Y-12

**OAK RIDGE
Y-12
PLANT**

MARTIN MARIETTA

Y-12 Plant Remedial Action Technology Logic Diagram

**Volume 1
Technology Evaluation**

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Prepared for the Office of
Environmental Restoration

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Prepared by
Oak Ridge K-25 Site
Oak Ridge, Tennessee 37831
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

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MARTIN MARIETTA ENERGY SYSTEMS, INC.
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Environmental Restoration Program

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ACRONYMS

ACL	Alternate concentration limit
AEA	Atomic Energy Act
ALARA	as low as reasonably achievable
ANPRM	advance notice of proposed rulemaking
APEG	ammonium polyethylene glycolate
ARAR	applicable, relevant, and appropriate requirements
BAT	best available technology
BCBG	Bear Creek Burial Ground
BDAT	Best Demonstrated Available Technology
BMP	best management practice
BRC	below-regulatory-concern
CAA	Clean Air Act of 1970
CEP	catalytic extraction process
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CNF	Central Neutralization Facility
COE	U. S. Army Corps of Engineers
CRADA	cooperative research and development agreement
CSF	carcinogen slope factor
CWA	Clean Water Act
D&D	decontamination and decommissioning
DCG	derived concentration guide
DES	Division of Ecological Services
DF	Decontamination factor
DNAPL	Dense nonaqueous phase liquid
DOE	Department of Energy
DOE-OR	DOE Oak Ridge Field Office
DOI	Department of the Interior
DOT	Department of Transportation
EBASCO	EBASCO Services
EIS	Environmental Impact Statement
EM	Environmental Management
Energy Systems	Martin Marietta Energy Systems, Inc.
EO	Executive Order
EPA	Environmental Protection Agency
ER	Environmental Restoration
ERWM	Environmental Restoration and Waste Management
ES&H	environmental, safety, and health
ESA	Endangered Species Act of 1973
FFA	Federal Facility Agreement
FFCA	Federal Facility Compliance Agreement
FFCA of 1992	Federal Facility Compliance Act of 1992
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act of 1947
FS	Feasibility Study
FWCA	Fish and Wildlife Coordination Act of 1958

GDP	gaseous diffusion plant
GIS	Geographic Information Systems
HA	Health Advisory
HAZWRAP	Hazardous Waste Remedial Actions Program
HMTA	Hazardous Materials Transportation Act of 1975
HQ	DOE Headquarters
HSWA	Hazardous and Solid Waste Amendments of 1984
IAEA	International Atomic Energy Agency
IAG	Inter-Agency Agreement
ICM	Interim Corrective Measure
IRIS	Integrated Risk Information System
KPEG	potassium polyethylene glycolate
LDR-FFCA/ORR	Federal Facilities Compliance Agreement for mixed waste subject to land disposal restriction for the Oak Ridge Reservation
LDR	Land Disposal Restrictions
LLW	low-level waste
M&O	management and operating
MCLG	maximum contaminant level goal
MCL	maximum contaminant level
NAAQS	National Ambient Air Quality Standards
NARM	naturally occurring and accelerator-produced radioactive material
NA	Natural Area
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NDE	nondestructive evaluation
NEPA	National Environmental Policy Act
NERP	DOE National Environmental Research Park
NESHAP	National Emission Standards for Hazardous Air Pollutants
NPDES	National Pollutant Discharge Elimination System
NPDWS	National Primary Drinking Water Standards
NPL	National Priorities List
NPRM	Notice of Proposed Rulemaking
NRC	Nuclear Regulatory Commission
NSDWS	National Secondary Drinking Water Standards
NSPS	New Source Performance Standards
ODW	Office of Drinking Water
OECD/NEA	Organization for Economic Cooperation and Development/Nuclear Energy Agency
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OSHA	Occupational Safety and Health Act
OSWER	Office of Solid Waste and Emergency Response
OTD	Office of Technology Development
OU	Operable Unit
PA	Preliminary Assessment
PCB	polychlorinated biphenyl

PEG	Program Execution Guidance
PEL	Permissible Exposure Limit
POTW	Publicly owned treatment works
PRDA	Program Research and Development Announcement
QA	quality assurance
RA	Remedial Action
RAD	radioactive contamination
RA	Reference Area
RCRA	Resource Conservation and Recovery Act
RFC	reference concentration
RFD	reference dose
RFI	RCRA Facility Investigation
RI	Remedial Investigation
RSA	Research Area
S/T	Science and Technology
SARA	Superfund Amendments and Reauthorization Act
SCS	Site Characterization Summary
SDMP	Site Decommissioning Management Plan
SDWA	Safe Drinking Water Act of 1974
SEG	Scientific Ecology Group, Inc.
SEN	Secretary of Energy Notice
SI	Site Inspection
SMCL	secondary maximum contaminant level
SNA	State Natural Area
SNM	Special Nuclear Material
SRS	Savannah River Site
SWDA	Solid Waste Disposal Act
SWMU	solid waste management units
TCA	Tennessee Code Annotated
TCE	trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TD	Technology Development
TDEC	Tennessee Department of Environment and Conservation
TEDS	Technology Evaluation Data Sheet
TLD	Technology Logic Diagram
TOA	Tennessee/DOE Monitoring and Oversight Agreement
TRU	transuranic
TSCA	Toxic Substance Control Act
TSCA-FFCA	PCB Federal Facilities Compliance Agreement Between the U.S. DOE and the EPA, Washington, D.C. for the Uranium Enrichment Facilities
TSD	treatment, storage, and disposal
TSP	Total suspended particulates
TS	Treatability Study
UCC	Union Carbide Corporation
UHPW	ultra-high pressure water
UIC	Underground injection control
USC	United States Code
USDW	underground sources of drinking water

UST	Underground storage tank
VOC	Volatile organic compound
WM	Waste Management
WMTLD	Waste Management Technology Logic Diagram
WPH&T	Waste Packaging, Handling, and Transportation
WQC	water quality criteria

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FOREWORD

The Y-12 Plant Remedial Action Technology Logic Diagram (TLD) was developed to provide a decision-support tool that relates environmental restoration (ER) problems at the Y-12 Plant to potential technologies that can remediate these problems. The TLD uses information from the *Strategic Roadmap for the Oak Ridge Reservation*, *Oak Ridge K-25 Site Technology Logic Diagram*, *Oak Ridge National Laboratory Technology Logic Diagram*, and a previous Hanford TLD.

The TLD identifies the research, development, demonstration, testing, and evaluation needed for sufficient development of these technologies to allow for technology transfer and application to remedial action (RA) activities. It is essential that follow-on engineering studies be conducted to build on the output of this project. These studies will begin by selecting the most promising technologies identified in the TLD and finding an optimum mix of technologies that will provide a socially acceptable balance between cost and risk.

The TLD consists of three fundamentally separate volumes: Vol. 1 (*Technology Evaluation*), Vol. 2 (*Technology Logic Diagram*), and Vol. 3 (*Technology Evaluation Data Sheets*). Volume 1 contains an overview of the TLD, an explanation of the program-specific responsibilities, a review of identified technologies, and the rankings of remedial technologies. Volume 2 contains the logic linkages among environmental management goals, environmental problems, and the various technologies that have the potential to solve these problems. Volume 3 contains the TLD data sheets.

Volume 1 has been divided into six chapters. The first chapter is an introduction, which defines problems specific to the ER Program for the Y-12 Plant. Chapter 2 provides a general overview of the TLD. Chapters 3 through 5 are organized into necessary subelement categories: characterization, RA, and robotics and automation. The final chapter contains regulatory compliance information concerning RA.

The technology evaluations contained in these volumes are based on the best information available during compilation of the TLD. New or more accurate information is solicited to improve the TLD data base. Please send comments to R. L. Fellows, Editor, *Y-12 Plant Remedial Action Technology Logic Diagram*, Martin Marietta Energy Systems, Inc., P.O. Box 2003, Oak Ridge, TN 37831-7274. FAX (615-576-8558).

EXECUTIVE SUMMARY

The Y-12 Plant Remedial Action Program addresses remediation of the contaminated groundwater, surface water and soil in the following areas located on the Oak Ridge Reservation: Chestnut Ridge, Bear Creek Valley, the Upper and Lower East Fork Poplar Creek Watersheds, CAPCA 1, which includes several areas in which remediation has been completed, and CAPCA 2, which includes dense nonaqueous phase liquid wells and a storage facility. There are many facilities within these areas that are contaminated by uranium, mercury, organics, and other materials.

This Technology Logic Diagram identifies possible remediation technologies that can be applied to the soil, water, and contaminants for characterization, treatment, and waste management purposes. In addition, regulatory impacts on the remediation have been identified for each area. The characterization, treatment, and waste management technology options are supplemented by identification of possible robotics or automation technologies. These would facilitate the cleanup effort by improving safety, of remediation, improving the final remediation product, or decreasing the remediation cost.

The Technology Logic Diagram was prepared by a diverse group of more than 35 scientists and engineers from across the Oak Ridge Reservation. Most are specialists in the areas of their contributions.

1. Introduction

1. INTRODUCTION

1.1 Y-12 Plant

The Y-12 Plant is located on the eastern portion of the Department of Energy's (DOE's) Oak Ridge Reservation (ORR) and is a production facility for nuclear weapon components. The plant occupied approximately 800 acres of land between Pine Ridge, to the north, and Chestnut Ridge, to the south. The Y-12 Plant was built by the Army Corps of Engineers in 1943 as part of the Manhattan Project. The original mission of the plant was to separate the fissionable isotope of uranium (^{235}U) using an electromagnetic separation process. After World War II, the process was replaced by the more economical gaseous diffusion process conducted at the K-25 Site (then known as the Oak Ridge Gaseous Diffusion Plant).

It is Y-12's mission to serve as a key manufacturing technology center for the development and demonstration of unique materials, components, and services of importance to the Department of Energy (DOE) and the nation.

This is accomplished through the reclamation and storage of nuclear materials, manufacture of nuclear materials, manufacture of components for the nation's defense capabilities, support to national security programs, and services provided to other customers as approved by DOE.

We are recognized by our people, the community, and our customers as innovative, responsive, and responsible. We are a leader in worker health and safety, environmental protection, and stewardship of our national resources.

1.2 Y-12 Environmental Restoration Program

The primary goals of the ORR Environmental Restoration Program are to reduce the risks to public health and the environment resulting from inactive disposal sites, and to achieve regulatory compliance. To this end, ER projects assess and clean up DOE sites and facilities that are no longer active. Waste of various types has accumulated at the Y-12 Plant from defense operations spanning nearly five decades. ER activities are divided into four areas:

1. Assessment of the nature and extent of environmental contamination;
2. Remedial Action (RA) to clean up inactive waste sites that have the potential for releasing contamination;
3. Decontamination and decommissioning (D&D) to clean up surplus facilities; and
4. Research, development, and demonstration to apply to new technologies to enhance restoration activities.

It is ORR policy to comply with both the letter and spirit of all applicable federal, state, and local regulations and with DOE policies governing environmental protection. Historical practices at many DOE sites, including the Y-12 Plant, although consistent with the standards of their time, did not fully recognize the potential hazards of certain materials. Many of these past practices are considered inadequate by modern standards. ER activities are conducted to ensure that all inactive ORR facilities meet current requirements for environmental cleanup and waste management (WM).

The fundamental goal of ER is to ensure that contaminants at inactive or surplus facilities and sites are either eliminated or reduced to prescribed, safe levels. Risks from these restored sites should be low and not endanger human health and safety or the environment. This goal is achieved for Remedial Actions by meeting the following strategic objectives:

1. Identify inactive, contaminated facilities and sites at ORR installations;
2. Assess these facilities and sites to determine the nature and extent of contamination;
3. Confine and contain existing contamination to the extent necessary to minimize further spread;
4. Coordinate with regulatory authorities for negotiated agreements that specify the requirements and schedule for cleaning up the identified facilities and sites;
5. Ensure that cleanup strictly complies with these agreements; and
6. Provide long-term monitoring to ensure continuing compliance.

The DOE has established four priority levels for ER, reflecting discrete goals:

1. To limit immediate or short-term health risk and contamination;
2. To comply with in-place or pending agreements;
3. To reduce out-year risk, promote out-year compliance, address public concern, and protect DOE missions; and
4. To accelerate overall compliance.

1.3 Y-12 Legacy of Contamination

1.3.1 Operable Unit Strategy

The Oak Ridge Reservation (ORR) consists of approximately 58,000 acres of federally owned land in Oak Ridge. Under its Resource Conservation and Recovery Act (RCRA) Hazardous and Solid Waste Amendments (HSWA) permit, DOE has begun the RCRA Facility Investigation (RFI) process at more than 5000 Solid Waste Management Units (SWMUs) at ORR. Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (the present strategy), operable units (OUs) are defined as waste area groupings (WAGs) for which an remedial investigation/feasibility study (RI/FS) will be performed. The OUs are grouped according to their proximity as well as by common physical and hydrological parameters.

Because the hydrologic regime of ORR is complex and because numerous sources contribute groundwater contamination within a geographical area, more timely investigations can be achieved by separating the sources of contamination from the groundwater and surface water for investigation and remediation. To permit effective evaluation of the cumulative impact of releases from multiple sources of contamination, ORR has adopted an approach that separates studies of the groundwater and surface water from studies of the sources. This was done by assigning WAGs as source OUs and the hydrogeologic regimes that are common to more than one source OU as integrator OUs. This approach will result in more immediate attention for source OUs, while investigation continues into remediation alternatives for the integrator OUs.

Groundwater at the Y-12 Plant has been divided into three distinct hydrologic regimes: Upper East Fork Poplar Creek, Chestnut Ridge, and Bear Creek Valley. This division is based on topography, surface water drainage, and groundwater flow patterns. It provides a basis for unifying monitoring efforts at the Y-12 Plant and for tailoring monitoring efforts to the hydrogeologic characterization of each regime. Operable units within these regimes are identified as integrator OUs or source OUs.

The sites which make up the OUs within the three on-site regimes, as well as the Lower East Fork Poplar Creek Integrator OU and the sites addressed by Closure and Postclosure Activity (CAPCA) Phases I and II will be addressed in this document.

1.3.2 Operable Units

The following explanation of the OUs is provided to show the organization of RAs at the Y-12 Plant. Throughout the remainder of the document, problems will be addressed at the site level rather than the OU level.

1.3.2.1 Upper East Fork Poplar Creek

The integrator unit for the Y-12 Plant is Upper East Fork Poplar Creek (UEFPC) OU 1. The boundaries of this unit are from the base of Chestnut Ridge to the base of Pine Ridge, and from the surface-water divide near the S-3 Site to the Weir at Lake Reality. Two source term OUs have been defined within UEFPC. UEFPC OU 2 includes the Abandoned Nitric Acid Pipeline, and UEFPC OU 3 includes the S-2 Site, Building 81-10, Tank Site 2063-U, Salvage Yard drum deheader, Salvage Yard waste oil storage tanks, Salvage Yard Oil/Solvent Drum Storage Area, and the Salvage Yard Scrap Metal Storage Area.

UEFPC OU 1—Surface Water and Groundwater Integrator Operable Unit

UEFPC OU 1 consists of both surface water and groundwater components of the hydrogeologic system within the UEFPC hydrologic regime. This OU is concerned with surface water, including minor amounts of sediment in the UEFPC channel, and with groundwater pathways that have a potential to transport contaminants to off-site receptors.

Numerous sources of contamination to both the surface water and groundwater flow systems exist within the plant area. The S-3 Ponds Waste Management Area dominates groundwater contamination in the western portion of the hydrologic regime. In addition to potential surface water and groundwater contamination sources identified in UEFPC OU 1, OU 2, and OU 3, the majority of the potentially contaminated units making up the Y-12 Study Area are within the UEFPC hydrologic regime. Potential surface water contamination associated with the storm sewer system and mercury use area is of primary interest and will be addressed in this OU.

The storm sewer system consists of an extensive array of storm drains that gather runoff from the main plant catch basins located throughout the plant. In addition, this drainage system, which was once connected to process equipment, discharged untreated waste streams. The storm sewer network contains several miles of drainage pipes and culverts that range up to 108 inches in diameter. UEFPC begins near the middle of the Y-12 Plant and is fed predominantly from storm sewer system discharges. Surface water runoff from the Y-12 production areas and groundwater seepage are additional sources of UEFPC flow.

From 1955 through 1963, a column-exchange process involving large quantities of mercury was employed to separate lithium isotopes. The mercury use areas include buildings and other facilities that have been designated as possible sources of mercury contamination because of known, suspected, or presumed releases. The area of investigation includes drainages associated with the following buildings and adjoining areas: 9201-2, 9201-5, 9204-4, 9202, 9733-2, and with mercury flask storage areas and deflasking facilities. Additional mercury use areas are addressed in this section, "Reduction of Mercury in Plant Effluents."

UEFPC OU 2—Nitric Acid Pipeline Source Control Operable Unit

UEFPC OU 2 is the Abandoned Nitric Acid Pipeline, which was used between 1951 and 1983 to transport a waste stream that consisted primarily of nitric acid and depleted uranium from the Building 9215 complex to the S-3 Ponds for disposal. The pipeline was constructed of 2.0- to 3.0-inch diameter stainless steel pipe and was buried an average of 5 feet below the ground surface. One leak was identified and repaired in 1951 at a weld about 350 feet east of the discharge point and other leaks are suspected.

The primary exposure pathways associated with the Nitric Acid Pipeline are soil contamination resulting from adsorption from leaked solution, groundwater contamination resulting from the waste solution infiltrating to the groundwater table, and surface water contamination resulting from groundwater seeps. Nitrate and uranium are the primary contaminants of concern.

UEFPC OU 3—Western Exclusion Area Source Control Operable Unit

UEFPC OU 3 consists of the S-2 Site; the soil underneath and around Building 81-10, Tank Site 2063-U, Salvage Yard drum deheader, Salvage Yard waste oil storage tanks,

Salvage Yard Oil/Solvent Drum Storage Area, and the Salvage Yard Scrap Metal Storage Area.

S-2 Site. The S-2 Site is located in the southeastern area of the plant, south of Building 9720-32. The site was used from about 1943 to 1951 to dispose of corrosive and toxic liquid wastes generated from the Y-12 operations. The site originally consisted of a 45- by 128-foot unlined earthen reservoir that was approximately 20 feet deep. The reservoir was filled and stabilized when disposal operations ended.

Salvage Yard. The Salvage Yard has been operating at the northwestern portion of the Y-12 Plant since 1950, when it was used solely for storage of uranium-contaminated and noncontaminated scrap metal. The total area of the Salvage Yard is approximately 2.2 acres, of which about 75% is covered with scrap metal and other salvage material. Waste oils containing PCBs were stored between 1980 and 1987 in two storage tanks located in the northern portion of the yard. The Salvage Yard Oil/Solvent Drum Storage Area was used to store waste oils contaminated with uranium and/or beryllium and chlorinated organic solvents. The Salvage Yard Oil/Solvent Drum Storage Area had a capacity of about 3200, 55-gallon drums and was in operation from 1976 until its RCRA closure in 1988. The Salvage Yard Drum Deheader is also located in the northern portion of the Salvage Yard and has been in use since 1959. Soil contamination resulting from uranium-contaminated salvage materials and solvents associated with the drum handling/storage operations, is of primary concern.

Building 81-10. Building 81-10 was used from 1957 to 1982 for mercury recovery operations employing physical separation or distillation in a furnace. Mercury releases associated with handling during physical separation and from operation of the furnace have been documented. Initial assessments of the site indicate mercury contamination of soil surrounding the building and storage pad.

Reduction of Mercury in Plant Effluents

Between 1950 and 1963, elemental (metallic) mercury was used at the Y-12 Plant in large quantities for lithium separation processes. These processes eventually led to widespread mercury contamination at the Y-12 Plant. An engineering project was initiated in 1986, Reduction of Mercury in Plant Effluents (RMPE), in an effort to control releases of mercury from the Y-12 Plant and provide treatment capabilities for mercury-contaminated water. The initial stages of the project entailed storm sewer inspection, cleaning, and relining using the insituform process, and the rerouting of certain pipe flows. Also part of the project is tank cleanout, described below, and the construction of a new on-line effluent treatment facility which will be constructed primarily to remove mercury from the Y-12 Plant storm sewer.

Pipe Reroute. Effluent discharging into mercury-contaminated storm drains and sumps in the basement of Building 9201-2 was bypassed to connect with an existing non-contaminated building drain. Mercury-contaminated storm drains and sumps in the basement of Building 9201-5 will be bypassed by a new ductile iron pipe to reroute nonmercury-contaminated water to existing storm drains located outside the building.

Tank Cleanout. Three underground storage tanks used for sedimentation of mercury contaminated water flowing from basement sumps have been identified as sources of mercury contamination in the upper reach of UEFPC. Tanks 2101-U and 2104-U, located southeast of Building 9201-4 and 9201-5, respectively, are divided into two open-topped compartments where sedimentation takes place. Tank 2100-U, located southwest of Building 9201-4, is divided into 4 open-topped sedimentation compartments.

RCRA Closures

This subproject consists of the Interim Drum Yard, the Building 9409-5 Tank Storage Area, and the Garage Underground Storage Tanks.

YS-030 Interim Drum Yard. The Interim Drum Yard west of Building 9720-32 is a RCRA outdoor storage facility for containerized hazardous waste. Drums were stored on wooden pallets and then placed on a gravel storage pad with no liner or containment system. Wastes stored at the facility consisted of mercury, metals, acetonitrile (ACN), methylene chloride, organics, Freon-113, cyanide, PCBs, uranyl nitrate, penetrant solution, and emulsifiers, asbestos, and sodium hypochlorite. All wastes previously stored in the yard have been removed, and a small area on the south side was previously closed.

YS-017 Building 9409-5 Diked Tank Storage Area. The Building 9409-5 Diked Tank Storage Area is a RCRA outdoor, concrete diked area having a capacity of approximately 238,000 gallons. This facility was constructed in 1942 as a four cell cooling tower basin but was modified in 1980 for use as a secondary containment facility for tanks and drums of liquid waste. These tanks and drums have contained, at various times, liquid waste coolant, solvents, and waste oils, all of which may have contained PCBs. Some of the waste liquids stored in this facility were known to have contained uranium and beryllium. Chromium may be present as a result of the water treatments used during cooling tower operations. All tanks and drums have been removed from this facility.

YS-019 Garage Underground Tanks. The Garage Underground Tank facility was originally constructed in 1945 as part of a vehicle fueling station. The initial construction consisted of two 10,000-gallon tanks for the storage of leaded gasoline and diesel fuel. These tanks were installed on a concrete slab below grade, inside an earthen dike with space for one additional tank. The third tank, a 20,000 gallon unit, was installed in 1974 for storage of unleaded gasoline. The use of this facility for the storage of fuel was discontinued in 1977.

Between 1980 and the removal of all liquid waste during initial closure in 1988, the 20,000-gallon west tank and the 10,000-gallon middle tank were used to store waste oils containing spent solvents (perchloroethylene and Freon-113), PCBs, and uranium. Laboratory analysis of these two tanks also indicates the presence of silver, chromium, and cadmium in excess of EP Toxicity guidelines. The easternmost 10,000-gallon tank was used for the storage of waste oil only.

Initial closure included removal of crushed stone fill around the tanks, removal of associated piping, relocation of tanks to temporary containment structures, and storage of approximately 10 ft³ of waste oil-contaminated soil in a shallow, plastic-lined trench on-site. The original excavation was filled and capped.

Rust Fuel Facility

The Rust Fuel Facility is located in the western end of the plant and originally consisted of three steel underground tanks in a single bay north of Building 9831 and a smaller tank south of Building 9720-15. The three tanks were a 12,000-gallon diesel tank, a 12,000-gallon gasoline tank, and an 8,000-gallon gasoline tank. The smaller tank contained 1000 gallons of gasoline. The leakage of these tanks and connecting pipeline is well documented. The tanks, piping, and all free liquid gasoline have been removed and disposed.

Study Areas

The Study Areas of UEFPC consist of approximately 180 individual sites within the Y-12 Plant that have been identified as potentially containing or having contained one or more hazardous substances or materials. Most of these sites lie in the western exclusion area. These sites will not be considered individually for the purposes of the Technology Logic Diagram.

1.3.2.2 Bear Creek Valley

Bear Creek Valley (BCV) is divided into 3 source OUs and one integrator OU. BCV OU 1 includes the Bear Creek Burial Grounds and WM Areas. BCV OU 2 includes the Rust Spoil Area, Spoil Area 1, and the SY-200 Yard. BCV OU 3, floodplain sediments for Bear Creek, has been incorporated into BCV OU 4, the integrator OU for Bear Creek groundwater and surface flow regime.

OU 1—Bear Creek Burial Grounds and Waste Management Areas

Bear Creek OU 1 comprised the following units: S-3 Waste Management Area; Oil Landfarm Waste Management Area including the Boneyard/Burnyard, Oil Landfarm, and Sanitary Landfill; and Bear Creek Burial Grounds, including Oil Retention Ponds 1 and 2. These units were used until the 1980s as the primary area for the disposal of various types of hazardous and nonhazardous wastes generated at the Y-12 Plant.

S-3 Waste Management Area. The S-3 Ponds, located near the west end of the Y-12 Plant main complex at the topographic divide separating the headwaters of Bear Creek to the west and the headwaters of UEFPC to the east, were constructed in 1951. Operated from 1951 to 1976, the ponds consisted of four unlined surface impoundments covering an area of roughly 400 feet on each side with a total storage capacity of about 10 million gallons. They received large quantities of liquid wastes from the Y-12 Plant (up to 5500 gallons per day), including nitrate salts, nitric acid solutions, and cleaning solutions that contained various organic solvents. Solutions containing radionuclides (uranium, technetium, and plutonium) were also disposed of in the ponds. Water treatment in the ponds began in 1983, and discharge of treated water was completed in May 1986.

In June 1989, the S-3 Ponds were closed in-place as a landfill under RCRA. The closure program began by treating residual water collected in the ponds. Contaminated stream sediments in the vicinity were excavated and deposited in the ponds, and bottom sludges and sediments were stabilized with riprap to provide a firm base for the placement of an engineered cap. Following cap construction, an asphalt surface was placed over the cap. Approved closure certification was received in 1990, and the site is now a parking lot.

The primary contaminants were nitrates and uranium, with lesser concentrations of heavy metals and organic solvents.

Oil Landfarm Waste Management Area. The Oil Landfarm Waste Management Area include the Oil Landfarm, Boneyard/Burnyard, and Sanitary Landfill. The Oil Landfarm, located approximately one mile west of the Y-12 Plant in the Bear Creek Valley Waste Disposal Area, was used for the land application of one million gallons of waste oils and coolants that contained beryllium compounds, depleted uranium, polychlorinated biphenyls (PCBs), and chlorinated organic compounds.

The Oil Landfarm was operated from 1973 to 1982 on a seasonal basis from April to October, when conditions were most favorable for soil microbial activity. Waste were collected in tanker trucks, distributed over the surface of the landfarm plots, and cultivated into the uppermost three inches of soil. The plots were cultivated frequently between application periods.

Disposal operations were discontinued in 1982, and soils contaminated with PCBs in excess of 25 ppm were excavated from the landfarm plots and stored in a vault. The plots and the Chemical Storage Area were covered with an engineered cap. Final RCRA closure of the site was certified by the Tennessee Department of Environment and Conservation (TDEC) in December 1990.

Sanitary Landfill I received various types of nonhazardous waste from the Y-12 Plant. Waste disposal at Sanitary Landfill I was terminated in 1982; and in 1983, the site was graded, capped, and closed.

The Boneyard/Burnyard consists of approximately 8 acres used for waste from the Y-12 Plant. Burning and disposal of debris and sanitary, metallic, chemical, and radioactive wastes are known to have occurred. The site has been abandoned and is predominantly covered with grassy vegetation. The southeastern portion of this site is overlain by the Hazardous Chemical Disposal area, now considered to be part of the Boneyard/Burnyard. The Hazardous Chemical Disposal area was approximately 2 acres in size and was used to burn or neutralize liquid and gaseous wastes from 1975 to 1981. The Hazardous Chemical Disposal area is presently covered with a RCRA-type cap.

Bear Creek Burial Grounds Waste Management Area. The Bear Creek Burial Grounds Waste Management Area, located on the southern slope of Pine Ridge approximately 2 miles west of the Y-12 Plant, comprises a series of waste disposal units (Burial Grounds A, B, C, D, E, and J the Walk-In Pits) covering an area about 5000 feet by 3000 feet. Each disposal unit consists of a series of trenches excavated to depths of 14-25 feet below grade. The trenches received a variety of hazardous and nonhazardous solid and liquid wastes. The Walk-In Pits contain unstable and shock-sensitive wastes, such as picric acid and aged ethers.

The burial grounds began operations in 1955, and all hazardous waste disposal operations were discontinued in 1981. All trenches known to have received RCRA hazardous material in Burial Grounds A and C have been capped as part of a RCRA closure. A wide range of contaminants was disposed of in the Bear Creek Burial Grounds. Volatile organic compounds (VOCs) in soil resulting from groundwater transport are of primary concern.

Oil Retention Ponds 1 and 2 were constructed in 1971 and 1972, respectively, to intercept seepage from burial trenches. Both ponds were RCRA-closed in 1990. Final in-place closure began by intercepting seepage of contaminated leachate entering the ponds. Liquids from the ponds were removed and treated. The bulk of contamination has been removed and stored pending treatment in the RCRA/TSCA Incinerator at K-25. The ponds were backfilled and capped.

OU 2—Spoil Areas

Bear Creek OU 2 consists of the Rust Spoil Area, Spoil Area 1, and the SY-200 Yard.

Rust Spoil Area. The Rust Spoil Area, located in Bear Creek Valley less than one half mile west of the Y-12 Plant on Old Bear Creek Road, was used from 1975 to 1983 for disposal of spoil material generated during various renovation, maintenance, and construction operations at the Y-12 Plant. Disposed material was periodically graded, resulting in changes in topography and filling of part of the Bear Creek Channel.

Approximately 100,000 yd³ of nonuranium-contaminated construction spoils were disposed of at the site. Small quantities of solvent-contaminated material and material containing asbestos, mercury, and uranium may have been disposed of in this area. Soil contamination is of primary concern.

Spoil Area 1. Spoil Area 1, located near the southwest end of the Y-12 Plant, bounded by Old Bear Creek Road and West Patrol Road, was used for the disposal of approximately 100,000 yd³ of nonhazardous, nonradiologically contaminated debris. Although plant controls eliminated the disposal of hazardous and radioactive waste, past plant practices indicate that some of the construction material may have been contaminated with trace amounts of asbestos, mercury, beryllium, thorium, and uranium.

SY-200 Yard. The SY-200 Yard is a 200-ft by 300-ft aboveground storage area located adjacent to Old Bear Creek Road. The site contains materials from several Y-12 and Oak Ridge National Laboratory (ORNL) divisions, including PCB transformers, lead shielding plates, and radioactively contaminated materials. Soil contamination is of primary concern.

OU 4—Bear Creek Hydrogeologic Regime Integrator OU

Bear Creek, which flows westward through Bear Creek Valley from its headwaters just west of the Y-12 Plant until it exits near State Highway 95, has received contaminated surface water and groundwater discharges from past waste management practices in the Bear Creek and S-3 Waste Management Areas. Since these operations ceased in the mid-1980s and many of the disposal units closed, contamination of Bear Creek has been drastically reduced. The principal contaminants remaining in the floodplain soils and sediments are PCBs, uranium, and cadmium.

Bear Creek OU 4 addresses contamination within the coupled groundwater/surface water system and downstream transport of Bear Creek channel deposits. The primary contaminants in the Bear Creek hydrologic regime are nitrates, VOCs, radionuclides, and, to a lesser extent, trace metals. Dense, nonaqueous phase liquids (DNAPLs) have been discovered at a depth of 270 feet below the Bear Creek Burial Grounds. The DNAPLs consist primarily of perchloroethylene (PCE), trichloroethylene (TCE), 1,1,1-trichloroacetic acid, and high concentrations of PCBs.

1.3.2.3 Chestnut Ridge

Chestnut Ridge consists of three source OUs: CR OU 1, Security Pits; CR OU 2, Filled Coal Ash Pond/Upper McCoy Branch; and CR OU 4, Rogers Quarry/Lower McCoy Branch.

OU 1—Chestnut Ridge Security Pits Hazardous Waste Disposal Area

The Chestnut Ridge Security Pits Hazardous Waste Disposal Area is located on the crest of Chestnut Ridge, southeast of the central portion of the Y-12 Plant. Operated since 1973, the unit consists of a series of trenches that were used for the disposal of classified hazardous and nonhazardous wastes until December 1984 and November 1988, respectively.

Ten major categories of unclassified wastes have been identified: acids, fiberglass, beryllium, biological material, debris, heavy metals, inorganics, thorium, and uranium.

Other classified waste forms are also present. The pits had capacity for 31,000 yd³ of waste material.

The unit was closed in 1988 in accordance with a TDEC-approved closure plan consisting of a low-permeability, low-maintenance cover over the trenches. Groundwater impacts from the disposal operations are the primary focus of this OU.

OU 2—Filled Coal Ash Pond/Upper McCoy Branch

The Filled Coal Ash Pond is situated within the McCoy Branch watershed about a half mile south of the Y-12 Plant. The pond was constructed in 1955 to serve as a settling basin for coal ash from the Y-12 Steam Plant. By 1967, the pond filled, spilling sediments directly into McCoy Branch. From 1967 to 1989, ash was carried within McCoy Branch to Rogers Quarry, about one half mile downstream of the Coal Ash Pond. Impact to surface water, stream sediments, and groundwater from metals, including uranium and major ions are of concern. Biomonitoring of aquatic organisms in McCoy Branch and Rogers Quarry has shown potential biological impact from the ash pond operations.

OU 4—Rogers Quarry and Lower McCoy Branch

Rogers Quarry is located within the McCoy Branch watershed about one mile south of the Y-12 Plant. The quarry, which is approximately 1150 x 250 x 275 feet, was the source of construction materials in the 1940s and 1950s. The quarry filled with water and was abandoned with quarrying equipment in-place in the early 1960s. Disposal of flyash and bottom ash from the Y-12 Steam Plant into the quarry began in the 1960s and continued through the spring of 1992. The quarry was also used for disposal of other plant process materials.

The Lower McCoy Branch begins at the surface water discharge point of Rogers Quarry and ends at the McCoy Branch embayment in the Clinch River/Melton Hill Lake.

1.3.2.4 Lower East Fork Poplar Creek

As a result of the loss to the environment of contaminants associated with plant operations, East Fork Poplar Creek has become contaminated with mercury and trace levels of other metals, organics, and radionuclides. During early 1982, data were produced that indicated that the Y-12 Plant could not account for as much as 20,000 gallons of mercury since 1953. Much of the elemental mercury may remain lodged in sumps, sewers, and in bedrock cavities beneath the plant. Although the process that used mercury at Y-12 was discontinued in 1963, mercury continues to enter EFPC primarily through storm flow inputs from the Y-12 Plant and floodplain erosion in the EFPC watershed.

The headwaters of EFPC are contained in 54- to 72-inch underground collection pipes that extend from the west end to the central area of the Y-12 Plant, where the above-ground portion of the creek begins. Historically, EFPC flowed into New Hope Pond, an equalization basin constructed by Y-12 in 1963. Lower East Fork Poplar Creek (LEFPC) served as the drainage outlet for New Hope Pond until November 8, 1988, when the water was diverted away from the pond and into Lake Reality, a new lined basin. The Lower East Fork Poplar Creek (LEFPC) OU begins at Lake Reality, where the creek exits the Y-12 property, and continues fourteen miles through the city of Oak Ridge to Poplar Creek. LEFPC is an integrator OU, addressing the portion of the creek and floodplain which are not on Y-12 property.

The primary contaminant of concern in LEFPC is mercury. Other contaminants are cadmium, arsenic, uranium, PCBs, and other PAHs.

1.3.2.5 CAPCA Phase I

CAPCA Phase I encompasses ten RCRA interim status units and a CERCLA unit. Four of the ten RCRA units are surface impoundments (New Hope Pond, S-3 Ponds, Oil Retention Ponds, and Kerr Hollow Quarry) and the other six are land based units (Chestnut Ridge Security Pits, Chestnut Ridge Sediment Disposal Basin, the Oil Landfarm, and Bear Creek Burial Ground A, C, and B/Walk-In Pits). The CERCLA unit is the United Nuclear Corporation Disposal Site located near the crest of Chestnut Ridge, in the southern portion of the Y-12 Plant. Two soil borrow areas were developed along with haul roads to be used in the site closure. Nine of the closures required installation of multilayered engineered caps, and two required structural stabilization (S-3 Ponds and New Hope Ponds).

Seven of the RCRA units have been discussed in earlier sections. The remaining three, along with the CERCLA unit, are discussed below.

New Hope Pond

New Hope Pond (NHP) was located at the eastern end of the Y-12 Plant and served as an equalization/settling basin for final facility effluent discharged to UEFC. NHP was operated from 1964 to 1988, when it was closed under RCRA regulations. NHP was an unlined, man-made pond. Flow entered the pond through a distribution ditch that received surface runoff. NHP was dredged in 1973 to remove sediment accumulations, and the dredged sediments were placed in the Chestnut Ridge Sediment Disposal Basin (CRSDB) on Chestnut Ridge above NHP. Since 1973, sediments have been removed several times from the pond inlet diversion ditch and placed in the CRSDB.

In November 1988, flow was diverted to Lake Reality, a man-made basin lined with 45-mil Hypalon. NHP was closed as a RCRA landfill in 1988, with closure consisting of removal and treatment of liquids, stabilization of sediments, and installation of an engineered cap.

Kerr Hollow Quarry

Kerr Hollow Quarry was used for disposal of waste materials from the Y-12 Plant from 1951 until 1988. The quarry is located about 1000 feet from the nearest public access on Bethel Valley Road and lies southeast of the main Y-12 Plant complex across Chestnut Ridge. The approximately 1 1/2-acre quarry is completely flooded with water to depths of 50 feet as measured by sonar and pressure surveys. The water surface of the quarry is surrounded by rock faces that are 60 feet high along the south and east sides and 15 feet high along the north side. Water flows from the quarry over a weir at the western end.

The waste materials that were treated in the quarry include water reactive (e.g., sodium and potassium) and compressed gas materials (e.g., phosgene and hydrogen sulfide) held within containers. The treatment process involved dropping a container from the quarry "high" wall into the water and then puncturing the container with a rifle shot, thereby allowing the waste to react with the quarry water and dissipate.

Chestnut Ridge Sediment Disposal Basin

The Chestnut Ridge Sediment Disposal Basin (CRSDB) is an unlined, man-made basin south of NHP. Since 1973, it has been used to dispose of sediments hydraulically dredged from NHP and the associated diversion ditch. It was designed to hold approximately 30,000 yd³ of sediments. Waste disposed of in the basin include metals (primarily mercury), organics, (primarily PCBs), cyanide, phenol, and radionuclides.

Toxicity analysis of the NHP sediment and those placed in the basin, including in-place sediment, did not detect any RCRA characteristics of toxicity. In 1989, TDEC approved the RCRA Certification of Closure. In-place closure of CRSDB consisted on the placement of clay backfill and the installation of an engineered cap.

United Nuclear Corporation Landfill

The United Nuclear Corporation Landfill is near a crest of Chestnut Ridge in the southern portion of the Y-12 Plant. The waste at this facility was generated at the UNC Recovery System Company in Wood River Junction, Rhode Island. This company was involved in recovering enriched uranium from scrap metals and was required to decontaminate its facilities after operations were shut down. This involved removing low-level radioactive wastes and lagoon sludges from the state of Rhode Island. DOE directed the waste to be shipped to the Y-12 Plant for disposal. Between June 1982 and November 1984, the landfill received 11,000 55-gallon drums of sludge fixed in cement; 18,000 drums of contaminated soil; and 288 wooden boxes of contaminated building and demolition materials.

The landfill consists of a 1.3-acre excavation cut into the side of Chestnut Ridge and ranges in depth from 5-30 feet. The drums are stacked no more than ten high and follow the contour of the excavation. Both the drums and wooden boxes are covered in polyvinyl chloride (PVC) sheeting. Many of the drums and boxes have deteriorated, exposing their contents to the environment.

Groundwater transport modeling and risk assessment indicated that nitrates and ⁹⁰Sr leaching from the landfill present a long-term risk to exposure from groundwater. Contaminated soils from the off-site Elza Gate site cleanup were placed in the landfill, which was then covered with a modified RCRA cap.

1.3.2.6 CAPCA Phase II

CAPCA Phase II involves DNAPL groundwater monitoring wells within the Bear Creek Hydrologic regime and the RCRA permitting requirements for the DARA Solid Storage Facility. The DNAPLs have been discussed in an earlier section. The DARA Solid Storage Facility stores soils that were removed as part of the closure of Oil Retention Ponds 1 and 2 under the DARA program. The soils will be stored until the closure method is determined. The material consists of PCB-contaminated soils/sediments, volatile and nonvolatile organics, and some possible uranium-contaminated soils excavated from the bottom of the ponds and seep areas.

1.4 Y-12 Remedial Action Problem Definition

The technology logic diagrams for Y-12 Remedial Actions have been divided into six site problems:

1. Quarries/Impoundments
2. Soil/Sediments
3. Groundwater/Surface Water
4. Buried Waste
5. Pipelines
6. Tanks

These groups were developed to expedite the identification of potential technology solutions for remedial action problems identified in the preceding section. Table 1.1 correlates the OUs identified in the previous section with site problems and contaminants of concern.

Mercury contamination is a pervasive problem at the Y-12 Plant in building drain systems, soils, sediments, groundwater, and surface water. This contamination arises from land disposal of mercury wastes and wastewater discharges to the ground and storm sewers. Due to the extent of mercury contamination throughout the plant, rather than addressing it as a separate site problem, mercury contamination has been addressed throughout the site problems as a problem area/contaminant, with specialized remediation alternatives described. Mercury has been identified as a problem at the Rust Spoil Area, Spoil Area 1, UEFPC OU 1—Surface Water and Groundwater Integrator, Building 81-10, Interim Drum Yard, the New Hope Pond, Chestnut Ridge Disposal Basin, and the RMPE activities (Tank Cleanout, Interim Hg Treatment, Hg Treatment Facility, and Pipe Re-routes).

1.4.1 Quarries/Impoundments

There are two quarries at the Y-12 Plant which are of concern to Remedial Actions: Rogers Quarry and Kerr Hollow Quarry. Rogers Quarry was the source of construction materials in the 1940's and 1950's, and was filled with water and abandoned with quarrying equipment in the early 1960's. It has since been used for disposal of flyash, bottom ash, and other plant process materials. Kerr Hollow Quarry was used for the disposal of water reactive waste materials from the Y-12 Plant from 1951 to 1988. The materials were containerized, dropped into the quarry, and punctured by rifle shot to allow the waste to react with the quarry water and dissipate. Soil and surface water are the main concerns in remediation of the quarries.

The impoundments under consideration at Y-12 are unlined manmade basins which received various waste streams, including process discharges, coal ash, sediments, and burial ground seepage. All have been recently emptied and capped. Contamination of surrounding soil and groundwater are of concern, with contaminants including organic solvents, nitrates, uranium, mercury, and heavy metals. The impoundments at Y-12 include the Filled Coal Ash Pond, S-3 Ponds, S-2 Site, New Hope Pond, Oil Retention Ponds, and the Chestnut Ridge Disposal Basin.

Table 1.1. Y-12 operable units and related site problems

ADS ^a	Project	Site problem	Contaminants of concern
2301	Chestnut Ridge		
	OU 1—Security pits	groundwater, buried waste, soil	Be, Th, U, heavy metals, VOCs
	OU 2—Filled Coal Ash Pond/ Upper McCoy Branch	impoundments, sediments, groundwater, surface water	metals (uranium and major ions)
	OU 4—Rogers Quarry/Lower McCoy Branch	quarries, surface water	metals (uranium and major ions)
2302	Bear Creek Valley		
	OU 1		
	S-3 Waste Management Area	impoundments, sediments, groundwater	VOCs, nitrates, Ba, Pb, Cr, U, Pu, Tc
	Oil Landfarm Waste Management Area		
	Sanitary Landfill I	soil, groundwater, buried waste	unknown (various nonhazardous waste)
	Boneyard/Burnyard	soil, groundwater, buried waste	VOCs, pesticides, PCBs, U
	Oil Landfarm	soil, groundwater	VOCs, PCBs, Be, Cr, As, Pb, Hg, U
	Burial Ground Waste Management Area	soil, groundwater, buried waste	VOCs, PCBs, Be, Cr, As, Pb, U, Th, shock-sensitive wastes
	OU 2—Spoil Areas		
	Rust Spoil Area	soil, buried waste	solvents, asbestos, Hg, U
	Spoil Area 1	soil, groundwater	asbestos, Hg, Be, Th, U
	SY-200 Yard	soil	Hg, asbestos
	OU 4—Hydrologic Regime Integrator	sediment, soil, groundwater, surface water, DNAPLs	nitrates, VOCs, radionuclides, trace metals, DNAPLs, PCBs, perc, TCE, PCE, acids
2303	Upper East Fork Poplar Creek		
	OU 1—Surface Water and Groundwater Integrator	sediment, groundwater, surface water, soil	Hg, radionuclides, metals

Table 1.1. (continued)

ADS ^a	Project	Site problem	Contaminants of concern
2303 (cont.)	OU 2—Abandoned Nitric Acid Pipeline	soil, pipelines	U, nitrates
	OU 3—Western Exclusion Area		
	S-2 Site	impoundments, sediment, soil, groundwater, surface water	nitrates, heavy metals, Hg, VOCs, U, methylene chloride, PCE, TCE
	Salvage Yard	soil, tanks	Be, Cr, Co, Pb, Hg, PCBs, PCE, Th, TCE, U
	Building 81-10	soil, surface water	Be, Hg, U
	RMPE—Tank Cleanout	surface water, tanks (sludges)	Hg
	RMPE—Interim Hg Treatment Facility (IHgTU)	groundwater	Hg
	RMPE—Hg Treatment Facility (HgTF)	groundwater, surface water	Hg, radionuclides (U), Li, asbestos
	RMPE—Pipe Reroutes	pipelines	Hg
	RCRA Closure		
	Interim Drum Yard	soil, groundwater	Hg, metals, organics, freon, cyanide, PCBs, uranyl nitrate, penetrant soln, emulsifiers, asbestos, NaOCl
	Building 9409-5 Diked Area Storage	soil, groundwater	liquid waste coolant, solvents, waste oils, U, Be, Cr
	Garage Underground Tanks	soil	gaseoline, diesel, solvents, PCBs, U, Be, Cr
	Rust Fuel Facility	soil, groundwater	diesel, gasoline
	Study Areas	quarries, impoundments, sediment, soil, surface water, pipes, buried waste	U, Mo, Th, MEK, Cd, Cr, Pb, waste coolant, carbon support forms

Table 1.1. (continued)

ADS ^a	Project	Site problem	Contamination of concern
2304	CAPCA^b I		
	New Hope Pond	impoundments, sediment, soil, groundwater, surface water	Hg, U, Th, Zn
	S-3 Ponds	impoundments, sediment, groundwater	nitrate salts, nitric acid solns, organic solvents, U, Tc, Pu, metals
	Oil Retention Ponds	impoundments, sediment, groundwater	VOCs
	Kerr Hollow Quarry	quarries, groundwater	water reactive wastes (Na, K), compressed gas (phosgene, HS)
	Chestnut Ridge Security Pits	groundwater, buried waste	acids, fiberglass, Be, Th, U, bio matl, heavy metals, inorganics
	Chestnut Ridge Disposal Basin	impoundments, sediment	metals, Hg, organics, PCBs, cyanide, phenol, radionuclides
	Oil Landfarm	soil	waste oils, coolant, Be, U, PCBs, 1,1,1-TCA, tetrachloroethane, chlorinated organic compounds
	Bear Creek Burial Grounds	soil, groundwater, buried waste	shock-sensitive waste (picric acid, aged ethers)
	United Nuclear Corporation Landfill	groundwater, buried waste	rad sludge fixed cement, nitrates, Sr-90
	CAPCA II		
	DNAPL ^c Wells	groundwater, DNAPLs	nitrates, VOCs, rad, trace metals, PCBs, DNAPLs
	DARA ^d Solid Storage Facility	sediment, soil	volatile and nonvolatile organics, U
9304	Lower East Fork Poplar Creek	sediment, soil surface water	Hg, Cd, As, PAHs, radionuclides (U)

^aADS = Activity Data Sheet^bCAPCA = closure and postclosure activity^cDNAPL = dense, nonaqueous phase liquid^dDARA = disposal area remedial action

1.4.2 Soil/Sediments

Soil contamination at the Y-12 Plant has primarily resulted from leaks and spills throughout the plant's operating life. Unlined impoundments, leaky underground pipes, buried waste and land farming have all contributed to contamination of the soil by organics, metals, and uranium.

Contaminated surface water and groundwater discharges from past waste disposal operations to bodies of water surrounding the Y-12 Plant have resulted in the accumulation of metals, PCBs, and uranium in river and floodplain sediments.

1.4.3 Groundwater/Surface Water

Groundwater contamination at the Y-12 Plant has resulted mainly from unlined impoundments and leaky burial grounds. A wide variety of contaminants have been found in the groundwater surrounding the Plant, including PCBs, uranium, solvents, and heavy metals.

DNAPLs have been discovered in wells in the Bear Creek OU 4, at a depth of 270 feet below the Bear Creek Burial Grounds. They consist primarily of perchloroethylene, trichloroethylene, 1,1,1-trichloroacetic acid, and high concentrations of PCBs. Remedial technologies in this area must focus on removal of the DNAPL without disturbing the fractured rock containing the DNAPL pools and remobilizing the organic contaminants, and preventing offsite releases of contaminants through active conduit flow systems.

Overflows from manmade ponds, run-off, and wastewater disposal through storm drains have resulted in the contamination of surface waters surrounding the Y-12 Plant.

1.4.4 Buried Waste

Several waste disposal areas at the Y-12 Plant, including the Chestnut Ridge Security Pits, Sanitary Landfill I, Boneyard/Burnyard, Burial Ground Waste Management Area, Upper East Fork Poplar Creek Study Areas, and the United Nuclear Corporation Landfill, contain buried debris and drummed hazardous and nonhazardous wastes. Disposal of both classified and unclassified materials occurred throughout the 50 years of Y-12's history, and the disposal practices are those that were acceptable at the time and do not necessarily meet current standards. Though all of these sites have been capped, most of the waste remains buried, and some has leached into the soil and groundwater surrounding the sites.

Two of the buried waste sites, Chestnut Ridge Security Pits and Bear Creek Burial Grounds, contain pits and trenches which were used for disposal of various kinds of classified and unclassified, hazardous and nonhazardous wastes.

1.4.5 Pipeline

The longest pipeline being addressed by the Y-12 ER Program, the Abandoned Nitric Acid Pipeline, was used between 1951 and 1983 to transport a waste stream consisting mainly of nitric acid and depleted uranium from the building 9215 complex to the S-3 Ponds for disposal. One leak was identified and repaired in 1951. Primary exposure pathways are soil (adsorption) groundwater (infiltration) and surface water (seeps). An RI has been completed and a no further action has been recommended. Other pipelines

associated with plant operations are included in the study areas and mercury use areas. Pipelines are also under consideration at the Upper East Fork Poplar Creek Study Areas.

1.4.6 Tanks

Three sedimentation tanks located near 9204-1 and 9205-1 have been identified as the source of mercury contamination in the upper reach of Upper East Fork Poplar Creek. Tanks are also considered a problem at the Upper East Fork Poplar Creek Study Areas.

1.5 Priorities for Site Remediation

Priorities for remediating the site problem areas discussed in the preceding sections are presented in Table 1.2. The priorities were assigned on the basis of the potential for releases of contaminants to the environment, the potential impact of the contaminant, and the difficulty of treating the contaminant. For the buried waste, soils and sediments, and groundwater and surface water problem areas, more than one priority was assigned to account for differences within a specific problem area.

Table 1.2. Remedial action site problem priorities

Site problem	Priority ^a	Comments
Buried waste	4	Major on-site problem
Subsidence	2	Not a current problem
Soils/Sediments	5	Major problem
Mercury	5	Major off-site issue
VOCs/fuels/PCBs	3	Primarily on-site
Radionuclides (U)	4	Limited mobility
Groundwater/Surface Water	5	Major problem
Mercury	5	Moving off-site
DNAPLs	5	Difficult to treat
Other (VOCs, nitrates, U)	3	Primarily on-site
Impoundments/quarries	2	Closed units/migration not an issue
Pipelines	1	Limited impact
Tanks	1	Limited impact

^aHighest priority designated by 5.

1.6 1993 Roadmap

1.6.1 Introduction

Roadmapping is a process used by the U.S. Department of Energy (DOE) Office of Environmental Restoration and Waste Management (EM) to establish issues-based planning activities for achieving waste minimization, final waste disposal, decontamination and decommissioning, and site remediation. The *1993 Roadmap for the DOE Environmental Restoration and Waste Management Programs at Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio* is a generalized planning document that identifies broad categories of issues that could keep Y-12, along with the other four sites, outside full compliance with the law and other legally binding agreements. The *Roadmap* identifies possible generic paths to compliance, issues, and the schedule for resolution of these issues. The role of the *Y-12 Plant Technology Logic Diagram* (TLD) is, then, to identify specific site issues (problems), identify specific technologies that can be used to remediate the issues, and assess the current status and readiness of these remediation technologies within the constraints of the schedule commitment.

Regulatory requirements and commitments contained in the *Roadmap* are also included in the TLD as constraints to the application of immature technologies. Some otherwise attractive technologies may not be used because they cannot be fully developed and deployed on the schedule required by the regulatory agreements. Conversely, negotiators in the process of defining regulatory agreements may utilize the TLD assessments to schedule remediation milestones that allow the use of cheaper, faster, better, or safer technologies.

The *Roadmap* includes a list of comprehensive logic diagrams for RA under CERCLA and RCRA at the five sites. The roadmapping process gives comparisons of the installations as they exist to the way they could exist under full compliance. The goal of roadmapping allows accurate and timely formulation of activities.

1.6.2 Roadmapping Methodology

The roadmapping methodology is divided into nine steps and covers three phases—assessment, analysis, and issue resolution.

The assessment phase identifies the current status and background of the installation. This phase is accomplished in four steps: (1) identifying installation assumptions that provide for the conduct of environmental management (EM) activities; (2) identifying regulations and codes at federal, state, and local levels, DOE orders, and other agreements that DOE is responsible to comply with; (3) describing those DOE commitments, which include Inter-Agency Agreements and FFAs; and (4) preparing a schedule that includes all commitments with all currently budgeted and forecasted activities.

The analysis phase identifies key issues and actions needed for resolution. This phase is accomplished in four steps: (1) identifying issues that prevent the installation from accomplishing EM objectives; (2) analyzing issues to determine the root causes; (3) converting issues to needs for the resolution of issues and the identification of activities that satisfy those needs; and (4) preparing the schedule for the desired activities.

The issue-resolution phase merges the issue-resolution activities with ongoing and planned activities as the ninth and final step. Specific recommendations for

modifications, additions, or deletions to current plans are formulated and captured in Activity Data Sheets or are forwarded to DOE Headquarters for resolution.

A "Revised Roadmap Methodology Document" was issued in May 1993.

 

2. Description of the Technology Logic Diagram

the first two, the third is a new one, and the fourth is a new one.

The first two are the same as the first two in the first set.

The third is a new one, and the fourth is a new one.

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2. DESCRIPTION OF THE TECHNOLOGY LOGIC DIAGRAM

2.1 PURPOSE AND SCOPE

The purpose of the TLD is to provide a planning document for DOE, DOE operating contractors, and private industry that relates the Environmental Restoration/Waste Management (ER/WM) problems at Y-12 to the technologies that can be used to remediate these problems. In doing so, the status of each potential remediation technology is evaluated. This is a significant focus of the diagram preparation.

Several important aspects impacting implementation of each technology are folded into the evaluation so that the appropriateness of each technology can be evaluated:

1. Potential efficacy of the technology—how successful will its application be to the site problem?
2. Level of maturity of the technology—when can it be applied to site problems?
3. Level of WM required for the technology—what wastes are generated as a result of the use of the technology?

The TLD addresses the enforceable compliance and cleanup agreements that have designated timetables for ameliorating the specific site problems. For potentially attractive but immature technologies, or those for which improvement paths (which make them faster, better, safer, and cheaper) are visualized, priorities are assigned to technology development activities.

Because of enforceable compliance agreements, DOE is bound by Executive Order 12088, which requires the Secretary of the Department of Energy to submit a plan and request sufficient funding each year to comply with federal pollution control standards. This document will aid in the annual planning and budget submittals.

This document will address all RA problems that have been identified at the Y-12 Plant. The technology listings in the diagrams were judged to have some reasonable prospect for application at the Y-12 Plant. In a few cases the prospects are limited, however.

The K-25 Site and ORNL TLD has been used whenever possible.

2.2 STAFFING FOR THE TLD

The formulation of the Y-12 TLD was led by the same teams that formulated and published the *Oak Ridge K-25 Site Technology Logic Diagram*,¹ and the *Oak Ridge National Laboratory Technology Logic Diagram*,² with participation from across ORR. Although a number of Y-12 personnel were involved, about half of the team was selected from other Energy Systems organizations in Oak Ridge, such as the K-25 Site, ORNL, Central Engineering, and other DOE contractors. The personnel from these organizations represent input from personnel associated with programs under the DOE Deputy Assistant Secretaries of Waste Management (EM-30), Environmental Restoration (EM-40), and Technology Development (EM-50), as well as professionals not associated with these programs. Figure 2.1 shows a staffing plan for the Y-12 TLD Team.

Specialists worked as members of each team formed for the *subelement* categories. Representatives from each team served on a coordinating committee, which functioned as a common communication forum for the TLD. More than 50 specialists were involved in this effort. The teams (1) compiled the site problems in terms that were applicable to each team; (2) identified and evaluated technologies that could be applied to remediate the problems; (3) furnished, through the technology evaluation, information on the opportunities that were evident for development and improvement in each technology; and (4) furnished the requirements for deployment of these developed and improved technologies.

Technology evaluation was a significant component of the TLD effort. Team members identified potential technologies, but it was not necessary for the technology evaluation experts to become familiar with the concepts of the TLD before their evaluations. The data sheets allowed the evaluations to be performed on a systematic basis. The data sheets (Vol. 3) provide detailed information and the basis upon which the diagram (Vol. 2) was devised.

The TLD provides several benefits to the DOE community. The diagram identifies technologies that can be used for EM programs. It serves as a vehicle to identify the deficiencies in technologies that otherwise have potential to (1) foster faster remediation; (2) allow safer project activities; (3) result in better remediation efforts; and (4) allow these projects to be accomplished at a lower cost to DOE and the United States. Improving existing technologies, demonstrating the applicability of promising technologies, developing immature technologies, and supporting fundamental technology investigations are options that DOE can pursue to deploy technologies necessary for successful EM of DOE facilities. The diagram will highlight areas for private industry and university involvement in EM.

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Fig. 2.1. The Y-12 Plant RA Technology Logic Diagram Team.

2.3 TECHNICAL APPROACH

This section describes the overall layout and development of the TLD. The logical progression flows from (DOE) EM Goal → EM Problem → Y-12 Problem → Problem Area (Target Constituent) → Reference Requirements → Subelement → Alternative (Generic Technology) → Technology → Technology Status → Science/Technology Need → Implementation Need.

Three different levels of information are provided. First, the technologies are evaluated and ranked in Vol. 1. Second, more detailed diagrams are provided in Vol. 2. Although each large sheet contains the entire logic path, several sheets are necessary to describe each evaluation area. Finally, each single logic path is published as a technology data sheet. These sheets are the most detailed source of information about each technology and are provided in Vol. 3.

The information found under each logic element is described below.

EM Goal has three components: clean up legacy waste, prevent future insult, and develop environmental stewardship. These problems are shared by all elements of the DOE complex to varying extents.

EM Problem contains problem areas agreed upon by EM/DOE such as decommissioning of facilities; cleanup of soils, groundwater, and surface water (RA); and WM from inception to final disposition.

Y-12 Problem describes the problem areas identified at the Y-12 Plant. These problem areas have been defined by D&D, ER and WM staff. The magnitudes of the site problems will be indicated in terms of floor areas, estimated metal tonnages, etc.

Problem Area/Constituent addresses a subelement-specific (see below) list of problems, all of which are traceable directly to the Y-12 problems.

Reference Requirements refers the reader to the final chapter of Vol. 1. Requirements can only be determined after consideration of detailed site-, waste-, and technology-specific characteristics.

Subelement specifies the different components that must be addressed to solve the problem. All RA activities are characterized into the following groups: treatment and fixation; retrieval; robotics/automation; and waste management. Table 2.1 lists these various subelements for RA and WM.

Alternative defines the general technology approaches that may be applied to the problem.

Technology identifies specific technologies that may be applied to remediate the problem.

Status provides information on the status of the technologies identified in the previous column using the standard categories.

Table 2.1. Subelement categories in the Technology Logic Diagram

Area of environmental management	Subelements (or "Universe" of Activities)				
Remedial action Waste management	Characterization	1. Treatment 2. Fixation	Retrieval	Robotics/ automation	Regulatory compliance
	Characterization	1. Processing 2. Stabilization 3. Minimization	1. Transportation 2. Retrieval 3. Disposal	Robotics/ automation	Regulatory compliance
	Crosscutting			Crosscutting	Crosscutting

Some accepted technologies are *fully developed* or *commercially available* and if so are noted. These terms are used to denote slightly different meanings. *Fully developed* means that both the basis of the technology and the methods for designing remediation equipment or operations using the method are well known and covered in public literature. *Commercially available* means that the technology is offered by one or more commercial firms, but the data, design methods, or experience needed to assess the technology are not fully available to the public. The only difference in these two categories is that the public's ability to assess the performance and reliability of the technology is restricted for commercial technology. It suggests an unknown degree of risk in the commercially available technologies that cannot be fully evaluated with generally available information (even though the amount of risk may be negligible).

- *In Use*—technology is presently being used to remediate the identified problem.
- *Accepted*—demonstrated technology exists for use at Y-12 and is accepted by site personnel.
- *Demonstration*—technology is available but is not demonstrated and/or accepted for the problem at Y-12.
- *Predemonstration*—technology is under laboratory-, bench-, or pilot-scale testing.
- *Evolving Technology*—technology status is at a conceptual or preconceptual stage.
 - *Conceptual*—a scientific or knowledge basis for the technology exists.
 - *Preconceptual*—only a partial scientific or knowledge basis of the technology exists.

These classifications should provide indirect, relevant information on the present view of the short-term or long-term availability of technologies.

Several different areas are specifically addressed to further clarify the status designations chosen above.

- *Efficacy*—effectiveness of the technology in remediating the problem is addressed. Normally, quantitative measures are given for the technology's performance in standard practice, such as, estimating the final dpm/cm² of surface contamination for a decontamination technology; the time to cut a 24-in. pipe for a dismantlement technology; the analysis time and lower detection limit for a characterization technology.
- *Waste*—output from the technology. This describes the nature and volume of both the waste and the potentially useful materials.

Science and Technology Needs are perceived needs, where support or development is needed for an immature technology. Science and technology needs are related to the fundamental understanding of the scientific phenomena that form the basis for the technology. These needs are typically for laboratory or bench-scale experiments. Technology development needs identify areas where work is necessary to successfully implement scientific principles that will lead to a technology. Technology Improvement needs suggest improvements that will make a current technology more economical to apply, safer, and more effective or efficient. The demonstration of a technology on a site-specific problem is classified as a technology improvement need.

If scientific needs are specified, it should be understood that the needs of scientific technology development or improvement are necessary to implement newly developed scientific understanding. Likewise, testing a technology development opportunity implies that technology improvements are also likely to be needed.

DOE funding for a project that addresses the technology deficits is indicated by a Technical Task Plan (TTP) number, Activity Data Sheet number, or other reference number. Other work related to the technology area may also be referenced.

Most new technologies that are not in common use will require a large-scale test or demonstration to show that they are capable of achieving expected results on the site-specific problem. These tests demonstrate that a suitable and workable process or facility can be designed, built, and operated successfully. They show that no unknown condition prevents the process or facility from functioning as it was designed and that the equipment can last an acceptable lifetime. Demonstrations are intended to provide final tests of all aspects of a technology. If, however, particular questions remain about the technology, these are specifically mentioned on the diagram.

Implementation Needs or specialized needs were evaluated for both development of a technology and deployment of a mature technology. These needs were evaluated in the areas of (1) resources, such as financial or personnel; (2) hardware, such as process equipment, development equipment, and computers; (3) software, such as models, procedures, computer programs; (4) facilities, such as labs, shops, and buildings; and (5) education, such as training classes or degreed personnel. An estimate of the cost of the process and any potential cost payback are also given. Only extraordinary needs are highlighted (i.e., those needs that would require long lead time or unusual procurements, such as line items for facility construction).

The cost of applying the technology and the payback cost potential has been estimated. There are many reasons for payback, such as reducing the waste volume compared to a reference process, the sale of useable products, and the reduction of labor compared to a reference technology.

When standard laboratory facilities are sufficient, facility needs are not identified. Since the facilities on ORR are relatively extensive—including the K-25 Site, ORNL, and the Y-12 Plant—the diagram does not address needs for standard facilities but focuses on unique facility needs.

However, additional conventional facilities may be needed to meet the technology needs for RA at Y-12 because the available facilities may not provide adequate capacity for testing the various technologies. To assess the availability of standard facilities for these programs, it will be necessary to know (1) the rate at which technology development in Oak Ridge will proceed and (2) the extent at which other programs will compete for the facilities.

2.4 TECHNOLOGY RANKINGS

Throughout the technology evaluation a method of conveying information about the priority and status of each technology and its application is used to communicate separate information about the following:

- Overall assessment of the usefulness of the technology (E, H, M, and L, where E is for essential, H for high, M for medium, and L for low).
- Significance of site problem to which the technology is applied (1-5 is the scale of lowest importance to highest importance).
- Time required to bring the technology to the state of acceptable for application at large scale (commercial or mature state) at the site. This is expressed in number of years and depends on the state of its development.
- The cost for bringing the technology from its present state to acceptable for use commercially or at large scale. The costs are presented as \$M or \$K, which indicates the number of millions or thousands of dollars without escalation.
- Projected unit processing cost for mature technology (\$ per ft² or other unit or N for no estimate). This includes annual ranking costs for software.

An example of a ranking follows:

H-5-5 (\$3.5M;N)

This means that this technology has a high overall usefulness; the technology is estimated to take 5 years before it is ready for application at the site; an approximate expenditure of \$3.5 million will be required to bring the technology to this state of readiness; and the unit processing cost cannot be projected at the present time.

2.4.1 Overall Assessment

Following are the criteria used to determine the overall assessment of a technology and its application.

- *Waste Generation Reduction*—ability of the technology to minimize additional waste generation (1—no confidence, 5—complete confidence).
- *Compliance with Requirements [Applicable or Relevant and Appropriate Requirements (ARARs)]*—confidence that the technology will comply with applicable, relevant, and appropriate requirements (1—no confidence, 5—complete).
- *Environmental, Safety, and Health (ES&H)*—ability of the technology to meet the requirements of ES&H (1—no confidence, 5—complete).
- *Versatility*—ability of the technology to meet a wide range of requirements and to adapt to changes in requirements (1—no confidence, 5—complete).
- *Complexity*—ability of the technology to be deployed without requirements for extraordinary levels of expertise, training, and oversight (1—very high level of requirements, 5—low level of requirements).
- *Technical Risk*—confidence that the technology will work at the site(s) being evaluated (1—no confidence, 5—complete confidence).

- **Technical Maturity**—readiness of the technology relative to final application at large (commercial) scale (1—very immature idea for research, 5—ready for commercial application).
- **Development Required**—relative amount of time required to bring the technology to commercial application (1—all research, development, and demonstration steps required, 5—now commercial/no tests required).
- **Development Cost**—relative cost of bringing the technology to commercial application (1—highest cost for development of a technology within a technical area, 5—no costs, not even field testing).
- **Process Cost**—relative cost of process in terms of unit production costs in application (1—prohibitively expensive relative to other methods, 5—very inexpensive compared with other methods).

After scoring the criteria, the scores were averaged and the overall assessment rating was determined by the scale in Table 2.2.

Table 2.2. Scale for overall assessment rating

Assessment code	Code meaning	Score	Meaning
E	Essential	Any score	No other processes or technology available for essential requirement
H	High	3.67 to 5	High potential for application
M	Medium	2.33 to <3.67	Medium potential for application
L	Low	<2.33	Low potential for application

2.4.2 Status of Technology

The development state for technology was assessed using the scale provided in Table 2.3.

Table 2.3. Scale for status of technology

State of Technology	Score
Accepted	5
Demonstration needed	4
Predemonstration—evolving	3
Conceptual	2
Preconceptual	1

2.4.3 Estimates for Time to Maturity

Definitions for progress of development and time periods, which were used as guidelines for estimating the total period required to bring technology to the state of large-scale application (state of acceptance), are provided in Table 2.4.

Table 2.4. Definitions for progress of development and time periods

Step in development	Definition of step	Years
New technology		
Applied research	Work required to define scientific feasibility	1-3
Development	Bench or engineering scale to define scaling of the technology	2-3
Pilot	Integrated test of process or technology at less than full scale	3-4
Prototype demonstration	Integrated demonstration at full scale	3-5
Commercialization or mature application	Application of the technology at large scale	1-2
Adaptation of existing technology (existing at mature state)		
Synthesis demonstration	Combining existing technologies to meet requirement—demonstrate at pilot scale	2-3
Field test	Testing on the exact site problems and configuration	1-3

These stages of development correspond to the state of the technology and are shown in Table 2.5.

Table 2.5. Correspondence of terms for state of the technology

Status of technology	Score	Development period expressed by time	Development stages
Accepted	5	Available	Mature
Demonstration	4	Short range	Field test
Predemonstration	3	Medium range	Development, pilot, prototype, or synthesis of technology
Evolving—conceptual	2	Long range	Development
Evolving—preconceptual	1	Unknown	Applied research

2.5 REFERENCES

1. *Oak Ridge K-25 Site Technology Logic Diagram*, K-2073, Martin Marietta Energy Systems, Inc., K-25 Site, February 26, 1993.
2. *Oak Ridge National Laboratory Technology Logic Diagram*, Martin Marietta Energy Systems, Inc., K-25 Site, September 1993.

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3. Characterization

3. CHARACTERIZATION

3.1 INTRODUCTION

Characterization for Remedial Action (RA) will answer the following questions:

1. What contaminants are present?
2. How concentrated are the contaminants?
3. Where are they?

In cases like mercury contamination, identification of the chemical form of the contaminant is essential to design treatment schemes. Characterization technologies are used to locate buried wastes and contaminated ground-water seeps and to define contaminant migration boundaries in soils and sediments in burial grounds and outside of tanks, pipelines, buildings, and other structures. It is required to meet NPDES discharge limits from the Y-12 site and other regulatory requirements, and to permit risk assessment. The technologies involve, for the most part, the analysis of soils, sediments, sludges, water, and air in the field and laboratory. The main contaminant groups of concern at Y-12 are mercury and other heavy metals, radionuclides (primarily uranium), polychlorinated solvents (DNAPLs, TCE etc.) and other organic compounds or mixtures of organic compounds (e.g., PCBs or fuels).

This chapter presents the characterization technologies required to support RA at Y-12, brief overviews of the science and technology needs to bring the technologies to a useable level, implementation needs to deploy these technologies, and rankings of these technologies for RA.

3.2 TECHNOLOGY OPTIONS

3.2.1 Characterization Technology Options

Characterization technology options for RA at Y-12 are listed in Table 3.1 of Sect. 3.5, along with their rankings. All technologies are not required for each EM problem, and many of the technologies for a given constituent are optional. Many of these technologies are broadly applicable to a variety of constituents and RA problem areas, and they are listed in Vol. 2 under a "general" problem category. This reflects the applicability of a technology to more than one group of constituents (e.g., metals, inorganic nonmetals and organics) and to more than one problem area (e.g., buried waste, soils and sediments, impoundments). Under this general heading, the technologies are grouped as the following alternatives: sampling design, sample collection, sample preparation, detection and measurement—field methods, and detection and measurement—laboratory methods. Technologies specific to a group of constituents are then listed in the TLD under a specific alternative: radioactive elements (which includes both specific radionuclides and radioactivity), inorganic constituents (cations, anions, and elemental metals such as mercury), organic constituents, physical characteristics, and pathogens. These constituent-specific technologies are subdivided by their deployment in the field or laboratory. Technologies for in situ and ex situ determinations are included in the field and laboratory classifications. Simple and commonly accepted characterization technologies, such as for pH measurements are omitted for simplicity in this compilation. Following these general listings are specific Y-12 problems to which technologies are particularly relevant.

3.2.1.1 Sampling Design

The main technologies needed under this alternative are statistical designs or approaches for planning sample collection. For example, the large number of samples called for by a conventional full-factorial sampling design applied to burial grounds can be reduced to a more manageable number by statistical considerations without sacrificing information value.

3.2.1.2 Sample Collection

Sample collection methods exist for most of the RA problems at Y-12, but many are inadequate or expensive, and technology improvements are needed. Examples are the collection of soils and sediments by EPA methodology for VOCs analysis and the collection of representative samples from liquids and sludges. Solid-phase in situ sampling or extraction technologies are an attractive alternative to current methods.

Perhaps the most difficult sample collection problem is the collection of truly representative samples from heterogeneous wastes. This would include many of the wastes buried in drums and boxes in the burial grounds. The contents of the former may range from bottles, gloves, wipes, and shoe covers to broken, damaged, or contaminated equipment and apparatus. Technology needs include not only statistical designs for directing the sample collection but also the physical means for obtaining the samples.

3.2.1.3 Sample Preparation

One of the most significant technology needs is a sensitive and reliable field analysis for mercury contamination. Current methodologies have not been able to meet regulatory requirements in some applications and therefore require sample preparation and laboratory analytical techniques.

3.2.1.4 Detection and Measurement—Field Methods

Measurement technologies for field use are needed to define areas and boundaries of contamination or to monitor groundwater purity. They can also screen samples in the field so that only those with appreciable contamination are returned to the laboratory for more extensive and expensive characterization. Field-method technologies are also discussed below under specific contaminant group alternatives. In this alternative, major technology needs are fieldable technologies for locating subsurface concentrations of mercury and chlorinated solvents (DNAPLS, TCE). This appears to be a challenge for seismic, magnetic, ultrasonic, tomographic, or other methods now known. Deployment of these measurement technologies with robotics and automation is an important crosscutting area that promises to streamline and reduce costs of such surveys. Please refer to the robotics and automation chapter (Chap. 5) of this volume.

3.2.1.5 Detection and Measurement—Laboratory Methods

Laboratory-based technologies capable of inorganic and organic component determinations are listed in the general alternative, while constituent group-specific technologies are presented under the specific alternatives. A technology need general to laboratory measurements is contamination control of the analytical equipment. Mercury analyses are particularly prone to equipment contamination because of the volatility of elemental mercury.

3.2.1.6 Data Analysis/Modeling and Management

A wide range of information management and data analysis technologies will be needed, perhaps in some cases required, to support the level of tracking and accounting necessary to assure compliance with environmental laws and guidelines for conduct of activities. Configuration-management support will be needed to meet the demands of working in a highly regulated environment, especially in dealing with hazardous materials. Decision aids, including simulation models, data bases, full-text information retrieval applications, and expert systems will be needed to assist with planning. Statistical analysis, graphical display, and geographical information system support will be needed to assist with analysis and interpretation of large quantities of data. Large amounts of information and data will need to be transferred between the various groups of people working on the various aspects of the ER effort. Quick, reliable access to data or information distributed among many different organizations will be needed. All of these areas of support are best taken care of using computer networks. Network-communications support then becomes yet another area of technology that must be included. The demands on project management and support made by environmental legislation, requirements for safe handling and processing of very hazardous materials, and having adequate resources to deal with problems on the large scales that are involved

make use of automation and networked computing capabilities essential or highly important.

3.2.1.7 Uranium and Other Radioactive Elements—Field Methods

Fieldable technologies are needed to define areas of radiological contamination and to quantify radionuclides or radiation fields. They can reduce the sample load (and thus costs) for laboratory analyses and ensure that only the most important contaminated samples are sent to the laboratory for detailed analysis.

3.2.1.8 Uranium and Other Radioactive Elements—Laboratory Methods

A general technology need is the upgrading of radiochemical laboratory procedures and equipment to make them more rapid and efficient and to reduce the generation of secondary laboratory wastes. This is important in view of the greatly increased sample load anticipated from RA programs and the need to minimize costs and wastes. A particularly important technology need is the development and validation of inductively coupled plasma—mass spectrometry (ICP-MS) methods for determining long-lived, low-specific activity radionuclides. Traditional chemical separation and counting methods are labor intensive and require long counting periods to meet sensitivity requirements. ICP-MS can also determine nonradioactive metals.

3.2.1.9 Mercury and Other Metals—Field Methods

Reliable, high sample throughput technologies for mercury analysis will find very high utilization. Promising technologies include X-ray fluorescence, which is especially useful for quickly measuring surface contamination by heavy metals.

3.2.1.10 Mercury and Other Metals—Laboratory Methods

The atomic absorption and emission techniques will continue to be the backbone of analytical techniques. High sample throughput is a significant issue for these accepted technologies.

3.2.1.11 Inorganics (Nonmetals)—Field Methods

Technologies for determining inorganic composition in the field are needed to define areas of inorganic contamination and to quantify their amounts. They can reduce the sample load (and thus costs) for laboratory analyses and ensure that only the most important contaminated samples are sent to the laboratory for detailed analysis. Glow discharge ionization mass spectroscopy may be fieldable, with some development work. Promising technologies include X-ray fluorescence, which is especially useful for quickly measuring surface contamination. New x-ray fluorescence technologies now make possible analysis of elements with $Z > 12$ (carbon).

3.2.1.12 Inorganics (Nonmetals)—Laboratory Methods

There are many established, accepted laboratory methods for inorganic analyses. A particularly useful technology is ICP-MS because of the particularly robust nature of the sample introduction technology.

3.2.1.13 Organics—Field Methods

Fieldable methods for organic compounds will be required for numerous deployments in large numbers. The technologies require development to make them more rugged and reliable in the field, simpler to operate so that the technical expertise required to use them is reduced. Fieldable gas chromatography and mass spectroscopy are particularly important technologies.

3.2.1.14 Organics—Laboratory Methods

Technologies that determine regulated organic compounds are required. Improvements that reduce secondary waste generation, increase analytical speed and efficiency are needed. Supercritical fluid extraction as a virtually waste-free sample preparation method and liquid chromatography-mass-spectrometry for low volatility analytes are examples of technologies whose development and deployment would greatly support site remediation.

3.2.1.15 Asbestos—Laboratory Methods

There are a very limited number of laboratory methods for asbestos identification and no EPA methods available for field use. Optical microscopy is the typical method used but it is labor intensive and sample throughput is slow.

3.2.1.16 Polychlorinated Biphenyls—Field and Laboratory Methods

A PCB screening and identification kit is the only simple test available for field use but it is not accepted as a quantitative tool.

3.2.1.17 Dense Nonaqueous Phase Liquids and Mercury Location and Detection—Field and Laboratory Methods

The challenges for detection of these materials in subsurface locations are considerable. DNAPLS and mercury are liquids and significant quantities can travel deep into the ground and through cracks in the bedrock because of their very dense and unreactive nature. At present, quantities of these materials underground can only be inferred by their presence at low concentrations in flowing groundwater.

3.2.1.18 Physical—Field and Laboratory Methods

Technologies for locating contaminated groundwater seeps and determining ground-water flows and directions are needed.

3.2.1.19 Pathogens—Laboratory Methods

Remediation of biological wastes will require surveillance for pathogenic organisms as a part of worker protection as well as waste treatment.

3.2.1.20 Buried Waste

Monitoring the condition of buried and capped waste sites (CAPCA) is an important function of surveillance and maintenance (S&M). Leaching and subsidence of the sites are important issues. Collection of groundwater samples from downgradient wells is a standard monitoring technique, as is surface monitoring using surveying technologies.

3.2.1.21 Quarries and Other Water Impoundments

The recovery of potentially hazardous materials from underwater locations has required adaptation and development of several technologies, leading to the successful remediation of some deepwater hazards which threatened the groundwater.

3.2.2 Crosscutting Technologies

An important area of technology crosscutting is robotics and automation. This is particularly relevant in robotic automation of measurements (as in mercury surveys of large land areas). These crosscutting technologies are discussed in Chap. 5 of this volume.

3.3 SCIENCE AND TECHNOLOGY NEEDS

The basic R&D needs for characterization technologies range from none to considerable. Many characterization technologies are already mature and available on site. Examples of such technologies are gas chromatography-mass spectrometry for identification and quantification of regulated organic compounds and inductively coupled plasma-emission spectroscopy for metals. Some technologies may require some development work, such as a reliable and sensitive field analysis technology for mercury.

Other technologies will require basic R&D. The specific needs are explained in the data sheets that are included in Vol. 3. For example, basic advances in technology are needed for sampling heterogeneous wastes, both in sampling strategy as well as in the physical method and equipment used to take the representative sample(s).

3.4 IMPLEMENTATION NEEDS

Implementation needs, like science and technology needs, range from none to considerable. Instruments and protocols already exist for the determination of many regulated organics and inorganics using EPA protocols. These technologies have essentially no implementation needs and are ready as is for samples that can be handled in nonzoned laboratories. Other mature technologies are available on site, but some work is needed to deploy them. This work may entail calibration for the specific constituents and/or sample matrices or adaptation for deployment in certain locations, such as fieldable-gas chromatography or radiation sensors. Performance validation of field and laboratory analytical technologies is a part of the technology quality assurance and is included in the implementation costs. Other technologies are not available on site and will require greater effort to obtain them and implement them at the Y-12 Plant.

Some facility upgrades at the Y-12 Plant are also required to handle the anticipated sample load.

3.5 TECHNOLOGY RANKINGS

The rankings assigned to the characterization technologies for RA at the Y-12 Plant are included in the last column of Table 3.1. The ranking system is essentially the same as that explained in Sect. 2.3 of Chap. 2 in this volume.

Table 3.1. Rankings of characterization technologies for remedial action

Alternative	Data sheet code numbers	Technology	Ranking ^a
General applicability to all remedial action problems			
Sampling design	CHAR-252-OZ	Sequential sampling plans	M-3-5 (\$.1M;\$0.5Kam ^b)
	CHAR-71-OZ	Optimization of sampling designs	H-5-5 (\$.1M;N)
	CHAR-228-OZ	Sampling program configuration management system	E-5-1 (\$0.5M;\$50Kam)
Sampling collection	CHAR-270-OZ	Sampling of heterogeneous wastes	H-5-3 (\$2.8M;N)
	CHAR-259-OZ	Ground Water Discharge Sampling	
	CHAR-302-OZ	Mercury in Air	
	CHAR-315-OZ	Push Core Sampling	
	CHAR-256-OZ	Soil/sediment sampling for volatile organics analysis	H-4-1 (\$.1M;\$50)
	CHAR-254-OZ	Solid sorbent sampling for airborne organics	H-5-1 (\$.2M;\$50)
	CHAR-55-OZ	Membranes for sample collection and concentration	M-5-1 (\$.25M;\$50)
	CHAR-64-OZ	Multiangle drilling for depth profiling of contaminants	M-4-1 (\$.2M;N)
Sample Preparation	CHAR-208-OZ	Supercritical fluid extraction of organics	M-5-1 (\$.33M;\$100)
	CHAR-201-OZ	Supercritical fluid extraction of inorganics	M-3-2 (\$.2M;N)
	CHAR-19-OZ	Microwave digestion	H-5-1 (\$.2M;\$100)
	CHAR-67-OZ	Metallographic sectioning and preparation	M-4-0 (\$0M;<\$500)
	CHAR-203-OZ	High-pressure ashing for sample preparation	H-4-1 (\$1M;N)
Detection/measurement— field methods	CHAR-25-OZ	Fiber-optic chemical sensors	H-5-1 (\$1M;\$10)
	CHAR-264-OZ	Ion mobility mass spectrometry	M-5-2 (\$1M;\$50)
	CHAR-23-OZ	Immunoassay detection	H-5-3 (\$1M;\$50)
	CHAR-84-OZ	Portable Raman spectrometer	M-5-2 (\$1M;\$10)
	CHAR-27-OZ	Optical absorption spectroscopy	H-5-1 (\$.6M;\$50)
	CHAR-258-OZ	In-Situ Groundwater Flow Meter	

Table 3.1 (continued)

Alternative	Data sheet code numbers	Technology	Ranking ^a
Detection/measurement— field methods (continued)	CHAR-59-OZ	Air monitoring	E-5-0 (\$.25M;\$500)
	CHAR-18-OZ	Infrared spectroscopy (wavelength dispersion)	M-5-1 (\$.5M;\$100)
	CHAR-52-OZ	Personnel monitoring	H-5-1 (\$.2M;N)
	CHAR-60-OZ	Tomographic seismic monitoring	M-5-N (N;N)
	CHAR-123-OZ	Ultrasonic ranging and data system	H-5-0 (\$0;N)
	CHAR-124-OZ	Ground-penetrating radar	H-5-0 (\$.03M;N)
	CHAR-125-OZ	Electrical and electromagnetic detection of ground and geologic features	H-5-1 (\$.2M;N)
	CHAR-126-OZ	Seismic methods (refraction, profiling, reflection)	M-5-1 (\$.2M;N)
	CHAR-127-OZ	Microgravity methods	M-5-1 (\$.2M;N)
	CHAR-322-OZ	Superconducting Quantum Interference Device (SQUID) Magnetic Field Detection	
	CHAR-128-OZ	Magnetics	M-5-1 (\$.2M;N)
	CHAR-92-OZ	Portable luminescence detection	M-5-1 (\$.5M;\$10)
	CHAR-10-OZ	Electrochemical methods	M-4-2 (\$.5M;\$100)
General Detection/Measurement— laboratory methods	CHAR-8-OZ	Fourier transform infrared spectroscopy	M-5-1 (\$.2M;\$50-\$500)
	CHAR-48-OZ	Isotopic dilution mass spectrometry	M-5-0 (\$0M;\$100-\$1000)
	CHAR-11-OZ	Nuclear magnetic resonance	M-5-1 (\$.2M;\$200-\$500)
	CHAR-26-OZ	Particle Size Analysis	
	CHAR-3-OZ	Secondary ion mass spectrometry	H-5-0 (\$0M;\$400)
	CHAR-9-OZ	Ultraviolet/visible spectroscopy	H-5-0 (<\$.1M;\$50-\$200)
	CHAR-4-OZ	Laser ionization mass spectrometry	M-5-0 (\$0M;\$300-\$500)

Table 3.1 (continued)

Alternative	Data sheet code numbers	Technology	Ranking ^a
Data analysis/Modeling/Management	DISM-151-OZ	Project information access services	E-5-1 (\$5M;\$100Kam)
	DISM-153-OZ	Client/server access to standards and regulatory guidelines	E-5-0.5 (\$.25M;\$25Kam)
	DISM-154-OZ	Data access services	E-5-1 (\$5M;\$200Kam)
	DISM-181-OZ	Geographic information system for DOE sites	E-5-1 (\$1M;\$200Kam)
	CHAR-325-OZ	Graphical Information System	
	DISM-155-OZ	Automated scanning and conversion of engineering drawings	E-5-2 (\$2M;\$300Kam)
	CHAR-233-OZ	Hazard analysis expert system	E-5-2 (\$5M;\$150Kam)
	CHAR-234-OZ	Application of approximate reasoning to data analysis/evaluation	E-5-2 (\$5M;\$150Kam)
	DISM-157-OZ	Client/server/architecture for data base access	E-5-1 (\$5M;\$200Kam)
	DISM-158-OZ	Hypertext information systems	E-5-1 (\$.3M;\$150Kam)
	CHAR-253-OZ	Spatial sample and data analysis plans	H-3-.5 (\$.1M;\$5Kam)
	CHAR-251-OZ	Statistical methods for the analysis of large data sets	M-3-3 (\$.5M;\$5Kam)
	CHAR-250-OZ	Quality control for measurement processes	E-4-.25 (\$.05M;\$5Kam)
	CHAR-249-OZ	Analysis of censored data	H-4-.25 (\$.05M;\$5Kam)
	CHAR-44-OZ	Criticality indices	L-2-1 (\$.25M;N)
	CHAR-53-OZ	Modeling of volatile organic compounds migration in porous materials	M-4-1 (\$.2M;N)
	CHAR-72-OZ	Database Management for Large Quantities of Data	
	CHAR-222-OZ	Multisensor fusion measurement systems	H-3-1 (\$.5M;\$.25/measurement)
	CHAR-223-OZ	Detection and measurement systems with feature extraction	M-4-2 (\$1M;\$1/image scanned)
	CHAR-225-OZ	Fractals used to select models for material transport in porous media	M-2-2 (\$.5M;\$20Kam)
	CHAR-229-OZ	Configuration management system	E-5-1 (\$.5M;\$50Kam)

Table 3.1 (continued)

Alternative	Data sheet code numbers	Technology	Ranking ^a
Data analysis/Modeling/Management (<i>continued</i>)	CHAR-242-OZ	Stored material neural net identification system	E-5-2 (\$1M;\$100/container analyzed)
	CHAR-45-OZ	Subsurface complexation model	
	CHAR-255-OZ	Dynamic modeling of material transport	H-5-2 (\$.3M;\$10Kam)
Uranium and Other Radioactive elements—field methods	CHAR-108-OZ	Proportional counter for alpha and beta activity	H-5-0 (\$.1M;\$100)
	CHAR-102-OZ	Passive monitors for weak beta radionuclides	M-4-2 (\$.6M;\$20)
	CHAR-65-OZ	Long-range alpha detector	M-4-1 (\$.4M;\$100)
	CHAR-216-OZ	Bubble dosimeters for neutron flux	M-4-1 (\$.2M;\$15)
	CHAR-269-OZ	Advanced radiation monitors (Smart Probes)	M-4-2 (\$.4M;\$50)
	CHAR-95-OZ	Electret passive surface alpha monitor	H-4-1 (\$.3M;\$15)
	CHAR-96-OZ	Alpha track etch detectors for surface alpha contamination	H-4-1 (\$.4M;\$10)
	CHAR-263-OZ	Portable gamma-ray scintillometers	H-4-0 (\$0M;\$100)
Uranium and Other Radioactive elements—laboratory methods	CHAR-107-OZ	Neutron activation, Delayed neutron analysis	H-4-1 (\$.2M;\$300)
	CHAR-106-OZ	Sodium iodine-germanium gamma spectroscopy	H-4-0 (\$0M;N)
	CHAR-97-OZ	Photon Electron Rejecting Alpha Liquid Scintillation (PERALS)	
	CHAR-108-OZ	Proportional counter for alpha and beta activity	H-5-0 (\$.1M;\$100)
	CHAR-266-OZ	Neutron activation analysis, Induced gamma analysis	H-4-1 (\$.2M;\$300)
	CHAR-268-OZ	Gamma-ray spectrometry	H-5-0 (\$.1M;\$100)
	CHAR-267-OZ	Liquid scintillation counting	H-5-0 (\$.1M;\$100)
Mercury and other metals—field methods	CHAR-76-OZ	Atomic emission spectroscopy	M-5-1 (\$.2M;\$N)
	CHAR-316-OZ	Gold Amalgam Resistance Analyzer	
	CHAR-308-OZ	Portable Mercury Headspace Analyzer	
	CHAR-6-OZ	Portable X-ray fluorescence	H-5-1 (\$.2M;\$25)

Table 3.1 (continued)

Alternative	Data sheet code numbers	Technology	Ranking ^a
Mercury and Other Metals—laboratory methods	CHAR-78-OZ	Inductively coupled plasma—mass spectroscopy	H-4-2 (\$1M;\$200)
	CHAR-77-OZ	Inductively coupled plasma atomic emission spectroscopy (ICPAE)	H-4-0 (\$1M;\$200)
	CHAR-76-OZ	Atomic Absorption Spectroscopy	H-4-0 (\$1M;\$200)
	CHAR-207-OZ	Capillary Electrophoresis	
	CHAR-50-OZ	Ion chromatography	H-4-0 (\$.1M;\$100)
	CHAR-37-OZ	Electron diffraction	M-4-0 (\$0M;\$100)
	CHAR-36-OZ	Wavelength dispersive X-ray spectroscopy	M-4-0 (\$0M;\$100)
	CHAR-35-OZ	Energy dispersive X-ray spectroscopy	M-4-0 (\$0M;\$100)
	CHAR-34-OZ	Transmission electron microscopy	M-4-0 (\$0M;\$100)
	CHAR-33-OZ	Scanning electron microscopy	M-4-0 (\$0M;\$100)
	CHAR-17-OZ	Particle-induced X-ray emission	M-4-0 (\$0M;\$100)
	CHAR-56-OZ	Glow discharge ionization mass spectroscopy	H-4-1 (\$.5M;N)
	CHAR-24-OZ	Cold vapor (mercury) analysis	H-4-0 (\$0M;\$100)
	CHAR-266-OZ	Neutron activation analysis, Induced gamma analysis	H-4-1 (\$.2M;\$200)
	CHAR-31-OZ	Powder X-ray diffraction	M-4-0 (\$0M;>\$100)
	CHAR-1-OZ	Electron spectroscopy for chemical analysis	M-4-0 (\$0M;\$200–\$600)
	CHAR-2-OZ	Auger electron spectroscopy	M-4-0 (\$0M;\$300–\$800)
Organics (except PCBs)—field methods	CHAR-5-OZ	Portable volatile organic compound detectors (Photo or Flame ionization)	H-5-0 (\$.25M;\$10)
	CHAR-90-OZ	Direct sampling ion trap mass spectrometry	H-5-2 (\$.2M;\$50)
	CHAR-101-OZ	Synchronous fluorescence screening for polycyclic aromatic hydrocarbons	M-4-1 (\$.2M;<\$50)
	CHAR-256-OZ	Volatile Organic Analysis (VOA)	
	CHAR-262-OZ	Gas chromatography in the field	H-5-0 (\$.25M;\$50)

Table 3.1 (continued)

Alternative	Data sheet code numbers	Technology	Ranking ^a
Organics (except PCBs)—laboratory methods	CHAR-207-OZ	Capillary Electrophoresis	M-5-1 (\$.25M;\$300)
	CHAR-115-OZ	On-line supercritical fluid extraction—multidetector gas chromatography	H-5-1 (\$.25M;\$300)
	CHAR-66-OZ	Gas chromatography-Fourier transform infrared spectroscopy	H-5-2 (\$.5M;\$400)
	CHAR-89-OZ	Liquid chromatography—mass spectrometry	H-5-1 (\$.34M;\$500)
	CHAR-88-OZ	Gas chromatography—mass spectrometry	E-5-0 (\$0M;\$200–\$800)
	CHAR-101-OZ	Synchronous fluorescence screening for polycyclic aromatic hydrocarbons	M-5-1 (\$.2M;\$10)
	CHAR-94-OZ	Gas chromatography	E-5-0 M;\$0M;\$300)
Asbestos—laboratory methods	CHAR-31-OZ	Powder X-ray Diffraction (XRD)	
	CHAR-32-OZ	Optical Microscopy	
	CHAR-33-OZ	Scanning Electron Microscopy (SEM)	
	CHAR-34-OZ	Transmission Electron Microscopy (TEM)	
Inorganic—Nonmetals—field methods	CHAR-317-OZ	Selective Reaction/Wet Chemistry Field Test Kits	
Inorganics—Nonmetals—laboratory methods	CHAR-50-OZ	Ion Chromatography	
	CHAR-207-OZ	Capillary Electrophoresis	
	CHAR-318-OZ	Selective Ion Electrodes	
	CHAR-319-OZ	Colorimetric Methods	
	CHAR-9-OZ	UV/VIS Spectrophotometry	
Polychlorinated Biphenyls (PCBs)—field methods	CHAR-100-OZ	Gas Chromatography with electron capture detector	
	CHAR-99-OZ	PCB Immunoassay Kit	
	CHAR-??	Surface Wave Detector, PCB sensitive	
	CHAR-90-OZ	Direct Sampling Ion Trap Mass Spectroscopy	
	CHAR-271-OZ	Sampling Interface for surface contamination	

Table 3.1 (continued)

Alternative	Data sheet code numbers	Technology	Ranking ^a
Polychlorinated Biphenyls (PCBs)—laboratory methods	CHAR-100-OZ	Gas Chromatography with electron capture detector	
	CHAR-90-OZ	Ion Trap Mass Spectroscopy (and other mass spec technologies)	
	CHAR-115-OZ	On-line supercritical fluid extraction—multidetector gas chromatography	
DNAPLS, Mercury—location of	CHAR-274-OZ	In-situ Groundwater Monitoring	
	CHAR-83-OZ	Wells..	
	CHAR-323-OZ	Ground Fracture Characterization	
	CHAR-60-OZ	Tomographic Seismic Monitoring	
	CHAR-256-OZ	Volatile Organic Detection from Soils and Sediments	
	CHAR-64-OZ	Multiangle Drilling for Depth Profiling of Contaminants	
	CHAR-123-OZ	Ultrasonic Ranging and Data System (USRADS)	
	CHAR-124-OZ	Ground Penetrating Radar...	
	CHAR-125-OZ	Electrical and Electromagnetic Detection of Ground and Geologic Features	
	CHAR-126-OZ	Seismic Methods (reflection, refraction, profiling)	
Physical Characterization—laboratory methods	CHAR-26-OZ	Particle size analysis	M-5-0 (\$0M;\$1000)
	CHAR-32-OZ	Optical microscopy	H-5-0 (\$0M;\$100-\$800)
Biological Waste			
Pathogens—laboratory method	CHAR-215-OZ	Pathogen surveillance	E-5-1 (\$.25M;\$50-\$250)
Buried Waste—Leaching			
Sample collection—field methods	CHAR-274-OZ	In-Situ ground-water monitoring	
	CHAR-273-OZ	SEAMIST inverted membrane	H-5-1 (\$.6M;\$15K)
	CHAR-25-OZ	Fiber-optic chemical sensors	H-5-1 (\$1M;\$3.3M)

Table 3.1 (continued)

Alternative	Data sheet code numbers	Technology	Ranking ^a
Buried Waste—Subsidence			
Physical Characterization	CHAR-272-OZ	Electromagnetic Offset Survey (CHECK THIS)	H-1-2 (\$5M;\$3.3M)
	CHAR-NEW	Surveying/Ranging	
Quarries/Impoundments			
Radiation Detection-field method	CHAR-320-OZ	Underwater Remote Radiation Monitor	
Physical Characterization—field methods	CHAR-321-OZ	Sonar Detection of Underwater Objects	
	CHAR-125-OZ	Electrical and Electromagnetic Methods	
	CHAR-128-OZ	Magnetics	
	CHAR-126-OZ	Seismic Methods (reflection, refraction, profiling)	

^a The technologies are ranked according to the following criteria:

- Overall assessment of the usefulness of the technology (E, H, M, and L, where E is for essential, H for high, M for medium, and L for low usefulness).
- A ranking of the site problem (1–5 is the scale of lowest significance to highest significance).
- Time required to bring the technology to an acceptable state for application at large scale (commercial or mature state) at the site (this is expressed in number of years and depends on the current state of its development).
- The cost for bringing the technology from its present state to large-scale commercial use (the costs are presented as \$M or \$K, which indicate the number of millions or thousands of dollars without escalation).
- Projected unit processing cost for mature technology (\$ per ft² or other unit or N for no estimate).

An example of a ranking follows: H-5-5 (\$3.5M;N). This means that this technology has a high overall usefulness; the problem is of highest significance to the site; the technology is estimated to take 5 years before it is ready for application at the site; an approximate expenditure of \$3.5 million will be required to bring the technology to this state of readiness; and the unit processing cost cannot be projected at the present time.

^b Kam = thousands of dollars annual maintenance.

^c EPA = Environmental Protection Agency.

^d PCBs = polychlorinated biphenyls.

4. Remedial Action

4. REMEDIAL ACTION

4.1 INTRODUCTION

In Chap. 1, environmental contamination at the Y-12 Plant was grouped according to source and media into the following site problem areas:

1. buried wastes,
2. soils and sediments,
3. impoundments/quarries,
4. groundwater and surface water,
5. pipelines, and
6. tanks.

The tanks problem area is not included in the RA section because it was assigned a low priority. Technologies currently in use are judged adequate for remediation of this problem area. Technologies for tanks are included in the characterization and waste management sections.

A technical team was organized to assess the RA needs and technologies for each problem area. Information collected for the K-25 Site and the Oak Ridge National Laboratory (ORNL) TLDs was utilized to the extent possible. Workshops focusing on areas not covered [i.e., mercury, dense nonaqueous-phase liquids (DNAPLs), quarries] in the previous TLDs were held with multiorganizational and multidisciplinary experts to define the problem areas and identify candidate remedial technologies. Efforts then focused on defining the status, science and technology needs, and implementation needs of the identified technologies. The team then gave rankings for development of the identified technologies (see Chap. 2 explanation). The approach taken for most problem areas was to identify technologies for the RA subelements: containment and isolation, in situ treatment, retrieval, and ex situ treatment. The technical team coordinated activities and cross-referenced data sheets (Vol. 2). In several instances it was necessary to prepare more than one data sheet for an individual technology due to differences in the status of development and needs associated with individual problem areas or contaminants.

This chapter is organized by sections discussing the technologies considered, science and technology needs, implementation needs, and technology rankings. Each section is in turn subdivided into the individual site problem areas.

4.2 DESCRIPTION OF TECHNOLOGIES CONSIDERED

4.2.1 Introduction

Technologies considered in each area are described and listed below. In all, this included more than 140 technologies, but even this is not a complete list. The list is the result of a selection by the experts who work in each area. The list includes technologies for interim, as well as permanent solutions, to the problem in each area. Some technologies may play an important role but may not be able to solve entire problems by themselves. For instance, some technologies can remove or destroy only one contaminant, and other technologies are only useful for retrieval of contaminated soil, wastes, etc. New technologies that are likely to be conceived and developed in the future are not covered.

4.2.2 Buried Wastes

Systematic evaluation of alternatives for buried waste sites resulted in three systems approaches: in situ hydrologic isolation or containment, in situ treatment, and retrieval followed by treatment. Each of the three systems entails a series of interrelated activities, each of which is essential for the success of the system. The in situ isolation/containment system includes definition of the design basis, which encompasses the design life, health/safety standards, structural criteria, environmental parameters, waste-form requirements, and cost limitations; site characterization; structural stabilization; actual isolation technologies; monitoring; and support activities (transportation, health & safety, decontamination of equipment, etc.). The in situ treatment system includes definition of the design basis; characterization of waste and site, and treatment technologies; verification of treatment effectiveness; site closure and monitoring; and support activities. The retrieval system includes definition of the design basis; waste and site characterization; retrieval; staging/storage; segregation/sorting/packaging; treatment/recycle/recovery/decontamination; disposal or recycle of residue; and support activities. Since other sections of the TLD examine technology development and support needs for characterization and monitoring, waste storage, site closure, and disposition of treatment residues, this section focuses on technology needs to support structural stabilization, containment and isolation, in situ treatment, retrieval, segregation/sorting/repackaging, and ex situ treatment.

Specific technologies that were evaluated for application to Y-12's buried waste problems are listed, along with their ranking, in Table 4.1 of Sect. 4.5. Data sheets for these technologies are available in Vol. 3.

Many of the technologies applicable to buried waste (e.g., barrier technologies) were also considered for remediation of contaminated solids and sediments and impoundments.

4.2.3 Soils and Sediments

Soil contamination at the Y-12 Plant has primarily resulted from leaks and spills from unlined impoundments, storage areas, underground pipelines, and buried waste/spoils. Additional contamination has resulted from waste burning and landfarming operations. Major contaminants include mercury, radionuclides (primarily uranium), volatile organic compounds (solvents and fuels), and PCBs. River and floodplain sediments have

accumulated mercury, uranium, and PCBs from contaminated surface water and groundwater discharges.

Technologies considered for the management of Y-12 contaminated soils and sediments are broadly divided into containment and isolation, treatment, and retrieval strategies. Within each type of strategy, individual technologies for both groups of contaminants and specific contaminants were considered. Due to the nature of plant operations and contaminant migration, remedial actions may consider the application of one or several types of strategies and technologies. For example, a combination of strategies may be required to remediate soil contaminated with both uranium and VOCs; however, only a single technology may be required to remediate soil contaminated with VOCs. The selection of a technology for remediation is highly dependent on the type of contaminant(s), their distribution in the soils/sediments (both in terms of depth within the profile and distribution among particle-size fractions), and its chemical form. Because this information is limited and because of the range of known contaminants, the descriptions of technologies are generalized in some instances. Because the prevailing waste management strategy for soil/sediments contaminated with radionuclides is disposal in burial grounds, technologies that reduce the volume of waste for disposal were also considered.

The following technologies were evaluated.

Treatment

- *Soil washing/extraction*—a broad term that involves size segregation of soil fractions using water as solvent to selectively extract specific contaminants (organic compounds, metals, and/or radionuclides) and using a variety of chemical leaching media. The major objective is volume reduction, when water is used, and the transfer of contaminants from the soil phase to a liquid phase, when specifically designed extraction media are used.
- *Thermal desorption*—for soils containing VOCs, ex situ vapor extraction techniques or thermal desorption processes could be readily applied. These technologies would be beneficial in the removal of RCRA volatile compounds from mixed wastes prior to containment in a burial ground.
- *Stabilization/fixation by grouting*—the primary purpose in the grouting of soils is to stabilize and reduce the mobility of contaminants in soil scheduled for disposal in landfills. The major detriment of grouting soils for disposal is the added volume. For most soils, grouting would be conducted using particulate-based grouting materials in commercially available mixers and blenders. Portland cements, because of their low cost, would be the predominant cementing agent. In certain instances, additives would be used for sorption or complexation of specific contaminants, depending on the mobility characteristics of the contaminant. In special cases, chemical-based grouting materials might be preferred because they do not add substantially to the volume of soil to be disposed of. However, their higher costs will generally preclude widespread use unless some low-cost chemical grouting materials are developed.
- *Soil vapor extraction*—for soils containing VOCs, in situ soil vapor extraction, thermally enhanced soil vapor extraction, and soil vapor extraction with radio frequency (RF) heating were evaluated. The latter two technologies are enhancements of soil vapor extraction.

- *High-temperature destruction*—several technologies (including incineration, molten glass combustor, chemical characterization process, plasma arc furnace, and cement kiln incineration) were considered for destruction of organic compounds in soil and sediments.
- *Chemical separation*—solvent extraction, chemical oxidation/reduction, and electrokinetics were considered for removal of organics, metals, and radionuclides from soils and sediments.
- *In situ vitrification*—encapsulation of metals and radionuclides in a durable glass and crystalline product by extreme heat.
- *Biotreatment*—this technology includes a wide range of biological processing options that rely on microbial transformation of organic compounds to remediate soils and sediments.

Retrieval

- *Entombed clamshell*—modified clamshell bucket used to dredge contaminated sediments.

Containment

- *Capping/barrier installation*—this technology involves the placement of a hydraulic barrier over and around contaminated soil. Materials used in this technology vary from flexible membrane liners to clay grouts. The major objective is to stop infiltrating rainwater and groundwater and inhibit the intrusion of plant roots and burrowing animals.

Mercury remediation

Technologies for remediation of mercury-contaminated soil and sediment were considered separately due to the unique nature of this contaminant and the extent of mercury contamination at the Y-12 Plant. The following technologies were considered.

- *Containment*—revetment systems for in-place containment of contaminated sediments and soils.
- *Physical separation*—beneficiation and roasting were considered for treatment of contaminated soils and sediments. Gas particulate removal for treatment of off-gases from remediation of mercury-contaminated soil was also considered.
- *Chemical separation*—acid washing, chemical extraction, and electrokinetics were considered for treatment of mercury-contaminated soil and sediments. Activated carbon, sulfur-impregnated activated carbon, and selenium sorbent were considered for treatment of off-gases from remediation of mercury-contaminated soil and sediment.
- *Fixation*—in situ vitrification and immobilization/fixation were considered for treatment of mercury-contaminated soil and sediment.

4.2.4 Pipelines

The longest pipeline being addressed by the ER Program, the Abandoned Nitric Acid Pipeline, which is buried, was used to transport a waste stream of nitric acid and uranium. Other pipelines being considered were primarily used to transport mercury-contaminated wastes.

Only two technologies were considered for treating the pipes themselves—excavation and fixation (probably with cement-based grout). Where the pipes have leaked considerably, there may be significant amounts of contaminated soil around pipes. Although such contamination may have to be removed or contained, treatment of contaminated soils around piping will be covered by soils and sediments technologies.

4.2.5 Impoundments/Quarries

The impoundments under consideration at the Y-12 Plant are primarily unlined basins that received process discharges resulting in contamination of the impoundment and potentially the surrounding soil and groundwater. The majority of the impoundments have been closed under the closure and postclosure activity (CAPCA) program. The surrounding soil in the impoundments, as well as some of the soils/sediments in the impoundments, can likely be treated with the technologies discussed in Sect. 4.2.3, but the localized concentrations in the impoundments may require special treatment. The major contaminants of concern include organic solvents, nitrates, radionuclides (primarily uranium), mercury, and heavy metals.

One of the two quarries under consideration at the Y-12 Plant was used for disposal of powerhouse fly ash and bottom ash. The other was used for disposal of containerized-water reactive waste. Remotely controlled operations have been used to remove/remediate the water reactive wastes.

Technologies considered for the remediation of impoundments and quarries are identified below. Technologies used or considered for remotely controlled remediation are discussed and evaluated in Chap. 5, Robotics and Automation.

Containment and Isolation

- *Capping*—this technology involves the placement of a hydraulic barrier over and around the contaminated impoundment.
- *Drains*—French drains, biopolymer drains, and horizontal wells aid in hydraulic isolation of the impoundments/quarries.
- *Walls/barriers*—grout curtains, slurry walls, sheet pile walls, clay bentonite additives and cryogenic barriers were considered for hydraulic isolation of the impoundments.

Treatment

- *Physical separation*—soil washing and in situ soil flushing were considered for removal of metals and radionuclides from impoundments. Sludge drying was also considered for removal of water from impoundment sediments as a pretreatment for storage/disposal.
- *Fixation*—in situ fixation using silicates, cements or polymers and ISV were considered for immobilizing contaminants in impoundment sediments.

Retrieval

- *Excavation*—mechanical excavation, vacuum loading, and dredging to retrieve contaminated impoundment/quarry sediments were considered.

Note that some technologies (sludge drying and soil washing) are ex situ treatment technologies that require mechanical excavation or vacuum loaders (technologies listed for waste retrieval), prior to processing. Similarly, cryogenic barriers are an in situ treatment that retain the contamination temporarily (perhaps for relatively long times) until permanent treatment plans are complete.

Several technologies aim to restrict the entry of water into the impoundment/quarry area. These include slurry walls, sheet-pile walls, grout curtains, French drains, capping, and biopolymer drains. These may be considered permanent or temporary solutions, depending upon the lifetime of the retention and the lifetime of the contaminant. These technologies can also be useful for preventing pollutant migration while the contaminated region is being treated.

Other impoundment technologies are in situ treatment for permanent solutions to the problems. These technologies may be of more interest for impoundments than for most soil contamination because impoundments are more likely to contain high local concentrations of contaminants that can be immobilized by solidification of relatively small volumes of soil.

4.2.6 Groundwater and Surface Water

Processes for removal of contaminants from groundwater and surface waters can be carried out in either of two general methods: in situ or aboveground. Some of the technologies considered have been practiced widely in the chemical process industries and can be designed with confidence for aboveground application. When such technologies (e.g., ion exchange) are considered for in situ application, uncertainties arise concerning the control of flow distribution and rate and monitoring concentrations and associating them with flow rates so that mass balances are closed properly. No experience is available to indicate efficiencies that may be expected when such materials must be replaced.

For radionuclides and heavy metals, the technologies evaluated were adsorption, ion exchange, precipitation, and artificial wetlands. For hydrocarbons, VOCs, and PCBs, the technologies evaluated were adsorption, biological oxidation, chemical oxidation, artificial wetlands, and air and steam stripping. For nitrates, the technologies evaluated were biological denitrification and artificial wetlands.

Adsorption requires that the water be contacted intimately with a solid sorbent, such as activated carbon, so that the contaminant distributes preferentially onto the solid phase. Usually such contacting is done in a tower filled with the sorbent (in the form of small pellets), providing a large surface area for mass transfer. Sorbents have been prepared from immobilized algae, which are said to be highly specific for certain contaminants. After the sorbent bed is fully loaded (exhausted), it may or may not be regenerated for reuse depending on process economics. Ion-exchange operations are quite similar to adsorption except that the contaminant must be an ionized species that replaces another ion carried by the fresh exchanger in the solid phase.

Precipitation of heavy metals and radionuclides can be enhanced by various reagents, iron hydroxide and aluminum hydroxide being the most common. Precipitation is carried

out in the ORNL Process Waste Treatment Plant and is an accepted technology. Artificial wetlands have been used for treating domestic sewage and coal mine runoff. Therefore, this technology has the potential to destroy organics and immobilize heavy metals. Application to Y-12 Plant groundwater and surface waters would require development work.

Biological degradation is used routinely to degrade water-soluble organics. More refractory contaminants, such as chlorinated solvents, may require specially designed treatment systems. Laboratory-scale tests have shown that higher-chlorinated PCBs can be dechlorinated anaerobically, and that lower-chlorinated PCBs can be dechlorinated aerobically. Chemical oxidation of organic contaminants has been demonstrated with potassium permanganate, ozone, and hydrogen peroxide.

For VOCs in water, air stripping has been promulgated a "best available technology." The operation is usually done by passing the water down a packed-column countercurrent to a rising air stream. The effluent air carrying organics may require treatment. The use of steam rather than air is a well-established industrial technology. The advantage of steam is that it can be condensed, which eliminates the problem of treating the effluent gas.

Technologies for remediating mercury and DNAPLs were evaluated separately (including some previously evaluated for groundwater/surface water) because of these contaminants unique characteristics and prominence at the Y-12 Plant. Physical separation treatment technologies evaluated included filtration systems, membrane systems, and soil vapor extraction. Chemical separation technologies evaluated for remediation of mercury-contaminated groundwater and surface water included adsorption technologies (activated carbon, sulfur-impregnated activated carbon, and biosorbents), ion exchange/chelating resins, chemical precipitation technologies, reverse osmosis, reduction mechanisms (chemical, borohydride, and biological), solvent extraction, and several patented processes (Empore process and Forager sponges). Destruction technologies considered for the remediation of DNAPLs included in situ bioremediation, in situ oxidation, and reactive gates. Isolation technologies considered for DNAPL remediation included clay expansion and sequestering in the brine zone. Product recovery technologies considered for remediating DNAPLs included surfactant flooding, air sparging, and pump and treat.

Many of the technologies considered are currently in use, including precipitation, adsorption, and reduction processes. Other technologies are being developed or demonstrated at the Y-12 Plant or other DOE facilities. For example, reactive gates are being developed at the PGDP.

4.3 SCIENCE AND TECHNOLOGY NEEDS

4.3.1 Introduction

This section highlights some of the R&D needed to make the technologies available for RA at the Y-12 Plant. For accepted technologies and even for some demonstrated technologies, there may be no science and technology needs. However, the soils, geology, and other conditions at the Y-12 Plant are unusually complex, and some testing, perhaps only treatability studies, may be needed, even for technologies that have been in common use elsewhere.

4.3.2 Buried Wastes

Needs for isolation/containment technologies include methods to minimize waste generation during application, guidance systems for grout injection/tunnelling, and development of waste-resistant materials for capping.

The applicability of thermal destruction technologies for buried wastes and the characteristics of the treated residue need to be determined. Methods for treating off-gas from thermal destruction are also needed.

Science and technology needs for fixation technologies include development of new chemical mixtures and application/injection equipment. This is especially critical to ensure and verify that containers are ruptured and grout/polymer has mixed with contents for in situ technologies. The development of compaction methods is needed to prevent flashing/overpressurization of waste during ISV.

Testing is needed to estimate the effectiveness and identify additives for freeze purification and thermal desorption. Soil simulation methods to promote conductivity for fractured air stripping are needed.

The majority of the structural stabilization technologies have been demonstrated and are available. Science and technology needs include testing to determine material compatibility for structural caps and solidification. Other needs include field tests with full-scale dynamic compaction equipment.

4.3.3 Soils and Sediments

One of the most important science and technology needs is an accurate and complete characterization of the contaminated soils and sediments. It is a gamble selecting the most appropriate remediation technology if properties of the contaminants and the soils and sediments are unknown. In many instances, the distribution and chemical form of the contaminants within particle-size fractions of the soils and sediments is important in determining the success or failure of a specific technology.

Once the soils and sediments at Y-12 have been fully characterized and the appropriate method chosen, material handling and in situ mixing/injection requirements will need to be studied. In situ operations are likely to be the least expensive, but environmental (weather) and topographical conditions may influence the final design of any facility. Ex situ methods, while more expensive, offer advantages in monitoring and control, not to mention operator convenience and comfort. Bench-scale studies should be initiated to investigate the potential advantages of volume reduction methods such as size classification, beneficiation, and soil washing/extraction, using soils presently on

hand. Other near-term science and technology needs include investigations relating to how much more efficiently vapor extraction of VOCs from Y-12 impermeable soils can be conducted. The effectiveness of chemical oxidation processes to destroy organic contaminants in these same high-silty and high-clayey soils also needs to be investigated.

Long-term science and technology needs at the Y-12 Plant involve the identification and testing of methods to remediate large volumes of soil that contain relatively low levels of uranium, mercury, and/or other hazardous contaminants. These include sediments contained in East Fork Poplar Creek and adjacent to many of the waste ponds and the contaminated soils along waste lines and in the low-level burial grounds. The first need is to thoroughly characterize these soils and sediments and evaluate the potential environmental and health risk associated with a "no remediation action" scenario. If an unacceptable risk is involved, bench-scale studies should be aggressively pursued. However, because of the time involved in making a risk analysis and in obtaining a regulatory approval of "no remediation action," it may be beneficial to start up (on a limited scale) some bench-scale testing of the more promising technologies.

Various methods of removing mercury vapor from gases generated during remediation of mercury-contaminated soil are being studied. Most of the current methods involve some type of filtration, using different filter media. Optimum operating conditions are not known for all methods, and studies must be done to resolve these unknowns. Key issues include characterization of off-gases to determine the types, species, and form of contaminants.

Methods of handling the spent filter media will also be a significant part of the project, because all treatment, whether disposal, regeneration, or neutralization, must meet regulatory requirements at all stages of the operation.

4.3.4 Pipelines

Both of the previously described technologies considered for treated buried piping are considered accepted, and there are not believed to be significant science and technology development needs. Only in the unexpected event that radioactivity or toxic hazard is sufficient to prevent direct participation of personnel with protective clothing would robotic or other new equipment be required.

4.3.5 Impoundments/Quarries

All of these technologies are accepted or have been demonstrated on somewhat similar sites. Usually the most important science and technology need is a sufficient understanding of the soil properties in the impoundment. In situ vitrification, in particular, needs an understanding of the behavior of all components during high-temperature treatment, such as volatilization, decomposition of organic compounds, and leachability of contaminants from the product glass. Although there is more experience with fixation of contaminants with cement-based grouts, this technology also needs treatability testing to confirm that all contaminants of interest are adequately contained within the grout.

Most of the in situ technologies, including the different types of barrier construction, have been used or demonstrated in soils that are far less complex than those in the Oak Ridge area. For instance, the complex flow patterns in the highly fractured soils at the Y-12 Plant make placement of barriers more complicated than in simpler and more nearly homogeneous sandy soils.

4.3.6 Groundwater and Surface Water

Chemical process operations are normally fine-tuned to operate at optimal conditions on the feed stream. A primary consideration concerning groundwater and surface water treatment is the variation in flow rates and contaminant concentrations that may be encountered. These variations are presently unknown, and determining them is a key factor in minimizing treatment costs. For aboveground treatment, consideration should be given to accumulating a feed reservoir to average out fluctuations in flow rates and concentrations.

For in situ technologies, the extent of the contaminated groundwater and its variation with climatological conditions must be identified, and this flow must be directed through the treatment zone. Subsurface structures to control groundwater flow must be demonstrated and costs established. Instrumentation for monitoring flow rates and contaminant levels for in situ applications is needed.

Actual remediation of the DNAPL is possible, but reduction of the DNAPL depends to a great extent on the ability to deliver the necessary remediation elements to the DNAPL. Methods must be devised to expose the DNAPL to the remediating agent, whether through injection directly into the DNAPL, or by excavation. In pump-and-treat remediation, more control over the in situ addition/removal process must be established.

Remediation of DNAPLs by surfactants will depend upon identification of a non-toxic surfactant within regulatory requirements that is capable of dispersing the DNAPL and the development of technology to collect (and prevent migration) the DNAPL once it is mobilized.

Science and technology needs for all methods of mercury reduction in ground and surface waters are likely to be significant. Some processes have been demonstrated in pilot-scale programs, while others exist only as concepts or theories. Some of the processes remove mercury and substitute more active contaminants, which is not an altogether satisfactory solution.

Some of the biological processes are subject to varying levels of performance due to climatic variations that are beyond the control of the most careful operators. Some of the filtration processes generate concentrated waste streams of significant proportions, and these waste streams will need treatment, thereby adding another level to the mercury-removal process.

Estimates of the costs for mercury removal vary depending upon the amount of mercury to be removed, the process chosen, and the volume of water to be treated. Engineering development of treatment facilities can only begin when these variables have been quantified.

4.4 IMPLEMENTATION NEEDS

4.4.1 Introduction

This section highlights some of the problems that must be overcome to use the technologies at the Y-12 Plant. These could include establishment of treatment limits and regulatory acceptance of the final treatment product. Some technologies do not solve the problems completely but are important single steps in the solution. In these cases, it will be necessary to have the other technologies available to complete the job. One particular group of technologies does not provide permanent solutions to the problems but provides containment of the pollutant, sometimes for long periods. Use of such technologies requires regulatory acceptance of delayed permanent treatment and development (perhaps future development) of permanent treatment technologies.

4.4.2 Buried Wastes

Field tests are needed to determine the long-term effectiveness of different materials for use as barrier walls or in fixation applications. Cold-test facilities are needed to check guidance systems for grout delivery prior to implementation.

Significant permitting and trial burn efforts are needed to establish the effectiveness of thermal destruction technologies and to obtain regulatory approval for implementation. Safety, product-quality, and field-process operations all need to be established.

Field testing of retrieval technologies under actual conditions is needed to demonstrate safety and precision.

4.4.3 Soils and Sediments

Pilot-scale testing of soil remediation technologies is needed before full-scale use. Presently, Y-12 and ORNL do not have facilities to conduct pilot-scale tests for soil remediation technologies, such as soil washing/extraction, chemical oxidation/reduction, thermal desorption, or incineration. Because of the potential to contaminate private vendor's equipment, contracting pilot-scale studies is not a cost-effective option. Contracting often restricts flexibility in design of experiments and in many cases does not offer a total systems approach. For example, many of the soil remediation technologies are based on separation of a contaminant from the soil (e.g., soil-vapor extraction, thermal desorption, soil washing/extraction, and electrokinetics) and treatment of the contaminant (using a destruction or containment process) is addressed separately. Accessibility to pilot-scale facilities at Y-12 or ORNL would be cost-effective, provide greater utility in technology evaluation, and ensure the correct scale-up to full-fledged treatment technologies.

To meet long-term science and technology objectives in soil remediation at Y-12, a determined program that evaluates potential environmental and health risks associated with large bodies of soils and sediments that contain relatively low levels of uranium, mercury and other toxic hazardous constituents, needs to be implemented. This program should include a major task in soil characterization that determines fate and transport of contaminants contained in the soils and sediments of concern. The program should be formed in such a manner so that the EPA and state of Tennessee regulatory agencies can actively participate. Goals should be established with a realistic timetable, dealing with expected dates of promulgation and cleanup levels. Implementation of a successful

program along these lines would aid significantly (in cost as well as time) in the selection of the most appropriate soil remediation technology for Y-12 sites.

4.4.4 Pipelines

Both of these technologies and the expected means of application are accepted. No unusual implementation needs are expected.

4.4.5 Impoundments/Quarries

Because the majority of the impoundments/quarries have been closed under CAPCA (or have had wastes removed in the case of Kerr Hollow Quarry), implementation needs center on determining final regulatory requirements. This will likely require a decision on future land use to determine the acceptability of continued containment and to weigh the costs/benefits of additional action.

4.4.6 Groundwater and Surface Water

Characterization of groundwater and surface water is needed to determine such parameters as pretreatment needs, flow rates, and contaminant form/specie. This information can then be used to design treatability studies to determine design parameters. Other implementation needs include regulatory guidance on cleanup levels and subsurface characterization for implementation of the DNAPL technologies. Many of the processes generate secondary waste streams and require additional treatment and disposal. Some of the biological treatment technologies generate mercury contaminated vegetation and/or sediments that themselves pose significant treatment/disposal problems.

4.5 TECHNOLOGY RANKINGS

4.5.1 Introduction

The rankings of RA technologies are presented in the following sections and summarized in Table 4.1. The criteria listed in Chap. 2, Sect. 2.4, were used to rank the technologies. It should be noted that the development and projected unit operating costs are rough order-of-magnitude estimates. Their validity is limited to the relative comparison of costs between technologies.

4.5.2 Buried Wastes

Table 4.1 summarizes the rankings of each technology addressed by the buried waste group. The rankings are briefly discussed by systems approach in the following sections.

4.5.2.1 Containment and Isolation Technologies

Challenges to hydrologic isolation of buried waste in the Y-12 Plant setting have been ranked in this study with direct-surface infiltration having the highest impact, near-surface storm-water flow of secondary impact, and deeper groundwater flow of least impact. Accordingly, technologies to prevent direct infiltration were ranked higher than technologies providing isolation from deeper groundwater.

In the evaluation of isolation technologies, vertical barriers were determined ineffective in the Y-12 Plant's geology, which does not provide an impermeable bottom seal. Higher priority was assigned to caps that prevent direct infiltration, and drains that divert shallow storm flow from buried waste areas. An exception was the high ranking of the slurry wall with HDPE screen, which can serve as a leachate collection/drainage/leak-detection system or possibly as a hydrobarrier to prevent contaminant migration through the wall down-gradient of contaminants.

4.5.2.2 In Situ Treatment

High priority was assigned to ISV, due primarily to its robustness and potential effectiveness in converting radionuclides to an excellent waste form, while destroying all organic hazards and combustible materials. Although ISV has been successfully demonstrated for contaminated soil, the challenges of off-gas pressurization and fluid pressurization within ambient containers must be addressed (possibly by in situ compaction) prior to application of this technology to buried waste.

Table 4.1. Rankings of remedial action technologies

Alternative	Data sheet code number	Technology	Contaminants	Ranking ^a
Buried waste group				
Containment and Isolation				
Structural Stabilization	REMA-1	Dynamic Compaction	Radionuclides, organics, metals	H-2-1 (\$0.5M;\$1.50/ft ²)
	REMA-81	Horizontal Mixed In-place	Radionuclides, organics, metals	H-2-2 (\$1.5M;\$275/yd ³)
	REMA-96	Structural Caps	Radionuclides, organics, metals	M-2-1 (\$.5M;\$1M/acre)
	REMA-82	Surcharge	Radionuclides, organics, metals	M-2-1 (\$0.25M;\$25/yd ³)
	REMA-5	In Situ Solidification	Radionuclides, organics, metals	M-2-2 (\$0.5M;\$150/yd)
	REMA-97	Thermal Set Resin Impregnation	Radionuclides, organics, metals	L-2-10 (>\$1M;<\$50/ton)
Capping	REMA-94	Intruder Barriers	Radionuclides, organics, metals	H-4-1 (<\$.5M;\$0.5M-\$7M/acre)
	REMA-46	Capping	Radionuclides, organics, metals	H-4-1 (<\$.5M;\$0.5M-\$7M/acre)
Bottom Seals	REMA-87	Vibrated Plastic Tube Bottom Seal	Radionuclides, organics, metals	L-4-3 (\$0.5M;\$200-\$300/ft ²)
	REMA-86	Microtunneled High-density Polyethylene Liner	Radionuclides, organics, metals	L-4-5 (\$3M;>\$500/ft ²)
	REMA-85	Jet Grouting	Radionuclides, organics, metals	L-4-1 (\$0.8M;\$150-\$300/ft ²)
Drains	REMA-44	Biopolymer Drains	Radionuclides, organics, metals	H-4-1 (<\$1M;\$15-\$20/ft ²)
	REMA-43	French Drains	Radionuclides, organics, metals	H-4-1 (<\$1;\$50-\$100/ft ²)
	REMA-45	Horizontal Wells	Radionuclides, organics, metals	H-4-1 (<\$1M;\$150/ft)
Walls	REMA-58	Cryogenic Barriers	Radionuclides, organics, metals	L-4-3 (<\$1M;-\$100/ft ²)
	REMA-84	Hydromill	Radionuclides, organics, metals	M-4-3 (<\$1M;\$40/ft ²)
	REMA-42	Grout Curtains	Radionuclides, organics, metals	M-4-1 (<\$1M;\$30-\$40/ft ²)
	REMA-40	Slurry Walls	Radionuclides, organics, metals	M-4-1 (<\$1M;\$15-\$20/ft ²)
	REMA-83	Slurry Walls with High-density Polyethylene Insert	Radionuclides, organics, metals	H-4-1 (\$2M-\$3M;-\$40/ft ²)
	REMA-41	Sheet Pile Walls	Radionuclides, organics, metals	M-4-2 (<\$1M;\$30-\$40/ft ²)
	REMA-88	Soil Saw	Radionuclides, organics, metals	L-4-2 (\$0.8M;\$70-\$80/ft ²)

Table 4.1. (continued)

Alternative	Data sheet code number	Technology	Contaminants	Ranking ^a
<i>In situ treatment</i>				
Destruction	REMA-99	In Situ Heating	Organics	L-4-8 (>\$1M;<\$50/ton)
	REMA-110	In Situ Biodegradation (buried waste)	Organics	L-4-5 (≤\$1M;<\$50/ton)
Fixation	REMA-3	In Situ Particulate Grouting	Radionuclides, organics, metals	M-4-2 (>\$1M;\$40-\$60/yd ³)
	REMA-2	In Situ Chemical Grouting	Radionuclides, organics, metals	M-4-2 (≤\$1M;\$60-\$100/yd ³)
	REMA-100	In Situ Vitrification (buried waste)	Radionuclides, organics, metals	H-4-5 (\$3M;\$60-\$100/yd ³)
Separation	REMA-89	Fracted Air Stripping	Organics	M-4-4 (\$2M;\$50-\$75/ton)
<i>Retrieval</i>				
Excavation	REMA-126	Bulk Item Exhumation	Large equipment	H-4-2 (≤\$1M;<\$50/ton)
	REMA-101	Vacuum Loader (buried waste)	Radionuclides, organics, metals	L-4-2 (≤\$1M;<\$50/ton)
	REMA-4	Borehole Mining (super soil stabilization management)	Radionuclides, organics, metals	L-4-3 (≤\$1M;\$50-\$100/yd ³)
	REMA-10	Solidify and Mine (freeze and mine)	Radionuclides, organics, metals	L-4-8 (≤\$1M;<\$50/ton)
	REMA-90	Precision Excavation	Radionuclides, organics, metals	H-4-1 (≤\$.5M;<\$50/ton)
	REMA-122	Modular Excavation	Radionuclides, organics, metals	M-4-8 (>\$1M;<\$50-\$100/ton)
<i>Ex situ treatment</i>				
Separation	REMA-93	Shredding and Magnetic Separation	Radionuclides, metals	L-4-1 (\$1M;\$0.2M/yr/system)
	REMA-121	Physical Sorting	Radionuclides, metals	M-4-1 (N;N)
	REMA-92	Thermal Desorption	Organics	L-4-3 (≤\$1M;\$35-\$120/ton)
	REMA-91	Freeze Purification	Radionuclides, organics, metals	L-4-5 (≤\$.5M;<\$50/ton)
	REMA-8	Gravity Sorting	Radionuclides, metals	L-4-3 (≤\$1M;\$0.35-\$1/lb)
	REMA-6	Soil Washing	Radionuclides, organics, metals	L-4-3 (≤\$.5M;\$70-\$150/ton)
Fixation	REMA-9	Cementitious Solidification	Radionuclides, organics, metals	H-4-3 (≤\$.5M;\$200-\$360/yd ³)
	REMA-112	Thermoplastic Encapsulation	Radionuclides, organics, metals	H-4-3 (≤\$.5M;\$25/ft ³)
	REMA-113	Thermoset Encapsulation	Radionuclides, organics, metals	H-4-3 (≤\$1M;\$30/ft ³)
	REMA-114	Sulfur Polymer Cement Encapsulation	Radionuclides, organics, metals	H-4-10 (≤\$1M;\$25/yd ³)

Table 4.1. (continued)

Alternative	Data sheet code number	Technology	Contaminants	Ranking ^a
Ex situ treatment (continued)				
Fixation (continued)	REMA-115	Polymer-impregnated Concrete/Polymer-modified Concrete	Radionuclides, organics, metals	M-4-8 (>\$1M;<\$50/ton)
	REMA-117	Vitrification	Radionuclides, organics, metals	M-4-6 (>\$1M;\$400-\$500/ton)
	REMA-116	Ceramic Encapsulation	Radionuclides, organics, metals	L-4-10 (N;N)
Destruction	REMA-95	Incineration	Organics, metals	H-4-1 (≤\$1M;>\$100/ton)
	REMA-98	Calcining/Sintering	Radionuclides, organics, metals	L-4-10 (>\$1M;<\$50/ton)
	REMA-7	Low-temperature Ashing	Radionuclides, organics, metals	H-4-6 (>\$1M;<\$50/ton)
Soils and sediments				
Containment	REMA-46	Capping	Radionuclides, organics, metals	M-5-1 (≤\$.5M;\$0.5-\$7M/acre)
	REMA-58	Cryogenic Barriers	Radionuclides, organics, metals	M-5-3 (≤\$1M;\$200-\$300/ft ²)
	REMA-148	Revetment System (Hg)	Mercury	H-5-1 (\$0.1M; NA)
Physical Separation	REMA-55	Soil Washing	Radionuclides, organics, metals	H-3-2 (≤\$.5M;\$70-\$150/ton)
	REMA-13	Low-temperature Thermal Treatment	PCBs	M-3-2 (\$1M;\$100-\$800/ton)
	REMA-11	Vapor Extraction with Radio Frequency Heating	Volatile organics	H-3-4 (≤\$1M;<\$100/ton)
	REMA-16	Thermal Desorption	Volatile organics, PCBs	H-3-2 (≤\$1M;\$35-\$120/ton)
	REMA-78	Soil Vapor Extraction	Volatile organics	H-3-3 (≤\$1M;\$50-\$75/ton)
	REMA-80	Thermally Enhanced Soil Vapor Extraction	Volatile organics	H-3-3 (≤\$1M;\$50-\$100/ton)
	REMA-143	Beneficiation (Hg)	Mercury	H-5-2 (\$.5M; N)
	REMA-144	Roasting (Hg)	Mercury	H-5-1 (\$.5M; N)
	REMA-163	Gas Particulate Removal (Air/Hg)	Mercury-Air ^d	M-5-1 (≤\$.5M; N)
Chemical Separation	REMA-119	Soils Treatment Using Solvent Extraction	Radionuclides, organics, metals	M-4-3 (\$3M-\$5M;\$200-\$300/ton)
	REMA-19	Electrokinetic Removal	Radionuclides, metals	L-4-4 (\$1M-\$10M;>\$100/ton)
	REMA-142	G.E. Iodine/Iodide (Hg)	Mercury	M-5-5 (\$5M; \$200-500/ton)
	REMA-145	Electrokinetics (Hg)	Mercury	M-5-5 (\$1-10M; ≥\$100/ton)
	REMA-141	Acid Washing (Hg)	Mercury	H-5-3 (\$.5M; 100-300 yd ³)

Table 4.1. (continued)

Alternative	Data sheet code number	Technology	Contaminants	Ranking ^a
Soils and sediments (continued)				
Chemical Separation (continued)	REMA-170	In Situ Emulsification/Amalgamation (Hg)	Mercury	M-5-5 (\$1M; N)
	REMA-160	Activated Carbon (Air/Hg)	Mercury-Air ^d	H-5-1 (\$0.1M; N)
	REMA-161	Sulfur-impregnated Carbon (Air/Hg)	Mercury-Air ^d	H-5-1 (\$0.1M; N)
	REMA-166	Mercury Scrubbers (Air/Hg)	Mercury-Air ^d	M-5-3 (\$1M; N)
	REMA-162	Selenium Sorbent (Air/Hg)	Mercury-Air ^d	M-5-5 (\$5M; N)
Destruction	REMA-118	Soils Treatment Using Bioremediation	Organics	M-3-3 (\$3M-\$5M;\$100-\$200/ton)
	REMA-120	Soils Treatment Using Oxidation or Reduction	Organics, metals	M-3-3 (\$3M-\$5M;\$100-\$200/ton)
	REMA-12	Incineration	Organics, PCBs ^b	M-3-2 (\$1M-\$2M;\$100-\$800/ton)
	REMA-15	Molten Glass Combustor	Organics, PCBs ^f , nitrates	M-3-3 ($\leq$ \$1M; $>$ \$200/ton)
	REMA-20	Chem Char Process	Organics, PCBs, metals	L-4-4 (\$1M; $<$ \$50-\$100/ton)
	REMA-17	Plasma Arc Furnace	Radionuclides, organics, PCBs, metals	M-4-3 (\$10M; $<$ \$50-\$100/ton)
	REMA-14	Incineration, Cement Kiln	Organics, PCBs	M-3-3 ($\leq$ \$1M; $<$ \$50/ton)
Fixation	REMA-18	In Situ Vitrification	Radionuclides, organics, metals	M-4-3 ($\leq$ \$5M;\$390/ton)
	REMA-54	Stabilization/Fixation by Grouting	Radionuclides, organics, metals	M-4-2 ($\leq$ \$1M;\$75/ft ³)
	REMA-139	Immobilization/Fixation (Hg)	Mercury	M-5-0 (\$0.1M; \$50-100/ton)
	REMA-171	Immobilization Using Elemental Sulfur (Hg)	Mercury	M-5-5 (\$1M; N)
	REMA-140	In Situ Vitrification (Hg)	Mercury	M-5-2 (\$1M; \$390/ton)
Retrieval	REMA-124	Entombed Clamshell	Radionuclides, organics, metals	H-5-0 ($\leq$ \$5M; $<$ \$25-\$50/yd ³)
Pipeline group				
Excavation	REMA-53	Pipeline Excavation	Mercury, nitrates, uranium	H-1-0 (\$0; $<$ \$25/yd ³)
Fixation	REMA-52	In Situ Grouting (pipeline)	Mercury, nitrates, uranium	H-1-1 (\$0;-\$25-\$70/yd ³)
Impoundments/Quarries				
Capping	REMA-46	Capping	Radionuclides, organics, metals	H-2-1 ($\leq$ \$5M;\$0.5-\$7M acre)
Drains	REMA-43	French Drains	Radionuclides, organics, metals	H-2-1 ($\leq$ \$1M;\$50-\$100/ft ²)
	REMA-44	Biopolymer Drains	Radionuclides, organics, metals	H-2-2 ($\leq$ \$1M;\$15-\$20/ft ²)
	REMA-45	Horizontal Wells	Radionuclides, organics, metals	H-2-3 ($\leq$ \$5M;-\$150/ft ²)

Table 4.1. (continued)

Alternative	Data sheet code number	Technology	Contaminants	Ranking ^a
Impoundments/Quarries (continued)				
Walls	REMA-58	Cryogenic Barriers	Radionuclides, organics, metals	M-2-3 ($\leq \$1M; \$200\text{--}\$300/\text{ft}^2$)
	REMA-42	Grout Curtains	Radionuclides, organics, metals	M-2-2 ($\leq \$1M; \$30\text{--}\$40/\text{ft}^2$)
	REMA-40	Slurry Walls	Radionuclides, organics, metals	M-2-3 ($\leq \$1M; \$15\text{--}\$20/\text{ft}^2$)
	REMA-41	Sheet Pile Walls	Radionuclides, organics, metals	M-2-2 ($\leq \$1M; \$30\text{--}\$40/\text{ft}^2$)
	REMA-60	Clay/Bentonite Additives	Radionuclides, organics, metals	L-2-1 ($\leq \$0.5M; \$0.55/\text{ft}^2$)
Physical/ Chemical Separation	REMA-51	Soil Washing (impoundments)	Radionuclides, organics, metals	M-2-2 ($\leq \$0.5M; \$70\text{--}\$150/\text{ton}$)
Physical Separation	REMA-47	In Situ Soil Flushing	Radionuclides, organics, metals	M-2-3 ($\leq \$0.5M; < \$50/\text{ton}$)
	REMA-56	Sludge Drying	Radionuclides, organics, metals	M-2-3 ($\leq \$1M; < \$50/\text{ton}$)
Fixation	REMA-57	In Situ Fixation	Radionuclides, organics, metals	H-2-1 ($\leq \$1M; \$50\text{--}\$75/\text{yd}^3$)
	REMA-59	In Situ Vitrification (impoundments)	Radionuclides, organics, metals	M-2-3 ($\leq \$0.5M; \$25/\text{yd}^3$)
Excavation	REMA-50	Mechanical Excavation	Radionuclides, organics, metals	H-2-1 ($\leq \$0.5M; < \$50/\text{ton}$)
	REMA-49	Vacuum Loaders	Radionuclides, organics, metals	H-2-1 ($\leq \$0.5M; < \$50/\text{ton}$)
	REMA-48	Dredging	Radionuclides, organics, metals	H-2-1 ($\leq \$0.5M; < \$50/\text{ton}$)
Groundwater and surface water				
Chemical separation	REMA-65	Ion Exchange	Radionuclides, inorganics	H-3-1 ($\$1M; \$5\text{--}\$10/1000\text{ gal}$)
	REMA-34	Precipitation	Radionuclides, inorganics	M-3-1 ($\$1M; \$100\text{--}\$1000/1000\text{ gal}$)
	REMA-167	Solvent Extraction (Hg)	Mercury	M-5-2 ($\$2M; N$)
	REMA-168	Bioreduction/Purging (Hg)	Mercury	M-5-3 ($\$2.5M; N$)
	REMA-66	Activated Carbon	Organics, inorganics	H-3-0 ($\$0M; \$5\text{--}\$10/1000\text{ gal}$)
	REMA-129	Activated Carbon (Hg)	Mercury	H-5-0 ($\$0; \$5\text{--}\$10/1000\text{ gal}$)
	REMA-128	Sulfur-impregnated Activated Carbon (Hg)	Mercury	H-5-1 ($\leq \$0.5M; \$5\text{--}\$10/1000\text{ gal}$)
	REMA-130	Biosorbents (Hg)	Mercury	H-5-2 ($\$2M; N$)
	REMA-131	Precipitation (Hg)	Mercury	M-5-3 ($\leq \$0.5M; \$5\text{--}\$10/1000\text{ gal}$)
	REMA-132	Sulfide Precipitation (Hg)	Mercury	H-5-1 ($\leq \$0.5M; \$5\text{--}\$10/1000\text{ gal}$)
	REMA-133	Ion Exchange/Chelating Resins (Hg)	Mercury	H-5-0 ($\$0; \$10\text{--}\$20/1000\text{ gal}$)

Table 4.1. (continued)

Alternative	Data sheet code number	Technology	Contaminants	Ranking ^a
Groundwater and surface water (continued)				
Chemical Separation (continued)	REMA-169	Electrowinning (Hg)	Mercury	M-5-1 (≤\$.5M; N)
	REMA-135	Reverse Osmosis (Hg)	Mercury	M-5-1 (≤\$.5M; \$10-100/1000 gal)
	REMA-136	Borohydride Reduction and Filtration/Hg	Mercury	M-5-3 (\$2M; N)
	REMA-137	Cementation (Hg)	Mercury	H-5-2 (\$2M; N)
	REMA-138	Empore Process (Hg)	Mercury	H-5-2 (\$2M; N)
	REMA-164	Chemical Reduction (Hg)	Mercury	M-5-2 (\$2M; N)
	REMA-165	Forager Sponge (Hg)	Mercury	H-5-1 (≤\$0.1M; N)
Physical Separation	REMA-76	Air Stripping	VOCs ^c	H-3-0 (\$0;\$6-\$4.10/1000 gal)
	REMA-77	Steam Stripping	VOCs ^c	H-3-0 (\$0;\$8/1000 gal)
	REMA-147	Filtration Systems (Hg)	Mercury	M-5-1 (≤\$.5M; \$1-10/1000 gal)
	REMA-146	Membrane Filtration (Hg)	Mercury	M-5-1 (≤\$.5M; \$10-100/1000 gal)
Destruction	REMA-68	Biological Oxidation	Organics	H-3-1 (\$1M;\$10/1000 gal)
	REMA-72	Chemical Oxidation	Organics	M-3-2 (\$2M;\$100/1000 gal)
	REMA-69	Anaerobic Dechlorination	PCBs ^b	L-3-5 (\$5M;N)
	REMA-75	Biological Denitrification	Nitrates	H-3-1 (\$1M;\$200/1000 gal)
Product Recovery	REMA-154	Surfactant Flooding	DNAPLs	M-5-3 (\$5M; N)
	REMA-155	Air Sparging	DNAPLs	L-5-7 (\$5M; N)
	REMA-156	Pump and Treat	DNAPLs	M-5-1 (<\$1M; \$100-1000/gal DNAPL)
In situ processes				
Isolation	REMA-151	Clay Expansion	DNAPLs	M-5-5 (\$5M; N)
	REMA-157	Sequestering in the Brine Zone	DNAPLs	L-5-7 (\$10M; N)
Physical Separation	REMA-153	Soil Vapor Extraction (DNAPL)	DNAPLs	M-5-3 (\$5M; N)
Chemical Separation	REMA-64	In Situ Ion Exchange	Radionuclides, inorganics	L-3-3 (\$3M;N)
	REMA-62	In Situ Precipitation	Radionuclides, inorganics	L-3-3 (\$3M;N)
	REMA-74	In Situ Bioremedia Adsorption	Radionuclides, inorganics	L-3-3 (\$3M;N)

Table 4.1. (continued)

Alternative	Data sheet code number	Technology	Contaminants	Ranking ^a
In situ processes (continued)				
Chemical Separation (continued)	REMA-67	In Situ Activated Carbon	Organics, inorganics	L-3-3 (\$3M;N)
	REMA-70	In Situ Biological Oxidation	Organics	M-3-3 (\$2M;N)
	REMA-134	Artificial Wetlands (Hg)	Mercury	M-5-3 (\$3M; N)
Fixation	REMA-79	Cryogenic Immobilization	Radionuclides, organics, inorganics	H-5-2 (\$2M;N)
Destruction	REMA-61	In Situ Chemical Oxidation	Organics	M-3-2 (\$2M; a few\$/1000 gal)
	REMA-63	Artificial Wetlands	Organics, inorganics	M-3-3 (\$3M;N)
	REMA-71	In Situ Anaerobic Dechlorination	PCBs ^b	M-3-5 (\$5M;N)
	REMA-111	In Situ Biological Denitrification	Nitrates	H-3-3 (\$3M;N)
	REMA-149	In Situ Bioremediation (DNAPL)	DNAPLs	M-5-4 (\$5M; \$10-100/1000 gal)
	REMA-150	In Situ Oxidation (DNAPL)	DNAPLs	L-5-5 (\$5M; N)
	REMA-152	Reactive Gates	DNAPLs	L-5-7 (\$10M; N)
	REMA-158	Lasagna Process (DNAPL)	DNAPLs	M-5-3 (\$5M; N)

^a The technologies are ranked according to the following criteria:

- Overall assessment of the usefulness of the technology (E, H, M, and L, where E is for essential, H for high, M for medium, and L for low usefulness).
- A ranking of the site problem (1-5 is the scale of lowest significance to highest significance).
- Time required to bring the technology to an acceptable state for application at large scale (commercial or mature state) at the site (this is expressed in number of years and depends on the current state of its development).
- The cost for bringing the technology from its present state to large-scale commercial use (the costs are presented as \$M or \$K, which indicate the number of millions or thousands of dollars without escalation).
- Projected unit processing cost for mature technology (\$ per ft² or other unit or N for no estimate).

An example of a ranking follows: H-5-5 (\$3.5M;N). This means that this technology has a high overall usefulness; the problem is of highest significance to the site; the technology is estimated to take 5 years before it is ready for application at the site; an approximate expenditure of \$3.5 million will be required to bring the technology to this state of readiness; and the unit processing cost cannot be projected at the present time.

^b PCBs = polychlorinated biphenyls

^c VOCs = volatile organic compounds

^d Treatment of off-gases from remediation (roasting, etc.) of mercury-contaminated soils/sediments.

4.5.2.3 Retrieval and Ex Situ Treatment

Two technologies were ranked a high priority in waste retrieval. Excavation technologies, including precision excavation, were selected because they are already highly developed and readily adaptable to retrieval of low-activity waste. The development/demonstration needs for precision excavation focus on contamination control. Also given a high ranking for development/demonstration was bulk item exhumation because of the need to remove large buried objects safely.

Segregation/sorting technologies ranked lower than other subelements for two reasons. First, the need for segregation will be driven by the primary treatment technology, which is undefined. Second, the buried waste is not characterized well enough to determine relative proportions of different treatment groups (e.g., metals). The highest ranked technology in this area was physical sorting, because it is already used for newly generated waste and because it provides for segregation into a larger number of treatment categories.

A group of thermal treatment technologies and a group of solidification technologies were ranked high in ultimate treatment. Incineration, vitrification, and low-temperature ashing were selected because of their effectiveness, robustness, and tremendous waste-reduction effects. Low-temperature ashing has the potential of providing better control of semi-volatile contaminants. Technology development/demonstration needs focus on off-gas treatment and development of a final waste form. High-ranking solidification technologies included cement solidification, thermoplastic encapsulation, thermoset encapsulation, and sulfur polymer cement encapsulation.

4.5.3 Soils and Sediments

Roasting (Hg) and acid washing (Hg) were ranked a high priority (Table 4.1) because of their demonstrated ability to remove mercury, the major contaminant of concern. Revetment systems and beneficiation were also given a high ranking because of their potential to isolate (or segregate) mercury. Adsorption processes (activated carbon and sulfur-impregnated activated carbon) were given a high ranking for treatment of mercury contaminated off-gases. Technologies such as soil vapor extraction and thermal desorption were given a high priority for physical separation of organic compounds. It should be noted, however, that since these technologies are limited to organics their site problem rankings are lower. Soil and sediment remediation technology rankings are expected to change over time as near-term priorities focused on ex situ treatment change to long-term priorities focused on in situ treatment.

4.5.4 Pipelines

Both technologies evaluated for remediation of buried pipelines were given high rankings (see Table 4.1). Both technologies are currently used for remediation of buried pipelines, and their effectiveness has been demonstrated.

4.5.5 Impoundments/Quarries

Technologies receiving the highest rankings (see Table 4.1) included all excavation and capping and drainage technologies because these are likely to be the most critical for remediation of impoundments. In situ fixation was also rated high, primarily for its

demonstrated ability to immobilize wastes. The other technologies were ranked lower due to their limited applicability and limited effectiveness for the site conditions.

4.5.6 Groundwater and Surface Water

Technologies receiving the highest rankings were adsorption (activated carbon, biosorbents, sulfur-impregnated activated carbon and Forager Sponge), ion exchange, cementation, and sulfide precipitation for their demonstrated effectiveness in the removal of mercury, the major contaminant of concern. Physical separation technologies for VOCs such as air stripping were also ranked high. Ion exchange received a high ranking for inorganics and denitrification for nitrates. It should be noted that because these technologies are of limited versatility their site problem ranking is lower.

5. Robotics and Automation

5. ROBOTICS AND AUTOMATION

5.1 INTRODUCTION

There are a number of reasons why robotics/automation would be used for RA activities, including (1) to perform a task more efficiently than by direct human involvement or (2) to remove the humans from the hazardous environment and minimize the danger level to the humans. Both of these reasons are encountered in RA activities.

For the purpose of identifying the robotics/automation technologies applicable to RA, the RA activities have been grouped into six problem areas, as follows:

- buried waste,
- impoundment,
- soils,
- groundwater, and
- buried pipes.

Some of these problem areas will require very little involvement by robotics/automation while others may require extensive involvement, at least until the hazard level associated with the activity has been better defined. Further, each of these problem areas requires a somewhat different mix of robotics/automation technologies. It should also be noted that, in general, robotics/automation supports those other technological activities—including characterization, retrieval, and treatment—necessary to perform the actual remediation tasks.

5.2 TECHNOLOGY OPTIONS

The robotics/automation technologies that are applicable to RA activities are listed in Table 5.1 (an X indicates which technologies are applicable to specific RA problem areas). As shown in the table, the robotics/automation technologies are grouped into nine functional categories. The technologies listed for RA tasks are primarily those required (1) to locate, characterize, and retrieve buried wastes, including buried pipes and (2) to sample and remove contaminated soil. Robotics/automation will have fewer applications in impoundment or groundwater treatment applications.

Generally, it will be necessary to combine a number of these robotics/automation technologies into integrated systems before a particular RA task can be performed effectively. For example, having a remotely operable vehicle (ROBA-2-OL) available to locate or characterize buried waste would not be particularly useful unless appropriate detection sensors (ROBA-47-OL), operator interfaces (ROBA-38-OL), and data/signal transmission devices (ROBA-13-OL) are also available. In setting priorities for needed R&D, consideration was also given to integrated robotics/automation systems.

Table 5.1. Relationship of robotics/automation technologies to remedial action problems

Data sheet code number	Remedial action problem area				
	Buried waste	Impound- ment	Soil	Ground water	Buried pipes
Mechanical—mobility					
ROBA-1-OL	X ^a	X	X	X	X
ROBA-7-OL		X			
ROBA-9-OL					
ROBA-10-OL	X	X	X	X	X
ROBA-11-OL	X		X		
ROBA-12-OL	X		X		X
ROBA-13-OL	X	X	X	X	X
Mechanical—manipulation					
ROBA-16-OL	X				X
ROBA-19-OL	X				X
Mechanical—mechanisms					
ROBA-21-OL					X
ROBA-22-OL	X				X
Mechanical—end-of-arm tooling					
ROBA-23-OL	X				X
ROBA-24-OL	X				X
ROBA-25-OL	X				X
ROBA-26-OL	X				X
Controls—algorithms					
ROBA-27-OL	X		X		X
ROBA-28-OL	X		X		X
ROBA-29-OL	X		X		X
ROBA-30-OL	X				X
ROBA-31-OL					
ROBA-32-OL	X		X		X
ROBA-33-OL					
ROBA-34-OL	X				X
ROBA-35-OL	X		X		X
ROBA-37-OL	X	X	X	X	X

Table 5.1 (continued)

Data sheet code number	Remedial action problem area				
	Buried waste	Impound- ment	Soil	Ground water	Buried pipes
Controls—human/machine interface					
ROBA-38-OZ	X	X	X	X	X
ROBA-39-OZ	X		X		X
ROBA-40-OZ	X		X		X
ROBA-41-OZ					X
ROBA-42-OZ	X	X	X	X	X
Sensors—perception					
ROBA-43-OZ	X	X	X	X	X
ROBA-44-OZ					
ROBA-45-OZ					
ROBA-46-OZ	X		X		X
ROBA-47-OZ	X		X		X
Sensors—control					
ROBA-48-OZ	X		X		X
ROBA-50-OZ	X				X
ROBA-51-OZ					
ROBA-52-OZ	X		X		X
Other technologies					
ROBA-53-OZ	X	X	X	X	X
ROBA-54-OZ	X				X
ROBA-55-OZ	X	X	X	X	X
ROBA-56-OZ	X	X	X	X	X
ROBA-57-OZ	X	X	X	X	X
ROBA-58-OZ	X	X	X	X	X
ROBA-59-OZ	X	X	X	X	X

^bAn X indicates that a technology is applicable to an RA problem area.

5.3 SCIENCE AND TECHNOLOGY NEEDS

Specific needs, with short explanations of the reasons why additional R&D is required, are given below for each of the RA problem areas.

5.3.1 Buried Wastes and Buried Pipes

Many of the records showing the location and the contents of buried-waste fields have either been lost or destroyed, or accurate records were never kept. Since the hazards associated with these waste fields are not well defined and may exceed those to which humans can be exposed, the surveys necessary to characterize these burial grounds will be performed remotely using teleoperated or robotic vehicles to deploy the detection sensors. Needs related to this activity are included in the following sections:

5.3.1.1 Remotely Deployable, Nonintrusive Sensors (ROBA-47-OZ)

Present sensors have limited usefulness. Ground-penetrating radar has limited range in the soil encountered on ORR, particularly if clay caps have been placed on the waste field. Conductivity probes can be disrupted by the metallic signature of the robotic vehicle used to deploy the probes. Radioactivity meters and organic gas detectors cannot indicate the burial depth or the quantity of buried materials. Efforts to improve the capabilities of sensors are required, and it is assumed this technology need will be addressed by characterization programs. The integration of these various types of sensors onto a remotely deployed vehicle is also a technology need that requires additional R&D. Addressing this need will minimize potential interference between the sensors and other systems on the deployment vehicle.

5.3.1.2 Low-Metallic Content, Remotely Driven Vehicle (ROBA-1-OZ)

A vehicle of this type is needed to minimize interference with the detection sensors carried by the vehicle. Some work in this area is presently being conducted by the Office of Technology Development Robotics Program, with a technical demonstration planned for later in this calendar year.

5.3.1.3 Tool Caddies (ROBA-21-OZ)

Methods of stowing various tools where they are easily accessible to a manipulator arm is a technology need that has not been adequately addressed in previous robotics/automation programs. The present approach is to move the manipulator away from the work site to a tool storage area when tool changes are necessary. Having an on-board tool caddy would greatly increase the efficiency of the remote operations and would be particularly useful in the repair or replacement of buried pipes where frequent tool changes may be necessary.

5.3.1.4 Navigation of Robotics Vehicles on Waste Sites (ROBA-29-OZ)

In the surveying of waste sites, relatively precise information on the position of the vehicles conducting the survey is required to relate data from the detection instruments to burial site location. Although several instruments to provide this information are

available commercially (e.g., Ultrasonic Ranging and Data System), they generally require line-of-sight between the detectors and the vehicle and may not be applicable to many of the terrains encountered on the Y-12 waste sites.

5.3.1.5 Force-Limiting and Compliant End-of-Arm Mechanisms (ROBA-26-OZ)

The development of a method of remotely adjusting and limiting the force that an arm or tool can exert on a surface is also a technology need for robotics/automation. Although force reflecting manipulators are commercially available, these units depend on the ability of an operator to sense forces transmitted back through the control system and are not sufficient to prevent damage during remote operations.

5.3.2 Soils

Large quantities of contaminated soils are present at Y-12. There is an economic incentive to minimize the amount of soil removed for treatment or waste disposal. The science and technology needs required for robotics/automation for soil remediation are summarized below.

5.3.2.1 Front-End Loaders and Backhoes for Minimum Soil Removal (ROBA-2-OZ)

A remotely operated, heavy-duty vehicle with sufficient sensors to control the depth of soil removal is a high priority science and technology need for robotics/automation. There is presently a jointly funded Department of Defense and DOE Office of Technology Development Robotics Program to develop the first prototype of a vehicle with these capabilities, and a technical demonstration was conducted late in calendar year 1993. This program should be continued to the point that the technology can be turned over to a private company for commercial deployment.

5.3.3 Impoundments

At present confinement of contaminants in sediments has been effectively controlled by lack of surface outflow from the quarries. In the future, however, if migration of the contaminants into the groundwater occurs, it may be necessary to consider techniques to remove the sediments from the impoundment areas or water-filled quarries.

5.3.3.1 Specialized Robotic Deployment Platforms (ROBA-7-OZ)

Use of available techniques for sediment removal (e.g., surface dredging) would result in a significantly greater release of contaminants during the treatment period. Methods of deploying equipment to remove sediments with minimal disturbance of the surrounding material are required. Underwater deployment of sediment removal equipment, using remotely operated submersibles, would be one method of accomplishing this task.

Remotely operated submersibles have been used for some time for off-shore oil rigs and ocean exploration. However, for shallow water operations in freshwater impoundments, experience has shown that the primary difficulty is the limited visibility. This is particularly true when the bottom sediment is being disturbed or, during warm weather months, when algae growth is at a maximum. In addition to specialized robotic

deployment platforms, specialized sensors (ROBA-43-OZ, -44-OZ, and -45-OZ) may also be required for these robotic applications.

5.4 IMPLEMENTATION NEEDS

For RA activities high-priority implementation needs are cold-test beds where the effectiveness of robotic systems to detect, characterize, sample, and remove buried wastes, buried pipes and soils can be demonstrated prior to performing the actual remediation effort.

An additional implementation need is quantitative information on the anticipated physical and radiological characteristics of the various waste materials, particularly those that are likely to be encountered in buried waste sites. Without this information, it will be very difficult to determine the required capabilities of the robotic systems used to deploy the sensors and tools needed for the remediation efforts.

5.5 TECHNOLOGY RANKINGS

The rankings of the robotics/automation technologies required for RA activities are given in Table 5.2. It should be noted that the criteria used for ranking are biased toward those technologies that are commercially available. Hence, a one-for-one comparison between the rankings and the science and technology needs identified in Sect. 5.3 is not possible (i.e. commercially available devices generally require little additional R&D). It should also be noted that several of the criteria suggested for ranking were not considered applicable to robotics/automation. These include (1) compliance with requirements or regulations, (2) ES&H requirements, and (3) unit processing costs. Others of the criteria have limited applicability to robotics/automation.

A number of the technologies were considered essential. However, many of these technologies also had a high ranking, which meant they were commercially available. The essential technologies were usually associated with highly ranked site problems also.

The development costs identified in Table 5.2 should be considered rough order-of-magnitude estimates. They have more validity in the comparison of relative costs between various robotics/automation technologies (i.e. they are internally consistent), than they do in their absolute magnitude.

Table 5.2. Rankings of robotics/automation technologies for remedial action

Data sheet code number	Technology	Ranking ^a
Mechanical—mobility		
ROBA-1-OZ	Wheeled/tracked vehicles	E-5-2 (\$3M;N)
ROBA-7-OZ	Specialized robotic deployment platforms	M-4-3 (\$5M;N)
ROBA-9-OZ	Long-arm deployed robotic platform	M-5-3 (\$5M;N)
ROBA-10-OZ	Power sources for mobile platforms	E-5-1 (\$0.5M;N)
ROBA-11-OZ	Failure recovery systems for mobile platforms	E-5-1 (\$0.5M;N)
ROBA-12-OZ	Transportation methods for mobile platforms	M-3-1 (\$0.5M;N)
ROBA-13-OZ	Data/signal transmission	E-5-1 (\$0.5M;N)
Mechanical—manipulation		
ROBA-16-OZ	Dexterous manipulators	E-5-1 (\$1M;N)
ROBA-19-OZ	Compact, high-capacity manipulators	H-5-1 (\$1M;N)
Mechanical—mechanisms		
ROBA-21-OZ	Tool caddies	H-4-1 (\$0.5M;N)
ROBA-22-OZ	Stabilization/support mechanisms or booms	M-3-1 (\$0.5M;N)
Mechanical—end-of-arm tooling		
ROBA-23-OZ	End effectors/alternatives	E-5-2 (\$1M;N)
ROBA-24-OZ	End-effector changeout mechanisms	M-3-1 (\$0.5M;N)
ROBA-25-OZ	General gripper/tool interface	H-4-1 (\$0.5M;N)
ROBA-26-OZ	Force limiting/compliant mechanisms	M-3-1 (\$0.5M;N)
Controls—algorithms		
ROBA-27-OZ	Control modes	E-5-N (\$N;N)
ROBA-28-OZ	Vehicle/mobility driving	E-5-1 (\$0.5M;N)
ROBA-29-OZ	Vehicle/mobility navigation	H-4-1 (\$0.5M;N)
ROBA-30-OZ	Manipulation (joint control)	H-4-1 (\$0.5M;N)
ROBA-31-OZ	Manipulation (Cartesian control)	H-4-1 (\$1M;N)
ROBA-32-OZ	Manipulation (special purpose control)	H-4-2 (\$1.5M;N)
ROBA-33-OZ	Manipulation (redundancy control)	M-3-2 (\$2M;N)
ROBA-34-OZ	Combined mobility/manipulation	M-2-2 (\$1M;N)
ROBA-35-OZ	Safety (collision avoidance)	H-4-1 (\$1M;N)
ROBA-36-OZ	Safety (load/rate limiting)	H-3-1 (\$0.5M;N)
ROBA-37-OZ	Emergency shutdown	E-4-1 (\$0.5M;N)
Controls—human/machine interface		
ROBA-38-OZ	Console (fixed/mobile/suitcase)	E-5-1 (\$0.5M;N)
ROBA-39-OZ	Console (data handling methods)	M-3-1 (\$1M;N)
ROBA-40-OZ	Operator interface (command input)	H-3-1 (\$0.5M;N)

Table 5.2 (continued)

Data sheet code number	Technology	Ranking ^a
Controls—human/machine interface (continued)		
ROBA-41-OZ	Operator interface (operator assistance)	H-3-2 (\$1.5M;N)
ROBA-42-OZ	Operator interface (status/alert system)	E-5-1 (\$0.5M;N)
Sensors—perception		
ROBA-43-OZ	Visual/aural systems	E-5-1 (\$1M;N)
ROBA-44-OZ	Range finders	M-3-2 (\$1.5M;N)
ROBA-45-OZ	Proximity probes	M-2-2 (\$1M;N)
ROBA-46-OZ	Force/torque (sensors)	M-2-1 (\$0.5M;N)
Sensors—control		
ROBA-48-OZ	Position/velocity sensors	E-5-1 (\$0.5M;N)
ROBA-50-OZ	Force/torque	H-3-1 (\$0.5M;N)
ROBA-51-OZ	Proximity probes as control sensors	H-3-1 (\$1M;N)
ROBA-52-OZ	Tooling sensors	H-3-1 (\$0.5M;N)
Other technologies		
ROBA-53-OZ	Field hardening	E-5-1 (\$0.5M;N)
ROBA-55-OZ	Integrated automated analytical laboratory	E-5-2 (\$3M;N)
ROBA-56-OZ	Information management for sample handling	E-5-1 (\$1M;N)
ROBA-57-OZ	Sample collection	E-5-1 (\$1.5M;N)
ROBA-58-OZ	Characterization sensor integration	M-5-2 (\$1M;N)
ROBA-59-OZ	Sample preparation	E-5-1 (\$1M;N)

^a The technologies are ranked according to the following criteria:

- Overall assessment of the usefulness of the technology (E, H, M, and L, where E is for essential, H for high, M for medium, and L for low usefulness).
- A ranking of the site problem (1-5 is the scale of lowest significance to highest significance).
- Time required to bring the technology to an acceptable state for application at large scale (commercial or mature state) at the site (this is expressed in number of years and depends on the current state of its development).
- The cost for bringing the technology from its present state to large-scale commercial use (the costs are presented as \$M or \$K, which indicate the number of millions or thousands of dollars without escalation).
- Projected unit processing cost for mature technology (\$ per ft² or other unit or N for no estimate).

An example of a ranking follows: H-5-5 (\$3.5M;N). This means that this technology has a high overall usefulness; the problem is of highest significance to the site; the technology is estimated to take 5 years before it is ready for application at the site; an approximate expenditure of \$3.5 million will be required to bring the technology to this state of readiness; and the unit processing cost cannot be projected at the present time.

6. Regulatory Compliance

6. REGULATORY COMPLIANCE

6.1 INTRODUCTION

Many government-owned facilities that supported the early nuclear energy research and defense programs have no current use and have been retired. Some of these DOE facilities have residual radioactive or chemical contamination levels that require cleanup. ER of these facilities is currently focusing on D&D of facilities and RA for contaminated soils, groundwater, and surface water. A related issue is WM of any wastes generated by these activities, as well as those wastes related to daily performance.

ORR was proposed by the EPA for placement on the National Priorities List under CERCLA on July 14, 1989 [54 *Federal Register (FR)* 29820], with final National Priorities Listing on Nov. 21, 1989, effective Dec. 21, 1989 (54 *FR* 48184). As a result of this listing, DOE, EPA, and TDEC (formerly the Tennessee Department of Health and Environment) have signed an FFA for the ER of ORR (effective Jan. 1, 1992). This FFA is an Interagency Agreement required by §120 of CERCLA. FFA §IV discusses the coordination between RCRA and CERCLA, and states that corrective actions previously established under DOE's current RCRA permit [Hazardous and Solid Waste Amendments (HSWA) of 1984 TN 001] and the TDEC RCRA permit (TN1 890 090 003) will be supplemented with response actions under CERCLA to ensure comprehensive remediation of ORR. Because ORR is on the National Priorities List, most RA activities and technologies will be legally subject to CERCLA regulation, and the FFA will govern the scheduling and character of such activities.

An effort is under way to incorporate into the FFA all inactive facilities that are known or suspected to contain significant quantities of residual hazardous materials. These facilities would be added to project lists under the FFA, and would subsequently undergo remediation pursuant to CERCLA or RCRA. Facilities that remain listed as D&D activities would be closed under the D&D program, subject to the regulatory drivers detailed in the *Y-12 D&D TLD for Bldg. 9201-4*, Chap. 8. The scope of this chapter will address regulatory drivers for remedial activities proceeding under RCRA and CERCLA.

Further, DOE has entered into a number of signed agreements with state and federal parties, as well as appraisals and audits that define committed milestones for ER and WM activities. Some of these major committed milestones impacting Y-12 RA activities include the *FFA for the ORR*, the *Tennessee/DOE Monitoring and Oversight Agreement (TOA)*, and the *Compliance Agreement Between the U.S. DOE - Oak Ridge Reservation and the EPA, Region IV (LDR-FFCA/ORR)*.

The FFA among DOE, EPA Region IV, and TDEC focuses on resolving compliance issues associated with ER of ORR. The agreement sets up a procedural framework and schedule for developing, implementing, and monitoring response actions conducted in compliance with RCRA, CERCLA, NEPA, Tennessee laws/regulations, and other applicable and appropriate requirements.

The TOA details the obligations and agreements between DOE and TDEC with respect to the DOE provision for technical and financial support of state environmental activities. These activities include participation in the FFA, covering ER of ORR, oversight, monitoring, accessing, and emergency response initiatives. Such activities are designed to ensure compliance with applicable federal, state, and local laws and regulations concerning ORR and its environs.

The LDR-FFCA/ORR was signed June 12, 1992, in order to bring mixed-waste generation and storage facilities at ORR into compliance with the RCRA land disposal restrictions (LDRs) for mixed waste. The LDR-FFCA/ORR allows DOE ORR facilities to continue to generate and store mixed wastes while addressing LDR mixed-waste compliance issues. The mixed wastes covered under the LDR-FFCA/ORR include flammable and corrosive liquids, solvents, paint waste, waste oils and organics, and solid-mixed wastes. The LDR-FFCA/ORR is addressed in more detail in Sect. 6.4.2.

The Federal Facility Compliance Act (FFCA) of 1992 (Public Law 102-386, October 6, 1992) will also have an impact on committed milestones for RA activities. This Act amends §6001 of the Solid Waste Disposal Act (SWDA) to waive immunity of the United States with respect to substantive and procedural requirements regarding control, abatement, or management of solid or hazardous waste, and is discussed in detail in Sect. 6.4.2.

DOE has also published its strategy for development of a national compliance plan for DOE mixed waste (57 FR 57170, December 3, 1992). DOE's National Compliance Plan will integrate ER and D&D activities with the development of appropriate mixed-waste treatment, storage and disposal capacity.

A second group of milestones, not considered commitments, are derived primarily from DOE's annual *Five Year Plan*, *Current Year Work Plans*, and *Activity Data Sheets*.

All of the above milestones, both committed and uncommitted, currently serve as regulatory drivers for RA activities in addition to applicable promulgated regulations triggered under CERCLA. This chapter will only define regulatory drivers for D&D and RA activities proceeding under CERCLA (i.e., FFA ER sites). These RA activities will address contaminated soil, groundwater, burial grounds, point and line sources of contamination, and pond-waste sludges. Regulatory drivers for those D&D activities that only involve decontamination and dismantling of buildings or structural components (i.e., sites that will not be listed under the FFA as ER sites) are addressed in the *Y-12 D&D TLD for Bldg. 9201-4*, Chap. 8. In addition to regulatory issues pertaining to RA, any wastes generated under any regulatory umbrella must be managed according to prescribed WM procedures.

6.2 OVERVIEW OF ENVIRONMENTAL LAWS AFFECTING RA ACTIVITIES

As DOE begins RA at some of its Y-12 facilities, special attention must be given to the environmental laws that will impact on these activities. These laws were promulgated to protect public health and the environment. The requirements of these environmental laws will dictate how the RA activities are to be carried out. This section gives a general overview of the major environmental regulations that will affect DOE RA activities.

The purpose of RCRA is to ensure the safe and environmentally acceptable management of hazardous and nonhazardous solid wastes. This law outlines the framework for national programs to achieve environmentally sound management of both hazardous and nonhazardous wastes. It is also concerned with the promotion of resource recovery techniques to reduce waste volume. The HSWA both expanded the scope of RCRA and increased the level of detail in many of its provisions.

CERCLA, as amended by Superfund Amendments and Reauthorization Act (SARA) of 1986, was passed in response to a growing national concern about the release of hazardous substances into the environment. CERCLA provides for liability, compensation, cleanup, and emergency response for hazardous substances released into the environment and the cleanup of inactive hazardous waste disposal sites. The intent of CERCLA is to provide for response to, and cleanup of, environmental problems that are not covered by the permit programs of the many other environmental laws.

CERCLA specifies that RA for cleanup of hazardous substances must comply with requirements or standards under federal or more stringent state environmental laws that are applicable or relevant and appropriate (ARAR) to the hazardous substances or particular circumstances at a site. Inherent in the interpretation of ARARs is the assumption that protection of human health and the environment is ensured. The National Oil and Hazardous Substances Pollution Contingency Plan was amended to reflect changes made by SARA. In particular, Subpart E, "Hazardous Substance Response," contains a detailed plan of authorized activities involved in abating and remediating releases or threats of releases of hazardous substances, including compliance with all ARARs. If remedial activities proceed under RCRA, compliance with all legally applicable federal and state regulations must be assured; under CERCLA, compliance is also required with regulations that meet the definition of "relevant and appropriate" as defined in the National Contingency Plan.

Despite the completion of RAs to clean up a release of a hazardous substance, a natural resource such as land, fish, wildlife, biota, air, water, groundwater, or drinking water supplies may suffer residual damages (i.e., the natural resource is not returned to the position it was in before the injury). In these situations, under the authority of CERCLA §122(j), a Natural Resource Trustee is authorized to conduct a natural resource damage assessment (NRDA). CERCLA authorized the Department of the Interior to promulgate regulations at 43 CFR 11 outlining the NRDA process. Because DOE caused the release, it becomes the responsible party and is liable to the Natural Resource Trustee(s) for financial compensation for the irreparable harm done to the natural resource. The NRDA process includes collecting, compiling, and analyzing information, statistics, or data through prescribed methodologies to determine damages for injuries to natural resources.

As a result of ORR's listing on the National Priorities List, DOE, EPA, and TDEC have signed a FFA for the ER of ORR. This FFA is an Interagency Agreement required by §120 of CERCLA. FFA §IV discusses the coordination between RCRA and CERCLA, and states that corrective actions established under DOE's current RCRA permit and the TDEC

RCRA permit will be supplemented with response actions under CERCLA to ensure comprehensive remediation at ORR. Because ORR is on the National Priorities List, most RA activities and technologies will be legally subject to CERCLA regulation, and the FFA will govern the scheduling and character of such activities. Following is a summary of all federal laws and regulations that may be legally applicable to cleanup of ER sites that are grouped in the FFA under the umbrella of CERCLA.

The Clean Air Act (CAA) of 1970 is the major federal law regulating process and facility air emissions. The objectives of the CAA are to protect and enhance the quality of the nation's air resources and to protect public health and welfare, while fostering a beneficial productive capacity. This is accomplished through National Ambient Air Quality Standards, National Emission Standards for Hazardous Air Pollutants, air permits, and other standards and requirements set forth under the CAA. The CAA amendments of 1990 established a list of 189 hazardous-air pollutants for which technology-based emission standards must be set. Depending on the type of activity or technology proposed, RA might be subject to any one or all of these CAA standards.

The Clean Water Act of 1972 (CWA) is the major water-related statute affecting D&D activities. The objectives of CWA include prohibition of toxic discharges, protection of fish and wildlife, and availability of federal funds for public waste treatment works. All DOE facilities that discharge wastewaters to either a surface-water body or a publicly owned treatment system must ensure compliance with the CWA.

The Safe Drinking Water Act (SDWA) of 1974 is an environmental statute that protects drinking water resources. Primary drinking water standards promulgated under the SDWA apply to drinking water "at the tap" as delivered by public water supply systems. As such, the standards are directly applicable to those DOE facilities that meet the definition of a public water supply system. Of equal significance to DOE is the fact that these drinking water standards are used to determine ground-water protection regulations under a number of other statutes.

The Atomic Energy Act (AEA) of 1954 delegates authority to DOE, NRC, and EPA to control nuclear energy. NRC has the authority to issue licenses for use of radioactive materials at certain types of facilities and can promulgate rules regulating that use. DOE is exempt from NRC's authority under the AEA. Although NRC regulations are not legally applicable to DOE sites, DOE addresses the regulation of radioactive materials in its DOE orders that are binding on all DOE sites. Standards outlined in the DOE orders reiterate, for the most part, the standards promulgated under NRC regulations.

The Toxic Substances Control Act (TSCA) of 1976 is a comprehensive act governing toxic substances. TSCA protects human health and the environment by requiring that specific chemicals be tested and that regulations restricting their processing and use be implemented. The objectives of TSCA include development of adequate data to determine the health and environmental effects of chemicals and control of any chemicals that present an unreasonable risk of injury. RA activities involving PCBs and asbestos-contaminated materials, in particular, would be regulated under this act.

The Hazardous Materials Transportation Act (HMTA) of 1975, as amended, is the major transportation-related statute affecting DOE. The objective of the HMTA is "to improve the regulatory and enforcement authority of the Secretary of Transportation to protect the nation adequately against risks to life and property which are inherent in the transportation of hazardous materials in commerce." Any transportation of hazardous or radioactive materials off ORR from an RA site would be regulated under HMTA.

The Occupational Safety and Health Act (OSHA) of 1970 is concerned with providing employees with a safe and healthy working environment. Under OSHA, rules have been promulgated to protect employees involved with cleanup operations at uncontrolled

hazardous-waste sites and to provide for worker protection during initial site characterization and analysis, monitoring activities, materials handling activities, training, and emergency response. All OSHA requirements apply to all DOE ER activities. DOE addresses occupational safety in DOE Orders 5480.11 (*Radiation Protection for Occupational Workers*), 5480.4 (*Environmental Protection, Safety, and Health Protection Standards*), 5483.1A (*Occupational Safety and Health Program for Contractors at Government-Owned, Contractor-Operated Facilities*), and 5480.9 (*Construction Safety and Health Program*), and it is understood that DOE will comply with these Orders. The DOE orders related to occupational safety are not addressed in this chapter unless they specifically apply to RAs.

NEPA establishes national policies and goals for protection of the environment. The purposes of NEPA include encouraging harmony between people and the environment, promoting efforts to prevent or eliminate damage to the environment and the biosphere, and encouraging the understanding of ecological systems and natural resources important to the country. NEPA ensures that federal agencies take into account the environmental impact of their actions through a procedure and detailed statement known as an Environmental Impact Statement. DOE Order 5440.1D (*National Environmental Policy Act Compliance Program*) mandates DOE compliance with the requirements of NEPA. Further, DOE Order 5400.4 [*Comprehensive Environmental Response, Compensation, and Liability Act Requirements (CERCLA)*] calls for integration of NEPA and CERCLA requirements for DOE RAs at CERCLA sites. This issue has been reaffirmed in the FFA §I(A)(3) and §III(A)(2) and Secretary of Energy Notice of Feb. 5, 1990 (SEN-15-90), which was issued to ensure that DOE's NEPA activities are carried out in a centralized and uniform manner.

The Endangered Species Act of 1973 and the Fish and Wildlife Coordination Act of 1958 are major federal statutes designed to protect plant and animal resources from adverse effects of development projects. Both acts require consultation with wildlife authorities before committing resources to certain types of projects. The Endangered Species Act provides for the designation and protection of invertebrates, wildlife, fish, and plant species that are in danger of becoming extinct and mandates conservation of the ecosystems on which such species depend. The Fish and Wildlife Coordination Act was enacted because the goals of water-related projects may at times conflict with the goal of conserving fish and wildlife resources. This act ensures that fish and wildlife resources receive equal consideration with other factors during the planning of development projects that affect water resources.

The Federal Insecticide, Fungicide, and Rodenticide Act of 1947 (FIFRA) regulates pesticides. Its purpose is to control the use of pesticides by requiring that all pesticides be registered with the EPA. Under FIFRA, EPA conducts inspections to ensure compliance with the Act, (e.g., having pesticides labeled and stored properly). The act regulates the proper disposal of pesticides, which may impact on RA activities involving pesticides or pesticide-contaminated materials.

It should be noted that all the major environmental laws also specify designated test methods and detailed sampling and analysis protocols that must be followed when testing materials or substances or verifying the applicability of a particular law to a given situation, substance, or material.

DOE has issued orders, as discussed above, addressing many of the activities regulated under the above-mentioned environmental statutes. These DOE orders are binding between DOE and its contractors, in this case, Martin Marietta Energy Systems, Inc., which operates the facilities in Oak Ridge, Tennessee. Pertinent DOE orders will be considered throughout the chapter as they relate to ER activities at DOE facilities.

Environmental laws enacted by the state of Tennessee generally correlate to their federal counterparts. The differences that arise between the state and federal laws will be pointed out throughout the chapter.

Specific requirements and standards promulgated under each of the above laws are discussed in detail in the following sections. This regulatory summary has been modified from the ER report *Applicable or Relevant and Appropriate Requirements (ARARs) for Remedial Action at the Oak Ridge Reservation, A Compendium of Major Environmental Laws*.¹ Regulations are grouped into four major areas: (1) *chemical-specific* regulations—standards or limits based on the particular contaminant or pollutant present; (2) *radiation protection* standards—regulations governing radioactivity, promulgated to protect the public health and environment; (3) *action-specific* regulations—performance or design standards or restrictions that set limits or controls based on the kind of activity planned at a site or designed into a particular technology; and (4) *location-specific* regulations—restrictions placed on pollutant concentrations or activities solely because they are in a particular location.

6.3 CHEMICAL-SPECIFIC REGULATIONS

Chemical-specific regulations set health- or risk-based concentration limits or discharge limitations in various environmental media for specific hazardous substances, pollutants, or contaminants. These requirements generally set protective cleanup levels for the chemicals of concern in a designated medium or indicate a safe level of discharge that may be incorporated when considering a specific remedial activity.

Although limited in number, chemical-specific standards have been established under several statutes, including RCRA, SDWA, CWA, TSCA, OSHA, CERCLA, and the CAA. Designated test methods and sampling/analysis protocols are delineated under each regulation for determining applicability of chemical-specific standards. These methods and protocols must be followed exactly as outlined in the regulation.

6.3.1 Groundwater and Surface Water

Table 6.1 lists available chemical-specific standards that have been promulgated under federal law for groundwater, surface water, and air. The regulations for air are listed in the table and described in Sect. 6.3.2.

All groundwater at ORR is scheduled to be cleaned up under CERCLA as part of the ER Program. As stated in the National Contingency Plan (55 FR 8666, March 8, 1990), the goal of EPA's approach to cleanup of contaminated groundwater is to return usable groundwater to its beneficial use within a given time frame that is reasonable for the particular circumstances at a CERCLA site. Groundwater at ORR has not been given an EPA classification. Although not legally applicable unless promulgated, EPA guidance on groundwater classification should be used to determine whether groundwater at ORR falls within Class I, II, or III. Classes I and IIA represent current sources of drinking water of varying value, Class IIB represents potential sources of drinking water, and Class III groundwater is not considered a potential source of drinking water and is of limited beneficial use. Restoration time periods vary, depending on the use classification of the groundwater, and may range from 1 year to several decades.

In the National Contingency Plan, EPA states the preference for SDWA maximum contaminant levels (MCLs) and nonzero maximum contaminant level goals (MCLGs) or other health-based standards, criteria, or guidance for cleanup of Class I and Class II groundwater at CERCLA sites (55 FR 8732). Alternate concentration limits may also be used when active restoration of the groundwater to MCLs or nonzero MCLGs is not practicable (55 FR 8754). For Class III groundwaters, EPA establishes remediation levels based on specific site conditions, the beneficial use of the groundwater, and environmental receptors (55 FR 8732). Final determination of applicable standards for site-specific cleanup of groundwater at ORR will depend on the chosen groundwater classification.

The state of Tennessee has issued draft ground-water classification rules that classify groundwater as: (1) Class A—current or future sources of drinking water; (2) Class B—current or future sources of drinking water but which will not support all uses as a water supply due to contamination; (3) Class C—not protected for drinking water or for other beneficial uses; and (4) Class D—groundwater that mixes with surface waters or flows to the surface of the ground.

Groundwater in Class D can also be identified as A, B, or C. According to this classification scheme, it appears that contaminated groundwater at ORR would be classified as Class B. The water quality criteria for Class B groundwater, proposed at

Table 6.1. Chemical-specific federal regulations for protection of human health^a

Chemical	RCRA ^b MCLs ^c (µg/L)	Safe Drinking Water Act MCLs (µg/L)	Safe Drinking Water Act MCLGs ^d (µg/L)	Clean Air Act NAAQS ^e (µg/m ³)
Acrylamide		TT ^f	0	
Adipates [di(ethylhexyl)adipate]		400	400	
Alachlor		2	0	
Aldicarb ^g		3	1	
Aldicarb sulfone ^g		2	1	
Aldicarb sulfoxide ^g		4	1	
Antimony		6	6	
Arsenic	50	50		
Asbestos (fibers >10µm)		7 ^h	7 ^h	
Atrazine		3	3	
Barium	1,000	2,000	2,000	
Benzene		5	0	
Benzo(a)pyrene		0.2	0	
Beryllium		4	4	
Cadmium	10	5	5	
Carbofuran		40	40	
Carbon monoxide				40,000 (1-h) ⁱ 10,000 (8-h) ⁱ
Carbon tetrachloride		5	0	
Chlordane		2	0	
Chromium (total)	50	100	100	
Copper		TT ^f	1,300	
Cyanide		200	200	
Dalapon		200	200	
1,2-Dibromo-3-chloropropane		0.2	0	
o-Dichlorobenzene		600	600	

Table 6.1 (continued)

Chemical	RCRA ^b MCLs ^c (µg/L)	Safe Drinking Water Act MCLs (µg/L)	Safe Drinking Water Act MCLGs ^d (µg/L)	Clean Air Act NAAQS ^e (µg/m ³)
<i>p</i> -Dichlorobenzene		75	75	
1,2-Dichloroethane		5	0	
1,1-Dichloroethylene		7	7	
<i>cis</i> -1,2-Dichloroethylene		70	70	
<i>trans</i> -1,2-Dichloroethylene		100	100	
Dichloromethane (methylene chloride)		5	0	
2,4-Dichlorophenoxyacetic acid (2,4-D)	100	70	70	
1,2-Dichloropropane		5	0	
Dinoseb		7	7	
Diquat		20	20	
Endothall		100	100	
Endrin	0.2	2	2	
Epichlorohydrin		TF ^f	0	
Ethylbenzene		700	700	
Ethylene dibromide		0.05	0	
Fluoride		4,000	4,000	
Glyphosate		700	700	
Heptachlor		0.4	0	
Heptachlor epoxide		0.2	0	
Hexachlorobenzene		1	0	
Hexachlorocyclopentadiene		50	50	
Lead	50	TF ^f	0	1.5 (90-day) ^k
Lindane (<i>gamma</i> -HCCH)	4	0.2	0.2	
Mercury	2	2	2	
Methoxychlor	100	40	40	
Monochlorobenzene		100	100	

Table 6.1 (continued)

Chemical	RCRA ^b MCLs ^c (µg/L)	Safe Drinking Water Act MCLs (µg/L)	Safe Drinking Water Act MCLGs ^d (µg/L)	Clean Air Act NAAQS ^e (µg/m ³)
Nickel		100	100	
Nitrate (as N)		10,000	10,000	
Nitrite (as N)		1,000	1,000	
Nitrate + Nitrite (as N)		10,000	10,000	
Nitrogen dioxide				100 (1-year) ^l
Ozone				235 (1-year) ^{lm}
Oxamyl (Vydate)		200	200	
Particulate matter				260 (24-h) ^l 75 (1-year) ⁿ
Pentachlorophenol		1	0	
Phthalates [di(ethylhexyl)phthalate]		6	0	
Picloram		500	500	
Polychlorinated biphenyls		0.5	0	
Selenium	10	50	50	
Silver ^p	50			
Simazine		4	4	
Styrene		100	100	
Sulfate ^p		400,000/500,000	400,000/500,000	
Sulfur oxides				365 (24-h) ^l 80 (1-year) ^l
Tetrachloroethylene		5	0	
Thallium		2	0.5	
2,3,7,8-Tetrachlorodibenzo-p-dioxin (Dioxin)		0.00003	0	
Toluene		1,000	1,000	
Toxaphene	5	3	0	

Table 6.1 (continued)

Chemical	RCRA ^b MCLs ^c (µg/L)	Safe Drinking Water Act MCLs (µg/L)	Safe Drinking Water Act MCLGs ^d (µg/L)	Clean Air Act NAAQS ^e (µg/m ³)
1,2,4-Trichlorobenzene		70	70	
1,1,1-Trichloroethane		200	200	
1,1,2-Trichloroethane		5	3	
Trichloroethylene		5	0	
Trihalomethanes (total) ^f		100		
2,4,5-Trichlorophenoxy-propionic acid (2,4,5-TP)	10	50	50	
Vinyl chloride		2	0	
Xylenes (total)		10,000	10,000	

^aFederally promulgated regulations under RCRA, SDWA, and the CAA are included in this table. Clean Water Act regulations are listed in Tables 6.4 and 6.5. Tennessee state drinking water MCLs/MCLGs (Chap. 1200-5-1 of the Rules of the TDEC) are identical to the federal.

^bRCRA = Resource Conservation and Recovery Act (40 CFR 264.94).

^cMCL = maximum contaminant level; RCRA MCLs are properly termed "maximum concentration limits."

^dMCLG = maximum contaminant level goal.

^eNAAQS = National Ambient Air Quality Standards (40 CFR 50.4, 50.6, 50.8 and 50.9-50.12).

^fTT = treatment technology.

^gEffective date for aldicarb compounds, originally set for January 1, 1993, is postponed indefinitely pending further study (57 FR 22178, May 27, 1992).

^hMillion fibers per liter.

ⁱMaximum concentration not to be exceeded more than once per year.

^jTT = treatment technology; 56 FR 26460 (June 7, 1991, effective December 7, 1992). When the "action level" of 15 or 1300 µg/L, for lead or copper, respectively, measured in the 90th percentile at the consumer's tap, is exceeded for lead or copper, corrosion control study and treatment requirements are triggered. However, an OSWER memorandum (dated June 21, 1990) recommends that a final cleanup level of 15 µg/L for lead in ground water usable for drinking water is protective of sensitive subpopulations; this is guidance, not an ARAR.

^kThree-month maximum arithmetic mean concentration.

^lAnnual arithmetic mean concentration.

^mHydrocarbon emissions are controlled as part of the ozone NAAQS strategy.

ⁿAnnual geometric mean.

^oThe interim SDWA MCL was revoked for this chemical (56 FR 3526, January 30, 1991) and a secondary MCL established instead (see Table 6.2).

^pThis is a proposed MCL/MCLG only (55 FR 30370, July 25, 1990). EPA has deferred setting a final MCL/MCLG for sulfate pending further study (57 FR 31776, July 17, 1992).

^qTotal trihalomethanes refers to the sum of the concentration of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.

Source: Etnier et al., 1993.

Chapter 1200-4-3-.08, would be the criteria for Class A groundwater (i.e., criteria established in 1200-4-3-.03, with the exception of those for fish and aquatic life) except where a groundwater use is shown to be impaired in accordance with 1200-4-3-.09(2)(c). Chapter 1200-4-3-.09 details steps to be taken to have groundwater registered as Class B, and includes a requirement for submittal of monitoring data, remediation history and plans, hydrogeologic studies, study of current and potential land uses, risk assessments, and permit applications. If the state Commissioner grants the petition for registration as Class B groundwater, water quality criteria for the contaminants of concern, as well as other permit conditions, will then be negotiated. Although many comments have been received on the draft rule, necessitating revisions before final promulgation, it is expected that the substantive provisions of the draft rule will remain as given in the proposed rule. Final promulgation of this groundwater classification rule is projected for mid-1994.²

6.3.1.1 Resource Conservation and Recovery Act

Subtitle C of RCRA lists maximum concentration levels for 14 chemicals; the concentration of these chemicals in groundwater at the plant boundary of a RCRA-permitted treatment, storage, and disposal facility may not exceed the stated maximum concentration level. In addition, background concentrations or alternate concentration limits are established in 40 CFR 264.94 as groundwater protection standards. Table 6.1 lists RCRA maximum concentration levels; however, as mentioned above, EPA has specified SDWA MCLs and nonzero MCLGs for cleanup of Class I and Class II groundwater and site-specific remediation levels for Class III groundwaters. This approach is consistent with the substantive requirements of RCRA maximum concentration levels, alternate concentration limits, or background limits (53 FR 51433). The newly promulgated regulations for municipal landfills (56 FR 50978, October 9, 1991) establish all SDWA MCLs by reference, and alternate concentration limits, or background concentrations as groundwater protection standards (40 CFR 258.55). Although not legally applicable to RAs found at Y-12, these regulations may prove relevant and appropriate for cleanup of groundwater at some of the sites. Alternate concentration limits may be calculated for chemicals without an MCL, using a risk-based approach (56 FR 51026).

Under the present RCRA Subtitle C hazardous-waste identification regulations, solid wastes ("solid wastes," as defined under RCRA, can be solid, liquid, semisolid, or contain gaseous material) generated during the D&D process would be subject to RCRA regulation under the following conditions: (1) if they are identified as RCRA-listed or RCRA-characteristic hazardous wastes pursuant to 40 CFR Part 261; (2) if they are a "mixture" of solid waste and listed hazardous waste "derived from" a listed hazardous waste, or (3) if they have a listed hazardous waste "contained in" the waste (40 CFR 261.3). Wastes are "characteristically hazardous" under RCRA if they (1) exhibit ignitability, corrosivity, reactivity, or toxicity, (2) meet certain toxicity criteria, or (3) contain certain toxic constituents (40 CFR 261.10-24). Currently, listed wastes remain hazardous unless they are "delisted" according to procedures set forth in 40 CFR 260.20 and 260.22.

In an attempt to address instances where regulation of listed hazardous waste under the jurisdiction of RCRA Subtitle C would cease without the need for a delisting petition, EPA proposed two alternative approaches for identifying a waste as a RCRA hazardous waste ("Hazardous Waste Identification Rule," 57 FR 21450, May 20, 1992). However, this proposed rule was withdrawn due to a large number of policy and technical issues.

Congress has charged EPA with promulgating rules to address the "derived from" and "mixture" issues by October 1994.³

6.3.1.2 Safe Drinking Water Act

EPA has promulgated primary and secondary drinking water regulations applicable to public water systems that have at least 15 service connections or serve an average of at least 25 people daily at least 60 days of the year. National Primary Drinking Water Standards are established in 40 CFR 141 and include MCLs and MCLGs. New drinking water standards promulgated for eight synthetic organic chemicals (52 FR 25690, July 8, 1987) added a new category of suppliers referred to as noncommunity, nontransient systems that regularly serve at least 25 people for 6 months of the year. Table 6.1 lists SDWA MCLs and MCLGs.

MCLs are enforceable standards that take into consideration human health effects, available treatment technologies, and costs of treatment. MCLGs are strictly health-based standards that disregard cost or treatment feasibility and are not legally enforceable. MCLs are legally applicable to water "at the tap" but are not applicable to cleanup of groundwater or surface water. However, they may be considered as relevant and appropriate in situations where groundwater or surface water may be used for drinking water. CERCLA §121(d)(2)(A) specifically mentions that RAs must require a level or standard of control that at least attains MCLGs and federal ambient water quality criteria (WQC) where such goals or criteria are relevant and appropriate under the circumstances of the release. Although MCLGs and WQC are nonenforceable guidelines, Congress elevated them to a higher status by specifically mentioning them in CERCLA. Therefore, promulgated MCLGs are listed in Table 6.1. At present, EPA is planning to use the SDWA MCLs for RA compliance for carcinogens that have an MCLG of zero and any nonzero MCLG for systemic toxicants (55 FR 8752).

EPA has revised its drinking water standards for lead and copper, eliminating the MCL and replacing it with a treatment technique requirement (56 FR 26460, June 7, 1991). If an "action level" of 15 or 1300 µg/L, for lead or copper, respectively, is exceeded at the tap, a state is required to analyze source water samples and to decide what treatment levels are necessary to minimize lead or copper levels delivered to users from the affected distribution system. In the instance of contaminated groundwater, the action levels for lead and copper are neither legally applicable nor relevant and appropriate for cleanup; however, for copper, the MCLG of 1300 µg/L is relevant and appropriate. In addition, the EPA Office of Solid Waste and Emergency Response final cleanup level of 15 µg/L for lead in groundwater usable for drinking water is protective of sensitive populations (Office of Solid Waste and Emergency Response memorandum dated June 21, 1990). This might be considered TBC guidance for remediation of lead-contaminated groundwater (footnoted in Table 6.1) and will serve as guidance to ensure the precision of analytical detection limits. TDEC has proposed a cleanup criteria of 15 µg/L for lead in groundwater (TDEC Rule 1200-1-13-.08, Table 8-1). When promulgated, this criteria will be applicable to cleanup.

Chapter 1200-5-1 of the Rules of the TDEC lists MCLs for public water systems that are identical to the federal MCLs. Therefore, the state regulations are not repeated here.

National Secondary Drinking Water Standards regulate contaminants that affect the aesthetic qualities related to public acceptance of drinking water and are implemented in 40 CFR 143.3 as secondary maximum contaminant levels (SMCLs) (see Table 6.2). These regulations are not federally enforceable but are intended to serve as guidelines for use by states in regulating water supplies. Tennessee has promulgated SMCLs in Chap.

Table 6.2. Federal and Tennessee secondary drinking water regulations

Chemical	Federal SMCL ^a (mg/L)	Tennessee SMCL ^b (mg/L)
Aluminum	0.05–0.2 ^{c,d}	0.2
Chloride	250	250
Color (color units)	15	15
Copper	1	1
<i>o</i> -Dichlorobenzene ^e	0.01	
<i>p</i> -Dichlorobenzene ^e	0.005	
Ethylbenzene ^e	0.03	
Fluoride	2.0	2.0
MBAS (methyl blue active substance)		0.5
Hexachlorocyclopentadiene ^f	0.008	
Iron	0.3	0.3
Manganese	0.05	0.05
Odor (threshold odor number)	3	3
Pentachlorophenol ^e	0.03	
pH	6.5–8.5	6.5–8.5
Silver	0.1 ^c	0.1
Styrene ^e	0.01	
Sulfate	250	250
Toluene ^e	0.04	
TDS (total dissolved solids)	500	500
Xylene ^e	0.02	0.02
Zinc	5	5

^aFinal rule [44 FR 42198 (July 19, 1979)]. National Secondary Drinking Water Standards (NSDWS) are included in this table for completeness because they will be incorporated into the TDEC secondary drinking water regulations when they are revised.

^bChapter 1200-5-1.12 of the Rules of the TDEC.

^cNSDWS final rule [56 FR 3526 (January 30, 1991)]. Effective date July 30, 1992.

^dLevel recommended to prevent posttreatment precipitation in the distribution system.

^eProposed NSDWS (54 FR 22062, May 22, 1989). EPA has deferred setting final standards for these chemicals pending further study (56 FR 3572, January 30, 1991).

^fProposed NSDWS (55 FR 30370, July 25, 1990); EPA has deferred setting a final standard for this chemical pending further study (57 FR 31776, July 17, 1992).

1200-5-1.12 of the Rules of the TDEC (see Table 6.2). These regulations are designed to provide water to the consumer that is aesthetically pleasing, and they apply to all community water systems and to those noncommunity water systems "as may be deemed necessary" by TDEC. In that context, they would not be legally applicable to cleanup of groundwater or surface water, but may be considered as relevant and appropriate in instances where these media may provide private drinking water sources. EPA has proposed National Secondary Drinking Water Standards for ten additional contaminants (54 FR 22062, May 22, 1989; 55 FR 30370 July 25, 1990); when these are promulgated, they will be incorporated into the TDEC secondary drinking water regulations.⁴ Therefore, they are included in Table 6.2 for completeness. EPA has published final National Secondary Drinking Water Standards for aluminum and silver (56 FR 3526, January 30, 1991).

6.3.1.3 Clean Water Act

CERCLA §121(d)(2)(A) specifically states that RAs shall at least attain federal ambient WQC established under the CWA if they are relevant and appropriate. In determining whether any WQC are relevant and appropriate, one must consider the "designated or potential use of the surface or groundwater, the environmental media affected, the purposes for which the criteria were developed, and the latest information available" [CERCLA §121(d)(2)(B)]. Federal WQC are derived for the protection of freshwater aquatic organisms and for the protection of human health from the consumption of contaminated drinking water and/or aquatic organisms.

Table 6.3 lists federal ambient WQC for the protection of human health. EPA has derived WQC for ingestion of drinking water and aquatic organisms and for the ingestion of aquatic organisms alone. Since neither of these categories is relevant and appropriate for consideration of contaminated groundwater, WQC derived for the ingestion of drinking water alone are also included in Table 6.3. The EPA Region IV Water Quality Standards Unit has adjusted WQC for human health based on recent human toxicity information [reference doses (RfDs) and carcinogen slope factors (CSFs)] obtained from the EPA *Integrated Risk Information System*⁵. The values presented in Table 6.3 reflect the EPA Region IV revised WQC and are current as of December 1992.⁶ They are intended to supersede all previous WQC. Federal WQC are not promulgated standards. They are intended to serve as guidelines for individual states to use in promulgating state water quality standards. When a state adopts federal WQC and promulgates them in their state regulations, then they become legally enforceable under that state's law.

As part of the federal requirement for a triennial review of state water quality standards, the TDEC Division of Water Pollution Control has promulgated amendments to Chaps. 1200-4-3 and 1200-4-4 of the Rules of the TDEC. TDEC has revised its water quality standards and promulgated the federal SDWA MCLs as WQC for domestic water supplies (effective date Aug. 30, 1991). Included in this revision are criteria for protection of recreational uses. These criteria are human health criteria derived to protect the consumer from consumption of contaminated fish; these criteria are similar to the federal WQC for the protection of human health from consumption of fish alone. However, they are based on a risk of 10^{-5} rather than the 10^{-6} risk on which the federal WQC are based. Tennessee WQC for human health are listed in Table 6.4.

Chapter 1200-4-3 of the Rules of the TDEC lists seven use-designation categories for Tennessee's surface waters and groundwaters. Specific water quality standards are promulgated for each use category. Under the Tennessee Water Quality Control Act, the Tennessee Water Quality Control Board has classified the Clinch River for domestic water supply, industrial water supply, fish and aquatic life, recreation, irrigation, and livestock watering and wildlife uses (Chap. 1200-4-4 of the Rules of the TDEC). The tributaries to the Clinch River have various use classifications that need to be analyzed on a site-specific basis. The standards also state that "all other streams, named and unnamed, which have not been specifically noted shall be classified for fish and aquatic life, recreation, irrigation, and livestock watering and wildlife uses." TDEC has promulgated a change in the use classification that adds recreation as a category for all segments of rivers and streams that are not currently classified as such (effective August 1991).

Table 6.5 lists federal WQC for the protection of freshwater aquatic life. EPA Region IV has also revised these WQC based on current toxicity and bioaccumulation data for aquatic organisms, and these appear in Table 6.5 as well. When the designated use classification requires protection of aquatic life or when environmental factors are being considered at an RA site, a WQC for the protection of aquatic life that is more stringent than the SDWA MCL may be appropriate for cleanup. TDEC has promulgated WQC for

**Table 6.3. Federal ambient water quality criteria (WQC)
for the protection of human health (µg/L)**

Chemical	WQC for aquatic organisms and drinking water ^a	WQC for aquatic organisms alone ^a	WQC for drinking water alone ^b
Acenaphthene	1220 (org) ^c	2,700	2,100
Acrolein	320	780	
Acrylonitrile	0 (0.059)	0 (0.66)	0 (0.065)
Aldrin	0 (1.3E-04) ^d	0 (1.4E-04)	0 (2.1E-03)
Anthracene	9,600	110,000	10,500
Antimony	14	4,300	14
Arsenic	0 (0.018)	0 (0.14)	0 (0.02)
Asbestos	0 (7,000,000 fibers/L)	NA ^e	
Benzene	0 (1.2)	0 (71)	0 (1.2)
Benzidine	0 (1.2E-04)	0 (5.4E-04)	0 (1.5E-04)
Benz(a)anthracene	0 (4.4E-03)	0 (0.049)	
Benzo(a)pyrene	0 (4.4E-03)	0 (0.049)	
Benzo(k)fluoranthene	0 (4.4E-03)	0 (0.049)	
3,4-Benzofluoranthene	0 (4.4E-03)	0 (0.049)	
Beryllium	f	f	
Bromoform	0 (4.3)	0 (360)	0 (4.4)
Carbon tetrachloride	0 (0.25)	0 (4.4)	0 (0.27)
Chlordane	0 (5.7E-04)	0 (5.9E-04)	0 (0.03)
Chlorinated benzenes			
Monochlorobenzene	680 (org)	21,000	700
1,2-Dichlorobenzene	2,700	17,000	3,150
1,3-Dichlorobenzene	400	2,600	
1,4-Dichlorobenzene	400	2,600	
1,2,4,5-Tetrachlorobenzene	38	48	
Pentachlorobenzene	74	85	
Hexachlorobenzene	0 (7.5E-04)	0 (7.7E-04)	
Chlorinated ethanes			
1,2-Dichloroethane	0 (0.38)	0 (99)	0 (0.38)
1,1,1-Trichloroethane	f	f	
1,1,2-Trichloroethane	0 (0.60)	0 (42)	0 (0.61)
1,1,2,2-Tetrachloroethane	0 (0.17)	0 (11)	0 (0.175)
Hexachloroethane	0 (1.9)	0 (8.9)	0 (2.5)
Chlorinated phenols			
2-Chlorophenol	120 (org)	400	175
2,4-Dichlorophenol	93 (org)	790	105
2,4,5-Trichlorophenol	1.0 (org)	NA	
2,4,6-Trichlorophenol	0 (2.1)	0 (6.5)	0 (3.2)
Pentachlorophenol	0 (0.28)	0 (8.2)	0 (0.29)
3-Methyl-4-chlorophenol	NA	NA	

Table 6.3 (continued)

Chemical	WQC for aquatic organisms and drinking water ^a	WQC for aquatic organisms alone ^a	WQC for drinking water alone ^b
Chloroalkyl ethers			
bis-(Chloromethyl) ether	0 (1.59E-04)	0 (0.0777)	0 (1.6E-04)
bis-(2-Chloroethyl) ether	0 (0.031)	0 (1.4)	0 (0.032)
bis-(2-Chloroisopropyl) ether	1,400	170,000	1,400
Chlorodibromomethane	0 (0.41)	0 (34)	0 (0.417)
Chloroform	0 (5.7)	0 (470)	0 (5.74)
Chromium (III)	f	f	
Chrysene	0 (4.4E-03)	0 (0.049)	
Copper	1,300 (org)	NA	
DDD	0 (8.3E-04)	0 (8.4E-04)	0 (0.15)
DDE	0 (5.9E-04)	0 (5.9E-04)	0 (0.103)
DDT	0 (5.9E-04)	0 (5.9E-04)	0 (0.103)
Dibenz(a,h)anthracene	0 (4.4E-03)	0 (0.049)	
3,3'-Dichlorobenzidine	0 (0.04)	0 (0.077)	0 (0.078)
Dichlorobromomethane	0 (0.27)	0 (22)	0 (0.27)
Dichlorodifluoromethane	0 (5.67)	0 (470.8)	
1,1-Dichloroethylene	0 (0.057)	0 (3.2)	0 (0.058)
Dichloropropanes/Dichloropropenes			
cis-1,3-Dichloropropene	10	1,700	10.5
trans-1,3-Dichloropropene	10	1,700	10.5
Dieldrin	0 (1.4E-04)	0 (1.4E-04)	0 (2.2E-03)
2,4-Dimethylphenol	540 (org)	2,300	200
2,4-Dinitrotoluene	0 (0.11)	0 (9.1)	
1,2-Diphenylhydrazine	0 (0.04)	0 (0.54)	0 (0.044)
Endosulfan(a-,b-)	74	159	1.8
Ethylbenzene	100	29,000	3,500
Fluoranthene	300	370	1,400
Fluorene	1,300	14,000	1,400
Halomethanes	0 (5.67)	0 (470.8)	
Heptachlor	0 (2.1E-04)	0 (2.1E-04)	0 (8.1E-03)
Heptachlor epoxide	0 (1.0E-04)	0 (1.1E-04)	0 (3.8E-03)
Hexachlorobutadiene	0 (0.44)	0 (50)	0 (0.45)
Hexachlorocyclohexanes (HC-CH)			
Alpha-HCCH	0 (0.004)	0 (0.013)	0 (5.5E-03)
Beta-HCCH	0 (0.014)	0 (0.046)	0 (0.02)
Gamma-HCCH	0 (0.019)	0 (0.063)	

Table 6.3 (continued)

Chemical	WQC for aquatic organisms and drinking water ^a	WQC for aquatic organisms alone ^a	WQC for drinking water alone ^b
Hexachlorocyclopentadiene	240 (org)	17,000	245
Indeno(1,2,3-cd)pyrene	0 (4.4E-03)	0 (0.049)	
Isophorone	0 (36)	0 (2,600)	0 (8.5)
Mercury	0.14	0.15	
Methyl bromide	48	4,000	49
Methyl chloride	f	f	
Methylene chloride	0 (4.7)	0 (1,600)	0 (4.7)
Nickel	610	4,600	700
Nitrobenzene	17	1,900	17.5
Nitrophenols			
2,4-Dinitrophenol	70	14,000	70
2-Methyl-4,6-dinitrophenol	13.4	765	
Nitrosamines			
n-Nitrosodimethylamine	0 (6.9E-04)	0 (8.1)	0 (6.8E-04)
n-Nitrosodiphenylamine	0 (5.0)	0 (16)	0 (7.1)
n-Nitrosopyrrolidine	0 (0.016)	0 (91.9)	
Pentachlorobenzene	74	85	
Phenol	21,000 (org)	4,600,000	21,000
Phthalate esters			
Butylbenzyl phthalate	3,000	5,200	7,000
Diethylphthalate	23,000	120,000	10,500
Dimethylphthalate	313,000	2,900,000	
Di-n-butylphthalate	2,700	12,000	3,500
Bis-2-ethylhexylphthalate	0 (1.8)	0 (5.9)	0 (2.5)
Polychlorinated biphenyls (1016, 1221, 1242, 1254, 1260)	0 (4.4E-05)	0 (4.5E-05)	0 (4.5E-03)
Polynuclear aromatic hydrocarbons	0 (4.4E-03)	0 (0.049)	
Pyrene	960	11,000	1,500
2,3,7,8-Tetrachlorodibenzo-p-dioxin	0 (1.3E-08)	0 (1.4E-08)	0 (2.2E-07)
1,2,4,5-Tetrachlorobenzene	38	48	
Tetrachloroethylene	0 (0.8)	0 (8.85)	
Thallium	1.7	6.3	
Toluene	6,800	200,000	70,000
Toxaphene	0 (7.3E-04)	0 (7.5E-04)	0 (0.032)
Trichloroethylene	0 (2.7)	0 (81)	
Trichlorofluoromethane	0 (5.67)	0 (470.8)	
Vinyl chloride	0 (2)	0 (525)	
Zinc	NA	NA	

^aThe criterion value of zero for all potential carcinogens is listed in the table. Concentrations in parentheses for potential carcinogens correspond to a risk of 10^{-6} .

^bThese adjusted criteria, for drinking water ingestion only, are estimated using a reference dose or carcinogen potency factor and a body weight of 70 kg and water ingestion rate of 2 L/day.

^cCriteria designated as organoleptic are based on taste and odor effects, not human health effects. Health-based WQC are not available for these chemicals.

^dRead as 1.3×10^{-4} .

^eNA = not available.

^fCriteria withdrawn in National Toxics Rule (57 FR 60848, Dec. 22, 1992).

Source: U.S. Environmental Protection Agency, Region IV Criteria Charts, December 1992.

**Table 6.4. Tennessee water quality criteria for
designated water uses (µg/L)^a**

Chemical	Domestic Water Supply	Recreation ^b	Fish and Aquatic Life	
			CMC ^c	CCC ^d
Acenaphthylene	NA ^e	0.3	NA	NA
Acrolein	NA	780	NA	NA
Acrylonitrile	NA	6.7	NA	NA
Aldrin	NA	0.0014	3	NA
Anthracene	NA	0.03	NA	NA
Antimony	NA	4310	NA	NA
Arsenic (III)	NA	NA	360	190
Arsenic (total)	50	NA	NA	NA
Benzene	5	710	NA	NA
Benz(a)anthracene	NA	0.3	NA	NA
Benzo(a)pyrene	NA	0.3	NA	NA
3,4-Benzofluoranthene	NA	0.3	NA	NA
Benzo(k)fluoranthene	NA	0.3	NA	NA
Beryllium	NA	1.3	NA	NA
<i>g</i> -BHC (Lindane)	4	0.63	2	0.08
Bis(2-chloroethyl)ether	NA	14	NA	NA
Bis(2-ethylhexyl)phthalate	NA	59	NA	NA
Boron	NA	NA	NA	NA
Bromoform - (Tribromomethane)	NA	4700	NA	NA
Cadmium	10	NA	4 ^f	1 ^f
Carbon tetrachloride	5	44	NA	NA
Chlordane	NA	0.006	2.4	0.0043
Chloroform - (Trichloromethane)	NA	4700	NA	NA
Chromium (III)	NA	670,000	NA	NA
Chromium (hexavalent)	NA	NA	16	11
Chromium (total)	50	NA	NA	100
Chrysene	NA	0.03	NA	NA
Cobalt	NA	NA	NA	NA
Copper	NA	NA	18 ^f	12 ^f
Cyanide	NA	NA	22	5.2
4,4'-DDT	NA	0.006	1.1	0.001
4,4'-DDE	NA	0.006	NA	NA
4,4'-DDD	NA	0.008	NA	NA
1,2-Dichlorobenzene	NA	17,000	NA	NA
1,3-Dichlorobenzene	NA	2600	NA	NA
1,4-Dichlorobenzene- (<i>para</i> -Dichlorobenzene)	75	2,600	NA	NA
Dichlorobromomethane	NA	4700	NA	NA

Table 6.4 (continued)

Chemical	Domestic Water Supply	Recreation ^b	Fish and Aquatic Life	
			CMC ^c	CCC ^d
1,2-Dichloroethane	5	990	NA	NA
1,1-Dichloroethylene	7	32	NA	NA
1,3-Dichloropropylene	NA	1700	NA	NA
Dieldrin	NA	0.0014	2.5	0.0019
Diethyl phthalate	NA	120,000	NA	NA
Dimethyl phthalate	NA	2,900,000	NA	NA
Di-n-butyl phthalate	NA	12,000	NA	NA
2,4-Dinitrophenol	NA	14,000	NA	NA
2,4-Dinitrotoluene	NA	42	NA	NA
Dioxin	NA	0.000001	NA	NA
<i>a</i> -Endosulfan	NA	2.0	0.22	0.056
<i>b</i> -Endosulfan	NA	2.0	0.22	0.056
Endrin	0.2	NA	0.18	0.0023
Ethylbenzene	NA	29,000	NA	NA
Fluoranthene	NA	54	NA	NA
Fluorene	NA	0.03	NA	NA
Heptachlor	NA	0.002	0.52	0.0038
Heptachlor epoxide	NA	0.001	0.52	0.0038
Hexachlorobenzene	NA	0.007	NA	NA
Hexachlorobutadiene	NA	500	NA	NA
Hexachlorocyclo- pentadiene	NA	NA	NA	NA
Hexachloroethane	NA	89	NA	NA
Lead	50	NA	82 ^f	3 ^f
Lindane (<i>g</i> -BHC)	4	0.63	2	0.08
Lithium	NA	NA	NA	NA
Manganese	50 ^g	NA	NA	NA
Mercury	2	0.15	2.4	0.012
Methyl chloride - (Chloromethane)	NA	4700	NA	NA
2-Methyl-4,6-dinitro- phenol (4,6-Dinitro- <i>o</i> -cresol)	NA	765	NA	NA
Methylene chloride - (Dichloromethane)	NA	16,000	NA	NA
<i>n</i> -Butylbenzyl phthalate	NA	NA	NA	NA
Nickel	NA	4600	1400	160
Nitrobenzene	NA	1900	NA	NA
Pentachlorophenol	NA	NA	20 ^h	13 ^h
Phenanthrene	NA	0.03	NA	NA

Table 6.4 (continued)

Chemical	Domestic Water Supply	Recreation ^b	Fish and Aquatic Life	
			CMC ^c	CCC ^d
Polychlorinated biphenyls				
PCB-1242	NA	0.0005	NA	NA
PCB-1254	NA	0.0005	NA	NA
PCB-1221	NA	0.0005	NA	NA
PCB-1232	NA	0.0005	NA	NA
PCB-1248	NA	0.0005	NA	NA
PCB-1260	NA	0.0005	NA	NA
PCB-1016	NA	0.0005	NA	NA
PCBs (total)	NA	0.001	NA	0.001
Pyrene	NA	0.03	NA	NA
Selenium	10	NA	20	5
Silver	50	NA	4 ^f	NA
1,1,2,2-Tetrachloroethane	NA	110	NA	NA
Tetrachloroethylene	NA	88	NA	NA
Toluene	NA	300,000	NA	NA
Toxaphene	5	0.008	0.73	0.0002
1,1,1-Trichloroethane	200	170,000	NA	NA
1,1,2-Trichloroethane	NA	420	NA	NA
Trichloroethylene	5	807	NA	NA
2,4,6-Trichlorophenol	NA	6.5	NA	NA
Vanadium	NA	NA	NA	NA
Vinyl chloride	2	5250	NA	NA
Zinc	5000 ^f	NA	117 ^f	106 ^f

^aRules of the TDEC, Chap. 1200-4-3.

^bBased on a 10⁻⁵ risk level for carcinogens.

^cCMC = criterion maximum concentration.

^dCCC = criterion continuous concentration.

^eNA = not available.

^fCalculated for a water hardness of 100 mg/L, the approximate average hardness of the Clinch River.

^gSecondary MCL; Rules of the TDEC, Chap. 1200-5-1.12.

^hAt pH = 7.8.

Table 6.5. Federal ambient water quality criteria for the protection of freshwater organisms

Chemical	Maximum (µg/L)	24-h (µg/L) ^b
Aldrin	3	NA ^c
Aluminum	750 ^d	87 ^d
Ammonia	Concentrations are temperature and pH dependent	
Arsenic (III)	360	190
Cadmium	1.8 ^e	0.66 ^e
Chlordane	2.4	4.3E-03 ^{f, g}
Chloride	860,000	230,000
Chlorine	19	11
Chlorpyrifos	0.083	0.041
Chromium (VI)	16	11
(III)	984 ^e	117 ^e
Copper	9.22 ^e	6.54 ^e
Cyanide	22	5.2
Dichlorodiphenyl-trichloroethane (DDT)	1.1	1.0E-03 ^h
Demeton	NA	0.1
Dieldrin	2.5	1.9E-03 ^g
Endosulfan	0.22	0.056
Endrin	0.18	2.3E-03 ^g
Guthion	NA	0.01
Heptachlor	0.52	3.8E-03 ^g
Heptachlor epoxide	0.52	3.8E-03 ^g
Hexachlorocyclohexanes (HCCH) gamma-HCCH (Lindane)	2	0.08
Hydrogen sulfide	NA	2
Iron	NA	1,000
Lead	33.8 ^e	1.32 ^e
Malathion	NA	0.1
Mercury	2.4	0.012 ^g
Methoxychlor	NA	0.03
Mirex	NA	1.0E-03
Nickel	789 ^e	88 ^e
Parathion	0.065	0.013
Pentachlorophenol	3.32 ⁱ	2.1 ⁱ
pH	NA	6.5-9
Polychlorinated biphenyls	NA	0.014 ^h
Selenium (inorganic selenite)	20	5
Silver	1.23 ^e	NA
Sulfides	NA	2
Zinc	65 ^e	59 ^e

^aOne-hour average concentration not to be exceeded more than once every 3 years.

^bFour-day average concentration not to be exceeded more than once every 3 years.

^cNA = not available.

^dpH 6.5-9.0.

^eWater hardness dependent criteria (50 mg/L as CaCO₃).

^fRead as 4.3 × 10⁻³.

^gBased on marketability of fish.

^hFinal residue value based on wildlife feeding study.

ⁱpH dependent criteria.

Source: U.S. Environmental Protection Agency, Region IV Criteria Chart, December 1992.

the protection of aquatic organisms, effective Aug. 30, 1991; these are identical, for the most part, to the federal WQC and are listed in Table 6.4.

6.3.2 Air Standards

Primary National Ambient Air Quality Standards for six chemicals appear in 40 CFR 50; these standards are based on the direct health effects of those chemicals to sensitive groups, with no economic factors considered. The National Ambient Air Quality Standards take into consideration all sources of exposure to a given chemical and establish ceilings that are not to be exceeded in the United States. Only major new sources, or major modifications to existing sources, must ensure regional attainment of National Ambient Air Quality Standards. Although ORR is in a Tennessee state "attainment" area, it is unlikely that any emissions from RA cleanup will be considered a "major" source under present federal law. EPA has, however, listed "site remediation" as a major source category under Section 112(c) of the CAA (57 FR 31576, July 16, 1992). A regulatory schedule was issued in September 1992 for promulgating emission standards under Section 112(e) of the CAA for these newly-listed major source categories.

National Ambient Air Quality Standards are established as the criteria state and local governments must plan to achieve and, thus, are not directly enforceable. Under §110 of the CAA, states are required to implement regulations to achieve the National Ambient Air Quality Standards. The ambient air quality standards established by the TDEC Division of Air Pollution Control appear in Chap. 1200-3-3 of the Rules of the TDEC and are identical to the federal primary National Ambient Air Quality Standards (see Table 6.1). The ambient standards of 1200-3-3 are translated into source-specific emission limitations (Rules of the TDEC, Chaps. 1200-3-4 to 1200-3-21) that must be considered legally applicable if they apply to any of the remedial activities selected. Tennessee state air emission standards are considered "hybrid" regulations and will be summarized as action-specific regulations in Sect. 6.5.3; they would have to be analyzed on a site-specific basis depending on the type of RA planned for a site.

National Emission Standards for Hazardous Air Pollutants (NESHAPs) for various industrial sources that emit one of several pollutants are established in 40 CFR 61. Most of the NESHAPs are generally not legally applicable to cleanup at CERCLA sites because they regulate particular types of sources that would not be expected to be found at these sites. However, the NESHAPs for asbestos and radionuclides should be considered as potential "hybrid" regulations on a site-specific basis depending on the RAs planned at a site. The NESHAP for radionuclides is discussed in Sect. 6.4.2.

The CAA Amendments of 1990 establish a list of 189 additional hazardous air pollutants for which technology-based standards must be promulgated. These will be applicable to categories of emission sources rather than to the substances emitted. A final schedule has been published for promulgation of these technology-based standards (58 FR 63941).

6.3.3 Soil Regulations

Very little legislation or guidance is available governing cleanup criteria for contaminated soils. RCRA has addressed land disposal of treated hazardous wastes in its LDRs (40 CFR 268), and these are addressed as action-specific regulations in Sect. 6.5.2. If a site is identified as a RCRA Sect. 3004(u) solid waste management unit, or if RCRA-characteristic or RCRA-listed hazardous waste as defined in 40 CFR 261 is present at the site, it is subject to RCRA corrective action regulations. The proposed RCRA corrective action regulations address risk-based cleanup standards for soils

(55 FR 30798); these are briefly discussed in Sect. 6.5.2. Treatment standards for contaminated soil and debris at CERCLA sites are discussed in Sect. 6.5.2.

The regulations found in the TSCA contain storage, disposal, and cleanup requirements for materials contaminated with PCBs. These regulations limit concentrations of PCBs disposed of in soil to 50 ppm and require that any soils containing concentrations of PCBs greater than 50 ppm (40 CFR 761.60) be incinerated (40 CFR 761.70) or stored in a chemical waste landfill (40 CFR 761.75). TSCA also specifies requirements that must be achieved for PCBs disposed of by incineration (40 CFR 761.70), in a chemical waste landfill (40 CFR 761.75), or by other disposal methods [40 CFR 761.60(a)(5)(iii)]. A further discussion of the TSCA requirements appears in Sect. 6.5.6.

6.3.4 Nonregulatory Guidance

EPA has suggested cleanup values for lead in soils based on studies of blood-lead levels in exposed children. The EPA Office of Solid Waste and Emergency Response Directive 9355.4-02 (dated Sept. 7, 1989) recommends a cleanup level for soils of 500–1000 ppm lead.

Although not a legal standard, EPA has published a TSCA PCB spill cleanup policy (52 FR 10688) that recommends cleanup standards for PCBs of 25–50 ppm for sites with restricted access; a 10-ppm cleanup level is recommended for residential and unrestricted access rural areas. In this latter case, a 10-inch cap of clean soil must cover the site. In the EPA guidance report for RAs at Superfund sites containing PCBs, preliminary remediation goals are set at 1 ppm for residential land use (a risk of 10^{-5}) and between 10 and 25 ppm for industrial and/or remote areas (a risk of 10^{-4}).⁷ Alternatives should reduce concentrations to these levels or limit exposures. EPA also presents an approach to deriving cleanup levels of PCBs in sediments.⁷ This approach results in "sediment quality criteria" as a function of organic carbon concentrations and is meant to protect wildlife consumers of freshwater benthic species.

In the absence of federally or state-promulgated standards, or in the case where standards are not adequately protective, EPA states a preference for RfDs or reference concentrations (RfCs) for systemic toxicants, and CSFs for carcinogens or Office of Drinking Water Health Advisories for drinking water contaminants.⁸ The RfDs, RfCs, and CSFs are available through the *Integrated Risk Information System* and the *EPA Health Effects Assessment Summary Tables*.^{5, 9}

The EPA Office of Drinking Water has developed nonregulatory health advisories for concentrations of noncarcinogenic contaminants in drinking water at which no adverse health effects would be expected to occur. EPA uses the lifetime HA (for noncarcinogens only) to develop MCLs and MCLGs; health advisories will most likely represent future MCL proposals.

6.4 RADIATION PROTECTION STANDARDS

Very few standards are available that are legally applicable to the cleanup of radioactively contaminated media at Y-12 RA sites. The AEA and its amendments delegated authority for control of nuclear energy to DOE, NRC, and EPA. In addition, certain states have regulatory authority and programs for radioactive waste. The EPA's regulations are derived from several other statutes as well, and cover many types of activities and all types of radioactive materials, including naturally occurring and accelerator-produced radioactive material (NARM). NRC licenses the possession and use of various types of radioactive materials at certain types of facilities. Tennessee is an NRC-agreement state and, as such, has its own authority and licensing regulations. In addition, Tennessee enforces NARM standards.

DOE is authorized to control all types of nuclear materials at sites under its jurisdiction and is exempt from NRC licensing and regulatory requirements; therefore, NRC regulations are not considered to be legally applicable to RA activities at DOE facilities. DOE regulations for handling and cleanup of radioactive materials are outlined in a series of internal DOE orders that are binding to DOE contractors.

Because a complete characterization of the identity and quantity of radioactive waste at Y-12 RA sites has not been completed, all of the available EPA regulations will be presented here, as well as the numerical NRC values. The proper definition of "mixed low-level waste and hazardous waste" has caused considerable debate with regard to dual jurisdiction by EPA and NRC. However, EPA has published a clarification of the problem (53 FR 37045, Sept. 23, 1988), as did DOE previously [52 FR 15937, May 1, 1987 and DOE Order 5400.3 (*Hazardous and Radioactive Mixed Waste Program*, dated Feb. 22, 1989)]. In effect, mixed wastes are those containing a RCRA hazardous waste as defined in 40 CFR 261 and a radioactive waste subject to the AEA. RCRA regulations apply to the hazardous component of the waste, and AEA regulations apply to the radioactive component. When the application of both standards is conflicting or inconsistent, RCRA yields to the AEA. Tennessee received final authorization to regulate radioactive mixed waste on July 3, 1986 (53 FR 37045, Sept. 23, 1988); however, the state has not implemented any regulations or guidance related to the handling of mixed waste.¹⁰

6.4.1 Generic Below Regulatory Concern Levels for Radioactive Wastes

The NRC has developed the concept of a risk threshold to distinguish those radioactive materials that do not warrant regulation to the same degree as other radioactive materials to ensure adequate protection of the public and the environment. The low levels of risk posed by these radioactive materials have been termed below regulatory concern (BRC). The NRC published a policy statement (55 FR 27522, July 3, 1990) to guide its decisions on exemptions of BRC materials from the full scope of the NRC's regulatory program.

The BRC policy was established, in part, to ensure adequate and consistent decisions on acceptable risks posed by decontaminated and decommissioned nuclear facilities. The BRC concept is based on the premise that risk from doses to individuals for practices that are under consideration for exemption are comparable to the voluntary and involuntary risks commonly accepted by the general public from radiation exposures in their daily lives (i.e., natural background radiation, which results in risks corresponding to doses on the order of 5–10 mrem/year or an annual risk of about 10^{-6}). This level of risk is within the risk-based guidelines of 10^{-4} to 10^{-7} established by the EPA.

Based on these considerations, the NRC policy states that the average dose to individuals in a critical group should be less than 10 mrem/year (a hypothetical incremental annual risk of 5×10^{-6}) for each exempted practice. In addition, for such practices that result in widespread distribution of radioactive materials (e.g., consumer products or recycled materials), the NRC recommends an interim dose criterion for individuals in the critical group of 1 mrem/year (a risk of 5×10^{-7}). These individual annual doses translate to a lifetime risk from continuing annual exposures in the order of 10^{-4} and 10^{-5} , respectively.

The adoption of the BRC policy generated widespread public concern over its implications and a general dissatisfaction with the process the NRC used to develop the BRC policy. Because of these concerns, the NRC declared a moratorium on implementation of the BRC policy and initiated a consensus process to provide advice to the NRC on the full range of issues related to the BRC policy (56 FR 36068, July 30, 1991).

The consensus-building process was terminated in December 1991 due to the difficulty of obtaining participation of all affected interests in the process, and NRC then indefinitely extended the moratorium on the implementation of the BRC policy. In October 1992, Congress enacted the Energy Policy Act of 1992, which was subsequently signed into law by President Bush. Section 2901 of the Act revoked the Commission's 1986 and 1990 BRC policy statements. In response to this Congressional action, NRC formally withdrew its two BRC policy statements on August 24, 1993 (58 FR 44610) and terminated the rulemaking action that was initiated to implement the 1986 BRC Policy ["Radioactive Waste Below Regulatory Concern; Generic Rulemaking," (ANPRM issued December 2, 1986, 51 FR 44620)].

EPA utilizes a similar policy in setting *de minimis* risk-based levels for exemption of hazardous chemicals from RCRA Subtitle C regulation (57 FR 21450, May 20, 1992). Health-based exemption levels are proposed for systemic toxicants and carcinogens based on RfDs and risk-specific doses, respectively. EPA has proposed a risk level of 10^{-6} to establish exemption criteria for Groups A, B, and C carcinogens (see 51 FR 33992, September 24, 1986, for a discussion of EPA's carcinogen classification scheme).

Unable to establish a BRC policy which could have served as a basis for establishing radiological criteria for decommissioning facilities, the Commission took a different tack and, in early 1993, initiated an enhanced participatory rulemaking process to establish radiological criteria specifically for the decommissioning of NRC-licensed facilities.

These NRC-developed residual radioactivity criteria for decommissioning will only be legally applicable to NRC-licensed facilities. In a separate but parallel rulemaking activity, EPA is working to develop standards for residual radioactive contamination for a broad array of sites, including commercial nuclear power reactors, DOE former atomic weapons production sites, industrial sites, military installations, university laboratories, hospitals, and pharmacies. The regulations would encompass DOD, DOE, NRC, and Superfund sites. Two separate EPA rulemakings are planned—one dealing directly with the cleanup of sites, the second pertaining to management of the waste that is removed. The Agency is working closely with NRC to avoid duplicative rules for NRC licensees, and is using information from the Commission's enhanced participatory rulemaking process to develop its standards. A proposed rule dealing with a cleanup standard for sites is scheduled to be issued in October 1994. The second proposed rule, dealing with waste management, will be issued about six months after the first proposed rule. These EPA rules will be directly legally applicable to decommissioning activities at DOE sites.

Until these rules are promulgated, the lack of a generic BRC policy for radioactive wastes that would guide cleanup and release of radioactive components at RA sites has

hampered RA activities at DOE facilities. At present, internal DOE orders (see Sect. 6.4.5) provide the only guidance for such cleanup activities.

6.4.2 Federal Agreements and Legislation

DOE has entered into a number of signed agreements with state and federal parties that define committed milestones and impact the handling of radioactive wastes at Y-12 RA sites. In addition, recent Congressional legislation, and DOE action in response to it, will also have an impact.

In June 1992, EPA and DOE signed the LDR-FFCA/ORR to bring mixed waste generation and storage facilities on the reservation into compliance with environmental law. Under the agreement, effective immediately, DOE-OR will submit plans that will include treatment and storage options for LDR mixed wastes to meet the requirements of RCRA. The plans, to be prepared by DOE, will include proposals for waste minimization, treatment studies, technology development, facility construction, and schedules for future treatment. The LDR-FFCA/ORR allows DOE ORR facilities to continue to generate and store mixed wastes while addressing LDR mixed waste compliance issues. The mixed wastes covered under the LDR-FFCA/ORR include flammable and corrosive liquids, solvents, paint waste, waste oils and organics, and solid mixed wastes.

On May 26, 1992, EPA published (57 FR 22024) a notice, proposing to find that DOE has made all but one of the demonstrations required in its application, under RCRA rules in 40 CFR 268.5, for a one-year, case-by-case extension of the May 8, 1992, effective date of the LDRs applicable to certain mixed wastes generated or stored at 31 DOE facilities; no official final action has been taken on this proposal as yet.

The FFCA of 1992 (Public Law 102-386, October 6, 1992) amends §6001 of the SWDA to waive immunity of the United States with respect to substantive and procedural requirements regarding control, abatement, or management of solid or hazardous waste. This waiver of immunity includes injunctive relief, administrative order, or civil or administrative penalties or fines, and subjects the federal government to the full range of available enforcement tools to penalize isolated, intermittent, or continuing violations. A delayed effective date of three years from enactment of the FFCA of 1992 is applied to the waiver of sovereign immunity for mixed waste regulated under SWDA §3004(j) so long as that waste is managed in accordance with other applicable requirements. Further, DOE is expressly exempt from the three year effective date for mixed waste in violation of SWDA of §3004(j) so long as DOE has in effect a plan that has been submitted and approved pursuant to SWDA §3021(b), and an order requiring compliance with such plan has been issued pursuant to SWDA §3021(b).

Even though the waiver is not delayed for DOE facilities that are subject to an existing agreement, permit, administrative or judicial order addressing compliance with the LDR storage prohibition for mixed wastes, the waiver will not apply to DOE as long as DOE meets certain conditions specified in the Act [FFCA of 1992, Sect. 102(c)(3)]. Specifically, the waiver shall not apply to DOE for mixed waste violations of §3004(j) of SWDA for as long as DOE has submitted, has in effect, and is in compliance with, a plan pursuant to §3021(b) of SWDA, and is in compliance with an order issued pursuant to SWDA §3021(b) requiring compliance with such plan.

Further sections of the Act regulate mixed waste inventory reports and plans required to be submitted by DOE within 180 days of the enactment of the FFCA of 1992. DOE has published its strategy for development of a national compliance plan for DOE mixed waste (57 FR 57170, December 3, 1992) and its Interim Mixed Waste Inventory Report

(58 *FR* 25822, Apr. 28, 1993). DOE's National Compliance Plan will integrate ER and D&D activities with the development of appropriate mixed-waste treatment, storage and disposal capacity.

6.4.3 EPA Regulations

EPA has promulgated MCLs for radionuclides in community water systems (see Table 6.6). These MCLs appear in two forms—concentration limits for certain alpha-emitting radionuclides (40 CFR 141.15) and an annual dose limit for the ingestion of certain beta- and gamma-emitting radionuclides (40 CFR 141.16). MCLs and MCLGs were proposed for radon and uranium and repropoed for ^{226}Ra and ^{228}Ra , beta emitters, and photon emitters on July 18, 1991, and are included in Table 6.6. Final promulgation of the concentration limits was scheduled for April 1993, but Congress voted to delay promulgation until the end of 1993. EPA proposed a schedule extension and will issue a final rule in October 1994.³ As with the chemical-specific MCLs, these concentration limits may be relevant and appropriate for cleanup of any contaminated groundwater at Y-12.

Table 6.7 lists EPA and DOE radiation protection standards that are described below. Subpart H of 40 CFR 61 addresses atmospheric radionuclide emissions from DOE facilities and may be applicable to airborne emissions during RA activities at Y-12. EPA has issued a final National Emission Standards for Hazardous Air Pollutants rule (54 *FR* 51654, Dec. 15, 1989) that limits emissions of radionuclides to the ambient air from DOE facilities to amounts that would not cause any member of the public to receive an effective dose equivalent of 10 mrem/year (40 CFR 61.92).

Environmental protection standards for the management, storage, and disposal of spent nuclear fuel, high-level wastes, and TRU wastes are found in 40 CFR 191. Management and storage must be conducted so as to provide a reasonable assurance that no member of the public in the general environment will receive a combined annual dose equivalent or greater than 25 mrem to the whole body and 75 mrem to any organ (40 CFR 191.03). The standards for disposal systems, originally listed in Subpart B of 40 CFR 191, were vacated by a federal appeals court decision in 1987; however, Subpart A was reinstated. The Waste Isolation Pilot Plant Land Withdrawal Act (WIPP LWA) was enacted on October 30, 1992 (Public Law 102-579); this act reinstated the Subpart B disposal standards except for the specific parts remanded by the court decision (§191.15 and §191.16). The WIPP LWA required EPA to issue final disposal standards by April 30, 1993. Accordingly, EPA proposed new environmental radiation protection standards for §191.15 as well as a new Subpart C to address groundwater protection requirements (58 *FR* 7924, February 10, 1993) and finalized these standards on December 20, 1993 (58 *FR* 66398), effective January 19, 1994. The original §191.04, which has been reinstated, established alternative standards for DOE facilities if EPA determines that such standards prevent any member of the public from receiving a continuous exposure of more than 100 mrem/year effective dose equivalent or an infrequent exposure of more than 500 mrem/year effective dose equivalent from all sources, excluding natural background and medical exposures.

The final §191.15 requires that "disposal systems for waste and any associated radioactive material shall be designed so that, for 10,000 years after disposal, undisturbed performance of the disposal system shall not cause the annual committed effective dose, received through all potential pathways from the disposal system, to any member of the public in the accessible environment, to exceed 15 mrem." The final §191.24 ("Subpart C—Environmental Standards for Groundwater Protection") states that

Table 6.6. Radionuclide-specific standards under the SDWA for ground water and surface water contamination at the Oak Ridge Reservation

Radionuclide	Current SDWA MCLs ^a	Proposed SDWA MCLs ^b
Radium ^c	5 pCi/L	20 pCi/L
Gross alpha ^d	15 pCi/L	15 pCi/L
Gross beta	4 mrem/year	4 mrem/year
Natural uranium		20 µg/L ^e
Radon-222		300 pCi/L
Strontium-90 ^f	8 pCi/L	52 pCi/L
Tritium ^f	20,000 pCi/L	60,900 pCi/L
All other manmade radionuclides	4 mrem/year ^g	4 mrem/year ^g

^a SDWA MCL = Safe Drinking Water Act maximum contaminant level.

^b Proposed rule, July 18, 1991 (56 FR 33050); final rule expected October 1994.

^c The present MCL applies to combined ²²⁶Ra and ²²⁸Ra; the proposed MCL applies to each separately.

^d The present MCL excludes radon and uranium but includes ²²⁶Ra; the proposed MCL excludes all three radionuclides.

^e Approximately equal to 30 pCi/L.

^f These values are not MCLs; rather they are concentrations that result in the effective dose equivalent (EDE) of 4 mrem/year, the MCL for gross beta emissions.

^g If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 mrem/year.

Source: E. L. Etnier, E. P. McDonald and L. M. Houlberg, *Applicable or Relevant and Appropriate Requirements (ARARs) for Remedial Action at the Oak Ridge Reservation, A Compendium of Major Environmental Laws*, ES/ER/TM-1/R2, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, July 1993.

“disposal systems for waste and any associated radioactive material shall be designed so that 10,000 years of undisturbed performance after disposal shall not cause the levels of radioactivity in any underground source of drinking water, in the accessible environment, to exceed the limits specified in 40 CFR 141.” Because of the many inherent problems with compliance assessments performed for such large time periods, EPA intends to develop criteria for certifying compliance with the 40 CFR 191 standards (58 FR 8029, February 11, 1993). The WIPP LWA requires that EPA issue proposed criteria by October 30, 1993, with final criteria by October 30, 1994. However, EPA will not be able to meet this schedule; proposed criteria will be issued in April 1994, and final criteria in April 1995.³

EPA intends to develop environmental radiation protection standards for the disposal of low-level waste (possibly including NARM) under 40 CFR 193 and 764. The intent of these standards will be to protect the public health and general environment from potential adverse effects from low-level waste disposal. These proposed regulations may provide guidance for cleanup of the RA sites when promulgated. The proposed rule is scheduled for October 1994, final rule December 1995.³

Table 6.7. Radiation protection standards that may be applicable to Oak Ridge Reservation D&D activities

Regulation	Applicability	Exposure conditions	Standard
40 CFR 61	National Emission Standards for Hazardous Air Pollutants for DOE facilities	Public exposure, airborne emissions	10 mrem/year
40 CFR 141	Drinking water maximum contaminant levels	Community water systems, gross beta	4 mrem/year
40 CFR 191	Spent nuclear fuel, high-level and transuranic wastes	Public exposure, all sources	25 mrem/year (total body) 75 mrem/year (thyroid)
DOE Order 5400.5 ^a	Radiation Protection of the Public and the Environment	Public exposure, all sources	100 mrem/year
		Temporary exemption, maximum limit	500 mrem/year 1 rad/d
		Aquatic organism exposure, absorbed dose	
DOE Order 5820.2A	Radioactive Waste Management	Public exposure, all sources, excluding air	25 mrem/year
		Public exposure, atmospheric releases	10 mrem/year
DOE Order 5480.11 ^b	Radiation Protection for Occupational Workers	Worker exposure limits, continuous exposure	5 rem/year, cancer effects 50 rem/year, noncancer effects, any organ or tissue
		Public exposures, controlled areas, effective dose equivalent	100 mrem/year

^a Proposed as 10 CFR 834 (58 FR 16268, March 25, 1993); final rule expected March 1994.

^b Proposed as 10 CFR 835 (56 FR 64334, Dec. 9, 1991); final rule expected July 1993.

Source: E. L. Etnier, E. P. McDonald and L. M. Houlberg, *Applicable or Relevant and Appropriate Requirements (ARARs) for Remedial Action at the Oak Ridge Reservation, A Compendium of Major Environmental Laws*, ES/ER/TM-1/R2, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, July 1993.

In addition, EPA intends to develop cleanup criteria for sites, including federal facilities, contaminated with radionuclides subject to the AEA and CERCLA. A proposed rule is planned for October 1994, final rule a year later.³

6.4.4 Department of Transportation Regulations

The Department of Transportation Regulations for Hazardous Materials list general requirements for shipping and packaging at 49 CFR 172 and 173, and for requirements for carriage by public highway at 49 CFR 177. General requirements for shipping of hazardous materials are defined in 49 CFR 172, with specific marking, labeling, and placarding regulations for radioactive materials in 49 CFR 172.310, 172.403, and 172.556, respectively. These regulations would be applicable to any off-site shipments of hazardous or radioactive materials from RA activities.

49 CFR 173, Subpart I, lists requirements for packaging and shipping radioactive materials. General package design requirements are given in 49 CFR 173.411, with specific design requirements for Type A and B packaging found in 49 CFR 173.412 and 173.413, respectively. Activity limits for normal form radioactive material (termed A_2 limits) are listed in 49 CFR 173.435 for various radionuclides. Type A packaging is authorized for shipment if each package does not exceed the A_2 value (49 CFR 173.431). If package quantities exceed the A_2 value, Type B packaging is required (49 CFR 173.431). In addition, each package of radioactive materials must be designed and prepared for shipment such that under normal conditions, the radiation level does not exceed 200 mrem/h at any external point on the package (49 CFR 173.441). Small quantities of solid radioactive materials are exempt from the packaging and shipping requirements of this part if the materials package limit is less than $10^{-3} A_2$ (49 CFR 173.4 and 173.423).

Standards for the packaging and shipment of NRC-licensed material are found in 10 CFR 71. These are not legally applicable to DOE activities. However, DOE Order 5480.3 (*Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes*) specifies the Type A packaging requirements, which are given in 49 CFR 173.411 and 412. Type B packages shall be in compliance with requirements found in 10 CFR 71. Reference is made to 10 CFR 71.41 et seq. for general standards for all packages and special requirements for Type B packages [DOE Order 5480.3(8)].

Regulations governing transportation of hazardous materials by public highway are found in 49 CFR 177, and specific loading and unloading requirements for radioactive materials are in 49 CFR 177.842. The number of packages in any one motor vehicle must be limited so that the total transport index number does not exceed 50. The total transport index is described as the sum of the numbers expressing the maximum radiation level in mrem/h at 1 meter (3.3 ft) from the external surface of each package (49 CFR 173.403bb).

6.4.5 DOE Orders

DOE orders are not promulgated regulations and thus are not considered to be legally binding by EPA. They are, however, binding between DOE and Martin Marietta Energy Systems, Inc., because of contractual agreements. The radiation exposure limits for members of the public from management and storage of TRU waste defined in DOE Order 5400.5 (*Radiation Protection of the Public and the Environment*, February 8, 1990) are: (1) an effective dose equivalent of 25 mrem/year to the whole body, or (2) 75 mrem/year to a single organ [5400.5(II.1c)]. The basic dose limit for routine DOE activities, including RA monitoring, cleanup, and control of residual radioactive material is 100 mrem/year. In addition, guidelines are given for levels of residual surface contamination that shall not be exceeded if a RA is to be considered completed and

property released to the public without restrictions on use [5400.5(II.5a)]. These levels are listed for specific isotopes and beta-gamma emitters in general. In all instances, the overriding principle of the DOE order is that all releases of radioactive material shall be ALARA. Chapter IV of the order lists guidelines for cleanup of radioactive real and personal property, management of the resulting wastes and residues, and release of property. Information on application of the guidelines and requirements presented in the order, including procedures for deriving specific property guidelines for allowable levels of residual radioactive material from basic dose limits, is contained in DOE/CH 8901, "A Manual for Implementing Residual Radioactive Material Guidelines, A Supplement to the U.S. Department of Energy Guidelines for Residual Radioactive Material at FUSRAP and SFMP Sites," June 1989 [5400.5(IV.2)]. Table 6.8 summarizes the contents of DOE Order 5400.5 with respect to RAs. DOE proposed for codification as 10 CFR 834 the contents of DOE Order 5400.5 as radiation protection requirements for the public and the environment for DOE and DOE Contractor operations (58 FR 16268, March 25, 1993).

DOE Order 5820.2A (*Radioactive Waste Management*, Sept. 9, 1988) states that the management of low-level waste must ensure that external exposure to the waste and concentrations of radioactive material that may be released into surface water and soil does not exceed 25 mrem/year to any member of the public. Releases to the atmosphere shall not exceed 10 mrem/year (Table 6.7). Reasonable effort should be made to maintain releases to the environment to ALARA levels. The order pertains to the management of radioactive waste and contains closure and post-closure care requirements. Table 6.9 summarizes the substantive requirements of this DOE order.

DOE Order 5480.11 (*Radiation Protection for Occupational Workers*) contains guidelines for worker protection, which are similar to those of 10 CFR 20 [i.e., 5 rem/year and 50 rem/year annual effective dose equivalent for stochastic (cancer) and nonstochastic (systemic) effects, respectively, from both internal and external sources for continuous exposures]. Also included in the order are standards for the general public when entering a controlled area. Exposures to the public are limited to an effective dose equivalent of 100 mrem/year (Table 6.7). As with the other DOE orders, the ALARA principle prevails. Remediation of radionuclide-contaminated soils must ensure that exposures to on-site workers or public intruders shall not exceed these standards. DOE codified in 10 CFR 835 these primary standards for radiation protection of occupational workers from normal operation of DOE facilities in a final rule issued December 21, 1993 (58 FR 67442), effective January 13, 1994. These standards are now legally applicable for RA activities at Y-12.

Table 6.8. DOE Order 5400.5, "Radiation Protection of the Public and the Environment"

Action	Requirement	Chapter
Planning and performance of all DOE activities	DOE will carry out all DOE activities to ensure that radiation doses to individuals will be as low as reasonably achievable (ALARA).	I.4
Routine DOE activities including remedial action	DOE must comply with all legally applicable requirements of 40 CFR 61 (NESHAPs ^a for DOE Facilities) and 40 CFR 191 (spent nuclear fuel, high-level, and transuranic wastes).	I
	Exposures to members of the public from all radiation sources shall not cause an effective dose equivalent to be greater than 100 mrem (1 mSv) per year.	II.1a
	Exposures to members of the public from all radiation sources released into the atmosphere shall not cause an effective dose equivalent to be greater than 10 mrem (0.1 mSv) per year.	II.1b
Management and storage of spent nuclear fuel, high-level or transuranic waste at a disposal facility that is not regulated by the NRC ^b	Members of the public shall not receive an effective dose equivalent greater than 25 mrem (0.25 mSv) to the whole body or 75 mrem (0.75 mSv) to a single organ per year.	II.1c
	Radioactive materials released into public drinking water supplies shall not cause an effective dose equivalent to be greater than 4 mrem (0.4 mSv) to an individual per year. Gross alpha activity shall not exceed 1.5×10^{-6} μ Ci/ml.	II.1d
	Liquid effluents shall not cause private or public drinking water systems downstream of the facility to exceed the MCL(s) of 40 CFR 141.	II.1d(3)
Discharge of liquid waste containing radionuclides to surface water	Implementation of best available technology (BAT) treatment required if discharge is at an annual average concentration greater than the derived concentration guide (DCG) level.	II.3a(1)

Table 6.8 (continued)

Action	Requirement	Chapter
Discharge of liquid waste containing radionuclides to surface water (continued)	Discharge of liquid waste containing radionuclides to surface water at an annual average concentration less than the DCG level does not require the implementation of BAT treatment.	II.3a(2)
	The absorbed dose to native aquatic animal organisms shall not exceed 1 rad/day from exposure to liquid wastes discharged to natural waterways.	II.3a(5)
	Liquid wastes containing concentrations of radioactive materials greater than 5 times the DCG(s) may be discharged to a federal sanitary sewerage system that provides liquid waste treatment prior to discharge to surface water according to II.3a(1). ALARA process considerations are required.	II.3d(3)
	If a waste stream contains multiple radionuclides, then the DCG shall be the sum of the fractional DCG values.	II.3a(3)
Management of low-level radioactive solid waste containing no RCRA ^c constituents	Design, operational, and monitoring requirements are found in DOE Order 5820.2A (Radioactive Waste Management).	II.4
Demonstration of compliance with the dose limits	DOE shall make appropriate documentation containing information about compliance with dose limits for members of the public in the immediate vicinity and within 80 km of the site.	II.6
Conduct of radiological environmental protection programs	DCGs for water ingestion, air inhalation, and immersion in a gaseous cloud are provided as reference values. These DCGs are based on a committed effective dose equivalent of 100 mrem for the radionuclide taken into the body by ingestion or inhalation during one year.	III.2
	The DCG values apply to only one mode of exposure (i.e., either ingestion or inhalation).	III.2a

Table 6.8 (continued)

Action	Requirement	Chapter
Conduct of radiological environmental protection program (continued)	For known mixtures of radionuclides the sum of the ratios of the observed concentration of each radionuclides to its corresponding DCG must not exceed 1.0.	III.2c
Cleanup of residual radioactive material and management of resulting wastes or residues	DOE facilities shall develop plans and protocols for the implementation of this guidance.	IV.1 & 2
	These guidelines are for levels of residual radioactive material that is acceptable for public use of property without restrictions because of residual radioactive material.	IV.2c
	Generic guidelines are taken from existing radiation protection standards.	IV.2c(1)
	Authorized limits are levels of residual radioactive material that shall not be exceeded if the remedial action is to be considered completed and the property is to be released without restrictions on use.	IV.2d
	Monitoring, cleanup, and control of residual radioactive material are subject to the ALARA policy.	IV.2e
	The basic dose limits for exposure to residual radioactive material is 100 mrem (1 mSv) annually.	IV.3a
	Under unusual circumstances, the dose limit for exposure to residual radioactive material is increased from 100 mrem (1 mSv) to 500 mrem (5 mSv) annually.	IV.3b
	Residual radioactive material in soil are those concentrations in excess of background concentrations averaged over an area of 100 m ² . These derivations are obtained by means of environmental pathway analysis and basic dose limits.	IV.4a

Table 6.8 (continued)

Action	Requirement	Chapter
Cleanup of residual radioactive material and management of resulting wastes or residues (continued)	Residual concentrations of radionuclides in the air and water shall not exceed 100 mrem (1 mSv) per year.	IV.4e
	Limits for hot spots shall be developed in cases where the average concentration in any surface or below surface area equal to or less than 25 m ² exceeds the limit or guidelines by a factor of (100/A) ^{0.5} . Reasonable effort must be made to remove any radionuclide source that exceeds 30 times the limit.	IV.4a(1)
	The generic guidelines for ²²⁶ Ra, ²²⁸ Ra, ²³⁰ Th, and ²³² Th are 5 pCi/g averaged over the first 15 cm of soil or 15 pCi/g averaged over 15-cm-thick layers of soil below the first 15 cm.	IV.4a(2)
Management of residual radioactivity above the guidelines specified in IV.1-4	Interim storage control and stabilization features shall be planned to have a minimum life of 25 years and, if reasonably achievable, an effective life of 50 years.	IV.6b(1)
	Control features must be designed so that radionuclide concentration in the ground water shall not exceed applicable federal and state standards.	IV.6b(3)
	If residual radioactive material is in inaccessible locations and would be unreasonably costly to remove and when residual radioactive material exceeds guideline values, an interim management plan may be arranged to maintain the property.	IV.6c(1)
	Administrative controls shall include (but are not limited to): <ul style="list-style-type: none"> · periodic monitoring as appropriate, · appropriate shielding, · physical barriers to prevent access, and · appropriate radiological safety measures. 	IV.6c(2)

Table 6.8 (continued)

Action	Requirement	Chapter
Management of residual radioactivity above the guidelines specified in IV.1-4 (continued)	Control and stabilization for uranium, thorium, and their decay products must be designed to last at a minimum of 200 years and if reasonably achievable have an effective life of 1000 years.	IV.6d(1)(a)
	In accordance with legally applicable federal and state standards, DOE facilities shall protect ground water.	IV.6d(1)(d)
	Use of and access to residual radioactive material shall be controlled through appropriate administrative and physical controls.	IV.6d(1)(e)
	Long-term management of other radionuclides shall be controlled by applicable requirements in Chapters II, III, and IV of DOE 5820.2A.	IV.6d(2)

^aNESHAPs = National Emission Standards for Hazardous Air Pollutants.

^bNRC = Nuclear Regulatory Commission.

^cRCRA = Resource Conservation and Recovery Act.

Source: E. L. Etnier, E. P. McDonald and L. M. Houlberg, *Applicable or Relevant and Appropriate Requirements (ARARs) for Remedial Action at the Oak Ridge Reservation, A Compendium of Major Environmental Laws*, ES/ER/TM-1/R2, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, July 1993.

Table 6.9. DOE Order 5820.2A, "Radioactive Waste Management"

Action	Requirement	Chapter
Management of low-level radioactive waste	Development of site-specific comprehensive closure plans shall address: • Disposal sites' closure after the site has been filled for 5 years and • National Environmental Policy Act (NEPA) requirements.	III.3j(1)
	Residual radioactivity levels for surface soil will comply with DOE decommissioning guidelines (DOE Order 5400.5).	III.3j(2)
	The Oak Ridge Reservation must correct problems that could jeopardize the attainment of this order's performance objectives.	III.3j(3)
	All disposal sites and units shall be maintained to conform with RCRA ^a , CERCLA ^b , and SARA ^c standards.	III.3j(4)
	An appropriate field organization shall review and approve any closure plans for new and existing low-level waste disposal sites.	III.3j(5)
	An analysis of site performance will be the basis for terminating the monitoring and maintenance activity at closed facilities or sites at the end of the institutional control period.	III.3j(6)
Management of buried transuranic waste	All disposal sites and units shall be maintained to conform with CERCLA and SARA standards.	II.1
	Transuranic waste shall be managed to protect the health and safety of the public and the workers at the site.	II.2
	Each DOE facility will develop a site closure plan which will include: • NEPA requirements; • Applicable federal, state, and local regulations; • Permits required; • Selected closure strategy and justification; and • Postclosure monitoring and control.	II.3i(4)

^aRCRA = Resource Conservation and Recovery Act.

^bCERCLA = Comprehensive Environmental Response, Compensation, and Liability Act.

^cSARA = Superfund Amendments and Reauthorization Act.

Source: E. L. Etnier, E. P. McDonald and L. M. Houlberg, *Applicable or Relevant and Appropriate Requirements (ARARs) for Remedial Action at the Oak Ridge Reservation, A Compendium of Major Environmental Laws*, ES/ER/TM-1/R2, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, July 1993.

6.5 ACTION-SPECIFIC REGULATIONS

Performance, design, or other action-specific requirements set controls or restrictions on particular kinds of activities related to the management of hazardous waste. Certain RAs at a site may invoke the appropriate action-specific regulations that specify particular performance standards or technologies, as well as specific environmental levels for discharged or residual chemicals. Action-specific regulations are established under RCRA, CERCLA, CAA, CWA, SDWA, TSCA, FIFRA, and OSHA.

6.5.1 Comprehensive Environmental Response, Compensation, and Liability Act

The intent of CERCLA as amended by SARA is to provide for the cleanup of inactive hazardous waste disposal sites and to provide for response to, and cleanup of, environmental problems that are not covered adequately by the permit programs of other environmental laws. RA activities that have been incorporated into the FFA would be subject to CERCLA regulations.

The administrative requirements of RCRA (e.g., permitting, reporting, and record keeping) or any other federal or state regulations are not required for on-site RA if a facility is being cleaned up under CERCLA [CERCLA §121(e) and FFA §XXII(A)]. However, under CERCLA §121(d)(3) and FFA §XXII(B), any removal or RA involving the off-site transfer of hazardous substances, pollutants, or contaminants must involve a facility in compliance with all RCRA substantive and administrative requirements. CERCLA response actions will be coordinated with, and supplement, the corrective measures required and conducted by DOE under its current RCRA permit [FFA §IV(A)].

6.5.2 Resource Conservation and Recovery Act

RCRA has nine distinct sections (subtitles) that regulate various aspects of hazardous waste. Three of these, Subtitle C "Hazardous Waste Management," Subtitle D "Solid Waste Management," and Subtitle I "Regulation of Underground Storage Tanks," provide the regulatory guidance for CERCLA actions and will be considered for regulations for on-site RA activities and cleanup at Y-12.

Minimum national standards for acceptable management of hazardous waste appear in RCRA, although Tennessee has been authorized by EPA to administer and enforce its own standards in lieu of the federal RCRA regulations. Federally authorized state RCRA programs relate only to RCRA standards before HSWA.

Tennessee's promulgated RCRA requirements supersede federal regulations as legally applicable. However, Tennessee's substantive RCRA regulations are identical for the most part to the federal RCRA regulations.¹¹ New regulations imposed in 1984 by HSWA are to be considered applicable under federal law in all states until each authorized state promulgates its own HSWA-related standards. Although the Tennessee Solid Waste Disposal Control Board has promulgated many of the HSWA regulations, EPA has not yet authorized the program.¹²

6.5.2.1 RCRA Subtitle C regulations

RCRA Subtitle C regulates the generation, transportation, treatment, storage, and disposal of hazardous waste. Standards for the management of hazardous waste at RCRA-permitted treatment, storage, and disposal facilities were promulgated July 26,

1982, and appear as 40 CFR 264. Standards for interim treatment, storage, and disposal facilities are found in 40 CFR 265.

In general, this text will address the Part 264 rather than the Part 265 standards as they are the more stringent. Table 6.10 lists the pertinent subparts of the permitted and interim standards and the equivalent section of the TDEC hazardous WM regulations.

As discussed in Sect. 6.2, D&D activities that generate RCRA hazardous wastes but are not incorporated as CERCLA Sites into the FFA would be subject to regulation under RCRA. In contrast to CERCLA, D&D activities subject to RCRA would be subject to the administrative as well as the substantive requirements of the law, including all the applicable permitting requirements.

The RCRA Subtitle C Part 264 regulations apply to particular WM processes (e.g., capping or incineration) or to general procedures (e.g., treatment, disposal, or closure), and it may be necessary to combine the two types of categories to adequately address the action-specific regulations for a particular remedial activity.

6.5.2.2 Land Disposal Restrictions

If RCRA-listed or -characteristic waste is generated/identified during the RA process, these wastes would be subject to the RCRA LDRs if they are land disposed. For each hazardous waste, EPA has established treatment standards that are protective of human health and the environment when the wastes are land disposed. Land disposal includes, but is not limited to placement in a landfill, surface impoundment, waste pile, and land treatment facility. In the final National Contingency Plan, EPA reaffirms that movement of waste within a unit does not constitute "land disposal" for purposes of application of the RCRA LDRs; however, waste consolidation from different units at a CERCLA site are subject to the restrictions (55 FR 8759).

These LDRs apply only to RCRA hazardous waste placed after the effective prohibition date. Wastes may be land disposed if they have been treated with the best demonstrated available technology (BDAT) set by EPA and meet the treatment standards. A final rule listing provisions for specific treatment standards and prohibiting land disposal of the following wastes has appeared. Table 6.11 lists the waste categories for which LDRs have been promulgated, the *Federal Register* citation, and the corresponding section in 40 CFR 268. Tennessee Rule 1200-1-11-.10 contains the state LDRs, which are similar to the RCRA LDRs. A final rule for corrective action at RCRA sites and CERCLA sites contaminated with RCRA hazardous waste regulates wastes generated for the purpose of implementing RAs, and exempts designated sites from the LDRs and minimum technology requirements (MTRs) under 40 CFR 268 (see "Correction Action Requirements" below).

EPA has determined that the RCRA treatment standards are generally inappropriate or infeasible when applied to contaminated soil or debris (55 FR 8760). Therefore, EPA is proposing separate rule makings to establish treatment standards for disposal of such contaminated soil and debris. The advance notice of proposed rule making (ANPRM) for debris appeared in 56 FR 24444, May 30, 1991, the notice of proposed rule making (NPRM) on Jan. 9, 1992 (57 FR 958) and the final rule on August 18, 1992 (57 FR 37194). The rule requires contaminated debris to be treated before land disposal using extraction, destruction, or immobilization technologies. Six different categories of debris and ten different categories of contaminants are specified in the rule. As with mixed waste, debris contaminated with both hazardous and radioactive waste must comply with the treatability standards for contaminated debris as well as those under the AEA. Disposal of treated debris and resultant wastes are discussed in the rule.

Table 6.10. RCRA^a Subtitle C—standards for the treatment, storage, and disposal of hazardous waste

Federal	Tennessee	Category
40 CFR Part 264	1200-1-11-.06^b	
Subpart I	Section 9	Containers
Subpart J	Section 10	Tanks
Subpart K	Section 11	Surface impoundments
Subpart L	Section 12	Waste piles
Subpart M	Section 13	Land treatment
Subpart N	Section 14	Landfills
Subpart O	Section 15	Incinerators
Subpart X	Section 19	Miscellaneous treatment units
40 CFR Part 265	1200-1-11-.05	
Subparts I-O	Sections 9-15	As listed above
Subpart P	Section 16	Thermal treatment
Subpart Q	Section 17	Chemical, physical, and biological treatment

^aRCRA = Resource Conservation and Recovery Act.

^bRule 1200 of the Tennessee Department of Environment and Conservation Hazardous Waste Management Regulations.

Table 6.11. Federal RCRA^a land disposal regulations

Waste category	Citation	40 CFR Part
Spent-solvent and dioxin-containing wastes	51 FR 40572 (Nov. 7, 1986)	268.30 268.31
"California List" wastes	52 FR 25760 (July 8, 1987)	268.32
First Third wastes ^b	54 FR 31138 (Aug. 17, 1988)	268.33
Second Third wastes ^b	54 FR 26594 (June 23, 1989)	268.34
Final Third wastes ^b	55 FR 22520 (June 1, 1990)	268.35

^aRCRA = Resource Conservation and Recovery Act.

^bAll listed hazardous wastes identified under 40 CFR 261.

In the debris rule, EPA established a new treatment unit for treating contaminated debris; a "containment building" has been added to the definitions of 40 CFR 260.10 to provide for storage and treatment of contaminated debris that does not contain free liquids and is not amenable to treatment in tanks or containers (57 FR 979, January 9, 1992). Performance standards for the design and operation of such containment buildings are promulgated for a new Subpart DD to 40 CFR 264 and 265 for permitted facilities and interim status facilities, respectively. All containment buildings, permitted or unpermitted must comply with the same level of performance. These standards would be legally applicable to any RA activities involving dismantlement of structures and subsequent decontamination in a building. Physical extraction technologies such as abrasive blasting or spalling used to treat debris in place, but that is intended for discard (e.g., treatment of a contaminated building prior to demolition), are subject to the permit standards of 40 CFR 264, Subpart X for miscellaneous units or the interim status standards for chemical, physical, or biological treatment in 40 CFR 265, Subpart Q (preamble to the final debris rule).

The ANPRM for soil appeared Oct. 24, 1991 (56 FR 55160); NPRM September 14, 1993 (58 FR 48092), final rule expected July 1994.³ In the interim, EPA has developed guidance for obtaining and complying with a treatability variance for soil and debris that are contaminated with RCRA hazardous wastes for which treatment standards have already been set (Office of Solid Waste and Emergency Response Directive 9347.3-06FS, July 1989). Alternate treatment levels are presented for structural functional groups of organics and for ten inorganics based on actual treatment of soil and best management practices (BMPs) for debris. These should be considered as guidance when RA activities are scheduled that may contaminate or deal with contaminated soil. In addition, EPA has granted an extension of a case-by-case capacity variance from the LDRs for certain debris until May 8, 1994 (58 FR 28506, May 14, 1993). A previously granted national capacity variance for hazardous soil to May 8, 1993 has now expired and will not be extended by EPA.

6.5.2.3 Corrective Action Requirements

Several sections of RCRA require promulgation of corrective action regulations; when finalized, these requirements will most likely be legally applicable to RA sites where there is RCRA hazardous waste contamination. Currently, only the 40 CFR 264 Subpart F regulations on ground-water protection at RCRA-regulated units are potentially applicable to RA activities within facility boundaries and these include ground-water protection standards (40 CFR 264.92 and 40 CFR 264.94) and ground-water monitoring requirements (40 CFR 264.97). The corrective action standards developed under RCRA §3004(u) will be applicable to any D&D or RA cleanup site that is also an active or a formerly active RCRA facility with an active solid waste management unit; thus, the standards will also be applicable to a D&D or RA site where disposal is currently occurring. In addition, RCRA §3004(v) authorizes cleanup beyond facility boundaries.

Requirements for corrective action for RCRA solid waste management units have been proposed (55 FR 30798, July 27, 1990). A final rule is expected to appear in October 1994.³ EPA proposes a risk-based approach to establish media cleanup standards for surface water, groundwater, soil, and air. These standards are to be established at concentrations that ensure protection of human health and the environment and are to be set for each media of concern during the remedy selection process. RCRA corrective action levels are not intended to be used as cleanup levels; they are intended only to "trigger" the corrective action process when exceeded. Target cleanup levels may initially

be set at these RCRA action levels but must be modified as appropriate to reflect site-specific exposure assumptions (55 FR 30826). Appendix A of the proposed rule lists proposed action levels for 165 compounds (55 FR 30865), and Appendix E gives governing equations for calculating action levels (55 FR 30870).

A portion of the proposed Subpart S rule was promulgated as a final rule for corrective action at Corrective Action Management Units (CAMUs) and Temporary Units (TUs). This rule establishes two sections in Subpart S (*Corrective Action for Solid Waste Management Units*): 40 CFR 264.552 (CAMUs) and 40 CFR 264.553 (TUs) (58 FR 8658, February 16, 1993). Both of these units function solely to manage wastes that are generated at a RCRA facility for the purpose of implementing RA (i.e., remediation wastes). As a result of this rule, regulatory requirements for remediation wastes will differ from those for "as-generated" wastes regulated under Subtitle C, particularly the LDRs and MTRs. The CAMU or TU designations must be made by EPA or the authorized state, and such designations would be subject to the public review and comment process as part of a remedy selection. These designations would be incorporated into permit modifications for a facility and would include specifications of applicable design, operating, and closure requirements that may be less stringent than the appropriate 40 CFR 264 standards.

Under the CAMU provisions, movement and consolidation of remediation wastes within a designated CAMU will not be subject to LDRs or other hazardous waste land disposal requirements. CAMUs would also not be subject to MTRs, since they are not classified as landfills, surface impoundments, or waste piles. Placement of remediation wastes into a CAMU from an area at a facility but outside the CAMU, or from one CAMU into another CAMU will not trigger LDRs or MTRs, nor will excavation, treatment outside the CAMU, and replacement back in the CAMU. However, movement of wastes from a CAMU to another area in a facility not designated a CAMU would trigger the appropriate LDRs or MTRs.

The EPA Regional Administrator may designate tanks and container storage units used for treatment or storage of remediation wastes as TUs. Permit specifications for TUs must include design, operating, and closure requirements. These may be less stringent than the 40 CFR 264 requirements as long as they are protective of human health and the environment and comply with statutory requirements.

The substantive requirements of this rule are expected to be legally applicable to RAs at CERCLA RA sites that involve the management of RCRA hazardous waste. In this context, CAMU designations would be incorporated into CERCLA decision documents.

6.5.2.4 RCRA Subtitle I Regulations

RCRA §9003 requires promulgation of regulations pertaining to detection, prevention, and correction of releases from underground storage tanks; implementing regulations appear in 40 CFR 280.50 ("Release Reporting, Investigation, and Confirmation"), 280.60 ("Release Response and Corrective Action for Underground Storage Tank Systems Containing Petroleum or Hazardous Substances"), and 280.70 ("Out-of-Service Underground Storage Tank Systems and Closure") and should be considered as regulations for cleanup of any Underground Storage Tanks located at RA sites. 40 CFR 280.66 specifies that corrective action plans designed to protect human health and the environment must be submitted to the "implementing agency" (TDEC Underground Storage Tank Division) for approval. The state must be notified of permanent closure plans not taken in response to corrective action (40 CFR 280.71); suggested cleaning and closure procedures are recommended in 40 CFR 280.71 and may be considered guidance for closure of any tanks at RA sites.

Tennessee Code Annotated (TCA) §68-53-101 *et seq.* authorized the Underground Storage Tank Board to promulgate regulations on July 1, 1988. The implementing regulations for release response and corrective action were promulgated April 15, 1990, and are found in TDEC Rules Chaps. 1200-1-15-.05 to 1200-1-15-.07. These regulations closely parallel the 40 CFR 280 regulations, although the state regulations only apply to Underground Storage Tanks containing petroleum products.

6.5.2.5 RCRA Subtitle D Regulations

EPA has promulgated a final rule establishing a new 40 CFR Part 258, which sets forth revised minimum federal criteria for municipal solid waste landfills (56 FR 50978, Oct. 9, 1991). These criteria include closure and postclosure care requirements (40 CFR 258.60 and 258.61).

In addition, the Tennessee (Rules of the TDEC Chap. 1200-1-7) and federal RCRA regulations governing solid WM facilities may regulate RA activities. Specifically, 40 CFR 257.3-3 prohibits nonpoint source contamination of surface waters from solid WM facilities. 40 CFR 257.3-3 also prohibits point source discharges of pollutants into surface waters that are in violation of the requirements of the National Pollutant Discharge Elimination System. 40 CFR 257.3-4 prohibits contamination of an underground drinking water source above SDWA MCLs.

6.5.3 Clean Air Act

Chapter 25, "Air Pollution Control," of the TCA provides for the purity of the air resources of the state "consistent with the protection of normal health, general welfare and physical property of the people, maximum employment and the full industrial development of the state." Implementing these objectives are the Tennessee ambient air quality standards established by the TDEC Division of Air Pollution Control, which appear in Chap. 1200-3-3 of the Rules of the TDEC and are identical to the federal primary National Ambient Air Quality Standards (see Sect. 6.3.2 and Table 6.1). The ambient standards of Chap. 1200-3-3 are translated into source-specific emission limitations (Rules of the TDEC, Chaps. 1200-3-4 to 1200-3-21) that must be considered legally applicable if they apply to any of the RA sites. Table 6.12 lists sections of the Tennessee air emission standards that should be analyzed on a site-specific basis for each remedial alternative.

The CAA (§111) requires EPA to promulgate standards for new sources of air emissions. This requirement has been implemented in 40 CFR 60 through the New Source Performance Standards that are based on the BDAT and set minimum federal emission limitations on classes of facilities. The National Emission Standards for Hazardous Air Pollutants have been discussed as potential "hybrid" regulations (see Sects. 6.2 and 6.4.1), which should be considered as remedial alternatives are selected.

Certain on-site construction and/or excavation activities may be necessary to prepare a site for remediation. Airborne pollutants may result from these construction activities. The primary concern is elevation of particulate concentrations resulting from earth-moving and site-grading activities. The TDEC, Division of Air Pollution Control has promulgated regulations governing fugitive dust emissions (Rules of the TDEC, Chap. 1200-3-8-.010). An operator must take reasonable precautions to prevent particulate matter from becoming airborne. In addition, fugitive dust may not be emitted as visible emissions beyond property boundary lines for more than 5 min/h or 20 min/day.

**Table 6.12. Rules of the TDEC^a Bureau
of Environment Division of Air Pollution Control**

Chapter	Subject
1200-3-1	General provisions
1200-3-2	Definitions
1200-3-4	Open burning
1200-3-5	Visible emissions
1200-3-6	Nonprocess emission standards
1200-3-7	Process emission standards
1200-3-8	Fugitive dust
1200-3-11	Hazardous air contaminants
1200-3-14	Control of sulfur dioxide emissions
1200-3-16	New source performance standards
1200-3-18	Volatile organic compounds
1200-3-21	General alternate emission standards
1200-3-22	Lead emission standards
1200-3-23	Visibility protection
1200-3-24	Stack height regulations

^aTDEC = Tennessee Department of Environment and Conservation.

6.5.4 Clean Water Act

The regulatory aspects of the CWA include site-specific pollutant limitations and performance standards designed to restore and maintain the chemical, physical, and biological integrity of the nation's surface waters. The National Pollutant Discharge Elimination System permit program includes applicable effluent standards, monitoring requirements, and conditions for discharge. Tennessee has an EPA-authorized state program that is equivalent to the federal program. Various National Pollutant Discharge Elimination System permits regulate discharges from ORR to the Clinch River and its tributaries. The effluent limitations and monitoring requirements found in the National Pollutant Discharge Elimination System permits should be analyzed on a site-specific basis for any cleanup at RA sites that would include discharge of pollutants to surface waters.

Direct discharge of dredge-and-fill material into navigable waters is regulated under CWA §404 and implemented through 33 CFR 320-330 and 40 CFR 230. Actions that may be considered dredge-and-fill activities include dredging of sediments from contaminated water bodies, disposal of contaminated soil or materials in surface water, capping of a site, building berms and levees to contain wastes, excavation for the containment of effluent, and dewatering of a site to obtain adequate flow.⁸

The U.S. Army Corps of Engineers issues dredge-and-fill permits for activities regulated under §10 of the Rivers and Harbors Act and §404 of the CWA; in addition, the Tennessee Valley Authority Act §26A approval application for streambed sediment removal may be necessary. Permits may be required by the Corps of Engineers for RA activities at Y-12 because portions of East Fork Poplar Creek and Bear Creek may be designated as "navigable waters" by the Corps of Engineers. All of the CWA §404 requirements for protection of wetlands from fill operations are potentially applicable to remedial activities at Y-12 that would impact wetland communities (see Sect. 6.6.3 and Table 6.13 for a further discussion of these issues). CERCLA §121(e) stipulates that

**Table 6.13. Action-specific regulations applicable to remedial action activities
at the Oak Ridge Reservation^a**

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Air emissions	Standards for control of emissions of volatile organics. These are based on CAA ^{f,g} , emission standards found in 40 CFR 60.480-60.489.	Emissions from process vents and equipment leaks at treatment, storage, and disposal (TSD) facilities handling or recycling hazardous waste containing 10% or more volatile organics	55 FR 25454 (June 21, 1990)	
	EPA is <i>proposing</i> to require organic emission controls be installed and operated on tanks, surface impoundments, containers, and certain miscellaneous treatment units if any hazardous waste having a volatile organic concentration equal to or greater than 500 ppm by weight is placed in the unit.	<i>Proposed</i> rule, not yet an ARAR ^h	<i>Proposed</i> rule, 56 FR 33490, July 22, 1991; Final rule expected March 1994	

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Capping	Placement of a cap over waste (e.g., closing a landfill, or closing a surface impoundment or waste pile as a landfill, or similar action) requires a cover designed and constructed to:	RCRA ^{h, i} hazardous waste placed at site after Nov. 19, 1980, or placement of hazardous waste into another unit will make requirements applicable when the waste is being covered with a cap for the purpose of leaving it behind after the remedy is completed.	40 CFR 264.228(a) (Surface impoundments) 40 CFR 264.258(b) (Waste piles) 40 CFR 264.310(a) (Landfills)	1200-1-11-.06(11)(i) 1200-1-11-.06(12)(i) 1200-1-11-.06(14)(k)
	<ul style="list-style-type: none"> Provide long-term minimization of migration of liquids through the capped area; Function with minimum maintenance; Promote drainage and minimize erosion or abrasion of the cover; Accommodate settling and subsidence so that the cover's integrity is maintained; and Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present. 	Capping without such placement will not make requirements applicable, but technical requirements are likely to be relevant and appropriate		
	Restrict postclosure use of property as necessary to prevent damage to the cover.	Final closure of a RCRA hazardous waste facility with some hazardous materials or residues left in place	40 CFR 264.117(c)	1200-1-11-.06(7)(h)
	Prevent run-on and run-off from damaging the final cover.	Postclosure care	40 CFR 264.228 (b) 40 CFR 264.310(b)	1200-1-11-.06(11)(i) 1200-1-11-.06(14)(k)
	Protect and maintain surveyed benchmarks used to locate waste cells (landfills, waste piles).	Postclosure care	40 CFR 264.310 (b)	1200-1-11-.06(14)(k)

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Clean closure (e.g., closure with no post-closure care)	<i>Closure and postclosure standards</i>	Applicable to land-based unit containing hazardous waste ^d . Applicable to RCRA hazardous waste (listed or characteristic) placed at site after Nov. 19, 1980, or placement of hazardous waste into another unit	40 CFR 264.110-120 (Subpart G)	1200-1-11-.06(7)(a)-(k)
	General performance standard requires elimination of need for further maintenance and control; elimination of postclosure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products to ground water, surface water, or the environment.	Not applicable to material undisturbed since Nov. 19, 1980, or if treated in situ or consolidated within area of contamination	40 CFR 264.111	1200-1-11-.06(7)(b)
		Designed for cleanup that will not require long-term management; designed for cleanup to health-based standards.		
	Removal or decontamination of waste residues, contaminated containment system components (e.g., liners and dikes), contaminated subsoils, and structures and equipment contaminated with waste and leachate, and management of them as hazardous waste.		40 CFR 264.114 40 CFR 264.178 40 CFR 264.197 40 CFR 264.228 40 CFR 264.258	1200-1-11-.06(9)(c) 1200-1-11-.06(11)(i) 1200-1-11-.06(12)(c) 1200-1-11-.06(13)(i) 1200-1-11-.06(14)(i)
	Must protect human health and the environment.		40 CFR 264.111(b)	1200-1-11-.06(7)(b)

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Closure with waste in place (capping)	Eliminate free liquids by removal or solidification.	Applicable to land-based unit containing RCRA hazardous waste ^d	40 CFR 264.228(a)(2) (Surface impoundments)	1200-1-11-.06(11)(i)
	Stabilization of remaining waste and waste residues to support cover.		40 CFR 264.258(b) (Waste piles)	1200-1-11-.06(12)(i)
			40 CFR 264.310(a) (Landfills)	1200-1-11-.06(16)(k)
	Installation of final cover to provide long-term minimization of infiltration (see "capping" for further restrictions).		40 CFR 264.310	1200-1-11-.06(14)(k)
	Postclosure care and ground-water monitoring. ^j		40 CFR 264.310	1200-1-11-.06(14)(k)
Consolidation between units	Placement on or in land outside unit boundary or area of contamination will trigger land disposal requirements and restrictions.	Placement of RCRA hazardous wastes subject to land disposal restrictions	40 CFR 268 (Subpart D)	1200-1-11-.10(3)
		Movement of hazardous waste (listed or characteristic) from one unit or area of contamination into another		
		Consolidation within a unit or area of contamination does not trigger applicability ^{d, k}		

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Container storage (on site)	Containers of hazardous waste must be:	Storage of RCRA hazardous waste (listed or characteristic) not meeting small quantity generator criteria held for a temporary period before treatment, disposal, or storage elsewhere, in a container (i.e., any portable device in which a material is stored, transported, disposed of, or handled)	40 CFR 264 (Subpart I)	1200-1-11-.06(9)
	• Maintained in good condition;		40 CFR 264.171	1200-1-11-.06(9)(b)
	• Compatible with hazardous waste to be stored; and		40 CFR 264.172	1200-1-11-.06(9)(c)
	• Closed during storage (except to add or remove waste).		40 CFR 264.173	1200-1-11-.06(9)(d)
	Inspect container storage areas weekly for deterioration.		40 CFR 264.174	1200-1-11-.06(9)(e)
		A generator who accumulates or stores hazardous waste on site for 90 days or less in compliance with 40 CFR 262.34 (a)(1-4) is not subject to full RCRA storage requirements.		
	Place containers on a sloped, crack-free base, and protect from contact with accumulated liquid. Provide containment system with a capacity of 10% of the volume of containers. Remove spilled or leaked waste in a timely manner to prevent overflow to the containment system.		40 CFR 264.175	1200-1-11-.06(9)(f)

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Container storage (on site) (continued)	Keep containers of ignitable or reactive waste at least 50 ft from the facility's property line.		40 CFR 264.176	1200-1-11-.06(9)(g)
	Keep incompatible materials separate. Separate incompatible materials stored near each other by a dike or other barrier.		40 CFR 264.177	1200-1-11-.06(9)(h)
	At closure, remove all hazardous waste and residues from the containment system, and decontaminate or remove all containers, liners.		40 CFR 264.178	1200-1-11-.06(9)(i)
	Storage of banned wastes must be in accordance with 40 CFR 268. When such storage occurs beyond one year, the owner/operator bears the burden of proving that such storage is solely for the purpose of accumulating sufficient quantities to allow for proper recovery, treatment, and disposal.		40 CFR 268.50	1200-1-11-.10(1)(e)
Dike construction	Design and operate facility to prevent overtopping from overfilling; wind and wave action; rainfall; run-on; malfunctions of level controllers, alarms, and other equipment; and human error.	Existing surface impoundment containing hazardous waste, or creation of new surface impoundment	40 CFR 264.221	1200-1-11-.06(11)(b)
	Construct dikes with sufficient structural integrity to prevent massive failure.		40 CFR 264.221	1200-1-11-.06(11)(b)

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Dike construction (continued)	Ensure that the dike, including that portion which provides freeboard, has structural integrity that will withstand stress of pressures from added wastes and will not fail due to scouring or piping.	Following a period of six months or greater when an impoundment has been out of service	40 CFR 264.226(c)	1200-1-11-.06(13)(g)3
	Inspect weekly for proper operation and integrity of the containment devices.		40 CFR 264.226	1200-1-11-.06(11)(g)
	Remove surface impoundment from operation if the dike leaks or there is a sudden drop in liquid level.		40 CFR 264.227	1200-1-11-.06(11)(h)
	U.S. Army Corps of Engineer permit approval may be required.	Structures or work in, or affecting, navigable waters of the U.S.	§§9 and 10, Rivers and Harbors Act.	
Direct discharge of treatment system effluent	<i>National Pollutant Discharge Elimination System (NPDES) Permitting Program</i>		40 CFR 122 (Clean Water Act) ^o	1200-4-5
	Use of best available technology economically achievable is required to control toxic and nonconventional pollutants. Use of best conventional pollutant control technology is required to control conventional pollutants. Technology-based limitations may be determined on a case-by-case basis.	Point source discharge to waters of the United States ^{m, n}	40 CFR 122.44(a)	
	The discharge must comply with applicable federal water quality requirements and more stringent state requirements under the Clean Water Act (CWA) ^p .		40 CFR 122.44(d) and state regulations approved under 40 CFR 131	1200-4-3-.03

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Direct discharge of treatment system effluent (continued)	The discharge must be consistent with the requirements of a Water Quality Management plan approved by EPA under CWA §208(b).		40 CFR 122.44(d)	
	Discharge limitations must be established for all toxic pollutants that are or may be discharged at levels greater than that which can be achieved by technology-based standards.		40 CFR 122.44(e)	
	Develop and implement a best management practice (BMP) program and incorporate in the NPDES permit to prevent the release of toxic constituents to surface waters.		40 CFR 125.100	
	<i>Criteria and standards for NPDES</i>		40 CFR 125	1200-4-5
	The BMP program must:	Discharge to waters of the United States ⁿ	40 CFR 125.104	
	<ul style="list-style-type: none"> Establish specific procedures for the control of toxic and hazardous pollutant spills; Include a prediction of direction, rate of flow, and total quantity of toxic pollutants where experience indicates a reasonable potential for equipment failure; Ensure proper management of solid and hazardous waste in accordance with regulations promulgated under RCRA. 			

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Direct discharge of treatment system effluent (continued)	<p>To ensure compliance, discharge must be monitored for:</p> <ul style="list-style-type: none"> • The mass of each pollutant; • The volume of effluent; • Frequency of discharge and other measurements as appropriate. <p>Approved test methods must be followed for monitored waste constituents. Detailed requirements for analytical procedures and quality control are provided.</p> <p>Comply with additional permit conditions such as:</p> <ul style="list-style-type: none"> • Duty to mitigate any adverse effects of any discharge; and • Proper operation and maintenance of treatment systems. 		40 CFR 122.44(i)	
			40 CFR 136.1-136.3(e)	
		Off-site discharges	40 CFR 122.41(d,e)	
Discharge of dredge and fill material to navigable waters	<p>The four conditions that must be satisfied before dredge and fill is an allowable alternative are:</p> <ul style="list-style-type: none"> • There must be no practicable alternative. • Discharge of dredge or fill material must not cause a violation of state water quality standards, violate any applicable toxic effluent standards, jeopardize an endangered species, or injure a marine sanctuary. 		40 CFR 230.10 (Marine Protection, Research, and Sanctuaries Act)	

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Discharge of dredge and fill material to navigable waters (continued)	<ul style="list-style-type: none"> No discharge shall be permitted that will cause or contribute to significant degradation of the water. Appropriate steps to minimize adverse effects must be taken. 		33 CFR 320-330 (Clean Water Act)	
	Determine long- and short-term effects on physical, chemical, and biological components of the aquatic ecosystems.		40 CFR 122.41(i)	
	Comply with additional substantive conditions such as:			
	<ul style="list-style-type: none"> Duty to mitigate any adverse effects of any discharge; and Proper operation and maintenance of treatment systems. 			
	Monitor and report results as required by permit (minimum of at least annually).	Off-site discharges	40 CFR 122.44(i)	
Dredging	Removal of all contaminated soil.	RCRA hazardous waste placed at site after Nov. 19, 1980, or movement of hazardous waste from one unit, area of contamination or location into another unit or area of concentration	40 CFR 264.228 (surface impoundments) 40 CFR 264.258 (waste piles)	1200-1-11-.06(11)(i) 1200-1-11-.06(11)(i)
	Prohibits construction of any structures, or work in or affecting navigable waters, without approval of the U.S. Corps of Engineers.	Work performed in navigable waters of U.S.	§§ 9 and 10, Rivers and Harbors Act.	

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Excavation	Site excavations must be shored or sloped to prevent accidental collapse in accordance with Subpart P of 29 CFR 1926.	Occupational Safety and Health Act (OSHA) regulations for workers at hazardous waste sites	29 CFR 1926, 54 FR 45894 (Nov. 31, 1989)	
	Movement of excavated materials to new location and placement in or on land will trigger land disposal restrictions for the excavated waste or closure requirements for the unit in which the waste is placed.	Materials containing RCRA hazardous wastes subject to land disposal restrictions are placed in another unit	40 CFR 268 (Subpart D)	1200-1-11-.10(3)
	Total suspended particulates (TSP) must be maintained below National Ambient Air Quality Standards	Nonpoint source contribution to fugitive dust emissions	40 CFR 50.6	1200-3-3-.03
	Control of fugitive dust emissions may be required under state air quality regulations.			
Gas collection	Standards for control of emissions of volatile organics. These are based on CAA emission standards found in 40 CFR 60.480-60.489.	Emissions from process vents and equipment leaks at TSD facilities handling or recycling hazardous waste containing 10% or more volatile organics	55 FR 25454 (June 21, 1990)	
Ground-water diversion	Excavation of soil for construction of slurry wall may trigger closure or land disposal restrictions.	Materials containing RCRA hazardous waste subject to land disposal restrictions if moved to another unit	40 CFR 268 (Subpart D)	1200-1-11-.10(3)
	Site excavations must be shored or sloped to prevent accidental collapse in accordance with Subpart P of 29 CFR 1926.	OSHA regulations for workers at waste sites	54 FR 9294 (March 3, 1989)	
Incineration (on site)	Analyze the waste feed.	RCRA hazardous waste	40 CFR 264.341	1200-1-11-.06(15)(b)

Table 6.13 (continued)

Actions^b	Requirements	Prerequisites^{c,d}	Federal citation	TDEC^e Rules, Chapter
Incineration (on site) (continued)	<p>Dispose of all hazardous waste and residues, including ash, scrubber water, and scrubber sludge.</p> <p>No further requirements apply to incinerators that only burn wastes listed as hazardous solely by virtue of combination, and if the waste analysis shows that no Appendix VIII constituent is present that might reasonably be expected to be present.</p> <p>Performance standards for incinerators:</p> <ul style="list-style-type: none"> • Achieve a destruction and removal efficiency of 99.99% for each principal organic hazardous constituent in the waste feed and 99.999% for dioxins; • Reduce hydrogen chloride emissions to 1.8 kg/h or 1% of the HCl in the stack gases before entering any pollution control devices; and • Limit emissions of particulate matter. 			
			40 CFR 264.343(a)	1200-1-11-.06(15)(d)
			40 CFR 264.343(b)	1200-1-11-.06(15)(d)
				1200-1-11-.06(15)(d)
			40 CFR 264.343(c)	

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Incineration (on site) (continued)	Monitoring of various parameters during operation of the incinerator is required. These parameters include:		40 CFR 264.347	1200-1-11-.06(15)(g)
	<ul style="list-style-type: none"> • Combustion temperature; • Waste feed rate; • An indicator of combustion gas velocity; and • Carbon monoxide 			
	Control fugitive emissions either by:		40 CFR 264.345(d)	1200-1-11-.06(15)(f)
	<ul style="list-style-type: none"> • Keeping combustion zone sealed; or • Maintaining combustion zone pressure lower than atmospheric pressure. 			
	Utilize automatic cutoff system to stop waste feed when operating conditions deviate.		40 CFR 264.345(e)	1200-1-11-.06(15)(f)
	Special performance standards for incineration of polychlorinated biphenyls		40 CFR 761.70(b) (Total Substances Control Act) ^f	
	New source performance standards for incinerators.	Incinerators with a charge rate greater than 45 metric tons/day	40 CFR 60.50-60.54 (Clean Air Act)	
Land treatment	Ensure hazardous constituents are degraded, transformed, or immobilized within the treatment zone.	RCRA hazardous waste being treated or placed into another unit	40 CFR 264.271(a)	1200-1-11-.06(13)(b)

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Land treatment (continued)	Maximum depth of treatment zone must be no more than 1.5 meters (5 ft) from the initial soil surface; and more than 1 meter (3 ft) above the seasonal high-water table.		40 CFR 264.271(c)	1200-1-11-.06(13)(b)
	Minimize run-off of hazardous constituents.		40 CFR 264.273(b)	1200-1-11-.06(13)(d)
	Maintain run-on/run-off control and management system.		40 CFR 264.273(c)	1200-1-11-.06(13)(d)
	Special application conditions if food-chain crops grown in or on treatment zone.		40 CFR 264.276	1200-1-11-.06(13)(g)
	Unsaturated zone monitoring program required.		40 CFR 264.278	1200-1-11-.06(13)(i)
	Special requirements for ignitable or reactive waste.		40 CFR 264.281	1200-1-11-.06(13)(l)
	Special requirements for incompatible waste.		40 CFR 264.282	1200-1-11-.06(13)(m)
	Special requirements for RCRA hazardous wastes.	RCRA waste FO20, FO21, FO22, FO23, FO26, FO27, (dioxin-containing wastes)	40 CFR 264.283	1200-1-11-.06(13)(n)
		May be superseded by new land ban regulations.		
	Prior to land disposal, waste must be treated to BDAT levels or meet a "no migration" standard.	RCRA hazardous waste being disposed of in another unit	40 CFR 268 (Part D)	1200-1-11-.10(3)

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
	Treatment standards and land disposal restrictions apply to: spent solvent wastes, dioxin-containing wastes, California-list wastes, and all RCRA hazardous waste (see Treatment).		52 FR 25760 (July 8, 1987) RCRA 3004(d)	
Operation and maintenance	30-year postclosure care to ensure that site is maintained and monitored.	Closure of hazardous waste management units	40 CFR 264.117	1200-1-11-.06(7)(h)
Placement of liquid waste in landfill	No bulk or noncontainerized liquid hazardous waste or hazardous waste containing free liquids may be disposed of in landfills. Containers holding free liquid may not be placed in a landfill unless the liquid is mixed with an absorbent or solidified.	Placement of a bulk or noncontainerized RCRA waste in a landfill	40 CFR 264.314(b)	1200-1-11-.06(14)(o)
Placement of waste in land disposal unit	Attain land disposal treatment standards to comply with "land ban" restrictions (see Treatment)	Placement of RCRA hazardous waste in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, or underground cave or mine	40 CFR 268 (Subpart D)	1200-1-11-.10(3)
Slurry wall	Excavation of soil for construction of slurry wall may trigger cleanup or land disposal restrictions.	RCRA hazardous waste placed at site after Nov. 19, 1980, or movement of hazardous waste from one unit into another unit or area of contamination	40 CFR 268 (Part D) See also Consolidation, Excavation, and Treatment regulations	1200-1-11-.10(3)

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Surface-water control	Prevent run-on and control and collect run-off from at least the amount of water volume resulting from a 24-h, 25-year storm (waste piles, land treatment facilities, landfills).	RCRA hazardous waste treated, stored, or disposed at a site after Nov. 19, 1980	40 CFR 264.251(c,d);	1200-1-11-.06(12)(b)
			40 CFR 264.273(c,d);	1200-1-11-.06(13)(d)
			40 CFR 264.301(c,d)	1200-1-11-.06(14)(b)
			40 CFR 264.221(c)	1200-1-11-.06(11)(b)
Surface-water control (continued)	Monitor surface water to ensure compliance with state water quality standards.	Discharge of wastes to adjacent streams or other surface water bodies	40 CFR 122	1200-4-3
Tank storage (on site)	Existing and new tanks must have sufficient structural strength, compatible with the waste, and corrosion protection to ensure that they do not collapse or rupture.	Storage of RCRA hazardous waste (listed or characteristic) not meeting small quantity generator criteria held for a temporary period greater than 90 days before treatment, disposal, or storage elsewhere, in a tank (i.e., any portable device in which a material is stored, transported, disposed of, or handled)	40 CFR 264.191-192	1200-1-11-.06(10)(b)-(c)
		A generator who accumulates or stores hazardous waste on site for 90 days or less in compliance with 40 CFR 262.34 (a)(1-4) is not subject to full RCRA storage requirements		

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Tank storage (on site) (continued)	Waste must not be incompatible with the tank material unless the tank is protected by a liner or by other means.		40 CFR 264.191	1200-1-11-.06(10)(b)
	Tanks must be provided with secondary containment and controls to prevent overfilling, and sufficient freeboard maintained in open tanks to prevent overtopping by wave action or precipitation.		40 CFR 264.193-194	1200-1-11-.06(10)(d)-(e)
	Prevent the migration of spills or leaks to soils or surface water. Remove and dispose of any visible containment of soils or surface water.	Leaks or spills from tanks or secondary containment systems containing RCRA hazardous waste	40 CFR 264.196(c)	1200-1-11-.06(12)(d)3
	Remove tank from service; remove waste from tank or secondary containment system.		40 CFR 264.196(a,b)	1200-1-11-.06(12)(d)3
	Repair any corrosion, crack, or leak.		40 CFR 264.196(c)	1200-1-11-.06(10)(g)
	Notify pursuant to 40 CFR 302 if spill or leak is above a reportable quantity		40 CFR 264.196(d)	1200-1-11-.06(12)(d)3
	Inspect the following: overfilling control; control equipment, monitoring data, waste level (for uncovered tanks), tank condition, aboveground portions of tanks (to assess their structural integrity), and the area surrounding the tank (to identify signs of leakage).		40 CFR 264.195	1200-1-11-.06(10)(f)

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Tank storage (on site) (continued)	At closure, remove all hazardous waste and hazardous waste residues from tanks, discharge control equipment, and discharge confinement structures.		40 CFR 264.197	1200-1-11-.06(10)(h)
	Store ignitable and reactive waste so as to prevent the waste from igniting or reacting. Ignitable or reactive wastes in covered tanks must comply with buffer zone requirements in "Flammable and Combustible Liquids Code," Tables 2-1 through 2-6 (National Fire Protection Association 1976, 1981).		40 CFR 264.198	1200-1-11-.06(10)(i)
	Storage of banned wastes must be in accordance with 40 CFR 268. When such storage exceeds one year, the owner/operator bears the burden of proving that the storage is solely for the purpose of accumulating sufficient quantities to allow for proper recovery, treatment, and disposal.		40 CFR 268.50	1200-1-11-.10(4)(a)
Transportation	Compliance with the RCRA manifest and pretransportation regulations must be achieved.	Transportation of RCRA waste to an off-site treatment, storage, or disposal facility	40 CFR 262	1200-1-11-.03
	Compliance with Department of Transportation (DOT) packaging, labeling, marking, and placarding requirements must be achieved (49 CFR 172-179)		40 CFR 262	1200-1-11-.03

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Treatment (in a unit)	Design and operating standards for units in which hazardous waste is treated must ensure protection of human health and the environment.	Treatment of RCRA hazardous waste in a unit	40 CFR 264.601 (Miscellaneous treatment units)	1200-1-11-.06(19)(b)
Treatment (in a unit) (continued)	Prevention of any releases that may have adverse effects on human health or the environment due to migration of waste constituents			
	Specific considerations must be made to prevent adverse effects in:		40 CFR 264.601(a)	1200-1-11-.06(19)(b)
	<ul style="list-style-type: none"> the ground water or subsurface environment. surface water, or wetlands, or the soil surface. or the air. 			
Treatment (chemical, physical, or biological)	Hazardous wastes or treatment reagents must not be placed in the treatment process or equipment if they could cause the treatment process or equipment to rupture, leak, corrode, or otherwise fail before the end of its intended life.		40 CFR 265.401	1200-1-11-.05(17)
	Where hazardous waste is continuously fed into a treatment process or equipment, the process or equipment must be equipped with a means to stop the inflow.		40 CFR 265.401	1200-1-11-.05(17)
	Special requirements for ignitive, reactive, or incompatible wastes.		40 CFR 265.17	1200-1-11-.05(2)

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Treatment in a containment building	Owners or operators of containment buildings designed and operated under the requirements of §268.1101 are not subject to the definition of land disposal in RCRA 3004(k) given certain provisions outlined in §268.1100.		40 CFR 264.1100	
	Design and operating standards are intended to assure containment of managed wastes and to prevent exposure to the elements via precipitation, wind, run-on, etc.		40 CFR 264.1101(a)	
	Maintain primary barrier to be free of significant cracks, gaps, corrosion, or other deterioration that could cause release of hazardous substances.		40 CFR 268.1101(c)(1)	
	Take measures to prevent the tracking of hazardous waste outside of the unit by the personnel or equipment.			
	Take measures to control fugitive dust emissions.			
	Obtain certification by a qualified registered professional engineer that the building design meets the requirements of §268.1101.		40 CFR 264.1101(c)(2)	

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Treatment in a containment building (continued)	Any condition that could lead to the release of a hazardous substance must be repaired promptly in accordance with prescribed procedures.		40 CFR 264.1101(c)(3)	
	Inspect at least weekly, and keep a log book of the facility's operating record.		40 CFR 264.1101(c)(4)	
	Secondary containment requirements are listed for management of hazardous wastes containing free liquids or treated with free liquids.		40 CFR 264.1101(b); 40 CFR 264.1101(d)	
	At closure, remove or decontaminate all waste residues, contaminated containment system components, contaminated subsoils, and structures or equipment contaminated with waste and leachate, and manage them as hazardous waste. The closure plan, etc., must meet all the requirements of 40 CFR 264 Subparts G and H.		40 CFR 264.1102(a)	
	If not all contaminated subsoils can be removed from the structure, it must be closed in accordance with the landfill closure and postclosure requirements of 40 CFR 264.310.		40 CFR 264.1101(b)	

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Treatment	Treatment of wastes subject to ban on land disposal must attain levels achievable by BDAT for each hazardous constituent in each listed waste if residual is to be land disposed. If residual is to be further treated, initial treatment and any subsequent treatment that produces residual to be treated need not be BDAT if it does not exceed the value in the Constituent Concentration in Waste Extract Table for each applicable wastewater	The following wastes have been prohibited from land disposal without treatment:	40 CFR 268 (Part D)	1200-1-11-.10(3)
		<ul style="list-style-type: none"> Spent solvent wastes and dioxin-containing wastes. "California List" wastes 	51 FR 40572 (Nov. 7, 1986) 52 FR 25760 (July 8, 1987)	
		All ranked and listed hazardous wastes identified under 40 CFR Part 261:		
		<ul style="list-style-type: none"> First third Second third Final third, and mixed radioactive hazardous waste Newly listed wastes and contaminated debris 	40 CFR 268.33 40 CFR 268.34 40 CFR 268.35 40 CFR 268.36; 40 CFR 268.45	
	No-migration variance for restricted hazardous waste land disposal	Proposed ARAR. Land disposal of untreated hazardous waste that has been restricted from land disposal	40 CFR 268 (Part D) Notice of Proposed Rule Making (NPRM) Aug. 11, 1992 (57 FR 35940); Final rule expected August 1994	1200-1-11-.10(3)

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Treatment (continued)	Treatment and disposal of hazardous soil	Proposed ARAR treatment standards for contaminated soil	40 CFR 268 (Part D) NPRM (soil) Sept. 14, 1993 (58 FR 48092); Final rule expected August 1994	1200-1-11-.10(3)
		Effective Nov. 8, 1990, disposal of contaminated soil or debris resulting from CERCLA ^s response actions or RCRA corrective actions is subject to land disposal prohibitions and/or treatment standards established for spent solvent wastes, dioxin-containing wastes, and "California List" wastes		
		Disposal of soil and debris contaminated with RCRA hazardous waste for which the treatment standard is incineration is not subject to the land disposal restrictions until Aug. 1990, July 1991, and Nov. 1991, for the three thirds, respectively		
		Mixed radioactive waste is included in the final third capacity national capacity variance schedule		
Underground injection of wastes and treated ground water	Underground Injection Control (UIC) program prohibits:		40 CFR 144 (Safe Drinking Water Act) ^t	1200-4-6

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Underground injection of wastes and treated ground water (continued)	<ul style="list-style-type: none"> Injection activities that allow movement of contaminants into underground sources of drinking water (USDW) and results in violation of MCLs or adversely affects health^u. 		40 CFR 144.12	1200-4-6-.04
	<ul style="list-style-type: none"> Construction of new Class IV wells, and operation and maintenance of existing wells. 	Excludes Class IV wells used to reinject contaminated ground water that has been treated if part of a CERCLA or RCRA remedial action	40 CFR 144.13	1200-4-6-.13
	Subsurface emplacement of waste fluids into ground water in area of regional rock deformation of the magnitude that occurs in east Tennessee	Class I wells		1200-4-6-.10(1)(c)
	All hazardous waste injection wells must also comply with the RCRA Part 264 permitting requirements.		40 CFR 144.14	
	Use or operation of unpermitted injection wells			1200-4-6-.03
	<i>General standards and methods</i>			
	Owners and operators must:		40 CFR 144.26	1200-4-6-.09
	<ul style="list-style-type: none"> Submit inventory information to the director of the UIC program for the state; including hydrogeologic data for wells, construction record, nature or composition of injected fluids, injection rate and pressure, and ground-water monitoring data. 		40 CFR 144.27	1200-4-6-.08(13)(j)

Table 6.13 (continued)

Actions^b	Requirements	Prerequisites^{c,d}	Federal citation	TDEC^e Rules, Chapter
Underground injection of wastes and treated ground water (continued)	<ul style="list-style-type: none"> Report noncompliance orally within 24 hours. Prepare, maintain, and comply with plugging and abandonment plan. 	Class I wells	40 CFR 144.28(b)	1200-4-6-.08(13)(l)
			40 CFR 144.28(c)	1200-4-6-.09(6)
	Monitor Class I wells by:	Class I wells are used to inject hazardous waste beneath the lowermost formation containing, within one quarter mile, a USDW	40 CFR 144.28(g)(1)	1200-4-6-.10(4)(f)
	<ul style="list-style-type: none"> Frequent analysis of injection fluid; Continuous monitoring of injection pressure, flow rate and volume; and Installation and monitoring of ground-water monitoring wells. 			
	Applicants for Class I permits must:			
	<ul style="list-style-type: none"> Identify all injection wells within the area of review; Take action as necessary to ensure that such wells are properly sealed, completed, or abandoned to prevent contamination of USDW. 		40 CFR 144.55	1200-4-6-.10(3)(b)
			40 CFR 146.4	1200-4-6-.10(5)
	Case and cement all Class I wells to prevent movement of fluids into USDW, taking into consideration well depth, injection pressure, hole size, composition of injected waste, and other factors.		40 CFR 146.12(a)(b)	1200-4-6-.10(3)(d)(2) 1200-4-6-.10(3)(f)
	Appropriate logs shall be recorded and other tests conducted during construction and a descriptive report prepared and submitted to the UIC program director.		40 CFR 146.12(d)	1200-4-6-.10(i)

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Underground injection of wastes and treated ground water (continued)	Injection pressure may not exceed a maximum level designed to ensure that injection does not initiate new fractures or propagate existing ones and cause the movement of fluids into a USDW.		40 CFR 146.13(b)	1200-4-6-.10(4)(b)(1) 1200-4-6-.10(4)(b)(2)
	Continuous monitoring of injection pressure, flow rate and volume, and annual pressure, if required.		40 CFR 146.13(a)	1200-4-6-.10(4)(e) 1200-4-6-.10(4)(f) 1200-4-6-.10(4)(g)
	Demonstration of mechanical integrity is required every 3 years.		40 CFR 146.12(a)(b)	1200-4-6-.10(4)(e)(6)
	Criteria for determining whether an aquifer may be an exempted aquifer include current and future use, yield, and water quality characteristics.			
	Ground-water monitoring may also be required.		40 CFR 146.13(b)	1200-4-6-.10(4)(e) 1200-4-6-.10(4)(f)
	Prohibits underground injection of hazardous wastes (solvents and dioxins) in Class I wells; amendments to existing UIC regulations.	Class I injection wells	53 FR 28118 (July 26, 1988) 40 CFR 148.10-16	1200-4-6-.10(1)
Underground storage tanks (UST) temporary closure	Continuous monitoring for leaks; leave vent lines open and functioning; cap and secure all other lines, pumps, man ways and ancillary equipment; notify implementing agency of return to service or permanent closure.	Pertains to releases of CERCLA hazardous substances from any one or a combination of tanks the volume of which is 10% or more beneath the surface of the ground (including pipes). Tanks that have been out of service for 3-24 months	53 FR 37082 (Sept. 23, 1988) 40 CFR Part 280.71	

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
Underground storage tanks permanent closure	Removal requires removing all flammable liquids from the UST, removing all pipes from the UST, and purging the UST of all hazardous vapors before removal and disposal.	Pertains to releases of CERCLA hazardous substances from any one or a combination of tanks the volume of which is 10% or more beneath the surface of the ground (including pipes). Tanks that have been out of service for 3-24 months	53 FR 37082 (Sept. 23, 1988) 40 CFR Part 280.71	
	Closure requires removal of all flammable liquids from the UST, disconnect or cap all pipes, fill tank system with an inert solid material		52 FR 12662 (April 17, 1987) 40 CFR 280.71	
Waste pile	Use liner and leachate collection and removal system.	RCRA hazardous waste, noncontainerized accumulation of solid, nonflammable hazardous waste that is used for treatment or storage in piles	40 CFR 264.251(a)	
	Operate and maintain run-on and run-off control systems for at least the amount of water resulting from a 14-h, 25-year storm.		40 CFR 264.251 (g)(h)	1200-1-11-.06(12)(b)
	Pile must be managed to control wind erosion.		40 CFR 264.251(j)	1200-1-11-.06(12)(b)
	Pile must be monitored and inspected.		40 CFR 264.254	1200-1-11-.06(12)(e)
Waste pile	Closure and postclosure care required.		40 CFR 264.258	1200-1-11-.06(12)(i)

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
	^a Adapted from EPA (1989). Currently only RCRA, CWA, and Safe Drinking Water Act requirements are included. Additional action-specific requirements will be added as additional statutes are analyzed.			
	^b Action alternatives from the Record of Decision keyword index, <i>FY 1986 Record of Decision Annual Report</i> , January 1987, Hazardous Site Control Division, EPA.			
	^c Requirements have been proposed but not promulgated for various remedial actions. When these regulations are promulgated, they will be included in the matrix.			
	^d Some action-specific requirements listed may be relevant and appropriate even if RCRA definitions of storage, disposal, or hazardous waste are not met (40 CFR 260.10), or if the waste at the site is similar to but not identifiable as a RCRA hazardous waste.			
	^e TDEC = Tennessee Department of Environment and Conservation.			
	^f CAA = Clean Air Act.			
	^g Title I of the CAA covers Air Pollution Prevention and Control, and implementing regulations are found in 40 CFR Parts 50-99.			
	^h RCRA = Resource Conservation and Recovery Act.			
	ⁱ Subtitle C of RCRA governs hazardous waste management (§3001-3020). Implementing regulations appear in 40 CFR Parts 260-268, 270, 271, 280, and 124.			
	^j Regional administrator may revise length of postclosure care period (40 CFR 264.117).			
	^k In many cases there are no defined "units" at a CERCLA site. Instead, there are areas of contamination with differing concentration levels (including hot spots) of hazardous substances, pollutants, or contaminants. When RCRA hazardous wastes are moved into or out of an area of contamination, RCRA disposal requirements are applicable to the waste being managed and certain treatment, storage, or disposal requirements (such as for closure) are applicable to the area where the waste is received.			
	^l Landfill units meeting the requirements of 40 CFR 264.301(f) are not subject to RCRA minimum technology requirements.			
	^m The term "Waters of the U.S." is defined broadly in 40 CFR 122.2 and includes essentially any water body and wetland.			
	ⁿ Section 121 of the Superfund Amendments and Reauthorization Act of 1986 (SARA) exempts on-site CERCLA activities from obtaining permits. However, the substantive requirements of a law or regulation must be met. In particular, on-site discharges to surface waters are exempt from procedural NPDES permit requirements. Off-site dischargers would be required to apply for and obtain an NPDES permit.			
	^o Titles III and IV of the CWA cover Standards and Enforcement, and Permits and Licenses, respectively. Implementing regulations appear in 40 CFR Parts 110, 112, 116, 117, 122, 124, 125, 131, and 136. 40 CFR Subchapter N sets forth effluent guidelines for various point source categories.			
	^p Federal Water Quality Criteria (WQC) may be relevant and appropriate depending on the designated or potential use of the water, the media affected, the purposes of the criteria, and current information [SARA §121(d)(2)(B)(i)]. Federal WQC for the protection of aquatic life will be relevant and appropriate when environmental factors (e.g., protection of aquatic organisms) are being considered (55 FR 8755, March 8, 1990).			
	^q Discharge to publicly owned treatment works (POTWs) is considered an off-site activity. Off-site actions must comply with all legally applicable requirements, both substantive and administrative. The concept of "relevant and appropriate" is not available for off-site actions.			
	^r Implementing regulations for the Toxic Substance Control Act of importance to cleanup at CERCLA sites are 40 CFR Parts 717 and 761.			
	^s CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act			
	^t Title IV of the Safe Drinking Water Act covers Safety of Public Water Systems. Implementing regulations are found in 40 CFR Parts 124 and 141-147.			

Table 6.13 (continued)

Actions ^b	Requirements	Prerequisites ^{c,d}	Federal citation	TDEC ^e Rules, Chapter
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^aUnderground sources of drinking water (USDW) is a nonexempted aquifer or its portion which: (1) supplies any public water system, or (2) contains sufficient quantity of ground water to supply a public water system and currently supplies drinking water for human consumption or contains fewer than 10,000 mg/L total dissolved solids (40 CFR 144.3).

^bARAR = applicable or relevant and appropriate requirements

Source: E. L. Etnier, E. P. McDonald and L. M. Houlberg, *Applicable or Relevant and Appropriate Requirements (ARARs) for Remedial Action at the Oak Ridge Reservation, A Compendium of Major Environmental Laws*, ES/ER/TM-1/R2, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, July 1993.

permits are not required for on-site CERCLA cleanup; however, the applicability of these regulations for on- or off-site RA activities should be addressed on a site-specific basis.

Storm water discharges from activities at industrial sites involving construction operations that result in the disturbance of five acres total land have been included in the final rule for National Pollutant Discharge Elimination System permits for storm water discharges (40 CFR 122). Consultation with TDEC is required to ensure compliance with the substantive requirements of the National Pollutant Discharge Elimination System permitting process for storm water discharges during construction activities for CERCLA sites (Chap. 1200-4-10-.05 of the Rules of the TDEC). For RA activities not operating under CERCLA, compliance with the full storm water permitting process is required. In either case, implementation of good site planning and BMPs to control storm water discharges is required.

6.5.5 Safe Drinking Water Act

Part C of Title XIV of the SDWA authorizes the establishment of an underground injection control permit program designed to prevent contamination of underground sources of drinking water. Any RA activities involving discharge by way of underground injection wells would be subject to these regulations. An underground drinking water source is defined in the underground injection control regulations (40 CFR 146.3) as an aquifer or its portion that supplies drinking water for human consumption, contains a sufficient supply of groundwater to supply a public water system, and contains fewer than 10,000 mg total dissolved solids per liter of water. Tennessee has a underground injection control program (Chap. 1200-4-6 of the Rules of the Water Control Board) that classifies all groundwater as useful for domestic water supply unless certain exemption criteria apply. Aquifers are exempted for various reasons, including economic or technical impracticability (1) in recovery because of depth or location or (2) in successful treatment of contaminated water for drinking water purposes.

6.5.6 Toxic Substances Control Act

Specific TSCA standards exist for incineration or alternate disposal of liquid and nonliquid waste and for articles and soils containing PCBs. TSCA storage requirements for PCBs (40 CFR 761.65) specify that PCBs and PCB-containing items at concentrations of greater than 50 ppm must be disposed of within one year after being placed in storage for disposal. The K-25 TSCA incinerator is the technology of choice for treatment of Y-12 mixed waste containing radionuclides and PCBs. Because of the limited disposal options for mixed waste contaminated with PCBs, the K-25 incinerator must store mixed waste for a time period exceeding 1 year. An FFCA (TSCA-FFCA) between DOE and EPA focuses on resolving compliance issues related to the regulation of PCBs under TSCA. It sets committed milestones for the final disposal of various PCB-contaminated materials at the five gaseous diffusion plants operated by DOE. Complete disposal of all waste PCBs must be achieved by December 31, 2015. There are also structural requirements for facilities and containers used for storage of PCBs. These requirements, too detailed to be listed here, are delineated in 40 CFR 761.65(b) for facilities and 40 CFR 761.65(c) for containers.

6.5.7 Federal Insecticide, Fungicide, and Rodenticide Act

The Federal Insecticide, Fungicide, and Rodenticide Act delegates authority to EPA to regulate the disposal and storage of excess pesticides and pesticide containers. To that end, EPA has published nonregulatory procedures for disposal of pesticides in 40 CFR 165, Subpart C. These recommendations might provide guidance for cleanup of pesticides and pesticide containers at RA sites and should be analyzed on a site-specific basis. EPA is currently updating these guidelines to make them consistent with current regulations and technologies. Regulatory initiatives for 40 CFR 165 will be published in three phases. An NPRM for Phase I, concerning suspended and canceled pesticides, was published May 5, 1993 (58 FR 26856). The NPRM for Phase II, concerning container design, residue removal storage, containment, and excess, is due in January 1994, and the Phase III NPRM is due in December 1994.³

6.5.8 Occupational Safety and Health Administration

Title I, §126(b) of CERCLA mandated that Occupational Safety and Health Administration (OSHA) promulgate standards for regulation of employee health and safety during hazardous waste operations at RCRA or CERCLA sites and during emergency response to hazardous substance releases. The final regulations for *Hazardous Waste Operations and Emergency Response* (29 CFR 1910) have appeared in 54 FR 9294 (Final Rule, March 6, 1989; effective date, March 1990). These regulations are designed to protect workers involved in cleanup operations at uncontrolled hazardous waste sites and to provide for worker protection during initial site characterization and analysis, monitoring activities, materials handling activities, training, and emergency response. These regulations do not apply to those workers who would not be exposed. Federal construction activities involving no potential for hazardous substance exposure are covered by the OSHA standards in 29 CFR 1926, *Federal Service Contracts*.

Standards for the protection of workers involved in construction, demolition, alteration, or repair activities involving asbestos-containing materials are listed in 29 CFR 1926.58 and would be applicable to RA activities involving asbestos-containing materials.

CERCLA provides in §126(b) that the OSHA regulations address certain worker protection provisions; however, employers would have to continue to comply with other pertinent OSHA standards found in 29 CFR 1910 (*General Industry*) as well. Air contaminant Permissible Exposure Limits for general industry for 212 substances were revised and updated on Jan. 19, 1989 (54 FR 2332), effective March 1, 1989, and are listed in Tables Z-1, Z-2, and Z-3 of the final rule. On July 7, 1992, a U.S. Circuit Court of Appeals vacated and remanded this final rule. The Clinton administration has decided not to appeal this ruling; this means the federal standards revert back to those in effect before 1989. However, the State of Tennessee has in place an OSHA-approved plan listing the limits set in the January 19, 1989 final rule, and plans to continue to enforce these standards which are listed in the TDEC regulations under TDEC 0800-1-1-.1000. These will take precedence over the federal pre-1989 standards. In the case of conflict or overlap of worker protection standards and general industry standards, the more restrictive provisions apply. DOE orders related to occupational safety, as well as the regulations promulgated by OSHA, are usually addressed in the site-specific Health and Safety Plan for each RA site.

6.5.9 Federal and State Regulations

Table 6.13 gives a preliminary list of federal and state action-specific regulations established under RCRA and various other statutes discussed above. Action alternatives are listed alphabetically, followed by a summary of the requirements found in the particular statute cited. The prerequisites for applicability are also given; however, the regulations must be related to site-specific conditions to determine whether the regulation cited is legally applicable. This table does not represent a complete listing of action-specific regulations; analysis of the regulations on a site-specific basis would be necessary to ensure a comprehensive summary.

6.6 LOCATION-SPECIFIC REGULATIONS

Location-specific requirements set restrictions upon the concentration of hazardous substances or the conduct of activities solely because they are in special locations. In determining the use of location-specific regulations for actions at Y-12 RA sites, one must investigate the jurisdictional prerequisites of each of the regulations. Basic definitions and exemptions should be analyzed on a site-specific basis to confirm the correct application of the requirements. Table 6.14 lists the major federal and state location-specific regulations that might be pertinent to RA actions at Y-12.

6.6.1 Caves, Salt-Dome Formations, Salt-Bed Formations, and Underground Mines

ORR, located in the Valley and Ridge Physiographic Province of eastern Tennessee, is characterized by gently to moderately sloping ridges and valleys.¹³ A variety of geologic formations of sedimentary origin underlie ORR. The most important formations are the Rome Formation and the Conasauga, Knox, and Chicamauga Groups. The Y-12 site has areas underlain by the Knox Group limestones, which are subject to cave formation and sink hole development and trends of groundwater movement that could cause problems for site modifications.¹⁴ There are no indications of salt-dome formations, salt-bed formations, or underground mines on or near the Y-12 Site.¹⁴ If any caves are located in areas where remedial activities might occur, the regulations found in RCRA [40 CFR 264.18(c)], which prohibit the placement of noncontainerized or bulk liquid hazardous waste in caves, might be applicable (Table 6.14).

6.6.2 Faults

The White Oak Mountain and Copper Creek thrust faults transect ORR; the faults on ORR are ancient (pre-Holocene) and are stable.¹⁵ The possibility of fault movement is considered extremely unlikely.¹⁶

Y-12 is exempted from compliance with the RCRA seismic requirements of 40 CFR 264.18 because 40 CFR 264.18(a) stipulates that all facilities located within political jurisdictions other than those listed in Appendix VI of 40 CFR 264.18 are assumed to be in compliance for location of new treatment, storage, and disposal facilities. Tennessee is not listed in the appendix.

6.6.3 Wetlands and Floodplains

ORR is located within the Clinch River drainage basin and is bound on the south and west by the Clinch River; Y-12 is located in a sub-basin of the Clinch River. Portions of Y-12 are located within 100- and 500-year floodplain of Bear Creek and East Fork Poplar Creek.¹⁷

There are a number of wetlands located in and around Y-12. A draft report of a recent wetlands survey was released in March 1991.¹⁸ Before any RA is taken, this report should be consulted and a survey conducted of the particular site to determine whether there are wetlands present that could be impacted by RA activities. If any RA activities are selected that would impact floodplains, the requirements found in Executive Order (EO 11988, 40 CFR 264.18(b), 40 CFR 6 (Appendix A), and 10 CFR 1022 would provide applicable requirements for Y-12. If wetlands are affected, consideration should

Table 6.14. Location-specific regulations applicable to remedial action activities at the Oak Ridge Reservation

Location characteristic(s)	Operating condition(s)	Requirement(s)	Citation(s)
Faults			
With displacement in Holocene time	New treatment, storage or disposal facility RCRA ^a -defined listed or characteristic hazardous waste (40 CFR 261) -or- RCRA-permitted facility	Portions of new facilities must not be within 61 meters (200 ft) of such fault	40 CFR 264.18(a)
Salt-dome formations, salt-bed formations, underground mines or caves			
	RCRA-defined listed or characteristic hazardous waste (40 CFR 261) -or- RCRA-permitted facility	Placement of noncontainerized or bulk liquid hazardous waste in these locations is prohibited	40 CFR 264.18(c)
Wetlands			
Presence of wetlands as defined in Executive Order 11990 §7(c) and 40 CFR 6, Appendix A §4(j)	Agency action which involves: - acquiring, managing, and disposing of lands and facilities - providing federally undertaken, financed, or assisted construction and improvements - conducting federal activities and programs affecting land use	Whenever possible, actions must avoid or minimize adverse impacts on wetlands and act to preserve and enhance their natural and beneficial values. New construction in wetlands areas should be particularly avoided unless there are no practicable alternatives Wetlands protection considerations shall be incorporated into planning, regulating, and decision-making processes	Executive Order 11990 40 CFR 6, Appendix A 10 CFR 1022

Table 6.14 (continued)

Location characteristic(s)	Operating condition(s)	Requirement(s)	Citation(s)
Presence of wetlands as defined in 40 CFR 230.3(t) and 33 CFR 328.3(b)	Action involving discharge of dredge or fill material into wetlands	Action to avoid degradation or destruction of wetlands must be taken to the extent possible. Discharges for which there is a practicable alternative with less adverse impacts or those which would cause or contribute to significant degradation are prohibited If adverse impacts are unavoidable, action must be taken to enhance, restore, or create alternative wetlands	Clean Water Act §404 40 CFR 230 33 CFR 320-330
Floodplains			
Within 100-year floodplain	Treatment, storage, or disposal facility RCRA-defined listed or characteristic hazardous waste (40 CFR 261) -or- RCRA- permitted facility	Facility must be designed, constructed, operated, and maintained to prevent washout of any hazardous waste by 100-year flood	40 CFR 264.18(b)

Table 6.14 (continued)

Location characteristic(s)	Operating condition(s)	Requirement(s)	Citation(s)
Within "lowland and relatively flat areas adjoining inland and coastal waters and other flood-prone areas such as offshore islands, including at a minimum, that area subject to a one percent or greater chance of flooding in any given year." [Executive Order 11988 §6(c) and 40 CFR 6, Appendix A §4(d)]	Action which involves: - acquiring, managing, and disposing of lands and facilities - providing federally undertaken, financed, or assisted construction and improvements - conducting federal activities and programs affecting land use	Action shall be taken to reduce the risk of flood loss, minimize the impact of floods on human safety, health and welfare, and restore and preserve the natural and beneficial values of floodplains The potential effects of actions in floodplains shall be evaluated and consideration of flood hazards and floodplain management ensured If action is taken in floodplains, alternatives that avoid adverse effects and incompatible development and minimize potential harms shall be considered	Executive Order (EO) 11988 40 CFR 6 (Appendix A) 10 CFR 1022
Wilderness areas, Wildlife resources, Wildlife refuges, Scenic rivers			
Within area encompassing or affecting waters of the state of Tennessee as defined in TCA- ^b 69-3-103(32) and the presence of wildlife or aquatic life	Action involving the discharge of any pollutants into the waters of the state [see TCA 69-3-103(18) and (21) for noninclusive list]	Discharge of "substances" which "will result or will likely result in harm, potential harm or detriment to the health of animals, birds, fish, or aquatic life" is prohibited	Tennessee Water Quality Control Act of 1977 (TCA 69-3-101 <i>et seq.</i>) Stream Use Classifications (TDEC ^c Rules - Chap. 1200-4-4)

Table 6.14 (continued)

Location characteristic(s)	Operating condition(s)	Requirement(s)	Citation(s)
Within area affecting stream or river <i>-and-</i> presence of fish or wildlife resources	Action which results in the control or structural modification of a natural stream or body of water	The effects of water-related projects on fish and wildlife resources must be considered Action must be taken to prevent, mitigate, or compensate for project-related damages or losses to fish and wildlife resources Off-site actions that alter a resource require consultation with the FWS ^d , NMFS ^f , and/or appropriate state agency Consultation is also strongly recommended for on-site actions	Fish and Wildlife Coordination Act (16 USC 661 <i>et seq.</i>)
Location encompassing aquatic ecosystem with dependent fish, wildlife, other aquatic life, or habitat	Action involving the discharge of dredge or fill material into aquatic ecosystem	Degradation or destruction of aquatic ecosystems must be avoided to the extent possible. Discharges which cause or contribute to significant degradation of the water of such ecosystem are prohibited	Clean Water Act §404 40 CFR 230 33 CFR 320-330
Location encompassing a state-designated natural area		The scientific, scenic, recreational, and educational values of these areas must be preserved and steps taken to prevent impairment thereof	TCA 11-14-101 <i>et seq</i>

Table 6.14 (continued)

Location characteristic(s)	Operating condition(s)	Requirement(s)	Citation(s)
Endangered, Threatened, or Rare Species			
Presence of endangered or threatened species -or- critical habitat of such species as designated in 50 CFR 17, 50 CFR 226, or 50 CFR 227	Action which is likely to jeopardize species or destroy or adversely modify critical habitat	Actions that jeopardize species/habitat must be avoided or appropriate mitigation measures taken Off-site actions that affect species/habitat require consultation with DOI ^f , FWS, NMFS, and/or state agencies, as appropriate, to ensure that proposed actions do not jeopardize the continued existence of the species or adversely modify or destroy critical habitat Consultation is also strongly recommended for on-site actions	Endangered Species Act of 1973 (16 USC 1531 <i>et seq.</i>) 50 CFR 402 Fish and Wildlife Coordination Act (16 USC 661 <i>et seq.</i>)
Presence of endangered or threatened species or critical habitat (see above citation) of same within an aquatic ecosystem as defined in 40 CFR 230.3(c)	Action involving discharge of dredge or fill material into aquatic ecosystem	Dredge or fill material shall not be discharged into an aquatic ecosystem if it would jeopardize such species or would likely result in the destruction or adverse modification of a critical habitat of the species	Clean Water Act §404 40 CFR 230.10(b)

Table 6.14 (continued)

Location characteristic(s)	Operating condition(s)	Requirement(s)	Citation(s)
Presence of Tennessee state-listed endangered or threatened animal species as created and amended pursuant to TCA 70-8-105		Protected species may not be taken, possessed, transported, exported, processed, sold, offered for sale, or shipped. Certain exceptions may be allowed such as for educational, scientific, etc., reasons or where necessary to alleviate property damage or protect human health or safety. These exceptions require a permit if the remedial action or its attendant effects are off site	Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974 (TCA 70-8-101 <i>et seq.</i>)
Archaeologic and Historic Resources			
Presence of archaeological resources on public land	Action which would impact resource	Steps must be taken to protect archaeological resources and sites	Archaeological Resources Recovery Act of 1979 (16 USC 470aa-ll) 43 CFR 7
Presence of archaeologic or historic resources	Action involving dam construction or other alteration of terrain which might cause irreparable loss or destruction of significant scientific, prehistoric, historic, or archaeologic data	The Secretary of Interior must be advised of the presence of the data A survey of affected areas for resources and data must be conducted and steps taken to recover, protect, and preserve data therefrom or request that DOI do so	Archaeological and Historic Preservation Act (16 USC 469a-c) 40 CFR 6.301

Table 6.14 (continued)

Location characteristic(s)	Operating condition(s)	Requirement(s)	Citation(s)
Presence of federally owned, administered, or controlled prehistoric or historic resources -or- the likelihood of undiscovered resources		Cultural resources included on or eligible for inclusion on the National Register of Historic Places (36 CFR 60) or National Historic Landmark Program (36 CFR 65) must be identified Action(s) that will affect such resources must be identified and alternatives to the action(s) examined and considered When alteration or destruction of the resource is unavoidable, steps must be taken to minimize or mitigate the impacts and to preserve records and data of the resource When all or part of a remedial action is off site, the consultation requirements of 16 USC 470f must be completed Consultation is also strongly recommended for on-site actions	National Historic Preservation Act (16 USC 470a-w) Executive Order 11593 40 CFR 6.301 36 CFR 800
Cemetery located on property within Tennessee		Destruction or degradation of property in a graveyard or cemetery is prohibited	Tennessee General Cemetery Act of 1968 (TCA 46-1-101 et seq.)

^aRCRA = Resource Conservation and Recovery Act; definitions appear at 40 CFR 260.10.

^bTCA = Tennessee Code Annotated.

^cTDEC = Tennessee Department of Environment and Conservation.

^dFWS = Fish and Wildlife Service.

^eNMFS = National Marine Fisheries Service.

^fDOI = Department of Interior.

Source: E. L. Etnier, E. P. McDonald and L. M. Houlberg, *Applicable or Relevant and Appropriate Requirements (ARARs) for Remedial Action at the Oak Ridge Reservation, A Compendium of Major Environmental Laws*, ES/ER/TM-1/R2, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, July 1993.

be given to EO 11990, 40 CFR 6 (Appendix A), 10 CFR 1022, CWA §404, 40 CFR 230, and 33 CFR 320-330 for applicable requirements.

6.6.4 Wilderness Areas, Wildlife Refuges, Wildlife Resources, and Scenic Rivers

There are no known designated wilderness areas, wildlife refuges, or scenic rivers on the Y-12 Site or within range of the reservation, such that RAs would likely impact these resources. However, if any RAs result in the control or structural modification of a natural stream or water body, the provisions found in the Fish and Wildlife Coordination Act (16 USC 661 *et seq.*) may be applicable. If any action involves the discharge of dredge or fill material into an aquatic system, the CWA §404, 40 CFR 230, and 33 CFR 320-330 may also be applicable.

The Clinch River, Poplar Creek with its various tributaries and forks (including Bear Creek and East Fork Poplar Creek), and White Oak Creek have all been classified by TDEC for a variety of uses, including fish and aquatic life and wildlife. It is therefore possible that the provisions of the Tennessee Water Quality Control Act (TCA 69-3-101 *et seq.*) would be legally applicable should any RAs at Y-12 cause, or be likely to cause, harm to wildlife or aquatic life in these waters.

Slightly over 5000 acres of ORR have been designated as a DOE National Environmental Research Park (NERP), which also includes research areas (RSAs) located both within and without the NERP itself.¹⁹ Portions of the NERP come to within at least 2-3 km of the K-25 Site, ORNL, and Y-12. Both RSA No. 27, Bear Creek characterization and monitoring, and RSA No. 28, East Fork Poplar Creek, are in close proximity to Y-12.¹⁹

In addition to the NERP and its associated research areas DOE has also designated areas on ORR as DOE-NERP reference areas and DOE-NERP natural areas. The reference areas and natural areas are located in various sites on ORR, with several in close proximity to Y-12. Eight of the reference areas and natural areas have also been registered by Tennessee as State Natural Areas.

Because of the unique purposes and goals in establishing the NERP, the uses and restrictions that apply to these resources should be considered nonregulatory guidance if remedial activities appear likely to impact the designated areas. Guidance regarding the permitted uses and restrictions of the various locations can be obtained from the NERP Project Manager at Y-12. For a general overview, please refer to Vol. 23 of *The Resource Management Plan for the Oak Ridge Reservation*.¹⁹ Such impacts should be avoided. In addition, should areas which are also designated State Natural Areas by the state of Tennessee be affected, the provisions of the Tennessee Natural Areas Preservation Act of 1971 (TCA 11-14-101 *et seq.*) may be applicable.

6.6.5 Rare, Threatened, or Endangered Species

In addition to the several Tennessee state-listed endangered or threatened plants found at Y-12, there are a number of federal- and state-listed endangered or threatened or "in need of management" animal and avian species known to inhabit east Tennessee (50 CFR 17).²⁰ An in-depth discussion of these species appears in Vol. No. 24 of *The Resource Management Plan of the Oak Ridge Reservation*.²⁰ The list of rare and endangered species for ORR, provided by the state of Tennessee, also includes two state-listed and federally listed endangered clams.²¹

Should any RAs at Y-12 impact any federally listed endangered or threatened species, the provisions found in the Endangered Species Act (16 USC 1531 *et seq.*), 50 CFR 492, and the Fish and Wildlife Coordination Act (16 USC 661 *et seq.*) may be legally applicable. Additionally, if the RAs involve the discharge of dredge or fill material, CWA §404 and 40 CFR 230.10(b) may be applicable. If any proposed actions impact state-listed endangered or threatened animal species, the Tennessee Non-Game and Endangered or Threatened Wildlife Species Conservation Act of 1974 (TCA 70-8-101 *et seq.*) may be applicable. The prohibitions of the Tennessee Rare Plant Protection and Conservation Act of 1985 (TCA 11-26-201 *et seq.*) do not apply to a landowner, lessee, or other person entitled to possession of the land on which the species is located (TCA 11-26-209). This also includes managers in the case of publicly owned land and those with written permission of the landowner or manager (TCA 11-26-209). These exclusions would apparently apply to ORR. However, the purpose of the statute to protect and preserve rare plants should be considered guidance for any RAs at Y-12.

6.6.6 Historic Sites and Archaeological Findings

ORR, as well as the surrounding region, is rich in both archaeological and historic resources.²² Although there have not been complete and exhaustive archaeological or historical surveys of the reservation, there have been a number of studies over the years, all indicating the presence of abundant resources on and around the reservation. These surveys are summarized in Vol. 3 of the *Resource Management Plan for the U. S. Department of Energy Oak Ridge Reservation*²² which also includes a list and descriptions of most of the documented sites. No archaeological sites were identified at Y-12.²² None of the surveys done is recent, however, nor have they covered all of the specific sites where RAs may be planned or contemplated. Several laws require that such information be obtained and documented if there is ample reason to suspect the presence of these resources [Archaeological and Historic Preservation Act (16 USC 469a-c); Archaeological Resources Recovery Act of 1979 (16 USC 470aa-ll)].

In addition, the National Historic Preservation Act (16 USC 470a-w) mandates identification of cultural resources eligible for the National Register of Historic Places (36 CFR 60) or the National Historic Landmark Program (36 CFR 65).

If any RA is undertaken which would cause irreparable harm, loss, or destruction to any historic or archaeological site, the provisions of the Archaeological Resources Recovery Act (16 USC 470aa-ll), 43 CFR 7, and the Archaeological and Historic Preservation Act (16 USC 469a-c) may be legally applicable.

Lastly, there are a number of cemeteries located on ORR which predate the acquisition of the property by the government. Any RAs that affect these cemeteries would be subject to the provisions of the Tennessee Cemetery Protection Act (TCA 46-1-101 *et seq.*), which prohibits their destruction or degradation.

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