the Shippingport decommissioning project, the south-middle and south-east vaults in the 317 area at Argonne National Laboratory, the Heavy Water Components Test Reactor at DOE’s Savannah River Site, the Experimental Boiling Water Reactor at Argonne National Laboratory, and the Weldon Spring site. Some examples of non-real property for which DOE sites have established criteria to support unrestricted release are also furnished.

1 INTRODUCTION

1.1 Purpose and Scope

This report summarizes the underlying historical and regulatory framework supporting the concept of authorizing release for restricted or unrestricted reuse or recycle of real and non-real U.S. Department of Energy (DOE) properties containing residual radioactive material. Topics addressed include applicable and relevant existing and proposed regulatory requirements and guidelines, current DOE property release policies and initiatives, and selected site-specific practices involving release from DOE radiological control of property containing residual radioactive contamination. Issues associated with releasing materials for disposal (e.g., radioactively contaminated soil and solid wastes) are not discussed.
1.2 Background

Order DOE 5400.5, "Radiation Protection of the Public and Environment," as amended, which was first issued on February 8, 1990, establishes the standards and requirements currently applied to DOE activities with respect to protection of members of the public and the environment from radiation exposures. Included are a primary public dose limit of 100 mrem/yr from all sources and pathways and a requirement that case-specific, single-source public dose limits that are a fraction of the all-sources limit (e.g., 30 mrem/yr) be derived through a process designed to identify limits that are as low as reasonably achievable (ALARA). On March 25, 1993, DOE proposed to codify and clarify such standards and requirements, as they have been interpreted in DOE guidance.2

Under both DOE 5400.5 and Title 10 Code of Federal Regulations Part 834 (10 CFR Part 834), DOE's stated objective is to operate its facilities and conduct its activities so that radiation exposures to members of the public are maintained within established limits and releases of radioactivity to the environment are controlled through management of real and non-real property. In achieving this objective, DOE is committed to making deliberate efforts to further reduce exposures and releases in accordance with a process that seeks to make any such exposures or releases ALARA.

In addition to complying with the requirements of Order DOE 5400.5 and 10 CFR Part 834 after its promulgation, DOE and DOE contractors are required to comply with legally applicable rules and regulations of other federal, state, and local agencies when releasing property containing residual radioactive material.

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2 See Response to Questions and Clarification of Requirements and Processes: DOE 5400.5, Section II.5 and Chapter IV Implementation (Requirements Relating to Residual Radioactive Material), DOE Assistant Secretary for Environment, Safety and Health, Office of Environmental Policy and Assistance (EH-41) (Nov. 17, 1995).
At the federal level, the U.S. Environmental Protection Agency (EPA) has authority to promulgate such regulations under the Atomic Energy Act (AEA), the Clean Air Act (CAA), the Safe Drinking Water Act (SDWA), the Resource Conservation and Recovery Act (RCRA) as amended by the Hazardous and Solid Waste Amendments of 1984 (HSWA) and the Federal Facility Compliance Act of 1992, and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Also, the Atomic Energy Act grants the U.S. Nuclear Regulatory Commission (USNRC) licensing authority over some DOE facilities. For facilities that are not subject to USNRC licensing authority, it is DOE’s policy to implement radiation protection standards that are generally consistent with USNRC standards.\(^3\)

Chapter IV, “Residual Radioactive Material,” of Order DOE 5400.5 establishes radiological protection requirements applicable to cleaning up residual radioactive material at DOE sites and managing the resultant wastes and decontaminated real and non-real properties. In the months immediately after this Order was issued, there was a lack of adequate guidance and no clear process for implementing such requirements. Before 1991, this situation resulted in some releases to unlicensed persons of residual radioactive materials in quantities and types required by USNRC to be managed only by licensed persons. The occurrence of such events diminished public acceptance of proposed releases and discouraged DOE management from authorizing release limits pursuant to Chapter IV of DOE 5400.5. Nevertheless, an ever increasing number of DOE sites are undergoing deactivation and decommissioning, yielding decontaminated land, facilities, equipment, and materials that are excess or temporarily not needed and that could be safely and productively reused for a variety of purposes. Therefore, DOE and DOE contractor activities (e.g., the Hanford Site) are now actively seeking defensible, tested methodologies, processes, and procedures that will overcome past impediments to both real and non-real property releases. Section 2 summarizes the radiation protection principles and regulatory history that underlie this quest. Section 3 describes DOE policies and initiatives, as well as site-specific examples of processes and procedures for releasing properties containing residual radioactive material. Section 4 provides conclusions and recommendations based on the discussions in Sections 1, 2, and 3.

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\(^3\) DOE and USNRC are negotiating a Memorandum of Understanding that would initiate a pilot program involving USNRC regulation of three to six DOE facilities beginning in 1999. The results of the pilot program will be used to evaluate the feasibility of fully transferring oversight of DOE nuclear safety to the USNRC. [USNRC, Briefing by DOE and NRC on Regulatory Oversight of DOE Nuclear Facilities (Transcript of Meeting) (Sept. 19, 1997).]
2 REGULATORY CONCEPTS, REGULATIONS, AND GUIDELINES

2.1 Radiation Protection Principles and Regulatory Concepts

For many decades, radiation protection programs throughout the world have generally been based on recommendations of the International Commission on Radiological Protection (ICRP). The ICRP was first formed in 1928 and has been issuing and updating its recommendations since then. In the United States, recommendations of the National Council on Radiation Protection and Measurements (NCRP) and the EPA are also often consulted. ICRP, NCRP, and EPA recommendations promote a system of dose limitations defined by the following three basic radiation protection principles:

1. **Justification of Practice** – No practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriments it causes.

2. **Optimization of Protection** – In relationship to any particular source within a practice, the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received should be kept as low as reasonably achievable, economic and social factors being taken into account.

3. **Individual Dose and Risk Limits** – The exposure of individuals resulting from the combination of all the relevant practices should be subject to dose limits, or to some control of risk in the case of potential exposures. These controls are intended to ensure that no individual is exposed to radiation risks that are judged to be unacceptable from these practices in any circumstances.

Regarding individual dose limits that are consistent with these principles, the ICRP has most recently recommended that doses received by members of the public not exceed 100 mrem per year from all sources. Similarly, the NCRP has recommended that for continuous exposure, the effective dose to individual members of the public not exceed 100 mrem per year from all sources.

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4 The NCRP is a nonprofit corporation chartered by the U.S. 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.

5 Executive Order 10831, the Atomic Energy Act of 1954, as amended, and Reorganization Plan No. 3 of 1970, among other measures, assign EPA responsibility to advise the President with respect to radiation matters directly or indirectly affecting health. EPA fulfills this responsibility in part by publishing (from time to time) the Federal Radiation Protection Guidance for Exposure of the General Public.

man-made sources, other than medical sources. In 1994, EPA published draft federal radiation protection recommendations. One of the proposed recommendations urged that the combined radiation doses incurred in any single year from all sources of exposure (excluding medical and natural background) should normally not exceed 100 mrem.

The ICRP, NCRP, and EPA have also historically agreed that, although the standard for maximum dose to individual members of the public should not exceed 100 mrem per year from all non-medical, man-made sources combined (hereafter referred to as the “all-sources” standard), the appropriate standard for maximum dose received from any single source should be no more than a fraction of this amount to account for the possibility that an individual may be exposed to multiple sources. Regarding the size of the fraction:

1. ICRP has offered no numerical guidance, but has observed that cumulative exposures to individuals from multiple sources rarely approach 100 mrem per year because of the widespread use of source-related dose constraints.

2. NCRP has noted that no single source or set of sources under one person’s control should result in an individual’s being exposed to more than 25 mrem per year. The NCRP viewed compliance with this fraction as a simple alternative to investigating all man-made exposures and demonstrating that the 100 mrem per year limit applicable to all sources combined would be met.

3. EPA has offered no numerical guidance, but has indicated that “authorized limits” for individual sources or categories of sources should be developed at “some fraction” of the all-sources standard, and that ALARA principles should be applied.

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9 ICRP Publication No. 60, Section 5.5.1 (1991).


11 59 FR 66414, Recommendation No. 4 (Dec. 23, 1994).
Regarding the level of risk that would be acceptable as a result of the public’s exposure to radiation, EPA’s 1994 proposal made the following statements, which reflect the prevailing attitude in the United States:  

It is anticipated that the proposed (100 mrem all-sources standard, if applied in the manner recommended by EPA [i.e., modified on a case-by-case basis with source-specific authorized limits and application of ALARA principles]) ... would, under most circumstances, result in lifetime risks to the most exposed members of the public from man-made radiation in the environment of less than one in ten thousand.... EPA has, in a number of previous actions, concluded that a lifetime risk level no greater than about one in ten thousand provides an acceptable level of protection. These include the National Emission Standards for Hazardous Air Pollutants (NESHAPs), the National Primary Drinking Water Standards, and the Agency’s guidelines for site-specific risk management under the Comprehensive Environmental Response, Compensation, and Liability Act ("Superfund"). These recommendations propose that this level of protection is also appropriate for application in this Federal Radiation Protection Guidance for Exposure of the General Public and would be achieved through the cumulative application of these recommendations.

Another standard-setting body that has been active in radiation protection is the International Atomic Energy Agency (IAEA). In the early 1990s, the IAEA recognized a gap in the guidance offered by international agencies concerned with radiation protection in the area of chronic exposure to residual radioactivity in media and on structures (i.e., real property) at decommissioned nuclear facilities. The gap results from the fact that currently accepted radiation protection principles were developed primarily for application to releases of radioactivity from activities such as facility operations and emergencies. Hence, the principles are difficult to apply in decommissioning situations where public doses result from residual radioactivity rather than releases of radioactivity, and where such doses may be low and the costs to further reduce them may be high. As a result, an IAEA working group has been developing radiological principles over the last 3 years to be used specifically in making cleanup decisions at

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12 59 FR 66414 (Dec. 23, 1994).

13 The IAEA is a specialized agency within the United Nations system that serves as an intergovernmental forum for scientific and technical cooperation in the nuclear field. It also serves as the international inspectorate for the application of nuclear safeguards and verification measures covering civilian nuclear programs (see Internet address http://www.iaea.org).

decommissioning nuclear sites. In the near future, the working group expects to circulate for comment a draft guidance reflecting such principles.\footnote{At its December 1-5, 1997, meeting, the IAEA Waste Safety Standards Advisory Committee plans to review the Safety Guide on Decommissioning of Nuclear Power and Large Research Reactors before submitting it to Member States for review.}

Generally, the approach being suggested is based on the ICRP’s justification/optimization principles of radiation protection and also defines a maximum generic annual dose limit to constrain the residual dose following cleanup operations. The recommended maximum generic annual dose level for a site depends on the site’s anticipated future use. At a site where the annual dose is constrained to less than 1 mrem above background after cleanup, the IAEA working group characterizes the risk of not imposing controls as “trivial” in the vast majority of situations. At a site where the annual dose is constrained to 10 mrem above background after cleanup, the IAEA working group indicates that the risk of site release without controls is “acceptable” as part of a set of planned actions that would result in an overall net benefit to society. At a site where the annual dose is constrained to 100 mrem above background after cleanup, the IAEA working group suggests that the risk of site release without controls “might be tolerable” provided that doses have been reduced to as low as reasonably achievable.

Regarding standards applicable to non-real property releases, the IAEA has also been active during the past decade. In its Safety Series No. 89, Principles for the Exemption of Radiation Sources and Practices from Regulatory Control (1988), and subsequent publications, the IAEA established standards for clearance (i.e., unrestricted release) of materials on the basis of risk levels regarded as trivial. Such standards evolved in 1996 into standards for clearance of solid materials containing residual radioactivity. According to the 1996 standards, unrestricted release of materials is acceptable when the effective dose expected to be incurred by any member of the public from the released material is on the order of 1 mrem or less in a year, and the collective dose from all releases of material associated with a practice will be no more than approximately 100 person-rem.\footnote{Clearance Levels for Radionuclides in Solid Materials. Application of Exemption Principles, IAEA-TECDOC-855 (interim report for comment) (Jan. 1996).}

As the above discussion indicates, organizations that establish radiation protection standards followed in the United States and throughout the world generally agree on the dose and risk levels that should adequately protect members of the public from all sources of radiation. However, there is much less consensus on exactly what residual radioactivity concentration levels must be maintained to ensure compliance with such dose and risk levels, especially if the radioactivity is associated with unrestricted release of sources such as non-real property. Fewer debates have developed with respect to acceptable residual radioactivity concentration levels associated with real property releases, probably because future-use scenarios for real property tend to be limited in number, making it easier to anticipate worst plausible exposure situations. Nevertheless, very
little guidance has been provided by standard-setting organizations that suggests universally acceptable residual radioactivity concentrations for clearance from regulatory controls of either real or non-real property containing residual radioactive material. Instead, the favored approach has been to set such criteria on a case-by-case basis, applying the above-mentioned risk-based dose constraints in conjunction with ALARA principles.

In discussing regulatory systems that would be consistent with the three basic radiation protection principles, the ICRP stated the following, which recognizes the need for a mechanism in regulatory systems to clear from regulatory controls certain sources that pose very low public risk:

In order to avoid excessive regulatory procedures, most regulatory systems include provisions for granting exemptions in cases where it is clear that a practice is justified, but where regulatory provisions are unnecessary.... The Commission believes that the exemption of sources is an important component of the regulatory function.

There are two grounds for exempting a source or an environmental situation from regulatory control. One is that the source gives rise to small individual doses and small collective doses in both normal and accident conditions. The other is that no reasonable control procedures can achieve significant reduction in individual and collective doses.

Notwithstanding the ICRP's stated recognition of the need for clearance, it has recommended no specific concentration values for use as clearance criteria.

Despite the lack of generally accepted clearance criteria, a number of regulatory agencies in the United States and abroad have recently been developing clearance criteria in the form of allowable residual radioactivity concentrations for specific sources or categories of sources (e.g., scrap metal, buildings, remediated land), or developing detailed guidance on appropriate methodologies for establishing site-specific clearance criteria. A number of these efforts are described in Sections 2.2 and 2.3 of this report.

2.2 International Clearance Criteria

2.2.1 Organization for Economic Cooperation and Development

A summary of current practices across the nations has been provided by the Organization for Economic Cooperation and Development (OECD). In its report of 1996,18 the OECD pointed out that, despite the absence of consistent international clearance criteria, national clearance criteria or


clearance criteria approved on a case-by-case basis have been applied to release for reuse approximately 173,000 tons of materials from various decommissioning projects since 1979. The released materials for reuse have included carbon and stainless steels, lead, concrete, and gravel. Table 1 summarizes the quantities and types of reusable materials released by the projects surveyed by the OECD.

The OECD also noted that the current clearance criteria vary among nations, sometimes by a factor of up to 10. Tables 2 and 3 list release criteria adopted in selected countries for unrestricted release for reuse or disposal.

TABLE 1 Material Released from the Projects Surveyed by OECD

<table>
<thead>
<tr>
<th>Release Practice</th>
<th>Estimated Quantity (tons)</th>
<th>Type of Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted reuse</td>
<td>169,000</td>
<td>Carbon steel, stainless steel, various metals (with and without decontamination), gravel, and other materials</td>
</tr>
<tr>
<td>Restricted reuse within the nuclear industry</td>
<td>2,300</td>
<td>Various metals (with and without decontamination), concrete, and other materials</td>
</tr>
<tr>
<td>Restricted release to a specific melter</td>
<td>2,050</td>
<td>Various metals (with and without decontamination)</td>
</tr>
</tbody>
</table>


TABLE 2 Surface Contamination Limits for Beta/Gamma Emitters

<table>
<thead>
<tr>
<th>Contamination Limit (pCi/cm²)</th>
<th>Country</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Germany</td>
<td>Over 100 cm² for fixed and removable contamination</td>
</tr>
<tr>
<td>10.8</td>
<td>Finland</td>
<td>Removable surface contamination over 100 cm² for accessible surfaces</td>
</tr>
<tr>
<td>10.8</td>
<td>Belgium</td>
<td>Mean value for removable surface contamination over 300 cm²</td>
</tr>
<tr>
<td>22.4</td>
<td>USA (Nuclear Regulatory Commission)</td>
<td>Surface contamination above background over no more than 1 m², with a maximum of 68 pCi/cm² above background if the contaminated area does not exceed 100 cm²</td>
</tr>
<tr>
<td>108</td>
<td>Sweden</td>
<td>Mean value for removable surface contamination over 300 cm², with a maximum of 1,080 pCi/cm² if the contaminated area does not exceed 10 cm²</td>
</tr>
</tbody>
</table>

### TABLE 3 Specific Activity Limits Regardless of Type of Emissions

<table>
<thead>
<tr>
<th>Contamination Limit (pCi/g)</th>
<th>Country</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.27</td>
<td>Sweden</td>
<td>Above the content of natural background outside of nuclear installation</td>
</tr>
<tr>
<td>10.8</td>
<td>Great Britain</td>
<td>Total activity for solids, other than sealed sources, that are substantially insoluble in water</td>
</tr>
<tr>
<td>10.8 pCi/mL</td>
<td>Great Britain</td>
<td>Total activity for organic liquids containing carbon-14 and/or tritium</td>
</tr>
<tr>
<td>27</td>
<td>Germany</td>
<td>Reuse of metal in a general melting facility</td>
</tr>
<tr>
<td>None</td>
<td>USA</td>
<td>No volumetric release standard has been established</td>
</tr>
</tbody>
</table>


#### 2.2.2 International Guidance Documents

Recent international clearance criteria guidance includes the following documents:

1. *Principles for the Exemption of Radiation Sources and Practices from Regulatory Control*, IAEA Safety Series No. 89 (1988);


Additionally, the European Commission (EC) Group of Experts referred to in Article 31 of the Treaty Establishing the European Atomic Energy Community (EURATOM Treaty) has drafted a document entitled *Recommended Radiological Protection Criteria for the Recycling of Metals from the Nuclear Power Industry*. The guidance in this and the IAEA documents listed above is focused on protecting against radiological risks.

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2.3 U.S. Regulations Applicable to Releases of Radioactive Real and Non-Real Property

In the United States, DOE and USNRC have primary responsibility for regulating design, construction, operation, and decommissioning of nuclear facilities, including commercial nuclear power plants, uranium fuel cycle facilities, federal facilities supporting the nuclear weapons program, nuclear research reactors, medical facilities, and other facilities. The EPA, although it has no jurisdiction over specific facilities, is responsible for protecting public health and the environment by, among other things, promulgating radiation protection standards for implementation by DOE and USNRC with respect to the facilities under their jurisdictions, and for promulgating standards for radioactive releases into air and water. A state may also have limited authority to regulate radioactive materials, either directly under state law or as part of programs delegated by federal agencies. The lines of responsibility among the several regulatory agencies have not been clearly drawn, and all regulatory bodies have not always agreed on how regulations should be formulated. As a result, parallel regulatory programs have developed that, while similar in most respects, may differ in their particulars. This situation can cause confusion when more than one of such programs apply to the same site, which is often the case for DOE sites. For example, at the DOE Hanford Site, DOE, EPA, and the State of Washington each have some regulatory authority (which they have agreed to apportion according to the Hanford Tri-Party Agreement) over radioactive materials. USNRC regulations also have an influence at Hanford because of DOE’s policy of adopting radiation protection standards that are generally consistent with USNRC standards (see p. 3), and because USNRC standards may be relevant and appropriate for remedial actions conducted pursuant to CERCLA.

At sites where requirements of multiple agencies apply, DOE and DOE contractor personnel must ensure that all applicable requirements have been met, regardless of the ultimate dispositioning of the property. In this regard, compliance with non-DOE requirements (e.g., CERCLA Record of Decision, RCRA corrective action permit conditions) does not necessarily constitute compliance with Order DOE 5400.5 or 10 CFR Part 834 requirements (e.g., reduction of public doses to levels as low as reasonably achievable), and vice versa. Hence, in cases involving releases of real property from DOE control, the property cannot be released until DOE verifies (and documents) compliance with all applicable DOE and non-DOE requirements.

The following subsections describe current DOE, USNRC, and EPA regulations that are applicable or relevant to situations involving DOE releases of real and non-real property. Also described, because of their relevance to the Hanford Site, are regulations adopted by the State of Washington.
2.3.1 DOE Requirements

As was mentioned in Section 1.2 of this report, Order DOE 5400.5, which will be codified and clarified by 10 CFR Part 834, contains the requirements that DOE imposes on releases of residual radioactive material located on or within real or non-real DOE properties. If property is to be released from DOE control, Order DOE 5400.5 and proposed 10 CFR Part 834 require that the release comply with a public dose limit of 100 mrem in a year from all sources and pathways, except medical and background (see p. 2). At sites where DOE 5400.5 applies, compliance with the all-sources dose standard (i.e., 100 mrem/yr) is typically ensured by calculating derived concentration guidelines (DCGLs) using both the all-sources standard and a single-source dose constraint that is a fraction of the all-sources standard (e.g., 30 mrem/yr). Release standards are then established by applying ALARA considerations to the DCGLs. DOE guidance and the proposed 10 CFR Part 834 also require that DOE sites complete the following four actions to protect the public and environment before release of property containing residual radioactive material:

1. The property is appropriately surveyed/measured to identify and characterize its radiological condition,
2. Residual radioactive material is determined to meet applicable release limits,
3. Required documentation is completed, and
4. The owner or recipient of the released property is appropriately notified of the radiological status of the property and the availability of required documentation.

Regarding item 2, Order DOE 5400.5 specifies release criteria for gamma radiation exposure rates in habitable structures and on open lands, and release criteria for:

1. Specified residual radionuclides in air and water,
2. Specified residual radionuclides in soil,
3. Specified residual radionuclides on surfaces, and
4. Airborne radon decay products.

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20 See 56 FR 16268 (March 25, 1993). Note: Promulgation of 10 CFR Part 834 has been delayed because the EPA has expressed concerns similar to those the EPA has voiced regarding the recently promulgated USNRC decommissioning rule (10 CFR Part 20, subpart E) (see Section 2.3.3, p. 17).
However, even in circumstances where such release criteria apply (i.e., the only contaminants present are among those for which release criteria are specified), a site-specific determination must be documented that doses to individual members of the public from property released pursuant to the criteria will be ALARA. A graded approach should be used to decide the complexity of the evaluation necessary to make such a determination. In other words, the level of detail for the analyses should be determined consistent with the complexity of the release and its potential to create risk to human health and the environment.

In circumstances where the release criteria stated in Order DOE 5400.5 do not apply (e.g., a contaminant is present for which the Order specifies no release criteria), or are inappropriate (e.g., the future-use assumptions associated with the release criteria specified by the Order do not apply to the actual circumstances encountered), DOE must approve site-specific authorized or supplemental release limits developed using the ALARA process.

Additional details about the standards and release criteria in Order DOE 5400.5 are presented in Appendixes A and B.

### 2.3.2 EPA Regulations

Under the mandates of the Atomic Energy Act, the Clean Air Act (CAA), the Safe Drinking Water Act (SDWA), and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), EPA has promulgated several sets of regulations establishing either dose standards applicable to specific categories of sources, or radioactivity concentration criteria applicable to specific modes of release. Existing EPA regulations with which DOE activities must comply that apply to releases of real or non-real property from DOE control are listed in Table 4. Additional details about the standards and release criteria contained in these EPA regulations are presented in Appendix A.

EPA is also in the process of developing regulations that will set standards for the remediation of radioactive material at sites that will be released for unrestricted use. The EPA’s stated goal for setting such standards is to expedite the cleanup of sites contaminated with radioactive materials and to promote beneficial reuse of the land. The rulemaking process began in 1993 when EPA published an advance notice of proposed rulemaking. However, EPA’s

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21 58 FR 54474 (Oct. 21, 1993).
TABLE 4 EPA Regulations Pertinent to Releases of DOE Property

<table>
<thead>
<tr>
<th>Regulation</th>
<th>Authorizing Statute</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 CFR Part 141, “National Primary Drinking Water Regulations”</td>
<td>Safe Drinking Water Act (42 U.S.C. 300f, 300g-1, 300g-2, 300g-3, 300g-4, 300g-5, 300g-6, 300g-9)</td>
<td>Establishes primary drinking water regulations applicable to public water systems. Also used as an applicable or relevant and appropriate requirement (ARAR) for cleanup of groundwater that is a current or potential source of drinking water at sites listed on the CERCLA National Priorities List (NPL) (40 CFR Part 300, Appendix B).</td>
</tr>
</tbody>
</table>

Promulgation of the radiation site cleanup regulations was recently delayed pending resolution of a disagreement between EPA and USNRC regarding USNRC’s promulgation of radiological criteria applicable to license terminations at USNRC-licensed facilities (see Section 2.3.3, p. 17). The disagreement stems from EPA’s position that in order for radiological risks at decommissioned sites to be comparable to risks deemed acceptable for carcinogenic chemical constituents at such sites, the regulatory release standards and criteria applicable to residual radioactive material should be such that unrestricted releases of real property will result in increased cancer risk to individual members of the public of not more than approximately 10⁻⁴. To ensure this risk level, preliminary discussion drafts released by EPA²² indicate that the radiation site cleanup regulations would restrict the committed effective dose to an individual member of the public during the 1,000 years following unrestricted release of a remediated radiation site to

no more than 15 mrem per year through all potential pathways under a residential land use scenario. Alternatively, restricted release would be allowed under specified conditions. Further, release concentration criteria would be established as indicated in Table 5 for residual radioactivity in groundwater and for radon in structures at remediated sites. Significantly, the preliminary draft radiation site cleanup regulations place no requirement on sites to reduce public doses to levels that are ALARA.

### Table 5 EPA Proposed Release Concentrations

<table>
<thead>
<tr>
<th>Medium</th>
<th>Proposed Release Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor air within existing and future structures</td>
<td>Shall meet the guidelines of the EPA Radon Program (i.e., radon-222 concentrations are limited to no more than 4 pCi/L of air).</td>
</tr>
<tr>
<td>Groundwater</td>
<td>Shall provide reasonable expectation that during the 1,000 years following cleanup, radioactivity concentrations will not exceed the limits specified in 40 CFR Part 141 in any groundwater that is a current or potential source of drinking water.</td>
</tr>
</tbody>
</table>

#### 2.3.3 USNRC Regulations

The vast majority of DOE activities are not subject to USNRC's regulatory jurisdiction. Nevertheless, as previously indicated, it is DOE's policy to adopt requirements in DOE Orders that are consistent with USNRC requirements (see Section 1.2, footnote 3, p. 3).

#### 2.3.3.1 10 CFR Part 20, Standards for Protection Against Radiation

Under authority granted by the Atomic Energy Act, the USNRC has promulgated standards for protection of workers and the public against ionizing radiation resulting from activities conducted under USNRC-issued licenses. Such regulations are located in 10 CFR Part 20, "Standards for Protection Against Radiation." Those regulations limit exposure of members of the public from the operations of USNRC licensees to a total effective dose equivalent of no more than 100 mrem in a year, exclusive of natural background, medical exposures, and otherwise regulated releases of radioactive materials to sanitary sewers. However, no provisions establish a level of radioactivity below which releases, regardless of their nature, would be considered acceptable (i.e., would create so little risk to the public and environment that regulatory controls would be unnecessary). In the early 1980s, Congress perceived the absence of such criteria as creating a burden on space in low-level radioactive waste landfills. As a result, Section 10 of the Low-Level Radioactive Waste Policy Amendments Act (LLRWPA) of 1985 directed the USNRC to develop criteria and procedures to act upon petitions "to exempt specific radioactive waste streams from regulation ... due to the presence of radionuclides ... in sufficiently low concentrations or quantities as to be below regulatory concern." One purpose of the LLRWPA was to clearly require states to provide for the disposal of low-level radioactive wastes generated...
within their borders (see 42 United States Code [U.S.C.] 2021c), and apparently Congress felt it would be senseless to use low-level waste landfill space for waste that did not pose a threat to human health or the environment. The USNRC responded by issuing a policy statement on August 29, 1986 (51 FR 30839) that contained criteria for evaluating petitions requesting determinations that specific radioactive waste streams need not be disposed of in low-level waste landfills.

Later, in order to establish a consistent risk framework for making regulatory exemption decisions across the broad spectrum of activities regulated by the USNRC, the Commission issued a second policy statement addressing the “below regulatory concern” issue on July 3, 1990 (55 FR 27522, “General Statement of Policy on Below Regulatory Concern”). The public reacted with considerable concern about the implications of the 1990 Policy on Below Regulatory Concern (BRC policy). Antinuclear groups were especially critical, accusing USNRC of adopting the BRC policy to aid nuclear utilities financially by making it possible for them to save on the cost of disposing of radioactive waste “while killing people.”23 An antinuclear coalition went to court and requested that the BRC policy be voided. The District of Columbia Circuit Court of Appeals dismissed the suit on the ground that it could not decide the issues until the USNRC actually took an action under the policy. Before the dismissal, however, the State of Maine joined the lawsuit, and 16 other states filed an amicus curiae brief protesting not the numbers or the technical findings used by USNRC to support its policy, but what they viewed as usurpation of power (i.e., their authority to enact stricter standards and bar waste deregulated by USNRC).

In July 1991, the USNRC initiated a consensus-building process to seek the advice of affected interests on a re-evaluation of the BRC policy. In conjunction with the initiation of the consensus-building process, the Commission placed a moratorium on the implementation of the 1990 BRC policy, and in October 1992, the Energy Policy Act of 1992 revoked both the 1986 and the 1990 BRC policy statements. On August 24, 1993, the USNRC formally withdrew both statements in response to the congressional action (58 FR 44610) and announced the termination of a rulemaking action that was initiated to implement the 1986 policy statement (58 FR 44620). The rulemaking had been initiated on December 2, 1986 (51 FR 43367) with an advance notice of proposed rulemaking entitled “Radioactive Waste Below Regulatory Concern; Generic Rulemaking.”

Still in need of a consistent approach for defining acceptable levels for cleanup of radioactive contamination, especially at sites undergoing decommissioning, the USNRC began an enhanced participatory rulemaking in November 1992 to establish radiological criteria for decommissioning. Workshops were held during the first half of 1993, with discussions focused on a USNRC

rulemaking issues paper\textsuperscript{24} that was developed with input from EPA, state, industry, and public interest groups in an attempt to ensure an unbiased presentation.

On August 22, 1994, the USNRC proposed its radiological criteria for decommissioning. The proposed rule would have limited exposure at decommissioned sites to 15 mrem per year and would have required a licensee to reduce residual radioactivity such that actual exposure would be as far below this limit as reasonably achievable (59 FR 43200). Additionally, the proposed rule contained a separate concentration limit on allowable groundwater contamination. On July 21, 1997, the USNRC published its final decommissioning rule,\textsuperscript{25} setting a 25-mrem-per-year radiation exposure standard and requiring additional reductions in exposure to levels as low as reasonably achievable. No special groundwater protection provision was included.

EPA, which has authority under the Atomic Energy Act to set radiation protection standards for implementation by the USNRC and DOE, has objected strongly to the USNRC final rule. A major reason for EPA’s objection was that the dose limits established by the USNRC final rule are not based on the risk range established under CERCLA as protective of human health and the environment for carcinogens, or on an analysis of other achievable protective cleanup levels used for radiation and other carcinogens. Rather, according to EPA,\textsuperscript{26} the rule is based on a different framework of risk management recommended by the ICRP and the NCRP which would allow exposures to radiation equating to a cancer risk of as much as $2 \times 10^{-3}$. EPA sees this as wholly inconsistent with CERCLA. On that basis, the Agency has advised EPA regional staff that EPA Headquarters has determined that USNRC’s final radiation cleanup standards should not generally be used as the basis for preliminary remedial goals at CERCLA sites because the standards are not adequately protective of human health and the environment.\textsuperscript{27} At present it is unclear how, or when, the disagreement between EPA and USNRC on this issue will be resolved. Additional details about the standards and release criteria contained in the USNRC license termination regulations are presented in Appendix A.

While DOE has historically adopted an approach regarding control of residual radioactivity that is similar to that of the USNRC, DOE believes it could comply with either the USNRC decommissioning regulations or EPA’s radiation site cleanup regulations as a result of its practice of applying ALARA principles to all releases. To avoid confusion, however, DOE has urged

\begin{footnotesize}
\begin{itemize}
\item \textsuperscript{24} Proposed Rulemaking to Establish Radiological Criteria for Decommissioning, Issues for Discussion at Workshops, USNRC (1992).
\item \textsuperscript{25} 62 FR 39058 (July 21, 1997).
\item \textsuperscript{26} Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination, OSWER No. 9200.4-18, EPA (Aug. 22, 1997).
\item \textsuperscript{27} Clarification of the Role of Applicable, or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals Under CERCLA, OSWER No. 9200.4-23, EPA (Aug. 22, 1997).
\end{itemize}
\end{footnotesize}
consistency between USNRC and EPA regulations. In any event, all DOE facilities will be subject to the EPA radiation site cleanup regulations when they are promulgated.

2.3.3.2 USNRC Regulatory Guide 1.86, Termination of Operating Licenses for Nuclear Reactors

For the benefit of its staff and licensees, the USNRC publishes a series of regulatory guides that explain how USNRC regulations are to be implemented. Such regulatory guides, while not legally enforceable unless expressly incorporated into the operating license of a specific facility, articulate USNRC policy.

USNRC Regulatory Guide 1.86, which outlines the process and criteria used by USNRC when terminating nuclear reactor operating licenses, contains a table of residual activity contamination levels that the USNRC has determined to be acceptable on surfaces of property being released for unrestricted use. USNRC licensees typically apply the release criteria in this table without further ALARA consideration when releasing materials with residual surface activity.

DOE has adopted the table from Regulatory Guide 1.86 in Order DOE 5400.5 (with the addition of tritium) as a guideline for surface activity release criteria. However, in guidance materials, DOE cautions that, while the residual radioactivity levels expressed in the table are protective, the level of protection is not uniform among radionuclides. Therefore, DOE sites that use the table as the basis for authorized release limits are expected to complete at least minimal review to satisfy ALARA process requirements. The allowable total residual surface activity table from Regulatory Guide 1.86, as adopted by Order DOE 5400.5, is presented in Appendix B.

2.3.4 State of Washington Laws and Regulations

The Washington State Department of Health (Health) is designated as the state radiation control agency and has sole responsibility for administering the state’s regulatory and inspection program for sources and uses of ionizing radiation (Revised Code of Washington [RCW] 70.98.050). In this role, Health regulates the use, storage, and disposal of radioactive materials not subject to DOE control or regulation by the USNRC. Health has adopted regulations that, among other things, set radiation protection standards applicable to the activities of its licensees and registrants (WAC 246-221); govern the termination of licenses and the

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29 Draft Handbook for Controlling Release for Reuse or Recycle of Non-Real Property Containing Residual Radioactive Material (for interim use and comment), DOE-HDBK (June 1997).

30 Health regulates source material, by-product material, and special nuclear material in quantities not sufficient to form a critical mass under the provisions of 10 CFR Part 150 and an agreement between the State of Washington and the USNRC.
decommissioning of activities at sites holding specific licenses 31 (Washington Administrative Code [WAC] 246-232-060); and set standards for protection of the general population from releases of radioactivity from radioactive waste disposal sites (WAC 246-250-170). Appendix A includes a summary of the Washington regulations that set standards or criteria for protection of the public from residual radioactivity at sites undergoing cleanup within Health’s jurisdiction. Depending on the nature of a DOE site undergoing cleanup in Washington pursuant to CERCLA, these regulations may be applicable or relevant and appropriate requirements (i.e., ARARs). 32

The Washington State Department of Ecology (Ecology) has been authorized by the EPA to implement the federal Resource Conservation and Recovery Act (RCRA) hazardous waste program pursuant to substantially equivalent state laws and regulations. Accordingly, Ecology regulates the cleanup of dangerous wastes (including mixed wastes 33) and dangerous waste constituents pursuant to RCW 70.105, “Hazardous Waste Management Act of 1976,” as amended in 1980 and 1983, at facilities seeking or required to have a permit to treat, store, recycle, or dispose of dangerous waste. Further, Ecology regulates the cleanup of sites where past activities have released hazardous substances (including radionuclides), or where current activities are releasing, or have the potential to release, hazardous substances (RCW 70.105D, “Hazardous Waste Cleanup — Model Toxics Control Act” [MTCA]). Finally, Ecology is authorized by RCW 43.21A to participate fully in and administer all programs of the federal CERCLA that are contemplated for state participation and administration. Appendix A includes a summary of the Washington regulations that set standards or criteria for protection of the public from residual radioactivity at sites undergoing cleanup within Ecology’s jurisdiction. At DOE sites undergoing cleanup in the State of Washington pursuant to CERCLA, the Ecology regulations are likely to be ARARs.

Health is in the process of developing a rule in collaboration with Ecology that will set cleanup standards for environmental radioactivity. If promulgated, such regulations would address all residual radionuclides in soil, sediment, and groundwater at any site licensed by Health.

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31 Specific license means a license issued after application to use, manufacture, produce, transfer, receive, acquire, own, or possess quantities of, or devices or equipment utilizing by-product, source, special nuclear materials, or other radioactive materials occurring naturally or produced artificially.

32 Cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site are “applicable” requirements. If such standards, requirements, criteria, or limitations are not applicable requirements, but nevertheless address problems or situations sufficiently similar to those encountered at a CERCLA site that their use would be well suited to the site, they are “relevant and appropriate requirements.” A given standard, requirement, criteria, or limitation may be either “applicable,” or “relevant and appropriate” at a CERCLA site, but not both.

33 Mixed waste means dangerous, extremely hazardous, or actually hazardous waste that contains both a nonradioactive hazardous component and, as defined by 10 CFR 20.1003, source, special nuclear, or by-product material subject to the Atomic Energy Act of 1954 (42 U.S.C. 2011 et seq.) (WAC 173-303-040).
where the license is being terminated and the site decommissioned. At sites not licensed by Health that are being cleaned up pursuant to CERCLA or MTCA (including DOE sites), these regulations would be ARARs.

Health has not published a formal proposal for its environmental radioactivity cleanup standards. However, in October 1995, an issues paper was released describing the need for standards and requesting comments on a list of "open questions" regarding how residual radioactivity should be regulated. The issues paper acknowledged that at that time, both EPA and USNRC were developing standards with scope and applicability similar to the radioactivity cleanup standards contemplated by Health. The issues paper further noted that should the federal standards be promulgated in a timely manner, the state could simply adopt such federal standards. In any event, if state standards were adopted before federal standards, the state standards would ultimately have to be adjusted to be at least as stringent as final federal standards. Because the USNRC finalized its decommissioning rule in July 1997 (see Section 2.3.3, p. 17) and EPA is objecting to that rule, the status of Health's effort to develop environmental radioactivity cleanup standards is unclear. DOE's Richland Operations Office filed comments on the issues paper in 1995.

2.3.5 U.S. Guidance Documents

This section lists guidance and resource documents that have been published by regulatory agencies and others to explain or implement U.S. regulatory requirements relevant to the release of property containing residual radioactivity. The list in each subsection is intended as a bibliography. No effort was made to review every document listed to determine its usefulness or current status, nor is the list in any subsection intended to be comprehensive.

2.3.5.1 DOE-Issued Guidance Documents


*Control of "High-Risk" Personal Property*, DOE Personal Property Letter (PPL) 970-3 (March 25, 1996).

*DOE Guidance on the Procedures in Applying the ALARA Process for Compliance with DOE 5400.5*, Interim Guidance, Assistant Secretary of Environmental, Safety and Health, Office of Environmental Policy and Assistance (EH-41) (March 8, 1991).

*DOE Guidance on the Procedures in Applying the ALARA Process for Compliance with 10 CFR Part 834*, Assistant Secretary of Environmental, Safety and Health, Office of Environmental

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Policy and Assistance (EH-41). [This document is under development; for information, contact EH-41.]


*Draft Handbook for Controlling Release for Reuse or Recycle of Non-Real Property Containing Residual Radioactive Material* (for interim use and comment), DOE-HDBK (June 1997).

*External Dose Conversion Factors for Calculation of Dose to the Public*, DOE/EH-0070.

*Internal Dose Conversion Factors for Calculation of Dose to the Public*, DOE/EH-0071.


*Responses to Questions and Clarification of Requirements and Processes: DOE 5400.5, Section II.5 and Chapter IV Implementation (Requirements Relating to Residual Radioactive Material)*, Assistant Secretary of Environmental, Safety and Health, Office of Environmental Policy and Assistance (EH-41) (Nov. 17, 1995).

**2.3.5.2 EPA-Issued Guidance Documents**


2.3.5.3 USNRC-Issued Guidance Documents


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

Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent, NUREG/CRC-5512.


2.3.5.4 Other Related Guidance and Resource Documents


Health Effects of Exposure to Low Levels of Ionizing Radiation (BEIR V), National Research Council (1990).

Health Risk of Radon and Other Internally Deposited Alpha Emitters (BEIR IV), National Research Council (1988).


3 DOE PRACTICES FOR RELEASING PROPERTY CONTAINING RESIDUAL RADIOACTIVE MATERIALS

Since U.S. research, production, and testing of nuclear weapons began in the 1940s, numerous facilities, both government and private, have been constructed or leased to support the weapons program (which is now a function of DOE). These facilities have generated large quantities of radioactive and hazardous materials, resulting in contamination of many of the facilities and surrounding areas. Before 1989, responsibility for cleaning up such facilities and surrounding areas was not centralized within DOE. Several focused cleanup efforts were established, but, in general, cleanup was not given high priority. Focused cleanup efforts before 1989 included the Formerly Utilized Sites Remedial Action Program (FUSRAP), the Uranium Mill Tailings Remedial Action (UMTRA) Project, and the Surplus Facilities Management Program (SFMP). The FUSRAP was established in 1974 to identify, investigate, and clean up or control radioactively contaminated properties that were used to support the Manhattan Project and subsequent Cold War nuclear research. The UMTRA Project was authorized in 1978 to ensure compliance with the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA). That Act gave DOE responsibility for identifying and remediating tailings at inactive uranium and thorium ore processing sites. In 1979, the SFMP was established to provide coordinated management of decommissioning of surplus contaminated DOE facilities.

In 1989, DOE created the Office of Environmental Restoration within the newly established Office of Environmental Restoration and Waste Management (EM) (now the Office of Environmental Management) to consolidate, centralize, and promote the cleanup of contaminated waste sites and surplus facilities within the DOE complex. Today, the Environmental Restoration Program has absorbed the SFMP. The UMTRA Project is managed by the DOE Environmental Restoration Division, Albuquerque Operations Office. Until October 1997, FUSRAP was a separate program within EM. FUSRAP, the UMTRA Project, and EM have all successfully remediated properties, some of which have been released from DOE control. This chapter identifies and describes some processes that have been developed for cleaning up both real and non-real properties in a manner that will protect the public and environment. Additionally, specific site experiences are described. However, the detail with which site experiences are described varies because the amount information available in the published literature varies from site to site.

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35 The Manhattan Project was a secret program to develop an atomic weapon that would end World War II. The effort was supported by production facilities, chemical plants, and laboratories throughout the United States.

3.1 Real Property

Real property containing residual radioactive material may be released from DOE control following remedial actions or decommissioning. Remedial actions are conducted at inactive waste sites or facilities where releases or spills have occurred and contamination has been released into the environment. Such actions at DOE sites typically proceed according to the requirements of the RCRA corrective action program or the CERCLA National Oil and Hazardous Substances Contingency Plan (NCP). Decommissioning involves the decontamination and/or dismantlement and removal of nuclear facilities that are no longer active and pose a risk to public health and the environment. Pursuant to a joint DOE/EPA policy memorandum, decommissioning activities at DOE facilities proceed as non-time critical removal actions under the NCP, unless facility-specific circumstances make that procedure inappropriate. Also, in all cases, DOE must ensure that the National Environmental Policy Act (NEPA) requirements for environmental review and public participation are satisfied before any property containing residual radioactive material is released.

3.1.1 Cleanup Processes

A literature search performed for this report revealed three processes (described below) that have been developed with DOE involvement for making decisions about real property cleanups at DOE facilities.

3.1.1.1 Ohio Federal Facilities Forum

In 1995, the Ohio Federal Facilities Forum (the Ohio Forum) was organized to provide an arena for understanding and addressing environmental cleanup and waste management issues and challenges that face federal facilities in Ohio. Participants include representatives from U.S. Department of Energy (DOE-Mound and DOE-Fernald), U.S. Department of Defense (Wright Patterson Air Force Base), Ohio Environmental Protection Agency (OEPA), Ohio Department of Health (Bureau of Radiological Protection), U.S. Environmental Protection Agency (EPA), and National Aeronautics and Space Administration (NASA). One of several committees formed by the Ohio Forum is the Cleanup Standards Committee, which has been assigned the task of addressing issues related to federal facility site cleanup standards, cleanup objectives, and procedures.

The Cleanup Standards Committee has developed a process to facilitate decisions about the unconditional release by federal agencies of buildings in Ohio containing residual radioactive material.

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37 Policy on Decommissioning Department of Energy Facilities Under CERCLA, EPA Assistant Administrators of the Offices of Enforcement and Compliance Assurance and of Solid Waste, and DOE Assistant Secretary for Environmental Management (May 22, 1995).

The major steps of the process are illustrated in Figure 1. Two incentives precipitated development of this process for use in Ohio:

1. Many federal facilities in Ohio are changing their missions from nuclear materials production to cleanup; and

2. Current federal initiatives are encouraging local economic development through the transfer of remediated federal buildings and land for reuse by the private sector.

Although developed specifically for federal facilities in Ohio, this process is sufficiently generic that it could be tailored for use elsewhere.

The intended users of the process are decision makers at federal facilities (i.e., regulators who must ultimately agree that a building at a federal facility meets the appropriate criteria to support its final disposition). Emphasis is placed on “teaming.” In this context, “teaming” refers to involving all appropriate decision makers in such activities as evaluating existing information for the purpose of radiologically characterizing buildings, establishing the appropriate level of survey needed to confirm or verify compliance with dispositioning criteria, and selecting the preferred building disposition. By involving the decision makers throughout (instead of using the traditional propose-review-comment-revise-approve approach), this process seeks to avoid unrealistic expectations regarding the degree to which buildings can be decontaminated and to identify issues and conflicts early in the process.

With respect to radiological characterization, this process defines a building as radiologically clean if an appropriate survey establishes that surface contamination does not exceed the surface activity concentrations or dose constraints specified in USNRC Regulatory Guide 1.86 or Order DOE 5400.5.

3.1.1.2 DOE Environmental Restoration Decommissioning Resource Manual

As previously mentioned, EPA and DOE have agreed that all decommissioning activities at DOE facilities will proceed as CERCLA non-time critical removal actions, regardless of whether the site has been listed on the CERCLA National Priorities List (NPL). DOE's Environmental Restoration Program has published a Decommissioning Resource Manual to assist in the

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Identify appropriate decision makers to involve based on site-specific scenario.

Evaluate existing information.

Based on existing information, is building expected to be radiologically clean?

Based on existing information, is building known to be contaminated or is building potentially contaminated?

Based on survey are anomalies present?

Are anomalies significant?

Obtain appropriate concurrence.

Design and conduct verification survey.

Is the building or portions thereof, radiologically clean based on verification survey?

Obtain appropriate concurrence from decision-makers.

Pursue preferred disposition alternative.

Disposition clean building.

Disposition clean building.

NOTE:
Identification of appropriate decision-makers will allow up-front input and approval, thereby mitigating potential conflicts. It is recommended that the decision-makers use a teaming approach rather than follow a propose/review/approve approach. The teaming approach also will allow decision-makers to modify this general process to reflect site-specifics.

effective implementation of a 42-step DOE decommissioning framework, which was established in
the earlier Decommissioning Implementation Guide.41

For the purpose of this report, all 42 steps
of the decommissioning framework are not
relevant. However, Section 2.2.3 and
Chapter 5 of the Decommissioning Resource
Manual regarding site release criteria and
release process are of interest.

According to Section 2.2.3, release criteria
to be used for the decontamination of equipment, structures, and the environment (i.e., soil, air,
groundwater) should be established as early as possible in planning a decommissioning project.
For facilities or sites to be released, Section 2.2.3 advises that the process for establishing such
release criteria should follow the ALARA requirements of Chapter IV in Order DOE 5400.5, and
the resultant release criteria should be clearly stated in the decommissioning operations plan and
approved by DOE and responsible regulators before decontamination starts.

Process,” states that in order to release a decommissioned facility or site for use with or without
radiological restrictions, it is necessary to verify, and in some cases certify, that decontamination
has been completed in accordance with DOE-approved release criteria established for the project.
For all properties or facilities being transferred to industry or the public, Section 5.5 advises that
formal site survey results, independent verification reports, and certification reports must be
reviewed and approved by DOE Headquarters before the property or facility is released or
transferred. Additionally, according to Section 5.5, the final condition of the facility or property
should be officially recorded with the local land records or deeds office.

3.1.1.3 Allowable Residual Contamination Level Method for
Decommissioning Facilities on the Hanford Site

The “allowable residual contamination level” (ARCL) method was originally developed in
198342 to assist the DOE Richland Operations Office decommission the retired nuclear production
reactors and associated facilities on the Hanford Site and was modified in 1988 to make it capable

42 Kennedy, W.E., Jr., and B.A. Napier, Allowable Residual Contamination Levels for Decommissioning the
115-F and 117-F Facilities at the Hanford Site, PNL-4704, UNI-2499, Pacific Northwest Laboratory
(1983); and Kennedy, W.E., Jr., and B.A. Napier, Allowable Residual Contamination Levels for
Decommissioning Facilities in the 100 Areas of the Hanford Site, PNL-4722, UNI-2522, Pacific
Northwest Laboratory (1983).
of analyses that are more site specific. The ARCL method assists in the consideration of decommissioning alternatives by using a site-specific radiation scenario/exposure-pathway analysis, based on an annual radiation dose limit, to determine the acceptable levels of residual radioactive contaminants that can remain at a nuclear facility that is decommissioned in situ. The primary objective of the method is to aid in determining whether radioactively contaminated sites require further decontamination or remedial action before their release. This objective is accomplished by completing seven basic activities, each comprising from one to five tasks. Each task in turn comprises one to eight procedures. Figure 2 identifies the seven basic activities and illustrates their relationship.

As the activities and flow paths in Figure 2 illustrate, the ARCL method is essentially a dose-to-concentration computational technique. The necessary first activity is preparation of a comprehensive site radionuclide inventory (i.e., locating and determining the identity and concentrations of radioactive material throughout the site) from the results of sampling and monitoring. The radionuclide inventory is adjusted in the second activity for application to each of three pre-defined, controlling exposure scenarios. Activities 3, 4, and 5, which consist of calculating individual radiation doses for each of the three controlling exposure scenarios when residual radioactive material is assumed to consist of particular isotopes at specific concentrations, can proceed concurrently. In activity 6, the dose estimates for the residential/home-garden and agricultural scenarios made during activities 3 and 4, respectively, are summed, and the sum is compared with the dose estimate made for the resource recycle scenario in activity 5. In

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activity 7, the most restrictive dose of the two doses is then compared with the mandated dose limit (e.g., 15 mrem/yr) to determine if the assumed residual radionuclide concentrations will result in a compliant dose.

The three pre-defined, controlling exposure scenarios identified in activities 3, 4, and 5 as the residential/home-garden scenario, the agricultural scenario, and the resource recycle scenario, respectively, were designed to estimate the exposure conditions for a maximally exposed individual who could live on a decommissioned site at Hanford after loss of institutional controls following decommissioning. Each scenario is described in more detail below.

The scope of the ARCL method is limited to determining whether specific radionuclide concentrations at a site undergoing decommissioning will cause a maximally exposed individual, as characterized by the three pre-defined, controlling scenarios, to receive a dose that exceeds the applicable regulatory limit. As such, the method is not intended as a process for choosing either the best means of hazard mitigation or the most appropriate final disposition for the decommissioned site.

### 3.1.1.3.1 ARCL Method Residential/Home-Garden Scenario

The residential/home-garden scenario is designed to represent the unrestricted use of a decommissioned site by an individual who resides there and engages in home gardening activities for 50 years. When the individual moves onto the site, he is assumed to construct a house with a basement that has a volume of 1,000 m$^3$ (dimensions of 20 x 10 x 5 meters). For purposes of determining if the inventory of radioactive materials will result in an annual dose rate that is less than a specified limit, the basement is located in an area where the greatest (or worst) radionuclide inventory associated with the particular facility being evaluated would occur. All of the contamination present in this volume is assumed to be uniformly mixed with the clean soil in the volume, and the resulting material is spread to a depth of 15 centimeters over about two-thirds of a hectare. After the house is constructed, the individual is assumed to spend 12 hours per day on the site, during which time he is exposed to direct penetrating radiation from the soil. The individual is also assumed to inhale resuspended contamination in the surface soil for 12 hours per day during his 50 years of exposure, with an air concentration calculated using a mass loading factor of $10^{-4}$ g/m$^3$ air. The individual is assumed to grow 25% of his fruit and vegetable diet in a backyard garden that is located in the soil contaminated from the excavation.

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3.1.1.3.2 ARCL Method Agricultural Scenario

The agricultural scenario is defined to account for the potential radiological exposure of an individual from ingesting agricultural products with roots that penetrated into buried radioactive materials. The contaminated material could be either deeply buried (i.e., at a depth of 5 meters or greater), or buried closer to the surface near facilities under consideration through the residential/home-garden (basement) scenario. The only pathway of radiation exposure in this scenario is the ingestion of agricultural products containing radionuclides. The maximum exposed individual is assumed to obtain 25% of his fruit and vegetable diet from this food source. Because of the limited size of the contaminated areas, animal products have been excluded from this scenario.

3.1.1.3.3 ARCL Method Resource Recycle Scenario

The resource recycle scenario is designed to represent the potential activities of individuals engaged in recycling materials recovered during salvage operation in the buried rubble left after demolition of a facility. A salvage worker is assumed to recover about 0.8 Mg of scrap metal per 8-hour day, and to work 250, 8-hour days per year. This effort would produce 200 Mg per year of scrap metal, which is assumed to be melted and made into consumer products. A worker in a scrap yard in a smelter or foundry is assumed to be exposed to the inhalation threshold limit value of metal particulate (5 mg/m³) for a sufficiently long period to process 200 Mg of recovered metal into consumer products. This worker is also assumed to be exposed to piles of metal scrap, metal ingots, and accumulated finished products.

3.1.2 DOE Real Property Cleanups

Table 6 summarizes information about real properties remediated by DOE that are discussed in this section. The information provided includes property names, applicable generic cleanup criteria, contaminants for which site-specific derivation of cleanup criteria was necessary, and methodologies used for deriving site-specific cleanup criteria. Some of the real properties in Table 6 have been released from DOE radiological control in recent years. The discussions following Table 6 provide additional information about site experience associated with each real property release. As previously stated, however, the detail with which site experiences are

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47 The U.S. Army Corps of Engineers is now responsible for FUSRAP (see Footnote 36, p. 24).
described varies because the amount information available in the published literature varies from site to site.

### 3.1.2.1 FUSRAP Sites

Since it started in 1974, FUSRAP has examined or performed surveys on more than 400 sites. Of these, 46 sites in 14 states were designated for further remediation. To date, DOE has completed remediation at 15 of those sites and at more than 175 vicinity properties, including homes, parks, and streams. Remediation of the remaining FUSRAP sites and vicinity properties will be completed by the U.S. Army Corps of Engineers (see Footnote 36, p. 24).

Most FUSRAP sites and vicinity properties are contaminated either with material from uranium and thorium ore processing (i.e., “by-product material” as defined by Section 11e(2) of the Atomic Energy Act) or with low levels of uranium from the machining of uranium metal on the property. Therefore, radionuclides of concern typically include uranium, thorium, and radium. Many properties have buildings that may include subsurface foundations.

Although each property is different, FUSRAP has applied the same general process to cleaning up all of them, based, as applicable, on the requirements of CERCLA and NEPA. First, historical information about the site is collected and reviewed. Next, the site is characterized (in terms of the extent of contamination) and either a remedial investigation/feasibility study or an engineering evaluation/cost analysis is completed. Then, remedial design and remedial action proceed. Finally, verification of site conditions and certification of readiness for future use are completed. Throughout the process, the public is informed about progress. A cleanup alternative is chosen only after appropriate public review. The cleanup process at a particular site may vary from the general approach because of site-specific conditions and influences.

The provisions of Order DOE 5400.5 dictate certain cleanup criteria applicable to releasing FUSRAP sites for unrestricted future use. These criteria were discussed in Section 2.3.1 (p. 12), with additional details reported in Appendixes A and B. As is indicated there, however, DOE 5400.5 provides no soil cleanup criterion for uranium, which is one of the most common radioactive contaminants in soil at FUSRAP sites. Hence, DOE has often derived site-specific
TABLE 6 Summary of Cleanup Information for Selected DOE-Remediated Real Properties

<table>
<thead>
<tr>
<th>Property Name</th>
<th>Year Cleanup Was Completed</th>
<th>Applicable Generic Cleanup Criteria</th>
<th>Contaminants Requiring Site-Specific Cleanup Criteria</th>
<th>Methodology for Deriving Release Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>FUSRAP (25 sites)</td>
<td>1981 - present</td>
<td>DOE 5400.5</td>
<td>Mostly uranium in soil, sometimes other radionuclides on surfaces of buildings destined for demolition</td>
<td>RESRAD</td>
</tr>
<tr>
<td>UMTRA Project (20 sites)</td>
<td>1978 - 1995</td>
<td>40 CFR Part 192</td>
<td>Uranium and thorium in soil</td>
<td>RESRAD</td>
</tr>
<tr>
<td>Shippingport</td>
<td>1989</td>
<td>SFMP Guidelines</td>
<td>Cobalt-60 and cesium-137 in soil</td>
<td>Site-specific computerized calculations</td>
</tr>
<tr>
<td>South-Middle &amp; South-East Vaults</td>
<td>1996</td>
<td>DOE 5400.5</td>
<td>Cesium-137, strontium-90, and americium-241 in soil</td>
<td>RESRAD</td>
</tr>
<tr>
<td>EBWR</td>
<td>1996</td>
<td>DOE 5400.5</td>
<td>None</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Weldon Spring</td>
<td>Ongoing</td>
<td>DOE 5400.5</td>
<td>Uranium in soil</td>
<td>RESRAD</td>
</tr>
<tr>
<td>HWCTR</td>
<td>Ongoing</td>
<td>DOE 5400.5</td>
<td>Several radionuclides in soil and on building surfaces</td>
<td>RESRAD for radionuclides in soil, RESRAD-BUILD for radionuclides on building surfaces</td>
</tr>
</tbody>
</table>
release limits (referred to in DOE 5400.5 as "authorized limits") for uranium in soil at FUSRAP sites. Also, at several FUSRAP sites, DOE determined the surface activity cleanup criteria provided by DOE 5400.5 to be inappropriate because site-specific conditions or intended future building uses were significantly different than those assumed for the purpose of deriving the criteria provided in DOE 5400.5. For example, the DOE 5400.5 generic surface activity cleanup criteria (developed on the assumption of building reuse) have been found to be inappropriate if a building is to be demolished rather than reused and the resulting debris are to be land disposed. In such cases, alternative risk-based surface activity cleanup criteria (referred to in DOE 5400.5 as "supplemental limits") that account for site-specific conditions and realistic future uses have been developed.

At several FUSRAP sites, implementation of authorized limits for uranium in soils or supplemental limits for surface activity coupled with other strategies has resulted in significant cleanup cost reductions, as reported in Table 7. The additional strategies used include (1) formation of a multidisciplinary management team to conduct a comprehensive analysis of site-specific circumstances and identify opportunities for innovative remediation strategies, cost reduction, and waste minimization; (2) proactive communication with site owners, regulators, and other stakeholders to develop effective partnerships, identify site-specific opportunities and constraints, and provide a forum for early and continuing discussions regarding potential remediation strategies; and (3) innovative application of technology to streamline the remediation process, reduce costs, and minimize waste generation.

**TABLE 7 Cost Savings at FUSRAP Sites**

<table>
<thead>
<tr>
<th>Site Name</th>
<th>New Approach Strategies*</th>
<th>Cost Estimate ($ Million)</th>
<th>Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Traditional Approach</td>
<td>New Approach</td>
</tr>
<tr>
<td>General Motors</td>
<td>(a), (b), (c), (d)</td>
<td>4.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Chapman Valve</td>
<td>(a), (b), (c), (d)</td>
<td>4.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Vention</td>
<td>(a), (b), (c)</td>
<td>11.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Aliquippa Forge</td>
<td>(a), (b), (c), (d)</td>
<td>5.7</td>
<td>5.0</td>
</tr>
<tr>
<td>New Brunswick Site</td>
<td>(d)</td>
<td>5.3</td>
<td>4.1</td>
</tr>
</tbody>
</table>

* New approach strategies include (a) supplemental limits; (b) multidisciplinary management team; (c) proactive communication with regulators and the public; and (d) innovative application of technology.

The following are examples of innovative applications of technology at FUSRAP sites that streamlined the remediation process, reduced costs, or minimized generation of wastes requiring off-site disposal:

1. Use of a pneumatically deployed, high-sensitivity, beta detector protected by a thin plastic membrane to perform in-situ post-remediation surveys of underground drainage systems. This approach, which significantly reduces the volume of investigation-derived wastes, was used at the General Motors site.

2. Use of a commercial rock crusher to process concrete and masonry building rubble into a soil-like material. After verifying that residual uranium levels in the crushed material are below site-specific authorized limits for uranium in soils and receiving state approval, the soil-like material has been beneficially used on-site as backfill or off-site as road construction material. This approach, which reduces the volume of concrete requiring off-site transportation and disposal and reduces the volume of on-site backfill material needed, was used at the Aliquippa Forge site and several other FUSRAP sites.

3. Use of a soil sorting system to identify and segregate soil that meets cleanup criteria. Such soil was beneficially used on-site as backfill at the New Brunswick site. The system reduced the volume of soil requiring off-site transportation and disposal and reduced the volume of on-site backfill material needed.

The DOE computer code RESRAD\(^{48}\) is typically used at FUSRAP sites when it is appropriate to derive site-specific authorized limits for uranium in soils. Scenarios used by the RESRAD code for making the dose to concentration conversions for these derivations are discussed below. Pursuant to Order DOE 5400.5, the dose is constrained to less than 30 mrem/yr for current-use and likely future-use scenarios and must not exceed 100 mrem/yr for any plausible future-use scenario.\(^{49}\)

For assessing dose using RESRAD, three potential exposure scenarios are normally considered: industrial worker scenario; resident scenario; and subsistence farmer scenario. For these scenarios, it is assumed that at sometime within 1,000 years, the site will be released for use without radiological restrictions. Potential radiation doses resulting from nine exposure pathways are considered: (1) direct exposure to external radiation from decontaminated soil material, (2) internal radiation from inhalation of contaminated dust, (3) internal radiation from inhalation of emanating radon-222, (4) internal radiation from ingestion of plant foods grown in the decontaminated area and irrigated with water drawn from a well located at the downgradient edge of the decontaminated area, (5) internal radiation from ingestion of meat from livestock fed with

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\(^{48}\) RESRAD computer code, Version 5.61 (released Aug. 28, 1995).

fodder grown in the decontaminated area and irrigated with water drawn from an on-site well, (6) internal radiation from ingestion of milk from livestock fed with fodder grown in the decontaminated area and irrigated with water drawn from an on-site well, (7) internal radiation from ingestion of fish from a pond downgradient from the decontaminated area, (8) internal radiation from incidental ingestion of on-site soil, and (9) internal radiation from drinking water drawn from an on-site well. If available, site-specific parameters are used in the RESRAD dose calculations for these pathways, otherwise RESRAD default values are used. The three scenarios are described below.

**Industrial Worker Scenario:** The industrial worker scenario assumes industrial use of the site. A hypothetical individual is assumed to work 8 hours per day at the site (6 hours working outdoors and 2 hours indoors), 5 days per week, 50 weeks per year. It is also assumed that the worker does not ingest water, plant foods, or fish obtained from the remediated area or meat or milk from livestock raised in the remediated area. The dose to the worker is assumed to be only from the remediated soil.

**Resident Scenario:** The resident scenario assumes that at some time in the future, the industrial activities at the site would be discontinued and the whole site would be transformed into a residential area. Over a period of 1 year a hypothetical resident is assumed to spend 50% of the time indoors in the remediated area, 25% of the time outdoors in the remediated area, and 25% of the time away from the site. The resident is assumed to ingest plant foods grown in a garden on the site. All water used by the resident for drinking, household purposes, and irrigation is from municipal sources that are not radiologically contaminated. For this scenario, it is assumed that no livestock are raised on the site for the production of meat and milk and that no pond is present to provide fish or other aquatic food.

**Subsistence Farmer Scenario:** The subsistence farmer scenario is similar to the resident scenario, in which a resident is assumed to ingest plant foods grown in the garden. However, under this scenario, the resident is a subsistence farmer who is also assumed to ingest meat and milk from livestock fed with forage grown on-site and to catch and consume fish and other aquatic organisms from an on-site pond. For this scenario, the groundwater drawn from a well located on-site is the only water source for drinking, household use, livestock watering, and irrigation.

### 3.1.2.2 Uranium Mill Tailings Remedial Action Project

From 1943 to 1970, much of the uranium ore mined in the United States was processed by private companies under procurement contracts with the U.S. Atomic Energy Commission (AEC). After fulfilling their contracts, many of the uranium mills closed and left large quantities of waste, such as uranium mill tailings, and abandoned mill buildings at the mill sites.

In the 1970s, direct gamma radiation, radon gas, and uranium decay products at the abandoned mill sites were determined to be potential health hazards. Congress passed the
Uranium Mill Tailings Radiation Control Act (UMTRCA) in 1978 in response to concerns raised about such potential hazards. The purposes of the UMTRCA provisions are to stabilize and control uranium mill tailings at designated inactive mill sites and to regulate uranium mill tailings at active processing sites. DOE is assigned responsibility, in consultation with USNRC, for stabilization and control of mill tailings at inactive processing sites and vicinity properties, USNRC is given authority to regulate uranium mill tailings at active processing sites, and EPA is required to establish standards for remediating and disposing of contaminated material from inactive uranium processing sites.

DOE established the UMTRA Project to comply with UMTRCA. The Environmental Restoration Division has responsibility through the Albuquerque Operations Office for implementing the UMTRA Project. DOE began remediation of the surface contamination (including uranium mill tailings and abandoned mill buildings) at inactive uranium mill tailings sites in 1983. Surface remedial actions have now been completed at 20 of the 24 inactive uranium processing sites and more than 5,000 vicinity properties covered by the project.50 Two of the four unremediated sites are located in North Dakota and will not be remediated by DOE because the State of North Dakota has declined to provide its statutorily required share of the cost.51 Surface remediation of the remaining two unremediated sites is expected to be completed in 1998.

In addition to the surface contamination present at UMTRA Project sites (i.e., mill tailings, soil, and structures), the groundwater is contaminated with metals (including uranium and radium) at all but one of the sites. However, active remediation of contaminated groundwater is expected to be necessary only at Monument Valley and Tuba City, Arizona.52 At the remaining UMTRA Project sites, groundwater contamination will be addressed passively through natural flushing and will be monitored in accordance with regulatory compliance actions.

The risk-based cleanup criteria in 40 CFR Part 192 for radium in soils and radium and uranium in groundwater were adopted through EPA’s administrative rulemaking process and serve as DOE release criteria. However, no cleanup criteria for uranium or thorium in soils were promulgated by EPA. Therefore, when such constituents are present at an UMTRA Project site, DOE must derive site-specific release criteria in accordance with Order DOE 5400.5 using dose-to-concentration conversions and the ALARA process.


At UMTRA Project sites, the DOE computer code RESRAD is typically used when it is appropriate to derive release limits for uranium or thorium in soils. In such cases, the scenarios modeled are the same as was reported for FUSRAP sites in Section 3.1.2.1 (p. 35).

DOE’s typical approach to meeting cleanup criteria at UMTRA Project sites has been to demolish all contaminated buildings; excavate all contaminated subsurface structures, tailings, and soil; and remove all resulting contaminated materials to an engineered disposal cell, which may be located either on-site or off-site. If the disposal cell is located on-site, the site is not released, but is retained by the DOE for long-term surveillance. If the disposal cell is located off-site, the UMTRA Project site may be released for restricted reuse after the USNRC certifies successful completion of the surface remediation. However, unrestricted use of each site not containing a disposal cell must await successful remediation of the groundwater.

3.1.2.3 Shippingport Decommissioning Project

The world’s first large-scale nuclear power plant, the Shippingport Atomic Power Station (SAPS), was located in Beaver County, Pennsylvania. It was built by the U.S. Atomic Energy Commission to demonstrate commercial use of the pressurized water reactor technology utilized in the U.S. Navy’s nuclear-powered submarines. The plant operated from 1957 until 1984. Its decommissioning, which was completed in December of 1989, was the first complete decontamination and decommissioning (D&D) of a power-producing reactor in the nation (i.e., all structures were demolished to 3 feet below grade). The SAPS D&D was also the first major remedial action project involving residual radionuclides other than uranium and uranium decay products. Principal radionuclide contaminants were cobalt-60, antimony-125, and cesium-137.

The decommissioning of the SAPS was performed by General Electric Company (the decommissioning operations contractor, or DOC) beginning in September 1984. In October 1984, DOE instructed the DOC to perform a sensitivity analysis to estimate costs associated with reducing future doses from the site to no more than 100, 25, and 10 mrem/yr to any member of the public. After reviewing the results, DOE established a site release standard at 100 mrem per year total committed effective dose equivalent to the maximum exposed individual of the general public under the worst-case scenario. In addition, the DOC was directed to follow the SFMP guidelines are generic, site-independent guidelines taken from existing radiation protection standards. They include the following:

1. Generic dose limit of 100 mrem/yr averaged over the lifetime of any individual member of the general public;
2. Hot spot limits;
3. Exposure rate limit of 20 μR/h in occupied or habitable structures;
4. Surface contamination limits as specified by Table 1 in USNRC Regulatory Guide 1.86; and
5. Average and maximum contact dose rates of 0.2 mR/h and 1 mR/h, respectively.
Guidelines for Residual Activity at Remote Surplus Facility Management Program Sites and apply the philosophy of ALARA. Authorized limits higher than the SFMP guidelines were allowed under given exceptional circumstances.

The first step in the process for implementing the release standard was to define all the exposure scenarios to be considered and the methodology for the application of the ALARA philosophy. Then pathway analyses were conducted with an in-house computational technique to calculate the concentrations of residual radioactive material that could remain without causing the annual dose limits (and ALARA values) to be exceeded. These concentrations were called limiting conditions. Finally, radiological surveys were conducted (and documented) to verify that the conditions on-site complied with the limiting conditions.

Four exposure scenarios were considered to make the dose-to-concentration calculations: (1) residential scenario, (2) occupancy scenario, (3) souvenir scenario, and (4) exposed slab scenario. The DOC considered all other scenarios to be either less probable than these or less restrictive. Descriptions of the four exposure scenarios and the derived release criteria for each follow. Figure 3 depicts the scenarios and indicates their respective release criteria.

**Residential Scenario:** This scenario addresses exposure pathways resulting from contaminated soil, occupiable monolithic concrete substructures, and broken and powdered concrete. It assumes that a house is built on the remediated SAPS site (including excavation of a basement down to a depth of 3 meters below the ground surface). A family is assumed to reside in the house, grow a garden, raise livestock, and use water from an on-site well. The release criteria derived from this scenario were:

- **Top 3 meters of soil:** The average concentration of cobalt-60, the limiting radionuclide, was less than 6 pCi/g in the top 3 meters of soil. Vertical averaging is limited to the top 0.15 meters and each 1 meter thereafter; horizontal averaging is limited to 100 m².

- **Other soil:** The average concentration must be less than 100 pCi/g cobalt-60. Horizontal averaging is limited to 100 m². Vertical averaging is limited to 3 meters. This limit effectively restricts the concentration of any isotope in the groundwater because the contamination of groundwater occurs through leaching of the trace contaminants in the soil.

- **Embedded Pipe:** Contamination in an embedded pipe was included with that in the adjacent concrete, and the total was shown to meet the limits specified for that depth of soil. The maximum volume for averaging was 1 m³ for each 1-meter length of pipe. Two provisions

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supplement these release criteria by placing restrictions on the magnitude and extent of hot spots allowed and by specifying the modifications required when one is confronted with mixtures of isotopes. These provisions are:

- **Hot Spots**: Concentrations up to 10 times the average are allowed, provided that the area bounding the hot spot does not exceed the value determined using the following relationship:

\[
\text{Maximum area of hot spot} = \frac{100 \text{ m}^2 \times \text{average concentration}}{\text{hot spot concentration}}^2
\]

- **Mixtures of Radionuclides**: If a radionuclide mixture is present, a region or area within a region can be released when the following sum is < 1.0

\[
\sum \text{concentration radionuclide } \times \text{release limit of radionuclide for region}
\]

This provision ensures that the dose to a future resident will not exceed the limiting conditions even if more than one radionuclide is present.

**Shippingport Decommissioning Scenarios and the Limiting Conditions for the Release**

![Diagram showing shippingport derived release criteria](FIGURE 3 Shippingport Derived Release Criteria)
Occupancy Scenario: This scenario addresses exposure pathways resulting primarily from use of occupiable monolithic concrete substructures. It assumes that an abandoned concrete substructure, which is open at the top somewhere within the top 3 meters of the ground surface, is excavated and turned into an office having 10 m² of floor space and 3-meter walls. Radiation exposure is calculated assuming that the office is occupied 40 hours per week during 50 weeks per year. The derived release criteria for occupiable abandoned concrete substructures under this scenario were:

- **Abandoned Substructure Walls**: Average exposure rate of less than 0.05 mR/h at 1 meter from the wall of any abandoned substructure that could conceivably be occupied in the future.

- **Hot spots**: Maximum exposure rate of 1 mR/h on contact, provided that the average contact exposure rate within the area of the hot spot (as defined in the residential scenario) would not exceed 0.2 mR/h.

Souvenir Scenario: This scenario addresses exposure pathways resulting from the presence of pieces of broken concrete near the surface. It assumes that a person digs up a piece of contaminated concrete and takes it home for a souvenir. The souvenir of concrete is assumed to weigh less than 50 kg and be found within 3 meters of the ground surface. Residual contamination would only be expected on one surface. The exposed person is assumed to live 2 meters from the souvenir for 18 hours per day, all year around. The derived release criteria for broken concrete pieces under this scenario were:

- Average exposure rate not to exceed 2 mR/h at contact. A 0.25-meter cube of concrete emitting less than 2 mR/h at contact will emit less than 0.015 mR/h at 2 meters.

Exposed Slab Scenario: This scenario addresses exposure pathways resulting from the presence of unoccupiable monolithic concrete substructures. It assumes that a portion of the concrete substructure (i.e., a slab) located within 3 meters of the ground surface is exposed by excavation and is visited intermittently by a curiosity seeker before being covered again. For this scenario, it is assumed that the exposed slab is not amenable to long-term occupancy. The slab is assumed to have a minimum area of 2 m², and a minimum thickness of 1 meter. The visitor is assumed to spend 168 hours (7 days) at the slab while it is exposed. The derived release criterion for unoccupiable abandoned concrete substructures under this scenario was:

- Average dose rate not to exceed 0.6 mrem/h at contact (5 centimeters).

Reducing doses to ALARA values at Shippingport was also required as part of the release criteria. Actions with cost-to-dose ratios in excess of $2,000 per person-rem were ordinarily not
taken, while actions with lower cost-to-dose ratios were pursued. For detailed information on the ALARA process applied at Shippingport, see DOE/SSDP-0024.55

3.1.2.4 Decontamination of the South-Middle and South-East Vaults in the 317 Area at Argonne National Laboratory-East

The south-middle and south-east vaults in the 317 Area of Argonne National Laboratory-East (ANL-E) were used from the late 1940s to the early 1980s for temporary storage of radioactive waste materials. Each vault is approximately 3 meters deep, 4 meters wide, and 30 meters long and is equipped with a series of removable 30-cm-thick concrete shield blocks. It is anticipated that the vaults will remain under the institutional controls of ANL-E for at least 100 years, during which time the area will be used for industrial purposes. After 100 years, the vaults may be released for unrestricted use.

The generic release criteria and all-sources dose standard in Order DOE 5400.5 apply to the south-middle and south-east vaults. However, DOE 5400.5 does not establish generic release criteria for americium-241, cesium-137, and strontium-90 in soils. Since these radionuclides were present in soils surrounding the vaults, it was necessary to calculate DCGLs for them and derive site-specific cleanup criteria consistent with the ALARA process. Although DCGLs are typically calculated under DOE 5400.5 on the basis of a single-source dose constraint of 30 mrem/yr,56 in anticipation of possible regulatory changes that might influence this assumption (see Sections 2.3.2 [p. 13] and 2.3.3 [p. 17]), DCGLs for americium-241, cesium-137, and strontium-90 were calculated for the south-middle and south-east vaults on the basis of a dose constraint of 15 mrem/yr. Also, since unrestricted release of the vaults is not anticipated until 100 years of institutional control have passed, the 15-mrem/yr dose constraint was assumed to apply after 100 years rather than at the end of D&D activities.

The RESRAD computer code was used to estimate maximum radiation doses that could result from radiation emitted by the residual radioactive materials. For this purpose, conservative estimates of the potential radiation doses from each residual radionuclide were made by assuming five homogenous contamination zones (i.e., walls, concrete fines, shield blocks, floor and trough, and soil). Each zone was assigned a specified thickness and an area of 200 m². This assumption was used to facilitate modeling of the localized and unevenly distributed contamination. The radionuclide concentration used for each contamination zone was the highest of the measured


56 Response to Questions and Clarification of Requirements and Processes: DOE 5400.5, Section II.5 and Chapter IV Implementation (Requirements Relating to Residual Radioactive Material), DOE Assistant Secretary for Environment, Safety and Health, Office of Environmental Policy and Assistance (EH-41) (Nov. 17, 1995).
concentrations in the zone. Two scenarios were considered: (1) an industrial worker with current industrial land use and indefinite institutional control of the site and (2) a hypothetical intruder residing at the site after 100 years of institutional control has ended. For the 15 mrem/yr dose constraint, the single-radionuclide, maximum-allowed concentrations established for americium-241, cesium-137, and strontium-90 in soils were 92, 94, and 470 pCi/g, respectively. The scenarios are described below.

**Industrial Worker Scenario:** Under this scenario, which represents current land use, a worker would be exposed to radiation emitted from radionuclides contained in the residual radioactive materials in and under the vaults. The worker is assumed to work 8 hours per day at the site (6 hours outdoors and 2 hours indoors), 5 days per week, 50 weeks per year.

**Intruder Scenario:** This scenario assumes that an individual would move directly onto the site after 100 years of institutional control of the site ends. The individual is assumed to spend 50% of his time indoors; 25% of his time outdoors; and 25% of his time away from the site over a 1-year period. It is assumed that the individual would drill a well 15 centimeters in diameter directly through the vaults to the water table 20 meters below the surface. Exhumed materials from drilling would be brought to the surface and sprayed on the 200-m² contaminated zone, and the individual could be exposed to radiation remaining in the materials after 100 years of radioactive decay. Hence, under this scenario a sixth homogenous contamination zone (i.e., exhumed radioactive material) has been added to the potential sources of radiation dose to the individual occupying the site.

The south-middle and south-east vaults underwent localized D&D in April 1996. The highly contaminated concrete and soil were removed and the upper sections of the vault walls were demolished and backfilled with clean soil.

### 3.1.2.5 Decommissioning of HWCTR at Savannah River Site

The Heavy Water Components Test Reactor (HWCTR) facility is located on approximately 2 acres in the northwestern quadrant of the Savannah River Site (SRS), on property known as U-Area. U-Area is 3 miles from the nearest SRS property boundary and about 2.5 miles from any major nuclear materials production facilities on the site. Cooled and moderated with pressurized heavy water, this uranium-fueled nuclear reactor was designed to test fuel assemblies for heavy water power reactors. It was operated for this purpose from March 1962 to December 1964. The area east of the HWCTR facility is wooded. Adjoining the HWCTR property to the west is the site security force headquarters. Other administrative buildings of B-Area lie nearby.

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57 For detailed information on the radionuclide breakdown for each of five contamination zones see: Hong, K., "Radiological Assessment for the South-Middle and Southeast Vaults in the 317 Area at ANL," memorandum from Hong (ANL-E) to R. Coley (ANL-E) (May 24, 1996).
The reactor is housed in a steel-domed, 70-foot-diameter, 65-foot-tall containment building. The lower part of this building is made of reinforced concrete that extends approximately 61 feet below grade, and the floor of the lowest level is at approximately 52 feet below grade.

DOE is currently planning the decommissioning of the HWCTR facility. The preferred decommissioning alternative is dismantlement, and the all-sources dose standard and generic release criteria specified by Order DOE 5400.5 apply (see Appendixes A and B). However, Order DOE 5400.5 does not establish specific release criteria for several radionuclides of concern at the HWCTR. Therefore, release limits for such radionuclides must be derived consistent with the ALARA process. To accomplish this, DCGLs have been calculated using the RESRAD and RESRAD-BUILD\(^58\) computer codes. Two exposure scenarios, which are described below, were analyzed.\(^59\)

**Scenario A:** Scenario A assumes use of the site as a family farm. A hypothetical individual is assumed to spend 50% of his time indoors in a house built on the remediated HWCTR site. Twenty-five percent of his time would be spent outdoors on the site, and the remaining 25% of his time would be spent away from the site. The resident is assumed to eat homegrown produce and meat and milk from livestock fed with forage grown on-site. Groundwater drawn from a well located on the site would be the only source of water for drinking, household use, and irrigation.

**Scenario B:** Scenario B assumes that an administrative building would be constructed on the HWCTR site. It is assumed that the building would have a 4-meter-deep basement that incorporates as one of its walls an existing wall of the HWCTR underground structure. It would not be plausible for the curved outer walls of the containment building, the sides of the small spent fuel basin, or the opening in the reactor biological shield to be utilized in such an application. Under this scenario, a hypothetical individual was assumed to work inside the building basement for 8 hours per day, 5 days per week, 50 weeks per year.

### 3.1.2.6 Decommissioning of the Experimental Boiling Water Reactor at Argonne National Laboratory-East

The Experimental Boiling Water Reactor (EBWR) was built at ANL-E as a test reactor to show the feasibility of operating an integrated power plant using a direct-cycle boiling water reactor as a heat source. Experimental work on EBWR was completed in July 1967, and the plant was shut down permanently and placed in a dry lay-up condition. Surveillance and maintenance of the facility continued throughout the dry lay-up period. In August 1979, accessible areas of the EBWR containment building were radiologically surveyed. This survey showed that significant


levels of cobalt-60 were present at various locations within the building. Iron-55 and nickel-63 were also radionuclides of concern, and trace amounts of many other radionuclides were present. In the first quarter of fiscal year 1986, decommissioning of the reactor was initiated. (Several outbuildings had been either demolished or converted for reuse by 1980.) The decommissioning alternatives were either decontamination or storage of the facility in the dry lay-up condition for an indefinite period (safe storage). Because of the deteriorating condition of the building, the inherent radiological risk, the need to use the area occupied by the facility for ANL-E programmatic purposes, and escalating waste disposal and decontamination activity costs, DOE rejected the indefinite safe storage option. Instead, ANL-E was assigned the lead role in decontaminating the EBWR for future unrestricted use of accessible areas by ANL-E programs.

The radioactive release criteria established for accessible areas in the EBWR were set at the Order DOE 5400.5 surface activity limits (see Appendix B). Actions to meet these limits included decontamination or removal as radioactive waste of all reactor systems and associated equipment and removal of exposed concrete to the point where residual activity was less than the limits. Areas in the EBWR facility where reasonable decontamination efforts still left residual radioactivity above the release criteria were capped (either with wood, metal, concrete, or a combination of these) to make them inaccessible.60

Dose assessments were performed to confirm that, following decontamination and capping, neither an ANL-E employee occupying the decommissioned EBWR reactor vessel cavity shell for programmatic purposes nor a member of the public would receive a dose exceeding 15 mrem/yr. The RESRAD code was used to assess the anticipated dose to a member of the public, and the RESRAD-BUILD code was used to assess the anticipated dose to an ANL-E employee. The two exposure scenarios are described below.

**Worker Exposure Scenario:** This scenario assumes that personnel will work in the EBWR reactor vessel cavity shell during D&D activities (workers installing the caps) and that after decommissioning ANL-E employees will work in the shell for programmatic purposes. The reactor vessel cavity shell is represented in this scenario by a 21.6-meter-square two-room building, with one upper and one lower room. The upper room represents the reactor vessel cavity shell above the main level, while the lower room represents the subterranean levels. The floor area of each room was chosen to equal the EBWR reactor vessel cavity shell floor area, and the room heights correspond to the height of the shell from the main floor up for the upper room and from the 4th-level floor to the main floor for the lower room. Under this scenario, it is

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61 Fifteen mrem/yr was chosen as the target dose for the same reason that 15 mrem/yr was the chosen dose constraint in calculating DCGLs for the ANL-E south-middle and south-east vaults as explained in Section 3.1.2.4 (p. 42) above.
assumed that the contaminated concrete comprising the reactor vessel cavity shell is the only source of radioactivity.

**Public Exposure Scenario:** This scenario assumes that 177 m³ of contaminated concrete is removed from the surface of the EBWR reactor vessel cavity shell during decontamination (e.g., by scabbing), rubblized (as a worst-case scenario), and placed in an aboveground off-site solid waste landfill. The rubblized concrete is assumed to be spread over an area of 1,770 m² to a depth of 10 centimeters with either no cover at all, or a 1-foot soil cover. A 1-foot soil cover is assumed because commercial solid waste landfills are usually covered at the end of each day with 1 foot of soil. It is further assumed that after the landfill closes, the surface will be used as a family farm. Under this scenario, the residents are assumed to ingest a portion of their diet from plant foods grown in the garden and from meat and milk produced by livestock fed with forage grown on-site. It is assumed that groundwater drawn from a well located on-site is the only water source for drinking, household use, livestock watering, and irrigation.

ANL-E health physics procedures were followed in conducting an EBWR release verification survey after decommissioning. The specific objectives of the survey included ensuring:

1. Average surface contamination levels for each survey unit were within the authorized limits.
2. Small areas of residual activity (hot spots) did not exceed three times the guideline value. The average activity within the 1-m² area containing a hot spot was within the guideline.
3. Reasonable efforts were made to clean up removable activity, and removable activity did not exceed the guideline value.
4. Exposure rates in locations that could be occupied were less than 5 µR/h above background. Exposure rates were measured at 1 meter from floor/lower wall surfaces and were averaged over floor areas, not to exceed 10 m². The maximum exposure rate at 1 meter did not exceed 10 µR/h above background.
5. The maximum dose rates associated with surface contamination resulting from beta-gamma emitters did not exceed 0.2 mR/h at 1 centimeter.
6. Reasonable efforts were made to identify and remove all activated structural material.
7. Reasonable efforts were made to identify and remove contaminated paint or coatings on the EBWR shell structure.

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Completion of the EBWR decommissioning project signaled release of the EBWR shell and surrounding area from EM-40 control. At this time, initial preparations by EM-30 for converting the facility to an interim transuranic waste storage facility have begun.

3.1.2.7  Weldon Spring Site

The Weldon Spring site in Missouri is a large site containing an industrial complex previously used to process uranium and explosives. The site consists of an 88-hectare (217-acre) chemical plant area and a 3.6-hectare (9-acre) limestone quarry, both of which are chemically and radiologically contaminated as a result of past processing and disposal activities. Nitroaromatic explosives were processed by the U.S. Department of the Army at the chemical plant area during the 1940s, and radioactive materials were processed by DOE’s predecessor agency, the U.S. Atomic Energy Commission, during the 1950s and 1960s. During the latter period, waste slurries were piped to four on-site raffinate pits that were excavated from existing clay. A small amount of solid waste was placed in one of the pits and in two dump areas on-site; most solid waste was disposed of in the quarry, which had also been used by the Army for waste disposal. An ash pond received fly ash slurry from the on-site power plant. As a result of these activities, low levels of radioactive and chemical contaminants are now present in soil at the chemical plant area, and more than 40 buildings and structures that were part of the chemical plant contain varying degrees of contamination. The radionuclides of concern are uranium-238, thorium-232, thorium-230, radium-228, and radium-226.

DOE is responsible for cleanup activities at the Weldon Spring site, which is listed on the CERCLA National Priorities List. Under the provisions of CERCLA, Order DOE 5400.5 is an ARAR. Hence, the all-sources dose standard and the generic release criteria specified by Order DOE 5400.5 (see Appendices A and B) for residual radium-226, radium-228, thorium-230, and thorium-232 in soil at DOE sites that will be released for unrestricted use are guideline cleanup levels. Such guidelines require that the combined activity of all four radionuclides not exceed 5 pCi/g, averaged over the first 15 centimeters of soil below the surface, and not exceed 15 pCi/g, averaged over 15-centimeter-thick layers of soil that are more than 15 centimeters below the surface. Also, the guidelines include procedures for addressing nonsecular equilibrium conditions (between thorium-232 and radium-228 and between thorium-230 and radium-226). Since the background concentration of radium-226, radium-228, thorium-230, and thorium-232 in the vicinity of the Weldon Spring site is 1.2 pCi/g, applicable surface and subsurface concentration limit guidelines pursuant to Order DOE 5400.5 are 6.2 pCi/g and 16.2 pCi/g, respectively.

No federal or state standards are available for uranium-238 in soil. Therefore, in accordance with the provisions of Order DOE 5400.5, results of a site-specific risk assessment were used in combination with a preliminary ALARA analysis to develop a site-specific soil cleanup criterion for uranium-238. The RESRAD computer code, which implements the methodology prescribed
in Order DOE 5400.5 for determining residual radioactive material guidelines, was used. The scenarios considered are described below.

**Surface Soil Scenario:** This scenario assumes that institutional controls might be lost at some time in the future and unrestricted use of the area could result. Because recreational and residential uses are the most likely long-term land uses in the area, it is assumed that a recreational visitor, ranger, or resident (including a resident farmer) could eventually occupy the site. It is also assumed that radon gas would be generated from subsurface radium and would enter a structure through the basement or foundation slab.

**Subsurface Soil Scenario:** Under this scenario, the general issue of subsurface contamination was addressed by two different analyses. First, a redistribution scenario was evaluated in which subsurface soil was excavated (e.g., for a basement) and then redistributed on the surface at that location. Thus, an individual (e.g., a resident) could be exposed to previously buried contaminants that had been moved to the surface during the excavation. Second, screening-level calculations were made to estimate groundwater concentrations that could result from soil leaching and to assess potential health effects if that groundwater was ingested.

The calculated annual dose to a farmer in the ash pond area, where the average uranium-238 concentration in soil was 190 pCi/g, was 42 mrem/yr. Doses were also calculated for uranium-238 concentrations in soil of 120, 60, 30, and 15 pCi/g, which could be achieved at the Weldon Spring site by removal of contaminated soil and backfill with clean soil. These actions would reduce and delay the dose after remediation due to shielding and erosion. Table 8 shows the relationship of target uranium-238 concentrations in soil to cost and dose. On the basis of these results, a soil cleanup target of 120 pCi/g without backfill was selected, with an ALARA goal of 30 pCi/g. State and EPA personnel have been involved with developing the proposed site cleanup plan.

**TABLE 8** Relationship of Target U-238 Concentrations in Soil to Cost and Dose at Weldon Spring Site

<table>
<thead>
<tr>
<th>U-238 concentration (pCi/g)</th>
<th>Volume (yd³)</th>
<th>Backfill (ft)</th>
<th>Cost ($ Million)</th>
<th>Annual dose (mrem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>190</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>42</td>
</tr>
<tr>
<td>120</td>
<td>11,000</td>
<td>0</td>
<td>0.58</td>
<td>25 @ present</td>
</tr>
<tr>
<td>60</td>
<td>26,000</td>
<td>1.0</td>
<td>1.4</td>
<td>6.7 @ 800 years</td>
</tr>
<tr>
<td>30</td>
<td>37,000</td>
<td>0</td>
<td>2.0</td>
<td>6.7 @ present</td>
</tr>
<tr>
<td>15</td>
<td>50,000</td>
<td>2.0</td>
<td>3.0</td>
<td>0.38 @ 10,000 years</td>
</tr>
</tbody>
</table>

3.2 Non-Real Property

3.2.1 Release Processes

3.2.1.1 Draft Handbook for Controlling Release for Reuse or Recycle of Non-Real Property Containing Residual Radioactive Material

DOE recently issued for interim use and comment a draft DOE standard concerning the release of non-real property containing residual radioactive material. The draft standard outlines a 10-step process that will assist DOE Operations Office and contractor personnel in ensuring that the actions (see Section 1.2) required by Order DOE 5400.5 prior to releasing non-real DOE property for reuse or recycle have been appropriately completed, and that radiological doses to the public from the released materials will meet applicable regulatory standards and be ALARA. Figure 4 provides an overview of the 10-step process. The draft standard recommends actions that guide field personnel in implementing each step.

3.2.1.2 Decision Methodology for Fernald Scrap Metal Disposition Alternatives

The DOE Fernald Environmental Management Project (FEMP) has developed a decision methodology based on life cycle analysis to evaluate the costs and benefits of recycling and reusing radioactive scrap metal (RSM), rather than disposing of it in an approved burial site. The Decision Methodology for Fernald Scrap Metal Disposition Alternatives takes into consideration both quantitative and qualitative factors in order to evaluate three “threshold criteria”: (1) protectiveness of human health and the environment, (2) compliance with applicable or relevant and appropriate requirements (ARARs) and consistency with the Record of Decision (ROD), and (3) cost within 25% of the lowest-cost alternative that meets the first two criteria. The methodology includes both the analytical requirements to develop defensible values for a comprehensive set of performance measures and the structure for using the performance measures to compare and rank alternative proposals.

The methodology is divided into two phases: the life cycle analysis phase, in which the possible impacts of each of the candidate alternatives are assessed, and the decision phase. In the first phase, the objectives and program scope are defined, the RSM disposition alternatives are identified, performance measures are specified, and the impacts of the alternatives are described in terms of the performance measures. In the decision phase, the methodology will aid decision makers in the comparison of alternatives and the selection of the preferred alternative. The FEMP experience implementing the first phase of the methodology was presented at the 1997 Waste

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64 Draft Handbook for Controlling Release for Reuse or Recycle of Non-Real Property Containing Residual Radioactive Material, DOE-HDBK (for interim use and comment) (June 1997).
RELEASE PROCESS
FOR DOE NON-REAL PROPERTY
CONTAINING RESIDUAL RADIOACTIVE MATERIAL

1. Describe property.
   - Can property be certified as not contaminated?
     - Yes
       - 10 CFR 834 does not apply.
     - No
       - Release property.

2. Do seemingly applicable release limits exist?
   - Yes
     - Are existing release limits appropriate?
       - Yes
         - Release property.
       - No
         - Define release limits needed.
   - No
     - Define release limits needed.

3. Define release limits needed.

   - Deriving Release Limits
     - Defining alternatives
     - Analyzing alternatives
     - Selecting preferred alternative
     - Documenting results

5. Compile and submit application for DOE Operation Office approval.


7. Implement approved limits.

8. Conduct surveys/measurements.

9. Does property meet applicable, appropriate, existing release limit?
   - Yes
     - Release property.
   - No
     - End alternative to release.


EXHIBIT 1

FIGURE 4  Release Process for DOE Non-Real Property Containing Residual Radioactive Material [Source: Draft Handbook for Controlling Release for Reuse or Recycle of Non-Real Property Containing Residual Radioactive Material (June 1997)]
Management Conference \(^{65}\) The life cycle analysis phase of the methodology, Phase 1, comprises six steps that, when combined, identify and assess all benefits and costs that result from a course of action over the entire period of time affected by the action and provide the results in a form that will promote sound decision making. These six steps include:

1. Define the nature of the decision and program scope,
2. Specify objectives and performance measures,
3. Identify alternatives,
4. Define analytical methods,
5. Assess the impacts of the alternatives, and

An important aspect of implementing the life cycle analysis phase of the decision methodology at FEMP has been the extent of stakeholder involvement. Stakeholder input was solicited through workshops with the public and regulators. Comments were solicited on the recycling methodology and on scoring of alternatives and the weighting factors used to express preferences among competing objectives.

Phase 2 of the methodology employs tools to aid decision makers in evaluating performance measures in the comparison of alternatives and the selection of the preferred alternative. One such tool is the multiattribute value theory (MAVT), which can be used as a method for analyzing tradeoffs between competing objectives. The MAVT, like many other decision methodologies, contains the following operational steps:

1. Define alternatives and criteria,
2. Evaluate each alternative separately on each criterion,
3. Assign weights to the criteria,
4. Aggregate the criteria weights and the single-criterion evaluations of the alternatives to obtain an overall measure of value or worth, and
5. Conduct sensitivity analyses and making recommendations.

The FEMP will be using the MAVT during Phase 2 of the decision methodology, but has not yet completed this phase.

3.2.2 DOE Site-Specific Approaches

3.2.2.1 Copper Coil Windings, Lawrence Berkeley Laboratory

In California, DOE’s Lawrence Berkeley Laboratory proposed to transfer slightly activated copper from its decommissioned cyclotron to a scrap metal dealer for recycling. The more highly

contaminated portions of the copper were removed before the action to recycle was analyzed. An
environmental assessment (EA) was prepared to support an application to DOE for approval of
authorized limits and to address the proposed recycle action, which was not covered under
previous NEPA documents.

The slightly activated copper consisted of 140 metric tons of cyclotron coil windings having
activities ranging from 0 to 20 pCi/g, with an average activity of 3 pCi/g. The copper contained a
total activity of approximately 0.42 mCi of cobalt-60. If the total amount of cobalt-60 in the
140 metric tons could be concentrated into a single small unshielded source, the dose rate at
1 foot from the source would be about 5.5 mrem/h. About 1.5 pCi/g of nickel-63 (half-life 92
years, beta emitter) was also present, but was of little radiological importance.

The California Department of Health Services (DHS) considered the copper to be a
nonradioactive material on the basis of its activity. Therefore, the DHS approved burial of the
copper as ordinary waste. However, DOE considered the copper a valuable resource that could
be sold as scrap for about $0.80 per pound (or approximately $247,000 for the 140 metric ton
lot) and recycled.

Five alternatives to the proposed action were evaluated in the EA. They included no action,
recycle for reuse at a DOE facility, sale/gift to a foreign government, disposal at a local sanitary
landfill, and disposal at the Hanford low-level waste burial site. The potential radiological effects
of the proposed action were calculated with the IMPACTS Code. It was assumed that the
slightly activated copper would be processed at only one facility. IMPACTS assumes that 20% of
the activated material will be lost to waste streams during reprocessing and disposed and that the
copper and the extraneous material will be contaminated at the same level. IMPACTS was used
to estimate the dose equivalents from recycling the slightly activated copper for use in home
wiring and plumbing and the dose equivalents to transportation workers while trucking the
material to the processing and disposal facilities. Other possible reuse scenarios considered for
the copper included use in alignment yoke magnets in video display terminals and in jewelry.

For the purpose of the cost comparison portion of an ALARA analysis, the monetary
equivalent value for a unit of collective dose (i.e., the cost-to-dose relationship) can vary. Typical
levels used range from $1,000 per person-rem to $10,000 per person-rem, although values
outside this range have also been considered. The ALARA analysis for the proposed release of
activated copper was performed with an assumed cost-to-dose relationship of $10,000 per
person-rem. This value is higher than DOE’s suggested cost-to-dose range of $1,000 to $6,000
per person rem, but was selected recognizing that the choice of $10,000 per person-rem or
$1,000 per person-rem would make no difference in the result of the analysis. This situation is

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67 Estimating Costs for Man-rem Exposures, DOE Office of Waste Management,
due to the fact that the potential individual and collective doses are insignificant compared with other factors in the analysis. As a result, it was not considered reasonable to expend resources to accurately define the monetary equivalent in this case. Hence, the conservative cost-to-dose relationship of $10,000 was selected as a worst-case estimate. Table 9 summarizes the costs and dose monetary equivalents for the copper disposal action alternatives.

The public and regulators provided input into the decision-making process as part of the review of the Finding of No Significant Impact (FONSI).

TABLE 9 Summary of Costs and Dose Monetary Equivalents

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Dose Monetary Equivalent*</td>
<td>($720.00)</td>
<td>($1.15)</td>
<td>($1.40)</td>
<td>($0.47)</td>
<td>($0.03)</td>
<td>($0.03)</td>
</tr>
<tr>
<td>Savings/(Cost) 1993 Dollars</td>
<td>$246,960</td>
<td>($1,000/year)</td>
<td>($323,370)</td>
<td>($30,000)</td>
<td>($235,300)</td>
<td>($4,245)</td>
</tr>
<tr>
<td>Resultant Monetary Equivalent Saving/(Cost)</td>
<td>$246,960</td>
<td>($1,000/year for as many years as the copper remains in storage + $1)</td>
<td>($323,370)</td>
<td>($30,000)</td>
<td>($235,300)</td>
<td>($4,245)</td>
</tr>
</tbody>
</table>

* The dose monetary equivalent represents the "cost" of the collective public radiation dose resulting from an alternative. As costs, dose monetary equivalents are shown in parentheses.

Source: Environmental Assessment for the Recycling of Slightly Activated Copper Coil Windings from the 184-inch Cyclotron at Lawrence Berkeley Laboratory, DOE/EA-0851, DOE (Oct. 1993).

3.2.2.2 Release of Non-Real Property at FUSRAP Sites

FUSRAP sites have been innovative in recent years in identifying protective, yet cost-effective, remediation strategies that have contributed to lower total site remediation costs. Among such strategies have been several involving the unrestricted release of non-real property. For example, at several sites containing significant amounts of structural steel or scrap metal potentially suitable for recycle, FUSRAP has awarded fixed-price subcontracts for building demolition that specify that materials from such demolition must be recycled when practicable. In these cases, Order DOE 5400.5 surface contamination guidelines (see Appendix B) have been used as release criteria. Another example involves the use of a commercial rock crusher to reduce volumes of concrete, brick, and masonry from demolished buildings. After verification that residual uranium levels in the crushed material are below site release criteria for uranium in soils,

and following coordination with state agencies as appropriate, the crushed material has been released from at least one site for use as road construction material. At other sites, cleared, crushed material has been used as on-site fill. The cost savings from this innovative application of technology are estimated to have exceeded $4 million throughout FUSRAP.\(^{69}\)

### 3.2.3 Telephone Survey Results

A poll of DOE sites was conducted for the purpose of this report to investigate existing programs and procedures across the DOE complex for releasing non-real property contaminated with residual radioactive material. The majority of sites contacted (see Table 10) indicated that they use the generic surface activity guidelines in Order DOE 5400.5 for determining whether materials can be released off-site for reuse. All sites indicated having procedures in place for performing comprehensive surveys of items that may be potentially contaminated. Results of the surveys are documented before release of any non-real property and are kept on file at the site. Most sites indicated that non-real properties, including scrap metal, office furniture, supplies, and scrap wood, have had only barely detectable levels of radioactivity when released and that decontamination is performed to remove radioactivity to the extent possible before release. Past practice has been to store or dispose of slightly radioactive materials that exceed the generic surface activity guidelines and cannot be cost-effectively decontaminated at low-level waste sites, such as Hanford and the Idaho National Engineering and Environmental Laboratory (INEEL).

Only a few DOE sites have released non-real properties with residual contamination levels above the generic guidelines in Order DOE 5400.5. Three sites (Mound, INEEL, and ANL-W) indicated that slightly contaminated scrap metal (steel and mixed-waste lead) has been transferred to Scientific Ecology Group, Inc. (SEG) for smelting, but such transfers are not considered to be releases from DOE control. Slightly radioactive metal at ANL-E has been released to a USNRC-licensed vendor for recycle into shielding blocks.

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\(^{69}\) Id.
### TABLE 10  DOE Sites Contacted Regarding Programs and Procedures for Making Non-Real Property Releases

<table>
<thead>
<tr>
<th>Site Contact Person</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Karen King, P2 Coordinator, Oakland, Calif.</td>
<td>See <em>Environmental Assessment for the Recycling of Slightly Activated Copper Coil Windings from the 184-inch Cyclotron at Lawrence Berkeley Laboratory</em>, DOE/EA-0851, DOE (Oct. 1993). Releases of steel and iron are planned similar to the release of copper described therein.</td>
</tr>
<tr>
<td>George Goode, P2 Coordinator, BNL</td>
<td>Use DOE 5400.5 as criteria for free release. Has released metals below criteria to Crestwood Metal. Referred to Mike Gaucci, head of scrap metal recycling program 516-344-2976.</td>
</tr>
<tr>
<td>Ken Isakson, Waste Minimization Coord., FERMI</td>
<td>All non-real materials are routinely surveyed, but none are identified as contaminated. No releases done for site.</td>
</tr>
<tr>
<td>Scott Larson, Environmental Head, Princeton Plasma Physics Laboratory (PPPL)</td>
<td>Use DOE 5400.5 as guideline, but any material that has been released so far has been non-contaminated. Contaminated material is sent to Hanford or decontaminated for release.</td>
</tr>
<tr>
<td>Larry Burke, Health Physics, ANL-W</td>
<td>Use DOE 5400.5. Materials below criteria are free released. Contaminated materials go to INEEL for low-level waste disposal. Plan on sending slightly contaminated lead to SEG for smelting. Lead is mixed waste. Call Rand Watson for details at 208-526-7102.</td>
</tr>
<tr>
<td>Frank Schmaltz, Mound Project</td>
<td>Was aware of two cases where slightly contaminated metals were released to SEG for recycle. Call Bill Naumann 937-865-3515 (mixed waste lead), and Sam Cheng 937-865-4778 (metals).</td>
</tr>
<tr>
<td>Phil Egidgi, ORNL, Grand Junction</td>
<td>UMTRA does not have specific guidelines for releasing non-real property. For each of 24 sites, there is a disposal cell.</td>
</tr>
<tr>
<td>Jason Darby, FUSRAP, Oak Ridge</td>
<td>FUSRAP has program to crush contaminated concrete into fine-grain material. Material is stockpiled then later surveyed for volume contamination. If below soil criteria in DOE 5400.5, release as clean.</td>
</tr>
<tr>
<td>Richard Cellamare, SLAC</td>
<td>Plan to prepare an environmental assessment for release from the Stanford Linear Accelerator of iron and steel for recycle.</td>
</tr>
<tr>
<td>Larry Boing, ANL-E</td>
<td>Has released slightly contaminated scrap metal to USNRC-licenced vendor for recycle into shielding blocks. Decontaminate to barely detectable or release to low-level waste facility.</td>
</tr>
</tbody>
</table>
4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The following conclusions regarding current practices for release of real and non-real property are based on the information presented in Sections 1 through 3 and Appendixes A and B.

1. A radiation protection standard specifying 100 mrem per year as the maximum acceptable dose to individual members of the public from all radiation sources except medical and background sources, referred to as the "all-sources" standard, has been generally accepted throughout the world. (See Section 2.1, p. 4.)

2. To ensure compliance with the all-sources standard, it has become common practice in the United States to constrain the dose caused by any one source, or group of sources under single control, to some fraction of 100 mrem per year, although the size of the fraction varies depending on the nature of the source and the responsible regulatory agency. Examples of single-source dose constraints are:

   a. DOE sites must develop and approve appropriate single-source dose limits applicable to doses resulting from releases of residual radioactivity at a fraction of the all-sources limit (e.g., 30 mrem in one year) using a process designed to identify a limit that is ALARA. (See Section 2.3.1, p. 12.)

   b. EPA has suggested in a preliminary draft rule that a single-source dose limit of 15 mrem in a year be imposed on radiation sites undergoing cleanup. To date, however, EPA has only promulgated the following single-source dose limits that are applicable to DOE sites: (1) the dose rate to members of the public from beta particle and photon activity caused by man-made radionuclides in drinking water is limited to an annual dose equivalent to the total body or any internal organ of 4 mrem per year, and (2) the dose rate to any member of the public from emissions of radionuclides other than radon to the ambient air from DOE facilities is limited to 10 mrem per year. (See Section 2.3.2, p. 13.)

   c. USNRC constrains the dose rate to the average member of the public from residual radioactivity that is distinguishable from background, including residual radioactivity in drinking water, at sites seeking USNRC license termination (i.e., release from USNRC control) to whatever total effective dose rate is less than 25 mrem in a year and is ALARA on a case-by-case basis. (See Section 2.3.3, p. 17.) This limit applies only to a few DOE facilities that hold USNRC licenses, but it is DOE's policy to conform its own standards as much as possible to those of USNRC.
3. Sometimes, other dose constraints will be imposed on a case-specific basis as a result of cleanup requirements mandated by CERCLA, RCRA, or state laws. (See Section 1.2, p. 2, and Section 2.3, p. 11.)

4. In certain circumstances where potential public exposure pathways are well defined, regulatory release criteria (expressed in radioactivity concentrations) have been adopted for residual radioactive materials on property. (See Appendixes A and B.) For example:
   a. Order DOE 5400.5 sets release criteria for radium and thorium in soils, for radon in occupied or habitable buildings, and for contamination on surfaces of structures, building components, equipment, and other materials;
   b. 40 CFR Part 192 sets release criteria for radium in soils; for radium, uranium, and gross alpha particle activity in groundwater; and for radon in occupied or habitable structures.

5. USNRC uses the same release criteria for contamination on surfaces as does DOE (except for tritium), but such criteria are published as guidance (USNRC Regulatory Guide 1.86) rather than as regulations. (See Section 2.3.3.2, p. 18.)

6. No regulatory release criteria have been established for property exhibiting volumetric contamination (i.e., contamination distributed throughout the volume of the property as a result of smelting or activation). (See Appendix A.)

7. In all circumstances where release criteria (surface or volumetric) have not been established by regulations, such criteria must be developed on a case-specific basis. For example, at FUSRAP sites with uranium contamination in soils, DOE has often derived case-specific release criteria. (See Section 3.1.2.1, p. 32.)

8. For property releases governed by DOE, case-specific release criteria must be derived by using the ALARA process when release criteria have not been established by DOE orders or applicable regulations. (See Section 2.3.1, p. 12.)

9. The ALARA process, as applied in deriving case-specific release criteria, involves, among other things (see Section 1.2, p. 2), using computer codes or other computational methods to make dose-to-concentration conversions. (See Section 3.1.2, p. 31, and Section 3.2.2, p. 51.)

10. Considerable professional judgment is typically involved when property is released, particularly if case-specific release criteria must be derived using computational methods. (See Section 3.1.1, p. 25, and Section 3.2.1, p. 49.)
11. The acceptability of establishing release criteria for property containing residual radioactivity is well established in the United States and throughout the world. (See Section 3, generally.)

12. A number of DOE properties (both real and non-real) in the United States containing residual radioactivity that have been released, or will be released after verification of compliance with applicable release criteria, are identified in this report. (See Section 3.1.2, p. 31, and Section 3.2.2, p. 51.)

13. Also identified in this report are several processes developed to guide responsible professionals in successfully managing the derivation and approval of case-specific release criteria. (See Section 3.1.1, p. 25, and Section 3.2.1, p. 49.)

14. The suggested processes for managing case-specific release criteria derivations and some of the reports of individual case-specific derivation experiences suggest that the key to success lies not only in sound professional judgments while implementing dose-to-concentration computational methods, but also in establishing early and effective communication with decision makers and the public.

15. EPA has suggested an approach for radiation cleanup of sites under which case-specific property release criteria, if needed, would be derived for radionuclides of concern on the basis of a mandated public dose limit of 15 mrem per year total effective dose equivalent. There would be no requirement (or prohibition) that the ALARA process be used during the derivation. (See Section 3.3.2, p. 13.)

16. The Washington Department of Ecology MTCA regulations, which apply to facilities undergoing decommissioning and remediation on the DOE Hanford Site pursuant to CERCLA, contain detailed specifications concerning acceptable levels of risk from carcinogens (including radionuclides) after cleanup, scenarios for calculating reasonable maximum exposure, and locations considered acceptable as points of compliance. (See Section 2.3.4, p. 18, and Appendix A.) These specifications unavoidably impact the assignment of input parameters to computations of case-specific release criteria.

4.2 Recommendations

On the basis of the information presented in the first three sections of this report and the conclusions listed above, it is recommended that the implementation plan for the property release program at the Hanford Site address establishment of methods and procedures for at least the following aspects of releasing properties:

1. Convening an appropriate multidisciplinary project team that includes personnel with expertise in, but not limited to, risk assessment, engineering cost evaluation, health physics, radiological dose evaluation, regulatory affairs, and decontamination technology.
2. Ensuring early and continuing involvement of regulatory agency decision makers and other stakeholders in decisions to release property and derivations of release criteria.

3. Deriving release criteria. [Note: Regardless of the source of the applicable dose constraints from which release criteria are to be derived, the method and procedures for deriving release criteria should address how to document the derivation process for the purpose of demonstrating compliance with DOE ALARA process requirements.]

4. Performing radiological characterization and compliance verification for properties to be released, including documentation requirements.

5. Ensuring that, if property transfer is planned, all other legal and DOE policy requirements are met and that such compliance is documented before transfer occurs. Examples of laws, regulations, and policy statements other than release limits that may apply to a property transfer include the following:

   a. National Environmental Policy Act (NEPA);
   b. Resource Conservation and Recovery Act (RCRA);
   c. Federal Property Management Regulations (FPMR);
   d. DOE Property Management Regulations (PMR);
   e. DOE Acquisition Regulations (DEAR);
   f. DOE Personal Property Letter (PPL) 970-3, Control of “High-Risk” Personal Property (March 25, 1996); and
   g. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Section 120(h).

This list is not intended to be comprehensive. DOE personnel responsible for releasing property must determine which laws, regulations, and policy statements apply on a site-specific basis.
APPENDIX A:
Summary of Federal and State of Washington Standards and Criteria for Radiologically Contaminated Sites and Structures
### APPENDIX A:
Summary of Federal and State of Washington Standards and Criteria for Radiologically Contaminated Sites and Structures

<table>
<thead>
<tr>
<th>Citations/Applicability</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Regulation:</strong></td>
<td>• No member of the public shall receive more than 100 mrem in a year from all sources and pathways.</td>
</tr>
<tr>
<td>Order DOE 5400.5, “Radiation Protection of the Public and the Environment”</td>
<td>• Authorized and supplemental limits must be derived consistent with the ALARA process, given the anticipated use of the property (either restricted or unrestricted).</td>
</tr>
<tr>
<td><strong>Authorizing Statute:</strong></td>
<td>• Authorized limits must be established such that:</td>
</tr>
<tr>
<td>Atomic Energy Act of 1954, as amended</td>
<td>1. Radium-226, radium-228, thorium-230, and thorium-232 in soils shall not exceed 5 pCi/g, averaged over the first 15 cm of soil below the surface;</td>
</tr>
<tr>
<td><strong>Applicability</strong></td>
<td>2. Radium-226, radium-228, thorium-230, and thorium-232 in soils shall not exceed 15 pCi/g, averaged over 15-cm-thick layers of soil more than 15 cm below the surface;</td>
</tr>
<tr>
<td>Establishes standards and requirements applicable to operations of DOE and DOE contractors at DOE facilities.</td>
<td>3. Adjustments to the above soil release criteria must be calculated according to the procedures given in DOE/CH-8901 [U.S. Department of Energy, A Manual for Implementing Residual Radioactive Material Guidelines; A Supplement to U.S. Department of Energy Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites” (June 1989)] for hot spots and circumstances where secular equilibrium cannot be assumed.</td>
</tr>
<tr>
<td></td>
<td>4. If radionuclides other than radium and thorium are present in soils, release criteria must be derived from primary dose limit according to the procedures given in DOE/CH-8901.</td>
</tr>
<tr>
<td></td>
<td>5. In any occupied or habitable building, the annual average (or equivalent) radon decay product concentration (including background) should not exceed 0.02 working level (WL) after reasonable remediation, but shall not exceed 0.03 WL (including background) in any case.</td>
</tr>
<tr>
<td></td>
<td>6. External gamma radiation shall not exceed background by more than 20 μR/h inside any building or habitable structure, provided that this level results in compliance with the primary dose limit in an “appropriate-use” scenario.</td>
</tr>
</tbody>
</table>
## Standard

7. On open land, external gamma radiation shall comply with the primary dose limit in an “appropriate-use” scenario.

8. Residual concentrations of radionuclides in air and water must not exceed limits specified in applicable EPA regulations, including 40 CFR Parts 61 (National Emission Standard for Radionuclide Emissions from DOE Facilities), 141 (National Interim Primary Drinking Water Regulations), and 192 (Standards for Remedial Actions at Inactive Uranium Processing Sites).

9. Surface contamination on existing structures, including building components and interior equipment, shall not exceed specified concentrations, which are consistent with USNRC Regulatory Guide 1.86. (The allowable surface contamination concentrations are reproduced as Appendix B to this report.)

### Regulation:

At designated processing and depository sites, and after the closure period at sites managing uranium and thorium byproduct materials:

- Controls must be designed to be effective for up to 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

- Controls must provide reasonable assurance that radon-220 or radon-222 flux will not exceed an average release rate of 20 pCi/m²/s.

### Authorizing Statute:

Atomic Energy Act of 1954, Section 275, as added by the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) [42 U.S.C. 2022]

### Applicability:

Restoration and control of uranium and thorium mill tailings, unprocessed ores, and other low grade radioactive materials at designated processing or depository sites.

- Controls must be designed such that residual radioactive materials do not cause constituents to enter the groundwater in concentrations that would exceed:

  1. Background levels; or
  2. The value given for each constituent (radioactive and nonradioactive) listed, if the background level for the listed constituent is below the value given. The following radioactive constituents are listed and corresponding values are given:

<table>
<thead>
<tr>
<th>Citations/Applicability</th>
<th>Standard</th>
</tr>
</thead>
</table>
| 40 CFR Part 192 (continued) | Combined radium-226 and radium-228 5 pCi/L  
Combined uranium-234 and uranium-238 30 pCi/L  
Gross alpha-particle activity (excluding radon and uranium) 15 pCi/L; or  
(3) Alternative concentration limits established pursuant to specified criteria. |

On land contaminated with residual radioactive materials from inactive uranium processing sites:

- The concentration of radium-226 in land averaged over any area of 100 m² shall not exceed the background level by more than:
  1. 5 pCi/g, averaged over the first 15 cm of soil below the surface, and
  2. 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface.

- There shall be a groundwater remedial action plan designed to achieve concentrations in groundwater that do not exceed:
  1. Background levels; or
  2. The value given for each constituent listed (radioactive and nonradioactive), if the background level for the listed constituent is below the value given. The following radioactive constituents are listed and corresponding values given:
     - Combined radium-226 and radium-228 5 pCi/liter
     - Combined uranium-234 and uranium-238 30 pCi/liter
     - Gross alpha-particle activity (excluding radon and uranium) 15 pCi/liter; or
  3. Alternative concentration limit established pursuant to specified criteria.

In any occupied or habitable building associated with land contaminated with residual radioactive materials from inactive uranium processing sites:

- Reasonable effort must be made not to exceed 0.02 WL annual average (or equivalent) radon decay product concentration (including background);

- In any case, radon decay product concentration (including background) shall not exceed 0.03 WL annual average.

- Gamma radiation shall not exceed background by more than 20 μR/h.
### APPENDIX A (continued): Summary of Federal and State of Washington Standards and Criteria for Radioactively Contaminated Sites and Structures

<table>
<thead>
<tr>
<th>Citations/Applicability</th>
<th>Standard</th>
</tr>
</thead>
</table>
| **Regulation:**  
40 CFR Part 141, “National Primary Drinking Water Regulations” | • The annual average concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 mrem/yr. |
| **Authorizing Statute:**  
Safe Drinking Water Act [42 U.S.C. 300f, 300g-1, 300g-2, 300g-3, 300g-4, 300g-5, 300g-6, 300j-4, 300j-9] |  |
| **Applicability:**  
Establishes primary drinking water regulations applicable to public water systems.[40 CFR Part 300, Appendix B] |  |
| **Regulation:**  
| **Authorizing Statute:**  
Clean Air Act [42 U.S.C. 7401, 7412, 7413, 7414, 7416, 7601] | • DOE facilities: |
| **Applicability:**  
Establishes hazardous pollutant emission standards applicable to owners and operators of stationary sources. | - No source shall emit more than 20 pCi/m²/s of radon-222, as an average for the entire source, into the air. |
<p>|  | - Emissions of radionuclides other than radon to the ambient air shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr. |
|  | • Uranium mill tailings piles designated under Title 1 of UMTRCA: |
|  | - Radon-222 emissions to the ambient air from uranium mill tailings piles that are no longer operational shall not exceed 20 pCi/m²/s of radon-222. |</p>
<table>
<thead>
<tr>
<th>Citations/Applicability</th>
<th>Standard</th>
</tr>
</thead>
</table>
| **Regulation:**  
40 CFR Part 300, “National Oil and Hazardous Substances Pollution Contingency Plan” | - Remediation goals shall establish acceptable exposure levels that are protective of human health and the environment.  
- For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between $10^{-4}$ and $10^{-6}$ using information on the relationship between dose and response. The $10^{-6}$ risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at a site or multiple pathways of exposure. |
| **Authorizing Statute:**  
| **Applicability:**  
Provides the organizational structure and procedures for preparing for and responding to discharges of oil and releases of hazardous substances, pollutants, and contaminants (including radioactive substances). |  |

<table>
<thead>
<tr>
<th>Citations/Applicability</th>
<th>Standard</th>
</tr>
</thead>
</table>
| **Regulation:**  
10 CFR Part 20, “Standards for Protection Against Radiation;” subpart E, “Radiological Criteria for License Termination” | • A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a total effective dose equivalent (TEDE) to an average member of the critical group that does not exceed 25 mrem/yr, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are ALARA. |
| **Authorizing Statute:**  
Atomic Energy Act of 1954, as amended (AEA) [42 U.S.C. 2073, 2093, 2111, 2133, 2134, 2201, 2232, and 2236] and Energy Reorganization Act of 1974, as amended [42 U.S.C. 5841, 5842, and 5846] | • When calculating TEDE to the average member of the critical group, the licensee shall determine the peak annual TEDE dose expected within the first 1,000 years after decommissioning. |
| **Applicability:**  
Establishes standards for protection against ionizing radiation resulting from activities conducted under licenses issued by the U.S. Nuclear Regulatory Commission. | • A site will be considered acceptable for license termination under restricted conditions if, among other things: |
|  | • Residual levels of radioactivity are ALARA, taking into account such detriments as traffic accidents and hazards expected to result from decontamination and waste disposal. |
|  | • Legally enforceable institutional controls are in place that provide reasonable assurance that the TEDE from residual radioactivity distinguishable from background will not exceed 25 mrem per year to the average member of the critical group. |
|  | • Residual radioactivity at the site has been reduced so that if the institutional controls fail, there is reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group is ALARA and would not exceed either: |
|  | (1) 100 mrem per year; or |
|  | (2) 500 mrem per year, provided that the licensee makes prescribed provisions and demonstrations. |
|  | • A license may be terminated using criteria other than those listed above only if the licensee makes prescribed provisions and demonstrations, and the USNRC approves after considering recommendations from the USNRC Staff, which must address comments submitted on the criteria by the public and the U.S. Environmental Protection Agency. |

<table>
<thead>
<tr>
<th>Citations/Applicability</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Regulation:</strong></td>
<td>• All cleanup actions under MTCA must:</td>
</tr>
<tr>
<td>Chapter 173-340 WAC, “Model Toxics Control Act-Cleanup”</td>
<td>- Protect human health and the environment;</td>
</tr>
<tr>
<td></td>
<td>- Comply with cleanup standards in WAC 173-340-700 through -760;</td>
</tr>
<tr>
<td></td>
<td>- Comply with applicable state and federal laws; and</td>
</tr>
<tr>
<td></td>
<td>- Provide for compliance monitoring.</td>
</tr>
<tr>
<td><strong>Authorizing Statute:</strong></td>
<td>• Cleanup standards for individual sites must specify:</td>
</tr>
<tr>
<td>State of Washington Model Toxics Control Act (MTCA)</td>
<td>- Hazardous substance cleanup levels;</td>
</tr>
<tr>
<td></td>
<td>- Points of compliance; and</td>
</tr>
<tr>
<td></td>
<td>- Additional regulatory requirements that apply because of the type of action and/or location of the site.</td>
</tr>
<tr>
<td><strong>Applicability:</strong></td>
<td>• Cleanup levels for individual sites are to be determined by one of three methods:</td>
</tr>
<tr>
<td>All facilities where there has been a release or threatened release of a hazardous substance that may pose a threat to human health or the environment.</td>
<td>- Method A (Tables) is used for sites undergoing routine cleanup actions or actions involving relatively few hazardous substances.</td>
</tr>
<tr>
<td></td>
<td>(1) Under Method A, where groundwater is a current or potential future source of drinking water, cleanup levels for radioactivity must be at least as stringent as all of the following:</td>
</tr>
<tr>
<td></td>
<td>Gross alpha particle activity (excluding uranium) ≤ 15 pCi/L;</td>
</tr>
<tr>
<td></td>
<td>Gross beta particle activity (including gamma activity) ≤ 4 mrem/yr;</td>
</tr>
<tr>
<td></td>
<td>Radium-226 and radium-228 ≤ 5 pCi/L;</td>
</tr>
<tr>
<td></td>
<td>Radium-226 ≤ 3 pCi/L; and</td>
</tr>
<tr>
<td></td>
<td>Concentrations established under applicable state and federal laws, including MCLs in 40 CFR Parts 141 and 143 and WAC 248-54.</td>
</tr>
<tr>
<td></td>
<td>(2) Method A tables establish no specific cleanup levels for radioactivity in surface water, soil or air.</td>
</tr>
<tr>
<td></td>
<td>- Method B (Standard Method) must be used to develop cleanup levels unless using Method A or C can be justified. Method B cleanup levels may be established using applicable state and federal laws, or risk equations. For individual carcinogens, cleanup levels are based on the upper bound of the estimated excess lifetime cancer risk of one in one million (1 x 10^-6). Adjustments are required for multiple carcinogens and multiple pathways. The total excess lifetime cancer risk must not exceed one in one hundred thousand (1 x 10^-5).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Citations/Applicability</th>
<th>Standard</th>
</tr>
</thead>
</table>
| Chapter 173-340 WAC, “Model Toxics Control Act-Cleanup” (continued) | - Method C (Conditional Method) is used if it is impossible to use Method A or B, or if cleanup levels established under Method A or B could cause greater environmental harm than if Method C were used. Method C cleanup levels can always be established for soils at qualified industrial properties. Otherwise, each medium must be evaluated separately to determine if it qualifies for a Method C cleanup level. Method C cleanup levels may be established using applicable state and federal laws, and a site-specific risk assessment. For individual carcinogens, cleanup levels are based on the upper bound of the estimated excess lifetime cancer risk of one in one hundred thousand ($1 \times 10^{-5}$). Adjustments are required for multiple carcinogens and multiple pathways. The total excess lifetime cancer risk must not exceed one in one hundred thousand ($1 \times 10^{-5}$).
- Risk assessments under Methods B and C must be based on the highest exposure that is reasonably expected to occur at a site under current and potential future site use.
  - The reasonable maximum exposure scenario for groundwater is use as drinking water.
  - The reasonable maximum exposure scenario for surface water must be determined in accordance with WAC 173-201.
  - The reasonable maximum exposure scenario for soil is residential use of the land, unless a specific determination is made otherwise.
  - The reasonable maximum exposure scenario for air is residential use of the land.
- For groundwater cleanup levels, unless hazardous substances remain at the site following cleanup, the point of compliance is every point within the hazardous substance plume. If hazardous substances remain at the site, a conditional point of compliance may be established as near to the remaining hazardous substances as practicable, but no farther away than the property boundary. Compliance is required at every point from the conditional point of compliance to the boundary of the hazardous substance plume.
- For surface water cleanup levels, the point of compliance is the point or points at which hazardous substances are released to surface water, unless a dilution zone is authorized.
- For soil cleanup levels based on the protection of groundwater, the point of compliance is every point in the soils throughout the site. For soil cleanup levels based on direct contact, the point of compliance is every point throughout the site from the ground surface to 15 ft below the ground surface.
- For air cleanup levels, the point of compliance is every point in the ambient air throughout the site. For sites determined to be industrial sites, a conditional point of compliance within the site boundary may be approved. |
### APPENDIX A (continued): Summary of Federal and State of Washington Standards and Criteria for Radioactively Contaminated Sites and Structures

<table>
<thead>
<tr>
<th>Citations/Applicability</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Regulation:</strong></td>
<td>• Facilities that treat, store, recycle, or dispose of dangerous waste (including hazardous waste composed of both radioactive and hazardous components) must institute corrective action as necessary to protect human health and the environment for all releases of dangerous wastes and dangerous constituents, including releases from all solid waste management units at the facility.</td>
</tr>
<tr>
<td>Chapter 173-303 WAC, “Dangerous Waste Regulations”</td>
<td>• Facilities may be required to fulfill corrective action responsibilities using an enforceable action issued pursuant to MTCA.</td>
</tr>
<tr>
<td><strong>Authorizing Statute:</strong></td>
<td>• A specific or general license is required to receive, possess, use, transfer, own, or acquire radioactive material, unless an exemption applies.</td>
</tr>
<tr>
<td>The Hazardous Waste Management Act of 1976, as amended, and the Resource Conservation and Recovery Act [42 U.S.C. 6901 et. seq.]</td>
<td>• If detectable levels of radioactive contamination attributable to activities conducted under the license are found at a facility holding a specific license, and the license has been revoked, or is expiring and licensee intends to terminate use of radioactive material, then the licensee must either begin decommissioning under the provisions of the license, or submit a decommissioning plan.</td>
</tr>
<tr>
<td><strong>Applicability:</strong></td>
<td>• The final step in decommissioning includes conducting a radiation survey of the premises to demonstrate, or demonstrating by some alternative means, that the premises are suitable for release for unrestricted use.</td>
</tr>
<tr>
<td>All persons who handle dangerous wastes and solid wastes that may be designated as dangerous wastes.</td>
<td>• Allowable levels of residual radioactivity at the time of decommissioning are specified by WAC 246-232-140, Schedule D.</td>
</tr>
<tr>
<td><strong>Regulation:</strong></td>
<td>• A specific or general license is required to receive, possess, use, transfer, own, or acquire radioactive material, unless an exemption applies.</td>
</tr>
<tr>
<td>Chapter 246-232 WAC, “Radioactive Material — Licensing Applicability”</td>
<td>• If detectable levels of radioactive contamination attributable to activities conducted under the license are found at a facility holding a specific license, and the license has been revoked, or is expiring and licensee intends to terminate use of radioactive material, then the licensee must either begin decommissioning under the provisions of the license, or submit a decommissioning plan.</td>
</tr>
<tr>
<td><strong>Authorizing Statute:</strong></td>
<td>• The final step in decommissioning includes conducting a radiation survey of the premises to demonstrate, or demonstrating by some alternative means, that the premises are suitable for release for unrestricted use.</td>
</tr>
<tr>
<td>Revised Code of Washington (RCW), Chapter 70.98, &quot;Nuclear Energy and Radiation&quot;</td>
<td>• Allowable levels of residual radioactivity at the time of decommissioning are specified by WAC 246-232-140, Schedule D.</td>
</tr>
<tr>
<td><strong>Applicability:</strong></td>
<td>• A specific or general license is required to receive, possess, use, transfer, own, or acquire radioactive material, unless an exemption applies.</td>
</tr>
<tr>
<td>Persons who receive, possess, use, transfer, own or acquire radioactive material.</td>
<td>• If detectable levels of radioactive contamination attributable to activities conducted under the license are found at a facility holding a specific license, and the license has been revoked, or is expiring and licensee intends to terminate use of radioactive material, then the licensee must either begin decommissioning under the provisions of the license, or submit a decommissioning plan.</td>
</tr>
</tbody>
</table>
APPENDIX B:
Table 1 Surface Activity Guidelines
# APPENDIX B: Table 1 Surface Activity Guidelines

Allowable Total Residual Surface Activity (dpm/100 sq-cm)

<table>
<thead>
<tr>
<th>Radionuclides</th>
<th>Average</th>
<th>Maximum</th>
<th>Removable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 - Transuranics, I-125, I-129, Ac-227, Ra-226, Ra-228, Th-228, Th-230, Pa-231</td>
<td>100</td>
<td>300</td>
<td>20</td>
</tr>
<tr>
<td>Group 2 - Th-natural, Sr-90, I-126, I-131, I-133, Ra-223, Ra-224, U-232, Th-232</td>
<td>1000</td>
<td>3000</td>
<td>200</td>
</tr>
<tr>
<td>Group 3 - U-natural, U-235, U-238, and associated decay products, alpha emitters</td>
<td>5000</td>
<td>15000</td>
<td>1000</td>
</tr>
<tr>
<td>Group 4 - Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above</td>
<td>5000</td>
<td>15000</td>
<td>1000</td>
</tr>
<tr>
<td>Tritium (applicable to surface and subsurface)</td>
<td>N/A</td>
<td>N/A</td>
<td>10000</td>
</tr>
</tbody>
</table>

**NOTES:**

1. As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by counts per minute measured by an appropriate detector for background, efficiency and geometric factors associated with the instrumentation.

2. Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

3. Measurements of average contamination should not be averaged over an area of more than 1 sq-m. For objects of smaller surface area, the average should be derived for each such object.

4. The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mR/h and 1.0 mR/h, respectively, at 1 cm.

5. The maximum contamination level applies to an area of not more than 100 sq-cm.

6. The amount of removable material per 100 sq-cm of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wiping with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 sq-cm is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. It is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

7. This category of radionuclides includes mixed fission products, including the Sr-90 present in them. It does not apply to Sr-90 that has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

8. Property recently exposed or decontaminated should have measurements (smears) at regular time intervals to ensure that there is not a build-up of contamination over time. Because tritium typically penetrates material it contacts, the surface guidelines in Group 4 are not applicable to tritium. The Department has reviewed the analysis conducted by the DOE Tritium Surface Contamination Limits Committee ("Recommended Tritium Surface Contamination Release Guides," Feb. 1991), and has assessed potential doses associated with the release of property containing residual tritium. The Department recommends the use of the stated guideline as an interim value for removable tritium. Measurements demonstrating compliance of the removable fraction of tritium on surfaces with this guideline are acceptable to ensure that nonremovable fractions and residual tritium in mass will not cause exposures that exceed DOE dose limits and constraints.

Source: Response to Questions and Clarification of Requirements and Processes: DOE 5400.5, Section II.5 and Chapter IV Implementation (Requirements Relating to Residual Radioactive Material), DOE Assistant Secretary for Environment, Safety and Health, Office of Environmental Policy and Assistance (EH-41) (Nov. 17, 1995).
APPENDIX C:
Computer Codes for Dose Calculations
APPENDIX C: Computer Codes for Dose Calculations

This appendix provides a list and descriptions of computer codes and models that can assist in converting residual radioactivity concentrations to estimated radiation dose, or vice versa. The codes and models are first grouped by application (Section C.1), and then listed alphabetically with descriptions (Section C.2).

C.1 Code Applicability

On-Site Workers - External Dose
- MICROSHIELD
- RESRAD-BUILD
- RESRAD-RECYCLE

Internal Dose (outside - air dispersal and stack releases)
- CAP88PC
- COMPLY
- GENII
- GENII-S
- MEPAS
- MMSOILS
- PATHRAE-EPA
- PRESTO-EPA-CPG
- RESRAD-RECYCLE

Internal Dose (inside buildings)
- USNRC NUREG-1500
- RESRAD-BUILD

Transportation
- RADTRAN
- RISKIND

Soils
- DECOM
- GENII
- GENII-S
- MMSOILS
- MEPAS
- USNRC NUREG-1500
- PATHRAE-EPA
- PRESTO-EPA-CPG
- RESRAD
C.2. Code Descriptions

CAP88PC

The CAP-88 computer model (EPA 1992b)\(^1\) is a set of computer programs, databases, and associated utility programs for estimating dose and risk from radionuclide emissions to air. CAP-88 consists of modified versions of AIRDOS-EPA (Moore et al. 1979) and DARTAB (ORNL 1981). The CAP88-PC software package allows users to perform full-featured dose and risk assessments in a personal computer environment for the purpose of demonstrating compliance with 40 CFR 61.93(a). CAP88-PC differs from the dose assessment software AIRDOS-PC in that it estimates risk as well as dose, it offers a wider selection of radionuclide and meteorological data, it provides the capability for collective population assessments, and it allows users greater freedom to alter values of environmental transport variables.

CAP88-PC uses a modified Gaussian plume equation to estimate the average dispersion of radionuclides released by up to six sources. The program computes radionuclide concentrations in air, rates of deposition on ground surfaces, concentrations in food, and intake rates to people from ingestion of food produced in the assessment area. Dose and risk are estimated by combining the inhalation and ingestion intake rates, and the air and ground surface concentrations with the dose and risk conversion factors used in CAP-88.

COMPLY

The COMPLY code (EPA 1989a) is a computer program that can be used to demonstrate compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAPs) in 40 CFR Part 61, Subpart I. It has various levels of complexity, the simplest being a computerized version of the tables of concentration and possession limits in EPA 1989b. The program has three levels of complexity beyond the possession or concentration limit tables. Level 2 is the lowest, requiring a minimum of input, and level 4 is the highest, requiring the most input. (Levels 2 and 3 correspond to the NCRP screening levels 2 and 3. NCRP screening level 1 is not used [NCRP 1989]). While the higher levels require more input, they have less conservatism built into the dose estimate. The most complicated is an air dispersion calculation using a wind rose. At all levels, the program determines whether one is in compliance with the standard.

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\(^1\) Full citations for references are provided at the end of the appendix.
DECOM

The DECOM code (Till and Moore 1988) allows the user to calculate doses from radionuclides with different concentrations in multiple soil layers (in 15-cm increments). The code calculates doses to a hypothetical receptor from the following pathways and exposure routes: external gamma dose from radionuclides in soil; inhalation dose from contaminated dust; and ingestion dose from intake of contaminated plants, meat, milk, and water.

GENII

The GENII code (Napier et al. 1988) is the predecessor of the GENII-S code. The function of the GENII code is similar to that of GENII-S (below) except it does not have the capability to perform uncertainty analysis for the input parameters.

GENII-S

The GENII-S code (Leigh et al. 1992) is a comprehensive package of models that address routine and accidental releases of radionuclides to air or water, as well as residual contamination from spills or decommissioning operations. Both population and individual doses can be calculated. The addition of the sensitivity and uncertainty analysis shell enables the user to perform stochastic as well as deterministic runs.

The code allows the user to model up to two layers of contaminated soil: surface and deep soil. Surface contamination is contained in the first 15 cm of soil. Deep soil contamination may be located at any depth below the first 15 cm. The code calculates doses to a hypothetical receptor from the following pathways and exposure routes: external gamma dose from radionuclides in soil and air; inhalation dose from contaminated dust; and ingestion dose from intake of contaminated soil, plants, meat, milk, fish, and water.

IMPACTS

The IMPACTS-BRC program (Forstom and Goode 1986) calculates the impacts (radiological doses) from the handling, recycling, incineration, and/or disposal of very low-level radioactive waste. The program includes a number of regional location, disposal facility, and waste treatment options. Pathways for which impacts are calculated include transportation, operations, air and water transport to off-site receptors, and intrusion into disposed waste. IMPACTS-BRC is a dynamic program that can be adapted from the generic form in which it is supplied to very specific situations.

MEPAS

The MEPAS (Buck et al. 1995) is a risk computational tool that evaluates health impacts to exposed individuals and surrounding populations caused by the release of chemical and
radioactive contaminants into the environment and their migration and fate in the groundwater, surface water, overland, and atmospheric pathways.

**MicroShield**

The MicroShield computer code (Negin and Worku 1992) is an adaption of the mainframe code ISOSHIELD for IBM-PC and compatibles. It is used to analyze shielding and estimate exposure from external gamma radiation.

**MMSOILS**

The MMSOILS model (EPA 1992a) is a methodology for estimating the human exposure and health risk associated with releases of chemical contaminants from hazardous waste sites. MMSOILS is intended primarily for screening hazard potential at a site and for conducting relative comparison of (1) hazards posed by individual chemicals at a site, (2) hazards at different waste sites, and (3) risk reduction potential of alternative remediation activities on the basis of user-supplied source-term modification. The human exposure pathways considered in MMSOILS include soil ingestion, air inhalation of volatiles and particulates, dermal contact, ingestion of drinking water, consumption of fish, consumption of plants grown on contaminated soil, and consumption of animals grazing on contaminated pasture.

**NUREG/CR-5512 Methodology (USNRC NUREG/CR-1500)**

The methodology described in NUREG/CR-5512 (Kennedy and Strenge 1992) incorporates a set of generic screening models to calculate radiation doses received by an individual from residual contamination in buildings and soil, as well as from potential groundwater contamination. The methodology encompasses building occupancy and renovation scenarios and a residential scenario. For the residential scenario, the contaminants are limited to the top 15 cm of soil. The potential pathways and exposure routes considered in NUREG/CR-5512 are external gamma dose from radionuclides in soil; inhalation dose from contaminated dust; and ingestion dose from intake of contaminated soil, plants, meat, milk, fish, and water.

**PATHRAE-EPA**

The PATHRAE-EPA code (Rogers and Hung 1987) was designed to calculate average annual and maximum annual effective doses and cancer risks to an on-site critical population group and an off-site population at risk. The approach used in PATHRAE is similar to that used in PRESTO (see below).

**PRESTO-EPA-CPG**

The PRESTO-EPA-CPG code (Hung 1989) is designed to estimate radiation doses to individuals and critical population groups over a 1,000-year period from disposal of low-level
radioactive waste. On-site doses resulting from farming and intrusion and off-site doses from exposure to contaminated air, surface water, and groundwater are considered. The code calculates doses to hypothetical individual receptors, both on-site and off-site, for the following pathways and exposure routes: external gamma dose from radionuclides in soil, water, and air; inhalation dose from contaminated dust; and ingestion dose from intake of contaminated plants, meat, milk, and water.

RADTRAN

The RADTRAN code (Neuhauser and Kanipe 1992) combines user-determined meteorological, demographic, transportation, packaging, and material factors with health physics data to calculate the expected radiological consequences and accident risk of transporting radioactive material.

The original RADTRAN code was developed in 1977 in conjunction with the preparation of NUREG-0170 (USNRC 1977; Taylor and Daniel 1977). The analytical capabilities of the code were expanded and refined in subsequent versions (Madsen et al. 1986; Taylor and Daniel 1982). RADTRAN 4 is used to evaluate radiological consequences of incident-free transportation, as well as the radiological risks from vehicular accidents occurring during transportation.

RESRAD

The DOE RESRAD code (Yu et al. 1993) is a pathway analysis code that calculates radiation doses to a hypothetical individual living on a contaminated site. RESRAD allows the user to define up to nine pathways and three exposure routes: external gamma radiation from radionuclides in soil; inhalation of contaminated dust and radon gas; and ingestion of contaminated plants, meat, milk, aquatic foods, water, and soil. Several scenarios, including residential, industrial, and recreational, can be modeled by adding or suppressing pathways and entering appropriate values for occupancy and consumption rates.

RESRAD-BUILD

The RESRAD-BUILD code (Yu et al. 1994) is a pathway analysis model designed to evaluate the potential radiological dose incurred by an individual who works or lives in a building contaminated with radioactive material. The radioactive material in the building structure can be released into the indoor air by mechanisms such as diffusion (radon gas), mechanical removal (decontamination activities), or erosion (removable surface contamination). The transport of radioactive material inside the building from one compartment to another is calculated with an indoor air quality model. The air quality model considers the transport of radioactive dust particulates and radon progeny due to air exchange, deposition and resuspension, and radioactive decay and ingrowth.

The design of RESRAD-BUILD is similar to that of the RESRAD code: the user can construct the exposure scenarios by adjusting the input parameters. Typical building exposure
scenarios include long-term occupancy (resident and office worker) and short-term occupancy (remediation worker and visitor). The RESRAD-BUILD code considers six exposure pathways: external exposure directly from the source; external exposure to materials deposited on the floor; external exposure due to air submersion; inhalation of airborne radioactive particulates; inhalation of aerosol indoor radon progeny (in the case of the presence of radon predecessors); and inadvertent ingestion of radioactive material, either directly from the sources or from materials deposited on the surfaces of the building compartments.

RESRAD-RECYCLE

The RESRAD-RECYCLE code (Nabelssi et al. 1996) is a pathway analysis tool designed to calculate potential radiation doses and risks associated with the recycling of radioactive scrap metal and the reuse of surface-contaminated material and equipment. RESRAD-RECYCLE is a member of the RESRAD family of computer codes developed to assess dose and risk from decontamination, decommissioning, and remediation activities involving radioactive and other hazardous materials. RESRAD-RECYCLE applies the latest methodology and modeling parameters to provide a comprehensive risk analysis of the entire recycle process. The code assesses individual and collective population risks and facilitates the derivation of release limits and standards.

RISKIND

The RISKIND code (Yuan et al. 1995) is designed to estimate potential radiological consequences and health risks to individuals and the collective population from exposures associated with transportation. Several models are included in RISKIND that have been tailored to calculate the exposure to individuals under various incident-free and accident conditions. The RISKIND code allows for user-specified accident scenarios as well as receptor locations under various exposure conditions, thereby facilitating the estimation of radiological consequences and health risks for individuals. The coding approach in RISKIND emphasizes the scenario descriptions, environmental settings, receptor locations, and potential health effects.
References for Appendix C


Nabelssi, B.K., et al., 1996, Unpublished information, Argonne National Laboratory, Argonne, Ill.


