DEPARTMENT OF THE ARMY | EM 1110-35-1
U.S. Army Corps of Engineers
CEMP-DE | Washington, DC 20314-1000

Manual
No. 1110-35-1 | 1 July 2005

Engineering and Design
MANAGEMENT GUIDELINES FOR WORKING WITH RADIOACTIVE AND MIXED WASTE

1. Purpose. This engineer manual (EM) contains planning and management guidelines to be used for United States Army Corps of Engineers (USACE) work with radioactive waste, either alone or combined with hazardous or toxic components. This manual primarily describes regulatory and management responsibilities and their relation to the Technical Project Planning (TPP) process and the Project Management Business Process (PMBP) applied to USACE activities at radioactive waste sites. This manual also disseminates USACE policies and provides guidance on how to accomplish those responsibilities. This manual is not intended to provide detailed technical recommendations or sophisticated scientific procedures. The manual will necessarily incorporate some technical information to provide background for the regulatory and management responsibilities. In addition to the Department of Defense (DOD) branches, these responsibilities are defined and enforced by other Federal agencies, including the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), the Environmental Protection Agency (EPA), the Department of Transportation (DOT), and the Occupational Safety and Health Administration (OSHA). While most of the guidance included will be applicable to work performed outside the United States, other regulatory agencies, dose limits, and radioactive handling and disposal regulations may be applicable.

2. Applicability. The guidelines within this manual are applicable to all USACE elements and major subordinate commands (MSC) having responsibility through governmental interagency agreement or by assignment from Headquarters (HQ) USACE for the remediation of sites contaminated with radioactive materials. These guidelines are applicable to the accomplishment of both the Military and Civil Works missions of the USACE. Strictly chemical or biological aspects of sites are not addressed except in passing reference to their component part of mixed waste.

This manual supersedes EM 1110-35-1, 30 June 1997 and EM 1110-1-4002, 30 June 1997.

3. Distribution Statement. Approved for public release; distribution is unlimited.

4. References. References are at Appendix A.

FOR THE COMMANDER:

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CHAPTER 1

Introduction

1-1. Purpose. This engineer manual (EM) contains planning and management guidelines to be used for United States Army Corps of Engineers (USACE) work with radioactive waste, either alone or combined with hazardous or toxic components. This manual primarily describes regulatory and management responsibilities, provides guidance on accomplishing those responsibilities, and explains their relation to the Project Management Business Process (PMBP) and Technical Project Planning (TPP) applied to USACE activities at radioactive waste sites. Additionally, this manual will promote USACE policies to ensure Corps-wide application across all programs. This manual is not intended to provide detailed technical recommendations or sophisticated scientific procedures. The manual will necessarily incorporate some technical information to provide background for the regulatory and management responsibilities. In addition to the Department of Defense (DOD) branches, these responsibilities are defined and enforced by other Federal agencies, including the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), the Environmental Protection Agency (EPA), the Department of Transportation (DOT), and the Occupational Safety and Health Administration (OSHA).

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1-3. Distribution Statement. Approved for public release; distribution is unlimited.

1-4. References. References are at Appendix A. Referenced documents throughout the text are hyperlinked to internet available copies when possible.

1-5. Scope.

a. Intended Audience. This document is intended to assist Project Managers in the development of Project Management Plans and supporting documents that will lead to the successful restoration of sites contaminated with radioactive material. Guidance is included to ensure that each Project Delivery Team (PDT) is established with the necessary disciplines and perspectives. Individuals asked to work on radioactively contaminated sites may find the document useful in understanding and fulfilling their role as members of the PDT. Various terms, regulations, and processes used in the restoration of radioactively contaminated sites are described to facilitate effective communication between the PDT members and stakeholders.

b. Contents.

- Chapter 1 explains the purpose, scope and intended audience of this guidance document. It lists some important units, quantities and conversions that are necessary to fully understand and work on remediation of radioactively contaminated sites.
- Chapter 2 explains how the presence of radioactive waste affects the necessary actions and associated management of a project.
- Chapter 3 explains the TPP approach to managing remediation at sites contaminated with radioactive materials.
- Chapter 4 discusses health and safety concerns relative to a radioactive site.
- Chapter 5 describes the conceptual site model and risk assessment.
- Chapter 6 describes sampling of radioactive materials.
- Chapter 7 describes characterization of sites.
- Chapter 8 describes characterizing radioactive waste.
- Chapter 9 addresses the primary regulatory processes involved at radioactive remediation sites.
- Chapter 10 addresses remedies and innovative technologies that may be used at radioactive remediation sites.
- Chapter 11 explains the procedures and issues involved in transportation of radioactive materials.
- Chapter 12 discusses options and methods of disposal of radioactive materials.
- Chapter 13 discusses the Multi-Agency Radiation Site Survey and Investigation Manual (MARSSIM) Final Status Survey (FSS).
- Appendix A provides references and bibliography of regulatory documents, regulations and laws.
- Appendix B provides contact information for Federal and state radiation control agencies.
- Appendix C includes technical information on radioactive materials, decay, measuring techniques, and instrumentation.
- Appendix D lists some typical remediation site characteristics.

1-6. Units, Definitions, and Conversions. Several systems of units are applicable to USACE radioactive materials sites. The following is a brief description of the units, what they measure, and how they will be used on USACE sites. Conversions between different systems of units are included where appropriate. A more complete explanation may be found in EM 385-1-80.

a. Radioactivity or Activity. Radioactivity is unstable atomic nuclei becoming more stable by emitting energy. The types and amounts of energy emitted are characteristic of the radioactive material. The radioactivity or activity of a material is the rate of decay per unit time. There are two systems that are used to measure activity: the US system and the System International (SI). In this manual, when reporting activity, the US system units will be listed first, followed by the SI unit in parentheses.

(1) US System. Activity is measured using the curie (Ci). 1 Ci is 3.7×10^{10} decays per second (1 gram of pure radium has 1 Ci of activity).

(2) SI. Activity is measured using the becquerel (Bq). 1 Bq is 1 disintegration per second.

$1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$

$1 \text{ Bq} = 2.7 \times 10^{-11} \text{ Ci}$

(3) Specific Activity (activity per unit mass). This is reported as Ci/g (Bq/kg). Note that DOT requires SI units to be entered on shipping papers and labels. US customary units may accompany the SI units in parentheses.

(a) Activities and specific activities may use metric prefix abbreviations as follows:

Prefix	Abbreviation	Quantity
Tera	T	1×10^{12}
Giga	G	1×10^{9}
Mega	M	1×10^{6}
Kilo	k	1×10^{3}
Milli	m	1×10^{-3}
Micro	μ	1×10^{-6}
Nano	n	1×10^{-9}
Pico	p	1×10^{-12}

(b) Several related units may be encountered on USACE sites. Their acceptability should be determined by the USACE health physicist assigned to the site.

b. dpm. Disintegrations (decays) per minute is often used in referring to surface contamination, most often as disintegrations per minute per one hundred square centimeters (dpm/100 cm^2); dpm can be converted to Bq or Ci. Some survey instruments purport to present data in dpm. This can only be done correctly under very specific circumstances. These circumstances and the accuracy of the readings must be verified by a health physicist.

c. cpm. Counts per minute (radiation interactions with the detector) is often reported for hand held instrument surveys. Under certain very specific circumstances, cpm can be converted to dpm. A health physicist must be consulted to ensure that an accurate conversion is performed.

d. (Ionizing) Radiation (as used here). This is the energy emitted from radioactive material traveling from one point to another in the form of photons or particles. Depending upon how and where it is measured, there are a number of units used to quantify radiation. The standard units used at USACE sites are the roentgen (coulomb per kilogram), rad (gray), and rem (sievert).

e. Exposure. This is the amount of ionization in air produced by x- or gamma radiation with energies less than 3 MeV (mega electron volt). Exposure is the most commonly measured parameter of radiation. It is measured in roentgen (R). One R is equal to 2.58×10^{-4} coulomb of electrical charge produced in one kilogram (C/kg) of air.

f. Exposure Rate. This is the readout used by many field survey instruments. It commonly uses a fraction of roentgen per hour (R/hr), usually milliroentgen per hour (mR/hr), or micro roentgen per hour (μR/hr).

g. Absorbed dose. This is the energy deposited in matter by radiation. It is measured in rad or gray (Gy).

1 rad = 100 erg/g = 0.01 Gy

1 gray = 1 J/kg = 100 rad

1 R in air is about equal to 1 rad in soft tissue.

h. Dose Equivalent. This is the absorbed dose in soft tissue multiplied by a quality factor. The quality factor normalizes the harm done by different types of radiation. The dose equivalent is a measure of the biological damage expected from absorption of radiation.

(1) Typical quality factors are:

- Beta/gamma radiation 1
- Alpha radiation.................20
- Neutron radiation 10

(2) Dose equivalent is measured in rem (sievert [Sv]).

100 rem = 1 Sv

1 Sv = 100 rem

(3) For x-ray/gamma radiation.

1 R = 1 rad = 1 rem (1 Sv = 1 Gy)

(4) For alpha radiation.

1 rad = 20 rem (1 Gy = 20 Sv)

i. Radioactive Waste. A generic term for wastes containing radioactive materials. Regulatory agencies have different definitions for different types of radioactive wastes. The NRC only regulates source, byproduct, and special nuclear materials. The EPA regulates the hazardous component of mixed wastes. States may regulate other radioactive materials and radioactive wastes.

j. High-Level Radioactive Waste (HLW). The NRC defines High-Level Radioactive Waste as 1) irradiated reactor fuel, 2) liquid wastes resulting from operation of the first cycle solvent extraction system, or the equivalent, and the concentrated wastes from subsequent extraction cycles or equivalent in a facility for reprocessing irradiated reactor fuel, and 3) solids into which such liquid wastes have been converted (10 CFR 60). In layman's terms, HLW is spent fuel, or spent fuel reprocessing wastes. USACE does no work with HLW at present.

k. Low-Level Radioactive Waste (LLRW). LLRW is source, byproduct, or special nuclear material waste not classified as HLW, transuranic waste, spent nuclear fuel, or byproduct material as defined in section 11e.(2) of the Atomic Energy Act. In layman's terms, LLRW is NRC regulated waste that is not HLW, transuranic waste, or uranium or thorium mill tailings.

l. Transuranic Waste (TRU). TRU is waste materials contaminated with alpha-emitting nuclides with an atomic number greater than 92, half-lives greater than 20 years, and in concentration greater than 100 nCi/g of waste at the time of assay (40 CFR 191).

m. Uranium Mill Tailings Radiation Control Act (UMTRCA). Enacted to ensure investigation and remediation of past uranium and thorium mine and mill tailings and regulation of tailings at currently licensed sites.

n. Uranium or Thorium Tailings (11e.(2) materials). The tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content (Atomic Energy Act). This designation only applies to tailings generated during or after 1978. This designation is sometimes incorrectly applied to tailings from the extraction of rare earth elements, which are often co-located in the same ores as uranium and thorium, or to the tailings from the extraction of radium. For legal reasons, those tailings generated prior to 1978 are referred to as “residuals from uranium or thorium ore processing prior to 1978.”

o. Mixed Waste. An NRC regulated radioactive waste containing source, byproduct, or special nuclear material (LLRW, 11e.(2) or HLW) mixed with an RCRA (Resource Recovery and Conservation Act) listed or characteristic hazardous material.

p. Combined or Commingled Waste. Any radioactive waste mixed with any hazardous substance. Mixed waste is a subset of combined or co-mingled waste.

q. DOT Radioactive Material. A material with a total activity concentration exceeding 70 Bq/g (2000 pCi/g) (49 CFR 173.403). Note, this definition shall change under DOT and NRC harmonization rulemaking on 1 October 2004 to agree with the international definition of radioactive material. The international definition of radioactive material shall mean any material containing radionuclides where both the activity concentration and the total activity in the consignment exceed the values specified in the table in 49 CFR 173.436 or values derived according to the instructions in §173.433.

CHAPTER 2

Radioactive and Mixed Waste Project Requirements

2-1. Introduction.

a. Radioactive materials have been used by the DOD and civilians for nearly 100 years. Radioactive commodities and radioactive wastes have been found on all types of projects. On BRAC (Base Realignment and Closure) and IRP (Installation Restoration Program) projects, radioactive commodities are the most common type of radioactive waste. These commodities may include:

- Dials and gauges on vehicles and equipment illuminated with radium paint.
- Electron tubes and diodes containing small quantities of radioactive materials used extensively in radar and fire control equipment.
- Radioactive tritium illuminators used in exit signs and fire control devices.
- Thorium used in radiation detection equipment and as an alloy.
- Magnesium-thorium, used in the manufacture of aircraft and missile parts.

b. Depleted uranium (DU-natural uranium with the fissionable component reduced or removed) is used in armor piercing penetrators, high-density armor, radiation shielding, and aircraft counterweights. A website containing information on all the commodities used in DOD is available from the Wright–Patterson Air Force Base site. Hospitals and laboratories use a very extensive list of radioactive materials, sometimes in liquid scintillation vials, and often combined with human or animal tissue or fluids. Nuclear reactors have a defined mix of source materials, activation products, and fission products. Nuclear weapons assembly and maintenance facilities may have uranium, plutonium, and tritium contamination, and the Formerly Used Sites Remedial Action Program (FUSRAP) sites may have uranium or thorium ores and mill tailings and their associated decay progeny. Superfund sites have encountered the widest variety of radionuclides, ranging from radium processing tailings to transuranics used in sealed source manufacturing.

c. The USACE approach for all projects is to follow the guidance and methodology outlined in Project Management Business Process (PMBP). Hazardous Toxic and Radioactive Waste (HTRW) projects follow EM 200-1-2, and when addressing a release of a hazardous substance to the environment, follow the Comprehensive Environmental, Response, Compensation, and Liability Act of 1980 (CERCLA) approach. On radioactive materials sites USACE applies guidance found in the Multi-Agency Radiation Site Survey and Investigation Manual (MARSSIM).

d. PMBP provides a means of ensuring that the right people, with the right skills and the right tools, work effectively to complete a project to the satisfaction of the customer, the regulators, and stakeholders. TPP (Technical Project Planning) outlines an iterative four-phased approach for ensuring that the project objectives are identified, data collection is efficient, and the project progresses towards site closeout. CERCLA provides a process for ensuring authority to conduct projects with public input, and regulatory oversight. MARSSIM provides guidance on meeting the final status survey and closing out a site. Projects involving radioactive material can be approached in the same way as other hazardous materials projects, but with some of the following additions to the team and modifications of the plan.

2-2. Health Physicist Involvement.

a. Health Physicists (HPs) are technical experts in radioactive materials and radiation. They can provide expert advice on identifying, sampling, handling, transporting, and disposing of radioactive materials, measurement of radiation levels and doses, the ecological and biological effects of exposure to radiation, and the applicable laws, regulations, and guidance concerning radiation and radioactive materials. A USACE project HP should be assigned very early in the project planning process, and may need to be involved in both the decision-making processes and execution throughout the project. Contractors will often be required to have HP staff and HP technicians.

b. ER 385-1-92 requires the use of Qualified Health Physics personnel for Remedial Design activities at HTRW sites. Qualified personnel must meet education and experience requirements listed in EM 385-1-80. The addition of certified health physicists (CHPs), HPs, and HP techs to a project can significantly increase project costs.

2-3. Chemist Involvement. The project chemist will need to be acquainted with the different methodologies used for identifying and quantifying radioactive materials. Approved methods, limits of detection, radionuclide emissions, and appropriate wet chemistry can be significantly different when radionuclides are involved. Analytical laboratories should be USACE validated and must be notified in advance that potentially radioactive samples are to be submitted. The lab will need to ensure appropriate contamination control measures are used for the radioactive samples. This is in addition to the chemical analyses that may be required. ER 1110-1-263 sets laboratory data quality requirements. These factors may increase lab turn around times and analytical costs.

2-4. On-site Radiochemistry Labs. A number of projects have found it economical to have an on-site radiochemistry lab instead of contracting an off-site lab for routine radiochemistry analyses. An on-site lab will provide a more rapid turn around for sample analyses.

2-5. Risk Assessor Involvement. To address the complexities of a risk-informed approach to site clean-up, a risk assessor will need to assist on-site remediation decisions. The data needs of risk assessors are often different from other team members and may require additional sampling and analyses. Where appropriate, a risk-informed regulatory approach can also be used to reduce unnecessary conservatism in purely deterministic approaches, or can be used to identify areas with insufficient conservatism in deterministic analyses and provide the bases for additional requirements or actions. Risk-informed approaches lie between the risk-based and purely deterministic approaches.

2-6. Considerations for Cleanup Level Development. How clean is clean? This fundamental question must be answered in all environmental remediation projects. It must be answered at the time when the decision is made as to what response is needed at a site, and it must be answered again at the end to determine if the required response has been completed and is successful in operation. The answers to this question are found in a complex analysis of technical and legal factors established in the laws governing environmental response action projects.

a. CERCLA requires that response actions be conducted in compliance with the implementing regulations promulgated by the Environmental Protection Agency, the National Oil and Hazardous Substances Pollution Contingency Plan, 40 CFR Part 300 (NCP). The NCP includes a list of hazardous substances, including radioactive elements and compounds. In addition, if other hazardous substances or pollutants and contaminants are present, then CERCLA also applies to the cleanup of these other contaminants. CERCLA authorizes the decision maker for the lead Federal agency to respond through removal or remedial actions when the release or threat of release of a hazardous substance has created or may create an imminent and substantial danger to humans or the environment. Remedial actions provide the permanent remedy necessary to prevent or minimize the release so that the hazardous substances or pollutants and contaminants do not migrate to cause substantial danger to present or future public health or welfare or the environment. Removal actions are required to contribute, to the extent practicable, to the efficient performance of any long-term remedial action in responding to a release or threatened release.

b. Chapter 9 describes the regulatory processes that authorize USACE to clean up a site. The primary environmental response authority that USACE follows when addressing a release of a hazardous substance to the environment is CERCLA.

2-7. Disposal Options.

a. Disposal options for radioactive materials will vary from readily disposable locally, to no immediate disposal options at all, depending on the type, quantity, concentration, and pedigree of the radioactive materials. Very early in the planning process and well before any execution, a disposal plan must be prepared. Kansas City District has a number of pre-placed contracts for disposal of radioactive waste that may be accessed by all of USACE. The project HP should be able to assist with initial estimates of potential disposal sites.

b. Low-Level Radioactive Waste (LLRW) is also under the control of the originating state's Low-Level Radioactive Waste Compact. The compacts were originally developed in 1985 to construct and operate radioactive waste disposal facilities within their boundaries. Currently, there are 10 approved compacts and three active LLRW disposal facilities. Only two of the three disposal facilities may accept Classes A, B, and C radioactive waste. The Hanford, Washington, facility only accepts LLRW from the Northwest and Rocky Mountain compacts, but will accept non-NRC regulated wastes from all states. The Envirocare (Utah) facility accepts Class A LLRW, 11e.(2), and non-NRC regulated wastes from all regions of the United States. The Barnwell, South Carolina, facility accepts LLRW from all generators in the United States except the Rocky Mountain and Northwest compacts. Beginning in 2008, Barnwell will only accept LLRW from the Atlantic Compact states. These compacts may control the import and export of LLRW to or from their compact, and may assess fees for import or export. In some cases, payment of these fees by the Federal Government may violate fiscal law. The appropriate Office of Counsel should be consulted for guidance on this matter. The Army Field Support Command (AFSC) of Army Materials Command (AMC) is the operating agency for the Executive Agent for radioactive waste from DOD activities. All disposal actions for DOD wastes need to be coordinated with AFSC through the USACE Hazardous, Toxic and Radioactive Waste Center of Expertise (HTRW-CX). Radioactive wastes generated by Civil Works activities, such as FUSRAP, may not be considered DOD wastes. Additional guidance on disposal is furnished in Chapter 9.

2-8. Transportation. Transportation requirements for radioactive materials, wastes, and samples are substantially different from transportation of other types of DOT hazardous materials. Department of Transportation (DOT) radioactive materials regulations are listed in 49 CFR 173.401 (Subpart I) et seq. The project HP will be familiar with transportation requirements. Certain states also charge a fee to transport radioactive waste through them. In some cases, payment of these fees by the Federal Government may violate fiscal law. The appropriate Office of Counsel should be consulted. Additional guidance on transportation is furnished in Chapter 8.

2-9. Public Perception.

a. Most projects involving radioactive materials will receive increased public interest. PMBP requires the project delivery team (PDT) to develop a communications plan. The plan requires input and assistance from the Public Affairs Office. Past experience has shown that addressing all concerns in a truthful and open manner is the simplest method of allaying public concerns. The HTRW-CX and the Radiation Safety Support Team (RSST) have developed a number of fact sheets that are available for general use by USACE, our customers, contractors, and regulators.

b. The communications plan will identify the project stakeholders' problems, concerns, and issues. It will then establish an internal and external communication strategy and determine the information needs of all PDT members and stakeholders: who needs what information, when they will need it, how it will be given to them, and by whom.

CHAPTER 3

Technical Project Planning (TPP) Approach to Managing Sites Contaminated with Radioactive and Mixed Waste

3-1. TPP Section 1.1 Phase I - Prepare Team Information Package. In addition to the TPP guidance, there are a number of guidance documents on various aspects of working with radioactive materials. The Project Manager's (PMs) guides for TPP, and Radioactive Materials and seven Engineer Pamphlets (EPs) specifically address work with radioactive materials. While the Engineer Circulars (ECs) are specifically oriented toward Formerly Utilized Sites Remedial Action Program (FUSRAP) site remediation, the guidance will help ensure that sound radiation safety principles are applied at any site. The following Engineer publications address work with radioactive materials. A brief description of each is included.

a. EM 200-1-2 Technical Project Planning Process. Describes the process for identifying project objectives and designing data collection programs at all Hazardous, Toxic and Radioactive Waste (HTRW) sites.

b. ER 385-1-80 Ionizing Radiation Protection. This is the Engineer Regulation for working safely with radioactive materials.

c. EM 385-1-80 Radiation Protection Manual. Provides explanation and guidance on methods of complying with ER 385-1-80.

d. ER 385-1-92 Safety and Health Requirements for HTRW Sites. Identifies documents and procedures required for executing HTRW projects.

e. EP 415-1-266 Resident Engineer Management Guide (REMG) For Hazardous, Toxic, And Radioactive Waste (HTRW) Projects. Provides requirements of which resident engineers must be aware regarding remedial design activities and response actions involving HTRW, and ordnance and explosives response actions.

f. Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). Provides detailed guidance for planning, implementing, and evaluating environmental and facility radiological surveys conducted to demonstrate compliance with a dose or risk based regulation. It is a consensus document prepared with concurrence of the EPA, NRC, DOE, and DOD.

3-2. TPP Section 1.1.1 Phase I - Identify the Team Members.

a. A diverse group of USACE Technical, Management, Legal, and Public Affairs personnel, as well as stakeholders, regulators, and contractors, are required for the Project Delivery Team (PDT). Guidance on establishing the team is provided in the Project Management Business Process (PMBP) Team Establishment procedure. The PM will need to identify the decision makers, the data users, and the data implementers needed for the project. The decision makers may include the PM, the customer, and the regulators. Regulators may include Federal agencies: the Nuclear Regulatory Commission (NRC), the Environmental protection Agency (EPA), or the Occupational Safety and Health Administration (OSHA). Twenty-nine states are NRC agreement states, in which the state office performs the oversight duties of the NRC. Most states also have a Department of Environmental Protection and Department of Health, which are concerned with radioactive materials in the environment and potential human exposure to radiation. State regulatory agencies do not usually have jurisdiction to regulate Federal facilities, but the final disposition of the property may be subject to state regulatory oversight. Ensure that the USACE Office of Counsel is included in the TPP team to determine which regulatory agencies have which oversight responsibilities.

b. The data users may include a radio-chemist, a health physicist (HP), an Industrial Hygienist (IH), a risk assessor, and quality assurance personnel for each discipline.

c. Stakeholders may include the local city, county, and state community, site owners, site workers and contractors, and trade unions, as well as local and national environmental organizations.

3-3. TPP Section 1.1.2 Phase I - Identify the Customer's Goals.

a. Once the customer has been identified, ensure that the entire TPP team understands exactly what the customer envisions at the completion of the project, and what the customer sees as the role of USACE in the project.

b. The customer's concept of site closeout may range from removal and disposal of all radioactive and hazardous materials and a survey to allow the site to be released without restrictions (unrestricted release), to treatment, on-site storage, or on-site disposal of the materials to allow for limited reuse of the site (restricted release). When a restricted release is contemplated, land use controls (LUCs) must be considered. The objective when implementing LUCs is to ensure that land use remains compatible with the remedial action goals, and that the remedy remains protective of human health and the environment. The customer's schedule requirements and site budget must also be considered at this time.

3-4. TPP Section 1.1.3 Phase I - Gather Existing Site Information. This operation, coupled with Paragraph 3-5, is the equivalent of the MARSSIM Historical Site Assessment, and the CERCLA Preliminary Assessment. In addition to the normal avenues, site information may be obtained from a wide variety of other sources. Atomic Energy Commission or Nuclear Regulatory Commission licenses and amendments, Army radiation authorizations, Air Force radiation permits, local land use permits, as well as the site owner or operator's records may provide information on the past activities at the site. Additionally, USACE archivists are available who are experienced in gathering documents relating to sites. If possible, attempt to obtain facility operating procedures and inventories, and define the receipt, use, storage, and disposal areas for the hazardous and radioactive materials on the site. Capture a description of all the background literature into a single document, and ensure that the background information is available to all data users and implementers. Appendix D lists contaminants of concern and items of interest on some typical sites where remediation may take place.

3-5. TPP Section 1.1.3.5 Phase I - Conduct Site History Interviews. Consider not only former and present site workers, but also past and present regulators and inspectors. Many sites using radioactive materials also had some form of area dose monitoring. These records may also prove valuable in estimating potential hazards at the site.

3-6. TPP Section 1.2.2 Identify and Document Project Objectives. Most project objectives are a consequence of governing statutes and applicable regulations. Identifying and interpreting these statutes and regulations varies quite widely from site to site, among regulatory agencies, and even among regional offices within the same agency. Chapter 9 looks in depth at the existing statutes and regulations that are commonly applicable to radioactive waste sites. The primary regulations used for remediation of radioactive materials at a site are:

- 10 CFR 20 NRC Subpart E
- 10 CFR 40 NRC
- 40 CFR 300 CERCLA
- 40 CFR 192 UMTRCA
- State Regulations

After review by counsel, the applicable regulations should be included in this document. This document should specifically identify all impacted areas. An impacted area is one where there is a potential for radioactive contamination. These areas need to be bounded, spatially and temporally. The document must also identify the potential radioactive contaminants, and identify the executable project stages to site closeout.

3-7. TPP Section 1.3.2 Define Courses of Action for Achieving Site Closeout. A release criterion is a regulatory limit expressed in terms of dose (mSv/year or mrem/year) or risk (cancer incidence or cancer mortality). The terms release limit or cleanup standard are also used to describe this expression. A release criterion is typically based on the total effective dose equivalent (TEDE), risk of cancer incidence (morbidity), or risk of cancer death (mortality) and generally cannot be measured directly. Exposure pathway modeling is used to calculate a radionuclide-specific predicted concentration or surface area concentration of specific nuclides that could result in a dose (TEDE) or specific risk equal to the release criterion. This concentration is termed the derived concentration guideline level (DCGL). Exposure pathway modeling is an analysis of various exposure pathways and scenarios used to convert dose or risk into concentration. In many cases screening level DCGLs can be obtained from responsible regulatory agency guidance based on conservative modeling input parameters, while other users may elect to take into account site-specific parameters to determine DCGLs. In general, the units for the DCGL are the same as the units for measurements used to demonstrate compliance (e.g., Bq/kg or pCi/g, Bq/m^2 or dpm/100 cm^2). This allows direct comparisons between the survey results and the DCGL. While exposure pathway models, such as RESRAD or RESRAD-BUILD, can provide a defensible starting point, stakeholders must concur with the exposure model parameters used as well as with the DCGLs determined. Other factors, such as ARARs (applicable or relevant and appropriate requirements), and public opinion, may set DCGLs at different quantities. The TPP and communication processes are meant to ensure that all interests are consulted and a consensus DCGL is reached that is acceptable to all stakeholders.

a. If the site is contaminated above the screening levels, the next step is to determine the DCGLs. Clean-up criteria provided by the EPA are given in units of risk, which cannot be measured. NRC criteria are provided in units of dose. DCGLs are the contaminant concentrations, which can be measured, that, when entered into an exposure model, yield a dose or risk that can be compared to the guidance provided by the regulatory authority. DCGLs are better explained in Paragraph 3-10. These DCGLs are the concentrations of contaminants below which the average concentration must fall for the project to be considered for release and closure. DCGLs will contain four units: an average radionuclide concentration that the site average concentration will not exceed, an area over which this concentration may be averaged, a maximum concentration that hot spots will not exceed, and the maximal area of these hot spots. Note that the DCGLs depend on the site conditions and the exposure models used. DCGLs may not be even in the same order of magnitude between different sites. For example, the DCGL determined for a site located in a residential area was 35 pCi/g while the DCGL for the same contaminant located in an industrial area was set at 1950 pCi/g.

b. For the project to be viewed as a success by all stakeholders, the ideal scenario is reaching a consensus value for the DCGLs. Federal and state regulators, as well as the lead agency at the site, the customer, and the other stakeholders, should all agree on the DCGLs.

c. The most common method of determining a starting point for DCGLs for a site is through the use of the RESRAD and RESRAD-BUILD dose modeling programs. These programs provide a method for calculating the dose to a recipient from the soil or building surface contamination concentrations, or both. The programs provide very conservative default parameters that may be used or modified if site-specific data are available for the parameters. These programs have both been approved for use by the NRC, EPA, DOD, and DOE.

d. When default parameters are not used, documentation explaining why the new value is considered appropriate must be included in the DCGL development report. Many default parameters will be changed on the basis of actual site conditions. For example, area of contamination, depth of cover, depth of contamination, depth to ground water, distance to nearest surface water, etc., can be referenced back to the site description and geological and hydrogeological reports. The report determining those actual site conditions must be referenced in the documentation of the parameter change.

e. NRC and USACE regulations also require all remediation to meet ALARA (doses as low as is reasonably achievable). This means that the DCGL will be the maximally allowed average contamination concentration, but the project will strive to remediate all media to as low a level of residual contamination as is reasonably achievable, taking into account the various social and economic factors affecting the site. However, if a site is remediated to NRC screening levels, it is considered to have met all ALARA requirements. Here, if there is a contaminant on-site that warrants any further investigation or remediation, decisions have to be made on what needs to be determined to select the method of remediation.

f. There are a number of methods that have been used to remediate sites. The primary method found to be cost effective and that meets the expectations of the regulators and the public, so far, is excavation and off-site disposal. A few sites have been allowed to use burial in place. There are also a few innovative technologies that have been investigated at different sites. The most common reduces waste volume using soil sorting and washing or segmented gate systems. Some efforts at bioremediation have been studied and shown to be effective in pilot studies.

g. The basic objective for radioactive waste sites is completion of a final status survey indicating that the Derived Concentration Guideline Levels (DCGLs) have been met at each impacted area. The phases necessary to reach this point will have interim objectives, and the interim objectives will have different data needs. Common problems are overestimating the amount and type of data actually needed for completion of a phase, and not ensuring that all data can be shared between phases for use in the final status survey. Another is project creep, where subsurface radioactive materials not discovered during the initial characterization are found during remediation and the remediation ‘chases’ the contamination into greater than expected volumes of contaminated soils.

3-8. TPP Section 2.1 Determine Data Needs. During the characterization phase, data gathered during the historical site assessment are used to determine potential radioactive and hazardous contaminants, and potentially impacted areas. From these data, a preliminary site conceptual model is constructed. From the site conceptual model, potentially impacted areas are selected. Data gaps will exist and additional information concerning the actual quantity, horizontal and vertical extent of contamination, the radionuclides actually present on-site, and the natural background concentrations of the radionuclide contaminants will be needed. Once samples are gathered and analyzed, and these data are available, the remediation phase data needs change. Isotopic analyses, necessary to determine the radionuclides of concern, may no longer be necessary and less expensive survey and analysis methods can be used. If no site work that could substantially concentrate or dilute the contaminants in the waste stream was done, the data from the characterization sampling and from the remediation surveys and sampling can be used to characterize the waste stream, lowering the total number of samples necessary. During the final status survey phase, the data needs may change again. Surveys and samples from the characterization and remediation phases may be used to show that the potentially impacted areas do in fact meet the DCGLs. Additional survey and samples will be needed to verify screening levels. A number of regulatory agencies have determined screening levels for site evaluations in the PA/SI (Preliminary Assessment/Site Inspection) and RI/FS (Remedial Investigation and Feasibility Study) stages of the investigation. The EPA has developed a web based Preliminary Remediation Goals (PRGs) calculator, and the NRC has released NUREGs providing guidance on using certain computer models to determine surface soil and building surface screening levels.

a. EPA PRGs for radionuclides are tools used to evaluate soils contaminated with radioactive materials at sites with various future land uses. PRGs are not national cleanup standards. PRGs alone do not trigger the need for response actions or define "unacceptable" levels of radionuclides in soil. In this guidance, "screening" refers to the process of identifying and defining areas, radionuclides, and conditions, at a particular site, that do not require further attention. Generally, at sites where radionuclide concentrations fall below the appropriate PRGs, no further action or study is warranted. Where radionuclide concentrations equal or exceed PRGs, further study or investigation, but not necessarily cleanup, is warranted.

b. By their nature these values will always be extremely conservative, sometimes to the point of being a fraction of background concentrations of a radioactive contaminant.

c. For example, uranium has a widely ranging background concentration depending on the rock/soil type. The National Council on Radiation Protection reported an average soil concentration of 1.8 pCi/g in its Report No. 94. The NRC NUREG-1757, Vol. 2 provides a U-238 plus progeny soil screening level of 0.5 pCi/g above background. The NRC assumes parameters based on a residential farmer scenario. Though not necessarily directly comparable to the NRC value, the EPA PRG calculator provides default PRGs for an agricultural scenario and a residential scenario. The default PRG values for U-238 plus progeny are 0.00147 pCi/g (agricultural), and 0.742 pCi/g (residential).

d. Should the average of all contaminant samples be less than the selected screening value, the site may be ready for closeout with no further action, provided the samples are of sufficient quality and number to meet the statistical tests provided in the MARSSIM.

3-9. Sample Quantity.

a. The number of samples required to adequately characterize a site or an incremental portion of a site, such as an operable unit (OU), depends on a number of variables. The NCP defines an OU as a discrete action that is an incremental step toward comprehensively addressing site problems. If one contaminant is present on-site, or a single decay chain is present on-site, the primary driver for the number of samples required to reach a certain confidence interval will depend on the variance of the total batch of samples. The confidence interval is the range of values with a specified probability (e.g., 90 or 95%) that the set contains the true value of the parameter tested.

b. The variance is the square of the standard deviation of the sample population. In general, the larger the variance is, the greater the number of samples needed. Additionally, as the number of contaminants increase, the number of samples required may also increase. When multiple radioactive contaminants coexist on a site, the clean-up criterion may require that a sum of fractions be used to determine compliance, i.e., for n radionuclides of concentration C:

$$\sum_{x=1}^{n} \frac{C_x}{DCGL_x} \leq 1$$

CHAPTER 4

Health and Safety

4-1. Introduction. This Chapter provides an introduction to the health and safety requirements unique to radioactive and mixed waste site remediation. HTRW health and safety requirements are described more fully in ER 385-1-92, ER 385-1-80, EM 385-1-80, and EM 385-1-1.

4-2. Responsibilities.

a. USACE has the primary responsibility for ensuring the health and safety of USACE personnel on-site and ensuring that all contractors on-site follow USACE accepted health and safety procedures. USACE and the contractor share the responsibility of ensuring that work performed on-site does not endanger the public on-site or off-site, in addition to protecting the environment. All personnel on-site are responsible for maintaining exposures to radiation as low as is reasonably achievable (ALARA). All personnel on-site are required to read and comply with the Site Safety and Health Plan (SSHP).

b. Many sites are under control of other agencies prior to USACE involvement. Where other agencies have the lead, that agency's safety and health program and plan will be followed by USACE and contractor personnel until responsibility for site safety has been turned over to USACE. The USACE PM may then elect to retain the existing safety and health program and plan, if it is in compliance with Federal, state, and local, as well as USACE, regulations, or elect to construct a USACE safety and health plan.

c. Some sites may be owned or operated by commercial parties. The operator or owner may have existing safety and health programs and plans, and may be regulated by other Federal agencies. USACE has a Memorandum of Understanding with the Nuclear Regulatory Commission (NRC) concerning USACE work at sites regulated by the NRC. Here again, the USACE PM may elect to retain the existing safety and health program and plan, if it is in compliance with Federal, state, and local, as well as USACE, regulations, or elect to construct a USACE safety and health plan. USACE may have no regulatory authority over the private owner and, therefore, no authority to impose an adequate health and safety plan. If the private owner objects, and USACE believes health, safety, and environmental protections to be inadequate, Federal and state agencies with jurisdiction must be notified.

4-3. Programs and Plans.

a. Contractors. All contractors shall have a written SHP (Safety and Health Plan) that addresses all aspects of HTRW worker health and safety.

b. Site Safety and Health Plan (SSHP). For each HTRW site, contractors shall have a written SSHP that addresses all expected hazards, and the methods proposed to mitigate those hazards that may be encountered on the site. The SSHP shall address all items discussed in ER 385-1-92, Appendix C. If portions of the contractor's SHP are referenced in the SSHP, those portions of the SHP shall be attached as appendices to the SSHP.

4-4. Radiation Protection Items Addressed in the SSHP. In addition to addressing the health and safety items for HTW sites, the SSHP must address the following items that are unique to radiation sites. These items shall be integrated with the rest of the SSHP to ensure coordination of all health and safety issues on-site.

a. USACE Personnel.

(1) USACE will provide the work plan, scope of work, site safety and health plan, etc., which will be reviewed by qualified health physics personnel who are trained in accordance with ER 385-1-92.

(2) USACE will provide site representatives who are trained according to EM 385-1-80.

b. Contractor Personnel.

(1) The contractor will provide a certified health physicist, responsible for the review and implementation of all documents and procedures related to radiation protection.

(2) The contractor will provide a sufficient number of radiation protection technicians (sometimes referred to as HP techs) who are trained as required (meeting health physics personnel requirements) in EM 385-1-80 to perform surveys, monitoring, and safety oversight on-site.

c. Contractor Dosimetry Responsibility.

(1) The contractor has two options concerning dosimetry.

(a) One alternative is that the contractor will monitor personnel exposures, provide appropriate external dosimetry to all personnel exposed to external sources of radiation (gamma or neutron radiation), and provide a method for dose determination for personnel who may become internally contaminated with radioactive materials.

(b) The other alternative is that the contractor will provide measurements and documentation that external or internal contamination could not result in doses to the individuals that exceed 10% of the annual TEDE.

(2) Common methods for meeting dosimetry requirements include providing thermoluminescent dosimeters or film badges to all personnel who enter the exclusion zone, and monitoring the air in the exclusion zone and documenting that the airborne concentrations of radionuclides are below 10% of the derived air concentrations listed in 10 CFR 20, Appendix B.

(3) Should a bioassay program be required, personnel should receive a baseline bioassay prior to entering the exclusion zone, periodic bioassays as determined by a health physicist, and a termination bioassay at the end of the project. Bioassay methods depend on the radionuclide and chemical form of concern and may include fecal sample analysis, urinalysis, organ counting, or whole body counting.

d. USACE Dosimetry Responsibility. USACE will provide appropriate dosimetry for USACE personnel. Dosimeters will be furnished and analyzed by the U.S. Army Ionizing Radiation Dosimetry Program at Redstone Arsenal in Alabama. Should bioassays be required for USACE personnel, these will be coordinated through the U.S. Army Center for Health Promotion and Preventive Medicine, at Aberdeen Proving Ground, Maryland.

e. Equipment.

(1) The contractor will provide surveying equipment capable of detecting the type and intensities of radiation expected on-site and to the limits of precision required in Data Quality Objectives (DQO) for personnel protection and cleanup of the site as specified in the work or safety plans.

(2) The contractor will provide monitoring equipment capable of accurately measuring the external radiation dose expected on-site.

f. Procedures. The contractor shall provide procedures that ensure that doses to on-site personnel and the general public are kept ALARA. These procedures will include, as appropriate:

(1) Limiting the time individuals are exposed to external radiation.

(2) Maintaining as much distance as reasonably possible between personnel and the sources of external radiation.

(3) Providing shielding, when necessary, to lower exposure to ionizing radiation.

(4) Surveying procedures to stop the spread of contamination from the exclusion zone.

(5) Monitoring procedures to ensure that contamination is not released from the site.

(6) Decontamination procedures to ensure that site worker doses are maintained ALARA and to minimize the amount of contaminated waste generated.

g. Emergency Contacts. The emergency contacts listed in the SSHP must include the appropriate NRC region or agreement state contact if licensable radioactive materials are involved, the appropriate EPA region or state contact, and the Radiation Protection Officer for the USACE District and Division. For work on a military installation, the installation Radiation Safety Officer shall also be included.

CHAPTER 5

Risk Assessment

5-1. Introduction. Risk assessments are a required element of CERCLA and RCRA site investigations. They are used on both non-radiological and radiological chemical environmental restoration projects to determine whether a site poses a potential threat to human health and the environment. Information from a risk assessment is used to demonstrate whether a site warrants further investigation, whether a removal or remedial action is warranted, or if a site may be closed with no further action. Dose is frequently assessed for radionuclides because many standards that regulate radionuclides, such as those issued by the Nuclear Regulatory Commission (NRC), which are based on radiological dose. However, CERCLA guidance requires that risk be assessed as part of site investigations. Differences between dose assessment and risk assessment are discussed below.

5-2. Risk Assessment and Dose Assessment Comparison.

a. In many ways, risk assessments and dose assessments are synonymous with one another. In both risk assessments and dose assessments, measurements of constituents of potential concern are used together with exposure assumptions to develop the "dose" that a receptor may receive. The meaning of the word "dose" is part of what distinguishes radionuclide from non-radiological chemical risk assessment. In chemical risk assessment "dose," or intake, means the mass of a substance taken into an organism through all pathways (such as inhalation, ingestion, absorption, etc.) per unit body weight per unit time and is usually expressed as mg/kg per day. This is combined with toxicity information to develop estimates of excess cancer risk, or a hazard index for non-carcinogenic risk. In terms of radiological risk, dose means energy imparted by ionizing radiation to matter per unit mass. This may be expressed in units of rad. Radiological dose assessments generally express dose in units of mrem/year; for example 1 rad of gamma radiation will produce 1 rem dose equivalent. Dose assessments estimate dose imparted to an organism by combining exposure information with radionuclide-specific characteristics. Dose will be a function of the type of radiation emitted by particular radionuclides and the frequency and duration of exposure of organisms to that radiation. Another difference between chemical and radionuclide risks is that radionuclide exposure estimates must consider an additional pathway, exposure to radiation that has sufficient energy to penetrate the skin. This is called the external pathway.

b. As stated above, information from a risk assessment or dose assessment is used to determine whether a site is safe, or whether it requires further action. The site risk assessment is used to develop remediation goals under CERCLA when there are no ARARs available, or when ARARs are not protective owing to multiple contaminants or pathways of exposure to contaminants. Remediation goals based on a dose assessment are used as components of many regulations, specifically, the NRC's Final Rule for Radiological Criteria for License Termination (10 CFR 20, Subpart E) and to develop supplemental standards under the Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings (40 CFR 192, UMTRCA). The following paragraphs further discuss the roles and procedures for dose and risk assessments in regulatory programs that commonly cover USACE projects where radionuclides contamination occurs.

5-3. Role of Risk Assessment in Regulatory Programs. There are certain instances, such as Work for Others on nuclear decommissioning projects, where USACE work may be carried out under direct regulation by the NRC. Most USACE environmental restoration projects with radionuclide contamination, however, will follow CERCLA with NRC regulations as a potential ARAR. The paragraphs below discuss the CERLCA process and how risk assessment is used in the various stages. Some projects may be regulated by the Resource Conservation Restoration Act (RCRA); the role of risk assessment or dose assessments in projects regulated by RCRA is functionally equivalent to that of CERCLA. The processes followed by RCRA are similar to those of CERCLA, except that different terminology is used.

a. At sites regulated by CERCLA, the first step after discovery of a site is preparation of a Preliminary Assessment/Site Inspection (PA/SI). The objectives of an SI are to eliminate from further consideration any releases that do not pose a threat to human health or the environment, to collect data to initially characterize any releases, and to identify any immediate threats to public health or the environment. A screening level risk assessment is used during the PA/SI stage to meet these objectives.

b. At the end of the PA/SI, EPA applies a scoring system known as the Hazard Ranking System (HRS) to determine if a site should be listed on the National Priorities List (NPL).

c. Performance of the HRS is EPA's responsibility and is generally not done by USACE or by DOD. However, site investigations should be designed to ensure that adequate data are available for EPA to conduct the scoring. Though DOD does not use the HRS, it does use a system for ranking sites for resource allocation and prioritization called the Relative Risk Ranking System. It is not a risk assessment, but does consider factors common to risk assessment, such as migration pathways, contaminant hazard, and receptors.

d. The purpose of the Remedial Investigation (RI) phase of the CERLCA process is to collect data to characterize the nature and extent of contamination and to quantify risks to human health and the environment in a baseline risk assessment. Results of the risk assessment are used to determine the contaminants, the media, and the areas of the site that require an evaluation of remedial alternatives in the Feasibility Study (FS). Risks are considered to be unacceptable if the non-cancer hazard quotient is above one or if excess cancer risk is above 10^{-4} (40 CFR 300), or if ARARs are exceeded. In the FS remedial alternatives are developed, screened, and analyzed, and potential remedies are evaluated against the nine criteria outlined in the NCP, as further discussed in Paragraph 9-2.

e. The first two criteria for evaluating remedial alternatives, overall protection of human health and the environment, and compliance with ARARs, relate to protectiveness of the remedy and to determination of remediation goals. The discussion of overall protectiveness in an FS will draw upon the analysis of other criteria, such as long-term effectiveness, short-term effectiveness, and attainment of ARARs. Long-term effectiveness considers the amount of residual risk remaining after a remedial alternative is implemented. For some projects this evaluation may require that a quantitative residual risk assessment be prepared. A residual risk assessment entails estimating residual concentrations of contaminants of concern, with a subsequent calculation of risk from exposures to those levels. For many projects, though, a qualitative evaluation of how remediation goals will be attained will suffice. The FS needs to discuss whether the analyzed remedial alternatives meet the ARAR or risk-based criteria for protectiveness.

5-4. Regulatory Guidance for Risk Assessments and Dose Assessments. EM 200-1-4, Risk Assessment Handbook Volume I: Human Health Evaluation (1999) and EM 200-1-4 Risk Assessment Handbook Volume II: Environmental Evaluation (1996) provide an extensive discussion of available guidance for human health and ecological risk assessments at sites regulated by CERLCA and RCRA. The reader is referred to these documents for more information. The discussion presented in the following paragraphs will focus on issues and guidance that are unique to radiological risk assessments and dose assessments.

5-5. CERCLA.

a. EPA has issued several guidance documents for conducting human health and ecological risk assessments. Chapter 10, “Radiation Risk Assessment Guidance,” of Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (RAGS Pt. A) (EPA 1989) covers data collection and evaluation, exposure and dose assessment, toxicity assessment, and risk characterization for sites contaminated with radionuclides. Chapter 4 of RAGS Pt. B Development of Risk-based Preliminary Remediation Goals (EPA 1991) presents standardized exposure equations for calculating preliminary remediation goals (PRGs) for radionuclides under residential and commercial/industrial land uses. When the PRG document was developed, EPA recommended that the equations be used with default exposure parameters to develop values for screening sites in the initial stages of the CERCLA process, as well as with site-specific information for developing PRGs in the FS. In 1996, though, EPA released Soil Screening Guidance, which gives equations to develop soil screening levels (SSLs) for screening sites with non-radiological contaminants. SSLs are based on residential use and also address contaminants leaching from soil to ground water, whereas the PRG calculations do not consider leachability. In 2000, EPA followed this document up with a document specific for radionuclides, Soil Screening Guidance for

Radionuclides (EPA 2000), which contains equations for calculating screening levels for radionuclides. The equations for exposures to soil supercede the residential equations contained in RAGS Pt. B. An electronic tool for running the calculations, the EPA PRG Calculator, is located at http://epa-prgs.ornl.gov/radionuclides/.

b. An ecological risk assessment must also be conducted on CERCLA sites. The guidance for ecological risk assessments at CERLCA sites is titled Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (EPA 1997).

c. Information regarding toxicity values for radiological risk assessments, additional models, and other information relative to risk assessment for radionuclides, may be obtained at EPA's radiation website http://www.epa.gov/radiation/.

5-6. RCRA Guidance. As stated above, RCRA human health assessments generally follow CERCLA guidance. There is no guidance regarding risk assessments or dose assessments specific to radionuclides available for the RCRA program.

5-7. NRC Guidance. Standards for Protection Against Radiation, Radiological Criteria for License Termination, and NRC decommissioning standards at 10 CFR 20.1401-1403 give dose requirements for restricted and unrestricted land use. The standard also requires that the dose assessment determine the peak annual total effective dose equivalent (TEDE) to the average member of the critical group expected within the first 1000 years. The NRC has developed draft guidance for performing dose assessments to show compliance with their standards and also developed the D and D computer code to perform dose assessments. Another computer code, RESRAD, is available that may be used to assess doses. RESRAD has certain advantages over D and D and is preferred by health physicists for assessing doses. The model may be downloaded at Argonne National Laboratory's website at http://web.ead.anl.gov/resrad/home2/.

5-8. Considerations for Project Risk Assessments. Since many USACE projects will follow the CERCLA process, the following paragraphs discuss aspects of CERCLA screening-level and baseline risk assessments that will be unique for projects where radionuclide contamination is confirmed or suspected. Further information on risk assessments may be found in Volume I of EM 200-1-4 and Volume II of EM 200-1-4 (USACE 1996, 1999).

a. Screening-Level Risk Assessments. To determine whether a site requires further investigation and to identify areas that may pose an immediate threat to human health and the environment, a screening-level risk assessment is carried out as part of the SI. The first step of this process is preparation of a preliminary conceptual site model (CSM) for both human and ecological receptors. A preliminary CSM should be prepared when scoping the PA/SI, using whatever site information is available at the time, and the CSM should be modified as more site-specific information is gathered. EM 1110-1-1200 provides guidance for preparing CSMs for human receptors, and integrates ordnance and explosives or hazardous, toxic, and radioactive waste. Guidance for preparing CSMs for ecological receptors with case study examples may be found in EM 200-1-4.

b. Human Health Screening. Human health screening level risk assessments are typically conducted by comparing the highest detection against health-based screening levels. Screening levels are media concentrations derived by back-calculating from protective risk values and conservative exposure parameters. To develop screening levels for radionuclides and other carcinogens, the risk value is set at the lower (most protective) end of the acceptable risk range, 1×10^{-6}, one in one million excess cancer risk. Screening levels are frequently called risk-based concentrations (RBCs), or PRGs. The EPA's PRG calculator should be used to develop radionuclide screening levels for this purpose. At this stage it is appropriate for screening levels to be conservative and it is important to note that that they should not be used as remediation goals for cleaning up a site, as they do not consider site-specific factors. Remediation goals should be based upon results of a site-specific risk assessment or ARARs. Owing to the nature of their effects on biological organisms, radionuclides present at background concentrations may fail a screen against health-based levels. Therefore, it is imperative that the assessment determines whether radionuclides have be released and whether they are present above background levels before a recommendation is given for further investigation or for a removal action.

c. Guidance for Conducting Screening Level Ecological Assessments. Guidance for conducting screening level ecological assessments may be found in ERAGS (EPA 1997) and in Volume II of EM 200-1-4 (USACE 1996). An excellent discussion of screening level and baseline ecological risk assessments is presented in the Tri-Service Remedial Project Manager's Guide for Ecological Risk Assessment (Simini et al. 2000). The DOE (DOE 2002) has developed a technical standard that contains spreadsheets that are useful for calculating dose to ecological receptors. The standard and spreadsheets can be downloaded at http://tis.eh.doe.gov/techstds/standard/std1153/1153.htm. The standard includes a graded method for evaluating sites that starts with a very generic whole-site approach. This is not in strict accordance with USACE and EPA guidance, and it is not necessary to follow the standard's approach in its entirety. The DOE recently published a companion software tool, RESRAD-BIOTA Release 1.0, to assist in implementing the technical standard and will be useful for many projects. It would be uncommon for an ecological risk assessment to go beyond the screening-level stage on a radionuclide site. If a baseline ecological risk assessment is performed, it needs to follow USACE and EPA guidance.

d. Baseline Risk Assessment. Baseline risk is defined as risk that might exist if no remediation or institutional controls were applied to the site (EPA 1989). Baseline risk assessments are a required element of CERCLA remedial investigations, whose results help determine whether remedial alternatives need to be evaluated in the FS to mitigate risk. A well-designed risk assessment will provide the project manager with sufficient information to make future risk management decisions regarding the site. Such information that should clearly be presented are the media, contaminants, exposure pathways, and specific areas at the site that are contributing to unacceptable risk. The primary adverse effect associated with most radionuclides are their potential for causing cancer; however, there are others, such as uranium that may cause other effects based upon its non-radiological chemical properties, in this case causing kidney damage. The risk assessment needs to express both excess cancer risk and non-cancer risks posed by potential exposures to contaminants at the site.

e. Dose Assessment. A dose assessment may be run concurrently with the risk assessment, and it is recommended that this be done if 10 CFR 20 Subpart E is a potential ARAR for the site. The preferred tool for assessing dose is RESRAD. RESRAD is widely accepted by the health physics community and has the capability to calculate risk and dose as well as modeling fate and transport in a single model. This model has been used on many USACE projects for estimating both dose and risk posed by radionuclides. However, there are differences between using this model and CERCLA guidance for risk assessments that the project delivery team needs to be aware of; these are discussed below. The EPA has recently developed an electronic calculator, similar to the risk-based radionuclide PRG calculator, to provide dose compliance concentrations for demonstrating compliance with dose-based ARARs at CERCLA sites. The dose calculator is located on-line at http://epa-dccs.ornl.gov/radionuclides/. As USACE health physicists and risk assessors gain experience with these new tools, the lessons learned will be shared through the appropriate communities of practice.

f. RESRAD. Within a single interface, RESRAD has the capability to account for factors such as erosion, leaching, and radiological decay and in-growth that are involved with predicting risk of future exposures, also termed a prospective risk assessment. While it is common to consider such factors as contaminants leaching from soil to ground water, ground water movement and ground water discharge in CERCLA risk assessments, it is not standard practice to erode surface soils to reveal contaminants in the subsurface. RESRAD default parameters will model exposures out to 1000 years to demonstrate compliance with NRC and DOE regulatory requirements. For a CERCLA baseline risk assessment, this is not necessary, though estimating the year of peak risk attributable to radionuclide decay alone may be useful. Another factor that must be considered is that RESRAD defaults to conservative exposure scenarios, such as a subsistence farmer and fisherman, while CERCLA risk assessments generally do not include such scenarios unless there is site-specific information suggesting that these are likely future land uses. The project risk assessor, health physicist, and hydro geologist need to work together with regulatory stakeholders to determine the appropriate parameters for the risk assessment and to determine if other fate and transport models are preferred to those in RESRAD before doing the radiological risk assessment.

CHAPTER 6

Sampling

6-1. Data Quality Objectives (DQO).

a. DQO are statements made to ensure sample taking is focused on achieving the objectives of the study. They define the type of data to collect, the conditions for collecting the samples, the decision error limits, the quantity of samples taken, and the required quality of the analyses. The MARSSIM (Appendix D) outlines the DQO process - seven steps used to ensure that the data gathered provide information that will allow an informed decision to be made about the next action to take at a site. An example of a good DQO is the following:

> (The purpose of this walkover survey is to determine if there is elevated 122 keV gamma radiation from Co-57 contamination in this area, and if so where it is and how elevated it is.) DQO: Identify potential small areas (100 cm^2) of Co-57 surface soil (<15 cm) contamination in the survey unit with a 95% confidence limit using radiation detection equipment and scanning methods with an estimated Scan-MDC below the Co-57 screening level of 8.7 pCi/g [EPA PRG for residential soil]. Each potential area will be considered contaminated if the result of a direct measurement exceeds the critical level, Lc, calculated from background measurements in a reference area similar to the survey unit using values of 0.05 for alpha and beta errors.

b. This DQO could be met through by implementing a survey procedure like the one that follows:

> 100% of the surface area will be surveyed using a 2”x 2” Sodium Iodide detector held 1 meter above the surface and moved at 2 inches per second. The detector is capable of measuring 5 μR/hr gamma radiation in the 80 to 180 keV energy range (850 cpm = 1 μR/hr). The survey meter is calibrated with the detector to read out in units of μR/hr. Background has been previously determined to be 12 μR/hr (10,200 cpm). The required level of confidence is 95% for detecting true positives and 0.05% of finding false positives. The minimum detectable count rate for the ideal observer is computed to be 10,531 cpm (12.4 μR/hr). The action level for this survey is set at 12.4 μR/hr. Each location where a reading of 12.4 μR/hr or greater is detected will be flagged with a pin flag. Each flagged point will be resurveyed for 1 minute and the readings and location recorded in the survey log.

6-2. Scanning. There are a number of types of scanning done at HTRW sites-area scanning, building surface scanning, soil surface scanning, and excavation surface scanning. Scanning is performed by passing a field instrument at a set distance and slow speed over an area suspected of having radioactive contamination. Scans can detect some alpha and many beta emitting radionuclides on a surface and most gamma emitting radionuclides on the surface or a few centimeters below the surface scanned. Methods for doing scans vary a little for each type of scan.

a. Area Scanning. This is usually done to determine if an area is safe to access. This scan may find areas of high gamma radiation, which could pose a hazard to workers in the area. This type of scan is usually performed inside buildings where large quantities of radioactive materials are used, or where radiation generating devices are in use. For an area scan, a gamma ray detecting probe is held 1 meter off the floor and the radiation readings are monitored throughout the room. The readings will be used by health physics personnel to determine work procedures in the room.

b. Building Surface Scans. This type of scan is used to determine if there is radioactive contamination on building surfaces or debris, or possibly infused into the building material or debris. The instrument selected for a building surface scan depends on the radiation emitted by the contaminant. Surface scanning instruments preferentially have a large window detector, allowing more surface area to be scanned at one time. The detector is held very close to the surface to be scanned. This detector is moved slowly over a prescribed percentage of the surface area. For final status survey of class 1 areas, see Chapter 13 for a discussion of area classification, this is typically 100% of the surface, and 25% of the total surface for class 2 areas, areas. Additionally, a wipe or smear survey is usually done in conjunction with a building or debris scan to determine if the contamination is removable. A health physicist will need to ensure that the combination of the type and size of the detector, the distance from the surface, and the speed that the detector is moved are such that the instrument will be capable of detecting contaminants at a low enough concentration to meet the survey goals. The building or debris surface scan should result in a report detailing the total square footage of the building or debris surface, the total square footage that was contaminated above the action level, the average level of contamination and the highest level of contamination measured, and whether the contamination is removable of non-removable.

c. Soil Surfaces. Soil surfaces are scanned similarly to building surfaces but may present other problems. Vegetation may need to be removed. Soil surfaces may be rugged, making it difficult to maintain the detector at a set distance from the surface. As with building scans, soil scans may detect gamma-emitting radionuclides a few centimeters deep in the soil. Most radionuclides would not be detectable at depths below a few centimeters unless they are present in large quantities. A health physicist can calculate the depth to which the instrument can detect a certain quantity of a specific radionuclide.

d. Excavation Surfaces. These are scanned in the same manner as soil surfaces. Open excavations are usually scanned to determine if further excavation is necessary. As before, if a sufficient thickness of soils is between the detector and the contaminant, the instrument will not be capable of detecting it. If an excavation is scanned and no contamination is detected, and the excavation is backfilled with clean fill, it can be expected that no contamination will be detected if the backfilled excavation is re-scanned.

6-3. In-Situ Measurements. These are made using a sodium iodide (NaI) detector or a high purity germanium (HPGe) detector in conjunction with a spectrum analyzer. This system will allow a spectrum of all gamma radiations to be recorded and analyzed. Most of these systems can identify the source radioisotope of each gamma radiation measured. Some systems have incorporated algorithms to enable the system to quantify the contaminants of concern, and attempt to determine the depth in the soil at which the contaminant is present. These systems are very complex and careful evaluation will be needed to provide a level of confidence in their measurements.

6-4. Down-hole or Well Logging. Another form of scanning is down-hole logging. In this situation, a detector is lowered into the borehole and a record of the measurements vs. the depth of the detector is recorded. This method can sometimes locate the depth that a contaminated layer of soil is at relative to the ground surface. It can also sometimes locate hotspots within the ground. Down-hole logs are influenced by a number of factors, including soil density, moisture content, and soil type. Ensure that the individual interpreting the survey is experienced in accurate down-hole survey interpretation techniques.

6-5. Sampling Surface Soils. This is commonly done at locations where scanning indicates elevated radiation levels. This is called biased sampling. A grid may be set out over the site and soil samples taken at selected grid nodes. Additionally, random surface soil samples may be taken to verify remediation effectiveness. A surface soil sample, usually about 1 kilogram, is removed and packaged then forwarded to a lab for analysis.

a. Subsurface soil sampling is usually done with a coring device. A soil core from the surface to a set depth is taken and soil from a certain layer is removed form the core, usually homogenized, and sent to the lab for analysis. Subsurface sampling may be achieved by other means, such as removing the cover or topsoil with a shovel or backhoe, then taking a soil sample at a specific depth. Often the contaminant is excavated to a prescribed depth, then samples of the soils in the bottom or on the sides of the excavation are taken to confirm that all the contaminated soil was removed from the site. Subsurface sampling may be necessary to determine the three-dimensional extent of contamination at a site.

b. As with all grab samples, care must be taken in the interpretation of surface and subsoil results. Biased sampling may indicate the areas and the maximum concentrations of a contamination a site, but is not representative of the site as a whole. Gridded samples may provide the best indicator of the site-wide conditions, but must be evaluated using statistical tools to ensure that enough samples were taken to have an acceptable level of confidence in the results. Subsurface samples are more difficult to acquire and so are more expensive.

Excavation sampling must consider the safety requirements for potential sloping and shoring before an individual is allowed into the excavation. All gridded sampling relies on the assumption at the contaminant is distributed over the site in some manner. Problems in interpretation can arise when the contaminant is heterogeneous over a site rather than homogeneous. A heterogeneously distributed contaminant is one where larger pieces of the radioactive contaminant are randomly scattered over a site, with little or no continuous contamination of surrounding soils. In this case, statistics based on a distribution break down.

CHAPTER 7

Characterization

7-1. Introduction. Characterization refers to three separate tasks that are part of the CERCLA process: site characterization, contaminant characterization, and waste characterization.

7-2. Chemical and Radioactive Contaminants. Radioactive materials can pose two separate hazards to human health at a site. They may be hazardous chemicals, and they also decay and emit ionizing radiation. The chemical hazard posed by an element is the same regardless of whether a stable or radioactive isotope is involved. The chemical hazard depends on the molecular complex to which the atom is affixed. Regardless of the chemical form, if the isotope is radioactive, the molecular form will emit radiation, and, therefore, be hazardous. Besides its chemical toxicity, the molecular form will determine its transportability in the environment.

a. A contaminant's characteristics can change over time. Chemical degradation occurs in many contaminants over periods of months or years. Radioactive decay transmutes the radionuclide from one element to another, which in turn can alter the way it behaves on the molecular level and also how it is transported in the environment. For example, radium-226 is often found in water-soluble compounds that can be dissolved and percolate through the soil column to ground water. Radium-226 decays to radon-222, an inert gas that may rise through the soil column and disperse in the air, but is also highly water soluble. Radon-222 decays to a number of short-lived decay products, all of which are solids and will attach electro-statically to dust particles in the air, further allowing air migration, or they will be washed out of the air by precipitation, and reenter the soil. In summary, the contaminant can change atomic form, change the radiations emitted, change chemical form, change fate and transport methods, and change chemical and radio toxicity over time.

b. For these reasons, it may be necessary to characterize both the radioactive and the chemical/molecular form of the suspected contaminants and to determine how these characteristics change over time. When this characterization is too complex or too expensive to determine, it is necessary to make some assumptions about how the characteristics will change and how these changes will affect transportation and exposure pathways in the environment. It is important to ensure that, whenever any assumptions are made, they are fully documented in the characterization report, and that an estimate of their reliability be incorporated in the report.

c. Samples taken and analyzed during the site characterization may be useful during the waste characterization. If the actions generating the waste stream do not greatly alter the type or concentration of the contaminants, site characterization sample results may be used for waste characterization. It is important to know the disposal site's waste acceptance criteria and the required sample analyses to ensure that site characterization sample analyses will be acceptable to the disposal site. This will aid in decreasing the number of samples being analyzed over the entire life of the project.

7-3. Site Characterization. This is the quantitative description of the site properties that influence the determination of risk to human health or the environment from a contaminant present at the site. The site characterization includes an investigation of the physical nature of the site and the contaminants at the site. It attempts to define the sources of the contamination, and determine the nature and extent of the contamination. It also seeks to identify exposure pathways and potential receptors for the risk assessors. As a corollary to this, it also is used to identify areas that are not contaminated. All sampling and characterization should be oriented toward provision of data necessary to complete the final status survey, and reach closure of the project.

a. The physical characteristics of the site may include geophysical and hydrogeological parameters, as well as the site use and accessibility in the past, present, and future. It also includes characterization of the volumetric distribution or dispersion of the contaminants or contaminant at the site.

b. The site characterization is attempting to answer the questions: What is the contaminant on-site? What are its radiological as well as its chemical characteristics? Where is the contamination? What is the pattern or distribution, if any, of the contaminants? What are the actual and potential modes of transport of the contaminant in the environment? Who are the potentially exposed populations? What are the routes of exposure?

c. Site characterization is described further in EPA CERCLA guidance. Important differences in site characterization on radioactive sites that may manifest themselves are the variations in radionuclide pathways from the standard chemical pathways. Especially the decay chain radionuclide series, where there is a change in physical form that accompanies the decay, such as solid radium-226 decaying to gaseous radon-222. There is also the change in chemical form and in chemical reactivity that will affect pathways. After most decays, the radionuclide is left in an ionized state, which is chemically highly reactive.

d. Contaminant characterization, a subtask of site characterization, describes the physical, chemical, and radiological parameters of the contaminants as they exist at the site.

7-4. Waste Characterization. Waste characterization defines the waste stream containing the contaminants as it will be delivered to the disposal facility. Waste characterization can be a multi-stage process. On many sites, large numbers of site characterization samples are taken of soils and debris. In most cases the act of removing and packaging the contaminated soil or debris does not significantly alter the radioactivity of the waste. In these cases we can use the site characterization sample data to contribute to the waste characterization data. This will significantly lower the number of samples and analyses needed on the waste stream. If this is the case, it is important to ensure that the site characterization sample data are of the same caliber needed for waste characterization. Additionally, removal and packaging methodology that ensures that concentrations of radioactive contaminants in the soil and debris are not significantly altered needs to be included in the data package.

a. The concentration, activity, and chemical form of the contaminant may have altered because of some remedial, removal, or other actions taken at the site, or on the waste stream. When this is the case, a more stringent waste-characterization sampling program will be required to ensure adequate confidence in the level of activity in the waste and the homogeneity of the waste.

b. For disposal, waste streams may sometimes be combined to allow for more economical transportation and disposal. While radioactive waste streams may be combined and the average concentration of radionuclides in one waste stream may be lowered by the combination, waste may not be diluted to become unregulated. Both waste streams must meet the waste acceptance criteria of the proposed disposal site to be blended. If one waste stream does not, it should not be blended. Waste will not purposefully be mixed with uncontaminated soils to lower its radioactive concentration. In the process of remediation, some clean material is unavoidably collected along with the contaminated material; this is acceptable and is not considered blending.

c. The following is an example: A site contains a radioactive waste burial pit. The remediation method chosen was to remove the soils covering the pit, segregate these soils from the waste in the pit, excavate the waste in the pit, try to treat 10 cubic yards of the waste with a new technology that minimizes the waste volume, and ship all waste to disposal facilities. A characterization survey is conducted to determine the radionuclides present, their concentrations at various locations and depths, and their volumetric extent at the site. Assume the 85 characterization samples showed that the soil covering is uniformly contaminated with very low concentrations of radioactive waste and can be disposed of at an RCRA Subtitle C facility. In the process of excavating the contaminated soils, the buckets sometimes cut a few inches deeper into uncontaminated soils, incorporating some uncontaminated soil into the waste stream. This generated 2500 cubic yards of waste. This particular RCRA facility requires one confirmatory sample per 100 cubic yards of waste, so 25 confirmatory samples are required for this waste stream.

(1) The waste excavated from the pit is known from the characterization sampling to be uniformly contaminated but with a much higher activity. This 10,000 cubic yards of material must go to an NRC licensed radioactive waste disposal facility. The facility requires five confirmatory samples be taken from the entire waste stream. They also have additional testing when the waste reaches their site. If this testing reveal concentrations vastly different

from those presented by our sampling, the shipment will be returned to the originating site. To ensure we meet the waste acceptance criteria for the site, we use the information collected during the characterization of the site, applicable to this waste stream. These 200 subsurface soil samples show the radionuclide concentration to be a total of 3400 pCi/g ± 1200 pCi/g at a 95% confidence level. The five confirmatory samples varied between 2500 and 4200 pCi/g with a mean value of 3250 pCi/g. Site and process knowledge, combined with the confirmatory samples, provides excellent confidence that excavation and handling procedures did not significantly alter the radioactive contaminant concentration of this waste stream.

(2) The 10 cubic yards of the pit waste that are treated resulted in a volume reduction of 60%; 30 samples taken from the 6 cubic yards of 'cleaned' waste show that the radionuclide concentration is lower than the remediation goal for the site. With the concurrence of the site regulators, it may be disposed of on-site as fill. The remaining 4 cubic yards are sampled twice and both samples show the radionuclide concentration has been increased.

(3) This site has three radioactive waste streams: the 2500 cubic yards of slightly contaminated soil covering, the 10,000 cubic yards of pit contents, and the 4 cubic yards of treated waste. Total samples taken of each waste are as follows:

(a) For the 2500 cubic yard soil covering, 85 characterization samples and 25 confirmatory samples were taken.

(b) For the 9,994 cubic yard pit contents, 200 characterization survey samples and 5 confirmatory samples were taken.

(c) For the 4 cubic yards of treated pit contents, 2 samples were taken. The 4 cubic yards was then blended in with the 9,990 cubic yards of the original pit contents, and was calculated to not significantly change the content of the pit radionuclide concentrations.

d. In summary, the site characterization will have identified the radioisotopes, and provided a range of concentrations in each waste stream, and an estimated volume of each waste stream. To meet disposal facility requirements and USACE quality control, additional samples needed to be taken and analyzed to ensure that the waste, excavated and ready for transport to the disposal facility, has not been inadvertently altered through the remediation process. The information gathered from these samples is combined with the information from the characterization and any other surveys and is used to define the waste. By ensuring that all the surveys have similar data quality, we can combine the results and achieve a very reliable statistical estimate of our confidence in the data.

7-5. Site History and Waste Pedigree. A comprehensive site history can be very helpful in determining potential radioactive contaminants. If materials arrive as ores, and were smelted on the site, the residuals may contain both parent and progeny decay products. If material was already refined, parent or certain progeny may not be reasonably expected at the site. Potential areas of contamination can be determined if knowledge of the physical flow of materials in, around, and off the site is known. Soil and water extraction processes, wells, or surface water systems used at a site may have contributed to technically enhanced NORM (naturally occurring radioactive materials). All these processes and materials movement may help explain the presence and migration of contaminants on and off the site. Additionally, it is important to know the site history to characterize and classify the radioactive material.

7-6. Quantifying Contaminated Materials. A characterization study and interpretation of the data collected should yield the following information:

- The range and extent of contamination at the site.
- Each radionuclide present on-site.
- The range of concentrations of each radionuclide on-site.
- The volume and mass of soil expected to exceed site screening levels/PRGs.
- The total activity and concentration of the radioactivity in soil exceeding site screening levels/PRGs.
- The volume and mass of debris to exceed site screening levels/PRGs.
- The total activity and concentration of the radioactivity in or on debris exceeding site screening levels/PRGs.
- The activity, concentration, and volume of the highest 'hot-spot' in soils on the site.
- The concentration and total activity expected to remain in the soil on the site.
- The concentration and total activity expected to remain on or in buildings or debris left on the site.

All of the above data shall be quality controlled and of an accuracy and precision to be acceptable as MARSSIM final status survey compatible data. By conforming to MARSSIM Data quality objectives, these data can be combined meaningfully with all the other data obtained on the site and the waste to provide a better statistical accuracy to the data.

7-7. Other Media - Air, Water, Sediments. Depending on the site, air, surface water, or ground water may require characterization. The primary difference in characterization is that these measurements are normally provided in activity per unit volume, as opposed to activity per unit mass.

CHAPTER 8

Radioactive Waste

8-1. Classification.

a. The NRC regulates only source, byproduct, and special nuclear materials. Waste classification starts with determining if the material is NRC regulated.

b. Licensable source material is defined as: (1) uranium or thorium in any physical or chemical form, or (2) ores containing one twentieth of one percent (0.05%) by weight of uranium or thorium or any combination thereof. Source material in any chemical mixture, compound, solution or alloy in which the source material is less than one twentieth of one percent (0.05%) by weight is considered an unimportant quantity of source material. Source material does not include special nuclear material.

c. Special nuclear material is plutonium, uranium-233, material enriched in uranium-233 or uranium-235, or anything else the NRC determines is special nuclear material but does not include source material.

d. Byproduct material is defined in a number of regulations. Byproduct material is 1) any radioactive material yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material, and 2) the tailings and wastes produced by the extraction or concentration of uranium or thorium from ore processed primarily for its source material content, including waste from uranium solution extraction processes. Byproduct material does not include source material or underground ore bodies depleted by solution extraction.

8-2. Waste Definitions.

a. Congress defines high-level radioactive waste as the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and other highly radioactive material that the NRC, consistent with existing law, determines by rule requires permanent isolation. The latter includes spent nuclear fuel. Low-level radioactive waste is radioactive material that is not high-level radioactive waste, spent nuclear fuel, or 11e.(2) byproduct material from uranium or thorium mining/milling operations; and NRC, consistent with existing law, classifies as low-level radioactive waste [42 USC 10101]. Additionally, NRC has ruled that it does not regulate uranium and thorium mining and milling wastes/tailings generated before 1978.

(1) The importance of these definitions and regulatory authorities to USACE is in the available methods for disposal of each type of waste. There is no present disposal option for high-level radioactive waste, or for transuranic waste not owned by DOE. Low-level radioactive waste is subject to regulation by the various state radioactive waste compact authorities as well as the NRC. Low level radioactive waste may be disposed of only in a compact authorized radioactive waste repository: one in Barnwell, South Carolina, or the other in Richland, Washington, or, with the permission of the compact, at Envirocare of Utah. DOE transuranic waste may be disposed of only at the Waste Isolation Pilot Plant in New Mexico.

(2) If the waste is not high-level or low-level radioactive waste, or transuranic waste, there may be other options for disposal.

b. Depending on the pedigree of the waste, the radionuclides involved, the concentrations of the radioactive materials and any hazardous waste constituents in the waste, other disposal options may include properly permitted or licensed RCRA landfills, hazardous waste disposal facilities, uranium mills, and uranium or thorium tailings ponds. Each individual disposal facility has its own waste acceptance criteria and the selection is a very complex decision that should be delegated to radioactive waste experts within USACE. The health physicists at the HTRW-CX have experience with many types of waste disposal and can assist any District. The Kansas City District has a number of pre-placed disposal contracts available for use by all USACE Districts and some outside agencies. While Districts are not obligated to use the Kansas City contracts, a good rule of thumb is that, for waste quantities under 3000 cubic yards, the use of the pre-placed contracts will usually be less expensive than the costs of the bidding process for other disposal sites and resulting disposal fees.

c. Another consideration is radioactive waste owned by DOD. The DOD Executive Agent for radioactive waste has been designated as the lead for disposal of these materials. All disposal of DOD-owned radioactive materials or waste must be coordinated with the Executive Agent through the HTRW-CX to comply with NRC and DOD licenses and authorizations. Radioactive wastes generated by Civil Works activities, such as FUSRAP, may not be considered DOD wastes.

d. Radioactive waste disposal regulations are very complex and some of the regulatory methods and procedures have not yet been set. It is also important to coordinate any characterization of waste and selection of disposal options with the HTRW CX to ensure that an action at one site is not setting a precedent that will affect disposal options at other USACE projects.

8-3. Waste Disposal Facility Criteria. Each waste disposal facility has its own waste acceptance criteria and lists what characteristics must be evaluated and what limits they allow on each contaminant. The common data that must be supplied on all materials for disposal include the following:

- Waste generator
- Location of waste generator
- Physical state of the waste
- Medium contaminated
- Radionuclide or radionuclides present
- Activity and concentration of each radionuclide
- Total weight and total volume of the waste
- Co-mingled hazardous substances
- Quantity and concentration of hazardous substances

CHAPTER 9

Primary Regulatory Processes

9-1. Introduction. This chapter will provide the project manager (PM) and project delivery team with an overview of the primary regulations and requirements that USACE and their contractors will follow while executing environmental restoration of sites contaminated with radioactive waste or radioactive waste that is commingled with either CERCLA hazardous substances or RCRA hazardous waste. Once the preliminary determination has been made that a response action is warranted, two important and related questions must be answered for every environmental remediation project:

- What regulatory authority governs this response action?
- What are the cleanup levels that must be achieved for the contaminants of concern for the remedy to be protective of human health and the environment?

a. To determine the cleanup criteria, it is essential to determine the regulations that apply to the site, as well as which Federal or state regulatory agency has the authority and responsibility for enforcing the regulations. This chapter will discuss the primary restoration programs that USACE follows when cleaning up radioactive waste or mixed waste contaminated sites. The responsibilities of the two major Federal agencies that regulate the environmental restoration activities will also be briefly discussed:

- The Nuclear Regulatory Commission (NRC) is responsible for decommissioning of licensed facilities under the Atomic Energy Act (AEA).
- The Environmental Protection Agency (EPA) has regulatory authority over sites under two separate environmental programs - CERCLA and RCRA.

In addition, there may be situations where more than one Federal regulatory agency or multiple offices from the same Federal agency may have responsibility for regulating different contaminants or activities at a site.

b. Characterization of the type of radioactive material or waste is a very important component of determining which regulatory authorities govern the management of radioactive material. The characterization process must examine the processing history of the waste as well as the type and quantity of radionuclides present. Chapter 1 of this manual contains definitions for the common types of radioactive wastes or materials that USACE may encounter. In some situations, radioactive waste is characterized by what isn't present instead of what is present (e.g., LLRW). The term "mixed waste" is defined in the Federal Facilities Compliance Act as waste that contains both RCRA hazardous waste and AEA regulated, source, byproduct or special nuclear material.

c. An excellent resource when dealing with radioactive contamination is the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), which was developed collaboratively by four Federal agencies having authority and control over radioactive materials (DOD, DOE, EPA, and NRC). Appendix C of MARSSIM provides an overview of the statutory authorities and regulations that are the responsibility of each Federal agency. It is interesting to note that the EPA, NRC, and DOE derive their respective authorities for promulgating regulations, standards, and orders from many of the same statutes.

d. A comprehensive explanation of all the regulations and administrative and procedural requirements that USACE must comply with will not be included in this chapter. However, a brief discussion will be provided on the primary environmental statutes and regulations that pertain to the restoration of the radioactively contaminated sites. The PM will need to coordinate with the appropriate disciplines of the project delivery team (e.g., Office of Counsel, health physicist, risk assessor, regulatory, etc.) to determine if there are unique or additional requirements (e.g., state regulations) applicable to the specific project.

9-2. Environmental Response Authorities for Radioactive Waste or Mixed Waste.

a. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)[42 USC 9601 et seq.]. CERCLA, commonly referred to as "Superfund," established a national program for responding to uncontrolled releases of hazardous substances into the environment from abandoned waste sites. CERCLA hazardous substances are defined as any substance designated or listed under the Clean Air Act, the Federal Water Pollution Control Act, the Toxic Substances Control Act, and the Resource Conservation and Recovery Act. CERCLA will be the primary restoration program that USACE will typically utilize to execute an environmental response action for sites that have been contaminated with radioactive waste or mixed waste. However, if USACE does work for others that operate under an NRC or agreement state license, the activities will be conducted under the NRC regulations. On NRC licensed sites where USACE is contemplating a FUSRAP cleanup under CERCLA, a Memorandum of Understanding (MOU) may be needed to minimize the potential for dual regulation. The current NRC-USACE MOU for FUSRAP sites is described in Section 9-3d.(1) below.

(1) Authority. CERCLA provided broad Federal authority to respond directly to releases or threatened releases of hazardous substances, pollutants, and contaminants that may endanger public health or the environment. For non-governmental National Priorities List (NPL) sites, undergoing a CERCLA remediation, EPA is the lead enforcement agency. Executive Order 12580, Superfund Implementation, dated 23 January 1987, as amended by Executive Order 13016, dated 28 August 1996 delegated many of the authorities of the President established in CERCLA to DOD, as well as other Federal agencies. One such authority is that DOD is the lead Federal agency for response actions at both NPL and non-NPL DOD installations. This includes the authority to select remedies, subject to the

concurrence of EPA if it is an NPL site [CERCLA, Section 120(e)]. USACE also has lead agency authority to select remedies at FUSRAP sites, regardless of whether the site is DOD or not [Pub. L. 106-60 section 611]. CERCLA applies to radiological events at DOD and DOE facilities, but does not apply to releases from NRC-licensed facilities subject to the requirements of the Price Anderson Amendment (Section 170) of the AEA-essentially nuclear power plants.

(2) Applicability. Radionuclides are considered hazardous substances under CERCLA by virtue of their listing as Hazardous Air Pollutants (HAPs) under the Clean Air Act (CAA), where they are listed in Appendix B to the List of Hazardous Substances (40 CFR 302.4). It is important to understand that hazardous substances and hazardous waste have specific meanings and are not synonymous. All RCRA hazardous wastes are by definition CERCLA hazardous substances, but not all hazardous substances are hazardous wastes. It is important to note that CERCLA excludes radionuclides that are considered source, byproduct, or special nuclear materials from the definition of "release" if from a nuclear incident as defined by the AEA, if such release is subject to requirements with respect to financial protection established by the NRC (Price Anderson Amendment Act of 1988-42 USC 2210 et seq.) or any release of source, byproduct, or special nuclear material from any processing site designated under UMTRCA (42 USC 7911 et seq.).

(3) Implementing Regulations. CERCLA response efforts are guided by the National Oil and Hazardous Substances Pollution Contingency Plan commonly referred to as the NCP (40 CFR 300). The NCP are the regulations that EPA has promulgated to implement CERCLA. The NCP establishes the criteria, methods, and procedures that must be followed to investigate contamination and determine if a response action should be taken at a site to protect human health or the environment.

(4) Process. In section 120(c) of CERCLA (42 USC 9620), Congress required EPA to develop a list of all Federal facilities that ever stored, treated, disposed of, released or spilled, or are currently generating, treating, storing or disposing of hazardous wastes, or have released a hazardous substance in a reportable quantity. The list, which EPA maintains, is called the Federal Agency Hazardous Waste Compliance Docket. CERCLA establishes the requirements for actions on sites listed on the docket. Once a Federal facility is listed on the docket, a preliminary assessment (PA) must be conducted at the facility. If, after completing the PA and consulting the NCP requirements, further action is warranted, the facility must perform a site inspection (SI). After completion of the PA/SI, EPA may elect to score the site using the hazard ranking system (HRS). If the HRS is high enough ($\geq$ 28.5), EPA will determine whether to make the site an NPL site. A NPL site must initiate a remedial investigation and feasibility study (RI/FS) no later than six months after inclusion on the NPL. Upon completion of the RI/FS, the Federal facility must enter into an Interagency Agreement with EPA within 180 days and commence on-site remedial action within 15 months. After the RI/FS has been completed, a proposed plan must be presented to the

public with an opportunity for comments to be received and considered by the agency, after which a record of decision (ROD) will be prepared and signed. Compliance with the NCP is required regardless of whether the Federal facility or site is on the NPL. This means the administrative and procedural requirements of the NCP must be followed. The site must have appropriate site investigation and characterization, analysis of remedial alternatives, and selection of a protective and cost-effective response action. The public must be allowed an opportunity to comment on any response action, even if there is no further action required. A further explanation of the CERCLA process is provided in Appendix F of MARSSIM and paragraph 1.3 of EM 200-1-4. Districts are encouraged to coordinate early with regulators to identify a single regulatory framework to guide the environmental restoration process. To minimize potential duplication of efforts by states, tribes, and the EPA, it is important that the lead regulator be clearly identified and communicated to all parties for each site. States or tribes should generally be the lead regulator for environmental investigations and response at non-NPL sites. In certain circumstances, EPA may serve as lead regulator where the state or tribe requests it or when EPA chooses to exert its lead regulator role. In instances where EPA assumes lead regulatory agency authority, roles should be documented and all parties notified. If USACE is performing work for others that are under an NRC or agreement state license, the lead regulator role may be the NRC or the agreement state.

(5) Cleanup Criteria. The CERCLA process [Section 121(d) of CERCLA (42 USC 9621)] requires that a "degree of cleanup" be determined for the remedial action. In determining what remedial action is necessary and appropriate, the lead agency must consider the nine criteria established by CERCLA, Section 121, and implemented in 40 CFR 300.430.(e). All CERCLA response actions must determine the applicable or relevant and appropriate requirements (ARARs) for remediation of the site. Once they are identified, the substantive elements of those ARARs must be determined, including all the conditions and alternatives to their application. The NCP does provide relief from strict compliance with the ARARs if certain conditions exist or can be met through a formal process to waive the ARAR [40 CFR 300.430(f)(1)(ii)(C)]. The ARAR analysis must determine if a requirement is a promulgated and legally enforceable Federal environmental law or regulation, or state environmental or facility locating law or regulation. The requirement must contain substantive criteria pertaining to the hazardous substances or pollutants or contaminants or the circumstances of their release at the site.

(a) The requirement is applicable if it specifically addresses the contamination or release at the site [40 CFR 300.5]. Another way to evaluate this is to pose the question; if the CERCLA permit waiver for on-site activities did not exist, would the regulator be able to impose the standard through a permit or other regulatory approval process? The ARAR analysis process should include a legal analysis by the District Office of Counsel to determine whether the requirement specifically addresses a hazardous substance, pollutant, contaminant, remedial action, location or other circumstance found at a CERCLA site. The District is cautioned against accepting or developing a "laundry list" of statutes or regulations that do not meet the CERCLA definition of an “Applicable” or “Relevant and Appropriate” requirement.

(b) The requirement may also be an ARAR if it is relevant and appropriate to the contaminants or the circumstances of their release, even if not applicable. Fundamentally, the law or regulation must address situations sufficiently similar to the circumstances of the release or the remedial action, and be well suited to the site. There are a number of factors that must be considered in making the determination whether a requirement is relevant and appropriate for the site [40 CFR 300.400(g)(2)]. It is very important to note that CERCLA and the NCP are very definitive that only state standards that are promulgated, are identified by the state in a timely manner, and are more stringent than Federal requirements may be ARARs for a CERCLA response action. In accordance with DERP and the NCP, USACE must formally request that the lead regulatory agency and support agency identify their potential ARARs for a particular site. The District should request the regulator agency provide the citation and explanation as to why they have identified a specific requirement as a potential ARAR for the site.

(6) Response Actions. CERCLA authorized two kinds of response actions to be taken where hazardous substances have been released or there is a potential for a release into the environment: removal actions (short-term) and remedial action (long-term).

(a) Removal Action. The removal action is intended to address actual or threatened releases in a prompt manner to protect human health and the environment. The removal action is to abate, prevent, minimize, stabilize, mitigate, or eliminate the threat to human health or the environment. Typically, the removal action is used to eliminate an imminent hazard to human health or the environment. Removal actions shall, to the extent practicable, contribute to the efficient performance of any anticipated long-term remedial action with respect to the release concerned. Removal actions, unlike remedial actions, are not required to comply (or waive) all ARARs except to the extent practicable considering the site conditions. It is important to remember that removal actions don’t necessarily always require removal of the contamination and may be erecting a fence to protect the public or providing an alternate drinking water source to the public. EPA has categorized removal actions, under CERCLA and the NCP, in three ways:

- Emergency removal actions (within hours of discovery)
- Time-critical removal actions (initiated within 6 months)
- Non-time critical removal actions (planning and evaluation takes 6 months or longer)

The NCP requires public involvement in the removal process, through the administrative record process, public notices, and other mechanisms. Removal actions can take place at any time during the entire CERCLA process. An engineering evaluation and cost analysis

(EE/CA), which serves as a decision document, is required for non-time critical removal actions.

(b) Remedial Action. The remedial action process is used under CERCLA to address actual or threatened releases of hazardous substances that are serious, but not immediately life threatening or dangerous to the environment. Remedial actions are typically conducted after several years of investigation, evaluation of alternatives, and selection of a permanent final remedy. The NCP provides the implementing regulations for conducting the preliminary assessment (PA) and site inspection (SI) to determine if further site investigation and characterization is necessary. The remedial investigation (RI) is the CERCLA phase that can be considered the site characterization phase, in which the nature and extent of contamination is determined and potential risks and exposure pathways are evaluated to determine if there are unacceptable risks to human health and environment. The next phase is the feasibility study (FS), which may be conducted concurrently with the RI. The FS is the process to evaluate potential remedial alternatives to clean up the site. An important aspect of the RI/FS process is to identify the potential ARARs for determining the cleanup standards that must be achieved, as well as what impacts the ARARs may have on the possible remedy alternatives. The nine criteria are used in the remedy selection process and it is important to note that the selected remedy must be protective of human health and the environment and comply with ARARs. This manual will not provide a comprehensive explanation of the individual tasks that must be accomplished in preparing the PA, SI, RI, FS, proposed plan, and ROD. EPA provides a guidance document on the necessary steps in performing a RI/FS on a CERCLA site (EPA/540/G-89/004.

(7) Important Aspects of the CERCLA Process.

(a) Lead Agency Authority. The NCP provides a definition for “lead agency” in 40 CFR 300.5 that is very important when executing a CERCLA response action. In the case of a release of hazardous substance, pollutant, or contaminant, where the release is on or the sole source of the release is from, any facility or vessel under the jurisdiction, custody, or control of DOD or DOE, then DOD or DOE will be the lead agency (as appropriate). The Federal agency maintains its lead agency responsibilities whether the remedy is selected by the Federal agency for non-NPL sites, or by EPA and the Federal agency (NPL sites), or by EPA alone under CERCLA section 120 (NPL site where there is non-concurrence). USACE acts as lead agency for several programs that are under their “jurisdiction, custody, or control.” This includes the FUSRAP and FUDS programs where USACE has been officially designated as the lead agency for the selection of the remedy. USACE may act as lead agency at the request of the Commanders for installation restoration program (IRP) sites and Base Realignment and Closure (BRAC) facilities.

(b) Permit Waiver for On-site Activities. CERCLA [Section 121(e)] and the NCP are very specific that no Federal, state or local permit shall be required for the portion of any removal or remedial action that is conducted entirely on-site, where such response action is selected and carried out in compliance with the CERCLA process. CERCLA response actions do not need to comply with administrative requirements such as administrative reviews, certifications, permitting, manifesting, reporting, and record keeping. However, substantive requirements, which are non-administrative, relating to numerical cleanup levels, required technology, emission control limitations, and other standards, must be complied with. The permit waiver does not preclude the response action from complying with an ARAR numerical standard that applies to the planned action.

(c) Use of "To Be Considered" (TBC) Documents. In the process of evaluating remedial alternatives, a lead Federal agency may consider other governmental documents that do not rise to the level of an ARAR. The NCP [§300.400(g)(3)] does make provisions for the use of advisories, criteria, or guidance developed by EPA (e.g., OSWER Directives), other Federal agencies or states that may be useful in developing CERCLA remedies. The designation and use of TBCs is a discretionary matter for the lead agency, and it should be carefully used, so as not to elevate to enforceability those guidance or policy statements that are not useful to support a decision on a remedy. Generally, TBCs should only be used when ARARs do not exist for a site, and only if they are not inconsistent with the nine criteria mandated by CERCLA for the remedy selection process.

(d) Removal Action as a Final Remedy. The general perception established by the NCP and understood by the public and the regulators is that the removal action is an interim measure taken to eliminate an immediate or potential hazard to human health or the environment. The removal action, to the extent practicable, is to contribute to the efficient performance of any anticipated long-term remedial action with respect to the release of hazardous substances. Unlike remedial actions, which must comply with (or invoke or justify a waiver) all ARARs, removal actions comply with ARARs only "to the extent practicable considering the exigencies of the situation." The removal action has a number of procedural requirements that do not correspond to the level of detail that is required of a remedial action. A few of the major items are as follows:

- Public participation is more limited and compressed during a removal action.
- The removal action does not perform a comprehensive site characterization to determine nature and extent of contamination in all media and all potential pathways of exposure.
- Human and ecological risk assessment is generally abbreviated.
- Removal action does not generally provide a screening and detailed evaluation of remedies.

The NCP does require an engineering evaluation and cost analysis (EE/CA) for non-time critical removal actions but it does not share some of the important features (freezing ARARs, site closeout, etc.) of the ROD for a remedial action. Therefore, a removal action is not the response action of choice for a final remedy. However, where circumstances dictate such an approach, e.g., time is of the essence, substantive CERCLA criteria for removal actions are met, and removal of the hazardous substance to unrestricted use levels does not compromise safety and is not significantly more costly or time consuming than cleanup to less conservative levels, a removal action to final remedy levels may be appropriate. If a removal action is being planned as a final remedy, it would be important to obtain approval from the USACE chain of command. Upon approval, the public and regulators should be provided early notification of the intention for the removal action to be a final remedy. The removal action should identify and comply with all ARARs that pertain to the response action as well as not take advantage of ARAR waivers as a subsequent remedial action would not be anticipated. The removal action should include a comprehensive site investigation to determine the nature and extent of contamination (e.g. soil, ground water, etc.) to ensure that the selected action protects human health and the environment. The removal action should be followed by a no further action record of decision to achieve site closeout. Removal actions taken by EPA, under the Superfund program, have a money ($2 million) and time (12 months) limitation. If the site is not on the NPL, DOD is not necessarily limited by these restrictions as they apply to the use of Superfund money, but based on the previous factors, complex and expensive response actions should still be performed as remedial actions, with the remedial investigation, feasibility study, proposed plan, and record of decision in accordance with the NCP.

b. Resource Conservation and Recovery Act (RCRA)[42 USC 6901 et seq.].

(1) Authority. RCRA is the primary Federal statute regulating the generation, transportation, treatment, storage, and disposal of solid and hazardous waste. RCRA was enacted by Congress to require proper management of waste generated at existing facilities. RCRA has kept in stride with current waste management issues and problems by way of Congressional amendments, the most notable being the Hazardous and Solid Waste Amendments (HSWA). Under provisions of HSWA, Congress established the authority for corrective action requirements at permitted or interim status hazardous waste management facilities. Mixed waste, as defined in Chapter 1, contains radioactive and hazardous waste. A dual regulatory framework exists for mixed waste, with the EPA or the RCRA-authorized states regulating the hazardous waste and the NRC or NRC agreement states, or possibly DOE, regulating the radioactive waste.

(2) Applicability.

(a) The RCRA Corrective Action program provides EPA (or authorized state) with the authority to require a current owner or operator of a hazardous waste management facility to take corrective action at a facility seeking a permit where there has been a release of a hazardous waste or constituent at the facility, regardless of when waste was disposed of at the facility, and to require work beyond the facility boundary where necessary to protect human health and the environment. It is important to note that under the RCRA regulations, source, special nuclear material, and byproduct material (as defined by the AEA) are expressly excluded from the definition of solid waste, and, thus from regulation under RCRA as a hazardous waste.

(b) Over the past two decades, EPA, the NRC and state agencies have identified a number of naturally occurring materials that, because of human activity, may present a radiation hazard to people and the environment. This material is called technologically enhanced naturally occurring radioactive material (TENORM). TENORM is generally defined by the National Academy of Science as “any naturally occurring material not subject to regulation under the Atomic Energy Act whose radionuclide concentrations or potential for human exposure has been increased above levels encountered in the natural state by human activities.” RCRA does not generally exempt this material from regulation, except it exempts solid waste, including TENORM produced from the extraction, beneficiation, and processing of ores and minerals (Bevill exclusion) and oilfield wastes from regulation as hazardous wastes. Some states consider pre-1978 ore processing residuals to be TENORM and subject to RCRA, however, USACE holds that these residuals meet the statutory definition of source material and are, therefore, exempt from RCRA. If the uranium and/or thorium content of the residuals exceeds 0.05% by weight, the residuals would become regulatable source material.

(3) Implementing Regulations. Unlike CERCLA, which imposes remediation requirements by establishing cleanup criteria with ARARs, the RCRA remediation process has never been codified federally. Comprehensive corrective action regulations, also known as “the Subpart S Initiative” were proposed on 27 July 90, 55 FR 30798, but were never finalized. The objective of the proposal was to establish Federal corrective action standards against which state programs could be assessed when determining whether to authorize them to manage the RCRA corrective program for their state. However, EPA has since authorized the majority of states for corrective action, even without the regulations. RCRA allows states to develop and administer hazardous waste programs that are at least as stringent as the Federal RCRA law.

(4) Closure. The cleanup standard for RCRA closure requires the owner or operator of an RCRA interim status or permitted treatment, storage or disposal facility (TSDF) to close in a manner that:

- Minimizes the need for further maintenance.
- Controls, minimizes, or eliminates post-closure release or migration of hazardous waste and other hazardous constituents into the soil, air, or water (ground water or surface).
- Protects human health and the environment to the extent necessary.

One method of obtaining RCRA closure of the TSD unit or facility is achieved by leaving the wastes in place, which is referred to as closure-in-place. The second method is to remove the hazardous waste and decontaminate any releases or spills to equipment, structures, or the soil. This method is referred to as closure by removal or decontamination (also known as "clean closure") and would not leave any contamination.

(5) Corrective Action. RCRA requires correction action for releases of hazardous waste or hazardous waste constituents from a solid waste management unit (SWMU) at TSDFs with a permit and those seeking a RCRA permit or approval of final closure. For example, a military installation may have a permit to store hazardous waste and would be subject to a corrective action if hazardous waste was spilled or released from the storage area. Note that only one regulatory authority, either Federal or state, shall possess RCRA corrective action authority. The goal of corrective action is to control or eliminate risks to human health and the environment. Risk-based decision-making is used to ensure protection of human health and the environment. RCRA corrective actions tend to be governed by media cleanup standards, which are similar to CERCLA ARARs. Media cleanup standards are the concentrations of a hazardous constituent that a remedy must achieve in a specific medium (e.g., soil, water). A cleanup standard may be based on promulgated Federal or state standards or developed through a site-specific risk assessment.

(6) Risk-Based Clean Closure.

(a) This closure method is a blend of the RCRA closure and the corrective action programs. A treatment, storage or disposal (TSD) unit can be considered clean-closed if it meets the risk-based standards appropriate under CERCLA cleanup or a RCRA corrective action. This method draws upon the removal and decontamination aspects of RCRA closure. EPA still requires the removal of the hazardous wastes and liners under this method, but it would not require that all contamination be removed. Limited amounts of hazardous constituents may remain in the media, provided the contaminants are below concentrations that would present a risk to human health or the environment. The second part to this process is the use of risk-based standards to determine your cleanup levels, which determine the level of decontamination that must be achieved for closure.

(b) The permittee/respondent may propose media cleanup standards. The standards must be based on promulgated Federal and state standards, risk derived standards, all data and information gathered during the corrective action process (e.g., interim measures, RCRA facility investigation, etc.) or other applicable guidance documents. If no other guidance exists for a given contaminant and media, the permittee/respondent shall propose and justify a media cleanup standard. The final media cleanup standards are determined by the implementing agency when the remedy is selected and documented in the Statement of Basis/Response to Comments or permit modification. It would be advisable to always propose media standards to the regulators instead of relying on the implementing agency to set the media standards for the corrective action. (Refer to MARISSIM, Appendix F, for explanation of CERCLA and RCRA process).

c. Atomic Energy Act of 1954, as amended (AEA) [42 USC 2011 et seq.]. This Act is the fundamental U.S. law on the civilian and military uses of source, byproduct, and special nuclear material. The Act requires that civilian uses of nuclear materials and facilities be licensed, and it empowers the NRC (AEC's co-successor) to establish by rule or order, and to enforce, such standards to govern these uses as in order to promote the common defense and security and protect health and safety of the public. Commission action under the Act must conform to the Act's procedural requirements, which provide an opportunity for hearings and Federal judicial review in many instances. The NRC regulatory responsibility pertains to the commercial operations involving radioactive material that are not associated with nuclear weapons development or research, or military uses of nuclear power. Their responsibility extends primarily to the commercial power industry, medical industry, and other commercial applications of radioactive material.

(1) DOE (AEC's co-successor) authority under the AEA extends to source material, special nuclear material, and byproduct material under the control or jurisdiction of the Secretary of Energy, and a limited number of specified programs, including nuclear weapons production and research related to national security interests. DOE is also the lead Federal agency in the remediation of legacy contamination at Federal facilities that were and remain engaged in those types of activities.

(2) EPA has the general responsibility for ensuring that all other Federal agencies remediate hazardous substances to levels that are protective for the public and the environment. EPA is provided the authority to issue applicable environmental radiation standards to protect human health and the environment from radioactive materials in the general environment outside the boundaries of the facilities under the control of the NRC.

d. Defense Environmental Restoration Program (DERP)[10 USC 2701 et seq.]. Congress created the Defense Environmental Restoration Account (DERA) when it enacted Section 211 of Superfund Amendments and Reauthorization Act (SARA) -also known as DERP. Although DERA is not limited to sites on the EPA NPL, per the statute, hazardous substance response activities funded by the DERA must be carried out subject to, and in a manner consistent with, Section 120 of CERCLA. DOD environmental managers should be aware of the significance of that limitation, particularly when EPA or state regulators insist the cleanup be conducted pursuant to RCRA corrective action or state requirements other than CERCLA. If regulators demand cleanup efforts that are inconsistent with CERCLA Section 120, DERA funds will not be available to support those activities. District legal counsel should be a part of the project delivery team when addressing which cleanup authority should be followed. DERP does not apply to Civil Works facilities in accordance with DOD policy.

(1) It is important to note that the DERP statute [10 USC 2705] requires that EPA and appropriate state and local authorities must receive prompt notice from DOD under the following conditions:

- Discovery of releases or threatened releases of hazardous substances at a facility.
- The extent of the threat to public health and the environment that may be associated with any such release or threatened release.
- Proposal made by the Secretary to carry out response actions with respect to any such release or threatened release.
- The initiation of any response action with respect to such release or threatened release and the commencement of each distinct phase of such activities.

(2) The DERP statute requires that EPA and state and local authorities shall have an adequate time to comment on notices and proposals for response actions (removal or remedial) and that investigations and cleanup actions be consistent with CERCLA and the NCP. The DERP statute also requires that the program be carried out in consultation with EPA (10 USC 2701).

e. Army Reactor Program. The Army Reactor Program has designated USACE as responsible for nuclear reactor engineering, design, construction, and decommissioning design and implementation. USACE is also responsible for assisting, when requested, in compliance and environmental restoration projects for deactivated reactors. The Department of Army, under the provisions of the AEA (Section 110), self regulates under the Army Reactor program. The Army's reactor policy is to "follow to the maximum extent possible, the regulations of the U.S. Nuclear Regulatory Commission and the recommendations of the National Council of Radiation Protection and Measurements" (AR 50-7). The Army Reactor Program is designed to ensure that Army reactors are designed, constructed, operated, maintained, and decommissioned per U.S. national standards. When NRC regulations and Army Reactor regulations prescribe the same or similar requirements, the NRC regulations will be followed with notifications through command channels. If an Army reactor is also NRC licensed, then the NRC regulations will be followed with documentation provided to the Army Reactor Office.

9-3. Roles and Responsibilities for Regulating Radioactive Material.

a. Federal Agencies.

(1) EPA's radiation protection responsibilities originate from both the AEA and several environmental statutes. Under Reorganization Plan No. 3, which became law on 2 December 1970, EPA was made responsible for establishing applicable environmental standards for the protection of the general environment from radioactive material. EPA was provided the research, monitoring, promulgating regulations, and enforcement authorities for

media-specific chemical and radioactive pollutants. However, the transfer of radiation protection responsibilities to EPA was more limited than other pollutants because the Atomic Energy Commission (AEC) retained the responsibility for implementing and enforcement of radiation standards. Under the AEA, these standards were defined as "limits on radiation exposures or levels, or concentrations or quantities of radioactive material in the general environment outside the boundaries of the facilities that were regulated by the AEC" (later became the NRC).

(a) It is important to note that over the 30 years of existence, EPA has gained or asserted enforcement authority for some radioactive materials under several environmental statutes that Congress passed subsequent to the AEA. Through enactment of new statutes (e.g., Clean Air Act, Safe Drinking Water Act, CERCLA), EPA has been given additional responsibility to regulate certain activities or aspects of radioactive materials. EPA has established multiple offices within their agency that may be responsible for implementing regulations, depending on the environmental media and statute. When USACE is executing a radioactive or mixed waste restoration project, it is important to understand which EPA offices are administering the different implementing regulations.

(b) A comprehensive explanation of the statutory authorities of EPA and the individual offices responsibilities may be found in Appendix C of MARSSIM. An additional publication that discusses EPA's authorities and responsibilities for the past three decades is EPA 402-B-00-001.

(2) The NRC is an independent regulatory agency, created by the Energy Reorganization Act of 1974. Congress abolished the AEC and made the NRC responsible for ensuring the protection of the public's health and safety in association with the operation of commercial nuclear power plants and fuel cycle plants, medical, industrial, and research applications of nuclear materials. Their authority includes protecting the public's health and safety as well as the environment with the storage, transportation, and disposal of nuclear materials and waste.

(a) NRC issued regulations establishing standards for the decommissioning of facilities regulated under NRC licenses. These standards are mainly codified at 10 CFR Part 20, Subpart E, and provide radiological criteria for termination of licenses. They apply to facilities decommissioned under 10 CFR Part 30, governing the licensing of byproduct materials, Part 40, governing the licensing of source material, and Part 70, governing the licensing of special nuclear material. The criteria are excluded from application to uranium and thorium recovery facilities subject to 10 CFR Part 40, Appendix A.. The decommissioning standards establish criteria for license termination with unrestricted use, license termination under restricted conditions, and allow the submission of alternate criteria for license termination. A facility is considered to be acceptable for unrestricted use if residual radioactivity exceeding background results in a total effective dose equivalent

(TEDE) of 25 millirem (mrem) per year, including ground water sources of drinking water, and must further reduce residual radioactivity to ALARA levels. The requirement for an ALARA analysis is provided in 10 CFR Section 20.1402 and 20.1403, but this new section provides that this analysis must also consider detriments from decontamination and waste disposal, such as deaths from transportation accidents. A facility will be considered acceptable for restricted use if the levels of residual radioactivity are ALARA, there are legally enforceable institutional controls that will assure the TEDE will not exceed 25 mrem per year and will not impose undue burdens on the local community, and, if the institutional controls fail, the TEDE is ALARA but not more than 100 mrem per year.

(b) Projects not regulated directly by NRC, may be subject to CERCLA or RCRA. The NRC regulations may not be “applicable” but under CERCLA, they may be “relevant and appropriate” and used to develop clean-up levels. The NRC standard titled, “Radiological Criteria for License Termination,” 10 CFR Part 20, Subpart E, may be relevant and appropriate for sites that were previously licensed or handled a licensable type of radioactive material. It may also be an ARAR if it is well suited to the particular site in accordance with Section 121 of CERCLA and the NCP. This regulation uses a dose assessment to establish criteria for license termination and release of the property. For unrestricted release of property, the acceptable total effective dose equivalent (TEDE) is 25 mrem/year above background and as low as is reasonably achievable (ALARA).

(c) NRC allows a party to propose alternate criteria for decommissioning if it is protective of public health and the environment, and the dose from all man-made sources combined, except medical, would be no more than 100 mrem per year. The alternative must include institutional controls as described in Section 1403, and achieve ALARA levels using the analysis described above. A licensee must submit a plan, demonstrate public participation in the development of the plan, and obtain approval from the Commission based on NRC staff recommendations.

(3) The DOE is responsible for developing and implementing a national energy policy and for developing new energy sources for domestic and commercial sources. DOE is also responsible for management of the U.S. nuclear weapons program and production facilities and obtains its basic authorities from the AEA of 1954. The DOE nuclear weapons program responsibilities encompass the Stockpile Stewardship Program (now handled by the National Nuclear Security Administration within DOE), management of low and high-level radioactive wastes generated by past nuclear weapons and research programs, and for constructing and maintaining a repository for civilian radioactive wastes generated by commercial nuclear reactors. DOE develops its own standards under the authority of the AEA by issuing DOE orders, and is responsible for enforcing their standards as well as EPA regulations at DOE facilities.

(a) DOE provides for the framework for DOE environmental management in DOE Order 450.1 by establishing environmental protection requirements, authorities, and responsibilities for their operations. DOE complies with applicable Federal, state and local environmental protection laws and regulations, executive orders, and DOE policy and guidance.

(b) DOE restricts off-site management of radioactive mixed waste through DOE Order 5400.5. All radioactive wastes and mixed waste must be disposed of at a DOE facility, unless DOE grants a specific exemption for that waste. If granted an exemption, mixed waste can be treated off-site at a licensed commercial TSD facility that has the required RCRA permit and a NRC or state license for the radionuclides being shipped.

(c) Specific requirements on the management of radioactive waste material are contained in DOE Order 435.1. The DOE order is meant to ensure that all DOE radioactive waste is managed in a manner that is protective of work and public health and safety, and the environment.

(d) Much of the DOE 5400 series orders have been codified at 10 CFR 835.

b. State Involvement. Under CERCLA, EPA does not authorize states to administer the program. However, states may promulgate their own “mini” CERCLA-type laws. It should be recognized that these are strictly state laws and do not preempt the authorities of EPA or other Federal agencies under CERCLA. CERCLA does include many provisions for consulting with and comment by state officials regarding response actions. In particular, Section 121(f) provides a list of CERCLA response phases in which the state is required to be given an opportunity for meaningful involvement. Section 120(a)(4) provides that, for current Federal facilities not listed on the NPL, state laws regarding removal and remedial actions are applicable to response actions conducted at such facilities. There are provisions in Section 121 regarding state ARARs, and relief from state laws that exceed ARARs or are not applied consistently to Federal and other facilities. Section 121(e) provides that Federal, state, and local permits are not required for response actions conducted on the CERCLA site, but that the substantive requirements that would otherwise be applicable shall be met in providing for removal or remedial actions. The NCP provides that this permit waiver applies to NPL sites, and also to other response actions led by Federal agencies. The authority to select the lead agency remedy is not subject to state concurrence or non-concurrence under any law, regulation, or executive order. The precise determination of state authority will depend on a particular factual circumstance and must be reviewed by agency counsel on a fact-specific basis. The state is expected to have a meaningful opportunity for consultation with the lead agency throughout the response process, and state laws must be identified and considered and their substantive standards and requirements complied with, but their approval or permits that might otherwise be required are not necessary before a lead Federal agency proceeds with necessary response actions.

c. LLRW Compacts. In 1980, Congress passed the Low-Level Radioactive Waste Policy Act to encourage states to develop low-level radioactive waste disposal facilities or to enter into regional compacts among several states to develop facilities to serve the member states. There are currently ten regional compacts, and additional states that remain unaffiliated. Each compact assigns a host state the first tenure, typically 20 years, for disposing of LLRW. Compacts may also enter into agreements with other compacts to dispose of their waste. At the time the Act was passed, there were three operational LLRW disposal sites in the country, Richland, Washington, Beatty, Nevada, and Barnwell, South Carolina. Since that time, the Beatty facility has closed and one new facility was opened in Utah. The Utah facility, which is not affiliated with the Compact system, accepts Class A LLRW nationwide, subject to the waste meeting its waste acceptance criteria under its operating licenses. The Richland facility accepts waste only from its own compact (the Northwest compact) and the Rocky Mountain compact. The Barnwell facility is the only facility accepting Class A, B, and C waste from outside the compact to which it belongs. However, under state law, the Barnwell facility is in a 6-year process to ramp down the amount of waste that may be accepted from outside the Atlantic Compact states. After 30 June 2008, the Barnwell facility may only accept LLRW from the Atlantic Compact states. This is a significant concern for future disposal of higher activity LLRW (Class A, B, or C) from decommissioning or CERCLA response actions.

(1) Compacts may prohibit the disposal of LLRW from outside the member states in certain circumstances, or charge increasing surcharges from states that have neither developed their own disposal facility nor entered into a compact that develops a disposal facility, subject to emergency authority in the NRC to grant access to a licensed compact facility if necessary to eliminate an immediate and serious threat to the public health and safety or the common defense and security [42 USC 2021e and 2021f.] The statute specifically allows a compact facility to refuse to accept for disposal material identified under the FUSRAP or may accept the material for disposal subject to meeting their waste acceptance criteria under their NRC/Agreement State license. The Act does state that the Federal government is responsible for disposal of LLRW generated by DOE, decommissioning Navy vessels, or waste generated by atomic weapons research, testing, or production.

(2) Compacts may state that, for waste to be sent out of their compact, the DOD must have permission. This issue must be coordinated with the District and HTRW-CX Office of Counsel to determine if there is a statutory requirement to obtain permission for the LLRW to be sent to a disposal facility outside the Compact where the LLRW is generated. The customer may request that USACE obtain this permission, even though it is determined to not be applicable.

d. Significant Memorandums of Understanding (MOUs).

(1) The NRC and USACE signed an agreement on 5 July 2001 to temporarily suspend NRC licenses on FUSRAP sites that were to be remediated to unrestricted levels, and to minimize dual regulation and duplication of regulatory requirements at NRC-licensed facilities. At the written request of USACE, NRC will initiate action for the suspension of the NRC license or portions of the license for a FUSRAP site to be remediated by USACE under CERCLA authority. USACE takes temporary control and responsibility for radiation control and for ensuring public health and safety during the CERCLA response action. Upon completion of the response action, NRC will reinstate the license for the facility. For activities where a potential dual regulation could exist, the two agencies agree to cooperate, share information, and coordinate activities in their respective programs. USACE, as provided for in section 121(e) of CERCLA and 40 CFR 300.400(3), is not required to obtain an NRC license for its on-site remediation activities conducted under its CERCLA authority. The NRC may observe, as it deems warranted, remediation activities being conducted by USACE and may issue comments or questions arising from their observations of the USACE response action. USACE agrees to remediate the licensed site to meet at least the requirements of CERCLA and of 10 CFR 20.1402. The ARARs in the final executed ROD will include 10 CFR 20.1402 or a more stringent requirement.

(2) The NRC and EPA signed an agreement on 9 October 2002 on the radiological decommissioning and decontamination of NRC-licensed sites. The MOU will defer EPA's authority under CERCLA for most of the NRC licensed sites that are being decommissioned under NRC authority. The MOU includes provisions for NRC and EPA to consult about certain sites when, at the time of license termination 1) ground water contamination exceeds EPA-permitted levels (MCLs), 2) NRC contemplates restricted release or use of alternate criteria at the site, and 3) residual radioactive soil concentrations exceed levels defined in Table 1 of the MOU for residential or industrial and commercial future land use.

9-4. Other Major Environmental Statutes and Regulations.

a. Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) [42 USC 7911 et seq.]. In the 1940's, the U.S. government began to purchase uranium for the atomic weapons program. Large quantities of uranium milling tailings, the waste byproduct of the extraction of uranium from ore ("yellowcake production"), were generated in the processing of the ore to obtain the uranium metal. The mill tailings (sand-like material) were stored in surface impoundments (piles) predominantly in the western United States where the ore was mined. Historically, uranium mill tailings were not covered under the AEA since they were not considered to be hazardous. Testing of the mill tailings indicated they were highly contaminated with radionuclides (Ra-226) and inorganics (arsenic, molybdenum, and selenium). The mill tailings were not regulated until the passage of the Uranium Mill Tailings Radiation Control Act (UMTRCA) in 1978. Section 275 of the AEA, as amended by Section 206 of UMTRCA, directed EPA to set generally applicable health and environmental standards to govern the stabilization, restoration, disposal, and control of effluents and emissions at both active and inactive mill tailings sites. Title I of the Act covers inactive uranium mill tailing sites, depository sites, and vicinity properties. It directs EPA, DOE, and NRC to do the following:

- EPA must set standards that provide protection that is as consistent with the requirements of RCRA as possible. The standards must include ground water protection limits.
- DOE must implement EPA's standards for the tailings piles and nearby properties and provide perpetual care for some properties.
- NRC must review completed site cleanups for compliance with EPA standards and licenses issued for the site to the state or DOE for perpetual care.
- Title II of the Act covers the operating uranium processing sites licensed by the NRC. EPA was directed to promulgate disposal standards in compliance with Subtitle C of the Solid Waste Disposal Act, as amended, to be implemented by NRC or the Agreement States.
- UMTRCA applies to residual radioactivity at NRC-licensed uranium mill sites and at specifically listed inactive mill sites (22 sites designated by Congress and 2 sites by DOE).

Though not "applicable" to FUSRAP sites that are undergoing a CERCLA response action, these regulations may be considered "relevant and appropriate" to on-site actions involving uranium or thorium mill tailings at some of the FUSRAP sites.

(1) 40 CFR 192. EPA promulgated these regulations in January 1983 to address the inactive tailing sites that qualified for remedial action under Title I of UMTRCA. The regulations were written to control the risks from four principal environmental pathways:

- Diffusion of radon-222, the decay product of radium-226, from tailings into indoor air.
- Direct exposure to gamma radiation that results from many of the decay products in tailings (lead-214, bismuth-214, thallium-210).
- Dispersal of small radioactive particles into the air by wind erosion of un-stabilized tailing piles.
- Waterborne transport of radioactive and toxic (heavy metals) material by erosion, wind or leaching to the surface and ground water.

(a) Subpart A of 40 CFR 192 contains design requirements for the control of disposal areas for tailings, resulting from processing or extraction of uranium, that are located at the processing site or adjacent properties. The control mechanism must be effective for a minimum of 200 years and up to 1000 years to the extent reasonably achievable. Releases from radon-222 to the atmosphere must not exceed 20 pCi/m^2. This regulation also contains ground water protection requirements for disposal sites.

(b) Subpart B of §192 contains cleanup standards for land and buildings and adjacent properties contaminated with residual radioactivity from processing ore for uranium. The soil cleanup levels are for residual radioactive materials from a processing site not to exceed a concentration of radium-226, averaged over any area of 100 square meters, of 5 pCi/g above background averaged over the first 15 centimeters of soil below the surface, and 15 pCi/g above background over 15 centimeter layers of soil below the first 15 centimeters of soil. This regulation does not apply to sites owned or controlled by a Federal agency after 1978 or to a site that is currently NRC licensed or had a NRC license in 1978 or thereafter. The standard includes requirements for occupied or habitable buildings and requires that the remedial action achieve an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 Working Level (WL), which is defined in the regulations. In addition, the gamma radiation level shall not exceed background by more than 20 microroentgens per hour. Ground water below the processing site and nearby areas with residual radioactive materials shall be monitored to ensure that the levels of constituents specified in Subpart A are not exceeded.

(c) Subpart C of §192 addresses the implementation of Subparts A and B and contains requirements for applying site-specific supplemental standards in lieu of strict compliance with Subparts A and B in limited circumstances. Any general standard may be changed if there is a clear and present risk of injury to workers or the public, despite reasonable protective measures, from compliance with the general standards. The standards for land, ground water, or surface control may be changed if remedial actions taken to meet standards would produce health and environmental harm that is long-term and grossly disproportionate to health and environmental benefits that may reasonably be anticipated. The standards may be changed if the estimated cost of remedial action to satisfy soil cleanup levels at a "vicinity" site is unreasonably high relative to the long-term benefits, and the residual radioactive materials do not pose a clear present or future hazard. In situations where radionuclides, other than radium-226 and its decay products, are present in sufficient quantity and concentration to constitute a significant radiation hazard, the remedial action shall reduce other residual radioactivity to levels that are as low as is reasonably achievable and conform to the standards of subparts A and B to the maximum extent possible. Supplemental standards for ground water must preserve all current and reasonably projected future uses of the water. UMTRCA requires that both the general standards and the implementation of them be developed on the basis of an analysis of the reasonableness of the benefits compared to the economic and environmental costs.

(d) Subpart D to §192 contains criteria for restoration of licensed uranium byproduct processing and disposal areas. Standards for closure of byproduct disposal areas are provided. The disposal area shall include a radon barrier to limit releases of radon-222 to 20 pCi/m^2 per second averaged over the entire impoundment for a design life of 1000 years, to the extent reasonably achievable, but no less than 200 years. This standard does not apply areas that require cleanup to the land standard (5/15 pCi/g) for radium-226.

(e) Subpart E to §192 contains criteria for restoration of licensed thorium byproduct processing and disposal areas. The standards govern facilities licensed for thorium processing and their byproduct disposal sites, and generally use the same standards as uranium processing and disposal areas, which require a permanent radon barrier to limit release of radon-220 and radium-228.

(2) 10 CFR 40, Appendix A.

(a) The NRC has established criteria in 10 CFR 40, Appendix A, for the operation of active licensed uranium and thorium mills and the disposition of tailings or wastes produced by the extraction or concentration of source material (uranium and thorium) from ores processed primarily for their source material content. This regulation is of interest primarily for situations where USACE would be performing a CERCLA remediation and it was determined to be “relevant and appropriate” for a milling site or mill tailings site that was inactive prior to the enactment of UMTRCA where byproduct materials were managed and radionuclides other than radium in soil are present, and where building surfaces are contaminated. This criterion uses a benchmark dose derived using site conditions and the assumption that 5 pCi/g radium above background is present in the top 15 centimeters and is present at 15 pCi/g above background in the subsurface. The benchmark dose is then back calculated to derive concentrations of the radionuclides to which the criterion is being applied. Normally, radionuclides that this criterion will be relevant and appropriate for will be total uranium and thorium-230.

(b) This regulation covers more activities than the EPA UMTRCA standards, but they conform to the EPA UMTRCA standards for comparable activities. It is important to note that the NRC considers milling wastes to include equipment and piping that was used for processing the ore. Byproduct material is disposed of in uranium mill tailings impoundments, subject to meeting NRC regulations. The NRC regulation provides more radiological criteria on the decommissioning of licensed uranium and thorium mills. The NRC regulation uses the existing 5/15 pCi/g soil radium standard to derive a dose criterion (benchmark approach) for the cleanup of byproduct material other than radium in soil for surface activity on structures and land. The NRC standard provides a regulatory basis for determining the extent to which lands and structures at uranium and thorium mills must be remediated before decommissioning of a site can be considered complete and the license terminated.

b. Clean Air Act (CAA) [42 USC 7401 et seq.]. The CAA standards called “National Emissions Standards for Hazardous Air Pollutants” (NESHAPs) limit the allowable level of air emissions of radionuclides, other than radon-222 and radon-220, from facilities owned or operated by DOE and from Federal facilities not owned or operated by DOE or licensed by the NRC. EPA has promulgated implementing regulations for the control of hazardous air pollutants (HAP) from major and area sources in 40 CFR 61. CERCLA response actions often times identify NESHAPs as a potential ARAR when close examination of the applicability of the regulation reveals that it does not pertain to the activity. It is important to note that EPA has proposed a NESHAP regulation for the category entitled "Site Remediation" (67 FR 49398) on 30 July 2002 for the control of HAP emissions to the ambient air. However, a final rule would still have to be promulgated before NESHAPS are established for remediation activities. The potential NESHAP subparts that may apply under limited scenarios are as follows:

- Subpart H - National Emission Standards for Emissions of Radionuclides Other Than Radon From DOE Facilities (does not apply to §§191 or 192 facilities).
- Subpart I - National Emission Standards for Radionuclide Emissions From Federal Facilities Other Than NRC Licensees and Not Covered by Subpart H (does not apply to §191, Subpart B or §192 mill tailing piles).
- Subpart Q - National Emission Standards for Radon Emissions From Department of Energy Facilities (does not apply to Title I facilities of UMTRCA but does apply to a specific list of DOE facilities).
- Subpart T - National Emission Standards for Radon Emissions From the Disposal of Uranium Mill Tailings.

(1) These regulations require that emissions of radionuclides 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. Also, for non-DOE Federal facilities, emissions of iodine shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 3 mrem/year. The owner or operator of facilities covered by these regulations must submit an annual report regarding emissions to EPA by 31 March of the following year.

(2) Title V of the CAA requires operating permits for all major sources (40 CFR 70). Some decommissioning activities, such as hazardous and mixed waste treatment, storage, and disposal units, may require Title V permits because of radionuclide emissions. Additionally, some activities (including treatment of mixed waste) may emit enough other regulated pollutants (e.g., volatile organic compounds and lead) to qualify as a major source. A Title V permit would not be required on a CERCLA response action because of the permit waiver [CERCLA, Section 121(e)]. Because Title V is a procedural requirement (administrative) and not a substantive requirement, the CERCLA response action would not need to comply for on-site activities.

c. Safe Drinking Water Act (SDWA) [42 USC 300f et seq.]. The SDWA requires EPA to promulgate and enforce primary standards for contaminants in public water systems, including radionuclides. The 1986 amendments required EPA to develop maximum contaminant level goals (MCLGs) and maximum contaminant levels (MCLs). In 1991, EPA proposed a revision to raise the MCLs for combined radium-226 and radium-228 from 5 pCi/L to individual MCLS of 20 pCi/L for each isotope. After further evaluation, EPA decided to retain the current combined radium-226/228 level of 5 pCi/L based on risk to humans (65 FR 76708). Under the 1996 amendments to the SDWA, EPA is required to ensure that any revision to a drinking water regulation maintains or provides for greater protection of the health of persons. The EPA rule (promulgated 7 December 2000) becomes effective in December 2003 and establishes the uranium MCL at 30 µg/L. The gross alpha (excluding uranium and radon but including radium-226) remained at the current level of 15 pCi/L. The beta particle and photon radioactivity MCL was also retained at the level of less than or equal to 4 mrem/year to the total body or any given internal organ.

(1) When determining cleanup criteria for contaminated ground water, MCLs established under the SDWA may be considered ARARs that must be attained by the selected remedy, if the affected ground water is a current or potential drinking water source. CERCLA, Section 121(d)(2)(A) and (B), provides that standards developed under the SDWA and the Clean Water Act may be relevant and appropriate, depending on the designated or potential use of the water, the purposes for the criteria, and the latest information. Radioactive substances' MCLs are applicable to community water systems, which are defined by EPA as 15 service connections used by year round residents or regularly serves at least 25 year-round residents. For non-community water systems, the radioactive substances' MCLs may still be considered relevant and appropriate if the water is an actual or potential source of drinking water.

(2) In addition to MCLs, maximum contaminant level goals (MCLGs) established under the SDWA are sometimes designated as ARARs for the response action. Because the SDWA has a MCLG of zero for all radionuclides, it is important to note the NCP states MCLGs can only be considered ARARs when non-zero concentrations are established.

(3) Some states have laws or regulations that establish a universal non-degradation standard for ground water. This has the effect of establishing background as the standard to be achieved if the law or regulation is considered an ARAR for the ground water remedy. In practice, satisfying a non-degradation standard is frequently not technically practicable or achievable. If information is developed that demonstrates technical impracticability, then a waiver of the ARAR under the NCP provisions would be possible.

(4) For radioactive or mixed waste remediation, where the NRC decommissioning standard is an ARAR, then ground water must also be considered in the all-pathways analysis of dose. The ground water exposure could lead to more restrictive cleanup levels than the MCLs, or additional restrictions may be necessary to control exposure. On some sites there may be no ground water pathway, so the exposure from ground water would not be included.

If there are no ARARs for contaminated ground water at a site, then the risk assessment process should be used to develop cleanup levels.

d. Clean Water Act (CWA) [33 USC 1251 et seq.]. The Federal Water Pollution Control Act commonly known as the Clean Water Act (CWA) is the principal law governing the restoration and protection of the nation's streams, lakes, and estuaries. The CWA's principal objectives are to prohibit discharges of pollutants into U.S. navigable waters, except in compliance with a permit, and achieve an interim goal of protecting water quality for fish, wildlife, and recreational uses. The CWA established several regulatory programs, standards, and plans for the prevention, reduction, and elimination of pollution in the nation's water, which include the following:

- National Pollutant Discharge Elimination System (NPDES) Program that establishes an effluent permit system for point source discharges into navigable waters. The NPDES storm water program is designed to prevent discharge of contaminated stormwater into navigable waters. The NRC regulates discharges of materials subject to the AEA.
- National and Local Pretreatment Standards that require new and existing industrial users to users to pre-treat their wastewater prior to discharging to a Publicly Owned Treatment Works (POTW) to prevent pollutants from overloading a POTW or interfering with the operation of the treatment facility.
- Dredge or Fill Discharge Permit Program that establishes a permit system administered by USACE to control the placement of dredge or fill material in waters of the United States, including wetlands.
- Sewage Sludge Use and Disposal Program that protects human health and the environment when POTW sludge is managed or disposed of.

(1) The NPDES requires all discharges to the waters of the United States to comply with certain pollutant discharge criteria. The term "pollutant" includes "radioactive materials, except those regulated by the AEA." Radioactive material that is covered by the AEA includes source, byproduct, and special nuclear material. The NPDES regulations specifically prohibit radiological discharges: "No permit may be issued for the discharge of any radiological, chemical, or biological warfare agent or high-level radioactive waste."

(2) EPA has the authority under the CWA to regulate radioactive materials not specifically addressed under the Atomic Energy Act. In particular, the CWA provided EPA the authority to limit liquid discharges of TENORM into surface waters from mines or mills used for the production of uranium, radium, and vanadium.

e. National Environmental Policy Act (NEPA) [42 USC 4321 et seq.]. NEPA was enacted on 1 January 1970 to ensure that Federal agency decision-making takes environmental factors into consideration. NEPA is generally only applicable to Federal agencies and Federal actions unless a state, local, or private entity is involved with Federal funding or actions. Close coordination with the District Office of Counsel is essential when determining whether NEPA is a requirement for the response action planned to address a radioactively contaminated site. Unlike other environmental laws, NEPA is a procedural requirement and does not contain specific enforcement provisions; EPA does not have enforcement authority under NEPA. NEPA requires the preparation of Environmental Assessments (EA) or Environmental Impact Statements (EIS), or both, for any project that will have a major impact on the environment. This would potentially include decommissioning activities under the jurisdiction of DOE, NRC, and DOD (e.g., Army Reactor Program).

(1) Individual actions, such as decommissioning facilities, are to be evaluated to determine the level of NEPA review needed. The NEPA process begins with a determination of whether the "proposed action" is subject to NEPA compliance. If the determination is made that the action cannot be categorically excluded from the EA, or EIS, the first step is to prepare the EA. The EA helps to determine if an agency needs to prepare an EIS or if the agency can make a finding of no significant impact (FONSI).

(2) It is important to note that on 23 January 1995, the Department of Justice (DOJ) made a decision that a Federal agency is not required to independently implement NEPA at CERCLA cleanup sites. The DOJ decision stated that the CERCLA process incorporates many of the NEPA values of public participation and collection of environmental and human health impacts that result from proposed Federal action. It is Army policy that response actions implemented in accordance with CERCLA or RCRA are not legally subject to NEPA and do not require separate NEPA analysis [32 CFR 651.5]. However, the CERCLA and RCRA response actions should incorporate the procedural requirements of NEPA, which include full and open public participation, analysis of all reasonable alternative remedies, evaluation of the significant impacts of the studied alternatives, and consideration of public comments when selecting the remedy.

f. Toxic Substances Control Act (TSCA) [15 USC 2601 et seq.].

(1) Contaminated sites that have polychlorinated biphenyls (PCBs) commingled with radionuclides can create a situation of dual regulation. TSCA does not preempt other more stringent Federal statutes and regulations (e.g., AEA), but it still needs to be considered. EPA has established regulations for the cleanup of PCB contamination that must be considered in conjunction with the applicable radioactive standards. Cleanup criteria for PCB remediation waste are found in 40 CFR 761.61. The concentrations of PCBs must be within a limited range and the appropriate controls must be in place to protect the public and environment from exposure or release. However, a CERCLA response action must meet the threshold criteria of being protective of human health and the environment and comply with ARARs, and the radioactive waste may not be appropriate for on-site disposal. PCBs commingled with radioactive material will typically require the off-site disposal at a facility

that is licensed and permitted to accept the remediation waste. For example, EPA has promulgated an exemption for low-level mixed waste for storage and treatment (40 CFR 266). The waste is not considered RCRA hazardous waste, if it meets the conditions of the exemption. The low-level mixed waste must be disposed of into a licensed low-level radioactive waste disposal facility, but it must meet the LDRs because it is being placed in a land disposal facility.

(2) Mixed waste can further complicate the regulatory requirements for the disposal of material having low concentrations of PCBs that may not even be regulated under TSCA. PCBs are not a RCRA hazardous waste; however, mixed waste must meet the Land Disposal Restrictions (LDRs) before it can be land disposed. For certain types of RCRA hazardous wastes, there is a requirement to comply with the universal treatment standards for the underlying hazardous constituents, which does include a treatment standard for PCBs. There may be a RCRA treatment standard for PCBs, even though waste is not a RCRA hazardous waste and complies with TSCA. EPA recognized the disparity between TSCA and RCRA and has put into practice a temporary deferral for specific RCRA hazardous wastes (metals: arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver) that contain less than 1000 ppm of PCBs. As this requirement is less stringent than previous promulgated RCRA regulation, this must be adopted in the RCRA authorized states to be effective.

9-5. Summary of Radiation Standards. In the development of cleanup criteria, it is important to understand the regulations that govern the response action. The regulatory authority must be established to determine what the potential standard or numerical limit is for the media of concern. Table 9-1 provides a summary of the regulations that might apply to an environmental restoration, processing, or disposal operation.

Table 9-1
Major Radiation Standards Summary Table

Regulation	Agency	Standard/Numerical Limit
General Public (10 CFR 20.1301)	NRC	Total Effective Dose Equivalent (TEDE): 100 mrem/year
Uranium mill tailings (40 CFR 192 & 10 CFR 40 App. A)	EPA & NRC	Ra-226/228: 5 pCi/g (surface) 15 pCi/g(subsurface) Rn-222 20 pCi/m^2-sec NRC standard includes benchmark dose for other radionuclides
High-level waste operations (10 CFR 60)	NRC	100 mrem/year
Low-level waste disposal (10 CFR 61)	NRC	Annual effective dose to public 25 mrem to the whole body 75 mrem to the thyroid, and 25 mrem to any other organ
Effluent emissions 10 CFR 20	NRC	Radionuclide specific activities, in Appendix B => 50 mrem/year
Drinking water (40 CFR 141)	EPA	Radium: 5 pCi/L Gross Alpha 15 pCi/L (excludes Rn & U) Beta/photon: 4 mrem/year Uranium: 30 µg/L
Uranium fuel cycle (40 CFR 190)	EPA	25/75/25 mrem/year
Air emissions (National Emission Standards for Hazardous Air Pollutants) (40 CFR 61, H)	EPA	10 mrem/year to nearest off-site receptor
Superfund (CERCLA) cleanup (40 CFR 300)	EPA	Protective of human health & environment, Complies with ARARs
Decommissioning (10 CFR 20, Subpart E)	NRC	Unrestricted Use: 25 mrem/yr TEDE plus ALARA Restricted Use: Up to 100 mrem/yr or 500 mrem/yr if institutional controls fail.
Occupational standards OSHA 29 CFR 1910.1096; NRC 10 CFR 20; DOE 10 CFR 835	OSHA, NRC, DOE	5,000 mrem/year & ALARA

9-6. Miscellaneous Criteria.

a. Building Cleanup Criteria. The cleanup criteria for building surfaces and structural materials that are contaminated with residual radioactivity is contingent on the regulatory authority that governs the response action. Decommissioning and decontamination of NRC licensed facilities is done in accordance with 10 CFR 20 Subpart E and the appropriate regulation for the type of licensed activity (e.g., Part 30 - Byproduct material, Part 40 - Source material, Part 70 - Special nuclear material). It is important to note that, under a CERCLA response action, the decommissioning and decontamination standards may not be applicable if the facility is not currently or never had an NRC license. However, the standards may still be relevant and appropriate. CERCLA response actions (e.g., FUSRAP) need to assess any actual or potential release or migration of contamination from the building to the environment. When soil or groundwater, outside of or underneath the building structure, become contaminated, cleanup criteria for these environmental media should also be developed in accordance with the CERCLA process.

(1) The NRC has developed generic screening models for building release. This guidance is being compiled and will be issued in one volume of NUREG-1757. When the use of generic screening is appropriate, a computer code developed by NRC, known as DandD, Version 1.0, may be used to generate concentration based cleanup levels for each contaminant of concern. NRC also acknowledges that D and D may not be the only appropriate computer model and has recognized that the RESRAD-BUILD, by Argonne National Laboratory, may be a better model for certain applications. NRC does recommend an uncertainty analysis be done if other models are used. The actual cleanup level derived from dose modeling is not altered when an ALARA analysis is conducted. However, if a remedial action required by the ALARA analysis is not performed, the final status survey must demonstrate that the level of residual contamination is less than the cleanup level by the percentage that would have been reduced if the action were taken. For example, it is almost always ALARA to scrub and wash the walls and floor of a building to remove loose radioactive contamination. If this action is taken, then the final status survey need only document that the cleanup level was met.

(2) At inactive uranium or thorium milling sites, where 40 CFR 192 is an ARAR, and where any occupied or habitable building is currently present, a reasonable attempt must be made to control the annual average radon decay concentration (including background) to not exceed 0.02 Working Level, and the gamma radiation shall not exceed the background by more than 20 microroentgens per hour. It is important to fully characterize a building site to ensure all the sources of radon (e.g., soil underneath floor) are understood. The decision document should address the actions that will be taken if the cleanup criteria for the building are not met after removal of the contaminated soil. Supplemental standards may need to be considered if the contamination is under the floor of the building.

b. Below Regulatory Concern (BRC). The NRC, in June 1990, attempted to establish regulations and procedures by which small quantities of low-level radioactive materials could be largely exempted from regulatory controls. The agency proposed that if radioactive materials did not expose individuals to more than 1 millirem per year or a population group to more than 1000 person-rem per year, they could be eligible for the exemption from full-scale regulation. It was intended that the BRC policy would apply to consumer products, landfills, and other sources of very low levels of radiation. However, the public and Congress objected to this proposed rulemaking and the NRC decided to defer any action on the BRC issue. Currently, there is no regulatory level (dose or activity concentration) for radionuclides that exempts them from regulatory control. There are promulgated NRC regulations that allow certain exemptions from licensing for byproduct material (10 CFR 30.14) that doesn't exceed the listed concentrations found in §30.70 - Schedule A. Source material (uranium or thorium) also has exemptions from licensing for persons or activities that are under the control of DOE or NRC contracts (§ 40.11); for material being transported by a contract carrier (§40.12); for material that is considered an unimportant quantity of source material (<0.05%) as described in §40.13; or by special request to the NRC (§40.14). Special nuclear material (enriched uranium, plutonium) are exempt from licensing if the material is under the control of the DOE or is under the control of DOD in accordance with Section 91 of the AEA for national defense (§70.14).

c. State Regulations for the Control of NORM. The status of state regulations for the control of NORM/TENORM contamination, as of 2000, can be summarized as follows (Reference: The NORM Report, Volume II, Number 2):

States with NORM regulations	Arkansas, Georgia, Louisiana, Mississippi, New Mexico, Ohio, Oregon, South Carolina, Texas, Washington,
States with radiation regulations that regulators believe address NORM	Arizona, Delaware, Idaho, Kansas, Maine, Maryland, Massachusetts, Michigan, Minnesota, Nebraska, New Hampshire, New Jersey, New York, Pennsylvania, Tennessee, Utah, Virginia, Wisconsin
States with no NORM regulations	Alabama, Alaska, California, Colorado, Connecticut, Florida, Hawaii, Illinois*, Indiana, Iowa, Kentucky, Missouri, Montana, Nevada, North Carolina, North Dakota, Oklahoma, Rhode Island, South Dakota, Vermont, West Virginia, Wyoming

CHAPTER 10

Remedies and Innovative Technologies

10-1. Introduction. This chapter addresses remedies and innovative technologies that may be used at radioactive remediation sites. There are only a few remedies available at sites contaminated with radioactive materials: attenuation through decay, decontamination of soils, buildings, and equipment, and disposal of the contaminant, or disposal of the contaminated soils, buildings or equipment. There are a number of potential disposal sites addressed in Chapter 12. In this chapter we will limit our discussion to disposal on-site and disposal off-site.

10-2. Attenuation through Decay. This can only prove feasible when the half-lives of all the radioactive contaminants are short enough for the attenuation to occur within a specified time. For example, if a site is contaminated with I-125, which has a 60-day half-life, attenuation could be considered as a means of accomplishing remediation. Within 2 years, 99.9% of the I-125 will have decayed away. However, attenuation would not be feasible at a site contaminated with uranium, which has a 4 billion year half-life.

10-3. Decontamination. This is the process of removing some or all of a radioactive contaminant from an object. For a procedure to be feasible, it must be able to remove enough of the radioactive material so that the object can pass a final status survey. Decontamination has been attempted on soils using soil-washing techniques. Results have been mixed because of varying soil parameters that may bind the contaminants to the soil, or make the soil handling difficult.

10-4. Soil Volume Reduction. This has been attempted using a number of processes. Segmented gate systems operate using an array of detectors positioned over a conveyor belt. The soils are loaded onto the conveyor belt in a thin layer, and passed under the detectors. When a detector senses some radioactive material in the soil, that particular portion of soil is diverted out of the waste stream into a contaminated material pile. The rest of the soil goes on to the ‘clean’ pile. A USACE pilot study results can be found at http://www.fusrapmaywood.com/Docs/MISS-106.pdf.

10-5. Soil Washing. The soil-washing process is a treatment method where dispersed, low-level radioactive contaminated particles are washed from the soil fraction. Low to intermediate levels of contamination are removed from the soil. The process can reduce the volume of a contaminated soil that would otherwise require special handling and packaging for off-site disposal by 98%. Soil can be washed in situ or ex situ and is done using a dilute solvent that is selective for the contaminants to be treated. Soil washing may be effective when there is an inverse relationship between particle size and contaminant concentration. Soil washing is effective for the remediation of soils with a high content of material with

large particle sizes (more than 90% sand and gravel). After size separation, a large portion of the radioactive material may be concentrated in the fine material, leaving a minor portion in the coarse material. The coarse material may then contain low enough amounts of radioactive material for replacement on-site. Soil washing has been successfully demonstrated (pilot scale) on soils contaminated with strontium, cesium, technetium, radium, uranium, thorium, barium, and lead. Soil washing can also be used for mixed wastes contaminated with organics or heavy metals. One problem with soil washing has been stakeholder acceptance of using the washed soil as fill at the site. Some pilot studies for chemical extraction methods can be found at:
http://www.frtr.gov/matrix2/section3/table3_8.html.

10-6. In-situ Phytoremediation. This is a method of using plants to bioaccumulate contaminants. It has been able to remove approximately 95% of the cesium and strontium contamination from a pond near Chernobyl, where sunflowers were grown hydroponically, and to remove uranium from water. Indian mustard and poplar trees have also been used. The plants take up certain contaminants and store them within their biomass. Most accumulation is in the root system, which may make it less amenable to soil remediation. Similarly, DOE research has shown promise in using bioaccumulation of uranium from soil matrices by certain bacteria.

10-7. Ex-situ Soil Treatment. The ex-situ soil treatment process combines dissolution with dilute selective solvents, contaminant recovery, and solvent regeneration to provide a continuous recirculating treatment process. The solvent chemistry combines well-established carbonate recovery chemistry with a chelant and an oxidant. Countercurrent extraction is used to dissolve and recover the contaminant in the ex-situ treatment process. The number of extraction stages and the contact time in the extractors are determined based on the contamination level in the soil, the physical and chemical characteristics of the soil, and the level to which the soil must be treated. Removal factors (the ratio of the contaminant level in the feed material divided by the contaminant level in the treated material) of 10 to 20 are typically achievable.

10-8. Equipment and Debris. Waste may be compacted to reduce its volume. First, one should determine whether compaction is beneficial to the treatment and disposal scheme of each waste. Compaction may be an appropriate technology to reduce disposal costs if the disposal facility charges on a volume basis. If debris will be sent off-site for disposal, it is important to determine if the disposal facility has any dimensional limitations on debris. Land disposal facilities sometimes limit dimensions to ensure proper compaction during placement in the disposal cell.

10-9. Cutting and Sawing. These operations may be appropriate on large metal or plastic items. This type of waste typically has to be reduced to make it fit into packaging containers or to prepare it for further treatment, such as incineration. The cutting may be carried out either in the dry state in cells, and with conventional tools, or underwater. The cutting may also be done with plasma-jets, laser torches, or explosive fuses. Crushing techniques may be used for size reduction of friable solids (e.g., glass, concrete, and ceramics). Crushing increases the apparent density of the waste. In principle, all types of mill, grinder, and crushing machines of conventional technology can be used. Shredding reduces void space and is particularly effective when plastics are compacted. Air, trapped between the folds of bulk plastic and in plastic bags, takes up container and disposal space.

10-10. Incineration. Incineration as a hazardous waste treatment technology is discussed in EM 1110-1-502. Major considerations in using incinerator technology for radioactive waste treatment involve shielding requirements, use of HEPA filters, and methods of ash disposal. Incineration is primarily a volume reduction technique. It has a secondary benefit of destroying hazardous organic chemicals often present in mixed waste. In all instances, incineration will create a final product, which is ash, with a higher radionuclide concentration. This ash may require treatment before disposal.

10-11. Building Demolition.

a. Demolition is the total destruction of a building, structure, or piece of equipment. Demolition usually occurs in conjunction with dismantling. Specific demolition techniques include complete burn-down, controlled blasting, wrecking with balls or backhoe-mounted rams, rock splitting, awing, drilling, and crushing. The debris may be treated (possibly by incineration) and is then disposed of. The building is usually pretreated for the majority of the radioactive material before demolition, and some structures within the building may have to be dismantled and removed before demolition.

b. Hazardous substances, such as PCBs and asbestos, may also be present in the building and typically warrant prior remediation or removal so as to avoid generating large quantities of commingled waste (TSCA or NESHAP regulated) during the building demolition. Contaminated structures and equipment can be physically separated from the environment by a barrier. These barriers may be plaster, epoxy resins, or concrete. Control effectiveness depends primarily on the correct choice of encapsulant.

10-12. Hydroblasting. This technique uses a high-pressure (3500- to 350,000-kPa), low volume water jet to remove contaminated debris from surfaces. The debris and water are collected, and the water is decontaminated. Hydroblasting may not effectively remove contaminants that have penetrated the surface layer. On the average, this technique removes 0.5 to 1.0 centimeters of concrete surface at the rate of 35 m^2/hr. The method can be used on contaminated concrete, brick, metal, and other materials. Hydroblasting can easily incorporate variations such as hot or cold water, abrasives, solvents, surfactants, and varied pressures.

10-13. Paint Removal. This might be needed in a building found to contain radioactive contamination on the wall surface or trapped between layers of paint. A combination of commercial paint removers, hand scraping, water washing, and detergent scrubbing may be necessary to remove the paint and radioactive contamination. Fixative/stabilizer coatings can be used on contaminated residues to fix or stabilize the contaminant in place and decrease or eliminate exposure hazards. These agents include molten and solid waxes, carbowaxes, organic dyes, epoxy paint films, gels, foams, and polyester resins. To create strippable coatings, compounds that bind with contaminants are mixed with a polymer, applied to a contaminated surface, and removed to achieve decontamination.

10-14. Scarification. This is capable of removing up to 2.5 centimeters of surface layer from concrete (not block) and cement. The scarifier tool consists of pneumatically operated piston heads that strike the surface, causing concrete to chip off. The piston heads consist of multipoint tungsten carbide bits. An almost identical or similar process to scarifying is scabbling, in which a super-high-pressure water system can be used. This water system is more easily operated remotely. Wall, floor, and hand-held scarifiers are available.

10-15. Steam. Steam cleaning physically extracts contaminants from building materials and equipment surfaces. Currently, steam cleaning is used mainly to remove contaminated particulate. This technique is known to be effective only for surface decontamination. Steam cleaning requires steam generators, spray systems, collection sumps, and waste treatment systems. Commercial-scale steam cleaners are available from many manufacturers. Several manufacturers make portable steam cleaning equipment.

10-16. Drilling and Spalling. This operation consists of drilling holes 2.5 to 4 centimeters in diameter and 7.5 centimeters deep into concrete. The spalling tool bit is inserted into the hole and hydraulically spreads to spall off the contaminated concrete. This technique can remove up to 5 centimeters of surface from concrete or similar materials. Vacuum filter systems and water sprayers can be used to control dust during drilling and spalling operations. Remotely operated drill and span rigs are available.

10-17. Disposal. Disposal may be accomplished through a number of methods. Burial and capping on-site, disposal at waste disposal facilities, and allowed effluent releases are the most common methods of disposal. AR 11-9 prohibits on-site burial at DA facilities, and on-site burial rarely will be allowed without site restrictions or institutional controls of some type.

CHAPTER 11

Transportation

11-1. Introduction. Transportation of hazardous materials is regulated by the US Department of Transportation (DOT). The regulations applicable to transportation of Class 7 (radioactive) materials can be found in Subpart I of 49 CFR 173. Under the AEA of 1954, the NRC has responsibility for safety in the possession, use, and transfer (including transport) of byproduct, source, and special nuclear material. Because of this overlap in statutory authorities of NRC and DOT, the two Federal agencies signed a MOU in 1979 with regard to regulation of the transport of radioactive material (44 FR 38690). DOT (in consultation with the NRC) is responsible for developing safety standards for the classification of radioactive materials; for design specifications and performance requirements of packages for quantities of radioactive materials (other than fissile) not exceeding Type A limits and for low specific activity materials; and for other transportation requirements. The NRC is responsible for greater than Type A quantities of radioactive materials and fissile materials. DOT acts as the US representative to the IAEA (International Atomic Energy Agency) and other internal governmental matters and the NRC provides DOT technical support and advice.

a. The NRC has promulgated in 10 CFR 71 requirements that must be met by licensees for packaging used to deliver certain types of licensed material to a carrier for transport if fissile material or quantities exceeding Type A quantities are involved. NRC also assists and advises DOT in establishing both national and international safety standards and in reviewing and evaluating packaging designs. Persons offering radioactive materials for transportation are responsible for ensuring that the package is in good physical condition and meets DOT specifications, the package is appropriate to the contents, all closures are in working order, all radiation and contamination levels are checked, and all labeling, marking, manifesting, and placarding requirements are met.

b. Only personnel trained in transporting hazardous materials will prepare, package mark, label, manifest, or offer for shipment any radioactive materials for USACE. Only USACE members formally designated and authorized by a MSC or District Commander or Deputy Commander shall be allowed to execute hazardous waste manifests and related documents for a site. The authorization letter should recognize that the individual is within his or her scope of employment when executing manifests and related documents. To document appropriate training and the scope of an individual's signature authority, a nomination and authorization procedure must be put into practice. All persons nominated to be manifest certifying officials must have completed the required training and obtained certification. The nomination package should contain a one-page summary of the person's training and experience in HTRW and manifesting. The nomination package should also have the authorization letter (to be coordinated with the local counsel) ready for signature. The authorization letter must clearly state that the execution of manifests and related documents are within the scope of the individual's official duties. (See EP 415-1-266, Resident Engineer Management Guide for HTRW Projects.)

c. It is USACE policy, if requested by its customers, to execute hazardous waste manifests and related documents on behalf of those customers when it is not precluded by state statutes or regulations. Currently, USACE is signing manifest forms and related documents on behalf of EPA, FEMA, and FSA. USACE personnel executing hazardous waste manifests and related documents must ensure that the USACE is authorized by its customers to execute hazardous waste manifests and related documents on their behalf prior to such documents being executed.

11-2. Determining if Packages are Radioactive for Shipping.

a. Currently, a material is considered Class 7 (radioactive) for shipping purposes if the material contents of the package have a specific activity greater than 70 becquerel per gram (Bq/g, which is approximately 2000 pCi/g). If more than one radionuclide is present in the package, such as when shipping radionuclides that decay to radioactive daughters, the sum of all the specific activities must not exceed 70 Bq/g.

b. On 26 January 2003, DOT published a final rule that will change the regulatory definition of Class 7 (radioactive) material by harmonizing the regulations with international standards. Under the system that will become effective 1 October 2004, the exempt material activity concentrations vary depending on the individual radionuclide. The exempt concentrations are published in 40 CFR 173.436. There is also an activity limit for an exempt consignment of material that, if exceeded, would require the consignment to be shipped as Class 7 even though each individual package may be exempt.

c. Materials, soils, and debris containing radioactive materials greater than natural background but exempt from DOT requirements, will be shipped and handled in such a way as to be protective of worker health and safety, the public, and the environment. Most truck and rail transporters require that these materials be packaged. Bulk shipments may use liners (i.e. 'burrito bags') inside rail gondolas, or intermodal containers. Smaller shipments may be made in strong, tight containers.

d. DOT radioactive materials are also classified by their containment, quantity, and exceptions.

(1) Containment. Radioactive materials may be considered as normal form or special form. Special form materials are those defined in accordance with DOT regulations (49 CFR 173.403). Special form materials must be a single, solid piece or be contained in a sealed capsule with one dimension greater than 5 millimeters and must pass tests to demonstrate its

resistance to breach or destruction. All other radioactive materials are considered normal form. Most USACE radioactive wastes are normal form.

(2) Quantity. The A_2 quantity (normal form) is the maximum activity of normal form material allowed in one Type A package. An A_1 quantity (special form) is the activity that will produce an external radiation level of 1 R/hr at 3 meters, up to a maximum of 1080 curies, and it is the maximum activity of special form material allowed in a Type A package. There are some radioisotopes currently assigned an unlimited A_2 value. This value is used in determining other quantity limits. The recently amended regulations also revised the A values for many radionuclide, therefore each on-going transportation program should assess the impact of the changes prior to 1 October 2004. A Type B quantity is one that exceeds the Type A quantity. A highway-route-controlled quantity means a quantity within a single package that exceeds:

- 3000 times the A_1 or A_2 quantity
- Any quantity exceeding 1000 TBq (27,000 Ci), whichever is the least

(3) Exceptions. Radioactive materials that qualify as exceptions may be shipped using less stringent requirements for packaging, marking, labeling, and manifesting. These exceptions are spelled out in 49 CFR 173.421 through 427: limited quantities of class 7 materials, instruments and articles, manufactured articles containing natural uranium or thorium, low specific activity Class 7 materials, and objects with contaminated surfaces.

(a) A Limited Quantity is not greater than one one-thousandth of the Type A quantity for solids, or not greater than one ten-thousandth of a Type A quantity for liquids.

(b) Instruments and articles are manufactured items containing radioactive material that would require destruction of the item to remove the material. The activity cannot exceed one one-hundredth of the type A quantity for solid material, one one-thousandth of a Type A quantity for gases, or one ten-thousandth of a Type A quantity for liquids. The radiation level at any point on the external surface of the package shall not exceed 0.005 mSv/hr (0.5 mrem/hr).

(c) Low Specific Activity material are uranium or thorium ores and their physical and chemical concentrates, or un-irradiated natural or depleted uranium or thorium, or mill tailings, contaminated earth, concrete, rubble, or other debris in which the Class 7 material is uniformly distributed and the average specific activity meets specified concentration limits determined by their A_2 values.

(d) Depending upon their total activity, some remediation wastes may not meet the definition of a Class 7 (radioactive) material but they are DOT hazardous material because they contain a reportable quantity (RQ) of a hazardous substance in a single package or bulk container under 49 CFR 172.101 Appendix A Table 2. Should any of these radioactive materials contain a hazardous substance, they may be subject to additional regulations on transport, depending on the hazardous substance involved.

11-3. Packaging. Radioactive soils and debris from site remediation that are DOT regulated normally contain low specific activities of radioactive contaminants and have a low external dose rate. These packages may be shipped under 49 CFR 173.427 Transportation Requirements For Low Specific Activity (LSA) Class 7 (radioactive) Materials and Surface Contaminated Objects (SCO). LSA materials have several options for packaging but, typically, strong, tight containers will suffice for domestic shipments of most soils and debris. These packages must meet the DOT requirements for LSA and must be shipped as exclusive use.

a. Small quantities, such as field samples may be shipped under 49 CFR 173.421 Excepted Packages, Limited Quantity of Class 7 Materials. Small quantities of higher activities may be shipped in Type A containers. Radioactive materials with high activities may require Type B packaging. Each successively greater packaging has additional requirements and is proportionately more expensive A trained and certified hazardous materials shipper must be consulted for packaging and shipping radioactive materials or waste.

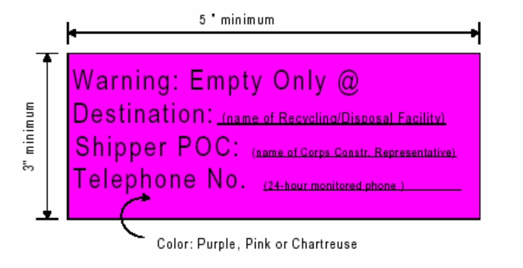
b. The outside of each container must meet DOT's specified contamination control limits. This is usually accomplished through smear or wipe testing the outside of the package, and assaying the smear to assure there is no removable contamination from the package.

11-4. Marking. Non-bulk packages will be marked with the proper shipping name, the UN identification number, and the consigner or consignee's name and address. The gross weight, RQ, package type and weight, and orientation markings, if applicable, will also be included on the package. Bulk packages must be marked with the UN identification number, and conditions may require that it be displayed on an orange panel or white square-on-point if certain conditions exist. Markings must be in English, meet specified size requirements, must be durably marked with a contrasting color background, and be isolated on the package and un-obscured.

11-5. Labeling.

a. Radioactive packages will be labeled with a White I, Yellow II or Yellow III radioactive label unless excepted by DOT from labeling. The label will include the Transport Index, the radionuclides in the shipment, and their activities. A subsidiary hazard labels may be necessary if required by regulation. The labels will be placed on opposite sides of the package. Empty packages may be shipped but must include the Empty label.

b. All packages of radioactive waste will also be labeled with a non-DOT USACE marking sticker adjacent to the specified DOT labels and placards to ensure the materials are properly disposed. Containers (bulk and non-bulk) of wastes or materials that are not DOT, EPA, or NRC regulated, but are being sent off-site for disposal shall also have the marking sticker even though there are no specification markings, labels or placards required.



11-6. Manifesting. If the material to be disposed of is NRC licensed material, an NRC Uniform Low-Level Radioactive Waste Manifest (forms 540 and 541) must be used. This manifest will fulfill the DOT shipping paper requirements as well as the NRC requirements. If the material to be disposed of is a hazardous waste, a state or uniform EPA Hazardous Waste Manifest must be used. If the material is a RCRA regulated waste and is also NRC regulated, the NRC manifest must accompany the EPA manifest. If the material is not a hazardous waste or NRC licensed, but is still regulated by DOT (e.g., RQ of radionuclides) then a DOT straight bill of lading may be used.

a. The manifest or shipping papers will be filled out completely. If the material is a hazardous waste, the appropriate hazardous waste manifest (see 40 CFR 262.21 for hierarchy) and land disposal notifications will be completed. The manifest must include the name, address, and phone numbers for the consignor and the consignee. DOT regulations require hazardous materials be listed first on the shipping paper or marked with a contrasting color or marked with an “X” in the hazardous materials column.

b. The proper shipping name, UN number, and hazard class will be filled out for each material. The physical and chemical form, the activity, the TI and Labeling applied to the package will be listed, and Highway Route Controlled Quantity (HRCQ) or RQ, if applicable, will be included in the description.

c. A 24-hour emergency telephone number must be listed on the manifest when transporting DOT hazardous materials. The emergency phone must be monitored at all times the hazardous material is in transportation (including storage incidental to transportation) by personnel knowledgeable of the shipment, its hazards, and proper emergency response and incident mitigation information in case of accident (49 CFR 172.604). Pagers and call backs are unacceptable to meet this requirement.

11-7. Placarding. Exclusive use shipments of LSA or SCO and packages labeled with Radioactive Yellow III labels will require vehicle placarding. The consignor is responsible for providing the shipper with the appropriate placards. Most commercial shippers will have their own placards available but the shipper should have the necessary placards on hand. HRCQ shipments of radioactive materials must have a radioactive placard placed on a square white background in accordance with DOT regulations.

11-8. Mixed or Co-Mingled Waste.

a. Except for Class 7 limited quantity packages, as defined in 49 CFR 173.421, radioactive materials that also meet the classification of more than one hazard class will be classified primarily as Class 7. Limited quantity packages will be classed as the additional hazard and prepared for transportation according to the other hazard class.

b. Mixed waste may have subsidiary hazard labeling, requirements under 49 CFR 172.402. Excepted packages under 49 CFR 173.421, 424 or 426 do not need to have a subsidiary "Radioactive" label.

11-9. DOT Required Security Plans. Security of hazardous materials in the transportation environment poses unique challenges. To address this DOT requires shippers and carriers to have security plans in place and provide training for personnel involved in shipments of certain hazardous materials. Radioactive materials and radioactive waste shipments of a HRCQ, a shipment that requires a placard, or shipments of hazardous materials in bulk or non-bulk packaging when specified limits (e.g., 468 cubic feet for solids for bulk, 5000 pounds gross weight or more of one hazard class in non-bulk packaging) are exceeded will require a security plan. Most exclusive use shipments of radioactive materials will require placards, and so will require a security plan. These new DOT security requirements are imposed industry-wide on transporters. USACE contracts require the contractor to provide site security, and contractors and transport companies are required to follow applicable Federal regulations. USACE duties for compliance with the DOT security plan requirements include the following:

- Ensuring that the contractor and transporter know that under their contracts they must comply with all Federal laws, including this new DOT requirement.
- Ensuring that the contractor is aware of the security clauses in his or her basic contract that requires they provide site security.
- Determine whether USACE needs to prepare a security plan to address the security of the hazmat during pre-transportation phases when the hazmat is on-site.

To demonstrate compliance with these regulations, the following procedure will be followed for all USACE shipments of DOT regulated hazmat by contractors when security plans are required by 49 CFR 172, Subpart I. Guidance on the new DOT security planning and training requirements for hazardous material shipments is forthcoming from HQ USACE in an Engineering Technical Letter. A fact sheet has been prepared by the HTRW-CX, which addresses the new DOT security requirements.

a. The contract will clearly require full compliance with DOT regulations, 49 CFR, Subchapter C.

b. The contract will clearly indicate, through the appropriate Federal Acquisition Regulations clauses, that the prime contractor is responsible for on-site security.

c. With each shipment of hazmat required to have a security plan, the USACE representative, responsible for signing the shipping documents, will require the initial transporter to sign a certification statement. Subsequent shipments of the same hazard class of materials transported by the same transporter need not provide additional certifications.

d. The certification will be typed on a separate page and read as follows:

> I hereby certify that (name of transportation company) has a Security Plan in place which meets the requirements of 49 CFR 172 Subpart I for the hazardous materials described in the attached shipping papers.

This certification will be signed by the initial transporter and dated.

e. The certification will be placed in the project files with the shipping documents, and retained for at least the period required for the shipping papers.

f. It is not USACE responsibility to review, accept, approve or even have copies of shipper's and transporters security plans.

CHAPTER 12

Disposal

12-1. Introduction. USACE policy is that USACE will dispose of radioactively contaminated materials only at facilities licensed by the Nuclear Regulatory Commission (NRC) or an Agreement State, or at facilities permitted by a Federal or state regulator to accept radioactive materials in accordance with their facility permit and all applicable laws and regulations. Materials will be disposed of in a cost-effective manner, considering all feasible options that achieve protectiveness and compliance with all applicable Federal and state laws. To assure that this policy is implemented, the project manager will document a disposal strategy containing the following elements in the Project Management Plan for each project.

12-2. Characterization of Materials. USACE will characterize materials to determine the laws and regulations that apply to off-site disposal of specific materials at each site. The use of appropriate analytical testing to determine physical and chemical characteristics and a determination of historical factors (generator knowledge) about the materials processed on the site are necessary to properly characterize the materials as to category of radioactivity and RCRA hazardous waste codes (if relevant), and determine who has regulatory authority. More than one type of material may be identified for a particular site. Characterization will be conducted in consultation with the appropriate technical and legal specialists. The characterization process will be coordinated with the Hazardous, Toxic, and Radioactive Waste Center of Expertise and the conclusion will be documented, and retained in the project file.

12-3. Identify and Coordinate with Potential Disposal Facilities. Based on the characterization of materials, USACE will identify potential disposal facilities and will assure that such interested off-site disposal facilities are provided accurate characterization information concerning material intended for off-site disposal.

12-4. Compare Transportation and Disposal Costs of Viable Facilities. USACE will determine the most cost-effective option for disposal of material. Packaging, transportation (including potential demurrage costs), and disposal fees will be included in the cost effectiveness analysis.

12-5. The Off-site Rule. Only facilities meeting the NCP Off-site Rule's (40 CFR 300.440) acceptability criteria will be used for disposal of materials that are CERCLA waste, including radionuclides. Under this rule, USACE will notify the EPA Regional Off-site Coordinator (ROC), in the region where the selected facility is located, of the intent to send CERCLA waste to that facility. USACE will transport CERCLA waste off-site only when the ROC has made a finding and notified USACE that the receiving facility meets the compliance and release criteria in 40 CFR §300.440 (b) and is therefore acceptable under the Off-site Rule.

a. In the event of an emergency posing an immediate and significant threat to human health or the environment, shipment may commence prior to the ROC's determination. The project manager may consider temporary measures, such as interim storage, to allow time to locate an acceptable facility. The ROC must be notified and the response received prior to final disposal of the CERCLA waste.

b. If shipments are not initiated within 60 days of the ROC's determination of the facility's acceptability status, then USACE will recheck the status with the ROC. In the event that the facility's status under the Off-site Rule changes to unacceptable, and EPA notifies the facility and the project manager, material will cease to be sent to that facility until the status of the facility is officially changed to acceptable by EPA under the Off-site Rule.

c. The ROC determination does not supersede the facility regulator's authority to determine the acceptability of a material under the facility's license or permit; however, waste may not be shipped and disposed of at the facility without the EPA finding of acceptability under the Off-site Rule.

12-6. Facility Regulators. USACE is responsible for ensuring that all appropriate contacts (NRC, EPA, or state) are made with regulators before shipment of materials off-site for disposal. Open and early communication with regulators is necessary for the successful execution of this policy.

a. A written description of the materials to be disposed of will be provided to the selected facility. The facility will seek to obtain written authorization from the appropriate regulators, indicating that the proposed disposal is consistent with applicable regulations and the permit or license of the disposal or treatment facility. USACE will ensure that:

(1) The nature of the material to be disposed of has been accurately represented.

(2) Acceptance is unqualified.

(3) The regulator indicates the proposed action would not violate applicable laws and regulations or the facility permit or license.

b. There may be low-level radioactive waste (LLRW), as defined by the LLRW Policy Amendments Act (reference 4.f.), on some sites. Disposal of such material may be affected by regulations governing the regional LLRW compacts. The Atlantic, Rocky Mountain[*], and

[*] Rocky Mountain compact contracts with the Northwest compact for use of the Northwest disposal facility at Hanford in Washington state

North West compacts have Low Level Radioactive Waste Disposal facilities that must be used for disposal of waste generated within their compact. Some compacts allow for export of waste but will charge an export fee. Since these vary among compacts, plans for disposal of LLRW must be coordinated with District Office of Counsel to ensure compliance with all applicable regulations.

c. All contacts will be documented and all records retained in the project file, as well as copies of all written agreements and approvals.

d. The State of Utah has enacted a requirement for a generator's site access permit to allow generators to dispose of radioactive waste at sites within their state. Office of counsel for USACE contends that application of this permit and the accompanying fees to the Federal government is not permissible. The State of Utah has agreed that the fee does not apply to the Federal government when disposing of AEA regulated material. However, the State of Utah has not concurred with the USACE position pertaining to the disposal of non-AEA regulated materials (e.g., NORM, radioactive residuals from ore processing prior to UMTRCA). USACE has agreed not to ship these materials to Utah without a permit or a resolution of the disagreement.

12-7. Transportation Requirements. Shipments of FUSRAP materials will comply with all applicable NRC and Department of Transportation requirements. Materials that are an RCRA hazardous waste must also comply with applicable EPA and state manifest and transportation requirements. See LLRW Policy Amendments Act (references 4.h. and 4.i.) for a discussion of these requirements. USACE will also follow the additional items below.

a. USACE personnel are responsible for signing shipping papers in accordance with LLRW Policy Amendments Act (reference 4.i.).

b. A secondary non-DOT marking sticker will be added to all bulk containers of material. The intent of this sticker is to ensure that all materials, no matter their hazardous characteristics, are appropriately disposed of.

c. A Certificate of Disposal or Placement is required for all off-site disposal of materials. This certificate will provide a complete record of the final disposition of the material. The certificate should identify the individual quantities of material received at the disposal facility and the location where the material is finally placed after disposal.

d. A Chain-of-Custody form will be required for the off-site disposal of all material, including material that is not regulated by DOT, EPA, or NRC.

12-8. Disposal Contracts. Kansas City District has a number of contracts in place for disposal of radioactive materials. These contracts are available for use to all DOD components and Federal agencies. These contracts offer very competitive disposal rates at a variety of sites, depending on the nature of the waste materials.

12-9. Disposal Options Available as of January 2003.

a. Chem-Nuclear Systems, L.L.C., Barnwell, South Carolina. This is the Atlantic Compact disposal site. It may accept waste from outside the Atlantic Compact. Acceptable waste includes LLRW Class A, B, and C, NORM and NARM. Will accept biological waste. No liquid waste accepted. Waste must be packaged. Requires annual allotment of space for Out of Compact users with large volumes. Costs range from $4.50 to $8.04 per pound, depending on density, plus $0.38 per millicurie, plus $1.00 to $1.50 per mR/hr, depending on exposure rate, plus $4.00 per cubic foot Compact Commission surcharge.

b. US Ecology, Hanford Reservation, Washington. This is the Northwest and Rocky Mountain Compacts disposal site. It accepts LLRW, Class A, B, and C, from within Compacts. NORM and NARM may be accepted from outside the compact. Will accept biological waste. No liquid waste accepted. Waste must be packaged.

c. Envirocare, Inc., Clive, Utah. Accepts LLRW Class A, NORM and NARM, 11e(2), and Mixed Waste. Offers treatment services.

d. Waste Control Specialists, Andrews County, Texas. Provides Interim Storage for LLRW Class A, B, C, and greater than Class C wastes. May dispose of non-NRC regulated radioactive waste.

e. American Ecology, Grandview, Idaho. May dispose of non-NRC regulated radioactive waste with activities less than 2000 pCi/g total activity.

f . American Ecology, Robstown, Texas. May dispose of non-NRC regulated radioactive waste with activities less than 2000 pCi/g total activity.

g. International Uranium Corp., Utah. May accept uranium for recycling as source material.

12-10. USACE and DA Coordination. The Department of Defense (DOD) has designated the US Army as the Executive Agent for disposal of DOD radioactive waste. The operational working of this has been delegated by the DOD Executive Agent to the Army Field Support Command (AFSC), Radioactive Waste Disposal Division. All DOD-generated radioactive waste must be disposed of in coordination with AFSC. Since USACE disposes of waste from a large number of generators, all waste disposed of by USACE must be coordinated with the HTRW CX. The HTRW CX will determine which disposal actions must be coordinated with AFSC and will provide case-by-case guidance and assistance on accomplishing this.

CHAPTER 13

Multi-Agency Radiation Site Survey and Investigation Manual (MARSSIM)

13-1. Introduction. The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) provides detailed guidance for planning, implementing, and evaluating environmental and facility radiological surveys conducted to demonstrate compliance with a dose- or risk-based regulation. The MARSSIM guidance focuses on the demonstration of compliance during the final status survey following scoping, characterization, and any necessary remedial actions.

13-2. Data Life Cycle. The process of planning the survey, implementing the survey plan, and assessing the survey results prior to making a decision is called the Data Life Cycle. MARSSIM provides detailed guidance on developing appropriate survey designs using the Data Quality Objectives (DQO) Process to ensure that the survey results are of sufficient quality and quantity to support the final decision. The survey design process is described, and guidance on selecting appropriate measurement methods (i.e., scan surveys, direct measurements, samples) and measurement systems (i.e., detectors, instruments, analytical methods) is provided. Data Quality Assessment (DQA) is the process of assessing the survey results, determining that the quality of the data satisfies the objectives of the survey, and interpreting the survey results as they apply to the decision being made. Quality Assurance and Quality Control (QA/QC) procedures are developed and recorded in survey planning documents, such as a Quality Assurance Project Plan (QAPP). MARSSIM does not provide guidance for translating the release criterion into derived concentration guideline levels (DCGLs). DCGLs must be coordinated with the stakeholders. DCGLs must include a $DCGL_W$, the average concentration of radionuclides in an area, the area over which the $DCGL_W$ may be averaged, and a $DCGL_{EMC}$, the maximum concentration acceptable in a small localized area.

a. MARSSIM discusses contamination of surface soil and building surfaces in detail. If other media (e.g., ground water, surface water, subsurface soil, equipment, vicinity properties) are potentially contaminated at the time of the final status survey, modifications to the MARSSIM survey design guidance and examples may be required. Figure 13-1 provides a diagram of the data life cycle within the MARSSIM process. Figure 13-2 provides a flow diagram for final status survey design.

b. MARSSIM defines the limits of a site, then classifies areas of the site as impacted or non-impacted. Areas that have no reasonable potential for residual contamination are classified as non-impacted. Areas with some potential for residual contamination are classified as impacted. Impacted areas are further divided into one of three classifications:

(1) Class 1 Areas. These are areas that have, or had prior to remediation, a potential for radioactive contamination (based on site operating history) or known contamination (based on previous radiation surveys) above the $DCGL_W$. Examples of Class 1 areas include: 1) site areas previously subjected to remedial actions, 2) locations where leaks or spills are known to have occurred, 3) former burial or disposal sites, 4) waste storage sites, and 5) areas with contaminants in discrete solid pieces of material and high specific activity.

(2) Class 2 Areas. These are areas that have, or had prior to remediation, a potential for radioactive contamination or known contamination, but are not expected to exceed the $DCGL_W$. To justify changing the classification from Class 1 to Class 2, there should be measurement data that provide a high degree of confidence that no individual measurement would exceed the $DCGL_W$. Other justifications for reclassifying an area as Class 2 may be appropriate, based on site-specific considerations. Examples of areas that might be classified as Class 2 for the final status survey include: 1) locations where radioactive materials were present in an unsealed form, 2) potentially contaminated transport routes, 3) areas downwind from stack release points, 4) upper walls and ceilings of buildings or rooms subjected to airborne radioactivity, 5) areas handling low concentrations of radioactive materials, and 6) areas on the perimeter of former contamination control areas.

(3) Class 3 Areas. These are areas any impacted areas that are not expected to contain any residual radioactivity, or are expected to contain levels of residual radioactivity at a small fraction of the $DCGL_W$, based on site operating history and previous radiation surveys. Examples of areas that might be classified as Class 3 include buffer zones around Class 1 or Class 2 areas, and areas with very low potential for residual contamination but insufficient information to justify a non-impacted classification.

(4) Summary. Class 1 areas have the greatest potential for contamination and therefore receive the highest degree of effort for the final status survey using a graded approach, followed by Class 2, and then by Class 3. Non-impacted areas do not receive any level of survey coverage because they have no potential for residual contamination. Non-impacted areas are determined on a site-specific basis.

c. MARSSIM then assists in determining the number and quality requirements of data collected, and provides statistical tests to ensure that sufficient data are collected so a defensible decision to remediate further or determine no further action for the site can be made. The statistics also take into account the stakeholder negotiated decision errors.

d. While MARSSIM is designed primarily to address the final status survey of a site, the methodologies and statistical tests are applicable to scoping surveys, characterization surveys, and remedial action surveys. Additional multi-agency guidance is in draft which addresses sub-surface soils, equipment and debris release, and radiological laboratory accreditation.

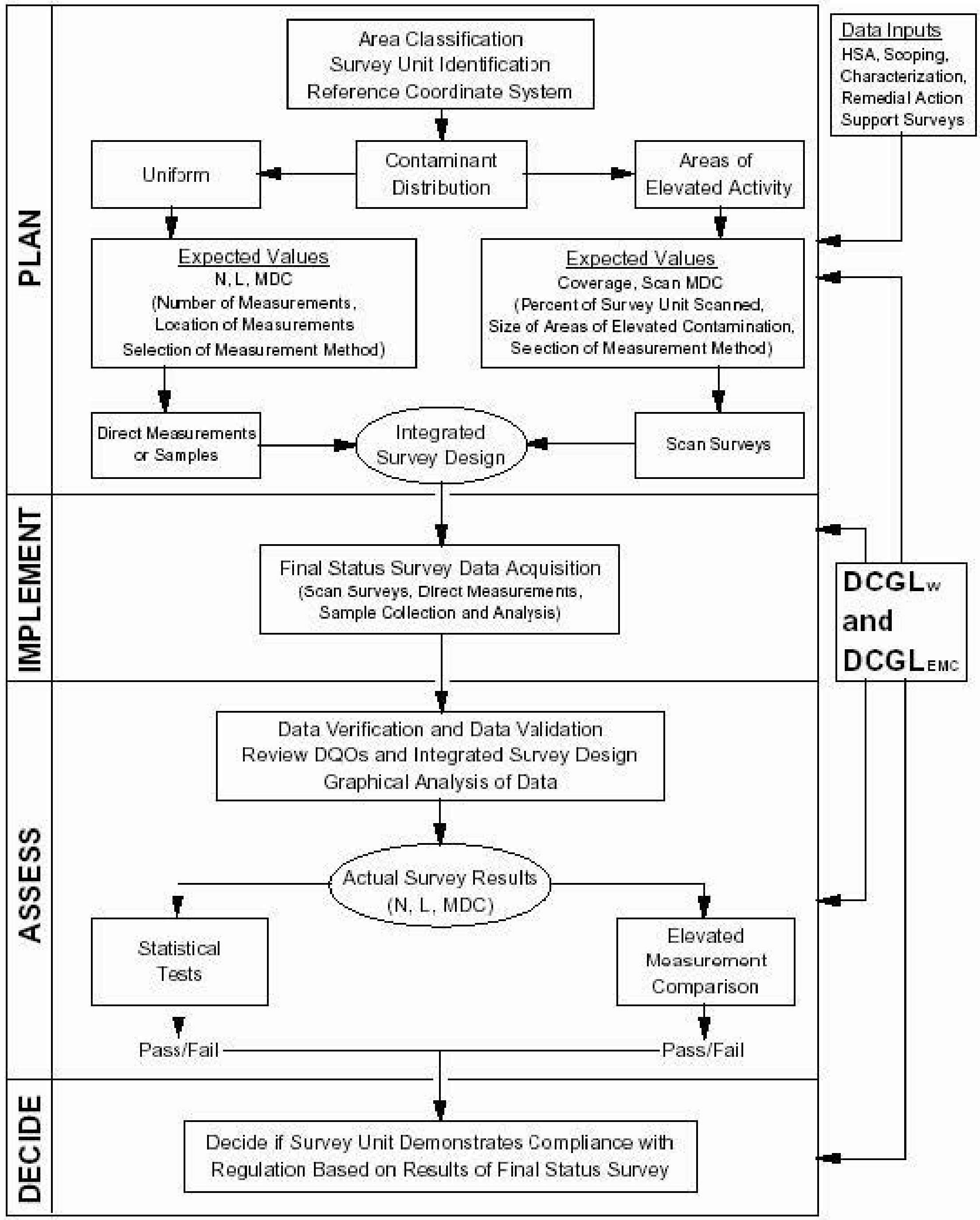


Figure 13-1. Data Life Cycle Applied to a Final Status Survey.

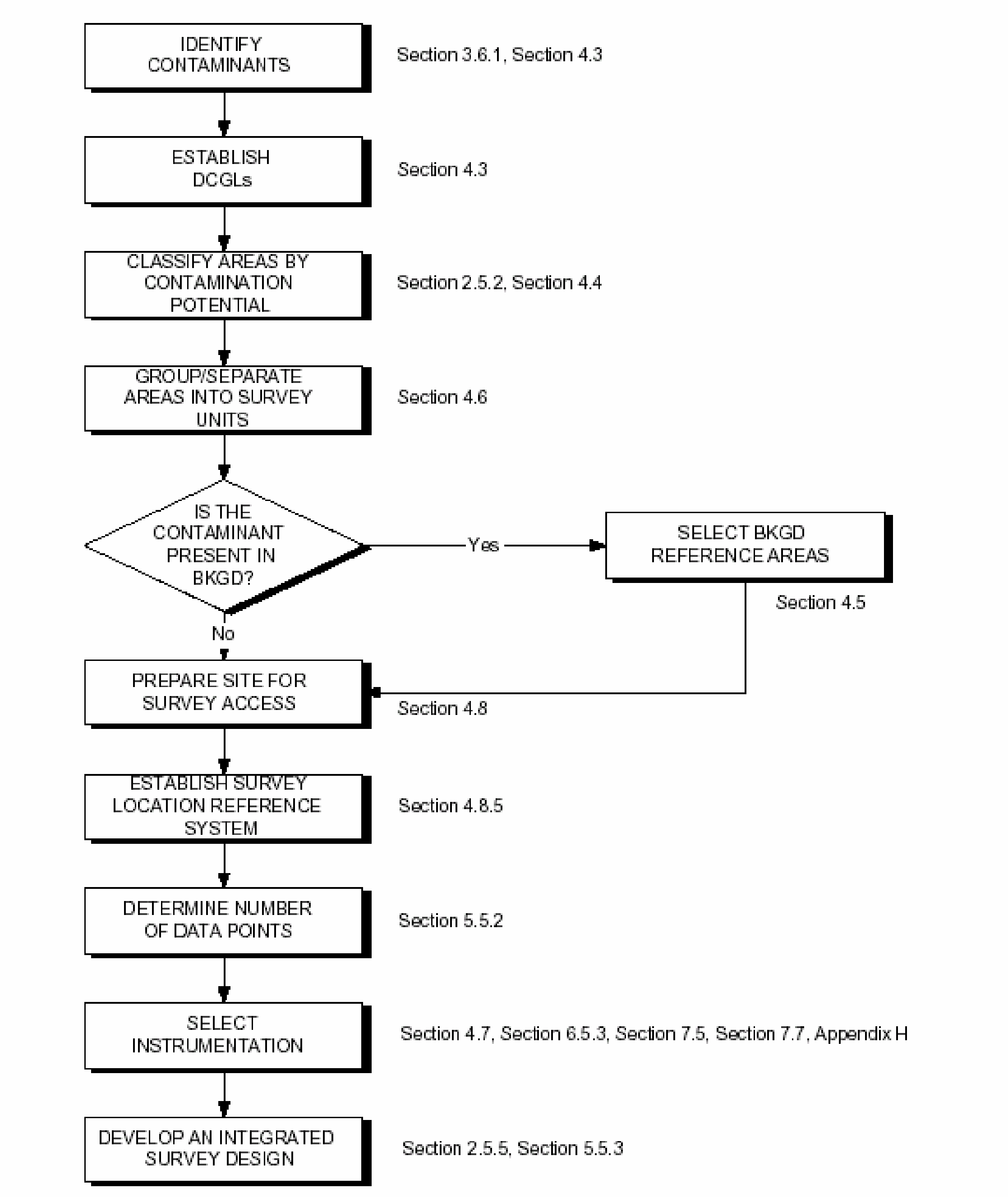


Figure 13-2. Flow Diagram for Designing a Final Status Survey.

APPENDIX A

References and Bibliography of Regulatory Documents, Regulations and Laws

A-1. Code of Federal Regulations (CFR)*

a. NRC Standards.

10 CFR 20
Standards for protection against radiation

10 CFR 60
Disposal of high-level radioactive wastes in geologic repositories

10 CFR 61
Licensing requirements for land disposal of radioactive waste

10 CFR 71
Packaging and transportation of radioactive material

b. OSHA Standards.

29 CFR 1910
Occupational safety and health standards

29 CFR 1926
Safety and health regulations for construction

c. EPA Standards

40 CFR 61
National emission standards for hazardous air pollutants

40 CFR 122
EPA administered permit programs: The national pollutant discharge elimination system

40 CFR 125
Criteria and standards for the national pollutant discharge elimination system

* Superintendent of Documents
Government Printing Office
Washington, DC 20402

40 CFR 141
National primary drinking water regulations

40 CFR 142
National primary drinking water regulations implementation

40 CFR 191
Environmental radiation protection standards for management and disposal of spent nuclear fuel, high-level and transuranic radioactive wastes

40 CFR 192
Health and environmental protection standards for uranium and thorium mill tailings

40 CFR 260
Hazardous waste management system: General

40 CFR 261
Identification and listing of hazardous waste

40 CFR 268
Land disposal restrictions

40 CFR 300
National Oil and Hazardous Substances Pollution Contingency Plan

d. General Standards.

41 CFR 101
Federal Property Management Regulations

48 CFR Chapter 2
Federal Acquisition Regulation Department of Defense

e. DOT Standards

49 CFR 171-178
Transportation of Hazardous Materials

A-2. Congressional Acts.

Clean Air Act
Public Law 88-206
42 U. S. C. 1857

Comprehensive Environmental Response, Compensation,
and Liability Act (CERCLA)
Public Law 96-510
42 U. S. C. 9601-et seq., as amended

Superfund Amendments and Reauthorization Act of 1986
(SARA, amending CERCLA)
Public Law 99-499

Federal Water Pollution Control Act (Clean Water Act)
Public Law 86-70 amended by PL 92-500
33 U. S. C. 1251 et seq.

National Environmental Policy Act (NEPA)
Public Law 91-190
42 U. S. C. 4321

Solid Waste Disposal Act as amended by the
Resource Conservation and Recovery Act of 1976 (RCRA)
Public Law 94-580
42 U. S. C. 6901et seq., as amended

Hazardous and Solid Waste Amendments of 1984(HSWA) amends the Solid Waste Disposal
Act as amended by RCRA
Public Law 98-616

Safe Drinking Water Act
Public Law 93-523
42 U. S. C. 300f et seq., as amended

Toxic Substances Control Act
Public Law 94-469
15 U. S. C. 2601 et seq., as amended

National Low Level Radioactive
Waste Policy Act of 1980
Public Law 96-573
42 U. S. C. 2021-2121D

The following three acts are available in NUREG 0980:
Low Level Radioactive Waste Policy Act Amendments Act of 1985
Public Law 99-240
42 USC 2021b et seq.
NUREG 0980 Vol. 2

Atomic Energy Act of 1954 (and amendments)
42 U. S. C. 2011-2296
NUREG 0980 Vol. 1

Energy Reorganization Act of 1974
Public Law 93-438
NUREG 0980 Vol. 1

A-3. DOD Regulations.

DOD 4715.6-R
Low-Level Radioactive Waste Disposal Program

A-4. Army Regulations.

AR 11-9
The Army Radiation Safety Program

AR 50-7
Army Reactor Program.

AR 200-1
Environmental Protection and Enhancement

AR 200-2
Environmental Effects of Army Actions.

AR 385-10
Army Safety Program.

AR 385-40
Accident Reporting and Records.

AR 750-43
Army Test, Measurement and Diagnostic Equipment Program.

A-5. USACE Publications.

a. Engineer Regulations.

ER 5-1-11
U.S. Army Corps of Engineers Business Process

ER 200-1-4
Environmental Quality - Formerly Utilized Sites Remedial Action Program (FUSRAP) - Site Designation, Remediation Scope, and Recovering Costs

ER 385-1-80
Ionizing Radiation Protection.

ER 385-1-92
Safety and Occupational Health Requirements for Hazardous, Toxic and Radioactive Waste (HTRW) Projects.

ER 1110-1-263
Chemical Data Quality Management For Hazardous, Toxic, Radioactive Waste Remedial Activities

ER 1110-3-1301
Hazardous, Toxic And Radioactive Waste (HTRW) Cost Engineering

ER 1165-2-132
Hazardous, Toxic And Radioactive Waste (HTRW) Guidance For Civil Works Projects

b. Engineer Manuals.

EM 200-1-2
Technical Project Planning (TPP) Process

EM 200-1-3
Requirements for the Preparation of Sampling and Analysis Plans

EM 200-1-6
Chemical Quality Assurance For Hazardous, Toxic And Radioactive Waste (HTRW) Projects

EM 385-1-1
Safety And Health Requirements Manual

EM 385-1-80
Safety - Radiation Protection Manual

APPENDIX B

Radiation Control Agency Points of Contact*

B-1. Federal Radiation Programs.

a. MARSSIM Appendix L.

MARSSIM Appendix L contains a directory list of Federal radiation program managers and is updated on a regular basis.

MARSSIM Appendix L

NRC Headquarters and Regional Offices

b. USACE and Radioactive Waste Disposal Points of Contact.

Headquarters, US Army Corps of Engineers
Radiation Safety Staff Officer
441 G St NW
Washington, DC 20314-1000
(202) 761-1953

US Army Corps of Engineers
HTRW Center of Expertise
12565 W Center Rd
Omaha, NE 68144-3869
(402) 697-2478 fax (402) 697-2595

Headquarters, Army Field Support Command AMSFS-SF
Building 350, 32 Floor
1 Rock Island Arsenal
Rock Island Arsenal, IL 61299-6500
(309) 782-2033
fax (309) 782-2988

* Because offices move and change, addresses and telephone numbers found at these hyperlinks cannot be guaranteed, but they should provide an excellent starting point the majority of the time.

B-2. State Agencies.

The Conference of Radiation Control Program Directors (CRCPD) maintains a directory of State Program POCs.

CRCPD

NRC Agreement States

Alabama	Kansas	Nevada	Oregon
Arizona	Kentucky	New Hampshire	Rhode Island
California	Louisiana	New Mexico	South Carolina
Colorado	Maine	New York	Tennessee
Florida	Maryland	North Carolina	Texas
Georgia	Massachusetts	North Dakota	Utah
Illinois	Mississippi	Ohio	Washington
Iowa	Nebraska	Oklahoma	

APPENDIX C

Technical Information on Radioactive Materials, Decay, Measuring Techniques, and Instrumentation

C-1. Decay Chains.

a. Many radioactive materials decay to other radioactive materials, which may in turn, also decay to other radioactive materials. When the parent radionuclide decays to a radioactive progeny, it is said to be part of a radioactive decay chain. Two very common decay chains are the uranium-238 decay chain, which includes, among other radionuclides, thorium-230, radium-226, and radon-222, and the thorium-232 decay chain, which includes radium-228 and radon-220.

b. Because of the existence of decay chains, a number of things important to contaminant characterization can happen. First, if a parent radionuclide is found on-site, the progeny radionuclide can be expected to be on-site, and inversely, if a progeny radionuclide is present, the presence of its parent radionuclide may be inferred. For example, if you have detected cesium-137 on a site, you will always find its progeny, barium-137m on the site, and its activity will be in equilibrium with the activity of the cesium-137.

C-2. Identifying Radionuclides.

a. Radionuclides are identifiable by the radiation they emit, and by their atomic properties. Most radionuclides found on USACE projects emit multiple types and energies of radiation. The types and energies of the all the radiations emitted by a radionuclide are a unique characteristic of that radionuclide.

b. Example: cesium-137 (^{137}Cs) decays by two pathways. 94.6% of the time ^{137}Cs will emit a beta particle with a maximum energy of 511.6 keV. 5.4% of the time ^{137}Cs will decay by emitting a beta particle with a maximum energy of 1173.2 keV. In both cases it decays to metastable barium-137m (^{137m}Ba), which is also radioactive. ^{137m}Ba decays to stable barium-137, 89.98% of the time by emitting a 661.649 keV gamma ray.

c. So anytime we have Cs-137 contamination on-site, we will be able to measure a spectrum of beta activity with a maximum beta energy of 1173 keV, and a ^{137m}Ba gamma peak with an energy of 662 keV.

d. An unknown sample of a radioactive material can be analyzed by determining what type of radiation it emits, determining at what energy the radiation is emitted, then looking up in tables which particular radionuclides emit that type of radiation at that particular energy. In the example above, ^{137}Cs could be analyzed using a liquid scintillation counter to determine the beta spectrum, and the maximum beta energy. The area under the curve of the beta spectrum is proportional to the activity of the ^{137}Cs. Noting that ^{137}Cs is part of a decay chain, one could also use a gamma counter to count the gamma rays at an energy of 662 keV from the ^{137m}Ba and divide the result by the gamma intensity of 89.98% to calculate the activity of the ^{137}Cs. Since gamma counting is much easier and cheaper to perform, this method is more commonly used. Many of the radionuclides of concern at USACE sites are parts of decay chains.

e. Surrogates can be used because, when a parent radionuclide has a half-life very much larger than its progeny, the progeny decay at a rate faster than it is generated, so it appears than the activity of the progeny is equal to the activity of the parent after sufficient in-growth. As a rule of thumb, seven half-lives of the progeny is considered sufficient time for this in-growth to be achieved.

f. This practice of measuring a surrogate radionuclide and calculating the activity of another radionuclide in the same decay chain is common, but there are a number of pitfalls that must be avoided. There are a number of actions that can invalidate this use of surrogates. Many of these involve actions that chemically separate the radionuclide from its progeny or not permit enough time for adequate in-growth of the surrogate. It is important to discover at which point in the decay chain materials were brought to the site or removed from the site.

g. A number of decay progeny may be gamma emitters but either the percent of time the gammas are emitted or the percent of time the decay chain goes by their path may be too small to make them useful at activities near remediation guidelines. All use of surrogates for determination of the presence and activity of a radioactive contaminant must be thoroughly investigated, documented and agreed to by the regulators.

h. Because the act of sampling soil or water can disrupt the concentrations of ingrown progeny, samples must be held for a number of days or weeks to ensure that the surrogate being measured has had sufficient time to approach equilibrium with the parent radionuclide being analyzed.

i. As an example, Ra-226 is commonly analyzed using gamma spectroscopy and measuring the activity of Bi-214. The decay chain is Ra-226 to Rn-222 to Po-218 to Pb-214 to Bi-214 to Po-214. The act of soil sampling often causes the Rn-222, which is a gas, to escape. This disrupts the decay chain and the sample should be held undisturbed for seven half-lives for each of the progeny to re-establish equilibrium. The half-lives of the progeny are Rn-222-3.82 days, Po-218-3.05 min., Pb-214-26.8 min., and Bi-214-19.9 min. This totals 3.85 days. The sample should be held for seven half lives, 27 days, to ensure that the Bi-214 activity is the same as the Ra-226 activity. Note that under certain conditions, ratio charts can be constructed to allow counting before the seven half-lives have passed. There are a number of factors that can influence the accuracy of the ratio chart. The project health physicist should be consulted to check if the method may be accurately used on any particular phase of a project.

j. Bi-214 emits a 0.609 MeV gamma 46.1% of the time when it decays. The gamma spectrometer will count the number of these gamma emitted. The radiochemist will divide the number of counts by the efficiency and the intensity to determine the number of disintegrations during the counting period. This is then assumed to be the number of disintegrations of the parent radionuclide over the same time period.

k. Since radionuclides can be measured by their atomic properties, some chemical quantification methods may be used to quantify the radionuclides. One common example is use of inductively coupled plasma-mass spectrometry to determine the isotopic abundance of enriched or depleted uranium isotopes.

C-3. Background.

a. A large number of radionuclides are present in the environment at concentrations that can interfere with the measurement of the contamination at a site. The radiation emitted by these radionuclides - mostly naturally occurring but some man-made is collectively referred to as background radiation. Primary radionuclides found in background include:

- The uranium (U) decay chain [U-238, thorium (Th)-234, protactinium (Pa)-234, U-234, Th-230, radium (Ra)-226, radon (Rn)-222, polonium (Po)-218, lead (Pb)-214, bismuth (Bi)-214, Po-214, Pb-210, Bi-210, and Po-210].
- The thorium decay chain [Th-232, Ra-228, actinium (Ac)-228, Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212 and Po-212].
- Potassium-40 (K-40), tritium (H-3) and carbon-14 (C-14).
- Mixed fission products from above ground nuclear testing (Cs-137, Sr-90, etc.).

b. The concentrations of radionuclides in background are highly variable, depending on types of soil throughout the entire soil column, precipitation, water table, temperature, and latitude. Concentrations can vary by orders of magnitude. For example, uranium found in igneous rock averages about 0.6 ppm, but uranium found in Florida phosphate rock averages about 120 ppm.

c. Because of this variability, it is important to select an area from which to take background survey readings and samples that has the same soil and water characteristics, and as near the physical location, of the contaminant as is possible. Additionally, when determining background concentrations, enough background samples must be obtained to determine the variability and standard deviation of the concentration at an acceptable confidence limit. MARSSIM, Sec. 4.5, provides guidance on selection of a background reference area, and a health physicist must be consulted to determine the proper number of background samples to take. This number may be as high as the total number of samples taken at the site, i.e., one background sample per contaminant sample.

C-4. Regulated Contaminants. Because of the nature of the regulatory process, radioactive contamination is regulated under a number of statutes. A more detailed description of the regulations and their interaction can be found in Chapter 9. Ongoing legislative changes have followed changes in the philosophy of radiation safety, but a number of older statutes are still applicable, and have led to a few confusing remediation goals at some sites. The Uranium Mill Tailings Control Act was one of the first acts specifically addressing radioactive contamination in the soil. This act set the remediation goal for uranium mill sites at 5 pCi/g of radium in the top 6 inches of soil and 15 pCi/g radium in each subsequent 15 inches of soil. Because there were no other promulgated standards on soil contamination, this prescriptive remediation goal was cited as relevant and appropriate and applied to other sites where the contaminants were not uranium mill tailings.

APPENDIX D

Typical Remediation Site Characteristics

D-1. Uranium and Thorium Mines and Mills.

a. Facility Operation Description. Uranium is mined using both open pits and underground shafts. Some facilities are now using a subsurface pumping and leaching process. Uranium mills are often co-located with the mines. A majority of the mines in the US are located in the states of Arizona, New Mexico, Utah, and Colorado, but active leaching also occurs in Nebraska and Texas. The majority of the contaminants are located in tailings from the mills and the mines. Co-mingled hazardous components such as Arsenic, and acids are commonly found at these sites.

b. Types of Radiation Expected. Alpha, beta, gamma and neutron radiation can be expected from these sites.

c. Types of Sources Present. Uranium 238, 235, and 234 and all their decay progeny can be found at these sites. Thorium-232 and 230 and their decay progeny may also be present at some sites. Since the mills selectively extracted uranium, the decay progeny at these sites can be expected to not be in equilibrium. There will still be residual uranium or thorium in the mill tailings, and can be expected to contain greater levels of decay progeny.

d. Radioactive Contamination Potential. There is nearly always contamination from mining and milling operations. Great piles of mine-and-mill tailings are left on-site. Often consolidation points from nearby mines exist, where ores were consolidated for transport to the mills. Surface and ground water contamination is common from rain percolating through the waste piles, and running off sites. Establishment of background can be troublesome because the naturally elevated background radiation is primarily attributable to the elevated Uranium in the local and subsurface soils.

e. Radioactive Waste Generated. Large quantities of source material, 11e.(2) byproduct material or residuals of ore processing prior to 1978, may be encountered.

f. Potentially Contaminated Areas. Mines, mills access roads, wide surrounding areas, associated heavy equipment, hand tools, transport vehicles, PPE, ground water, creeks and rivers, and workers' houses can be expected to be contaminated. Cross contamination is a common problem.

D-2. Nuclear Weapons Facilities.

a. Facility Operation Description. The nuclear weapons facilities considered here are those where nuclear weapons are inspected, stored, and maintained. TRU materials and wastes may be present. Both radioactive wastes and co-mingled wastes may be present as byproducts of the processes and operations in the facilities. The weapons were disassembled, inspected, repaired, reassembled, and stored until shipped from these facilities.

b. Types of Radiation Expected. Alpha, beta, gamma and neutron radiation can be expected.

c. Types of Sources Present. The radioactive material can be considered a sealed source when a weapon is assembled. During inspection and maintenance, the radioactive material is an unsealed source. Examples of radionuclides present in nuclear weapons are uranium-233, and -235, plutonium-239 and -241, americium-241, and hydrogen-3. Depleted uranium is also used in testing and training for weapons maintenance.

d. Radioactive Contamination Potential. There is little potential for radioactive contamination when a weapon is assembled unless it is subjected to severe physical damage such as a fire. When a weapon is disassembled, there is a slight potential for contamination. This potential increases if the radioactive material is damaged in any way during inspection and maintenance.

e. Radioactive Waste Generated. Very small volumes of slightly contaminated solid waste can be generated during inspection and maintenance. No significant amount of liquid radioactive waste is generated.

f. Potentially Contaminated Areas. Areas of potential contamination include disassembly, inspection, maintenance, and reassembly areas; radioactive waste handling and packaging areas; and decontamination facilities. Sinks, drains, trash receptacles, and formerly used radioactive waste disposal cells are probable contaminated areas.

D-3. Research Laboratories.

a. Facility Operation Description. Depending on its mission, a research laboratory may be involved in a wide variety of activities, including the analysis of materials activated by neutron radiation, the effects of radiation exposure on animals, and the use of radioactive tracers in chemistry experiments. Various radionuclides may be used in a typical laboratory environment or may be used in closed, shielded cells, or glove boxes to protect personnel from radioactive hazards. A reactor or accelerator may also be used at the facility.

b. Types of Radiation Expected. Depending on the facility mission, a number of different radionuclides may be used, and alpha, beta, X, gamma, or neutron radiation can be expected.

c. Types of Sources Present. Sealed, partially sealed, and unsealed sources can be expected to be used.

d. Radioactive Contamination Potential. There is a high potential for contamination in any area of a laboratory where unsealed sources are used.

e. Radioactive Waste Generated. Moderate to large volumes of solid radioactive waste can be expected. Small to moderate volumes of liquid radioactive waste can also be generated. Research labs characteristically produce larger quantities of mixed or co-mingled wastes compared to radioactive wastes.

f. Potentially Contaminated Areas. Areas of potential contamination include:

- Laboratory areas (bench tops, fume hoods, glassware, centrifuges, scintillation counters, hot cells, glove boxes, and refrigerators used for radioactive material storage)
- Animal cage areas
- Solid radioactive waste-handling and packaging areas
- Liquid radioactive waste system (tanks, pumps, valves, piping)
- Ventilation system (ducting, filters, filter housings)

D-4. Medical Facilities.

a. Facility Operation Description. Medical facilities perform a variety of diagnostic and therapeutic procedures using radioactive materials and radiation-producing machines. For diagnostic procedures, radioactive material may be injected into a patient in liquid form or taken orally. Radiation-producing machines such as X-ray units and computerized tomography scanners may be used. For therapeutic procedures, radioactive material may be injected into a patient in liquid form, taken orally, or implanted in solid form. These implanted sources may remain in the patient or can be removed later. Accelerators and highly radioactive cobalt-60 source capsules are also used for radiation therapy.

b. Types of Radiation Expected. Beta, X, gamma, neutron and charged particle radiation sources could occur.

c. Types of Sources Present. Sealed, partially sealed, and unsealed sources can be expected to be used.

d. Radioactive Contamination Potential. There is a high potential for contamination where unsealed sources are used for diagnosis or therapy. Most unsealed radionuclides used in medicine have short half-lives and, therefore, may not present major decontamination problems for decommissioning. There is a minimum potential for contamination when sources are implanted if the sources are mishandled. There is a slight potential for contamination from sealed sources such as high radioactivity cobalt-60 sources that are used in radiation therapy units. Contamination may occur from activation products created by high-energy accelerators (> 10 million electron volts) used in research-oriented medical facilities.

e. Radioactive Waste Generated. Small to moderate volumes of solid radioactive waste can be expected. Small to moderate volumes of liquid radioactive waste will be generated.

f. Potentially Contaminated Areas. Areas of potential contamination may include the following:

- Radio-pharmacies that are producing, storing, or dispensing radioactive drugs
- Laboratories where liquid sources are prepared for use
- Operating rooms where sources are implanted
- Patients' rooms and examination rooms where patients who have been administered radioactive materials are located
- Nuclear medicine hot labs
- Solid radioactive waste-handling, packaging, and storage areas
- Liquid radioactive waste system (tanks, pumps, valves, piping)
- Areas where liquid radioactive sources are stored prior to preparation for administration

D-5. Pool Reactors and Neutron Radiography Reactors.

a. Facility Operation Description. These reactors are atmospheric-pressure, water-cooled assemblies generally used to produce long-term, steady-state fluxes of thermal neutron radiation. Some reactors can also produce a high flux of thermal neutron radiation for a very short period of time. The neutron radiation is made available for use outside the reactor by beam ports which penetrate the reactor structure. Items to be irradiated are placed in front of the beam ports.

b. Types of Radiation Expected. Primarily gamma and neutron radiation are expected from the reactor. Beta and gamma radiation are expected from the irradiated test items, reactor structures, or impurities in the cooling water.

c. Types of Sources Present. The reactor fuel elements can be considered a sealed source because the uranium fuel and fission products are contained in cladding. Impurities in the cooling water that become activated can be considered an unsealed source. Any radioactive material resulting from neutron activation of test items or reactor structures could be classified as sealed or unsealed sources based upon the types of materials being activated. Sealed and partially sealed sources will be used for instrument checks and calibrations.

d. Radioactive Contamination Potential. The potential for contamination in a pool-reactor facility can be characterized as moderate. The radioactive material in the cooling water, which results from neutron activation of impurities, may be pumped through the cooling system and deposited in pipes, valves, pumps, and other system components. When these components are opened for maintenance or repair, or if leaks occur, contamination is likely. The inventory for the coolant radioactive material will be increased if the fuel cladding leaks or is damaged in some manner, releasing fission products into the cooling water. If neutron activation of test items or the structures surrounding a reactor occurs, the radioactive material will be fixed.

e. Radioactive Waste Generated. Moderate volumes of solid and liquid radioactive wastes will be produced at this type of facility.

f. Potentially Contaminated Areas. Areas and other sources of potential contamination include:

- Area housing the reactor
- Areas housing the reactor auxiliary system
- Test items
- Beam ports and equipment used to handle activated test items
- Maintenance areas
- Solid radioactive waste-handling and packaging areas
- Liquid radioactive waste system (tanks, pumps, valves, piping)
- Ventilation system (ducting, filters, filter housings)
- Decontamination areas

D-6. <u>Power Reactors</u>.

a. Facility Operation Description. The majority of the power reactors in the United States are pressurized water reactors (PWR) or boiling water reactors (BWR). Other types of reactors include gas-cooled, liquid metal, and heavy water. The reactor fuel produces large amounts of heat as a result of the fission process. This heat is used to generate steam directly in a BWR or is carried by the coolant in the primary system to the steam generator in a PWR or other indirect-cycle reactors. The heat is transferred through the walls of the tubes in the steam generator to the water in the secondary side of the steam generator. The temperature is sufficiently high to change the secondary water into steam. In most plants, the steam travels to a turbine that drives an electric generator to produce electrical power.

b. Types of Radiation Expected. Primarily, gamma and neutron radiation are expected from the reactor. Beta and gamma radiation are expected from the irradiated reactor structures or impurities in the coolant. Alpha, beta, and gamma radiation may arise from the spent fuel rods stored at the facility.

c. Types of Sources Present. The fuel rods inside the reactor itself are designed to contain the uranium fuel and fission products within the cladding. The fuel rods are the main source of gamma and neutron radiation in the reactor. However, cladding failure, or the presence of tramp uranium on reactor surfaces, may result in the release of radioactive fission products to the surrounding coolant. Activated impurities and corroded activated metals in the reactor coolant can be considered an unsealed source. Activated materials in the reactor structure can also be the source of gamma and beta radiation.

d. Radioactive Contamination Potential. The potential for contamination in a power reactor facility is greater than that in other facilities primarily because of repair and maintenance activities. The radioactive material in the reactor coolant, which results from neutron activation of corrosion products and fission products from fuel-cladding failures or tramp uranium, is carried through the system and deposited in pipes, valves, pumps, the steam generator, and other components. When these components are opened for maintenance or repair, or if leaks occur, contamination is likely. The radioactive material inventory will be greatly increased if a substantial number of fuel-cladding leaks occur or the fuel is damaged in some manner, releasing fission products into the primary coolant. When neutron activation of the structures surrounding a reactor occurs as the system ages, the radioactive material is fixed but may become removable if the material is dislodged through corrosion and erosion.

e. Radioactive Waste Generated. Great volumes of solid and liquid radioactive waste can be produced at this type of facility.

f. Potentially Contaminated Areas. Areas of potential contamination include:

- Area housing the reactor
- Areas housing reactor auxiliary systems
- Maintenance areas
- Equipment decontamination areas
- Personnel decontamination areas
- Protective clothing laundry area
- Respiratory protective equipment decontamination area
- Solid radioactive waste-handling and packaging area

- Liquid radioactive waste-system (tanks, pumps, valves, piping)
- Ventilation systems (ducting, filters, filter housings)

D-7. Accelerator Facilities.

a. Facility Operation Description.

(1) Particle accelerators are radiation-producing machines used for medical, industrial, and research purposes.

(2) Electron linear accelerators (linacs) are used to produce a primary beam of electron radiation (similar to beta radiation though highly directive and of much greater energy) or a secondary beam of X-radiation (similar to gamma radiation) for use in therapy. The patient is positioned relative to the output beam port of an electron linacs and the machine is energized for the time required to produce the amount of radiation desired for the therapy.

(3) Electron linacs are used in industrial applications to produce a secondary beam of X-radiation. The radiation is used for the radiography of such items as welds, castings, and munitions. Electron linacs are used in research to determine the effects of irradiation on various materials under study.

(4) Other types of particle accelerators are used for engineering physics research.

b. Types of Radiation Expected. Electrons make up the primary beam of electron linacs. If the output energy of electron linacs exceeds about 10 million electron volts, neutrons may be produced. Other types of particle accelerators emit, protons, alpha particles or other nuclear particles, resulting in secondary radiations and activation of materials. The activated material normally decays by beta- (positive or negative) and gamma-radiation emission.

c. Types of Sources Present. Linacs incorporate radioisotopes of various species in their sources and in some of their targets. If the output energy of an electron linac exceeds about 10 million electron volts, neutron radiation may be produced. This neutron radiation and output from other types of particle accelerators may activate areas of the device around the output beam port and the structure surrounding the device. If this occurs in solid objects, the radioactive material is considered a sealed source; activated liquids or gases will usually be in unsealed form and more mobile.

d. Radioactive Contamination Potential. There are several different types of particle accelerators. Each type and its specific operation must be reviewed to determine the potential contamination.

e. Radioactive Waste Generated. No liquid or solid radioactive waste is expected unless the electron linac exceeds 10 million electron volts, in which case small volumes of solid, liquid, or gaseous waste resulting from neutron activation may be produced. Small volumes of radioactive waste may be generated by other types of particle accelerators.

f. Potentially Contaminated Areas. If the output energy of electron linacs is less than 10 million electron volts, none of the surrounding structure will be contaminated. Energies greater than 10 million electron volts from electron linacs or other particle accelerators may activate components, targets, and surrounding structures, which may result in contamination from loose or disturbed material, during maintenance of the devices, and during decommissioning of the devices.

D-8. Radiographic Facilities.

a. Radiographic Facilities using Electromagnetic Radiation. The primary purpose of radiographic facilities is to nondestructively test items for defects. For example, welds are radiographed to reveal any hidden porosity or cracks, castings are radiographed to reveal any hidden voids, and munitions are radiographed to check for proper assembly. Electromagnetic radiation penetrates a test item and exposes a sheet of film or array of detectors in the same manner that light exposes film or video systems to produce an image. Radiographic films are processed and checked for defects in the item radiographed. The electromagnetic radiation needed for radiography may be produced by a sealed source of radioactive material such as cobalt-60 or iridium-192, or by X-ray machines or election linacs. Sealed radioactive sources must be housed in shielded containers when not in use. The containers may be fixed or portable. X-ray machines require no shielding when not in use because radiation is produced only when a machine is electrically energized. Shielding is required when a machine is energized. X-ray machines may be installed in a fixed configuration or may be portable.

(1) Types of Radiation Expected. Gamma radiation is expected from sealed radioactive sources. Linacs may be used to generate the radiographic beam and their characteristic radiation and waste potential should be expected.

(2) Types of Sources Present. When radioactive material is used, the sources will be sealed.

(3) Radioactive Contamination Potential. There is no potential for contamination from an X-ray machine or from a sealed source unless the source is damaged in a manner that breaches the integrity of the material used to encapsulate the radioactive material, or unless the sealed source leaks for any other reason.

(4) Radioactive Waste Generated. None is expected from most radiographic systems. However, if linacs are used to generate the radiographic beam, the sources and targets are probable waste sources.

(5) Potentially Contaminated Areas. There are none, except in the case of linac-generation radiographic systems.

b. Radiographic Facilities using Neutron Radiography. Neutron radiography is used to detect moisture and corrosion in bonded honeycombed structures and to test other materials. The secondary radiations created by the neutrons reacting with the material are detected and displayed on monitors that have the capability of digital and imaging enhancement. Most frequently, sources such as radium, americium, or plutonium can be used as sources of alpha radiation impinging on beryllium. The beryllium is activated by alpha radiation to emit neutrons. The radiography occurs in a shielded and interlocked bay, which is accessible only when the source is withdrawn into a shield.

(1) Types of Radiation Expected. Neutrons from the source are to be expected. Due to neutron activation, alpha, beta, neutron, and gamma radiation may result from irradiated test items and structural materials.

(2) Types of Sources Present. The source is typically sealed hermetically. Source encapsulation may fail, causing the direct release of alpha and neutron radiation. Any radioactive material resulting from activation of test items or structural material can be classified as sealed or unsealed, based on the types of material being activated.

(3) Radioactive Contamination Potential. The potential for contamination is low for properly used and maintained sources. Abandoned or lost source capsules present a serious hazard. It must be noted that the beryllium used to produce the secondary neutron radiation is a very toxic heavy metal. Neutron activation of test items or the structure surrounding the source of neutrons could result in contamination if the material were dislodged and became loose and spreadable.

(4) Radioactive Waste Generated. Very little waste will be generated that is radioactive so long as proper operational, maintenance, and storage practices are followed. Decommissioning of radiographic equipment will generate the largest portion of LLRW of the entire use cycle. The potential for uncontrolled radioactive waste is greater in the event of equipment abandonment, fire, or other catastrophic event.

(5) Potentially Contaminated Areas. Areas of potential low-level contamination are restricted to the radiography bay and test-material-handling areas.

D-9. Radioluminous-device Storage Facilities.

a. Facility Operation Description. These facilities store new and used radioluminous devices such as clocks, instruments, gunsights, night-vision testers, exit signs, and radioluminescent airfield lighting systems.

b. Types of Radiation Expected. Radioluminescent devices use radioactive sources to energize phosphorescent elements or chemicals. The radioactive materials primarily used to generate luminosity are tritium, promethium-147, krypton-85, and radium-226. Tritium and promethium-147 emit beta radiation only, krypton-85 emits beta and gamma radiation, and radium-226 emits alpha and gamma radiation. Decay products of radium-226, which are radioactive, will also emit beta radiation. Radon-222 is a gaseous decay product and poses the risk of inhalation.

c. Types of Sources Present. Radioluminous devices may consist of instrument faces with the radiation source painted on or may incorporate vials or capsules of radioluminous materials. Because the devices frequently rely on tritium or radium as primary radiation sources, they have great potential to be effectively unsealed. This is because tritium may be a gaseous radioisotope, and because one of the daughters of the decay of radium is radon, which is a gaseous radioisotope. Guaranteed seals, even of encapsulated radioluminous materials, are difficult to achieve and should not be expected.

d. Radioactive Contamination Potential. Radioluminous paint is a probable surface and water contaminant when scraped or dissolved off its substrate. The most serious and difficult contamination arising from radioluminous devices is from radium-doped paint.

e. Radioactive Waste Generated. Damaged equipment components that are painted with radioluminous materials may be radioactive waste. Maintenance of radioluminous systems will generate contaminated cleanup materials. Radioluminous materials characteristically produce gaseous radioactive contaminants. Tritium and radon are readily soluble in water, are easily spread, and can contaminate biological organisms, soil, and ground water. The great mobility of radioluminescent-generated waste makes it difficult to clean up. Fortunately, the low energy levels and the small volumes of the original sources commonly encountered will lessen the environmental impact.

f. Potentially Contaminated Areas. There are none, provided the device containing the radioactive material remains intact. Devices with tritium or radium-226 should be treated as suspect to having leakage because of the gaseous radioisotopes involved.

D-10. Depleted Uranium Usage and Storage Facilities.

a. Facility Operation Description. Depleted uranium is used to manufacture various types of munitions. These munitions are stored in various facilities and are used in test and practice firings as well as actual warfare. Depleted uranium has been used as armor in some military vehicles and as counterweights in aircraft. Depleted uranium is also used for shielding radiography and teletherapy sources.

b. Types of Radiation Expected. Alpha, beta, gamma and neutron radiation can all be expected. Additionally, the radioactive decay of the Uranium will produce a sequence of daughter radioisotopes, each of which generates its own characteristic suite of ionizing radiation. Uranium is also a kidney toxin and in some cases the chemical toxicity may be more of a hazard than the radiation exposure. Controls should be based on the more limiting of the chemical or radiological exposures.

c. Types of Sources Present. The depleted uranium in the stored munitions is encased in aluminum or painted, so this source is considered sealed if the case or paint is intact. After the munitions are fired, the sources would be unsealed because the depleted uranium shatters and is dispersed. Depleted uranium used for shields is usually encased in steel and is considered a sealed source.

d. Radioactive Contamination Potential. Airborne dust, machine shavings, cutting lubricants, etc., will arise from the fabrication of components from depleted uranium. Waste disposal areas, water drains, and ventilation ducts will be contaminated by the depleted uranium. Once assembled, there is no potential while the munitions are in storage. After the munitions are fired, there will be contamination of target areas and target materials.

e. Radioactive Waste Generated. There is little from storage except for radon-222 (inhalable alpha radiation source) produced as a decay daughter. Large fragments of the depleted uranium dispersed after firing and the contaminated targets may be collected and disposed of as waste. Small fragments and uranium oxide dust are not collected and are generally dispersed around the target site. The volumes and dispersal of this contamination are substantial.

f. Potentially Contaminated Areas. Firing ranges and targets are areas of contamination.

D-11. Maintenance Shops Repairing Components Containing Magnesium-Thorium Alloys and Depleted Uranium.

a. Facility Operation Description. Machine shops at Air Force Logistics Command Bases repair aircraft parts consisting of depleted uranium and magnesium-thorium alloys by machining, cutting, drilling, welding, and grinding.

b. Types of Radiation Expected. Alpha, beta, gamma, and X-ray from thorium-232 and uranium-238, and radionuclides resulting from their decay are expected. Uranium is also a kidney toxin and in some cases the chemical toxicity may be more of a hazard than the radiation exposure. Controls should be based on the more limiting of the chemical or radiological exposures.

c. Types of Sources Present. Depleted uranium as aircraft counterweights and aircraft components manufactured from magnesium-thorium alloys are considered sealed sources except during repair operations which remove metal.

d. Radioactive Contamination Potential. There is no potential while the parts are in service or storage. Contamination results from machining, cutting, drilling, welding, and grinding operations.

e. Radioactive Waste Generated. Grindings, filings, grinding oils, and broken parts are disposed of as radioactive waste. During grinding of magnesium-thorium alloys, water is used to prevent fires. This water is collected in the hood sump and the water is filtered prior to release to the environment. Both liquid filters and high-efficiency particulate air filters for the hoods are disposed of as radioactive waste. The waste volume generated is not large enough to require a specific on-site storage facility.

f. Potentially Contaminated Area. This is limited to the hoods, exhaust ductwork, and immediate area in which repair operations are conducted.

GLOSSARY

Terms, Abbreviations, and Acronyms

µ	micro-
AFSC	Army Field Support Command
ALARA	As Low As is Reasonably Achievable
ARAR	Applicable, Relevant and Appropriate Regulations
Bq	becquerel
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CHP	Certified Health Physicist
Ci	curie
cpm	counts per minute
Cs	cesium
CX	Center of Expertise
CY	cubic yard
DA	Department of the Army
D&D	Decontamination and Decommissioning
DCGL	Derived Concentration Guideline
DERP	Defense Environmental Restoration Program
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
dpm	disintegrations (decays) per minute
DQO	Data Quality Objective
EC	Engineering Circular
EM	Engineer Manual
EPA	Environmental Protection Agency
EM	Engineering Manual
ER	Engineering Regulation
FUSRAP	Formerly Used Sites Remedial Action Program
FSS	Final Status Survey
G	giga-
g	gram
Gy	gray
HLW	High-Level Radioactive Waste
HP	Health Physic(s)(ist)
HPGe	High Purity Germanium
HQ	Headquarters
hr	hour

HSWA	Hazardous and Solid Waste Amendments
HTRW	Hazardous, Toxic and Radioactive Waste
k	kilo-
keV	kilo-electron volts
L	liter
LLRW	Low-Level Radioactive Waste
LUC	Land Use Control
μR	microroentgen
^{m}X	metastable
M	mega-
m	meter or milli-
MARSSIM	Multi-Agency Radiation Site Survey and Investigation Manual
MDC	Minimum Detectable Concentration
mR	milliroentgen
mrem	millirem
MSC	Major Subordinate Commands
n	nano-
NaI	sodium iodide
NORM	Naturally Occurring Radioactive Materials
NRC	Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Administration
PA/SI	Preliminary Assessment/Site Investigation
p	pico-
pCi	picocurie
PM	Project Manager
POC	Point of Contact
ppm	parts per million
PRG	Preliminary Remediation Guideline
QA	Quality Assurance
QC	Quality Control
R	roentgen
Ra	radium
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SHP	Safety and Health Program
SI	Systeme Internationale
Sr	strontium
SSL	Soil Screening Level
Sv	sievert
SWMU	Solid Waste Management Unit
T	tera-

TEDE	Total Effective Dose Equivalent
Th	Thorium
TPP	Technical Project Planning
TRU	Transuranic Waste
TSDF	Treatment, Storage or Disposal Facility
U	uranium
US	United States
USACE	US Army Corps of Engineers