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ORNL NATIONAL LABORATORY
TECHNOLOGY LOGIC DIAGRAM

VOLUME 2

TECHNOLOGY LOGIC DIAGRAM

PART C Waste Management

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Prepared for the
Office of Technology Development
U.S. Department of Energy

1993
Edition

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The *Oak Ridge National Laboratory Technology Logic Diagram* that relates environmental restoration (ER) and waste management potential technologies that can remediate these problems. The *Oak Ridge Reservation* and a previous Hanford TLD.

The TLD identifies the research, development, demonstration technologies to a state that allows technology transfer and application (RA), and WM activities. It is essential that follow-on engineering studies will begin by selecting the most promising technologies. These studies will begin by selecting the most promising technologies that will provide a socially acceptable balance between the two.

The TLD consists of three fundamentally separate volumes: Vol. 1 (*Technology Logic Diagram*), and Vol. 3 (*Technology Evaluation Data Sheets*). Part A focuses on the RA of contaminated facilities. Part C of Vols. 1 and 3, the TLD, an explanation of the program-specific responsibilities, and the technologies. Volume 2 (Pts. A, B, and C) contains the logic linking the technologies that have the potential to solve these problems. Volume 1

Waste management is the focus of Vol. 2, Pt. C, which includes characterization, WM, and robotics and automation. Each of the volumes is broken down by problem area/constituents and linked to potential technologies. Information about a technology's status, its science and technology is explained in detail in the Explanation and Understanding Key to the TLD.

The TLD *Index*, a stand-alone volume, facilitates information search. It comprises three separate indexes, one for each of the corresponding technologies searched by specific ORNL problem, problem area/constituents, or technology.

The technology evaluations contained in these volumes are the result of the TLD. New or more accurate information is solicited to improve the TLD. Editor, *Oak Ridge National Laboratory Technology Logic Diagram*, Oak Ridge, TN 37831-7274. FAX (615-576-8558).

Diagram (TLD) was developed to provide a decision support tool for environmental (WM) problems at Oak Ridge National Laboratory (ORNL) to address the TLD uses information from the *Strategic Roadmap for the Oak*

demonstration, testing, and evaluation needed to develop these technologies for decontamination and decommissioning (D&D), remedial engineering studies be conducted to build on the output of this project. Technologies identified in the TLD and finding an optimum mix of technologies to meet cost and risk.

Diagrams: Vol. 1 (*Technology Evaluation*), Vol. 2 (*Technology Logic*). Part A of Vols. 1 and 2 focuses on D&D. Part B of Vols. 1 and 2 focuses on WM. Each part of Vol. 1 contains an overview of a review of identified technologies, and the rankings of remedial technologies among EM goals, environmental problems, and the various diagrams. Part 3 (Pts. A, B, and C) contains the TLD data sheets.

The TLD has been divided into the three necessary subelements of WM: these sections address general ORNL problems, which are then specific WM technologies. The diagrams also contain summary information on technology needs, and its implementation needs. The diagram structure is as follows.

Information searches on specific technologies. The *Index* actually contains the following parts (A, B, and C) of Vols. 1 and 2. Information can be searched by technology name.

Diagrams are based on the best information available during compilation of the TLD data base. Please send comments to R. L. Fellows, ORNL, Martin Marietta Energy Systems, Inc., P.O. Box 2003, Oak

Explanation and Understanding Key f

The logic elements described in the "Technical Approach" section of Chap. 1

for the Technology Logic Diagram

of the Executive Summary serve as column headings in this diagram.

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
es the general or generic technology approaches to m remediation.	Provides a specific technology that may reasonably be applied to remediate the problem. Technology Evaluation Data Sheet (TEDS) Codes, located after the technology names in this column, refer to TEDSs in Vol. 3. The TEDS address each technology in more detail. Each TEDS contains a single, unique logic path from the Diagrams. Rankings appear after the TEDS code for each technology. The technologies are ranked according to the following criteria: • Overall assessment of usefulness (E—essential, H—high, M—medium, L—low) • Ranking of the site problem (1–5 from lowest significance to highest) • Time required to bring the technology to commercial or mature state at the site—expressed in years. • Cost for bringing the technology from its present state to large-scale commercial use (millions [\$M] or thousands [\$K] of dollars). • 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 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.	Provides information on the status of the preceding technology. • In Use—problem is in the process of being remediated with this technology. • Accepted—accepted by industry and/or the problem owner. The demonstrated technology exists for use at ORNL. • Demonstration—technology is available but is not demonstrated and/or accepted for the problem at ORNL. • Pre-demonstration—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. The following areas further define the applicability of a technology to the problem: • Efficacy—the effectiveness of the technology in remediating the problem. Normally, quantitative measures are given for the technology's performance in standard practice, such as decontamination, estimating the final dpm/cm² of surface contamination, dismantlement, the time to cut a 24-in. pipe, and characterization, the analysis time and lower detection limit. • Waste—the potential output from the technology. This describes the nature and volume of both the waste and the potentially useful materials (recyclable) suitable for materials disposition evaluation.	Lists needs in Science and Technology where support should be applied to develop an "immature" technology to a field-deployable state. Science 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, and, when possible, experiments addressing specific areas of uncertainty are suggested. Technology development (TD) conversion of a scientifically understood phenomenon into an operating system (technology) that can be applied to, and can remediate an EM problem. Technology improvement needs relate to improvements that 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 TD opportunity implies that technology improvements are also likely to be needed. Past and currently funded Technical Task Plans (TTP) were correlated with the technologies. If a match was found, "TTP Match" appears in this column. The TTP number and technology number matches can be found in the TTP tables of Vol. 1, Pt. A, Pt. B, and Pt. C.	Covers many of the areas of concern for technology transfer activities. Specialized needs for both development of a technology and deployment of a mature technology are identified. These needs were evaluated in the areas of (1) resources (financial or personnel); (2) hardware (process equipment, development equipment, and computers); (3) software (models, procedures, computer programs); (4) facilities (labs, shops, and buildings); and (5) education (training classes or degree personnel). Only extraordinary needs are highlighted (i.e., those needs that would require long lead time or unusual procurements such as fine items for facility construction). Technology integration identifies the technologies which can be integrated to produce a safer, better or cheaper remediation system. 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.

Characterization for V

The Characterization section is grouped into a large section which most of the characterization technologies are applied to various problems, where a more select group of technologies is applied to a specific section. The former section is divided into several subsections. The subsections are sampling design, sample collection, sample analysis, detection/measurements—laboratory, and data analysis. The latter section are listings under the specific subsections of radioactive materials, chemical, and biological pathogens. Each of these is divided into field methods and laboratory deployment.

Waste Management

, generally inclusive section of ORNL Problems to applicable and smaller sections for specific ORNL called for in addition to those offered in the general sections under the Alternatives column. These sample preparation, detection/measurements—field, /management. Following these general subsections e elements, inorganics, organics, physical, and and laboratory methods according to their primary

Characterization for V

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Solid Wastes Contaminated concrete rubble and gravel (MTC 5210) Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) Discarded asbestos and transits (MTC 5290) Contaminated fiberglass insulation (MTC 5220) Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) Scrap nonferrous metals (MTC 5190) Combustible debris (e.g., paper, cloth, personal protective clothing (PPE), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) Compactable debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (MTC 5400) Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) Discarded filters (including HEPA filters) (MTC 5410) Spent ion exchange media (MTC 3115) Other uncategorized heterogeneous debris (MTC 5490) Lab packs (MTC 6100) Irradiated and spent fuel elements and components (NA) Sealed sources (NA) Graphite moderator (NA) Fissile materials (NA) Steam plant ash (NA) Solid-Liquid Wastes (Including Sludges) Waste processing sludges (MTC 3120) Ignitable and reactive wastes (MTC 6390) Corrosive wastes (MTC 1100/1200) Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) Toxic organic wastes (MTC 2200) Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 6900) Coal yard run-off sludge (NA) Infectious medical wastes (NA) Liquid Wastes Listed halogenated solvents (MTC 2210) Listed nonhalogenated solvents (MTC 2220) Process/dilute liquid low-level wastes (LLW) (MTC 1000) Melton Valley and REDC caustic aqueous wastes (MTC 1200) REDC acidic aqueous wastes (MTC 1100) REDC liquid organic wastes (MTC 2900) Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes Volatile organic compounds (VOCs) in gases (NA) Semi-volatile organic compounds in gases (NA) Particulates in gases (NA) Inorganics in gases (NA) RAD in gases (NA) Adsorbable RAD in gases (NA) Nonadsorbable RAD in gases (NA) Sulfur oxides (SO₂) in gases (NA) Nitrogen oxides (NO₂) in gases (NA) Entrained vapors/acids in gases (NA) Orphan gas cylinders (MTC 6400)	General	Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the ORR, radiation protection standards, DOE Orders, and non-regulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization	Sa
EM Problems - Facility Decontamination and Decommissioning (D&D) - Remedial Action (RA)—Soils, Ground Water and Surface Water - Waste Management (WM)					Sa

Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Sampling Design	M Sequential Sampling Plans CHAR-252-OL <i>Ranking:*</i> M-3-.5 (\$0.1;\$5Kam*)	Accepted TTP Match	Experimental site data Available at X-10.	Initial planning time
	E Sampling Program Configuration Management System CHAR-228-OL <i>Ranking:*</i> E-5-1 (\$.5M;\$50Kam)	Accepted A range of application software to assist with configuration management is available both commercially and in the public domain. TTP Match	Enhancements to existing products may be required to provide the level of support needed for a large sampling program. Available at X-10.	Separate configuration management systems should be considered for each of (a) Characterization Sampling Program, (b) Remedial Action, (c) Waste Management, and (d) Decontamination and Decommissioning instead of setting up one large all- encompassing system.
	H Optimization of Sampling Designs CHAR-71-OL <i>Ranking:*</i> H-5-0.5 (\$0.1M;\$N)	Demonstration	Literary searches for finding useful sampling designs from investigations in other fields. New statistical methods for sampling design.	Normal
Sample Collection	M Ultrasonic Extraction CHAR-20-OL <i>Ranking:*</i> M-4-1 (\$.2M;\$400/sample)	Predemonstration, technology not yet demonstrated. TTP Match	Testing needs to be performed to establish the enhancement of material retrieval from porous media using various solvents, acids, and bases.	Hardware cost: \$2-5K; Development cost: \$200K; Inverse heads need to be designed for sampling from the floors and other horizontal (top side) applications.
	M Vacuum-Assisted Reverse Flow, Solvent Extraction Methods CHAR-62-OL <i>Ranking:*</i> M-4-2 (\$.4M;\$N)	Conceptual Evolving technology. TTP Match	Model studies are needed to develop to technique.	Development cost: \$400K.
	H In-Situ Solid Phase Micro-Extraction of Organics CHAR-210-OL <i>Ranking:*</i> H-4-1 (\$.25M;\$200/sample)	Predemonstration Technology requires final development	Extraction conditions need to be optimized for the specific target analytes and matrices at the ORNL site. Available at X-10.	Hardware cost: \$30K; Development cost: \$300K.
	E Sampling and Mixing Methods CHAR-81-OL <i>Ranking:*</i> E-4-1 (\$.25M;\$N)	Accepted TTP Match	Need to optimize methods for collection of representative samples and to mix samples into a homogeneous state.	Requires statistical sampling design and proper laboratory blenders, mixers, and other equipment.
	M Membranes for Sample Collection and Concentration CHAR-55-OL <i>Ranking:*</i> M-4-1 (\$.25M;\$50/sample)	Accepted Membranes are predominantly permeable to selected components in mixtures, allowing separation for accumulation or to facilitate analysis/detection.	System development or adaptation for specific applications; validation.	Sample collection systems for Site-specific applications.
	H Sampling Underground Storage Tanks for Volatile Organics CHAR-257-OL <i>Ranking:*</i> H-4-1 (\$.26M;\$500/sample)	Demonstration; the technology has been applied at the Hanford USTs. It is based on reasonable well- proven air sampling methods.	Adapt techniques to field sampling within or immediately outside USTs. Available at X-10.	Hardware cost: \$10K. Development cost: \$250K.

* See the Explanation and Understanding
Key in the front of this document for a
description of the ranking code/scheme.

Characterization

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Solid Wastes Contaminated concrete rubble and gravel (MTC 5210) Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) Discarded asbestos and transits (MTC 5290) Contaminated fiberglass insulation (MTC 5220) Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) Scrap nonferrous metals (MTC 5190) Combustible debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) Compactible debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (MTC 5400) Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) Discarded filters (including HEPA filters) (MTC 5410) Spent ion exchange media (MTC 3115) Other uncategorized heterogeneous debris (MTC 5490) Lab packs (MTC 6100) Irradiated and spent fuel elements and components (NA) Sealed sources (NA) Graphite moderator (NA) Fissile materials (NA) Steam plant ash (NA) Solid-Liquid Wastes (including Sludges) Waste processing sludges (MTC 3120) Ignitable and reactive wastes (MTC 6390) Corrosive wastes (MTC 1100/1200) Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) Toxic organic wastes (MTC 2200) Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 8900) Coal yard run-off sludge (NA) Infectious medical wastes (NA) Liquid Wastes Listed halogenated solvents (MTC 2210) Listed nonhalogenated solvents (MTC 2220) Process/dilute liquid low-level wastes (LLW) (MTC 1000) Melton Valley and REDC caustic aqueous wastes (MTC 1200) REDC acidic aqueous wastes (MTC 1100) REDC liquid organic wastes (MTC 2900) Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes Volatile organic compounds (VOCs) in gases (NA) Semi-volatile organic compounds in gases (NA) Particulates in gases (NA) Inorganics in gases (NA) RAD in gases (NA) Adsorbable RAD in gases (NA) Nonadsorbable RAD in gases (NA) Sulfur oxides (SO₂) in gases (NA) Nitrogen oxides (NO₂) in gases (NA) Entrained vapors/acids in gases (NA) Orphan gas cylinders (MTC 6400)	General	Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the ORR, radiation protection standards, DOE Orders, and non-regulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

or Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Sample Collection	H Solid Sorbent Sampling for Airborne Organics CHAR-254-OL <i>Ranking:*</i> H-4-1 (\$2M;\$50/sample)	Demonstration , technology is available, but validation is required for particular sampling conditions and target species. TTP Match	Develop methods for specific applications.	Depends on specific contaminants. Development cost: \$100-200K.
	H Sampling Heterogenous Wastes CHAR-270-OL <i>Ranking:*</i> H-4-3 (\$2.8M;N)	Conceptual TTP Match	Development of statistical approaches, strategies, and methods for removing a representative sample must be developed.	Ca. \$2.8M over 3 years.
	M Sampling Interface System for Surface Contamination by Organics CHAR-271-OL <i>Ranking:*</i> M-4-3 (\$775M;N)	Conceptual TTP Match	Development of rapid heating interface and software for rapid contaminant identification by direct sampling ion trap mass spectrometry.	Development costs of \$775K over 3 years.
	M Sediment Sampling from Restricted Access Locations CHAR-276-OL <i>Ranking:*</i> M-4-2 (\$.45M;N)	Predemonstration - the technology is based upon refinements of current methods. TTP Match	Develop articulated sampling arm with coring device.	Hardware cost: \$50K, Development cost: \$400K.
	M Multi-Angle Drilling for Depth Profiling of Contaminants CHAR-64-OL <i>Ranking:*</i> M-4-1 (\$2M;N)	Demonstration	Model studies need to be performed. Available at K-25.	\$200K development costs.
Sample Preparation	H Radioactive Sample Preparation CHAR-205-OL <i>Ranking:*</i> H-4-1 (\$1M;N)	Demonstration , current work shows that methods can be adapted to meet these needs. TTP Match	Adaptation of EPA and other methods, and development of new technologies for the safe and efficient preparation of radioactive samples for analysis. Available at X-10.	Development cost: \$500K , each of 2 years; personnel and facilities are available.
	M Supercritical Fluid Extraction of Organics CHAR-208-OL <i>Ranking:*</i> M-3-1 (\$.33M;\$100/sample)	Predemonstration , technology requires final development. TTP Match	Extraction conditions need to be optimized for the specific target analytes and matrices at the ORNL site. Available at X-10.	Hardware cost: \$30K, Development cost: \$300K.
	E Adaptation of the EPA Toxicity Characteristic Leaching Process for Use with Radioactive Samples CHAR-209-OL <i>Ranking:*</i> E-4-1 (\$45M;N)	Predemonstration , some work has been conducted at ORNL, but full adaptation and testing remain to be done. TTP Match	The leaching equipment and protocol must be adapted to glove box and hot cell operations. Available at X-10.	Development cost: \$450K. Equipment must be modified and tested under containment and shielding.
	Metallographic Sectioning and Preparation CHAR-67-OL <i>Ranking:*</i> Not Ranked	Accepted	Procedure development for specific applications are needed; then protocols for standardized preparation should be developed. Available at X-10, K-25.	None. Facilities available (See also core drilling).
	H Microwave Digestion CHAR-19-OL <i>Ranking:*</i> H-4-1 (\$2M;\$100/sample)	Accepted Demonstrated TTP Match	This technology shows much promise in reducing the amount of waste produced in analyzing samples as well as increasing the quality of the data obtained. Available at X-10.	Protocols are needed to optimize the digestion of environmental samples in preparation for subsequent analytical techniques.

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Characterization for W

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Solid Wastes Contaminated concrete rubble and gravel (MTC 5210) Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) Discarded asbestos and transits (MTC 5290) Contaminated fiberglass insulation (MTC 5220) Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) Scrap nonferrous metals (MTC 5190) Combustible debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) Compactible debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (MTC 5400) Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) Discarded filters (including HEPA filters) (MTC 5410) Spent ion exchange media (MTC 3115) Other uncategorized heterogeneous debris (MTC 5490) Lab packs (MTC 6100) Irradiated and spent fuel elements and components (NA) Sealed sources (NA) Graphite moderator (NA) Fissile materials (NA) Steam plant ash (NA) Solid-Liquid Wastes (Including Sludges) Waste processing sludges (MTC 3120) Ignitable and reactive wastes (MTC 6390) Corrosive wastes (MTC 1100/1200) Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) Toxic organic wastes (MTC 2200) Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 8300) Coal yard run-off sludge (NA) Infectious medical wastes (NA) Liquid Wastes Listed halogenated solvents (MTC 2210) Listed nonhalogenated solvents (MTC 2220) Process/dilute liquid low-level wastes (LLW) (MTC 1000) Mellon Valley and REDC caustic aqueous wastes (MTC 1200) REDC acidic aqueous wastes (MTC 1100) REDC liquid organic wastes (MTC 2900) Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes Volatile organic compounds (VOCs) in gases (NA) Semi-volatile organic compounds in gases (NA) Particulates in gases (NA) Inorganics in gases (NA) RAD in gases (NA) Adsorbable RAD in gases (NA) Nonadsorbable RAD in gases (NA) Sulfur oxides (SO₂) in gases (NA) Nitrogen oxides (NO₂) in gases (NA) Entrained vapors/acids in gases (NA) Orphan gas cylinders (MTC 6400)	General	Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the ORR, radiation protection standards, DOE Orders, and non-regulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization	Sam
EM Problems - Facility Decontamination and Decommissioning (D&D) - Remedial Action (RA)—Soils, Ground Water and Surface Water - Waste Management (WM)					Dele Field

Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Sample Preparation	H High Pressure Ashing for Sample Preparation CHAR-203-OL <i>Ranking:*</i> H-4-1 (\$1M;N)	Demonstration: Commercially available, but not mature.	High Pressure Ashing (HPA) is useful for the dissolution of organics and other difficult to dissolve materials. Commercially available but lacks sufficient validation to meet QA requirements. Some special sample types may be at the development stage. Available at X-10.	Some equipment/personnel currently available at ORNL to develop new procedures, but needs to be expanded to meet the increased work load. Estimated cost \$60-120K/year for 2 years.
	M Supercritical Fluid Extraction of Inorganics CHAR-201-OL <i>Ranking:*</i> M-3-2 (\$2M;N)	Predemonstration: Supercritical fluid extraction of inorganics, extraction of metal ions from liquid and solid material by supercritical carbon dioxide and chelators. TTP Match	Need to determine optimum extraction conditions, including chelators. Available at X-10.	Equipment cost: \$30K; Development cost: \$400K over 2 years.
Detection/Measurement Methods	H Fiber-Optic Chemical Sensors CHAR-25-OL <i>Ranking:*</i> Not Ranked	Accepted; Demonstration: Remote detection using a variety of methods including optical absorption, Raman scattering and luminescence spectroscopy. The fiber optic is used to deliver or return light to or from the sample. This technology allows remote sensing in hazardous environments. TTP Match	A combination of waveguides and spectroscopic techniques are needed that have been matched not only for each other but also for specific monitoring scenarios.	Waveguides are needed that can withstand the harsh chemical environment that may be present in some of the sampling locations.
	M Ion Mobility Mass Spectrometry (IMMS) CHAR-264-OL <i>Ranking:*</i> M-4-2 (\$1M;\$50/sample)	Predemonstration: Provides a means for the rapid separation and identification of complex mixtures based on the mobility of ions in an electric field of atmospheric pressure.	Software control of high-speed data acquisition and interpretation and instrument control. Available at X-10.	Hardware cost: \$30K. Software development costs additional.
	H Immunoassay Detection CHAR-23-OL <i>Ranking:*</i> H-4-3 (\$1M;\$50/sample)	Accepted: Immunoassay detectors are used to determine environmentally important analytes. The technique is very selective and sensitive, extremely easy to use.	This is a mature and emerging technology. Kits are designed to perform in specialized waste streams. DOE has calibrated PCB kits in the Analytical Field Screening Program.	Automated sampling and reading systems for quick on-line testing of groundwater and waste stream contamination.
	M Portable Raman Spectrometer CHAR-84-OL <i>Ranking:*</i> M-4-2 (\$1M;\$10/sample)	Demonstration: Demonstration of field capabilities at ORNL. Raman spectra provide fingerprint identification of chemical species. No direct contact with the sample is necessary. Often interfaced with fiber optics for remote sensing in inaccessible areas. TTP Match	Need portable equipment (laser, etc.) for insitu use. Develop methods which exploit surface enhancement and resonance excitation for vastly improved sensitivity.	Equipment available at ORNL. Not yet assembled for specific applications.
	H Optical Absorption Spectroscopy (OAS) CHAR-27-OL <i>Ranking:*</i> H-4-1 (\$6M;\$50/sample)	Accepted: Measures the transmission of UV, visible, and near IR to determine the concentration of chemical species in gases, liquids, or solids. OAS can be applied to the analysis of any species which absorbs electromagnetic radiation in the region of excitation, UV through IR. TTP Match	Mature, field-portable technology available in IR, UV. Available at all sites.	It can be implemented for site-specific needs.

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Characterization

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Solid Wastes: - Contaminated concrete rubble and gravel (MTC 5210) - Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) - Discarded asbestos and transits (MTC 5290) - Contaminated fiberglass insulation (MTC 5220) - Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) - Scrap nonferrous metals (MTC 5190) - Combustible debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) - Compactible debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (MTC 5400) - Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) - Discarded filters (including HEPA filters) (MTC 5410) - Spent ion exchange media (MTC 3115) - Other uncategorized heterogeneous debris (MTC 5490) - Lab packs (MTC 6100) - Irradiated and spent fuel elements and components (NA) - Sealed sources (NA) - Graphite moderator (NA) - Fissile materials (NA) - Steam plant ash (NA) Solid-Liquid Wastes (Including Sludges) - Waste processing sludges (MTC 3120) - Ignitable and reactive wastes (MTC 6390) - Corrosive wastes (MTC 1100/1200) - Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) - Toxic organic wastes (MTC 2200) - Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 8900) - Coal yard run-off sludge (NA) - Infectious medical wastes (NA) Liquid Wastes - Listed halogenated solvents (MTC 2210) - Listed nonhalogenated solvents (MTC 2220) - Process/dilute liquid low-level wastes (LLW) (MTC 1000) - Melton Valley and REDC caustic aqueous wastes (MTC 1200) - REDC acidic aqueous wastes (MTC 1100) - REDC liquid organic wastes (MTC 2900) - Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes - Volatile organic compounds (VOCs) in gases (NA) - Semi-volatile organic compounds in gases (NA) - Particulates in gases (NA) - Inorganics in gases (NA) - RAD in gases (NA) - Adsorbable RAD in gases (NA) - Nonadsorbable RAD in gases (NA) - Sulfur oxides (SO₂) in gases (NA) - Nitrogen oxides (NO₂) in gases (NA) - Entrained vapors/acids in gases (NA) - Orphan gas cylinders (MTC 6400)	General	Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the ORR, radiation protection standards, DOE Orders, and non-regulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

or Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Detection/Measurement— Field Methods	L Air Monitoring CHAR-59-OL <i>Ranking:*</i> L-4-0 (\$0.25M;\$500/sample)	Accepted Encompasses several methods of monitoring particulate loading and characteristics during remedial action and decontamination and decommissioning activities. Collected samples can be analyzed for many different species. TTP Match	This is a mature sampling technology with EPA protocols. Available at all sites.	This is a mature technology.
	M Infrared Spectroscopy CHAR-18-OL <i>Ranking:*</i> M-4-1 (\$0.5M;\$100/sample)	Accepted This method includes: long-path (LP-FTIR); diffuse reflectance and attenuated total reflectance (ATR) for determination of compounds found in the air and water and on surfaces. TTP Match	No units currently exist on-site. Several vendors are marketing equipment. Software development would enhance site-specific applications. Available at all sites.	Centralized mounting areas with robotically controlled unit would allow multiple site areas to be monitored with one unit.
	H Personnel Monitoring CHAR-52-OL <i>Ranking:*</i> H-4-1 (\$0.2M;N)	Demonstration	Model studies are needed to correlate exposure and quantitative analysis from various human factors. Available at all sites.	We need a detailed monitoring program for personnel protection.
	M Electrochemical Methods CHAR-10-OL <i>Ranking:*</i> M-4-2 (\$0.5M;\$100/sample)	Accepted Oxidizable or reducible species, excited by a voltage or current function in an electrical circuit, yield quantitative and qualitative information about species of interest. Selective and sensitive sampling is possible in many situations. TTP Match	Adaptation and protocols for model studies to be performed on complex systems are needed.	Hardware cost: \$50K-\$250K; development costs are \$250K.
	M Luminescence Detection CHAR-92-OL <i>Ranking:*</i> M-4-1 (\$0.5M;\$10/sample)	Predemonstration; Demonstration The detection of organic and inorganic status chemicals using fluorescence, phosphorescence, and chemiluminescence. TTP Match	The technology is mature, but may not provide absolute identification of compounds in complex mixtures. Available at X-10.	Hardware is available at ORNL. Specific techniques need development and procedures written.
Detection/Measurement— Laboratory Methods	H Contamination Control— Analytical Equipment CHAR-204-OL <i>Ranking:*</i> H-5-2 (\$0.5M;N)	Commercially available for some systems, but usually must be done on a case-by-case basis due to facility limitations and different containment requirements. TTP Match	Contamination control for analytical equipment/instrumentation frequently requires extensive instrument modification to contain the equipment in radiochemical hoods, gloves boxes, or hot cells. Requires special expertise, but must be done for higher levels of radioactivity. Available at X-10.	Some equipment/personnel currently available at ORNL but needs to be expanded to meet the expected increase in work load. Implementation includes engineering design, fabrication of containment/shielding, and modification of facility. Typical cost for containment of an ICP in a glove box was approximately \$150K several years ago; this did not include the cost of the instrument.
	M Fourier Transform Infrared Spectroscopy (FT-IR) CHAR-8-OL <i>Ranking:*</i> M-4-1 (\$0.2M;\$50-500/sample)	Accepted TTP Match	Data base for rapid materials identification and model studies of materials interaction is needed. Available at all sites.	Hardware cost: \$25K-\$500K; Development cost: <\$200K, \$75K hardware cost projected for EPA-certified unit.

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Characterization for V

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Solid Wastes - Contaminated concrete rubble and gravel (MTC 5210) - Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) - Discarded asbestos and transit (MTC 5290) - Contaminated fiberglass insulation (MTC 5220) - Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) - Scrap nonferrous metals (MTC 5190) - Combustible debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) - Compactable debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (MTC 5400) - Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) - Discarded filters (including HEPA filters) (MTC 5410) - Spent ion exchange media (MTC 3115) - Other uncategorized heterogeneous debris (MTC 5490) - Lab packs (MTC 6100) - Irradiated and spent fuel elements and components (NA) - Sealed sources (NA) - Graphite moderator (NA) - Fissile materials (NA) - Steam plant ash (NA) Solid-Liquid Wastes (Including Sludges) - Waste processing sludges (MTC 3120) - Ignitable and reactive wastes (MTC 6390) - Corrosive wastes (MTC 1100/1200) - Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) - Toxic organic wastes (MTC 2200) - Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 8900) - Coal yard run-off sludge (NA) - Infectious medical wastes (NA) Liquid Wastes - Listed halogenated solvents (MTC 2210) - Listed nonhalogenated solvents (MTC 2220) - Process/dilute liquid low-level wastes (LLW) (MTC 1000) - Melton Valley and REDC caustic aqueous wastes (MTC 1200) - REDC acidic aqueous wastes (MTC 1100) - REDC liquid organic wastes (MTC 2900) - Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes - Volatile organic compounds (VOCs) in gases (NA) - Semi-volatile organic compounds in gases (NA) - Particulates in gases (NA) - Inorganics in gases (NA) - RAD in gases (NA) - Adsorbable RAD in gases (NA) - Nonadsorbable RAD in gases (NA) - Sulfur oxides (SO₂) in gases (NA) - Nitrogen oxides (NO₂) in gases (NA) - Entrained vapors/acids in gases (NA) - Orphan gas cylinders (MTC 6400)	General	Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the ORR, radiation protection standards, DOE Orders, and non-regulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization	Det Lab
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					Data

Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Ion/Measurement Laboratory Methods	M Isotopic Dilution Mass Spectroscopy (ID-MS) CHAR-48-OL Ranking:* M-4-0 (\$0M;\$100-1000/sample)	Accepted	Models studies are needed to enable quick analysis. Available at X-10.	Equipment, as well as the model studies mentioned above, is needed.
	M Nuclear Magnetic Resonance (NMR) CHAR-11-OL Ranking:* M-4-1 (\$.2M;\$200-500/sample)	Accepted, available on site TTP Match	None, available on-site. Available at X-10.	Hardware cost: \$200K-\$2M; developments costs, \$200K-\$500K.
	H Secondary Ion Mass Spectroscopy (SIMS) CHAR-3-OL Ranking:* H-4-0 (\$0M;\$400/sample)	Accepted	This is a mature technology. Model studies are needed to calibrate for depth profiling studies. Available at all sites.	Instrumentation and personnel exist at the three plants.
	M Laser Ionization Mass Spectrometry (LIMS, LAMMA, LIMMA) CHAR-4-OL Ranking:* M-4-1 (\$.25M;\$300-500/sample)	Accepted TTP Match	This is a mature technology. Model studies are needed to optimize results interpretation.	Prototype instrumentation and research instrumentation exists. More equipment would be required. The necessary personnel are available.
	H Ultraviolet/Visible (UV-VIS) Spectroscopy CHAR-9-OL Ranking:* H-4-0 (<\$.1M;\$50-200/sample)	Accepted, available on-site TTP Match	Model studies and application design. Available at all sites.	Hardware cost: <\$200K; Development cost: <\$100K.
Analysis/Management	Project Information Access Services (Needed Enabling Technologies) CHAR-220-OL Ranking:* Not Ranked	Demonstration, an integrated project information access and management system is sufficiently different from current types of electronic information access support within DOE facilities as to warrant requiring a demonstration before deciding to proceed with implementation.	Technology to implement such a system is commercially available.	Computer networks, especially Ethernet (cable, fiber), need to be extended throughout the Laboratory and other Energy Systems facilities.
	Network Architecture with Integrated Workstations CHAR-221-OL Ranking:* Not Ranked	Demonstration, commercial engineering workstations provide the capabilities to support this technology.	The greatest obstacle to use of this technology is the current legacy of older operating systems (DOS, MacOS) not designed to support integration of desktop applications with each other and with network services. Available at X-10.	This technology is best introduced in the context of a commitment to use open system standards for all new computer acquisitions.
	E Client/Server Access to Standards and Regulatory Guidelines (Needed Enabling Technologies) DISM-152-OL Ranking:* E-5-1 (\$.5M;\$60K/yr)	Demonstration Component technologies are well-established, commercially available, and affordable. They have not yet been integrated for use in a client/server environment.	A product is needed that provides network access to the databases on CD-ROM using the TCP/IP communications protocols between client and server.	Automated, on-line access to basic reference documents is essential to reducing costs and increasing reliability of operations in a highly regulated work environment.

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Characterization

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Solid Wastes - Contaminated concrete rubble and gravel (MTC 5210) - Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) - Discarded asbestos and transit (MTC 5290) - Contaminated fiberglass insulation (MTC 5220) - Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) - Scrap nonferrous metals (MTC 5190) - Combustible debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) - Compactable debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (MTC 5400) - Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) - Discarded filters (including HEPA filters) (MTC 5410) - Spent ion exchange media (MTC 3115) - Other uncategorized heterogeneous debris (MTC 5490) - Lab packs (MTC 6100) - Irradiated and spent fuel elements and components (NA) - Sealed sources (NA) - Graphite moderator (NA) - Fissile materials (NA) - Steam plant ash (NA) Solid-Liquid Wastes (Including Sludges) - Waste processing sludges (MTC 3120) - Ignitable and reactive wastes (MTC 6390) - Corrosive wastes (MTC 1100/1200) - Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) - Toxic organic wastes (MTC 2200) - Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 8300) - Coal yard run-off sludge (NA) - Infectious medical wastes (NA) Liquid Wastes - Listed halogenated solvents (MTC 2210) - Listed nonhalogenated solvents (MTC 2220) - Process/dilute liquid low-level wastes (LLW) (MTC 1000) - Melton Valley and REDC caustic aqueous wastes (MTC 1200) - REDC acidic aqueous wastes (MTC 1100) - REDC liquid organic wastes (MTC 2900) - Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes - Volatile organic compounds (VOCs) in gases (NA) - Semi-volatile organic compounds in gases (NA) - Particulates in gases (NA) - Inorganics in gases (NA) - RAD in gases (NA) - Adsorbable RAD in gases (NA) - Nonadsorbable RAD in gases (NA) - Sulfur oxides (SO₂) in gases (NA) - Nitrogen oxides (NO₂) in gases (NA) - Entrained vapors/acids in gases (NA) - Orphan gas cylinders (MTC 6400)	General	Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the ORR, radiation protection standards, DOE Orders, and non-regulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

for Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Data Analysis/Management	Data Access Services (Needed Enabling Technologies) DISM-153-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration The particular network and communications configurations needed to support restoration activities may not exist, so would have to set up and their successful operation demonstrated.	Some software will be available commercially; some will have to be developed locally.	Requirements and specifications for such services must be identified and documented to serve as a common reference so that data can be accessed using a single set of services regardless of the type of computer at each node on the network.
	Geographic Information System for DOE Sites (Needed Enabling Technologies) DISM-181-OL <i>Ranking:*</i> <i>E-5-1 (\$1M;\$200Kam)</i>	Accepted Most information, data, and computer system components for a basic geographic information system (GIS) for each DOE site already exists but must be integrated to meet the needs of the environmental restoration program.	Existing technology must be enhanced by adding a tagging mechanism to permit the system to be used for tracking activities and to link information in databases associated with a physical location to appropriate map and drawing displays on desktop computers.	A large initial effort may be required to scan and digitize diagrams and drawings for electronic storage and quick retrieval or transfer across networks.
	Automated Scanning and Conversion of Engineering Drawings (Needed Enabling Technologies) DISM-154-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration The basic technology is well established. Whether the current state of the art can adequately process the large number of drawings needed for reference and how effectively this technology can be integrated with other aspects of automated support needs to be demonstrated.	Improvements are needed in the speed and accuracy of converting scanned images to graphical representations that will meet the needs (e.g., ability to change scale to show more detail) of the environmental restoration program.	Considerable human intervention may be required to handle large drawings or drawings that cannot easily be laid flat on a scanning bed.
	E Hazard Analysis Expert System CHAR-233-OL <i>Ranking:*</i> <i>E-5-2 (\$.5M;\$150Kam)</i>	Demonstration Expert systems have been very effective tools for some applications; success or failure depends critically on how well the problem domain has been analyzed and how thoroughly the knowledge base has been specified.	Availability of and access to specification and design tools for developing the knowledge base and structure of the rules are the biggest needs.	Implementation strategy and problem analysis process used are the most important elements of developing a successful hazard analysis expert system.
	E Application of Approximate Reasoning to Data Analysis/Evaluation CHAR-234-OL <i>Ranking:*</i> <i>E-5-2 (\$.5M;\$150Kam)</i>	Demonstration Effective and successful use of this technology depends on availability of experienced and qualified technical people.	Development is needed of tools (e.g., a range of graphical models designed to assist in visualizing relationships) to assist with conceptual analysis or to examine consequences of choosing a logical strategy (e.g., automated theorem provers) in the analysis of problems.	Powerful computing capabilities exist for applying approximate reasoning techniques but are not widely used. Education and training in the use of this technology will be needed.
E	Simulated Walkthrough Facility for Robotics Task Sequence Analysis (Needed Enabling Technologies) DISM-171-OL <i>Ranking:*</i> <i>E-5-2 (\$2M;(\$300Kam)</i>	Demonstration The IGRIP applications software running on a Silicon Graphics workstation is capable of identifying situations in which collisions will occur. It can also use human factors and ergonomics data to indicate which tasks requiring human assistance are or are not possible or safe for a human operator to perform.	Development of support reference databases (e.g., human factors, ergonomics) to increase the effectiveness of this technology is an area of need.	The greatest need is to acquire the site-specific data, organize, assemble, and store it for rapid retrieval across computer networks. Integration of this technology with other networked resources will also be required at each site.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for W

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Solid Wastes - Contaminated concrete rubble and gravel (MTC 5210) - Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) - Discarded asbestos and transite (MTC 5290) - Contaminated fiberglass insulation (MTC 5220) - Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) - Scrap nonferrous metals (MTC 5190) - Combustible debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) - Compactible debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (MTC 5400) - Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) - Discarded filters (including HEPA filters) (MTC 5410) - Spent ion exchange media (MTC 3115) - Other uncategorized heterogeneous debris (MTC 5430) - Lab packs (MTC 6100) - Irradiated and spent fuel elements and components (NA) - Sealed sources (NA) - Graphite moderator (NA) - Fissile materials (NA) - Steam plant ash (NA) Solid-Liquid Wastes (Including Sludges) - Waste processing sludges (MTC 3120) - Ignitable and reactive wastes (MTC 6390) - Corrosive wastes (MTC 1100/1200) - Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) - Toxic organic wastes (MTC 2200) - Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 8900) - Coal yard run-off sludge (NA) - Infectious medical wastes (NA) Liquid Wastes - Listed halogenated solvents (MTC 2210) - Listed nonhalogenated solvents (MTC 2220) - Process/dilute liquid low-level wastes (LLW) (MTC 1000) - Melton Valley and REDC caustic aqueous wastes (MTC 1200) - REDC acidic aqueous wastes (MTC 1100) - REDC liquid organic wastes (MTC 2900) - Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes - Volatile organic compounds (VOCs) in gases (NA) - Semi-volatile organic compounds in gases (NA) - Particulates in gases (NA) - Inorganics in gases (NA) - RAD in gases (NA) - Adsorbable RAD in gases (NA) - Nonadsorbable RAD in gases (NA) - Sulfur oxides (SO₂) in gases (NA) - Nitrogen oxides (NO₂) in gases (NA) - Entrained vapors/acids in gases (NA) - Orphan gas cylinders (MTC 6400)	General	Refer to Vol. 1, PLC, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the ORR, radiation protection standards, DOE Orders, and non-regulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization	Data
EM Problems - Facility Decontamination and Decommissioning (D&D) - Remedial Action (RA)—Soils, Ground Water and Surface Water - Waste Management (WM)					

Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Analysis/Management				
E	Computer Based Training Systems (Needed Enabling Technologies) DISM-191-OL Ranking:* E-5-2 (\$5M;\$150Kam)	Demonstration Application software is available that permits rapid development of courses using many media (visual, audio), including support for a variety of testing strategies.	Further development is needed in the area of authoring support.	A well-defined course development life cycle does not yet exist. Currently used software engineering development life cycle methods should work well.
E	Computer Aided Task Analysis and Procedure Preparation (Needed Enabling Technologies) DISM-172-OL Ranking:* E-5-2 (\$5M;\$150Kam)	Demonstration This technology is used extensively in planning by various federal agencies, most notably the Department of Defense in military operations planning.	More natural language analysis tools are needed to assist with analysis of information used for planning, much of which is provided in text form.	Knowledge base development will require the largest effort, followed by development of expert systems and decision aids needed to make effective use of the information in the knowledge bases.
E	Client/Server Architecture for Database Access DISM-157-OL Ranking:* E-5-1 (\$3M;\$60Kam)	Demonstration The effectiveness and appropriateness of a particular architecture design to meet the requirements of the restoration activities needs to be demonstrated.	This technology will benefit most from improvements in network technology (higher transmission speeds, improved transmission protocols and data access services) needed to support it.	Effectiveness depends strongly on the definition, design and implementation of the data dictionaries, data directories and data models that are the essential foundation for use of this technology.
E	Hypertext Information Systems (Needed Enabling Technologies) DISM-158-OL Ranking:* E-5-1 (\$3M;\$100Kam)	Demonstration A range of products exists to support development of hypertext information systems having many capabilities such as mechanisms for linking related items, for starting, execution and controlling other applications, and for navigating documents for faster access to information.	Authoring and design tools are needed.	Hypertext information systems must be designed with great care to avoid problems with maintenance (e.g., modifying or replacing blocks of text from which or to which many links have been made to selected text strings within the block).
H	Spatial Sample and Data Analysis Plans CHAR-253-OL Ranking:* H-3-0.5 (\$1M;\$5Kam)	Accepted TTP Match	Personnel and computer time, access to survey data Available at X-10.	Time and data
M	Statistical Methods for the Analysis of Large Data Sets CHAR-251-OL Ranking:* M-3-3 (\$5M;\$5Kam)	Conceptual	To allow for the survey of many areas statistical methods to take advantage of new parallel processors may need to be developed. Available at X-10.	Possible large-scale computer needs and software development time.
E	Quality Control for Measurement Process CHAR-250-OL Ranking:* E-4-.25 (\$0.05M;\$5Kam)	Accepted TTP Match	Data from standards evaluations Available at X-10.	Access to Quality Standards measurements
H	Analysis of Censored Data CHAR-249-OL Ranking:* H-4-.25 (\$0.05M;\$5Kam)	Demonstration , some work is available in the literature. The application likely will have to be expanded to meet current needs.	Computer work station with access to appropriate databases. Available at X-10.	Access to appropriate databases, computer time, mathematical development time, and programming time.
L	Criticality Indices (CI) CHAR-44-OL Ranking:* L-2-1 (\$0.25M;N)	Accepted	The program must be implemented to specifically address the D&D technologies to be implemented and suggest the modifications that are needed for low-versus high-enrichment materials.	Same as Science/Technology Needs.

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Characterization

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Solid Wastes Contaminated concrete rubble and gravel (MTC 5210) Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) Discarded asbestos and transits (MTC 5290) Contaminated fiberglass insulation (MTC 5220) Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) Scrap nonferrous metals (MTC 5190) Combustible debris (e.g., paper, cloth, personal protective clothing (PFC), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) Compactable debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (MTC 5400) Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) Discarded filters (including HEPA filters) (MTC 5410) Spent ion-exchange media (MTC 3115) Other uncategorized heterogeneous debris (MTC 5490) Lab packs (MTC 6100) Irradiated and spent fuel elements and components (NA) Sealed sources (NA) Graphite moderator (NA) Fissile materials (NA) Steam plant ash (NA) Solid-Liquid Wastes (Including Sludges) Waste processing sludges (MTC 3120) Ignitable and reactive wastes (MTC 6390) Corrosive wastes (MTC 1100/1200) Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) Toxic organic wastes (MTC 2200) Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 6900) Coal yard run-off sludge (NA) Infectious medical wastes (NA) Liquid Wastes Listed halogenated solvents (MTC 2210) Listed nonhalogenated solvents (MTC 2220) Process/dilute liquid low-level wastes (LLW) (MTC 1000) Melton Valley and REDC caustic aqueous wastes (MTC 1200) REDC acidic aqueous wastes (MTC 1100) REDC liquid organic wastes (MTC 2900) Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes Volatile organic compounds (VOCs) in gases (NA) Semi-volatile organic compounds in gases (NA) Particulates in gases (NA) Inorganics in gases (NA) RAD in gases (NA) Adsorbable RAD in gases (NA) Nonadsorbable RAD in gases (NA) Sulfur oxides (SO₂) in gases (NA) Nitrogen oxides (NO₂) in gases (NA) Entrained vapors/acids in gases (NA) Orphan gas cylinders (MTC 6400)	General	Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the ORR, radiation protection standards, DOE Orders, and non-regulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization
EM Problems - Facility Decontamination and Decommissioning (D&D) - Remedial Action (RA)—Soils, Ground Water and Surface Water - Waste Management (WM)				

for Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Data Analysis/Management				
M	Modeling of Volatile Organic Compounds Migration in Porous Materials CHAR-53-OL <i>Ranking:*</i> M-4-1 (\$0.25M;N)	Demonstration TTP Match	Models need to be developed that are applicable to Site-specific scenarios.	Software and hardware are needed to implement the modeling systems.
E	Task Scheduling Aids CHAR-241-OL <i>Ranking:*</i> E-5-1 (\$0.5M;\$80Kam)	Demonstration Several component technologies must be integrated to provide the level of support needed for the highly regulated environment in which restoration activities will be conducted.	A combination of automated analysis tools (e.g., automated reasoning, theorem provers) and a conceptual framework for representing regulatory requirements needs to be developed that can identify possible logical conflicts that arise in scheduling tasks on jobs for which many requirements must be met.	Validation of data used for generating schedules will require much more attention in cases in which many regulations and requirements must be met.
H	Integrated Microprocessor/Sensor Monitoring for Radioactive Waste Storage Containers CHAR-260-OL <i>Ranking:*</i> H-5-1 (\$0.5M;\$50/sensor unit installed)	Pre-demonstration The component technologies (fiber optics, solar cell, high power density batteries), though still evolving, are mature enough to warrant consideration of their use in an integrated system for automated monitoring of stored hazardous wastes.	Problems associated with integrating the various component technologies will need attention.	Estimated costs and implementation experience for integrated microprocessor/sensor applications will most likely have to come from use in military applications.
E	Waste Management Configuration Management System CHAR-230-OL <i>Ranking:*</i> E-5-1 (\$0.5M;\$25Kam)	Accepted A range of application software to assist with configuration management is available both commercially and in the public domain. TTP Match	Enhancements to existing products may be required to provide the level of support needed for a large waste management program. Available at X-10.	Separate configuration management systems should be considered for each of (a) Characterization Sampling Program, (b) Remedial Action, (c) Waste Management, and (d) Decontamination and Decommissioning instead of setting up one large all-encompassing system.
M	Fiber-Optic Detection and Monitoring System (Intelligent Materials) CHAR-240-OL <i>Ranking:*</i> M-4-3 (\$3M;\$1000/container fabricated)	Evolving This technology holds much promise for continuous monitoring of radioactive waste storage systems.	Long-term stability and environmental testing are expected to be needed before considering applications for long-term radioactive waste monitoring applications.	TBD
E	3-D CAD Database of Buildings and Other Structures (Needed Enabling Technologies) DISM-156-OL <i>Ranking:*</i> E-5-2 (\$2M;\$300Kam)	Accepted The basic technology is in wide use. A variety of commercial products is available for use on systems ranging from desktop computers to large mainframes.	Integration of this technology with the other supporting technologies that must work together with it to provide the high level of automation needed to assure proper compliance with environmental legislation governing restoration activities will be the main technology need.	Identification of all possible uses (e.g., "training" robots, visual "walkthroughs", tags for tracking activities) of this technology and development of database requirements to support them are very important foundations for effective use of this technology.

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Characterization for V

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Solid Wastes Contaminated concrete rubble and gravel (MTC 5210) Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) Discarded asbestos and transits (MTC 5290) Contaminated fiberglass insulation (MTC 5220) Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) Scrap nonferrous metals (MTC 5190) Combustible debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) Compactable debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (MTC 5400) Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) Discarded filters (including HEPA filters) (MTC 5410) Spent ion exchange media (MTC 3115) Other uncategorized heterogeneous debris (MTC 5490) Lab packs (MTC 6100) Irradiated and spent fuel elements and components (NA) Sealed sources (NA) Graphite moderator (NA) Fissile materials (NA) Steam plant ash (NA) Solid-Liquid Wastes (including Sludges) Waste processing sludges (MTC 3120) Ignitable and reactive wastes (MTC 6390) Corrosive wastes (MTC 1100/1200) Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) Toxic organic wastes (MTC 2200) Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 8900) Coal yard run-off sludge (NA) Infectious medical wastes (NA) Liquid Wastes Listed halogenated solvents (MTC 2210) Listed nonhalogenated solvents (MTC 2220) Process/dilute liquid low-level wastes (LLW) (MTC 1000) Melton Valley and REDC caustic aqueous wastes (MTC 1200) REDC acidic aqueous wastes (MTC 1100) REDC liquid organic wastes (MTC 2900) Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes Volatile organic compounds (VOCs) in gases (NA) Semi-volatile organic compounds in gases (NA) Particulates in gases (NA) Inorganics in gases (NA) RAD in gases (NA) Adsorbable RAD in gases (NA) Nonadsorbable RAD in gases (NA) Sulfur oxides (SO₂) in gases (NA) Nitrogen oxides (NO₂) in gases (NA) Entrained vapors/acids in gases (NA) Orphan gas cylinders (MTC 6400)	General Radioactive Elements	Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the ORR, radiation protection standards, DOE Orders, and non-regulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified. Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the ORR, radiation protection standards, DOE Orders, and non-regulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization Characterization	Data Field
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					

Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Analysis/Management	E Generalized Object-Oriented Simulation Software (Needed Enabling Technologies) DISM-173-OL Ranking:* E-3-2 (\$5M;\$200Kam)	Demonstration The simulation environment is being used currently in ongoing studies associated with several different nuclear reactor design concepts. Modules would have to be written to model other types of systems.	Improvements are needed most in graphical display support systems.	Successful deployment depends on availability of applications programmers who understand object-oriented design and programming principles and have experience applying this understanding to models of physical systems.
	E Automated Engineering System Life Cycle Planning (Needed Enabling Technologies) DISM-174-OL Ranking:* E-5-1 (\$3M;\$60Kam)	Accepted A variety of commercial products developed to assist with managing large software development processes can be adapted for effective use in other engineering disciplines.	Improvements are needed to provide new types of support in order to satisfy regulatory requirements.	The usual life cycle planning methods must be modified to accommodate requirements of applicable environmental legislation which imposes constraints and requires additional elements to augment common practice.
	E Automated System Reliability and Safety Analysis (Needed Enabling Technologies) DISM-175-OL Ranking:* E-5-2 (\$5M;\$150Kam)	Accepted/Demonstration Tools for some types of analyses are in common use in engineering development environments for things like software, aircraft, communications satellites, and medical diagnostic equipment.	Few automated analysis tools exist since much of the effort for these analyses requires checking for consistency, correctness, completeness, tolerance of designs to various kinds of system failures, and unintended function.	Detailed knowledge of the system being analyzed (its behavior and attributes), its intended use, operation, and constraints that apply is essential to being able to automate any such analysis.
Methods	H Proportional Counter for Alpha and Beta Activity CHAR-108-OL Ranking:* H-5-0 (\$1M;\$100/sample)	Accepted	This is a well-established technology. Some minor development may be needed to distinguish Technetium activity from uranium. Probes for measuring vertical or overhead items are needed.	Normal
	M Passive Monitors for Weak Beta Radionuclides CHAR-102-OL Ranking:* M-4-2 (\$6M;\$20/sample)	Predemonstration The thermally stimulated exoelectron (TSEE) technique is the weakly penetrating radiation analog to thermoluminescence. The exposed TSEE dosimeter is heated to liberate low-energy electrons from a thin surface layer. The thin exoelective layer is especially sensitive to low energy beta radiations such as those from H-3, C-14 or Tc-99.	A thorough evaluation of this technology is needed for differentiating Tc-99 from other radionuclides in mixed surface contaminants. Pairs of detectors, one with a beta absorber on its surface, will be needed to discriminate weak beta from more penetrating radiations.	A commercial TSEE reader is available at ORNL. Different types of ceramic exoelectron materials should be tested to select the most suitable type for H-3, Tc-99 and other applications. ~\$100K will be needed for development.
	M Thermoluminescence Dosimeter Array for Spatial Characterization of Alpha-Contamination CHAR-103-OL Ranking:* M-4-3 M;\$6M;\$20/sample)	Demonstration A flexible sheet containing a fine grid of miniature thermoluminescence dosimeter elements that have a preferential sensitivity to alpha rays. Exposed sheets are scanned with a laser beam to heat the individual chips and produce a readable thermoluminescence that is converted into a two-dimensional map.	Technique is well-established but investigation of potentially confounding factors is needed. Such factors include moisture, oil, and radon.	It will need to be adapted to specific D&D needs. Size and shape of detector sheets needs tailoring to specific geometrics. Discriminating ability in mixed radiation fields needs further definition. Development cost: ~\$200K.
	M Long-Range Alpha Detector (LRAD) CHAR-65-OL Ranking:* M-4-1 (\$4M;\$100/sample)	Demonstration This is a screening device for detecting alpha radioactivity on surfaces or personnel and in soil or waste. It measures ionized air drawn from a container holding a contaminated object, irrespective of shape. TTP Match	Measurement probes and other devices must be developed for specific applications.	Overall cost \$10K/device; after commercialization price should decrease. Adaptation for site-specific applications. Field testing is needed (~\$300K)

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Characterization

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Solid Wastes - Contaminated concrete rubble and gravel (MTC 5210) - Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) - Discarded asbestos and transit (MTC 5290) - Contaminated fiberglass insulation (MTC 5220) - Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) - Scrap nonferrous metals (MTC 5190) - Combustible debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) - Compactible debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (MTC 5400) - Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) - Discarded filters (including HEPA filters) (MTC 5410) - Spent ion exchange media (MTC 3115) - Other uncategorized heterogeneous debris (MTC 5490) - Lab packs (MTC 6100) - Irradiated and spent fuel elements and components (NA) - Sealed sources (NA) - Graphite moderator (NA) - Fissile materials (NA) - Steam plant ash (NA) Solid-Liquid Wastes (Including Sludges) - Waste processing sludges (MTC 3120) - Ignitable and reactive wastes (MTC 5390) - Corrosive wastes (MTC 1100/1200) - Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) - Toxic organic wastes (MTC 2200) - Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 8900) - Coal yard run-off sludge (NA) - Infectious medical wastes (NA) Liquid Wastes - Listed halogenated solvents (MTC 2210) - Listed nonhalogenated solvents (MTC 2220) - Process/dilute liquid low-level wastes (LLW) (MTC 1000) - Melton Valley and REDC caustic aqueous wastes (MTC 1200) - REDC acidic aqueous wastes (MTC 1100) - REDC liquid organic wastes (MTC 2900) - Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes - Volatile organic compounds (VOCs) in gases (NA) - Semi-volatile organic compounds in gases (NA) - Particulates in gases (NA) - Inorganics in gases (NA) - RAD in gases (NA) - Adsorbable RAD in gases (NA) - Nonadsorbable RAD in gases (NA) - Sulfur oxides (SO₂) in gases (NA) - Nitrogen oxides (NO₂) in gases (NA) - Entrained vapors/acids in gases (NA) - Orphan gas cylinders (MTC 6400)	Radioactive Elements	Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the ORR, radiation protection standards, DOE Orders, and non-regulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

for Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Field Methods	H Integrated Microprocessor/Sensor Monitoring for Radioactive Waste Storage Containers CHAR-260-OL Ranking:* H-5-1 (\$5M;\$50/sensor unit installed)	Pre-demonstration The component technologies (fiber optics, solar cell, high power density batteries), though still evolving, are mature enough to warrant consideration of their use in an integrated system for automated monitoring (e.g., radiation, temperature, volume) of stored hazardous wastes.	Problems associated with integrating the various component technologies will need attention.	Estimated costs and implementation experience for integrated microprocessor/sensor applications will most likely have to come from use in military applications.
	M Bubble Dosimeters for Neutron Flux CHAR-216-OL Ranking:* M-4-1 (\$2M;\$15/sample)	These dosimeters are an integral part of a field neutron dosimetry system for use where neutron sources and shielding are not well known. They are capable of measuring neutron dose equivalent in low level fields and of providing simple spectral information.	The measurement principle is well established for measuring neutron flux around personnel. It must be evaluated for potential confounding effects in less benign environments.	~\$200K is needed to develop acoustic coupler for applications requiring real-time measurement of neutron dose rate and for development of a less expensive, automated bubble counter for reliable processing of passive detector results.
	H Alpha Track Etch Detectors for Surface Alpha Contamination CHAR-96-OL Ranking:* H-4-1 (\$4M;\$10/sample)	These are Alpha-sensitive plastics that can be cut to a size appropriate for specific applications, e.g., to fit inside pipes or on narrow crevices. After exposure, the plastic is developed chemically to visualize damage tracks produced by alpha-emitting contamination.	Technique is well-established (i.e., commercially available for measuring alpha activity in indoor air. Potentially confounding factors in surface or soil applications include: inhomogeneously sized particles, moisture, oils and radon in soil.	Plastic monitors of differing sizes and flexibilities need to be tailored and fabricated for specific tasks to be identified in pilot testing on-site. Deployment of detectors in large numbers will require establishment of on-site chemical etching and truck rendering capabilities.
	M Waste Curie Monitor (Bag or Barrel Counter for Low-Level Gamma Radioactivity CHAR-109-OL Ranking:* M-4-0 (\$0M;\$200/sample)	Accepted	Development may be necessary for containers larger than 55 gal drums.	Normal
	Advanced Radiation Monitors CHAR-269-OL Ranking:* Not Ranked	Predemonstration Digital display with replaceable, multiple "smart" probes for alpha and beta activity self-calibrating. TTP Match	Development of additional probes is needed. Available at X-10.	Ca. \$400K development costs over 2 years.
	H Portable Gamma Ray Scintillometers CHAR-263-OL Ranking:* H-4-0 (\$0M;\$100/sample)	In either single-channel or multichannel format, they are available commercially. The instrument consists of a NaI crystal, photomultiplier tube, portable battery-operated power supply, pulse height analyzer, and readout. TTP Match	Robotic technology needed for remote control applications.	The technology is commercially available. Specialized detector holders may need to be developed for particular applications.

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Characterization for W

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Solid Wastes - Contaminated concrete rubble and gravel (MTC 5210) - Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) - Discarded asbestos and transite (MTC 5290) - Contaminated fiberglass insulation (MTC 5220) - Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) - Scrap nonferrous metals (MTC 5190) - Combustible debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) - Compactible debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (MTC 5400) - Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) - Discarded filters (including HEPA filters) (MTC 5410) - Spent ion exchange media (MTC 3115) - Other uncategorized heterogeneous debris (MTC 5430) - Lab packs (MTC 6100) - Irradiated and spent fuel elements and components (NA) - Sealed sources (NA) - Graphite moderator (NA) - Fissile materials (NA) - Steam plant ash (NA) Solid-Liquid Wastes (Including Sludges) - Waste processing sludges (MTC 3120) - Ignitable and reactive wastes (MTC 6390) - Corrosive wastes (MTC 1100/1200) - Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) - Toxic organic wastes (MTC 2200) - Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 8900) - Coal yard run-off sludge (NA) - Infectious medical wastes (NA) Liquid Wastes - Listed halogenated solvents (MTC 2210) - Listed nonhalogenated solvents (MTC 2220) - Process/dilute liquid low-level wastes (LLW) (MTC 1000) - Melton Valley and REDC caustic aqueous wastes (MTC 1200) - REDC acidic aqueous wastes (MTC 1100) - REDC liquid organic wastes (MTC 2300) - Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes - Volatile organic compounds (VOCs) in gases (NA) - Semi-volatile organic compounds in gases (NA) - Particulates in gases (NA) - Inorganics in gases (NA) - RAD in gases (NA) - Adsorbable RAD in gases (NA) - Nonadsorbable RAD in gases (NA) - Sulfur oxides (SO₂) in gases (NA) - Nitrogen oxides (NO₂) in gases (NA) - Entrained vapors/acids in gases (NA) - Orphan gas cylinders (MTC 6400)	Radioactive Elements	Refer to Vol. 1, Pt.C, Chap. 6; for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the ORR; radiation protection standards, DOE Orders, and non-regulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization	Labo
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					

aste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Laboratory Methods	H Neutron Activation CHAR-107-OL and CHAR-266-OL Ranking:* H-4-1 (\$2M;\$300/sample)	Demonstration (drum) Accepted (other application) TTP Match	Development is needed for containers that are larger than 55-gal drums. Separate calibration standards are needed for each matrix.	Instrumentation and personnel currently exist at ORNL but needs to be expanded to meet the expected work load. Estimated cost of upgrade and expansion \$250K.
	M Sodium Iodide-Germanium Gamma Spectroscopy CHAR-106-OL Ranking:* M-4-0 (\$0M;N)	Accepted TTP Match	Correction factor methodology needs to be published.	None
	H Passive Neutron Detection CHAR-104-OL Ranking:* H-4-2 (\$1M;N)	Accepted	None	None
	H Radioanalytical Procedures CHAR-202-OL Ranking:* H-5-0 (\$1M;\$100/sample)	Development Upgrade of Radioanalytical Procedures, general upgrade and modernization of radiochemical separation technology. TTP Match	Considerable new technology is available but lacks sufficient validation to meet QA requirements. Other areas are at the basic development stage. Available at X-10.	Some instrumentation/personnel currently exist at ORNL to develop new procedures but needs to be expanded to meet the increased work load. Estimated cost \$600K/year for 5 years.
	H Proportional Counter for Alpha and Beta Activity CHAR-108-OL Ranking:* H-4-0 (\$0M;N)	Accepted	This is a well-established technology. Some minor development may be needed to distinguish Technetium activity from uranium. Probes for measuring vertical or overhead items are needed.	Normal
	H Phyton Electron Rejecting Alpha Liquid Scintillation (PERALS) CHAR-97-OL Ranking:* H-5-1 (\$2M;\$100/sample)	Accepted A very sensitive (pCi/g) technique for measuring alpha-emitting isotopes in soil, water, and airborne dust. TTP Match	Cost effective, timely analysis of select alpha emitting radionuclides in large numbers of samples is needed to verify nonviolation of cleanup standards. Available at X-10, Y-12.	A PERALS laboratory is already set up at the ORNL DOR/SAR facility. It can be adapted for rapid "on-line" monitoring of both airborne and loose contamination.
	H Gross Fissile Analysis by Neutron Activation and Delayed Neutron Counting CHAR-200-OL Ranking:* H-5-0 (\$1M;\$100/sample)	Mature technology for U235 measurements. Gross Fissile Analysis by Neutron Activation and Delayed Neutron Counting, non-destructive measurement of fissile actinides, characterization of wide variety of sample types, most useful for solids but can be applied to liquids. TTP Match	Mature technology, startup studies need to be done to evaluate possible interferences. Available at X-10.	Instrumentation and personnel currently exist at ORNL but needs to be expanded to meet the expected work load. Estimated cost of upgrade and expansion \$250K.
	H Gamma-Ray Spectrometry CHAR-268-OL Ranking:* H-5-0 (\$1M;\$100/sample)	Mature technology. TTP Match	Commercially available and mature. Available at X-10.	Some equipment/personnel currently available at ORNL but needs to be expanded to meet the expected increase in work load. Detector costs range from \$10K to \$50K.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization

or Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Laboratory Methods	M Liquid Scintillation Counting CHAR-267-OL <i>Ranking:*</i> M-5-1 (\$.2M;N)	Mature technology TTP Match	Commercially available and mature. Available at X-10.	Some equipment/personnel currently available at ORNL but needs to be expanded to meet the expected increase in work load. Instrumentation costs range from \$30K - \$40K.
Field Methods	M Atomic Emission Spectroscopy CHAR-76-OL <i>Ranking:*</i> M-5-1 (\$.2M;N)	Accepted TTP Match	The technology is well-developed and applicable as is.	Technology is available at the K-25 Site.
	H X-Ray Fluorescence for In Situ Monitoring of Toxic Heavy Metals CHAR-219-OL and CHAR-6-OL <i>Ranking:*</i> H-5-1 (\$.2M;\$25/sample)	Accepted Can be use for in situ monitoring of toxic heavy metals in paints, on surfaces, and in soils. Portable XRF units are commercially available and have been widely used for screening painted surfaces for lead contamination. TTP Match	This is a mature technology.	Substrate effects need to be studied. The lower limit of detection for some metals on surfaces needs to be measured (~\$200K).
Laboratory Methods	H Inductively Coupled Plasma—Mass Spectroscopy (ICP-MS) CHAR-78-OL <i>Ranking:*</i> H-4-2 (\$.1M;\$200/sample)	Demonstration - available, but not fully developed. TTP Match	It is applicable as is for multi-element analysis of aqueous solutions. Development is progress to use the technology for surface analysis using laser ablation techniques, and for low specific activity, long-lived radionuclides.	It is now available at the X-10 Site. \$400K development costs to extend to long-lived, low specific activity radionuclides.
	H Inductively Coupled Plasma Spectroscopy (ICP) CHAR-77-OL <i>Ranking:*</i> H-4-0 (\$.1M;\$200/sample)	Accepted TTP Match	It is applicable as is. This is a well-developed technology.	It is available at ORNL.
	H Atomic Emission Spectroscopy (AE) CHAR-76-OL <i>Ranking:*</i> H-4-0 (\$.1M;\$200/sample)	Accepted TTP Match	The technology is well-developed and applicable as is.	Technology is available at the K-25 Site.
	H Ion Chromatography (IC) CHAR-50-OL <i>Ranking:*</i> H-4-0 (\$.1M;\$100/sample)	Accepted TTP Match	A detector system that is optimized for the expected waste streams that will be generated needs to be determined. Available at all sites.	Systems are available for process control of WM efforts.
	M Electron Diffraction (ED, SAED, LEED) CHAR-37-OL <i>Ranking:*</i> M-4-0 (\$0M;\$100/sample)	Accepted TTP Match	None Available at all sites.	None
	Wavelength Dispersive X-Ray Spectroscopy (WDS, WDX) CHAR-36-OL <i>Ranking:*</i> Not Ranked	Accepted	None Available at all sites.	None

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for V

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Solid Wastes - Contaminated concrete rubble and gravel (MTC 5210) - Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) - Discarded asbestos and transits (MTC 5290) - Contaminated fiberglass insulation (MTC 5220) - Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) - Scrap nonferrous metals (MTC 5190) - Combustible debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) - Compactable debris (e.g., glass, lights, ceramics, glove boxes, manipulator booms) (MTC 5400) - Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) - Discarded filters (including HEPA filters) (MTC 5410) - Spent ion exchange media (MTC 3115) - Other uncategorized heterogeneous debris (MTC 5490) - Lab packs (MTC 6100) - Irradiated and spent fuel elements and components (NA) - Sealed sources (NA) - Graphite moderator (NA) - Fissile materials (NA) - Steam plant ash (NA) Solid-Liquid Wastes (Including Sludges) - Waste processing sludges (MTC 3120) - Ignitable and reactive wastes (MTC 6390) - Corrosive wastes (MTC 1100/1200) - Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) - Toxic organic wastes (MTC 2200) - Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 8900) - Coal yard run-off sludge (NA) - Infectious medical wastes (NA) Liquid Wastes - Listed halogenated solvents (MTC 2210) - Listed nonhalogenated solvents (MTC 2220) - Process/dilute liquid low-level wastes (LLW) (MTC 1000) - Melton Valley and REDC caustic aqueous wastes (MTC 1200) - REDC acidic aqueous wastes (MTC 1100) - REDC liquid organic wastes (MTC 2900) - Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes - Volatile organic compounds (VOCs) in gases (NA) - Semi-volatile organic compounds in gases (NA) - Particulates in gases (NA) - Inorganics in gases (NA) - RAD in gases (NA) - Adsorbable RAD in gases (NA) - Nonadsorbable RAD in gases (NA) - Sulfur oxides (SO₂) in gases (NA) - Nitrogen oxides (NO₂) in gases (NA) - Entrained vapors/acids in gases (NA) - Orphan gas cylinders (MTC 6400)	Inorganics	Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the ORR, radiation protection standards, DOE Orders, and non-regulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization	Lab
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					

Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Laboratory Methods				
M	Energy Dispersive X-Ray Spectroscopy (EDS, EDX, EDAX) CHAR-35-OL <i>Ranking:*</i> M-4-0 (\$0M;\$100/sample)	Accepted TTP Match	None Available at all sites.	None
M	Transmission Electron Microscopy (TEM) CHAR-34-OL <i>Ranking:*</i> M-4-0 (\$0M;\$100/sample)	Accepted TTP Match	This is a mature technology. Available at all sites.	This is a mature technology.
M	Scanning Electron Microscopy (SEM) CHAR-33-OL <i>Ranking:*</i> M-4-0 (\$0M;\$100/sample)	Accepted TTP Match	This is a mature technology. Available at all sites.	This is a mature technology.
M	Particle-Induced X-Ray Emission (PIXIE) CHAR-17-OL <i>Ranking:*</i> M-4-0 (\$0M;\$100/sample)	Accepted	This is not a mature technology; photon source is under development. Available at K-25.	The instrumentation is available on-site. Analysis is available at outside laboratories. Sampling scenarios could be designed to identify and use the strengths of the technique.
H	Cold Vapor (Mercury) Analysis CHAR-24-OL <i>Ranking:*</i> H-4-0 (\$0M;\$100/sample)	Accepted This technique is based on the atomic absorption spectroscopy of mercury and very sensitive and highly selective.	This is a mature technology which needs to be part of a mobile laboratory.	This is a mature technology which needs to be part of a mobile laboratory.
H	Neutron Activation Analysis CHAR-266-OL <i>Ranking:*</i> H-4-1 (\$.2M;\$200/sample)	Accepted, mature technology TTP Match	Mature technology, startup studies to be done to evaluate possible interferences. Available at X-10.	Instrumentation and personnel currently exist at ORNL but needs to be expanded to meet the expected work load. Estimated cost of upgrade and expansion \$250K.
M	Powder X-Ray Diffraction CHAR-31-OL <i>Ranking:*</i> M-4-0 (\$0M;\$100/sample)	Accepted	This is a mature technology. Available at all sites.	None
M	Electron Spectroscopy for Chemical Analysis (ESCA) CHAR-1-OL <i>Ranking:*</i> M-4-0 (\$0M;\$200-600/sample)	Accepted	Model studies are needed to identify binding energies for standard compounds of Tc and U for suspected matrices. Available at all sites.	Instrumentation and personnel currently exist at K-25.
M	Auger Electron Spectroscopy (AES) CHAR-2-OL <i>Ranking:*</i> M-4-0 (\$0M;\$300-800/sample)	Accepted TTP Match	Mature, model studies are needed to probe the host/contaminant effects for accurate depth profiling. Available at X-10, Y-12, K-25.	Instrumentation and personnel exist within the three plants.
H	Glow Discharge Ionization Mass Spectroscopy CHAR-56-OL <i>Ranking:*</i> H-4-1 (\$.5M;N)	Accepted (laboratory) Predemonstration (field) TTP Match	Need to determine relative sensitivity factors, and use of DC and rf glow discharges. Available at X-10.	Hardware cost: \$200K Development cost: \$500K

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Characterization

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Solid Wastes - Contaminated concrete rubble and gravel (MTC 5210) - Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) - Discarded asbestos and transit (MTC 5290) - Contaminated fiberglass insulation (MTC 5220) - Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) - Scrap nonferrous metals (MTC 5190) - Combustible debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) - Compactible debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (MTC 5400) - Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) - Discarded filters (including HEPA filters) (MTC 5410) - Spent ion exchange media (MTC 3115) - Other uncategorized heterogeneous debris (MTC 5490) - Lab packs (MTC 6100) - Irradiated and spent fuel elements and components (NA) - Sealed sources (NA) - Graphite moderator (NA) - Fissile materials (NA) - Steam plant ash (NA) Solid-Liquid Wastes (Including Sludges) - Waste processing sludges (MTC 3120) - Ignitable and reactive wastes (MTC 6390) - Corrosive wastes (MTC 1100/1200) - Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) - Toxic organic wastes (MTC 2200) - Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 6900) - Coal yard run-off sludge (NA) - Infectious medical wastes (NA) Liquid Wastes - Listed halogenated solvents (MTC 2210) - Listed nonhalogenated solvents (MTC 2220) - Process/dilute liquid low-level wastes (LLW) (MTC 1000) - Mellon Valley and REDC caustic aqueous wastes (MTC 1200) - REDC acidic aqueous wastes (MTC 1100) - REDC liquid organic wastes (MTC 2900) - Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes - Volatile organic compounds (VOCs) in gases (NA) - Semi-volatile organic compounds in gases (NA) - Particulates in gases (NA) - Inorganics in gases (NA) - RAD in gases (NA) - Adsorbable RAD in gases (NA) - Nonadsorbable RAD in gases (NA) - Sulfur oxides (SO₂) in gases (NA) - Nitrogen oxides (NO₂) in gases (NA) - Entrained vapors/acids in gases (NA) - Orphan gas cylinders (MTC 6400)	Organics	Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the ORR, radiation protection standards, DOE Orders, and non-regulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization
EM Problems - Facility Decontamination and Decommissioning (D&D) - Remedial Action (RA)—Soils, Ground Water and Surface Water - Waste Management (WM)				

for Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Field Methods	Synchronous Fluorescence Screening for Polycyclic Aromatic Hydrocarbons CHAR-101-OL Ranking:* Not Ranked	Demonstration, technology available; Predemonstration. When light of a specific wavelength is directed onto a sample, certain organic compounds (such as PAHs) absorb and re-emit that light (fluoresce) at a higher wavelength. In this technique, exciting and fluorescing wavelengths are scanned synchronously. Analytes can be differentiated because they absorb and fluoresce at different wavelengths. TTP Match	Technology needs to be validated in the EPA program. Numerous situations at X-10 have involved used oils and lubricants which contain PAHs. Available at X-10.	Hardware cost: \$25K; Development cost: \$200K.
M	Portable Gas Chromatograph/Electron Capture Detector for Analyzing PCBs CHAR-100-OL Ranking:* M-4-0 (\$0.25M;\$50/sample)	Accepted TTP Match	Available at Y-12.	We need to order GC/ECD devices (~\$15K each).
M	Portable Volatile Organic Compound (VOC) Detectors CHAR-5-OL Ranking:* M-4-0 (\$0.25M;\$10/sample)	Accepted A valuable, quick, and yet inexpensive method to screen for the contamination of soils based on flame ionization or photoionization of sampled air. Useful at a variety of sites including leaking underground tanks pits in spillage. TTP Match	This is a mature technology. Available at X-10., Y-12	For quick screening and surveying, instruments are available commercially. Interfacing the instruments with an ion mobility mass spectrometer would allow detection of individual compounds (~\$30K).
H	Direct Sampling Ion Trap Mass Spectrometry (DSITMS) CHAR-90-OL Ranking:* H-5-2 (\$0.2M;\$50/sample)	Predemonstration, method development needed. TTP Match	Methods need to be developed for specific applications. Available at X-10.	Hardware cost: \$100K; personnel are needed for development, training, and implementation costs, \$200K.
H	Gas Chromatography in the Field CHAR-262-OL Ranking:* H-4-0 (\$0.25M;\$50/sample)	Accepted. Using flame ionization, electron capture, thermal conductivity, photoionization, flame photometric, or thermionic detectors with gas chromatography can determine a variety of environmentally important analytes. TTP Match	Technology needs are minimal. While improvements can be made, in general, the technology is ready to use. Available at all sites.	A variety of gas chromatography equipment exists already at ORNL and may be useful for many needs. Various groups at ORNL have large sample handling capabilities.

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Characterization for W

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Solid Wastes - Contaminated concrete rubble and gravel (MTC 5210) - Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) - Discarded asbestos and transit (MTC 5290) - Contaminated fiberglass insulation (MTC 5220) - Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) - Scrap nonferrous metals (MTC 5190) - Combustible debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) - Compactable debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (MTC 5400) - Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) - Discarded filters (including HEPA filters) (MTC 5410) - Spent ion exchange media (MTC 3115) - Other uncategorized heterogeneous debris (MTC 5490) - Lab packs (MTC 6100) - Irradiated and spent fuel elements and components (NA) - Sealed sources (NA) - Graphite moderator (NA) - Fissile materials (NA) - Steam plant ash (NA) Solid-Liquid Wastes (Including Sludges) - Waste processing sludges (MTC 3120) - Ignitable and reactive wastes (MTC 6390) - Corrosive wastes (MTC 1100/1200) - Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) - Toxic organic wastes (MTC 2200) - Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 8900) - Coal yard run-off sludge (NA) - Infectious medical wastes (NA) Liquid Wastes - Listed halogenated solvents (MTC 2210) - Listed nonhalogenated solvents (MTC 2220) - Process/dilute liquid low-level wastes (LLW) (MTC 1000) - Melton Valley and REDC caustic aqueous wastes (MTC 1200) - REDC acidic aqueous wastes (MTC 1100) - REDC liquid organic wastes (MTC 2900) - Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes - Volatile organic compounds (VOCs) in gases (NA) - Semi-volatile organic compounds in gases (NA) - Particulates in gases (NA) - Inorganics in gases (NA) - RAD in gases (NA) - Adsorbable RAD in gases (NA) - Nonadsorbable RAD in gases (NA) - Sulfur oxides (SO₂) in gases (NA) - Nitrogen oxides (NO₂) in gases (NA) - Entrained vapors/acids in gases (NA) - Orphan gas cylinders (MTC 6400)	Organics	Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization	Labo
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					

Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Laboratory Methods:	H Analytical Methods for Chelators and Decontamination Agents CHAR-206-OL <i>Ranking:*</i> H-4-1 (\$0.25M;\$500-1000/sample)	Demonstration , an existing method shows the technology is promising, but further development is needed. TTP Match	Adapt current methods to the specific constituents and sample matrices at the ORNL site, conduct method performance validation, and prepare an analytical protocol.	Development cost: \$250K.
	M Capillary Zone Electrophoresis CHAR-207-OL <i>Ranking:*</i> M-4-1 (\$0.25M;\$300/sample)	Demonstration , the technology is gaining widespread acceptance in biomedical applications, and appears useful for RMW applications. TTP Match	Adaptation and validation for the specific target compounds and sample matrices at the ORNL site. Available at X-10.	Hardware cost: \$30K-\$60K; development costs: \$250K.
	H On-Line Supercritical Fluid Extraction—Multidetector Gas Chromatography (SPE-GC) CHAR-115-OL <i>Ranking:*</i> H-4-1 (\$0.25M;\$300/sample)	Predemonstration , technology requires final development and demonstration. TTP Match	The technology requires optimization for the most efficient extraction and chromatography of both total petroleum hydrocarbons and PCBs in a single operation.	Capital costs: \$60K; Development cost: \$250K.
	H Gas Chromatography—Fourier Transform Infrared Spectroscopy (GC-FIR) CHAR-66-OL <i>Ranking:*</i> H-4-2 (\$0.5M;\$400/sample)	Demonstration , technology is available	Specific methods for targeted analytes and general methods for unknown identification need to be developed. Available at X-10.	Hardware cost: \$200K; Development cost: \$400K. One instrument is available at ORNL.
	H Liquid Chromatography—Mass Spectrometry (LC-MS) CHAR-89-OL <i>Ranking:*</i> H-4-1 (\$0.3M;\$500/sample)	Demonstration , not yet available on-site for service work. TTP Match	Case-by-case development and demonstration for specific applications is needed. Available at X-10, Y-12.	Hardware cost: \$200K; Development cost: \$300K.
	E Gas Chromatography—Mass Spectrometry (GC-MS) CHAR-88-OL <i>Ranking:*</i> E-5-0 (\$0M;\$2-800/sample)	Accepted , available on-site. TTP Match	Technology is applicable as is. Benefit would be derived from faster chromatography to shorten analysis time. Available at all sites.	Technology is available at ORNL.
	E Gas Chromatography CHAR-94-OL <i>Ranking:*</i> E-5-0 (\$0M;\$300/sample)	Accepted , technology available on-site. TTP Match	Technology needs are minimal. While improvements can be made, in general, the technology is ready to use.	A variety of gas chromatography equipment exists already at ORNL and may be useful for many needs.
	H Solid Phase Microextraction Method CHAR-211-OL <i>Ranking:*</i> H-4-1 (\$0.3M;\$500/sample)	Predemonstration , technology demonstrated but requires refinement for quantitative analysis.	Adapt a conventional automated sample injector and develop quantitative method. Influence of waste sample characteristics on partition coefficient and sampling efficiency must be determined.	Hardware cost: \$20K; Development cost: \$300K.

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Characterization

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Solid Wastes - Contaminated concrete rubble and gravel (MTC 5210) - Contaminated asphalt and building materials (e.g., roofing, tar, felt) (MTC 5210) - Discarded asbestos and transite (MTC 5290) - Contaminated fiberglass insulation (MTC 5220) - Scrap ferrous metals (structural and sheet steel, drums, etc.) (MTC 5110) - Scrap nonferrous metals (MTC 5190) - Combustible debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (MTC 5300) - Compactable debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (MTC 5400) - Biological wastes (e.g., carcasses and discarded bedding materials) (MTC 5350/5360) - Discarded filters (including HEPA filters) (MTC 5410) - Spent ion exchange media (MTC 3115) - Other uncategorized heterogeneous debris (MTC 5490) - Lab packs (MTC 6100) - Irradiated and spent fuel elements and components (NA) - Sealed sources (NA) - Graphite moderator (NA) - Fissile materials (NA) - Steam plant ash (NA) Solid-Liquid Wastes (Including Sludges) - Waste processing sludges (MTC 3120) - Ignitable and reactive wastes (MTC 6390) - Corrosive wastes (MTC 1100/1200) - Toxic metal wastes (including electroplating sludges and photographic wastes) (MTC 5420) - Toxic organic wastes (MTC 2200) - Other RCRA hazardous wastes (including DOT poisons and uncategorized unknown wastes) (MTC 8900) - Coal yard run-off sludge (NA) - Infectious medical wastes (NA) Liquid Wastes - Listed halogenated solvents (MTC 2210) - Listed nonhalogenated solvents (MTC 2220) - Process/dilute liquid low-level wastes (LLW) (MTC 1000) - Melton Valley and REDC caustic aqueous wastes (MTC 1200) - REDC acidic aqueous wastes (MTC 1100) - REDC liquid organic wastes (MTC 2900) - Sanitary/industrial wastewater (MTC 1900) Gaseous Wastes - Volatile organic compounds (VOCs) in gases (NA) - Semi-volatile organic compounds in gases (NA) - Particulates in gases (NA) - Inorganics in gases (NA) - RAD in gases (NA) - Adsorbable RAD in gases (NA) - Nonadsorbable RAD in gases (NA) - Sulfur oxides (SO₂) in gases (NA) - Nitrogen oxides (NO₂) in gases (NA) - Entrained vapors/acids in gases (NA) - Orphan gas cylinders (MTC 6400)	Physical Pathogens	Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified. Refer to Vol. 1, Pt.C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization Characterization
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

for Waste Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Laboratory Methods	M Particle Size Analysis CHAR-26-OL <i>Ranking:*</i> M-4-0 (\$0M;\$1000/sample)	Accepted	None, this is a mature technology. Available at all sites.	In situ devices need to be implemented for more aggressive IH-HP protection of personnel and to ensure the control (spread) of radioactive contamination.
	M Optical Microscopy CHAR-32-OL <i>Ranking:*</i> M-4-0 (\$0M;\$100-800/sample)	Accepted	A particle atlas of site-specific materials is needed to allow rapid identification. Available at all sites.	A centralized image collection system is needed to establish a site-specific database.
	Computer Tomography CHAR-41-OL <i>Ranking:*</i> M-4-0 (N;N)	Accepted Can characterize LLW for water content. TTP Match	Uncertain	Uncertain
Field Methods	Instrument Response Models for Remote Sensing CHAR-246-OL <i>Ranking:*</i> Not Ranked	Accepted Instrument response models have been used for many years to evaluate satellite sensor, control, and communication systems.	Information necessary for developing models of the instrument subsystems and measurement processes must be provided.	Instrument response models are usually represented in software that executes on a computer, so implementation needs would be those of software developed for engineering and scientific applications.
	Fiber-Optic Systems for Measuring Multiple Physical Variables CHAR-248-OL <i>Ranking:*</i> Not Ranked	Pre-demonstration Proof-of-principle of this technology can be demonstrated in devices suitable for use in underground waste storage tanks.	A range of applications can be developed using this technology.	This technology should lend itself well to economies of scale in the manufacture of rugged, replaceable devices that should require low (or no) maintenance.
Laboratory Methods	Pathogen Surveillance CHAR-215-OL <i>Ranking:*</i> Not Ranked	Accepted (pathogenic bacteriology) and demonstrated (pathogenic virology).	The pathogenicity of newly discovered bacteria associated with free-living amoeba needs delineation since such amoebae are ubiquitous and can harbor and amplify known pathogens. There is a need to develop pathogenic virology capabilities. We need equipment necessary for speciation by DNA fingerprinting and phospholipid fatty acid analysis which can further aid in identification of isolates not readily speciated by conventional methodology. Available at all sites.	Hardware cost: \$80K-\$90K; Development cost: \$250K.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

The Waste Management (WM) section of the TLD f ing the waste streams likely to result from decontaminat (RA), and current WM operations at the ORNL Site. To merate and evaluate the likely WM options and to rank essential to least-effective in managing the wastes. The "Problem" areas in this order: Waste Processing (Mixed RCRA Mixed Waste, Gaseous Waste, and Uncontamin Waste Stabilization, Waste Packaging, Handling, & Tra greater applicability to RA operations, Waste Retrieval volume containing the RA diagrams, Vol. 2, part B.

It should be noted that Waste Stabilization, as used processes for the final treatment of residual solid waste stabilize them prior to WM operations.

Rankings were limited to the waste processing t retrieval, waste minimization, waste stabilization, WPH the following reasons:

- Waste retrieval operations at ORNL are expected to options are discussed in Sects. 4 and 6.
- Waste minimization is an operating philosophy that the WM operations. It consists of a set of guidelines tion is conducted. These guidelines are given on the The guidelines exist as a set and there are no option
- The generically specified waste descriptions are not tion technologies. These waste stabilization method of the waste residues to be stabilized, the type and residues that require immobilization, and the waste mined. Resolving the final wasteform issues to mee
- Each waste type has identified acceptable packaging PH&T options will be utilized.
- The waste disposal technologies (sites) have or will listed options are likely to be utilized.

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focuses on addressing the technologies for process-
tion and decommissioning (D&D), remedial action
e objectives of the WM wiring diagrams are to enu-
these options in four broad categories ranging from
e WM wiring diagrams address the following "EM
Waste, Radiological Waste, Transuranic Waste,
ated Waste), Waste Retrieval, Waste Minimization,
nsportation, and Waste Disposal. Because of its
Technology Logic Diagrams are given in detail in the

in the ORNL Technology Logic Diagram, consists of
s and does not include pretreatment of the wastes to

technologies. The other WM subelements (waste
&T, and waste disposal) were not ranked because of

be fairly routine. The potential waste retrieval

should be recognized and practiced at every stage of
which need to be followed whenever a unit opera-
e waste minimization sheet in Vol.2 of this document.
ns that can be ranked.

sufficiently detailed to allow ranking of the stabiliza-
s could be ranked at a later date when the specifics
the concentrations of the contaminants in the
acceptance criteria (WAC) of the disposal are deter-
t the disposal site WAC will be paramount.
g, handling, and transportation (PH&T) criteria. All

have specific waste acceptance criteria. All available

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	• Contaminated concrete rubble (mixed waste contaminated) (MWTP treatability code (MTC) = 5210)	• Concrete Rubble • RAD • PCBs • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				Ch

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Waste Stabilization	Encapsulation H Ranking:* H-2-1 (\$0.5M;\$300/t ³)	See Waste stabilization		
Thermal Treatment	Thermal Desorption WPRO-106-OL H Ranking:* H-2-2 (\$1M;1/lb)	Accepted Efficacy: This technology has been used by industry to remove and recover volatiles from contaminated media (i.e., soils). The process purportedly has a >99% removal efficiency for recovering volatile organic compounds (VOCs) from soil. The application of the process to treat other contaminated media (such as concrete rubble) needs to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: Knowledge of process application, funding, and regulatory approval. Treatment costs are estimated to be \$-1 per pound of waste treated (1992 dollars).
	Plasma Arc Furnace WPRO-107-OL M Ranking:* M-2-3 (\$4M;N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive thus, it is likely to be expensive. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: The RD&D effort is estimated to require 3 years and \$3 million.
	Microwave Treatment WPRO-115-OL M Ranking:* M-2-3 (\$4M;N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: The RD&D effort is estimated to require \$3-4 million.
Chemical Treatment	Supercritical Fluid Extraction WPRO-118-OL M Ranking:* M-2-5 (\$3M;N)	Efficacy: The process has been demonstrated using carbon dioxide and propane as the extracting fluids for extracting caffeine from coffee beans and fragrances from flowers. The waste management applications of the technology require additional development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$3-5 million (1992 dollars) over a 3 to 5 year period.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Contaminated concrete rubble (mixed waste contaminated) (MTC = 5210)	• Concrete Rubble • RAD • PCBs • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)		• Asbestos • PCBs • Oils • RAD • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	M Gamma-Radiolysis WPRO-100-OL Ranking:* M-2-5 (\$2M;N)	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic byproducts.	Development Costs: The RD&D effort is estimated to require \$1.25 - 2.5 million.
	M Leaching and Stripping WPRO-213-OL Ranking:* M-2-3 (1M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99% however, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
	M Electropolishing/Osmosis/Migration DCON-20-OL Ranking:* M-2-4 (\$2M;N)	Evolving Technology Efficacy: Initial data indicate 90+% removal of uranium and technetium from concrete. The process could also be used to remove oils and organics however, this application needs additional RD&D.	Some development work is required to apply the method to treat the site wastes.	Development Costs: Normal implementation needs. Development costs are estimated to be \$400-1000K. Capital Costs: Not available. Operating Costs: Likely to be more expensive than other waste treatment methods.
Waste Stabilization	H Encapsulation Ranking:* H-2-1 (\$.5M;\$300/FT³)	Waste Stabilization		
Chemical Treatment	H Electropolishing/Osmosis/Migration DCON-20-OL Ranking:* H-2-2 (\$1M;1/b)	Evolving Technology Efficacy: Initial data indicate 90+% removal of uranium and technetium from concrete. The process could also be used to remove oils and organics however, this application needs additional RD&D.	Some development work is required to apply the method to treat the site wastes.	Development Costs: Normal implementation needs. Development costs are estimated to be \$400-1000K. Capital costs: Not available. Operating costs: Likely to be more expensive than other waste treatment methods. Capital Costs: Not available Operating Costs: Likely to be more expensive than other waste treatment methods.
	L Catalytic Destruction WPRO-109-OL Ranking:* L-2-3 (\$3M;N)	Predemonstration Catalytic destruction has been shown to be an efficient method for destroying organics in different media and matrices. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$ 0.75-1 million (1992 dollars).

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	M Supercritical Fluid Extraction WPRO-118-OL <i>Ranking:*</i> M-2-5 (\$3M;N)	Demonstration Efficacy: The process has been demonstrated using carbon dioxide and propane as the extracting fluids for extracting caffeine from coffee beans and fragrances from flowers. The waste management applications of the technology require additional development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$3-5 million (1992 dollars) over a 3 to 5 year period.
	M Solvent Extraction (General) WPRO-211/212-OL <i>Ranking:*</i> M-2-2 (\$2M;N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (i.e., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organics solutions. Centrifugal, contactor-based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal, contactor-based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, when used with other waste treatment processes, would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional RD&D. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites.	Development Costs: The RD&D effort is estimated to require \$1-2.5 million. The payback could be significant.
	M Gamma-Radiolysis WPRO-100-OL <i>Ranking:*</i> M-2-5 (\$2M;N)	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic byproducts.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Incineration WPRO-108-OL Ranking:* M-2-2 (\$1M;\$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: Knowledge of process application, funding, and regulatory approval. For example, the K-25 Site TSCA Incinerator is a 30 MMBtu/h unit that is permitted to destroy low-level radioactively contaminated mixed wastes. The unit was built at a capital cost of \$26 million (1987 dollars). Obtaining regulatory approval for the TSCA Incinerator took over 8 years. The 1992 destruction costs at the incinerator are estimated to be \$6 per pound of waste incinerated.
	M Calcination/Roasting DCON-60-OL Ranking:* M-2-1 (\$1M;\$2/lb)	Demonstration Efficacy: This is accepted industrial technology for the treatment of ores. However, its use for the removal and destruction of oils and organics from the site waste needs to be demonstrated.	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: The RD&D is estimated to require \$2.5 million. The payback could be significant.
	M Plasma Arc Furnace WPRO-107-OL Ranking:* M-3-5 (\$3M;N)	Demonstration Efficacy: This is developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive thus, it is likely to be expensive. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: The RD&D effort is estimated to require 3 years and \$3 million.
Waste stabilization	H Encapsulation Ranking:* H-2-1 (\$0.5M;\$400/t ³)	See Waste stabilization		
Thermal Treatment	H Incineration WPRO-108-OL Ranking:* H-2-1 (\$1M;\$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: Knowledge of process application, funding, and regulatory approval. For example, the K-25 Site TSCA Incinerator is a 30 MMBtu/h unit that is permitted to destroy low-level radioactively contaminated mixed wastes. The unit was built at a capital cost of \$26 million (1987 dollars). Obtaining regulatory approval for the TSCA Incinerator took over 8 years. The 1992 destruction costs at the incinerator are estimated to be \$6 per pound of waste incinerated.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Contaminated Asphalt and Building Materials (e.g., roofing, tar, felt) (Mixed Waste Contaminated) (MTC = 5210)	• Debris • RAD • PCBs • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Plasma Arc Furnace WPRO-107-OL Ranking:* M-2-3 (\$3M;N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive thus, it is likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: The RD&D effort is estimated to require 3 years and \$3 million.
	M Calcination/Roasting DCON-60-OL Ranking:* M-2-1 (\$1M;\$1/lb)	Demonstration Efficacy: This is an accepted industrial technology for the treatment of ores. However, its use for the removal and destruction of oils and organics from the site wastes needs to be demonstrated.	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: The RD&D effort is estimated to require \$2-5 million. The payback could be significant.
	M Pyrolysis WPRO-110-OL Ranking:* M-2-1 (1M;\$1/lb)	Accepted Efficacy: This is an accepted industrial process for the destruction of organics. The process has an organic destruction efficiency greater than 99%.	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated.	Knowledge of process application, funding, and regulatory approval.
	M Chem Char Process WPRO-114-OL Ranking:* M-2-7 (\$1M;N)	Predemonstration Efficacy: This is a developmental technology based on coal char gasification. The process is claimed to achieve near total destruction of the organics and produces an inert char residue that contains the non-volatile toxic metals and radionuclides. This char residue can either be vitrified to yield a glassy slag or immobilization in cement.	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$4 million.
	H Thermal Desorption WPRO-106-OL Ranking:* H-2-2 (\$1M;\$1/lb)	Accepted Efficacy: This technology has been used by industry to remove and recover volatiles from contaminated media (i.e., soils). The process is claimed to have a >99% removal efficiency for recovering volatile organic compounds (VOCs) from soil. The application of the process to treat other contaminated media needs to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Knowledge of process application, funding, and regulatory approval. Treatment costs are estimated to be \$ 1 per pound of waste treated (1992 dollars).

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Molten Glass Combustor WPRO-116-OL Ranking:* M-2-2 (\$2M;N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1-10 million. The payback could be significant.
Chemical Treatment	M Solvent Extraction WPRO-111-OL Ranking:* M-2-2 (\$1M;N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (e.g., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology when used with other waste treatment processes would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional RD&D. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1-2.5 million. The payback could be significant.
	M Supercritical Fluid Extraction WPRO-118-OL Ranking:* M-2-5 (\$3M;N)	Efficacy: The process has been demonstrated using carbon dioxide and propane as the extracting fluids for extracting caffeine from coffee beans and fragrances from flowers. The waste management applications of the technology require additional development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$3-5 million (1992 dollars) over a 3 to 5 year period.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	M Gamma-Radiolysis WPRO-100-OL Ranking:* M-2-5 (\$2M;N)	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic byproducts.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.
	M Electropolishing/Osmosis/Migration DCON-20-OL Ranking:* M-2-4 (\$2M;N)	Evolving Technology Efficacy: Initial data indicate 90+ % removal of uranium and technetium from concrete. The process could also be used to remove oils and organics however, this application needs additional RD&D	Technology Improvement: Some development work is required to apply the method to treat the site wastes. Science Development:	Development Costs: Normal implementation needs. Development costs are estimated to be \$400-1000K. Capital costs: Not available. Operating costs: Likely to be more expensive than other waste treatment methods. Capital Costs: Not available Operating Costs: Likely to be more expensive than other waste treatment methods
	M Leaching and Stripping WPRO-213-OL Ranking:* M-2-3 (\$1M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: Demonstrate the effectiveness of the technology to meet the site requirements.
Waste Stabilization	M Encapsulation Ranking:* M-2-1 (\$0.5M;\$400/m ³)	See Waste Stabilization		
Chemical Treatment	M Leaching and Stripping WPRO-213-OL Ranking:* M-2-3 (\$1M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
	M Supercritical Fluid Extraction WPRO-118-OL Ranking:* M-2-5 (\$3M;N)	Demonstration Efficacy: The process has been demonstrated using carbon dioxide and propane as the extracting fluids for extracting caffeine from coffee beans and fragrances from flowers. The waste management applications of the technology require additional development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$3-5 million (1992 dollars) over a 3 to 5 year period.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Contaminated Fiberglass Insulation (Mixed Waste Contaminated) (MTC = 5220)	• Fiberglass Insulation • RAD • PCBs • Oils • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Thermal Desorption WPRO-105-OL Ranking:* M-2-2 (\$1M;1/b)	Accepted Efficacy: This technology has been used by industry to remove and recover volatiles from contaminated media (i.e., soils). The process claimed to have a >99% removal efficiency for recovering volatile organic compounds (VOCs) from soil. The application of the process to treat other contaminated media needs to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: Knowledge of process application, funding, and regulatory approval. Treatment costs are estimated to be \$ 1 per pound of waste treated (1992 dollars).
	M Molten Glass Combustor WPRO-116-OL Ranking:* M-2-2 (\$3M;N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DRES greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1-10 million. The payback could be significant.
	M Plasma Arc Furnace WPRO-107-OL Ranking:* M-2-5 (\$3M;N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DRES), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
	M Chem Char Process WPRO-114-OL Ranking:* M-2-7 (\$3M;N)	Predemonstration Efficacy: This is a developmental technology based on coal char gasification. The process is claimed to achieve near total destruction of the organics and produces and inert char residue that contains the non-volatile toxic metals and radionuclides. This char residue can either be vitrified to yield a glassy slag or immobilized in cement.	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$4 million.
	H Microwave Treatment WPRO-115-OL Ranking:* H-2-5 (\$3M;N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: \$3-4 million

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Scrap Ferrous Metal (iron, structural and sheet steel, drums, etc.) (Mixed Waste Contaminated) (MTC = 5110)	• Steel • RAD • Organics • Inorganics • PCBs	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing	V
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EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					TI

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Waste Stabilization	M Encapsulation Ranking:* M-1-1 (\$0.5M;\$6/lb)	See Waste Stabilization		
Physical Treatment	M Sonification WPRO-121-OL Ranking:* M-1-2 (\$1M;N)	Accepted Efficacy: This is an accepted process for the removal of physically attached contaminants from metal surfaces. The process generally does not chemically react with the surface but physically dislodges the attached contaminants from the surface. The process is often quite effective for the removal of surface contaminants. TTP Match	The application of the technology to meet the site requirements needs to be demonstrated.	The RD&D effort is estimated to require \$1 million. The payback could be significant in terms of avoided waste disposal costs.
Thermal Treatment	H Smelting WPRO-111-OL Ranking:* H-1-1 (\$3M;\$2/lb)	Demonstration Efficacy: This is accepted industrial technology for the treatment and processing of metals. The technology has a DRE for organics greater than 99%. However, its use for the removal and separation of the radionuclides from the wastes requires additional RD&D. The process could be used for the removal of for example, uranium from the waste but it may not be suitable for the removal of for example, uranium. The disadvantage is that smelting may cause the surface radioactive contamination to become bulk contamination of the waste. TTP Match	Technology Improvement: The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: The RD&D effort is estimated to require \$3-5 million. The payback could be significant yielding a major waste minimization effort due to recovery and recycle of the metals.
	M Plasma Arc Furnace WPRO-107-OL Ranking:* M-1-5 (\$3M;N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
	H Thermal Desorption WPRO-106-OL Ranking:* H-1-2 (\$1M;\$1/lb)	Accepted Efficacy: This technology has been used by industry to remove and recover volatiles from contaminated media (i.e., soils). The process is claimed to have a >99% removal efficiency for recovering volatile organic compounds (VOCs) from soil. The application of the process to treat other contaminated media (such as concrete rubble) needs to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: Knowledge of process application, funding, and regulatory approval. Treatment costs are estimated to be \$-1 per pound of waste treated (1992 dollars).

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Scrap Ferrous Metal (iron, structural and sheet steel, drums, etc.) (Mixed Waste Contaminated) (MTC = 5110)	• Steel • RAD • Organics • Inorganics • PCBs	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
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EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	M Supercritical Fluid Extraction WPRO-118-OL Ranking:* M-1-5 (\$3M;N)	Demonstration Efficacy: The process has been demonstrated using carbon dioxide and propane as the extracting fluids for extracting caffeine from coffee beans and fragrances from flowers. The waste management applications of the technology require additional development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$3-5 million (1992 dollars) over a 3 to 5 year period.
	H Electrochemical Metal Removal WPRO-205-OL Ranking:* H-1-3 (\$2M;N)	Demonstration The process is effective (>95% efficiency) in treating contaminated metals. However, the process is likely to be expensive due to high energy costs. TTP Match	The application of the technology to meet the site requirements needs to be demonstrated.	The RD&D effort to implement the technology is estimated to require \$2 million (1992 dollars) and take approximately three years. However, the payback for successful implementation could be significant in terms of avoided waste disposal costs.
	Solvent Extraction WPRO-211/212-OL Ranking:* Not Ranked	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (e.g., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology when used with other waste treatment processes would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional RD&D. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites.	Development Costs: The RD&D effort is estimated to require \$1-2.5 million. The payback could be significant.
	M Leaching and Stripping WPRO-213-OL Ranking:* M-1-3 (\$1M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	Al
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Scrap Non-Ferrous Metals (Mixed Waste Contaminated) (MTC # 5190)	- Non-Ferrous Metals - RAD - PCBs - Organics - Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing	Waste Sta
EM Problems Facility Decontamination and Decommissioning (D&D)					Physical T
Remedial Action (RA)—Soils, Ground Water and Surface Water					Chemical T
Waste Management (WM)					

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Stabilization	H Encapsulation Ranking:* H-4-1 (\$0.5M;\$0.6/lb)	See Waste Stabilization		
Treatment	M Sonification WPRO-121-OL Ranking:* M-4-2 (\$1M;N)	Accepted Efficacy: This is an accepted process for the removal of physically attached contaminants from metal surfaces. The process generally does not chemically react with the surface but physically dislodges the attached contaminants from the surface. The process is often quite effective for the removal of surface contaminants. TTP Match	The application of the technology to meet the site requirements needs to be demonstrated.	The RD&D effort is estimated to require \$1 million. The payback could be significant in terms of avoided waste disposal costs.
Treatment	Supercritical Fluid Extraction WPRO-118-OL Ranking:*	Demonstration Efficacy: The process has been demonstrated using carbon dioxide and propane as the extracting fluids for extracting caffeine from coffee beans and fragrances from flowers. The waste management applications of the technology require additional development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$3-5 million (1992 dollars) over a 3 to 5 year period.
	M Leaching and Stripping WPRO-213-OL Ranking:* M-4-3 (\$1M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
	H Electrochemical Metal Removal WPRO-205-OL Ranking:* H-4-3 (\$2M;N)	Demonstration The process is effective (>95% efficiency) in treating contaminated metals. However, the process is likely to be expensive due to high energy costs. TTP Match	The application of the technology to meet the site requirements needs to be demonstrated.	The RD&D effort to implement the technology is estimated to require \$2 million (1992 dollars) and take approximately three years. However, the payback for successful implementation could be significant in terms of avoided waste disposal costs.
	M Gamma-Radiolysis WPRO-100-OL Ranking:* M-4-5 (\$2M;N)	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (~90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic byproducts.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Scrap Non-Ferrous Metals (Mixed Waste Contaminated) (MTC = 5190)	- Non-Ferrous Metals - RAD - PCBs - Organics - Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems - Facility Decontamination and Decommissioning (D&D) - Remedial Action (RA)—Soils, Ground Water and Surface Water - Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	H Mond Process WPRO-112-OL Ranking:* H-4-1 (\$1M;N) (for nickel only)	Demonstration Efficacy: This is accepted technology for the refining of nickel. However its use to separate the nickel from some of the radionuclides (e.g., technetium) needs to be demonstrated.	The application of the technology to meet the site requirements needs to be demonstrated.	The technology demonstration is estimated to require \$ 1-2 million (1992 dollars). However, the payback could be significant in terms of avoided waste disposal costs.
	M Nitrate-Ammonia-Ceramic Process WPRO-105-OL Ranking:* M-4-3 (\$4M;N) (for Al only)	Demonstration Efficacy: The feasibility of the process has been proven at the benchscale. If proven effective at the industrial scale, the process could treat and dispose of all the contaminated aluminum from D&D operations. This aluminum would be used in the process to treat the radioactively contaminated nitrate wastes in the Hanford site tanks. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$ 2-5 million. However, the payback is expected to be significant especially because the process enables the use of the scrap aluminum to simultaneously destroy the nitrate wastes at ORNL, for example. Thus, the process permits the disposal of two wastes at the site.
	L Gas Phase Treatment DCON-16-OL Ranking:* L-4-3 (\$2M;N)	Predemonstration Efficacy: Laboratory scale studies have shown that this process can effectively remove uranium deposits at room temperature. The process should also be effective in removing other radionuclides such as technetium. However, additional RD&D is needed to demonstrate the full capabilities of the process.	Knowledge of process application, funding, and regulatory approvals. Development and demonstration of the optimum process conditions and unit operations for the removal of radioactive contaminants from the wastes and the recycle of the reactant (ClF3).	The RD&D effort is estimated to require \$ 5 million. The payback could be significant.
Thermal Treatment	L Incineration WPRO-108-OL Ranking:* L-4-1 (\$1M;\$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over 8 years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	H Smelting WPRO-111-OL Ranking:* H-4-1 (\$3M;\$2/lb))	Demonstration Efficacy: This is accepted industrial technology for the treatment and processing of metals. The technology has a DRE for organics greater than 99%. However, its use for the removal and separation of the radionuclides from the wastes requires additional RD&D. The process could be used for the removal of for example, uranium from the waste but it may not be suitable for the removal of or example, uranium. The disadvantage is that smelting may cause the surface radioactive contamination to become bulk contamination of the waste. TTP Match	Technology Improvement: The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: The RD&D effort is estimated to require \$3-5 million. The payback could be significant yielding a major waste minimization effort due to recovery and recycle of the metals.
	H Thermal Desorption WPRO-106-OL Ranking:* H-4-2 (\$1M;\$1/lb)	Accepted Efficacy: This technology has been used by industry to remove and recover volatiles from contaminated media (i.e., soils). The process is claimed to have a >99% removal efficiency for recovering volatile organic compounds (VOCs) from soil. The application of the process to treat other contaminated media (such as concrete rubble) needs to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: Knowledge of process application, funding, and regulatory approval. Treatment costs are estimated to be \$1 per pound of waste treated (1992 dollars).
Waste Stabilization	L Encapsulation Ranking:* L-3-1 (\$0.5M;\$300/ft ³)	See Waste Stabilization		
Chemical Treatment	M Supercritical Fluid Extraction WPRO-118-OL Ranking:* M-3-5 (\$3M;N)	Demonstration Efficacy: The process has been demonstrated using carbon dioxide and propane as the extracting fluids for extracting caffeine from coffee beans and fragrances from flowers. The waste management applications of the technology require additional development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$3-5 million (1992 dollars) over a 3 to 5 year period.
	M Leaching and Stripping WPRO-213-OL Ranking:* M-3-3 (\$1M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Combustible Debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (Mixed Waste Contaminated) (MTC # 5300)	• Combustible Debris • RAD • PCBs • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	M Gamma-Radiolysis WPRO-100-OL <i>Ranking:*</i> M-3-5 (\$2M;N)	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic byproducts.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.
	H Incineration WPRO-108-OL <i>Ranking:*</i> H-3-1 (\$1M;\$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: Knowledge of process application, funding, and regulatory approval. For example, the K-25 site TSCA incinerator is a 30-MMBtu/hr unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
Thermal Treatment	M Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> M-3-3 (\$2M;N)	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort
	M Chem Char Process WPRO-114-OL <i>Ranking:*</i> M-3-7 (\$1M;N)	Predemonstration Efficacy: This is a developmental technology based on coal char gasification. The process is claimed to achieve near total destruction of the organics and produces and inert char residue that contains the non-volatile toxic metals and radionuclides. This char residue can either be vitrified to yield a glassy slag or immobilized in cement.	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$4 million.

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship .	Combustible Debris [e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter] (Mixed Waste Contaminated) (MTC = 5300)	• Combustible Debris • RAD • PCBs • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
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EM Problems				
• Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	Microwave Treatment WPRO-115-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment Available at K-25.	Development Costs: \$3-4 million
	M Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> <i>M-3-2 (\$2M;N)</i>	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application; funding, and regulatory approval
	M Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> <i>M-3-5 (\$3M;N)</i>	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
Biological Treatment	L Biosorption WPRO-226-OL <i>Ranking:*</i> <i>L-3-5 (\$2M;N)</i>	Predemonstration Efficacy: Data in the scientific literature suggests that given the right conditions, this process should be able to achieve impressive (>95%) treatment efficiencies; however, most of the information is based on laboratory-scale data. There is little pilot plant or industrial scale data on the process. TTP Match	Further research, development, and demonstration (RD&D) is required on the process to develop the technology to deployment.	Development Costs: \$2 million
	Aerobic Digestion WPRO-224-OL <i>Ranking:*</i> <i>Not Ranked</i>	Predemonstration Efficacy: This is a promising technology for destroying hazardous organics. Under the right conditions, this process should be able to achieve >99% destruction of the organics. Additional RD&D is needed to determine the applicability of the process to meet the site requirements. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$1-2 million to meet site-specific needs

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Combustible Debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (Mixed Waste Contaminated) (MTC = 5300)	• Combustible Debris • RAD • PCBs • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)	Compactible Debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (Mixed Waste Contaminated) (MTC = 5400)	• Compactible Debris • RAD • PCBs • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Biological Treatment	L Anaerobic Digestion WPRO-225-OL Ranking:* L-3-1 (\$0.5M;N)	Predemonstration Efficacy: This is a promising technology for destroying hazardous organics. Under the right conditions, this process should be able to achieve >99% destruction of the organics. Additional RD&D is needed to determine the applicability of the process to meet the site requirements. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$1.5-2 million to meet site-specific needs
Waste stabilization	H Encapsulation Ranking:* H-3-1 (\$0.5M;\$300K/r³)	See Waste Stabilization		
Chemical Treatment	M Supercritical Fluid Extraction WPRO-118-OL Ranking:* M-3-5 (\$3M;N)	Demonstration Efficacy: The process has been demonstrated using carbon dioxide and propane as the extracting fluids for extracting caffeine from coffee beans and fragrances from flowers. The waste management applications of the technology require additional development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$3-5 million (1992 dollars) over a 3 to 5 year period.
	M Leaching and Stripping WPRO-213-OL Ranking:* M-3-3 (\$2M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
	M Gamma-Radiolysis WPRO-100-OL Ranking:* M-3-5 (\$2M;N)	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic byproducts.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Compactible Debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (Mixed Waste Contaminated) (MTC = 5400)	• Compactible Debris • RAD • PCBs • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing	Thermal
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Treatment	M Molten Glass Combustor WPRO-116-OL Ranking:* M-3-2 (\$2M;N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	L Incineration WPRO-108-OL Ranking:* L-3-1 (\$3M;\$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
	H Plasma Arc Furnace WPRO-107-OL Ranking:* H-3-5 (\$3M;N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
	M Microwave Treatment WPRO-115-OL Ranking:* M-3-5 (\$3M;N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development.	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: \$3-4 million

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Discarded Filters (incl. HEPA filters) (Mixed Waste Contaminated) (MTC = 5410)	• Discarded Filters • RAD • PCBs • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Waste Stabilization	H Encapsulation Ranking:* H-3-1 (\$0.5M;\$300K/yr³)	See Waste Stabilization		
Chemical Treatment	M Leaching and Stripping WPRO-213-OL Ranking:* M-3-3 (\$1M;N) L Supercritical Fluid Extraction WPRO-118-OL Ranking:* L-3-5 (\$3M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match Demonstration Efficacy: The process has been demonstrated using carbon dioxide and propane as the extracting fluids for extracting caffeine from coffee beans and fragrances from flowers. The waste management applications of the technology require additional development. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: Demonstrate the effectiveness of the technology to meet the site requirements. The RD&D effort is estimated to require \$3-5 million (192 dollars) over a 3 to 5 year period.
Thermal Treatment	M Incineration WPRO-108-OL Ranking:* M-3-2 (\$1M;\$6/lb) Molten Salt Oxidation WPRO-113-OL Ranking:* Not Ranked M Microwave Treatment WPRO-115-OL Ranking:* M-3-5 (\$3M;N)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.99% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. TTP Match Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability. Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10. Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Knowledge of process application, funding, and regulatory approval. For example, the K-25 site TSCA Incinerator is a 30-MMBtu/hr unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars) Development Costs: \$2 million for a three-year development effort Development Costs: \$3-4 million

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Discarded Filters (incl. HEPA filters) (Mixed Waste Contaminated) (MTC = 5410)	• Discarded Filters • RAD • PCBs • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards; DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing	Ther
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					Biolog

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Molten Glass Combustor WPRO-116-OL Ranking:* M-3-2 (\$2M;N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	M Plasma Arc Furnace WPRO-107-OL Ranking:* M-3-1 (\$1M;N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years.
	L Chem Char Process WPRO-114-OL Ranking:* L-3-7 (\$1M;N)	Predemonstration Efficacy: This is a developmental technology based on coal char gasification. The process is claimed to achieve near total destruction of the organics and produces and inert char residue that contains the non-volatile toxic metals and radionuclides. This char residue can either be vitrified to yield a glassy slag or immobilized in cement.	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$4 million.
Biological Treatment	M Biosorption WPRO-226-OL Ranking:* M-3-1 (\$M;N)	Predemonstration Efficacy: Data in the scientific literature suggest that, given the right conditions, this process should be able to achieve impressive (>95%) treatment efficiencies. However, most of the information is based on laboratory-scale data. There is little pilot-plant or industrial-scale data on the process. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$2 million
	Microbial Dechlorination WPRO-227-OL Ranking:* Not Ranked	Predemonstration Efficacy: This process is at an early stage of development. Based on the available information, it appears the process should be able to achieve destruction efficiencies greater than 90%. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$5-10 million. The payback could be significant.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Waste stabilization	M Encapsulation Ranking:* M-1-1 (\$0.5M;\$300K/yr³)	See Waste Stabilization		
Chemical Treatment	M Leaching and Stripping WPRO-213-OL Ranking:* M-1-3 (\$1M;N) L Supercritical Water Oxidation WPRO-216-OL Ranking:* L-1-3 (\$2M;N) L Supercritical Fluid Extraction WPRO-118-OL Ranking:* L-1-5 (\$3M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match Demonstration TTP Match Efficacy: The process has been demonstrated using carbon dioxide and propane as the extracting fluids for extracting caffeine from coffee beans and fragrances from flowers. The waste management applications of the technology require additional development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Significant development is needed to solve the problems of corrosion, plugging, and caking of the reactors. Overall experience is also needed on the specific problems that may be associated with the processing of particular types of wastes. This information could be used to develop a technology database to support the applicability and relative merits of this promising technology. Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements. Development Costs: The RD&D effort is estimated to require \$2 million for a 3 year development plan. The RD&D effort is estimated to require \$ 3-5 million (1992 dollars) over a 3 to 5 year period.
Thermal Treatment	M Incineration WPRO-108-OL Ranking:* M-1-2 (\$1M;\$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DRES greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. For example, the K-25 Site TSCA Incinerator is a 30 MMBtu/h unit that is permitted to destroy low-level radioactively contaminated wastes. The unit was built at a capital cost of \$26 million (1987 dollars). Obtaining regulatory approval for the TSCA incinerator took over 8 years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Spent Ion Exchange Media (Mixed Waste Contaminated) (MTC = 3115)	- Ion Exchange Media - RAD - PCBs - Organics - Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems - Facility Decontamination and Decommissioning (D&D) - Remedial Action (RA)—Soils, Ground Water and Surface Water - Waste Management (WM)				

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	L Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> L-1-1 (\$2M;\$1/lb)	Demonstration Efficacy: This is not a new process. However, its application for treating hazardous and radioactive contaminants has not been demonstrated. One advantage of the process is that the process and equipment is transportable (as opposed to a fixed treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a > 99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: The RD&D effort is estimated to require \$2 million for a 3 year development effort.
	M Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> M-1-1 (\$1M;N)	Demonstration Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DRES greater than 99%. EPA has accepted this process as best demonstrated available technology (BDAT) for the treatment of hazardous high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	L Thermal Desorption WPRO-106-OL <i>Ranking:*</i> L-1-1 (\$1M;\$1/lb)	Accepted Efficacy: This technology has been used by industry to remove and recover volatiles from contaminated media (i.e., soils). The process is claimed to have a >99% removal efficiency for recovering volatile organic compounds (VOCs) from soil. The application of the process to treat other contaminated media (such as concrete rubble) needs to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: Knowledge of process application, funding, and regulatory approval. Treatment costs are estimated to be \$ 1 per pound of waste treated (1992 dollars).
	Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> M-1-5 (\$3M;N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DRES), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Spent Ion Exchange Media (Mixed Waste Contaminated) (MTC = 3115)	• Ion Exchange Media • RAD • PCBs • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
	Waste Processing Sludges (Mixed Waste Contaminated) (MTC = 3120)	• Sludges • RAD • PCBs • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Chem Char Process WPRO-114-OL Ranking:* M-1-5 (\$1M;N)	Predemonstration Efficacy: This is a developmental technology based on coal char gasification. The process is claimed to achieve near total destruction of the organics and produces an inert char residue that contains the non-volatile toxic metals and radionuclides. This char residue can either be vitrified to yield a glassy slag or immobilized in cement.	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$4 million.
Waste stabilization	M Encapsulation Ranking:* M-2-1 (\$0.5M;\$300K/r³)	See Waste Stabilization		
Chemical Treatment	M Solvent Extraction WPRO-211/212-OL Ranking:* M-2-3 (\$2M;N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (e.g., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology when used with other waste treatment processes would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional RD&D. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites.	Development Costs: The RD&D effort is estimated to require \$1-2.5 million. The payback could be significant.
	M Leaching and Stripping WPRO-213-OL Ranking:* M-2-3 (\$2M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
	M Supercritical Fluid Extraction WPRO-118-OL Ranking:* M-2-5 (\$3M;N)	Efficacy: The process has been demonstrated using carbon dioxide and propane as the extracting fluids for extracting caffeine from coffee beans and fragrances from flowers. The waste management applications of the technology require additional development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$3-5 million (1992 dollars) over a 3 to 5 year period.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Waste Processing Sludges (Mixed Waste Contaminated) (MTC = 3120)	• Sludges • RAD • PCBs • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Incineration WPRO-108-OL <i>Ranking:*</i> M-2-1 (\$1M,\$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.99% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. For example, the K-25 Site TSCA Incinerator is a 30 MMBtu/h unit that is permitted to destroy low-level radioactively contaminated wastes. The unit was built at a capital cost of \$26 million (1987 dollars). Obtaining regulatory approval for the TSCA Incinerator took over 8 years. The 1992 destruction costs at the incinerator are estimated to be \$6 per pound of waste incinerated.
	Chem Char Process WPRO-114-OL <i>Ranking:*</i> Not Ranked	Predemonstration Efficacy: This is a developmental technology based on coal char gasification. The process is claimed to achieve near total destruction of the organics and produces an inert char residue that contains the non-volatile toxic metals and radionuclides. This char residue can either be vitrified to yield a glassy slag or immobilized in cement.	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$4 million.
	M Thermal Desorption WPRO-106-OL <i>Ranking:*</i> M-2-2 (\$1M,\$1/lb)	Accepted Efficacy: This technology has been used by industry to remove and recover volatiles from contaminated media (i.e., soils). The process is claimed to have a >99% removal efficiency for recovering volatile organic compounds (VOCs) from soil. The application of the process to treat other contaminated media (such as concrete rubble) needs to be demonstrated. TTP Match	Technology Improvement: The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: Knowledge of process application, funding, and regulatory approval. Treatment costs are estimated to be \$1 per pound of waste treated (1992 dollars).
	M Wet Air Oxidation WPRO-215-OL <i>Ranking:*</i> M-2-2 (\$2M,N)	Demonstration Efficacy: The process is commercially available. It is capable of greater than 99% destruction of some organics. However, it may not be able to completely destroy certain refractory organics such as halogenated aromatics (e.g., PCB). Processing costs are likely to be high. TTP Match	Demonstrate the effectiveness of the technology to meet the site requirements.	Development Costs: The development effort is estimated to require approximately \$1 million.
	M Microwave Treatment WPRO-115-OL <i>Ranking:*</i> M-2-3 (\$3M,N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: The RD&D effort is estimated to require \$3-4 million.

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Waste Processing Sludges (Mixed Waste Contaminated) (MTC = 3120)	• Sludges • RAD • PCBs • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D)				
• Remedial Action (RA)—Soils, Ground Water and Surface Water	Waste Processing Solid Residuals (Mixed Waste Contaminated) (MTC = 5490)	• Solid Residuals • RAD • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
• Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Molten Glass Combustor WPRO-116-OL Ranking:* M-2-2 (\$2M;N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated available technology (BDAT) for the treatment of hazardous high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	M Plasma Arc Furnace WPRO-107-OL Ranking:* M-2-5 (\$3M;N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
Biological Treatment	M Biodegradation WPRO-117-OL Ranking:* M-2-3 (\$2M;N)	Evolving Technology Efficacy: This is a promising technology for hazardous waste treatment. The process can achieve impressive treatment efficiencies for certain organics. However, the process is slow and may not be able to completely destroy certain refractory organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1 - 10 million. The payback could be significant.
Waste stabilization	L Encapsulation Ranking:* L-3-3 (\$0.5M;\$300K/ft ³)	See Waste Stabilization		
Chemical Treatment	M Leaching and Stripping WPRO-213-OL Ranking:* M-4-1 (\$1M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
	M Supercritical Fluid Extraction WPRO-118-OL Ranking:* M-3-5 (\$3M;N)	Efficacy: The process has been demonstrated using carbon dioxide and propane as the extracting fluids for extracting caffeine from coffee beans and fragrances from flowers. The waste management applications of the technology require additional development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$ 3-5 million (192 dollars) over a 3 to 5 year period.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/schema.

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	M Solvent Extraction WPRO-211/212-OL Ranking:* M-3-3 (\$2M;N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (e.g., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology when used with other waste treatment processes would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional RD&D. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites.	Development Costs: The RD&D effort is estimated to require \$1-2.5 million. The payback could be significant.
	L Transmutation WPRO-219-OL Ranking:* L-3-10 (\$10M;N)	Conceptual Efficacy: The future of an industrial scale transmutation facility is highly dependent on the availability of a permanent high level waste repository. A "national" transmutation facility would greatly facilitate the destruction and disposal of "problem" radionuclides such as ruthenium. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: An industrial-scale national transmutation facility would need to be developed and built. The cost for such a "national" facility is estimated to be in the billion dollars range and would require several years to build.
Thermal Treatment	L Incineration WPRO-108-OL Ranking:* L-3-2 (\$1M;\$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.99% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval: For example, the K-25 Site TSCA Incinerator is a 30 MMBtu/h unit that is permitted to destroy low-level radioactively contaminated wastes. The unit was built at a capital cost of \$26 million (1987 dollars). Obtaining regulatory approval for the TSCA Incinerator took over 8 years. The 1992 destruction costs at the incinerator are estimated to be \$6 per pound of waste incinerated.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Waste Processing Solid Residuals (Mixed Waste Contaminated) (MTC = 5490)	• Solid Residuals • RAD • Organics • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Thermal Desorption WPRO-106-OL <i>Ranking:*</i> M-3-2 (\$1M;\$1/lb)	Accepted Efficacy: This technology has been used by industry to remove and recover volatiles from contaminated media (i.e., soils). The process is claimed to have a >99% removal efficiency for recovering volatile organic compounds (VOCs) from soil. The application of the process to treat other contaminated media (such as concrete rubble) needs to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: Knowledge of process application, funding, and regulatory approval. Treatment costs are estimated to be \$ 1 per pound of waste treated (1992 dollars).
	M Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> M-3-2 (\$2M;N)	Demonstration Efficacy: This is not a new process. However, its application for treating hazardous and radioactive contaminants has not been demonstrated. One advantage of the process is that the process and equipment is transportable (as opposed to a fixed treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a > 99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: The RD&D effort is estimated to require \$2 million for a 3 year development effort.
	L Wet Air Oxidation WPRO-215-OL <i>Ranking:*</i> L-3-2 (\$2M;N)	Demonstration Efficacy: The process is commercially available. It is capable of greater than 99% destruction of some organics. However, it may not be able to completely destroy certain refractory organics such as halogenated aromatics (e.g., PCB). Processing costs are likely to be high. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The development effort is estimated to require approximately \$1 million.
	L Chem Char Process WPRO-114-OL <i>Ranking:*</i> L-3-7 (\$3M;N)	Predemonstration Efficacy: This is a developmental technology based on coal char gasification. The process is claimed to achieve near total destruction of the organics and produces an inert char residue that contains the non-volatile toxic metals and radionuclides. This char residue can either be vitrified to yield a glassy slag or immobilized in cement.	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$4 million.
	M Microwave Treatment WPRO-115-OL <i>Ranking:*</i> M-3-5 (\$3M;N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: The RD&D effort is estimated to require \$3-4 million.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> <i>Not Ranked</i>	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DRES greater than 99%. EPA has accepted this process as best demonstrated available technology (BDAT) for the treatment of hazardous high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Knowledge of process application, funding, and regulatory approval.
	Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DRES), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years

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EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Contaminated Concrete Rubble <i>(RAD Contamination Only)</i>	• Concrete Rubble • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problem • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Waste Stabilization	Encapsulation Ranking:* H-3-1 (\$5M; \$300/ft ³)	See Waste Stabilization		
Thermal Treatment	Thermal Desorption WPRO-106-OL Ranking:* H-3-2 (\$1M; \$1/lb)	Accepted Efficacy: This technology has been used by industry to remove and recover volatiles from contaminated media such as soils. The process is claimed to have a >99% removal efficiency for recovering volatile organic compounds (VOCs) from soil. The application of the process to treat other contaminated media (such as concrete rubble) needs to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Knowledge of process application, funding, and regulatory approval. Treatment costs are estimated to be \$ 1 per pound of waste treated (1992 dollars).
	Plasma Arc Furnace WPRO-107-OL Ranking:* M-3-3 (\$2M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive thus, it is likely to be expensive. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: The RD&D effort is estimated to require 3 years and \$3 million.
	Microwave Treatment WPRO-115-OL Ranking:* M-3-3 (\$4M; N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: \$3-4 million.
Chemical Treatment	Gamma-Radiolysis WPRO-100-OL Ranking:* M-2-5 (\$2M; N)	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic byproducts.	Development Costs: The RD&D effort is estimated to require \$ 1.25-2.5 million.
	Leaching and Stripping WPRO-213-OL Ranking:* M-2-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99% however, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	M Electropolishing/Osmosis/Migration DCON-20-OL Ranking: M-3-4 (\$2M; N)	Evolving Technology Efficacy: Initial data indicate 90+% removal of uranium and technetium from concrete. The process could also be used to remove oils and organics however, this application needs additional RD&D.	Some development work is required to apply the method to treat the site wastes.	Development Costs: Normal implementation needs. Development costs are estimated to be \$400-1000K. Capital Costs: Not available. Operating Costs: Likely to be more expensive than other waste treatment methods.
Waste Stabilization	H Encapsulation Ranking: H-3-1 (\$.5M;\$400/r³)	See Waste Stabilization		
Chemical Treatment	M Electropolishing/Osmosis/Migration DCON-20-OL Ranking: M-3-4 (\$2M; N)	Evolving Technology Efficacy: Initial data indicate 90+% removal of uranium and technetium from concrete. The process could also be used to remove oils and organics however, this application needs additional RD&D.	Some development work is required to apply the method to treat the site wastes.	Development Costs: Normal implementation needs. Development costs are estimated to be \$400-1000K. Capital Costs: Not available. Operating Costs: Likely to be more expensive than other waste treatment methods.
	M Solvent Extraction WPRO-211/212-OL Ranking: M-3-2 (\$2M; N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (e.g., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology when used with other waste treatment processes would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional RD&D. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1-2.5 million. The payback could be significant.

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EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Scrap, Transit, Asbestos Pipe & Insulation <i>(RAD Contamination Only)</i>	• Asbestos • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws; signed and pending agreements for ORR; radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problem • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	Gamma-Radiolysis WPRO-100-OL <i>Ranking:*</i> M-2-5 (\$2M; N)	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic byproducts.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.
	Thermal Treatment			
	Incineration WPRO-108-OL <i>Ranking:*</i> M-3-2 (\$1M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. For example, the K-25 Site TSCA Incinerator is a 30 MMbtu/h unit that is permitted to destroy low-level radioactively contaminated mixed wastes. The unit was built at a capital cost of \$26 million (1987 dollars). Obtaining regulatory approval for the TSCA Incinerator took over 8 years. The 1992 destruction costs at the incinerator are estimated to be \$6 per pound of waste incinerated.
	Calcination/Roasting DCON-60-OL <i>Ranking:*</i> M-3-1 (\$1M; N)	Demonstration Efficacy: This is accepted industrial technology for the treatment of ores. However, its use for the removal and destruction of oils and organics from the site wastes needs to be demonstrated.	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: The RD&D effort is estimated to require \$2-5 million. The payback could be significant.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Plasma Arc Furnace WPRO-107-OL Ranking:* M-3-5 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive thus, it is likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: The RD&D effort is estimated to require 3 years and \$3 million.
Waste Stabilization	H Encapsulation Ranking:* H-3-1 (\$.5M; \$400/ft ³)	See Waste Stabilization.		
Thermal Treatment	H Incineration WPRO-108-OL Ranking:* H-3-1 (\$1M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability. Science Development:	Knowledge of process application, funding, and regulatory approval. For example, the K-25 Site TSCA Incinerator is a 30 MMBtu/h unit that is permitted to destroy low-level radioactively contaminated mixed wastes. The unit was built at a capital cost of \$25 million (1987 dollars). Obtaining regulatory approval for the TSCA Incinerator took over 8 years. The 1992 destruction costs at the incinerator are estimated to be \$6 per pound of waste incinerated.
	M Plasma Arc Furnace WPRO-107-OL Ranking:* M-3-3 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive thus, it is likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: The RD&D effort is estimated to require 3 years and \$3 million.
	M Molten Glass Combustor WPRO-116-OL Ranking:* M-3-2 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.

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EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Other Scrap Building Materials (e.g. gravel, asphalt, roofing, tar, felt) (RAD Contamination Only)	• Debris • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
	Contaminated Fiberglass Insulation (RAD Contamination Only)	• Fiberglass Insulation • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problem • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment M	Leaching and Stripping WPRO-213-OL Ranking:* M-3-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99% however, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
Waste Stabilization H	Encapsulation Ranking:* H-2-1 (\$.5M; \$400/ft ³)	See Waste Stabilization		
Chemical Treatment M	Leaching and Stripping WPRO-213-OL Ranking:* M-3-2 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99% however, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
Thermal Treatment M	Molten Glass Combustor WPRO-116-OL Ranking:* M-2-2 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
M	Plasma Arc Furnace WPRO-107-OL Ranking:* M-2-5 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	\$3 million over three years
H	Microwave Treatment WPRO-115-OL Ranking:* H-2-5 (\$4M; N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$3.4 million

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Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Waste Stabilization	M Encapsulation Ranking:* M-3-1 (\$0.5M; \$0.6/lb)	See Waste Stabilization		
Thermal Treatment	H Smelting WPRO-111-OL Ranking:* H-3-1 (\$3M; \$2/lb)	Demonstration Efficacy: This is accepted industrial technology for the treatment and processing of metals. The technology has a DRE for organics greater than 99%. However, its use for the removal and separation of the radionuclides from the wastes requires additional RD&D. The process could be used for the removal of for example, uranium from the waste but it may not be suitable for the removal of for example, technetium. The disadvantage is that smelting may cause the surface radioactive contamination to become bulk contamination of the waste. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: The RD&D effort is estimated to require \$3-5 million. The payback could be significant yielding a major waste minimization effort due to recovery and recycle of the metals.
	M Plasma Arc Furnace WPRO-107-OL Ranking:* M-3-5 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
Physical Treatment	M Sonification WPRO-121-OL Ranking:* M-3-2 (\$1M; N)	Efficacy: This is an accepted process for the removal of physically attached contaminants from metal surfaces. The process generally does not chemically react with the surface but physically dislodges the attached contaminants from the surface. The process is often quite effective for the removal of surface contaminants. TTP Match	The application of the technology to meet the site requirements needs to be demonstrated.	The RD&D effort is estimated to require \$1 million. The payback could be significant in terms of avoided waste disposal costs.
Chemical Treatment	H Electrochemical Metal Removal WPRO-205-OL Ranking:* H-3-3 (\$2M; N)	The process is effective (>95% efficiency) in treating contaminated metals. However, the process is likely to be expensive due to high energy costs. TTP Match	The application of the technology to meet the site requirements needs to be demonstrated.	The RD&D effort to implement the technology is estimated to require \$2 million (1992 dollars) and take approximately three years. However, the payback for successful implementation could be significant in terms of avoided waste disposal costs.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Scrap Ferrous Metals (Iron, structural and sheet steel, drums, etc.) (RAD Contamination Only)	- Steel - RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problem Facility Decontamination and Decommissioning (D&D)				
Remedial Action (RA)—Soils, Ground Water and Surface Water	Scrap Non-Ferrous Metals (RAD Contamination Only)	- Non-Ferrous Metals - RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
Waste Management (WM)				

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	Solvent Extraction WPRO-211/212-OL Ranking:* Not Ranked	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (e.g., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology when used with other waste treatment processes would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional RD&D. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1-2.5 million. The payback could be significant.
	Leaching and Stripping WPRO-213-OL Ranking:* M-1-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99% however, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
Waste Stabilization	Encapsulation Ranking:* H-3-1 (\$5M; \$6/lb)	See Waste Stabilization		
Physical Treatment	Sonification WPRO-121-OL Ranking:* M-3-2 (\$1M; N)	Efficacy: This is an accepted process for the removal of physically attached contaminants from metal surfaces. The process generally does not chemically react with the surface but physically dislodges the attached contaminants from the surface. The process is often quite effective for the removal of surface contaminants. TTP Match	The application of the technology to meet the site requirements needs to be demonstrated.	The RD&D effort is estimated to require \$1 million. The payback could be significant in terms of avoided waste disposal costs.
Chemical Treatment	Leaching and Stripping WPRO-213-OL Ranking:* M-4-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99% however, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	H Electrochemical Metal Removal WPRO-205-OL <i>Ranking:*</i> H-3-3 (\$2M; N)	The process is effective (>95% efficiency) in treating contaminated metals. However, the process is likely to be expensive due to high energy costs. TTP Match	The application of the technology to meet the site requirements needs to be demonstrated.	The RD&D effort to implement the technology is estimated to require \$2 million (1992 dollars) and take approximately three years. However, the payback for successful implementation could be significant in terms of avoided waste disposal costs.
	H Mond Process WPRO-112-OL <i>Ranking:*</i> H-3-3 (\$1M; N) (for Ni only)	Demonstration Efficacy: This is accepted technology for the refining of nickel. However its use to separate the nickel from some of the radionuclides (e.g. technetium) needs to be demonstrated.	The application of the technology to meet the site requirements needs to be demonstrated.	The technology demonstration is estimated to require \$1-2 million (1992 dollars). However, the payback could be significant in terms of avoided waste disposal costs.
	M NAC Process WPRO-105-OL <i>Ranking:*</i> M-3-3 (\$4M; N) (for Al only)	Demonstration Efficacy: The feasibility of the process has been proven at the bench-scale. If proven effective at the industrial-scale, the process could treat and dispose of all the contaminated aluminum from D&D operations. This aluminum would be used in the process to treat for example the radioactively contaminated nitrate wastes at ORNL. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$2-5 million. However, the payback is expected to be significant especially because the process enables the use of the scrap aluminum to simultaneously destroy the nitrate wastes at ORNL, for example. Thus, the process permits the disposal of two wastes at the site.
	L Gas Phase (ClF ₃) Treatment DCON-16-OL <i>Ranking:*</i> L-3-3 (\$2M; N)	Predemonstration Efficacy: Laboratory scale studies have shown that this process can effectively remove uranium deposits at room temperature. The process should also be effective in removing other radionuclides such as technetium. However, additional RD&D is needed to demonstrate the full capabilities of the process.	Knowledge of process application, funding, and regulatory approvals. Development and demonstration of the optimum process conditions and unit operations for the removal of radioactive contaminants from the wastes and the recycle of the reactant (ClF ₃).	The RD&D effort is estimated to require \$5 million. The payback could be significant.
Thermal Treatment	L Incineration WPRO-108-OL <i>Ranking:*</i> L-3-1 (\$1M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)

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EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Scrap Non-Ferrous Metals (RAD Contamination Only)	• Non-Ferrous Metals • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problem • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)	Combustible Debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (RAD Contamination Only)	• Combustible Debris • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment H	Smelting WPRO-111-OL <i>Ranking:*</i> H-4-3 (\$3M; \$2/lb)	Demonstration Efficacy: This is accepted industrial technology for the treatment and processing of metals. The technology has a DRE for organics greater than 99%. However, its use for the removal and separation of the radionuclides from the wastes requires additional RD&D. The process could be used for the removal of for example, uranium but it may not be suitable for the removal of for example, ruthenium. The disadvantage is that smelting may cause the surface radioactive contamination to become bulk contamination of the waste. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: The RD&D effort is estimated to require \$3-5 million. The payback could be significant yielding a major waste minimization effort due to recovery and recycle of the metals.
Waste Stabilization L	Encapsulation <i>Ranking:*</i> L-3-1 (\$.5M; \$300/ft ³)	See Waste Stabilization		
Chemical Treatment M	Leaching and Stripping WPRO-213-OL <i>Ranking:*</i> M-3-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
Thermal Treatment H	Incineration WPRO-108-OL <i>Ranking:*</i> H-3-1 (\$1M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
M	Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> M-3-3 (\$2M; N)	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. TTP Match	Additional RD&D is required to fully develop the process to treat mixed wastes. Available at X-10.	Development Costs: \$2 million for a three-year development effort

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	Microwave Treatment WPRO-115-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$3.4 million
	M Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> <i>M-3-5 (\$3M; N)</i>	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy-slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
	M Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> <i>M-3-2 (\$2M; N)</i>	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
Biological Treatment	L Biosorption WPRO-226-OL <i>Ranking:*</i> <i>Not Ranked L-3-5 (\$2M; N)</i>	Predemonstration Efficacy: Data in the scientific literature suggests that given the right conditions, this process should be able to achieve impressive (>95%) treatment efficiencies; however, most of the information is based on laboratory-scale data. There is little pilot plant or industrial scale data on the process. TTP Match	Further research, development, and demonstration (RD&D) is required on the process to develop the technology to deployment.	Development Costs: \$2 million
Site Stabilization	H Encapsulation <i>Ranking:*</i> <i>H-3-1 (\$.5M; \$300/FT³)</i>	See Waste Stabilization		
Chemical Treatment	M Leaching and Stripping WPRO-213-OL <i>Ranking:*</i> <i>M-3-3 (\$2M; N)</i>	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	L Incineration WPRO-108-OL Ranking:* Not Ranked L-3-1 (\$1M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Technology Improvement: Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
	M Molten Glass Combustor WPRO-116-OL Ranking:* M-3-2 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	M Plasma Arc Furnace WPRO-107-OL Ranking:* M-3-5 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	\$3 million over three years
	M Microwave Treatment WPRO-115-OL Ranking:* M-3-5 (\$4M; N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$3-4 million

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Waste Stabilization	Encapsulation Ranking:* H-3-1 (\$5M; \$300/ft ³)	See Waste Stabilization		
Chemical Treatment	Leaching and Stripping WPRO-213-OL Ranking:* M-3-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry, with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
Thermal Treatment	Incineration WPRO-108-OL Ranking:* M-3-1 (\$1M; \$6lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
	Molten Salt Oxidation WPRO-113-OL Ranking:* M-3-2 (\$3M; N)	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. TTP Match	Additional RD&D is required to fully develop the process to treat mixed wastes. Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$2 million for a three-year development effort
	Microwave Treatment WPRO-115-OL Ranking:* Not Ranked L-3-4 (\$4M; N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$3.4 million
	Molten Glass Combustor WPRO-116-OL Ranking:* M-3-2 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.

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EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Discarded Filters (including HEPA filters) (RAD Contamination Only)	• Discarded Filters • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problem • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)	Spent Ion Exchange Media (RAD Contamination Only)	• Ion Exchange Media • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> Not Ranked	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
Biological Treatment	Biosorption WPRO-226-OL <i>Ranking:*</i> M-3-1 (\$1M; N)	Predemonstration Efficacy: Data in the scientific literature suggests that given the right conditions, this process should be able to achieve impressive (>95%) treatment efficiencies; however, most of the information is based on laboratory scale data. There is little pilot plant or industrial scale data on the process. TTP Match	Further research, development, and demonstration (RD&D) is required on the process to develop the technology to deployment.	Development Costs: \$2 million
Waste Stabilization	Encapsulation <i>Ranking:*</i> M-4-1 (\$.5M;\$300/ft ³)	See Waste Stabilization		
Chemical Treatment	Leaching and Stripping WPRO-213-OL <i>Ranking:*</i> M-1-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99% however, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.

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EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Spent Ion Exchange Media (RAD Contamination Only)	• Ion Exchange Media • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing	Ther
EM Problem • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Incineration WPRO-108-OL Ranking:* M-4-1 (\$1M; \$6lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: Knowledge of process application, funding, and regulatory approval. For example, the K-25 Site TSCA Incinerator is a 30 MMBtu/h unit that is permitted to destroy low-level radioactively contaminated mixed wastes. The unit was built at a capital cost of \$26 million (1987 dollars). Obtaining regulatory approval for the TSCA Incinerator took over 8 years. The 1992 destruction costs at the incinerator are estimated to be \$6 per pound of waste incinerated.
	M Molten Salt Oxidation WPRO-113-OL Ranking:* M-4-2 (\$2M; N)	Demonstration Efficacy: This is not a new process however, its application for treating hazardous and radioactive contaminants has not been demonstrated. One advantage of the process is that the process and equipment is transportable (as opposed to a fixed treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$2 million for a 3 year development effort.
	M Molten Glass Combustor WPRO-116-OL Ranking:* M-4-2 (\$2M; N)	Demonstration Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated available technology (BDAT) for the treatment of hazardous high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	L Thermal Desorption WPRO-106-OL Ranking:* Not Ranked	Accepted Efficacy: This technology has been used by industry to remove and recover volatiles from contaminated media (i.e., soils). The process purportedly has a >99% removal efficiency for recovering volatile organic compounds (VOCs) from soil. The application of the process to treat other contaminated media (such as concrete rubble) needs to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Knowledge of process application, funding, and regulatory approval. Treatment costs are estimated to be \$1 per pound of waste treated (1992 dollars).

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EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Spent Ion Exchange Media (RAD Contamination Only)	• Ion Exchange Media • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problem • Facility Decontamination and Decommissioning (D&D)	Waste Processing Sludges (RAD Contamination Only)	• Sludges • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
• Remedial Action (RA)—Soils, Ground Water and Surface Water				
• Waste Management (WM)				

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	Plasma Arc Furnace WPRO-107-OL Ranking:* Not Ranked	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
	M Chem Char Process WPRO-114-OL Ranking:* M-1-5 (\$4M; N)	Predemonstration Efficacy: This is a developmental technology based on coal char gasification. The process is claimed to achieve near total destruction of the organics and produces an inert char residue that contains the non-volatile toxic metals and radionuclides. This char residue can either be vitrified to yield a glassy slag or immobilized in cement.	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$4 million.
Waste Stabilization	M Encapsulation Ranking:* M-2-1 (\$0.5M; \$500/ft ³)	See Waste Stabilization		
Chemical Treatment	M Solvent Extraction WPRO-211/212-OL Ranking:* M-2-3 (\$2M; N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (e.g., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology when used with other waste treatment processes would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional RD&D. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1-2.5 million. The payback could be significant.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	Leaching and Stripping WPRO-213-OL Ranking:* M-2-3 (\$2M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99% however, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
Thermal Treatment	Incineration WPRO-108-OL Ranking:* M-2-1 (\$1M; \$6lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: Knowledge of process application, funding, and regulatory approval. For example, the K-25 Site TSCA Incinerator is a 30 MMBtu/h unit that is permitted to destroy low-level radioactively contaminated mixed wastes. The unit was built at a capital cost of \$26 million (1987 dollars). Obtaining regulatory approval for the TSCA Incinerator took over 8 years. The 1992 destruction costs at the incinerator are estimated to be \$6 per pound of waste incinerated.
	Microwave Treatment WPRO-115-OL Ranking:* M-2-3 (\$3M; N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$2.5 million.
	Molten Glass Combustor WPRO-116-OL Ranking:* M-2-2 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated available technology (BDAT) for the treatment of hazardous high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Waste Processing Sludges (RAD Contamination Only)	• Sludges • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problem • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)	Waste Processing Solid Residuals (RAD Contamination Only)	• RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Plasma Arc Furnace WPRO-107-OL Ranking: M-2-5 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
Biological Treatment	Biosorption WPRO-226-OL Ranking: Not Ranked	Predemonstration Efficacy: Data in the scientific literature suggests that given the right conditions, this process should be able to achieve impressive (~95%) treatment efficiencies however, most of the information is based on laboratory scale data. There is little pilot plant or industrial scale data on the process. TTP Match	Further research, development, and demonstration (RD&D) is required on the process to develop the technology to deployment.	Development Costs: \$2 million
Waste Stabilization	L Encapsulation Ranking: L-3-3 (\$2M; \$300/ft ³)	See Waste Stabilization		
Chemical Treatment	M Leaching and Stripping WPRO-213-OL Ranking: M-3-2 (\$2M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99% however, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
	L Transmutation WPRO-219-OL Ranking: L-3-10 (\$10M; N)	Conceptual Efficacy: The future of an industrial scale transmutation facility is highly dependent on the availability of a permanent high level waste repository. A "national" transmutation facility would greatly facilitate the destruction and disposal of "problem" radionuclides such as ruthenium. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: An industrial-scale national transmutation facility would need to be developed and built. The cost for such a "national" facility is estimated to be in the billion dollars range and would require several years to build.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Incineration WPRO-108-OL <i>Ranking:*</i> M-3-2 (\$1M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: Knowledge of process application, funding, and regulatory approval. For example, the K-25 Site TSCA Incinerator is a 30 MMBtu/h unit that is permitted to destroy low-level radioactively contaminated mixed wastes. The unit was built at a capital cost of \$ 26 million (1987 dollars). Obtaining regulatory approval for the TSCA Incinerator took over 8 years. The 1992 destruction costs at the incinerator are estimated to be \$ 6 per pound of waste incinerated.
	L Microwave Treatment WPRO-115-OL <i>Ranking:*</i> L-3-5 (\$4M; N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$3-4 million.
	M Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> M-3-2 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated available technology (BDAT) for the treatment of hazardous high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> Not Ranked	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Waste Stabilization	H Encapsulation Ranking:* H-3-1 (\$5M; \$300/m³)	See Waste Stabilization		
	E Package to meet Waste Isolation Pilot Plant (WIPP) Waste Acceptance Criteria (WAC) WPRO-128-OL Ranking:* E-3-5 (\$5M; N)	Demonstration The WIPP WAC are still being debated. TTP Match	Additional studies may be needed to define the WIPP waste acceptance criteria.	Funding to develop facilities to prepare the site TRU wastes to meet the Waste Isolation Pilot Plant (WIPP) waste acceptance criteria when this criteria is established. These funding requirements cannot be estimated at this time because of uncertainty regarding the operational status of the WIPP.
Thermal Treatment	H Thermal Desorption WPRO-106-OL Ranking:* H-3-2 (\$1M; \$1/lb)	Accepted Efficacy: This technology has been used by industry to remove and recover volatiles from contaminated media such as soils. The process is claimed to have a >99% removal efficiency for recovering volatile organic compounds (VOCs) from soil. The application of the process to treat other contaminated media (such as concrete rubble) needs to be demonstrated. TTP Match	Technology Improvement: The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: Knowledge of process application, funding, and regulatory approval. Treatment costs are estimated to be \$1 per pound of waste treated (1992 dollars).
	M Plasma Arc Furnace WPRO-107-OL Ranking:* M-3-3 (\$2M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive; thus, it is likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process. Science Development::	Development Costs: The RD&D effort is estimated to require 3 years and \$3 million.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Microwave Treatment WPRO-115-OL Ranking:* M-3-3 (\$4M; N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development deployment. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: \$3-4 million
Chemical Treatment	M Gamma Radiolysis WPRO-100-OL Ranking:* M-2-5 (\$2M; N)	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic by-products.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.
	M Leaching and Stripping WPRO-213-OL Ranking:* M-3-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
	M Electropolishing/Osmosis/Migration DCON-20-OL Ranking:* M-3-4 (\$2M; N)	Evolving Technology Efficacy: Initial data indicate 90-95% removal of uranium and technetium from concrete. The process could also be used to remove oils and organics. However, this application needs additional RD&D.	Some development work is required to apply the method to treat the site wastes.	Development Costs: Normal implementation needs. Development costs are estimated to be \$400-1000K. Capital costs: Not available. Operating costs: Likely to be more expensive than other waste treatment methods.
Waste Stabilization	H Encapsulation Ranking:* H-3-1 (\$5M; \$400/ft ³)	See Waste Stabilization		
Chemical Treatment	E Package to meet WIPP WAC WPRO-128-OL Ranking:* E-3-5 (\$5M; N)	Demonstration The WIPP WAC are still being debated. TTP Match	Additional studies may be needed to define the WIPP waste acceptance criteria.	Funding to develop facilities to prepare the site TRU wastes to meet the Waste Isolation Pilot Plant (WIPP) waste acceptance criteria when this criteria is established. These funding requirements cannot be estimated at this time because of uncertainty regarding the operational status of the WIPP.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment M	Electropolishing/Osmosis/ Migration DCON-20-OL <i>Ranking:*</i> M-3-4 (\$2M; N)	Evolving Technology Efficacy: Initial data indicate 90+% removal of uranium and technetium from concrete. The process could also be used to remove oils and organics. However, this application needs additional RD&D.	Some development work is required to apply the method to treat the site wastes.	Development Costs: Normal implementation needs. Development costs are estimated to be \$400-1000K. Capital costs: Not available. Operating costs: Likely to be more expensive than other waste treatment methods.
Chemical Treatment M	Solvent Extraction WPRO-211/212-OL <i>Ranking:*</i> M-3-2 (\$2M; N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (i.e., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal, contactor-based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal, contactor-based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, when used with other waste treatment processes, would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional RD&D. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1-2.5 million. The payback could be significant.
M	Gamma Radiolysis WPRO-100-OL <i>Ranking:*</i> M-2-5 (\$2M; N)	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic by-products.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Incineration WPRO-108-OL <i>Ranking:*</i> M-3-2 (\$1M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated, mixed wastes. The unit was built at a capital cost of \$26 million (1987 dollars). Obtaining regulatory approval for the TSCA Incinerator took over eight years. The 1992 destruction costs at the incinerator are estimated to be \$6 per pound of waste incinerated.
	M Calcination/Roasting DCON-60-OL <i>Ranking:*</i> M-3-1 (\$1M; N)	Demonstration Efficacy: This is accepted industrial technology for the treatment of ores. However, its use for the removal and destruction of oils and organics from the site wastes needs to be demonstrated.	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: The RD&D effort is estimated to require \$2.5 million. The payback could be significant.
	M Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> M-3-5 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and, thus, likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: The RD&D effort is estimated to require three years and \$10 million.
Waste Stabilization	H Encapsulation <i>Ranking</i> H-3-1 (\$5; \$400/ft ³)	See Waste Stabilization		
Chemical Treatment	E Package to meet WIPP WAC WPRO-128-OL <i>Ranking</i> E-3-5 (\$5; \$N)	Demonstration The WIPP WAC are still being debated. TTP Match	Additional studies may be needed to define the WIPP waste acceptance criteria.	Funding to develop facilities to prepare the site TRU wastes to meet the Waste Isolation Pilot Plant (WIPP) waste acceptance criteria when this criteria is established. These funding requirements cannot be estimated at this time because of uncertainty regarding the operational status of the WIPP.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	H Incineration WPRO-108-OL <i>Ranking:*</i> H-3-1 (\$1M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated, mixed wastes. The unit was built at a capital cost of \$26 million (1987 dollars). Obtaining regulatory approval for the TSCA Incinerator took over eight years. The 1992 destruction costs at the incinerator are estimated to be \$6 per pound of waste incinerated.
	M Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> M-3-3 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and, thus, likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: The RD&D effort is estimated to require three years and \$3 million.
	M Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> M-3-3 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
Chemical Treatment	M Leaching and Stripping WPRO-213-OL <i>Ranking:*</i> M-3-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions.	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Contaminated Fiberglass Insulation (TRU Contamination Only)	• Fiberglass Insulation • TRU	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing W PI CR Th
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Waste Stabilization	H Encapsulation Ranking: * H-2-1 (\$5M; \$400/t)	See Waste Stabilization		
Physical Treatment	E Package to meet WIPP WAC WPRO-128-OL Ranking: * E-2-5 (\$5M; N)	Demonstration The WIPP WAC are still being debated. TTP Match	Additional studies may be needed to define the WIPP waste acceptance criteria.	Funding to develop facilities to prepare the site TRU wastes to meet the Waste Isolation Pilot Plant (WIPP) waste acceptance criteria when this criteria is established. These funding requirements cannot be estimated at this time because of uncertainty regarding the operational status of the WIPP.
Chemical Treatment	M Leaching and Stripping WPRO-213-OL Ranking: * M-2-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
Thermal Treatment	M Molten Glass Combustor WPRO-116-OL Ranking: * M-2-2 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	M Plasma Arc Furnace WPRO-107-OL Ranking: * M-2-5 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
	H Microwave Treatment WPRO-115-OL Ranking: * H-2-5 (\$4M; N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$3-4 million

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Scrap Ferrous Metals (iron, structural and sheet steel, drums, etc.) (TRU Contamination Only)	• Steel • TRU	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
↓				
EM Problems				
• Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Waste Stabilization	M Encapsulation Ranking:* M-3-1 (\$0.5M; \$0.6/lb)	See Waste Stabilization		
Physical Treatment	E Package to meet WIPP WAC WPRO-128-OL Ranking:* E-3-5 (\$5M; N)	Demonstration The WIPP WAC are still being debated TTP Match	Additional studies may be needed to define the WIPP waste acceptance criteria.	Funding to develop facilities to prepare the site TRU wastes to meet the Waste Isolation Pilot Plant (WIPP) waste acceptance criteria when this criteria is established. These funding requirements cannot be estimated at this time because of uncertainty regarding the operational status of the WIPP.
Thermal Treatment	H Smelting WPRO-111-OL Ranking:* H-3-1 (\$3M; \$2/lb)	Demonstration Efficacy: This is an accepted industrial technology for the treatment and processing of metals. The technology has a DRE for organics greater than 99%. However, its use for the removal and separation of the radionuclides from the wastes requires additional RD&D. The disadvantage is that smelting may cause the surface radioactive contamination to become bulk contamination of the waste.	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: The RD&D effort is estimated to require \$3-5 million. The payback could be significant, yielding a major waste minimization effort due to recovery and recycle of the metals.
	M Plasma Arc Furnace WPRO-107-OL Ranking:* M-3-5 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
Chemical Treatment	H Electrochemical Metal Removal WPRO-205-OL Ranking:* H-3-3 (\$2M; N)	The process is effective (>95% efficiency) in treating contaminated metals. However, the process is likely to be expensive due to high energy costs. TTP Match	The application of the technology to meet the site requirements needs to be demonstrated.	The RD&D effort to implement the technology is estimated to require \$2 million (1992 dollars) and take approximately three years. However, the payback for successful implementation could be significant in terms of avoided waste disposal costs.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	Solvent Extraction WPRO-211/212-OL Ranking:* Not Ranked	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (i.e., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal, contactor-based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal, contactor-based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, when used with other waste treatment processes, would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional RD&D. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1-2.5 million. The payback could be significant.
	M Leaching and Stripping WPRO-213-OL Ranking:* M-1-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
Waste Stabilization	H Encapsulation Ranking:* H-3-1 (\$0.5M; \$0.6M/b)	See Waste Stabilization		
Physical Treatment	E Package to meet WIPP WAC WPRO-128-OL Ranking:* E-3-5 (\$5M; N)	Demonstration The WIPP WAC are still being debated. TTP Match	Additional studies may be needed to define the WIPP waste acceptance criteria.	Funding to develop facilities to prepare the site TRU wastes to meet the Waste Isolation Pilot Plant (WIPP) waste acceptance criteria when this criteria is established. These funding requirements cannot be estimated at this time because of uncertainty regarding the operational status of the WIPP.
Chemical Treatment	M Leaching and Stripping WPRO-213-OL Ranking:* M-3-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process condition. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	H Electrochemical Metal Removal WPRO-205-OL Ranking:* H-3-3 (\$2M; N)	The process is effective (~95% efficiency) in treating contaminated metals. However, the process is likely to be expensive due to high energy costs. TTP Match	The application of the technology to meet the site requirements needs to be demonstrated.	The RD&D effort to implement the technology is estimated to require \$2 million (1992 dollars) and take approximately three years. However, the payback for successful implementation could be significant in terms of avoided waste disposal costs.
	H Mond Process WPRO-112-OL Ranking:* H-3-3 (\$1M; N) (for Ni only)	Demonstration Efficacy: This is accepted technology for the refining of nickel. However its use to separate the nickel from some of the radionuclides (e.g. technetium) needs to be demonstrated.	The application of the technology to meet the site requirements needs to be demonstrated.	The technology demonstration is estimated to require \$1-2 million (1992 dollars). However, the payback could be significant in terms of avoided waste disposal costs.
	M NAC Process WPRO-106-OL Ranking:* M-3-3 (\$4M; N) (for Al only)	Demonstration Efficacy: The feasibility of the process has been proven at the bench scale. If proven effective at the industrial scale, the process could treat and dispose of all the contaminated aluminum from D&D operations. This aluminum would be used in the process to treat the radioactively contaminated nitrate wastes ORNL and the Hanford sites, for example. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$2-5 million. However, the payback is expected to be significant especially because the process enables the use of the scrap aluminum to simultaneously destroy the nitrate wastes at ORNL, for example. Thus, the process permits the disposal of two wastes at the site.
Thermal Treatment	L Incineration WPRO-108-OL Ranking:* L-3-1 (\$1M; \$6//lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Technology Improvement: Knowledge of process application, funding, and regulatory approval. For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years.	Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
	H Smelting WPRO-111-OL Ranking:* H-3-1 (\$3M; \$2//lb)	Demonstration Efficacy: This is accepted industrial technology for the treatment and processing of metals. The technology has a DRE for organics greater than 99%. However, its use for the removal and separation of the radionuclides from the wastes requires additional RD&D. The disadvantage is that smelting may cause the surface radioactive contamination to become bulk contamination of the waste. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: The RD&D effort is estimated to require \$3-5 million. The payback could be significant, yielding a major waste minimization effort due to recovery and recycle of the metals.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Site Stabilization	L Encapsulation <i>Ranking:*</i> L-3-1 (\$5M; \$300/ft ³)	See Waste Stabilization		
Physical Treatment	E Package to meet WIPP WAC WPRO-128-OL <i>Ranking:*</i> E-3-5 (\$5M; N)	Demonstration The WIPP WAC are still being debated TTP Match	Additional studies may be needed to define the WIPP waste acceptance criteria.	Funding to develop facilities to prepare the site TRU wastes to meet the Waste Isolation Pilot Plant (WIPP) waste acceptance criteria when this criteria is established. These funding requirements cannot be estimated at this time because of uncertainty regarding the operational status of the WIPP.
Chemical Treatment	M Leaching and Stripping WPRO-213-OL <i>Ranking:*</i> M-3-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
Thermal Treatment	H Incineration WPRO-108-OL <i>Ranking:*</i> H-3-1 (\$1M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Technology Improvement: Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability. Science Development::	Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
	M Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> M-3-3 (\$2M; N)	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort
	Microwave Treatment WPRO-115-OL <i>Ranking:*</i> Not Ranked	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$3-4 million

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Combustible Debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (TRU Contamination Only)	• Combustible Debris • TRU	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)	Compactible Debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (TRU Contamination Only)	• Compactible Debris • TRU	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	M Plasma Arc Furnace WPRO-107-OL Ranking:* M-3-5 (\$3M; N) M Molten Glass Combustor WPRO-116-OL Ranking:* M-3-2 (\$2M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process. Some development work is required to apply the method to treat the site wastes.	Development Costs: \$3 million over three years Knowledge of process application, funding, and regulatory approval.
Waste Stabilization	H Encapsulation Ranking:* H-3-1 (\$5M; \$300/t³)	See Waste Stabilization		
Physical Treatment	E Package to meet WIPP WAC WPRO-128-OL Ranking:* E-3-5 (\$5M; N)	Demonstration The WIPP WAC are still being debated. TTP Match	Additional studies may be needed to define the WIPP waste acceptance criteria.	Funding to develop facilities to prepare the site TRU wastes to meet the Waste Isolation Pilot Plant (WIPP) waste acceptance criteria when this criteria is established. These funding requirements cannot be estimated at this time because of uncertainty regarding the operational status of the WIPP.
Chemical Treatment	M Leaching and Stripping WPRO-213-OL Ranking:* M-3-3 (\$2M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> M-3-2 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DRES greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	M Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> M-3-5 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
	M Microwave Treatment WPRO-115-OL <i>Ranking:*</i> M-3-5 (\$4M; N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$3-4 million
Waste Stabilization	H Encapsulation <i>Ranking:*</i> H-3-1 (\$5M; \$300/ft ³)	See Waste Stabilization		
Chemical Treatment	M Leaching and Stripping WPRO-213-OL <i>Ranking:*</i> M-3-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
Physical Treatment	E Package to meet WIPP WAC WPRO-128-OL <i>Ranking:*</i> E-3-5 (\$5M; N)	Demonstration The WIPP WAC are still being debated TTP Match	Additional studies may be needed to define the WIPP waste acceptance criteria.	Funding to develop facilities to prepare the site TRU wastes to meet the Waste Isolation Pilot Plant (WIPP) waste acceptance criteria when this criteria is established. These funding requirements cannot be estimated at this time because of uncertainty regarding the operational status of the WIPP.

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Discarded Filters (including HEPA filters) (TRU Contamination Only)	• Discarded Filters • TRU	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Incineration WPRO-108-OL <i>Ranking:*</i> M-3-1 (\$1M; \$6//lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
	L Microwave Treatment WPRO-115-OL <i>Ranking:*</i> L-3-4 (\$4M; N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$3-4 million
	M Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> M-3-2 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	M Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> M-3-1 (\$1M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	\$3 million over three years

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Waste Stabilization	M Encapsulation Ranking: M-4-1 (\$5M; \$300/m ³)	See Waste Stabilization		
Physical Treatment	E Package to meet WIPP WAC WPRO-128-OL Ranking: E-4-5 (\$5M; N)	Demonstration The WIPP WAC are still being debated TTP Match	Additional studies may be needed to define the WIPP waste acceptance criteria.	Funding to develop facilities to prepare the site TRU wastes to meet the Waste Isolation Pilot Plant (WIPP) waste acceptance criteria when this criteria is established. These funding requirements cannot be estimated at this time because of uncertainty regarding the operational status of the WIPP.
Chemical Treatment	M Leaching and Stripping WPRO-213-OL Ranking: M-4-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
	L Supercritical Water Oxidation WPRO-216-OL Ranking: L-4-3 (\$2M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Significant development is needed to solve the problems of corrosion, plugging, and caking of the reactors. Overall experience is also needed on the specific problems that may be associated with the processing of particular types of wastes. This information could be used to develop a technology database to support the applicability and relative merits of this promising technology.	The RD&D effort is estimated to require \$2 million for a three-year development plan.

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Spent Ion Exchange Media (TRU Contamination Only)	• Ion Exchange Media • TRU	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)	Waste Processing Sludges (TRU Contamination Only)	• Sludges • TRU	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Incineration WPRO-108-OL <i>Ranking:*</i> M-4-1 (\$1M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated, mixed wastes. The unit was built at a capital cost of \$26 million (1987 dollars). Obtaining regulatory approval for the TSCA Incinerator took over eight years. The 1992 destruction costs at the incinerator are estimated to be \$6 per pound of waste incinerated.
	M Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> M-4-2 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
Waste Stabilization	M Encapsulation <i>Ranking:*</i> M-2-1 (\$.5M; \$500/ft ³) (for Melton Valley Storage Tank Sludges) M-3-1 (\$.5M; \$500/ft ³) (for Process Waste Treatment Plant and Nonradiological Waste Water Treatment Plant Sludges)	See Waste Stabilization		

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	M Solvent Extraction WPRO-211/212-OL Ranking:* M-4-3 (\$2M; N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (i.e., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal, contactor-based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal, contactor-based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, when used with other waste treatment processes, would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional RD&D. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1-2.5 million. The payback could be significant.
	M Leaching and Stripping WPRO-213-OL Ranking:* M-4-3 (\$2M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
Thermal Treatment	M Incineration WPRO-108-OL Ranking:* M-4-1 (\$1M; \$6/b)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated, mixed wastes. The unit was built at a capital cost of \$26 million (1987 dollars). Obtaining regulatory approval for the TSCA Incinerator took over eight years. The 1992 destruction costs at the incinerator are estimated to be \$6 per pound of waste incinerated.
	M Microwave Treatment WPRO-115-OL Ranking:* M-4-3 (\$3M; N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$3-4 million.

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Waste Processing Sludges (TRU Contamination Only)	• Sludges • TRU	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	M Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> M-4-2 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	H Evaporation WPRO-223-OL <i>Ranking:*</i> H-4-1 (\$1M; N)	Demonstration Efficacy: This is similar to distillation and is an accepted industrial process for treating contaminated liquids. It is usually used when the solvent is of low value and can be disposed. Like distillation, the operating costs can be high for certain applications. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Knowledge of process application(s) and funding.
	M Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> M-4-5 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
Biological Treatment	L Biosorption WPRO-226-OL <i>Ranking:*</i> L-4-5 (\$2M; N)	Predemonstration Efficacy: Data in the scientific literature suggests that given the right conditions, this process should be able to achieve impressive (>95%) treatment efficiencies however, most of the information is based on laboratory-scale data. There is little pilot plant or industrial scale data on the process. TTP Match	Further research, development, and demonstration (RD&D) is required on the process to develop the technology to deployment.	Development Costs: \$2 million

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Waste Stabilization	Encapsulation Ranking:* L-3-3 (\$2M; \$300/tp)	See Waste Stabilization		
Physical Treatment	Package to meet WIPP WAC WPRO-128-OL Ranking:* E-3-5 (\$5M; N)	Demonstration The WIPP WAC are still being debated. TTP Match	Additional studies may be needed to define the WIPP waste acceptance criteria.	Funding to develop facilities to prepare the site TRU wastes to meet the Waste Isolation Pilot Plant (WIPP) waste acceptance criteria when this criteria is established. These funding requirements cannot be estimated at this time because of uncertainty regarding the operational status of the WIPP.
Chemical Treatment	Leaching and Stripping WPRO-213-OL Ranking:* M-3-2 (\$2M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
	Transmutation WPRO-219-OL Ranking:* L-3-10 (\$10M; N)	Conceptual Efficacy: The future of an industrial-scale transmutation facility is highly dependent on the availability of a permanent, high-level waste repository. A "national" transmutation facility would greatly facilitate the destruction and disposal of "problem" radionuclides such as actinides. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	An industrial-scale, national transmutation facility would need to be developed and built. The cost for such a "national" facility is estimated to be in the billions of dollars range and would require several years to build.
Thermal Treatment	Incineration WPRO-108-OL Ranking:* M-3-2 (\$1M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated, mixed wastes. The unit was built at a capital cost of \$26 million (1987 dollars). Obtaining regulatory approval for the TSCA Incinerator took over eight years. The 1992 destruction costs at the incinerator are estimated to be \$6 per pound of waste incinerated.
	Microwave Treatment WPRO-115-OL Ranking:* L-3-5 (\$4M; N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$2.5 million.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment M	Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> M-3-2 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1-10 million. The payback could be significant.
	Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> Not Ranked	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Ignitable Reactive Wastes (RCRA hazardous and/or RAD contaminated) (MTC = 6390)	• Organics • RAD • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment	M Leaching and Stripping WPRO-213-OL <i>Ranking:*</i> M-5-3 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
	M Solvent Extraction WPRO-211/212-OL <i>Ranking:*</i> M-5-3 (\$2M; N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (i.e., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor-based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor-based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, when used with other waste treatment processes, would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional RD&D. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites.	Development Costs: \$1-2.5 million (the payback could be significant)
	M Supercritical Fluid Extraction WPRO-118-OL <i>Ranking:*</i> M-5-5 (\$3M; N)	Demonstration Efficacy: The process has been demonstrated using carbon dioxide and propane as the extracting fluids for extracting caffeine from coffee beans and fragrances from flowers. The waste management applications of the technology require additional development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$3.5 million (192 dollars) over a 3 to 5 year period.
Thermal Treatment	H Incineration WPRO-108-OL <i>Ranking:*</i> H-5-1 (\$0.5M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Ignitable Reactive Wastes (RCRA hazardous and/or RAD contaminated) (MTC = 6390)	• Organics • RAD • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Thermal Treatment	H Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> H-5-3 (\$2M; N)	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	\$1.4 million for a three-year development effort
	H Catalytic Destruction WPRO-109-OL <i>Ranking:*</i> H-5-2 (\$1M; N)	Predemonstration Catalytic destruction has been shown to be an efficient method for destroying organics in different media and matrices. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$0.75-1.5 million
	M Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> M-5-5 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$10 million over three years
	M Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> M-5-2 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Physical Treatment	M Reverse Osmosis WPRO-206-OL Ranking:* M-4-2 (\$1M;N)	Demonstration Efficacy: Reverse osmosis is commercial technology for treating aqueous streams. When properly designed and operated, the technology is capable of rejecting greater than 99% of the salts. However, additional RD&D may be required to develop membranes that meet the site-specific requirements. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: \$1 million
	L Inorganic Microporous Filters WPRO-207-OL Ranking:* L-4-8 (\$4M;N)	Predemonstration Efficacy: This is a novel technology being developed for filtration applications. Some of the advantages of these filters are that they can be used in severe environments; they can be readily cleaned if they become fouled, and they can be reused indefinitely. Their separation efficiency can be >99%. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$4 million The payback is estimated to be \$20-25 million based on significantly reduced waste disposal costs.
Chemical Treatment	H Neutralization WPRO-230-OL Ranking:* H-4-1 (\$.5M;N)	Accepted This is a common industrial treatment process.	The application of the process to meet the site requirements may need to be demonstrated. Available at X-10.	These are estimated to be \$0.5 million (1992 dollars) for assessing the applicability of the process to meet the site waste management needs.
	M Chemical Precipitation WPRO-210-OL Ranking:* M-4-1 (\$.5M;N)	Demonstration Efficacy: Precipitation technologies are fairly mature. Iron co-precipitation is presently being used at the K-25 Site Central Neutralization Facility for separating radionuclides from the aqueous wastes. However, significant development may still be necessary to meet the increasingly stringent regulatory limits on the wastewater discharges. For example, precipitation using potassium ferrate has not been demonstrated and additional RD&D is required to prove its applicability and performance in treating the wastewater. TTP Match	Demonstrate the effectiveness of the technology to meet the site requirements. Available at K-25.	Development Costs: The demonstration effort is estimated to require \$1 million.
	M Ion Exchange WPRO-217/218-OL Ranking:* M-4-2 (\$1M;N)	Demonstration Efficacy: This is one of the accepted methods used in industry for treating liquids. Treatment efficiencies can be greater than 99% depending upon the application, the ion exchange media, and the solutes to be removed. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$1-2 million

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Corrosive Wastes (RCRA hazardous and/or RAD contaminated) (MTC = 1100/1200)	- Inorganics - Organics - RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems - Facility Decontamination and Decommissioning (D&D) - Remedial Action (RA)—Soils, Ground Water and Surface Water - Waste Management (WM)	Toxic metal wastes (incl. electroplating sludge) (RCRA hazardous and/or rad contaminated) (MTC = 5420)	- Sludges - Toxic Metals - RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

Management

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment	Electrochemical Metal Removal WPRO-205-OL <i>Ranking:*</i> Not Ranked	Demonstration The process is effective (>95% efficiency) in treating contaminated metals. However, the process is likely to be expensive due to high energy costs. TTP Match	The application of the technology to meet the site requirements needs to be demonstrated.	The RD&D effort to implement the technology is estimated to require \$ 2 million (1992 dollars) and take approximately three years. However, the payback for successful implementation could be significant in terms of avoided waste disposal costs.
Thermal Treatment H	Evaporation WPRO-223-OL <i>Ranking:*</i> H-4-1 (\$5M;N)	Demonstration Efficacy: This is similar to distillation and is an accepted industrial process for treating contaminated liquids. It is usually used when the solvent is of low value and can be disposed. Like distillation, the operating costs can be high for certain applications. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Knowledge of process application(s) and funding.
Physical Treatment M	Reverse Osmosis WPRO-206-OL <i>Ranking:*</i> M-3-2 (\$1M;N)	Demonstration Efficacy: Reverse osmosis is commercial technology for treating aqueous streams. When properly designed and operated, the technology is capable of rejecting greater than 99% of the salts. However, additional RD&D may be required to develop membranes that meet the site-specific requirements. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: \$1 million
L	High Gradient Magnetic Separation (HGMS) WPRO-204-OL <i>Ranking:*</i> L-3-4 (\$2M;N)	Predemonstration Efficacy: The treatment is commercially available, for example, for the removal of trace impurities from kaolin clays. Removal efficiencies for the process are greater than 99%. However, its use to treat mixed waste contaminated fluids needs additional RD&D. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$2 million
L	Inorganic Microporous Filters WPRO-207-OL <i>Ranking:*</i> L-3-8 (\$4M;N)	Predemonstration Efficacy: This is a novel technology being developed for filtration applications. Some of the advantages of these filters are that they can be used in severe environments; they can be readily cleaned if they become fouled; and they can be reused indefinitely. Their separation efficiency can be >99%. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$4 million The payback is estimated to be \$20-25 million based on significantly reduced waste disposal costs.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Toxic metal wastes (incl. electroplating sludge) (RCRA hazardous and/or rad contaminated) (MTC ≈ 5420)	• Sludges • Toxic Metals • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing	Phys
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EM Problems					
• Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					Chen

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment M	Adsorption WPRO-202/203-OL Ranking:* M-3-2 (\$1M;N)	Demonstration Efficacy: Laboratory studies indicate removal efficiencies greater than 90% for the removal of radioactive species using various adsorbing media. Further development is necessary to develop more effective adsorption media for the treatment of mixed waste contaminated liquids. Development would include, for example, scale-up studies; development of high surface area and appropriate particle size media for continuous operations; and development of appropriate media for the removal of various contaminants. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$2 million.
Chemical Treatment H	Ion Exchange WPRO-217/218-OL Ranking:* H-3-2 (\$1.5M;N)	Demonstration Efficacy: This is one of the accepted methods used in industry for treating liquids. Treatment efficiencies can be greater than 99% depending upon the application, the ion exchange media, and the solutes to be removed. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$1-2 million
	Gamma Radiolysis WPRO-100-OL Ranking:* Not Ranked	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic byproducts	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.
	Chemical Precipitation WPRO-210-OL Ranking:* H-3-2 (\$1M;N)	Demonstration Efficacy: Precipitation technologies are fairly mature. Iron co-precipitation is presently being used at the K-25 Site Central Neutralization Facility for separating radionuclides from the aqueous wastes. However, significant development is may still be necessary to meet the increasingly stringent regulatory limits on the wastewater discharges. For example, precipitation using potassium ferrate has not been demonstrated and additional RD&D is required to prove its applicability and performance in treating the wastewater. TTP Match	Demonstrate the effectiveness of the technology to meet the site requirements.	Development Costs: The demonstration effort is estimated to require \$1 million.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment	M Solvent Extraction WPRO-211/212-OL Ranking: M-3-2 (\$1M;N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (i.e., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organics solutions. Centrifugal contactor-based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor-based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, when used with other waste treatment processes, would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites.	Development Costs: \$1-2.5 million (the payback could be significant)
Thermal Treatment	H Evaporation WPRO-223-OL Ranking: H-3-1 (\$0.5M;N)	Demonstration Efficacy: This is similar to distillation and is an accepted industrial process for treating contaminated liquids. It is usually used when the solvent is of low value and can be disposed. Like distillation, the operating costs can be high for certain applications. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Knowledge of process application(s) and funding.
	L Incineration WPRO-108-OL Ranking: L-3-1 (\$.5M;\$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Thermal Treatment	L Molten Salt Oxidation WPRO-113-OL Ranking:* L-3-2 (\$2M;N)	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: \$1.4 million for a three-year development effort.
	Plasma Arc Furnace WPRO-107-OL Ranking:* L-3-5 (\$3M;N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$10 million over three years
Physical Treatment	Filtration WPRO-201-OL Ranking:* Not Ranked	Demonstration Efficacy: This is an accepted process for separating solids from fluids. The process can achieve removal efficiencies greater than 99%. The use of the process to meet the site requirements will, however, need to be demonstrated.	The use of the technology to meet the site requirements needs to be demonstrated. Available at X-10.	Demonstration Costs: Up to \$1 million
	Inorganic Microporous Filters WPRO-207-OL Ranking:* Not Ranked	Predemonstration Efficacy: This is a novel technology being developed for filtration applications. Some of the advantages of these filters are that they can be used in severe environments, they can be readily cleaned if they become fouled, and they can be reused indefinitely. Their separation efficiency can be >99%.	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$4 million The payback is estimated to be \$20-25 million based on significantly reduced waste disposal costs.

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Toxic Organic Wastes (RCRA hazardous and/or RAD contaminated) (MTC = 2200)	• Organics • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
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EM Problems				
• Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Physical Treatment	Adsorption WPRO-202/203-OL Ranking: L-4-2 (\$1M;N)	Demonstration Efficacy: Laboratory studies indicate removal efficiencies greater than 90% for the removal of radioactive species using various adsorbing media. Further development is necessary to develop more effective adsorption media for the treatment of mixed waste contaminated liquids. Development would include, for example, scale-up studies, development of high surface area and appropriate particle size media for continuous operations, and development of appropriate media for the removal of various contaminants. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$2 million.
Chemical Treatment	Solvent Extraction WPRO-211/212-OL Ranking: Not Ranked	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (i.e., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor-based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor-based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, when used with other waste treatment processes, would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional RD&D. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites.	Development Costs: \$1-2.5 million (the payback could be significant)
	Gamma Radiolysis WPRO-100-OL Ranking: L-4-5 (\$2M;N)	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic byproducts.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment	M Leaching & Stripping WPRO-213-OL Ranking:* M-4-1 (\$1M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
Thermal Treatment	H Distillation WPRO-222-OL Ranking:* H-4-2 (\$2M;N)	Demonstration Efficacy: This is an accepted industrial process for treating liquids. Depending upon the contaminant being removed, the separation efficiency can be greater than 99%. However, the use of the process to meet site requirements will need to be demonstrated. Capital and operating costs could be high. TTP Match	The use of the technology to meet site requirements needs to be demonstrated.	Knowledge of process application(s) and funding.
	E Incineration WPRO-108-OL Ranking:* E-4-1 (\$.5M;\$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.99% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
	H Molten Salt Oxidation WPRO-113-OL Ranking:* H-4-2 (\$2M;N)	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Thermal Treatment	M Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> M-4-2 (\$3M;N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match:	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	M Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> M-4-3 (\$3M;N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match:	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process. Science Development:	Development Costs: \$3 million over three years
Biological Treatment	M Aerobic Digestion WPRO-224-OL <i>Ranking:*</i> M-4-3 (\$2M;N)	Demonstration Efficacy: This is a promising technology for destroying hazardous organics. Under the right conditions, this process should be able to achieve >99% destruction of the organics. Additional RD&D is needed to determine the applicability of the process to meet the site requirements. TTP Match:	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$1-2 million to meet site-specific needs
	M Anaerobic Digestion WPRO-225-OL <i>Ranking:*</i> M-4-3 (\$2M;N)	Demonstration Efficacy: This is a promising technology for destroying hazardous organics. Under the right conditions, this process should be able to achieve >99% destruction of the organics. Additional RD&D is needed to determine the applicability of the process to meet the site requirements. TTP Match:	Technology Improvement: The use of the technology to meet the site requirements needs to be demonstrated. Science Development:	Development Costs: \$1-2 million to meet site-specific needs
Chemical Treatment	M Leaching & Stripping WPRO-213-OL <i>Ranking:*</i> M-4-1 (\$1M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match:	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment	Solvent Extraction WPRO-211/212-OL <i>Ranking:*</i> M-4-2 (\$1M;N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (i.e., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor-based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor-based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, when used with other waste treatment processes, would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites.	Development Costs: \$1-2.5 million (the payback could be significant)
	Incineration WPRO-108-OL <i>Ranking:*</i> Not Ranked	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.99% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Technology Improvement: Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$25 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
Thermal Treatment	Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> Not Ranked	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Lab Packs (MTC = 6100)	- Organics - Inorganics - RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems - Facility Decontamination and Decommissioning (D&D) - Remedial Action (RA)—Soils, Ground Water and Surface Water - Waste Management (WM)	Listed Wastes (halogenated solvents) (RCRA hazardous and/or RAD contaminated) (MTC = 2210)	- Organic Solvents - RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Thermal Treatment	Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> <i>Not Ranked</i>	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
Physical Treatment	Filtration WPRO-201-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration Efficacy: This is an accepted process for separating solids from fluids. The process can achieve removal efficiencies greater than 99%. The use of the process to meet the site requirements will, however, need to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated. Available at X-10.	Demonstration Costs: Up to \$1 million.
	L Adsorption WPRO-202/203-OL <i>Ranking:*</i> L-4-2 (\$1M;N)	Demonstration Efficacy: Laboratory studies indicate removal efficiencies greater than 90% for the removal of radioactive species using various adsorbing media. Further development is necessary to develop more effective adsorption media for the treatment of mixed waste contaminated liquids. Development would include, for example, scale-up studies, development of high-surface-area and appropriate particle-size media for continuous operations, and development of appropriate media for the removal of various contaminants. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$2 million.

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Physical Treatment	Inorganic Microporous Filters WPRO-207-OL Ranking:* Not Ranked	Predemonstration Efficacy: This is a novel technology being developed for filtration applications. Some of the advantages of these filters are that they can be used in severe environments; they can be readily cleaned if they become fouled, and they can be reused indefinitely. Their separation efficiency can be >99%. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$4 million The payback is estimated to be \$20-25 million based on significantly reduced waste disposal costs.
Chemical Treatment	Solvent Extraction WPRO-211/212-OL Ranking:* L-4-2 (\$1M;N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (i.e., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor-based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor-based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, when used with other waste treatment processes, would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional RD&D. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites.	Development Costs: \$1-2.5 million (the payback could be significant)
	Wet Air Oxidation WPRO-215-OL Ranking:* L-4-2 (\$2M;N)	Demonstration Efficacy: The process is commercially available. It is capable of greater than 99% destruction of some organics. However, it may not be able to completely destroy certain refractory organics, such as halogenated aromatics (e.g., PCBs). Processing costs are likely to be high. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: Approximately \$1 million

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment	L Gamma Radiolysis WPRO-100-OL Ranking:* L-4-5 (\$2M;N)	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic byproducts.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.
	M Supercritical Water Oxidation WPRO-216-OL Ranking:* M-4-3 (\$3M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Significant development is needed to solve the problems of corrosion, plugging, and caking of the reactors. Overall experience is also needed on the specific problems that may be associated with the processing of particular types of wastes. This information could be used to develop a technology database to support the applicability and relative merits of this promising technology.	Development Costs: The RD&D effort is estimated to require \$1.6 million for a three-year development plan.
	L Chemical Dechlorination WPRO-209-OL Ranking:* L-4-5 (\$2M;N)	Demonstration Efficacy: This process consists of chemically reacting the contaminants with appropriate reagents to alter the chemical state of the contaminants to make them easier to remove from the fluid. Treatment efficiencies should generally be greater than 95%. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.
	M Leaching & Stripping WPRO-213-OL Ranking:* M-4-2 (\$2M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment M Thermal Treatment H L	Ozonation Photolysis WPRO-214-OL Ranking: M-4-2 (\$1M;N)	Demonstration Efficacy: This process can be very useful in destroying organics (especially refractory organics) in water. DREs for the process can be greater than 90%. Even though some organics are easily destroyed by the process, they are rarely completely oxidized and may be converted to other hazardous species. To be successful, a thorough knowledge of the waste to be treated is essential. The process is comparatively expensive for the treatment of organics. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$1-2 million to meet site-specific needs
	Distillation WPRO-222-OL Ranking: H-4-1 (\$1M;N)	Demonstration Efficacy: This is an accepted industrial process for treating liquids. Depending upon the contaminant being removed, the separation efficiency can be greater than 99%. However, the use of the process to meet site requirements will need to be demonstrated. Capital and operating costs could be high. TTP Match	The use of the technology to meet site requirements needs to be demonstrated.	Knowledge of process application(s) and funding.
	Plasma Arc Furnace WPRO-107-OL Ranking: L-4-3 (\$3M;N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years.
	Molten Salt Oxidation WPRO-113-OL Ranking: L-4-2 (\$2M;N)	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Listed Wastes (halogenated solvents) (RCRA hazardous and/or RAD contaminated) (MTC = 2210)	• Organic Solvents • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)	Listed Wastes (non-halogenated solvents) (RCRA hazardous and/or RAD contaminated) (MTC = 2220)	• Organic Solvents • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Thermal Treatment	Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> <i>Not Ranked</i>	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	M Catalytic Destruction WPRO-109-OL <i>Ranking:*</i> <i>M-4-2 (\$1M;N)</i>	Predemonstration Efficacy: Catalytic destruction has been shown to be an efficient method for destroying organics in different media and matrices. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$0.75-1.5 million
Biological Treatment	L Microbial Dechlorination WPRO-227-OL <i>Ranking:*</i> <i>L-4-8 (\$4M;N)</i>	Predemonstration Efficacy: This process is at an early stage of development. Based on the available information, it appears the process should be able to achieve destruction efficiencies greater than 90%. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$5-10 million. The payback could be significant.
Physical Treatment	M Air Stripping WPRO-200-OL <i>Ranking:*</i> <i>M-4-1 (\$5M;N)</i>	Accepted Efficacy: This is an acceptable industrial process with removal efficiencies of 90%+. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: The implementation needs will be determined by the site requirements.
	L Adsorption WPRO-202/203-OL <i>Ranking:*</i> <i>L-4-2 (\$1M;N)</i>	Demonstration Efficacy: Laboratory studies indicate removal efficiencies greater than 90% for the removal of radioactive species using various adsorbing media. Further development is necessary to develop more effective adsorption media for the treatment of mixed waste contaminated liquids. Development would include, for example, scale-up studies, development of high-surface-area and appropriate particle-size media for continuous operations, and development of appropriate media for the removal of various contaminants.	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$2 million.
	Filtration WPRO-201-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration Efficacy: This is an accepted process for separating solids from fluids. The process can achieve removal efficiencies greater than 99%. The use of the process to meet the site requirements will, however, need to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated. Available at X-10.	Demonstration Costs: Up to \$1 million.

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment				
M	Solvent Extraction WPRO-211/212-OL Ranking:* M-4-2 (\$1M;N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (i.e., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor-based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor-based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, when used with other waste treatment processes, would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites.	Development Costs: \$1-2.5 million (the payback could be significant)
M	Wet Air Oxidation WPRO-215-OL Ranking:* M-4-2 (\$2M;N)	Demonstration Efficacy: The process is commercially available. It is capable of greater than 99% destruction of some organics. However, it may not be able to completely destroy certain refractory organics, such as halogenated aromatics (e.g., PCBs). Processing costs are likely to be high. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: Approximately \$1 million
M	Supercritical Water Oxidation WPRO-216-OL Ranking:* M-4-3 (\$3M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Significant development is needed to solve the problems of corrosion, plugging, and caking of the reactors. Overall experience is also needed on the specific problems that may be associated with the processing of particular types of wastes. This information could be used to develop a technology database to support the applicability and relative merits of this promising technology.	Development Costs: The RD&D effort is estimated to require \$1.6 million for a three-year development plan.

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment	Gamma Radiolysis WPRO-100-OL <i>Ranking:*</i> <i>Not Ranked</i>	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic byproducts.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.
	M Ozonation Photolysis WPRO-214-OL <i>Ranking:*</i> <i>M-4-2 (\$2M;N)</i>	Demonstration Efficacy: This process can be very useful in destroying organics (especially refractory organics) in water. DRES for the process can be greater than 90%. Even though some organics are easily destroyed by the process, they are rarely completely oxidized and may be converted to other hazardous species. To be successful, a thorough knowledge of the waste to be treated is essential. The process is comparatively expensive for the treatment of organics. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$1-2 million to meet site-specific needs
Thermal Treatment	E Incineration WPRO-108-OL <i>Ranking:*</i> <i>E-4-1 (\$5M;\$6/lb)</i>	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DRES greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Technology Improvement: Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: Knowledge of process application, funding, and regulatory approval. For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars). Operating Costs: \$6 per pound of waste incinerated (1992 dollars)

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Thermal Treatment	H Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> H-4-3 (\$2M;N)	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort
	H Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> H-4-2 (\$2M;N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	H Catalytic Destruction WPRO-109-OL <i>Ranking:*</i> H-4-2 (\$1M;N)	Predemonstration Catalytic destruction has been shown to be an efficient method for destroying organics in different media and matrices. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$0.75-1.5 million
	H Distillation WPRO-222-OL <i>Ranking:*</i> H-4-1 (\$1M;N)	Demonstration Efficacy: This is an accepted industrial process for treating liquids. Depending upon the contaminant being removed, the separation efficiency can be greater than 99%. However, the use of the process to meet site requirements will need to be demonstrated. Capital and operating costs could be high. TTP Match	The use of the technology to meet site requirements needs to be demonstrated.	Knowledge of process application(s) and funding.
	M Low-Temperature Separation WPRO-220-OL <i>Ranking:*</i> M-4-2 (\$1M;N)	Predemonstration This is an accepted industrial process for the separation of low-boiling components from higher-boiling components. The process can achieve separation efficiencies greater than 99%.	Further RD&D on the use of the process to develop the optimum processing conditions for treating the appropriate site wastes.	Development Costs: \$1-2 million

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Listed Wastes (non-halogenated solvents) (RCRA hazardous and/or RAD contaminated) (MTC = 2220)	• Organic Solvents • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)	Infectious and Medical Wastes (RCRA hazardous and/or RAD contaminated) (No MTC)	• Medical Wastes • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Thermal Treatment	Chem Char Process WPRO-114-OL Ranking:* M-4-5 (\$4M;N)	Predemonstration Efficacy: This is a developmental technology based on coal char gasification. The process is claimed to achieve near total destruction of the organics and produces and inert char residue that contains the non-volatile toxic metals and radionuclides. This char residue can either be vitrified to yield a glassy slag or immobilized in cement.	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$4 million.
Biological Treatment	Aerobic Digestion WPRO-224-OL Ranking:* M-4-1 (\$1M;N) Anaerobic Digestion WPRO-225-OL Ranking:* M-4-1 (\$1M;N)	Demonstration Efficacy: This is a promising technology for destroying hazardous organics. Under the right conditions, this process should be able to achieve >99% destruction of the organics. Additional RD&D is needed to determine the applicability of the process to meet the site requirements. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$1-2 million to meet site-specific needs
Thermal Treatment	Incineration WPRO-108-OL Ranking:* H-3-1 (\$.5M;\$6/b)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
	Autoclaving WPRO-119-OL Ranking:* E-3-1 (\$.5M;N)	Accepted This is an accepted commercial process.	These are expected to be minimal and may involve demonstrations of the process to meet the site waste disposal requirements.	Development Costs: \$0.5 million
	Molten Salt Oxidation WPRO-113-OL Ranking:* M-3-3 (\$2M;N)	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Thermal Treatment	M Plasma Arc Furnace WPRO-107-OL Ranking:* M-3-3 (\$3M;N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
	M Molten Glass Combustor WPRO-116-OL Ranking:* M-3-2 (\$2M;N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	H Incineration WPRO-108-OL Ranking:* H-3-1 (\$.5M;\$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. For example, the K-25 site TSCA incinerator is a 30-MMBtu/hr unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
	M Molten Salt Oxidation WPRO-113-OL Ranking:* M-3-3 (\$2M;N)	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Thermal Treatment	M Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> M-3-3 (\$3M;N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
	M Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> M-3-2 (\$2M;N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	M Catalytic Destruction WPRO-109-OL <i>Ranking:*</i> M-3-2 (\$1M;N)	Predemonstration Catalytic destruction has been shown to be an efficient method for destroying organics in different media and matrices. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$0.75-1.5 million
Chemical Treatment	L Gamma Radiolysis WPRO-100-OL <i>Ranking:*</i> L-3-5 (\$2M;N)	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic byproducts.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.
Physical Treatment	Recharacterize and Dispose/Reuse WPRO-130-OL <i>Ranking:*</i> Not Ranked	Accepted	These are expected to be minimal and may involve demonstrations of the operation(s) to meet the site waste disposal requirements.	Development Costs: \$0.5 million

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Physical Treatment	H Shallow Land Burial in Lined Pit WPRO-132-OL Ranking:* H-2-1 (\$.2M;N)	Accepted	These are expected to be minimal and may involve assessing alternate disposal options for the wastes.	Development Costs: \$0.2 million
	M Recycle/Reuse (Sell as Roadbed Aggregate/Filler) WPRO-130-OL Ranking:* M-1-1 (\$.5M;N)	Accepted	These are expected to be minimal and may involve demonstrations of the operation(s) to meet the site waste disposal requirements.	Development Costs: \$0.5 million
Physical Treatment	M Recycle/Reuse (Reuse in Steam Boiler) WPRO-130-OL Ranking:* M-1-1 (\$.5M;N)	Demonstration	The application of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$0.5 million
	M Reverse Osmosis WPRO-206-OL Ranking:* M-5-2 (\$1M;N)	Demonstration Efficacy: Reverse osmosis is commercial technology for treating aqueous streams. When properly designed and operated, the technology is capable of rejecting greater than 99% of the salts. However, additional RD&D may be required to develop membranes that meet the site-specific requirements. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: \$0.75 million
	H Filtration WPRO-201-OL Ranking:* H-5-1 (\$1M;N)	Demonstration Efficacy: This is an accepted process for separating solids from fluids. The process can achieve removal efficiencies greater than 99%. The use of the process to meet the site requirements will, however, need to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated. Available at X-10.	Demonstration Costs: Up to \$1 million
	L Inorganic Microporous Filters WPRO-207-OL Ranking:* L-5-8 (\$4M;N)	Predemonstration Efficacy: This is a novel technology being developed for filtration applications. Some of the advantages of these filters are that they can be used in severe environments, they can be readily cleaned if they become fouled, and they can be reused indefinitely. Their separation efficiency can be >99%. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$4 million The payback is estimated to be \$20-25 million based on significantly reduced waste disposal costs.

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	• Process/Dilute Liquid Low-Level Waste (RCRA hazardous and/or RAD contaminated) (MTC = 1000)	• Aqueous Wastes • RAD • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
↓				
EM Problems				
• Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Physical Treatment	M Adsorption WPRO-202/203-OL Ranking:* M-5-3 (\$2M;N)	Predemonstration Efficacy: Laboratory studies indicate removal efficiencies greater than 90% for the removal of radioactive species using various adsorbing media. Further development is necessary to develop more effective adsorption media for the treatment of mixed waste contaminated liquids. Development would include, for example, scale-up studies; development of high surface area and appropriate particle size media for continuous operations; and development of appropriate media for the removal of various contaminants. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$2 million.
	M Electrolysis WPRO-205-OL Ranking:* M-5-4 (\$3M;N)	Demonstration Efficacy: The basic technology is well established in industry. However, its application to meet the site requirements needs to be developed and demonstrated. Removal efficiencies for the process are, in general, greater than 90%. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1.25 million.
	L High Gradient Magnetic Separation (HGMS) WPRO-204-OL Ranking:* L-5-4 (\$2M;N)	Predemonstration Efficacy: The treatment is commercially available; for example, for the removal of trace impurities from kaolin clays. Removal efficiencies for the process are greater than 99%. However, its use to treat mixed waste contaminated fluids needs additional RD&D. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$2 million
	Air Stripping WPRO-200-OL Ranking:* Not Ranked	Accepted Efficacy: This is an acceptable industrial process with removal efficiencies of 90%+. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: The implementation needs will be determined by the site requirements.
Chemical Treatment	H Ion Exchange WPRO-217/218-OL Ranking:* H-5-4 (\$2M,\$.2/gal)	Demonstration Efficacy: This is one of the accepted methods used in industry for treating liquids. Treatment efficiencies can be greater than 99% depending upon the application, the ion exchange media, and the solutes to be removed. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$1-2 million

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment	H Chemical Precipitation WPRO-210-OL Ranking:* H-5-2 (\$2M;N)	Demonstration Efficacy: Precipitation technologies are fairly mature. Iron co-precipitation is presently being used at the K-25 Site Central Neutralization Facility for separating radionuclides from the aqueous wastes. However, significant development may still be necessary to meet the increasingly stringent regulatory limits on the wastewater discharges. For example, precipitation using potassium ferrate has not been demonstrated and additional RD&D is required to prove its applicability and performance in treating the wastewater. TTP Match	Demonstrate the effectiveness of the technology to meet the site requirements. Available at K-25.	Development Costs: The demonstration effort is estimated to require \$1 million.
	M Ozonation Photolysis WPRO-214-OL Ranking:* M-5-3 (\$3M;N)	Demonstration Efficacy: This process can be very useful in destroying organics (especially refractory organics) in water. DREs for the process can be greater than 90%. Even though some organics are easily destroyed by the process, they are rarely completely oxidized and may be converted to other hazardous species. To be successful, a thorough knowledge of the waste to be treated is essential. The process is comparatively expensive for the treatment of organics. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$1-2 million to meet site-specific needs
	M Solvent Extraction WPRO-211/212-OL Ranking:* M-5-3 (\$2M;N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (i.e., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor-based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor-based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, when used with other waste treatment processes, would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites.	Development Costs: \$1-2.5 million (the payback could be significant)

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment	M Electrochemical Metal Removal WPRO-205-OL Ranking:* M-5-3 (\$2M;N)	Demonstration The process is effective (>95% efficiency) in treating contaminated metals. However, the process is likely to be expensive due to high energy costs. TTP Match	The application of the technology to meet the site requirements needs to be demonstrated.	The RD&D effort to implement the technology is estimated to require \$2 million (1992 dollars) and take approximately three years. However, the payback for successful implementation could be significant in terms of avoided waste disposal costs.
	M Chemical Reduction WPRO-209-OL Ranking:* M-5-2 (\$2M;N)	Demonstration Efficacy: This process consists of chemically reacting the contaminants with appropriate reagents to alter the chemical state of the contaminants to make them easier to remove from the fluid. Treatment efficiencies should generally be greater than 95%. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.
Thermal Treatment	H Evaporation WPRO-223-OL Ranking:* H-5-1 (\$5M;N)	Demonstration Efficacy: This is similar to distillation and is an accepted industrial process for treating contaminated liquids. It is usually used when the solvent is of low value and can be disposed. Like distillation, the operating costs can be high for certain applications. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Knowledge of process application(s) and funding.
	Distillation WPRO-222-OL Ranking:* Not Ranked	Demonstration Efficacy: This is an accepted industrial process for treating liquids. Depending upon the contaminant being removed, the separation efficiency can be greater than 99%. However, the use of the process to meet site requirements will need to be demonstrated. Capital and operating costs could be high. TTP Match	The use of the technology to meet site requirements needs to be demonstrated.	Knowledge of process application(s) and funding.
Biological Treatment	L Biosorption WPRO-226-OL Ranking:* L-5-5 (\$2M;N)	Predemonstration Efficacy: Data in the scientific literature suggest that, given the right conditions, this process should be able to achieve impressive (>95%) treatment efficiencies. However, most of the information is based on laboratory scale data. There is little pilot-plant or industrial-scale data on the process. TTP Match	Further research, development, and demonstration (RD&D) is required on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$2 million.

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Melton Valley and REDC Caustic Aqueous Wastes and REDC Acidic Aqueous Wastes (RCRA hazardous and/or RAD contaminated) (MTC = 1100/1200)	• Aqueous Wastes • RAD • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Physical Treatment	L Reverse Osmosis WPRO-206-OL <i>Ranking:*</i> L-5-2 (\$1M;N) (for MTC=1200) L-4-2 (\$1M;N) (for MTC=1100)	Demonstration Efficacy: Reverse osmosis is commercial technology for treating aqueous streams. When properly designed and operated, the technology is capable of rejecting greater than 99% of the salts. However, additional RD&D may be required to develop membranes that meet the site-specific requirements. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: \$1 million
	L Filtration WPRO-201-OL <i>Ranking:*</i> L-5-1 (\$1M;N) (for MTC=1200) L-4-1 (\$1M;N) (for MTC=1100)	Demonstration Efficacy: This is an accepted process for separating solids from fluids. The process can achieve removal efficiencies greater than 99%. The use of the process to meet the site requirements will, however, need to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated. Available at X-10.	Demonstration Costs: Up to \$1 million.
	L Inorganic Microporous Filters WPRO-207-OL <i>Ranking:*</i> L-5-8 (\$4M;N) (for MTC=1200) L-4-8 (\$4M;N) (for MTC=1100)	Predemonstration Efficacy: This is a novel technology being developed for filtration applications. Some of the advantages of these filters are that they can be used in severe environments, they can be readily cleaned if they become fouled, and they can be reused indefinitely. Their separation efficiency can be >99%. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$4 million The payback is estimated to be \$20-25 million based on significantly reduced waste disposal costs.
	M Electrolysis WPRO-205-OL <i>Ranking:*</i> M-5-4 (\$3M;N) (for MTC=1200) M-4-4 (\$3M;N) (for MTC=1100)	Demonstration Efficacy: The basic technology is well established in industry. However, its application to meet the site requirements needs to be developed and demonstrated. Removal efficiencies for the process are, in general, greater than 90%. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1.25 million.
	Air Stripping WPRO-200-OL <i>Ranking:*</i> Not Ranked	Accepted Efficacy: This is an acceptable industrial process with removal efficiencies of 90%+. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: The implementation needs will be determined by the site requirements.
Chemical Treatment	M Ion Exchange WPRO-217/218-OL <i>Ranking:*</i> M-5-2 (\$2M;\$.2/gal) (for MTC=1200) M-4-2 (\$2M;\$.2/gal) (for MTC=1100)	Demonstration Efficacy: This is one of the accepted methods used in industry for treating liquids. Treatment efficiencies can be greater than 99% depending upon the application, the ion exchange media, and the solutes to be removed. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$2 million

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment	M Chemical Reduction WPRO-209-OL Ranking:* M-5-2 (\$2M;N) (for MTC=1200) M-4-2 (\$2M; N) (for MTC=1100)	Demonstration Efficacy: This process consists of chemically reducing the contaminants with appropriate reagents to alter the chemical state of the contaminants to make them easier to remove from the fluid. Treatment efficiencies should generally be greater than 95%. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.
	M Nitrate-Ammonia-Ceramic Process WPRO-106-OL Ranking:* M-5-3 (\$4M;N) (for MTC=1200) M-4-3 (\$4M;N) (for MTC=1100)	Demonstration Efficacy: The feasibility of the process has been proven at the bench scale. If proven effective at the industrial scale, the process could treat and dispose of all the contaminated aluminum from D&D operations. This aluminum would be used in the process to treat for example the radioactively contaminated nitrate wastes at ORNL. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$ 2-5 million. However, the payback is expected to be significant especially because the process enables the use of the scrap aluminum to simultaneously destroy the nitrate wastes at ORNL, for example. Thus, the process permits the disposal of two wastes at the site.
	M Bradtec Process WPRO-228-OL Ranking:* M-5-3 (\$4M;N) (for MTC=1200) M-4-3 (\$4M;N) (for MTC=1100)	Predemonstration Efficacy: This is a potential alternate treatment process for aqueous nitrate wastes. Some initial development of the process has been successfully completed at British Nuclear Fuels Limited (BNFL) facilities in England. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$ 4 million (1992 dollars) over a 3-year period.
	M Chemical Precipitation WPRO-210-OL Ranking:* M-5-3 (\$2M;N) (for MTC=1200) M-4-2 (\$4M;N) (for MTC=1100)	Demonstration Efficacy: Precipitation technologies are fairly mature. Iron co-precipitation is presently being used at the K-25 Site Central Neutralization Facility for separating radionuclides from the aqueous wastes. However, significant development may still be necessary to meet the increasingly stringent regulatory limits on the wastewater discharges. For example, precipitation using potassium ferrate has not been demonstrated and additional RD&D is required to prove its applicability and performance in treating the wastewater. TTP Match	Demonstrate the effectiveness of the technology to meet the site requirements. Available at K-25.	Development Costs: The demonstration effort is estimated to require \$1 million.

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment	M Solvent Extraction WPRO-211/212-OL <i>Ranking:*</i> M-5-3 (\$2M;N) (for MTC=1200) M-4-3 (\$2M;N) (for MTC=1100)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (i.e., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor-based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor-based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, when used with other waste treatment processes, would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites.	Development Costs: \$1-2.5 million (the payback could be significant)
	M Electrochemical Metal Removal WPRO-205-OL <i>Ranking:*</i> M-5-3 (\$2M;N) (for MTC=1200) M-4-3 (\$2M;N) (for MTC=1100)	Demonstration The process is effective (>95% efficiency) in treating contaminated metals. However, the process is likely to be expensive due to high energy costs. TTP Match	The application of the technology to meet the site requirements needs to be demonstrated.	The RD&D effort to implement the technology is estimated to require \$2 million (1992 dollars) and take approximately three years. However, the payback for successful implementation could be significant in terms of avoided waste disposal costs.
	M Ozonation Photolysis WPRO-214-OL <i>Ranking:*</i> M-5-3 (\$3M;N) (for MTC=1200) M-4-3 (\$3M;N) (for MTC=1100)	Demonstration Efficacy: This process can be very useful in destroying organics (especially refractory organics) in water. DREs for the process can be greater than 90%. Even though some organics are easily destroyed by the process, they are rarely completely oxidized and may be converted to other hazardous species. To be successful, a thorough knowledge of the waste to be treated is essential. The process is comparatively expensive for the treatment of organics. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$1-2 million to meet site-specific needs
Thermal Treatment	H Evaporation WPRO-223-OL <i>Ranking:*</i> H-5-1 (\$1M;N) (for MTC=1200) H-4-1 (\$1M;N) (for MTC=1100)	Demonstration Efficacy: This is similar to distillation and is an accepted industrial process for treating contaminated liquids. It is usually used when the solvent is of low value and can be disposed. Like distillation, the operating costs can be high for certain applications. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Knowledge of process application(s) and funding

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Melton Valley and REDC Caustic Aqueous Wastes and REDC Acidic Aqueous Wastes (RCRA hazardous and/or RAD contaminated) (MTC = 1100/1200)	• Aqueous Wastes • RAD • Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
	REDC Liquid Organic Wastes (RCRA/TSCA hazardous and/or RAD contaminated) (MTC = 2900)	• Organics • RAD • PCBs	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Thermal Treatment	Microwave Treatment WPRO-115-OL Ranking:* M-5-3 (\$4M;N) (for MTC=1200) M-4-3 (\$4M;N) (for MTC=1100)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: \$2.5 million
Biological Treatment	Biodenitrification WPRO-229-OL Ranking:* M-5-2 (\$1M;N)	Accepted The process is relatively efficient in using microorganisms to convert aqueous nitrate wastes to nitrogen gas. TTP Match	Need to design and demonstrate treatment schemes for specific ORNL aqueous nitrate waste streams. Available at Y-12.	The design and demonstration of the treatment of the site nitrate streams is estimated to cost approximately \$1 million (1992 dollars)
Physical Treatment	Filtration WPRO-201-OL Ranking:* L-4-1 (\$1M;N)	Demonstration Efficacy: This is an accepted process for separating solids from fluids. The process can achieve removal efficiencies greater than 99%. The use of the process to meet the site requirements will, however, need to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Demonstration Costs: Up to \$1 million.
	Inorganic Microporous Filters WPRO-207-OL Ranking:* L-4-8 (\$4M;N)	Predemonstration Efficacy: This is a novel technology being developed for filtration applications. Some of the advantages of these filters are that they can be used in severe environments; they can be readily cleaned if they become fouled, and they can be reused indefinitely. Their separation efficiency can be >99%. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: \$4 million. The payback is estimated to be \$20-25 million based on significantly reduced waste disposal costs.
	Adsorption WPRO-202/203-OL Ranking:* M-4-3 (\$2M;N)	Predemonstration Efficacy: Laboratory studies indicate removal efficiencies greater than 90% for the removal of radioactive species using various adsorbing media. Further development is necessary to develop more effective adsorption media for the treatment of mixed waste contaminated liquids. Development would include, for example, scale-up studies; development of high-surface-area and appropriate particle-size media for continuous operations; and development of appropriate media for the removal of various contaminants. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$2 million.
	Air Stripping WPRO-200-OL Ranking:* Not Ranked	Accepted Efficacy: This is an acceptable industrial process with removal efficiencies of 90%+. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: The implementation needs will be determined by the site requirements.

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment	M Solvent Extraction WPRO-211/212-OL Ranking: M-4-3 (\$2M;N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (i.e., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor-based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor-based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, when used with other waste treatment processes, would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites.	Development Costs: \$1-2.5 million (the payback could be significant)
	L Chemical Oxidation/Reduction WPRO-209-OL Ranking: L-4-2 (\$2M;N)	Demonstration Efficacy: This process consists of chemically reacting the contaminants with appropriate reagents to alter the chemical state of the contaminants to make them easier to remove from the fluid. Treatment efficiencies should generally be greater than 95%. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.
	M Chemical Precipitation WPRO-210-OL Ranking: M-4-2 (\$2M;N)	Demonstration Efficacy: Precipitation technologies are fairly mature. Iron co-precipitation is presently being used at the K-25 Site Central Neutralization Facility for separating radionuclides from the aqueous wastes. However, significant development may still be necessary to meet the increasingly stringent regulatory limits on the wastewater discharges. For example, precipitation using potassium ferrate has not been demonstrated and additional RD&D is required to prove its applicability and performance in treating the wastewater. TTP Match	Demonstrate the effectiveness of the technology to meet the site requirements. Available at K-25.	Development Costs: The demonstration effort is estimated to require \$1 million.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Subelements	Reference Requirements	Problem Areas/Constituents	ORNL Problems	EM Goals

Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

- Organics
- RAD
- PCBs

REDCLiquid Organic Wastes (RCRA/TSCA hazardous and/or RAD contaminated) (MTC = 2900)

- Clean Up Legacy Waste
- Prevent Future Insult
- Develop Environmental Stewardship

EM Problems

- Facility Decontamination and Decommissioning (D&D)

- Remedial Action (RA)—Soils, Ground Water and Surface Water

- Waste Management (WM)

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Thermal Treatment	M Incineration WPRO-108-OL Ranking:* M-4-1 (\$1M;\$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. FTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability. Science Development:	Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
	M Molten Salt Oxidation WPRO-113-OL Ranking:* M-4-3 (\$2M;N)	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. FTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort.
	M Molten Glass Combustor WPRO-116-OL Ranking:* M-4-2 (\$2M;N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. FTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	M Wet Air Oxidation WPRO-215-OL Ranking:* M-4-3 (\$3M;N)	Demonstration Efficacy: The process is commercially available. It is capable of greater than 99% destruction of some organics. However, it may not be able to completely destroy certain refractory organics, such as halogenated aromatics (e.g., PCBs). Processing costs are likely to be high.	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: Approximately \$1 million

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/schema.

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Physical Treatment	H Filtration WPRO-201-OL Ranking:* H-4-1 (\$1M;N)	Demonstration Efficacy: This is an accepted process for separating solids from fluids. The process can achieve removal efficiencies greater than 99%. The use of the process to meet the site requirements will, however, need to be demonstrated. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated. Available at X-10.	Demonstration Costs: Up to \$1 million.
	M Adsorption WPRO-202/203-OL Ranking:* M-4-2 (\$2M;N)	Predemonstration Efficacy: Laboratory studies indicate removal efficiencies greater than 90% for the removal of radioactive species using various adsorbing media. Further development is necessary to develop more effective adsorption media for the treatment of mixed waste contaminated liquids. Development would include, for example, scale-up studies, development of high-surface-area and appropriate particle-size media for continuous operations, and development of appropriate media for the removal of various contaminants. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$2 million.
Chemical Treatment	M Solvent Extraction WPRO-211/212-OL Ranking:* M-4-3 (\$2M;N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (i.e., centrifugal contactors) is demonstrated technology for the separation of heavy metals or organics from aqueous or organic solutions. Centrifugal contactor-based processes for the separation and recovery of radionuclides has been technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. The advantages of the centrifugal contactor-based extraction process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, when used with other waste treatment processes, would enhance the overall waste treatment strategy. However, the use of the technology for the treatment of solid wastes requires additional TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites.	Development Costs: \$1-2.5 million (the payback could be significant)

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Management

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment	M Gamma Radiolysis WPRO-100-OL Ranking: M-4-3 (\$2M;N)	Evolving Technology Efficacy: The radiolytic destruction of halogenated and aromatic compounds at the laboratory scale is well documented. However, its application on an industrial scale needs additional RD&D. The process is capable of high (>90%) destruction efficiencies for organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Some of the issues to be resolved are the complete characterization of the radiolytic decomposition products under different conditions and for different waste materials and their relative toxicity. Another issue is the possibility of combining the radiolysis with enhanced biodegradation of the radiolytic byproducts.	Development Costs: The RD&D effort is estimated to require \$1.25-2.5 million.
	Ozonation Photolysis WPRO-214-OL Ranking: Not Ranked	Demonstration Efficacy: This process can be very useful in destroying organics (especially refractory organics) in water. DREs for the process can be greater than 90%. Even though some organics are easily destroyed by the process, they are rarely completely oxidized and may be converted to other hazardous species. To be successful, a thorough knowledge of the waste to be treated is essential. The process is comparatively expensive for the treatment of organics. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$1-2 million to meet site-specific needs.
	M Wet Air Oxidation WPRO-215-OL Ranking: M-4-3 (\$3M;N)	Demonstration Efficacy: The process is commercially available. It is capable of greater than 99% destruction of some organics. However, it may not be able to completely destroy certain refractory organics, such as halogenated aromatics (e.g., PCBs). Processing costs are likely to be high. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: Approximately \$1 million
	M Supercritical Water Oxidation WPRO-216-OL Ranking: M-4-3 (\$3M;N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Significant development is needed to solve the problems of corrosion, plugging, and caking of the reactors. Overall experience is also needed on the specific problems that may be associated with the processing of particular types of wastes. This information could be used to develop a technology database to support the applicability and relative merits of this promising technology.	Development Costs: The RD&D effort is estimated to require \$1.6 million for a three-year development plan.

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Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Chemical Treatment H	Evaporation WPRO-223-OL Ranking: H-4-1 (\$1M;N)	Demonstration Efficacy: This is similar to distillation and is an accepted industrial process for treating contaminated liquids. It is usually used when the solvent is of low value and can be disposed. Like distillation, the operating costs can be high for certain applications. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: Knowledge of process application(s) and funding.
Chemical Treatment E	Aerobic Digestion WPRO-224-OL Ranking: E-4-1 (\$.5M;\$.5/gal)	Predemonstration Efficacy: This is a promising technology for destroying hazardous organics. Under the right conditions, this process should be able to achieve >99% destruction of the organics. Additional RD&D is needed to determine the applicability of the process to meet the site requirements. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$1-2 million to meet site-specific needs
Chemical Treatment M	Dry Storage WPRO-123-OL Ranking: M-4-2 (\$2M;N)	Accepted While the use of the process is accepted in nuclear plant operations, the application of the technology to the site problem will need to be demonstrated.	Additional design and analyses would be required to adapt the existing dry storage methods to the meet the specific site needs.	Estimated to be about \$ 5-10 million (1992 dollars) to place all the site spent fuel through 1993 into acceptable dry storage.
M	Pool Storage WPRO-124-OL Ranking: M-4-2 (\$2M;N)	Accepted While the use of the process is accepted in nuclear plant operations, the application of the technology to the site problem will need to be demonstrated.	Additional design and analyses would be required to adapt the existing dry storage methods to the meet the specific site needs.	Estimated to be about \$ 5-10 million (1992 dollars) to place all the site spent fuel through 1993 into acceptable dry storage.
L	Reprocessing WPRO-122-OL Ranking: L-4-3 (\$3M;N)	Accepted TTP Match	These include the need to optimize the established reprocessing technology to meet the site reprocessing needs for the disposal of the spent fuel elements and components.	Estimated to be \$ 3-5 million (1992 dollars) for shipping the site spent fuel components to the Savannah River Site for reprocessing. Alternately, an on-site reprocessing facility at ORNL is estimated to require more than \$ 200 million.
M	Develop cask to ship spent fuel elements to Savannah River Site for storage WPRO-125-OL Ranking: M-4-3 (\$3M;N)	Demonstration	Additional design and analyses would be required to adapt the existing dry storage methods to the meet the specific site needs.	Estimated to be \$ 3-5 million (1992 dollars) to obtain the certified acceptable shipping container for shipping the spent fuel elements and/or components to the Savannah River Site.

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Graphite Moderator	• Graphite • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
↓				
EM Problems				
• Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Thermal Treatment	H Incineration WPRO-108-OL <i>Ranking:*</i> H-2-1 (\$1M; \$6/b)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
	M Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> M-2-2 (\$2M;N)	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort
	M Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> M-2-5 (\$2M;N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process. Science Development:	Development Costs: \$3 million over three years

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Graphite Moderator	• Graphite • RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing	Th
	Fissile Materials	• RAD	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing	Ch
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Thermal Treatment M	Molten Glass Combustor WPRO-116-OL Ranking: M-2 2 (\$2M;N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DREs greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
Chemical Treatment L	Transmutation WPRO-219-OL Ranking: L-3-10 (\$10M;N)	Conceptual Efficacy: The future of an industrial-scale transmutation facility is highly dependent on the availability of a permanent, high-level waste repository. A "national" transmutation facility would greatly facilitate the destruction and disposal of "problem" radionuclides such as actinides. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	An industrial-scale, national transmutation facility would need to be developed and built. The cost for such a "national" facility is estimated to be in the billions of dollars range and would require several years to build.

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Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Physical Treatment	M Low-Temperature Separation WPRO-220-OL Ranking:* M-4-1 (\$5M; N)	Predemonstration This is an accepted industrial process for separation of low-boiling components from high-boiling components. The process can achieve separation efficiencies greater than 99%.	Technology Improvement: Further RD&D on the process to develop optimum processing conditions.	Development Costs: The RD&D effort is estimated to require \$1-2 million to meet site-specific needs.
	M Inorganic Membrane Separation WPRO-300-OL Ranking:* M-4-5 (\$4M; N)	Predemonstration The RD&D effort to develop inorganic membranes is estimated at \$4 million. The payback is estimated at \$20-25 million based on significantly reduced waste disposal costs. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: RD&D effort estimated at \$4 million to further develop the process to meet site needs.
	M Adsorption WPRO-202/203-OL Ranking:* M-4-2 (\$1M; N)	Predemonstration Laboratory studies indicate removal efficiencies greater than 90% for radioactive species using various adsorbing media. Further study is necessary to develop more effective adsorption media for the treatment of mixed waste contaminated liquids. Development would include, for example, scale-up studies, development of high-surface-area and appropriate-particle-size media for continuous operations, and development of appropriate media for the removal of various contaminants. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: RD&D effort estimated at \$1.25 million.
	H Scrubbers WPRO-301-OL Ranking:* H-4-1 (\$5M; N)	Demonstration Scrubbers are commercially available though need to be demonstrated for particular applications at ORNL. TTP Match	Technology Improvement: Though an accepted technology, use of the technology to meet site requirements needs to be demonstrated.	Knowledge of process application(s) and funding:
Chemical Treatment	M Leaching and Stripping WPRO-213-OL Ranking:* M-4-2 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Demonstrate effectiveness of the technology to meet site requirements:
	M Ozonation Photolysis WPRO-214-OL Ranking:* M-4-2 (\$1M; N)	Demonstration This process can be very useful in destroying organics (especially refractory organics) in water. DREs for the process can be greater than 90%. Even though some organics are easily destroyed by the process, they are rarely completely oxidized and may be converted to other hazardous species. To be successful, a thorough knowledge of the waste to be treated is essential. The process is comparatively expensive for the treatment of organics. TTP Match	Demonstration of effectiveness of technology to meet site requirements.	Development Costs: \$1-2 million to meet site-specific needs.

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EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Waste Off Gases from D&D, RA, and WM Operations	Volatile Organic Compounds (VOC) in Gases	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems - Facility Decontamination and Decommissioning (D&D) - Remedial Action (RA)—Soils, Ground Water and Surface Water - Waste Management (WM)		Semi-Volatile Organics in Gases	Refer to the Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	E Incineration WPRO-108-OL <i>Ranking:*</i> E-4-1 (\$5M; \$6/lb)	Accepted Efficacy: The EPA considers incineration the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve destruction removal efficiencies (DREs) > 99.999% for certain organics. However, additional research, development, and demonstration (RD&D) on several aspects of incineration is still required. Waste: Off gas and salt ash. TTP Match	Technology Improvement: Though an accepted technology, use of the technology to meet site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Knowledge of process application, funding, and regulatory approval. (For example, the K-25 site TSCA incinerator is a 30-MMBtu/h unit permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years.) Capital Costs: \$26 million (1987 dollars). Operating Costs: \$6/pound of waste incinerated (1992 dollars).
	H Catalytic Destruction WPRO-109-OL <i>Ranking:*</i> H-4-1 (\$1M; N)	Predemonstration Efficacy: This technology has been demonstrated to be effective (DRE: 99.1%) for the destruction of liquid and gaseous organic wastes. However, its use to remove and destroy the organics from solids needs additional RD&D. TTP Match	Technology Improvement: Further RD&D on the process to develop technology to deployment.	The RD&D effort is estimated to require \$0.75-1.5 million.
	Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> Not Ranked	Demonstration Efficacy: Although not a new process, the ability to treat hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both process and equipment are transportable (as opposed to a fixed treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. TTP Match	Technology Improvement: Further RD&D on the process to develop technology to deployment. Additional RD&D is required to fully develop the process to treat mixed wastes. Available at X-10.	Development Costs: \$2 million for a three-year development effort.
	L Electron Beam Destruction WPRO-304-OL <i>Ranking:*</i> L-4-2 (\$1M; N)	Predemonstration Development work with the compounds of interest at the bench scale needs to be done to justify scale-up testing. TTP Match	Technology Improvement: Further RD&D on the process to develop technology to deployment.	RD&D effort estimated at \$0.75-1.5 million.
	M Flameless Thermal Oxidizers WPRO-305-OL <i>Ranking:*</i> M-4-2 (\$1M; N)	Demonstration Development work with the compounds of interest at the bench scale needs to be done to justify scale-up testing. TTP Match	Technology Improvement: Further RD&D on the process to develop technology to deployment.	RD&D effort estimated at \$1-1.5 million.
Physical Treatment	M Low-Temperature Separation WPRO-220-OL <i>Ranking:*</i> M-4-1 (\$5M; N)	Predemonstration This is an accepted industrial process for the separation of low-boiling components from high-boiling components. The process can achieve separation efficiencies > 99%.	Technology Improvement: Further RD&D needed on the process to develop optimum processing conditions.	RD&D effort estimated at \$1-2 million to meet site-specific needs.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Waste

EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Waste Off-Gases from D&D, RA, and WM Operations	Semi-Volatile Organics in Gases continued	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Physical Treatment continued	M Adsorption WPRO-202/203-OL Ranking:* M-4-2 (\$1M; N)	Demonstration Laboratory studies indicate removal efficiencies greater than 90% for radioactive species using various adsorbing media. Further development is needed to develop more effective adsorption media for treatment of mixed-waste contaminated liquids. Development would include, for example, scale-up studies, high-surface-area and appropriate-particle-size media for continuous operations, and appropriate media for removal of various contaminants. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	RD&D effort estimated at \$1.25 million.
	M Inorganic Membrane Separation WPRO-300-OL Ranking:* M-4-5 (\$.4M; N)	Predemonstration RD&D effort to develop inorganic membranes is estimated at \$4 million. Payback is estimated at \$20-25 million based on significantly reduced waste disposal costs. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: RD&D effort estimated at \$4 million to further develop the process to meet site needs.
	H Scrubbers WPRO-301-OL Ranking:* H-4-1 (\$.5M; N)	Demonstration Scrubbers are commercially available though need to be demonstrated for particular applications at ORNL. TTP Match	Though an accepted technology, use of the technology to meet site requirements needs to be demonstrated.	Knowledge of process application(s) and funding.
Chemical Treatment	H Catalytic Destruction WPRO-109-OL Ranking:* H-4-1 (\$1M; N)	Predemonstration The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DRES greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: RD&D effort estimated at \$0.75-1.5 million.
	M Leaching and Stripping WPRO-213-OL Ranking:* M-4-2 (\$1M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Demonstrate effectiveness of the technology to meet site requirements.
	M Ozonation Photolysis WPRO-214-OL Ranking:* M-4-2 (\$1M; N)	Demonstration Efficacy: This process can be very useful in destroying organics (especially refractory organics) in water. DRES can be greater than 90%. Though some organics are easily destroyed by the process, they are rarely completely oxidized and may be converted to other hazardous species. To be successful, a thorough knowledge of the waste to be treated is essential. The process is comparatively expensive for the treatment of organics. TTP Match	Technology Improvement: Demonstrate effectiveness of the technology to meet site requirements.	Development Costs: \$1-2 million to meet site-specific needs.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Waste Off-Gases from D&D, FIA, and WM Operations, continued	Semi-Volatile Organics in Gases	Refer to Vol. 1; Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing	TI
EM Problems Facility Decontamination and Decommissioning (D&D)					
Remedial Action (RA)—Soils, Ground Water and Surface Water		Particulates in Gases	Refer to the Vol. 1; Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing	Phy
Waste Management (WM)					

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	E Incineration WPRO-108-OL <i>Ranking:*</i> E-4-1 (\$5M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Technology Improvement: Though an accepted technology, use of the technology to meet site requirements needs to be demonstrated. RD&D is required to develop better understanding of process technology to improve acceptability.	Development Costs: Knowledge of process application, funding, and regulatory approval. (For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years.) Capital Costs: \$26 million (1987 dollars). Operating Costs: \$6/pound of waste incinerated (1992 dollars).
	Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> Not Ranked	Demonstration Although not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage is that both the process and the equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort.
	L Electron Beam Destruction WPRO-304-OL <i>Ranking:*</i> L-4-2 (\$1M; N)	Predemonstration Development work with the compounds of interest at the bench scale needs to be done to justify scale-up testing. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: RD&D effort estimated at \$0.75-1.5 million.
	M Flameless Thermal Oxidizers WPRO-305-OL <i>Ranking:*</i> M-4-2 (\$1M; N)	Demonstration Development work with the compounds of interest at the bench scale needs to be done to justify scale-up testing. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: RD&D effort estimated at \$1-1.5 million.
Aqueous Treatment	M Inorganic Membrane Separation WPRO-300-OL <i>Ranking:*</i> M-2-5 (\$4M; N)	Predemonstration RD&D effort to develop inorganic membranes is estimated at \$4 million. Payback is estimated at \$20-25 million based on significantly reduced waste disposal costs. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: RD&D effort estimated at \$4 million to further develop the process to meet site needs.
	M Adsorption WPRO-202/203-OL <i>Ranking:*</i> M-2-2 (\$1M; N)	Demonstration Laboratory studies indicate removal efficiencies greater than 90% for radioactive species using various adsorbing media. Further development of more effective adsorption media is needed to treat mixed waste contaminated liquids. Development would include, for example, scale-up studies, high-surface-area and appropriate particle-size media for continuous operations, and appropriate media for removal of various contaminants. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: RD&D effort estimated at \$1.25 million.

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EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Waste Off-Gases from D&D, RA, and WM Operations, continued	Particulates in Gases continued	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Physical Treatment, continued	E Filtration WPRO-201-OL Ranking:* E-2-1 (\$1M; N)	Demonstration Efficacy: This is an accepted process for separating solids from fluids. The process can achieve removal efficiencies greater than 99%. The use of the process to meet site requirements will need to be demonstrated. TTP Match	Technology Improvement: Use of the technology to meet site requirements needs to be demonstrated.	Development Costs: Demonstration costs estimated at \$1 million.
	H Scrubbers WPRO-301-OL Ranking:* H-2-1 (\$1M; N)	Demonstration Efficacy: Scrubbers are commercially available though need to be demonstrated for particular applications at ORNL. TTP Match	Technology Improvement: Though an accepted technology, use of the technology to meet site requirements needs to be demonstrated.	Development Costs: Knowledge of process application(s) and funding.
	H Cyclone Separation WPRO-302-OL Ranking:* H-2-1 (\$1M; N)	Demonstration Application of commercially available cyclones to specific K-25 problems must be investigated before full-scale use. TTP Match	Technology Improvement: Though an accepted technology, use of the technology to meet site requirements needs to be demonstrated.	Development Costs: Demonstration costs estimated at \$1 million.
	L High-Gradient MMagnetic Separation WPRO- 204-OL Ranking:* L-2-4 (\$2M; N)	Demonstration The treatment is commercially available for, as an example, the removal of trace impurities from kaolin clays. Removal efficiencies for the process are greater than 99%. However, its use to treat mixed waste contaminated fluids needs additional RD&D. TTP Match	Technology Improvement: Use of the technology to meet site requirements needs to be demonstrated.	Development Costs: Demonstration costs estimated at \$2 million.
Chemical Treatment	H Leaching and Stripping WPRO-213-OL Ranking:* H-2-2 (\$1M; N)	Demonstration This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: Demonstrate the effectiveness of the technology to meet site requirements.
Thermal Treatment	Molten Salt Oxidation WPRO-113-OL Ranking:* Not Ranked	Demonstration Efficacy: Although not a new process, application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage is that both process and equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort.

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EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Waste Off-Gases from D&D, RA, and WM Operations, continued.	Inorganics in Gases	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing	Phys
EM Problems - Facility Decontamination and Decommissioning (D&D) - Remedial Action (RA)—Soils, Ground Water and Surface Water - Waste Management (WM)					Phys cont Cher

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
ical Treatment	M Inorganic Membrane Separation WPRO-300-OL <i>Ranking:*</i> M-2-5 (\$4M; N)	Predemonstration Efficacy: RD&D effort to develop inorganic membranes is estimated at \$4 million. Payback is estimated at \$20-25 million based on significantly reduced waste disposal costs.	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: RD&D effort estimated at \$4 million to further develop process to meet site needs.
	H Adsorption WPRO-202/203-OL <i>Ranking:*</i> H-2-2 (\$1M; N)	Predemonstration Efficacy: Laboratory studies indicate removal efficiencies greater than 90% for radioactive species using various adsorbing media. Further development is needed of more effective adsorption media for the treatment of mixed waste contaminated liquids. Development would include, for example, scale-up studies, high-surface-area and appropriate particle-size media for continuous operations, and appropriate media for the removal of various contaminants.	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: RD&D effort estimated at \$1.25 million.
	E Filtration WPRO-201-OL <i>Ranking:*</i> E-2-1 (\$1M; N)	Demonstration Efficacy: This is an accepted process for separating solids from fluids. The process can achieve removal efficiencies greater than 99%. Use of the process to meet site requirements will need to be demonstrated.	Technology Improvement: Use of the technology to meet site requirements needs to be demonstrated.	Development Costs: Estimated at up to \$1 million.
ical Treatment nued	Cyclone Separation WPRO-302-OL <i>Ranking:*</i> Not Ranked	Demonstration Efficacy: Application of commercially available cyclones to specific K-25 problems must be investigated before full-scale use.	Technology Improvement: Though an accepted technology, use of the technology to meet site requirements needs to be demonstrated.	Development Costs: Estimated at up to \$1 million.
	L High-Gradient Magnetic Separation WPRO-204-OL <i>Ranking:*</i> L-2-4 (\$2M; N)	Demonstration Efficacy: The treatment is commercially available for removal of trace impurities from kaolin clays. Removal efficiencies are greater than 99%. However, use to treat mixed waste contaminated fluids needs additional RD&D.	Technology Improvement: Use of the technology to meet site requirements needs to be demonstrated.	Development Costs: Estimated at \$2 million.
ical Treatment	Leaching and Stripping WPRO-213-OL <i>Ranking:*</i> Not Ranked	Demonstration This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions.	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: Demonstrate the effectiveness of the technology to meet site requirements.

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EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Waste Off-Gases from D&D, RA, and WM Operations, continued	Radioactive Elements in Gases,	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
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EM Problems				
• Facility Decontamination and Decommissioning (D&D)				
• Remedial Action (RA)—Soils, Ground Water and Surface Water				
• Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Physical Treatment	M Scrubbers WPRO-301-OL <i>Ranking:*</i> M-4-1 (\$1M; N)	Demonstration Scrubbers are commercially available though need to be demonstrated for particular applications at K-25. TTP Match	Technology Improvement: Though an accepted technology, use of the technology to meet site requirements needs to be demonstrated.	Development Costs: Knowledge of process application(s) and funding.
	M Adsorption WPRO-202/203-OL <i>Ranking:*</i> M-4-2 (\$1M; N)	Predemonstration Laboratory studies indicate removal efficiencies greater than 90% for radioactive species using various adsorbing media. Further development is needed of more effective adsorption media for treatment of mixed waste contaminated liquids. Development would include, for example, scale-up studies, high-surface-area and appropriate particle-size media for continuous operations, and appropriate media for removal of various contaminants. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: RD&D effort estimated at \$1.25 million.
Physical Treatment	H Filtration WPRO-201-OL <i>Ranking:*</i> H-4-2 (\$2M; N)	Demonstration This is an accepted process for separating solids from fluids. The process can achieve removal efficiencies greater than 99%. Use of the process to meet site requirements needs demonstration. TTP Match	Technology Improvement: Use of the technology to meet site requirements needs to be demonstrated.	Development Costs: Demonstration costs are estimated at up to \$1 million.
Chemical Treatment	M Leaching and Stripping WPRO-213-OL <i>Ranking:*</i> M-4-2 (\$2M; N)	Demonstration This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: Demonstrate the effectiveness of the technology to meet site requirements.
	L Bucky Ball Chemistry WPRO-101-OL <i>Ranking:*</i> L-4-10 (\$10M; N)	Evolving Technology This is a novel technology with many potential applications in fields such as mixed wastes treatment, nuclear medicine, tribology, and material science. Conceptually, the technology is sophisticated (uses lasers) and yet simple. For mixed wastes treatment, the process would essentially encapsulate radio-active and hazardous metals at the elemental level in high molecular weight carbon cages (fullerenes), isolating them from the environment.	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: RD&D effort to develop the technology is estimated at \$10 million. Payback is estimated to be approximately \$150 million considering savings in waste treatment, disposal costs, and potential spin-offs in other fields (nuclear medicine and new materials).

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EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Waste Gases of Unknown Characteristics from D&D and RA Operations (some possibly in cylinders of uncertain integrity)	Orphan Gas Cylinders with No Information on Cylinder Contents	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing	Phys
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EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					Che

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	H Recharacterization and Disposal WPRO-303-OL Ranking:* H-1-1 (\$2M; N)	Accepted	Technology Improvement: Though an accepted technology, use of the technology to meet site requirements needs to be demonstrated.	Knowledge of process application(s) and funding.
	H Recycle/Reuse WPRO-303-OL Ranking:* H-1-1 (\$5M; N)	Accepted	Technology Improvement: Though an accepted technology, use of the technology to meet site requirements needs to be demonstrated.	Knowledge of process application(s) and funding.
Chemical Treatment	H Scrubbers WPRO-211/212-OL Ranking:* H-1-1 (\$2M; N)	Demonstration Efficacy: Continuous solvent extraction in counter-current contactors (e.g., centrifugal) is a demonstrated technology to separate heavy metals or organics from aqueous or organic solutions. Centrifugal contactor-based processes to separate and recover radionuclides have been accepted technology at DOE nuclear processing sites for over 25 years. The technology can be applied to treat and recover a wide range of contaminant concentrations. Advantages of this process are its relatively small size, small hold-up volume, and rapid start-up characteristics. This technology, used with other waste treatment processes, would enhance the overall waste treatment strategy. Use of the technology for treatment of solid wastes requires additional RD&D. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment. Available at all sites.	Development Costs: \$1-2.5 million (payback could be significant).

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EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Waste gases from D&D, RA, and WM Operations	Criteria Pollutant (SOx)	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)		Criteria Pollutant (NOx)	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment E	Flue Gas Desulfurization Process WPRO-308-OL Ranking:* E-2-1 (\$1M; \$900/ton)	Accepted	These are expected to be minimal because the treatment technology is commercially available. The S/T needs may consist of conducting technology assessments to select the optimum technology SOx control strategy.	Development Costs: Estimated to be \$1 million (1992 dollars) for conducting technology assessments for selecting optimum strategy for remediating the site problem.
Thermal Treatment H	Incineration WPRO-108-OL Ranking:* H-2-1 (\$5M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Technology Improvement: Though an accepted technology, use of the technology to meet site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: Knowledge of process application, funding, and regulatory approval. (For example, the K-25 site TSCA incinerator is a 30-MMBtu/h unit permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA incinerator took over eight years.) Capital Costs: \$26 million (1987 dollars). Operating Costs: \$6/pound of waste incinerated (1992 dollars).
M	Molten Salt Oxidation WPRO-113-OL Ranking:* M-2-2 (\$2M; N)	Demonstration Efficacy: Although not a new process, application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage is both process and equipment are transportable (as opposed to a fixed treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: \$2 million for a three-year development effort.
Chemical Treatment E	De NO _x Processes WPRO-307-OL Ranking:* E-2-1 (\$1M; \$700/ton)	Accepted	These are expected to be minimal because the treatment technology is commercially available. The S/T needs may consist of conducting technology assessments to select the optimum technology NOx control strategy.	Estimated to be \$1 million (1992 dollars) for conducting technology assessments for selecting optimum strategy for remediating the site problem.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	H Incineration WPRO-108-OL <i>Ranking:*</i> H-2-1 (\$5M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Technology Improvement: Though an accepted technology, use of the technology to meet site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: Knowledge of process application, funding, and regulatory approval. (For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years.) Capital Costs: \$26 million (1987 dollars). Operating Costs: \$6/pound of waste incinerated (1992 dollars).
	M Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> M-2-2 (\$2M; N)	Demonstration Efficacy: Although not a new process, application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both process and equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. Additional RD&D is required to fully develop the process to treat mixed wastes. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort.
Physical Treatment	H Adsorption WPRO-202/203-OL <i>Ranking:*</i> H-2-1 (\$1M; N)	Predemonstration Efficacy: Laboratory studies indicate removal efficiencies greater than 90% for radioactive species using various adsorbing media. Further development is needed for more effective adsorption media for treatment of mixed waste contaminated liquids. Development would include, for example, scale-up studies, high-surface-area and appropriate-particle-size media for continuous operations, and appropriate media for removal of various contaminants. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: RD&D effort estimated at \$1.25 million.
	M Inorganic Microporous Filters WPRO-207-OL <i>Ranking:*</i> M-2-5 (\$4M; N)	Predemonstration Efficacy: This is a novel technology being developed for filtration applications. Some advantages of these filters are that they can be used in severe environments, readily cleaned if they become fouled, and reused indefinitely. Their separation efficiency can be >99%. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: \$4 million Payback estimated at \$20-25 million based on significantly reduced waste disposal costs.

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EM Goals	ORNL Site Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Waste gases from D&D, RA, and WM Operations continued	Entrained Vapors/acids continued	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
		Adsorbable RAD Gases	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)		Nonadsorbable RAD Gases	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Physical Treatment continued M	Leaching and Stripping WPRO-213-OL <i>Ranking:*</i> M-2-1 (\$2M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Demonstrate effectiveness of the technology to meet site requirements.
Physical Treatment M	Adsorption WPRO-202/203-OL <i>Ranking:*</i> M-4-2 (\$1M; N)	Predemonstration Efficacy: Laboratory studies indicate removal efficiencies greater than 90% for removal of radioactive species using various adsorbing media. Further development is necessary to develop more effective adsorption media for treatment of mixed waste contaminated liquids. Development would include, for example, scale-up studies, high-surface-area and appropriate particle-size media for continuous operations, and appropriate media for removal of various contaminants. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Development Costs: RD&D effort estimated at \$1.25 million.
Chemical Treatment M	Leaching and Stripping WPRO-213-OL <i>Ranking:*</i> M-4-2 (\$2M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop technology to deployment.	Demonstrate effectiveness of the technology to meet site requirements.
Physical Treatment	Fugitive Atmospheric Discharge WPRO-306-OL <i>Ranking:*</i> Not Ranked	Accepted	Identify and quantify the non-adsorbable RAD gases prior to release to the atmosphere.	Estimated to be \$ 0.5 million (1992 dollars) for conducting assessment studies to safely manage the non-adsorbable noble RAD gases.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/schema.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Physical Treatment	H Recycle/Reuse WPRO-130-OL <i>Ranking:*</i> H-1-1 (\$5M; N)	Accepted Has been reused as roadbed material.	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5 million (1992 dollars) for assessing the potential reuse options for the waste.
	H Landfill Disposal WPRO-131-OL <i>Ranking:*</i> H-1-1 (\$5M; \$30/yd ³)	Accepted TTP Match	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5-1 million (1992 dollars) for assessing the potential for the disposal of the waste. Current landfill disposal costs are around \$ 30 per cubic yard of waste.
Physical Treatment	H Landfill Disposal WPRO-131-OL <i>Ranking:*</i> H-1-1 (\$5M; \$30/yd ³)	Accepted TTP Match	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5-1 million (1992 dollars) for assessing the potential for the disposal of the waste. Current landfill disposal costs are around \$ 30 per cubic yard of waste.
Physical Treatment	H Recycle/Reuse WPRO-130-OL <i>Ranking:*</i> H-1-1 (\$5M; N)	Accepted	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5 million (1992 dollars) for assessing the potential reuse options for the waste.
	H Landfill Disposal WPRO-131-OL <i>Ranking:*</i> H-1-1 (\$5M; \$30/yd ³)	Accepted TTP Match	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5-1 million (1992 dollars) for assessing the potential for the disposal of the waste. Current landfill disposal costs are around \$ 30 per cubic yard of waste.
Physical Treatment	H Recycle/Reuse WPRO-130-OL <i>Ranking:*</i> H-1-1 (\$5M; N)	Accepted	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5-1 million (1992 dollars) for assessing the potential for the disposal of the waste. Current landfill disposal costs are around \$ 30 per cubic yard of waste.
	H Landfill Disposal WPRO-131-OL <i>Ranking:*</i> H-1-1 (\$5M; \$30/yd ³)	Accepted TTP Match	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5-1 million (1992 dollars) for assessing the potential for the disposal of the waste. Current landfill disposal costs are around \$ 30 per cubic yard of waste.
Thermal Treatment	M Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> M-1-2 (\$2M; N)	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DRES greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Technology Improvement: Some development work is required to apply the method to treat the site wastes.	Knowledge of process application; funding; and regulatory approval.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Uncontaminated Fiberglass Insulation (No RAD or RCRA hazardous waste contamination) MTC 5220	- Scrap - Fiberglass Insulation	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems Facility Decontamination and Decommissioning (D&D)	Uncontaminated Scrap Ferrous Metals (iron; structural and shack steel, drums, etc.) (No RAD or RCRA hazardous waste contamination) MTC 5110	Scrap Ferrous Metals	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
Remedial Action (RA)—Soils, Ground Water and Surface Water	Uncontaminated Scrap Non-Ferrous Metals (No RAD or RCRA hazardous waste contamination) MTC 5190	Scrap Non-Ferrous Metals	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment continued	M Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> M-1-3 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
	M Microwave Treatment WPRO-115-OL <i>Ranking:*</i> M-1-3 (\$4M; N)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: \$3-4 million
Physical Treatment	M Recycle/Reuse WPRO-130-OL <i>Ranking:*</i> M-1-1 (\$.5M; N)	Accepted	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5 million (1992 dollars) for assessing the potential reuse options for the waste.
	H Sell as Scrap WPRO-130-OL <i>Ranking:*</i> H-1-1 (\$.5M; N)	Accepted	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5-1 million (1992 dollars) for assessing the market potential for the waste material as scrap waste.
	M Landfill Disposal WPRO-131-OL <i>Ranking:*</i> M-1-1 (\$.5M; \$30/yd ³)	Accepted TTP Match	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5-1 million (1992 dollars) for assessing the potential for the disposal of the waste. Current landfill disposal costs are around \$ 30 per cubic yard of waste.
Physical Treatment	H Recycle/Reuse WPRO-130-OL <i>Ranking:*</i> H-1-1 (\$.5M; N)	Accepted	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5 million (1992 dollars) for assessing the potential reuse options for the waste.
	H Sell as Scrap WPRO-130-OL <i>Ranking:*</i> H-1-1 (\$.5M; N)	Accepted	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5-1 million (1992 dollars) for assessing the market potential for the waste material as scrap waste.
	M Landfill Disposal (exc. Ba, Pb, Hg, Ag, As, Se, Cr) WPRO-131-OL <i>Ranking:*</i> M-1-1 (\$.5M; \$30/yd ³)	Accepted TTP Match	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5-1 million (1992 dollars) for assessing the potential for the disposal of the waste. Current landfill disposal costs are around \$ 30 per cubic yard of waste.

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	• Uncontaminated Scrap Non-Ferrous Metals (No RAD or RCRA hazardous waste contamination) MTC 5190	• Scrap Non-Ferrous Metals	Refer to Vol. 1, Pt. C, Chap. 6.	Waste Processing	C
	• Biological Wastes (e.g., animal carcasses and discarded bedding materials) for • RAD Contamination Only • TRU Contamination Only • Mixed Waste Contaminated (MTC-5350-5360), and • Uncontaminated Wastes	• Animal carcasses • Bedding material Plus: • RAD, (for RAD contamination only), or • TRU, (for TRU contamination only), or • Organics, • Inorganics, • PCBs (for mixed waste contaminated wastes), or • No RAD or hazardous components (for uncontaminated wastes).	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing	T
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment	Acid Digestion WPRO-127-OL <i>Ranking:*</i>	Predemonstration	Additional research, development, and demonstration (RD&D) is required to meet the site specific needs.	The RD&D effort is estimated to require \$ 1 million (1992 dollars) and take approximately 2 years to complete.
Thermal Treatment	Incineration WPRO-108-OL <i>Ranking:*</i> E-3-1 (\$5M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DRES greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Technology Improvement: Knowledge of process application, funding, and regulatory approval. For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Science Development: Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: \$5 Million over 3 years (for improvements) Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
	Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> L-3-2 (\$2M; N)	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. TTP Match	Technology Improvement: Additional RD&D is required to fully develop the process to treat mixed wastes. Science Development: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort
	Molten Glass Combustor WPRO-116-OL <i>Ranking:*</i> Not Ranked	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DRES greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Technology Improvement: Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Biological Wastes (e.g., animal carcasses and discarded bedding materials) for • RAD Contamination Only • TRU Contamination Only • Mixed Waste Contaminated (MTC-5350-5360), and • Uncontaminated Wastes	• Animal carcasses • Bedding material Plus: • RAD, (for RAD contamination only), or • TRU, (for TRU contamination only), or • Organics, • Inorganics, • PCBs (for mixed waste contaminated wastes), or • No RAD or hazardous components (for uncontaminated wastes).	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)	Uncontaminated Combustible Debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (No RAD or RCRA hazardous waste contamination) MTC 5300	• Combustible Debris	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment continued	Plasma Arc Furnace WPRO-107-OL Ranking: L-3-5 (\$3M; N)	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
Physical Treatment	Recycle/Reuse WPRO-130-OL Ranking: H-2-1 (\$.5M; N)	Accepted	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5 million (1992 dollars) for assessing the potential reuse options for the waste.
	Sell as Scrap WPRO-130-OL Ranking: H-2-1 (\$.5M; N)	Accepted	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5-1 million (1992 dollars) for assessing the market potential for the waste material as scrap waste.
	Landfill Disposal WPRO-131-OL Ranking: L-2-1 (\$.5M; \$30/yr³)	Accepted TTP Match	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5-1 million (1992 dollars) for assessing the potential for the disposal of the waste. Current landfill disposal costs are around \$ 30 per cubic yard of waste.
Thermal Treatment	Incineration WPRO-108-OL Ranking: H-2-1 (\$.5M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Technology Improvement: Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Science Development: Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: \$5 Million over 3 years (for improvement) Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. TTP Match	Technology Improvement: Additional RD&D is required to fully develop the process to treat mixed wastes. Science Development: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort
	Chem Char Process WPRO-114-OL <i>Ranking:*</i> <i>Not Ranked</i>	Predemonstration	Further research, development, and demonstration (RD&D) is required on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$4 million (1992 dollars) and take about 7 years to complete.
	Microwave Treatment WPRO-115-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: \$3-4 million
	Plasma Arc Furnace WPRO-107-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
Biological Treatment	Aerobic Digestion WPRO-224-OL <i>Ranking:*</i> <i>Not Ranked</i>	Predemonstration Efficacy: This is a promising technology for destroying hazardous organics. Under the right conditions, this process should be able to achieve >99% destruction of the organics. Additional RD&D is needed to determine the applicability of the process to meet the site requirements. TTP Match	The use of the technology to meet the site requirements needs to be demonstrated.	Development Costs: \$1-2 million to meet site-specific needs

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Uncontaminated Combustible Debris (e.g., paper, cloth, personal protective clothing (PPC), lint, plastics, wood, rubber, vegetable matter) (No RAD or RCRA hazardous waste contamination) MTC 5300	• Combustible Debris	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
	Uncontaminated Compactible Debris (e.g., glass, lights, ceramics, glove boxes, manipulator boots) (No RAD or RCRA hazardous waste contamination) MTC 5400	• Compactible Debris	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Biological Treatment	Anaerobic Digestion WPRO-225-OL Ranking:* Not Ranked	Predemonstration Efficacy: This is a promising technology for destroying hazardous organics. Under the right conditions, this process should be able to achieve >99% destruction of the organics. Additional RD&D is needed to determine the applicability of the process to meet the site requirements. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Science Development:	Development Costs: \$1.5-2 million to meet site-specific needs
Physical Treatment	H Recycle/Reuse WPRO-130-OL Ranking:* H-2-1 (\$5M; N)	Accepted	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$0.5 million (1992 dollars) for assessing the potential reuse options for the waste.
	H Sell as Scrap WPRO-130-OL Ranking:* H-2-1 (\$5M; N)	Accepted	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$0.5-1 million (1992 dollars) for assessing the market potential for the waste material as scrap waste.
Thermal Treatment	Molten Glass Combustor WPRO-116-OL Ranking:* Not Ranked	Accepted Efficacy: This is accepted industrial technology for mixed wastes treatment. The process can achieve DRES greater than 99%. EPA has accepted this process as best demonstrated technology (BDAT) for the treatment of hazardous, high-level nuclear wastes. Operating costs for the process are likely to be high. TTP Match	Technology Improvement: Some development work is required to apply the method to treat the site wastes.	Knowledge of process application, funding, and regulatory approval.
	Plasma Arc Furnace WPRO-107-OL Ranking:* Not Ranked	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DRES), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process. Science Development:	Development Costs: \$3 million over three years

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	Microwave Treatment WPRO-115-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: \$3-4 million
Physical Treatment	H Sell as Scrap WPRO-130-OL <i>Ranking:*</i> <i>H-2-1 (\$5M; N)</i>	Accepted	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5-1 million (1992 dollars) for assessing the market potential for the waste material as scrap waste.
	Landfill Disposal WPRO-131-OL <i>Ranking:*</i> <i>Not Ranked</i>	Accepted TTP Match	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5-1 million (1992 dollars) for assessing the potential for the disposal of the waste. Current landfill disposal costs are around \$ 30 per cubic yard of waste.
Thermal Treatment	Incineration WPRO-108-OL <i>Ranking:*</i> <i>Not Ranked</i>	Accepted Efficacy: The EPA considers incineration to be the best demonstrated and available technology (BDAT) for organic destruction. Incineration can achieve DRES greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Technology Improvement: Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactive-contaminated mixed wastes. Obtaining regulatory approval for the TSCA Incinerator took over eight years. Science Development: Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: \$5 Million over 3 years (for improvement) Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
	Molten Salt Oxidation WPRO-113-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration Efficacy: Although this is not a new process, its application for treating hazardous and radioactive contaminants has yet to be demonstrated. One advantage of the process is that both the process and the equipment are transportable (as opposed to a fixed-treatment facility) and can be located near the waste site. The process should be capable of destroying organics with a >99% efficiency. TTP Match	Technology Improvement: Additional RD&D is required to fully develop the process to treat mixed wastes. Science Development: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10.	Development Costs: \$2 million for a three-year development effort

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EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Uncontaminated Discarded Filters (including HEPA filters) (No RAD or RCRA hazardous waste contamination) MTC 5410	Discarded Filters	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing
EM Problems - Facility Decontamination and Decommissioning (D&D) - Remedial Action (RA)—Soils, Ground Water and Surface Water - Waste Management (WM)	Uncontaminated Waste Processing Sludges (e.g., Coal Yard Runoff Sludge) (No RAD or RCRA hazardous waste contamination)	- Sludges - Organics - Inorganics	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Processing

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment	Microwave Treatment WPRO-115-OL Ranking:* Not Ranked	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: \$3-4 million
	Plasma Arc Furnace WPRO-107-OL Ranking:* Not Ranked	Demonstration Efficacy: This is a developmental technology proposed for the destruction of organics and the immobilization of non-volatile radionuclides and toxic metals in a glassy slag matrix. The attractive features of the technology are that it can be used to treat almost any solid waste and that it does not require extensive pre-treatment of the waste feed. The negative aspect of the process is that it is very energy intensive and therefore likely to be expensive. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. RD&D is required on the process to determine, for example, waste destruction and removal efficiencies (DREs), electrode life, materials of construction, power efficiency, effluent characteristics for different waste feeds, and the viability of the process.	Development Costs: \$3 million over three years
Physical Treatment	Shallow Land Burial WPRO-132-OL Ranking:* H-1-1 (\$2M; N)	Accepted	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$0.2 Million for assessments
	Recycle/Reuse (e.g. in Boiler) WPRO-130-OL Ranking:* M-1-1 (\$5M; N)	Accepted	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$0.5 million (1992 dollars) for assessing the potential reuse options for the waste.
Thermal Treatment	Thermal Desorption WPRO-106-OL Ranking:* M-3-2 (\$1M; \$1/lb)	Accepted Efficacy: This technology has been used by industry to remove and recover volatiles from contaminated media (i.e., soils). The process purportedly has a >99% removal efficiency for recovering volatile organic compounds (VOCs) from soil. The application of the process to treat other contaminated media (such as concrete rubble) needs to be demonstrated. TTP Match	Technology Improvement: The use of the technology to meet the site requirements needs to be demonstrated.	Knowledge of process application, funding, and regulatory approval. Treatment costs estimated to be \$1/lb of waste treated.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Thermal Treatment continued	M Incineration WPRO-108-OL Ranking:* M-3-3 (\$3M; N)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Technology Improvement: Knowledge of process application, funding, and regulatory approval. Insert 10: For example, the K-25 site TSCA Incinerator is a 30-MMBtu/h unit that is permitted to destroy low-level, radioactively contaminated, mixed wastes. Science Development: Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: \$5 Million over 3 years (for improvement) Capital Costs: \$26 Million (1987 dollars) Operating Costs: \$6/lb of waste incinerated (1992 dollars)
	M Microwave Treatment WPRO-115-OL Ranking:* M-3-1 (\$0.5M; \$6/lb)	Demonstration Efficacy: This is a novel technology for the thermal treatment of radioactive wastes. The technology is at the laboratory scale of development. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at K-25.	Development Costs: \$3-4 million
Biological Treatment	M Biodegradation WPRO-117-OL Ranking:* M-3-3 (\$2M; N)	Evolving Technology Efficacy: This is a promising technology for hazardous waste treatment. The process can achieve impressive treatment efficiencies for certain organics. However, the process is slow and may not be able to completely destroy certain refractory organics. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Development Costs: The RD&D effort is estimated to require \$1-10 million. The payback could be significant.
Encapsulation	See Waste Stabilization			
Landfill Treatment	H Landfill Disposal WPRO-131-OL Ranking:* H-3-1 (\$1M; \$30/yr)	Accepted TTP Match	These are expected to be minimal and may consist of reviewing more innovative methods.	Estimated to be \$ 0.5-1 million (1992 dollars) for assessing the potential for the disposal of the waste. Current landfill disposal costs are around \$ 30 per cubic yard of waste.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Chemical Treatment M	Leaching and Stripping WPRO-213-OL Ranking:* M-3-2 (\$2M; N)	Demonstration Efficacy: This is an accepted technology in industry with removal efficiencies greater than 99%. However, each application requires additional RD&D to determine optimum leachant composition and process conditions. TTP Match	Technology Improvement: Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Demonstrate the effectiveness of the technology to meet the site requirements.
Thermal Treatment M	Incineration WPRO-108-OL Ranking:* M-3-2 (\$1M; \$6/lb)	Accepted Efficacy: The EPA considers incineration to be the best demonstrated available technology (BDAT) for the destruction of organics. Incineration can achieve DREs greater than 99.999% for certain organics. However, additional RD&D on several aspects of incineration is still required. TTP Match	Technology Improvement: Knowledge of process application, funding, and regulatory approval. Science Development: Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, RD&D is required to develop better understanding of the process technology to improve its acceptability.	Development Costs: \$5 Million over 3 years (for improvement) Capital Costs: \$26 million (1987 dollars) Operating Costs: \$6 per pound of waste incinerated (1992 dollars)
M	Thermal Desorption WPRO-106-OL Ranking:* M-3-2 (\$1M; \$1/lb)	Accepted Efficacy: This technology has been used by industry to remove and recover volatiles from contaminated media (i.e., soils). The process reportedly has a >99% removal efficiency for recovering volatile organic compounds (VOCs) from soil. The application of the process to treat other contaminated media (such as concrete rubble) needs to be demonstrated. TTP Match	Technology Improvement: The use of the technology to meet the site requirements needs to be demonstrated.	Knowledge of process application, funding, and regulatory approval. Treatment costs estimated to be \$1/lb of waste treated.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Mechanical Retrieval	Wheeled/Tracked Vehicles – Front-end Loader – Backhoe – Fork Lift	See Waste Retrieval under Remedial Action		
	Demolition – Jackhammers – Controlled Blasting	See Waste Retrieval under Remedial Action		
Hydraulic Retrieval	Fluid Systems	See Waste Retrieval under Remedial Action		

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Minimize the generation of hazardous and mixed wastes.	• Solvents • RAD • PCB • Organics • Inorganics • Metals • Wood • Plastics • Cloth • Lint • Paper • Asbestos	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Minimization
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
• Minimize the creation of wastes. • Characterize and segregate the wastes as early in the operation as possible to minimize hazardous waste generation. • Maximize the use of non-hazardous substitutes. • Transfer potential waste materials (e.g. specialty freons) to other DOE plants having a need for the material. • Seek opportunities to use contaminated spent materials in other DOE applications (e.g. contaminated metal for use in supercollider). • Maximize the recycle of treated spent materials. • Sell maximum materials as scrap as legally permitted. • Establish acceptable Below Regulatory Concern (BRC) and "de minimus" values. • Think Waste Minimization!		Demonstration	The science and technology needs are expected to be minimal because incorporating the waste minimization ethic will not require new technology but a change in operating philosophy, attitudes and behavior.	General implementation needs include inculcating the waste minimization philosophy among site personnel through education and establishing acceptable BRC and de-minimus values for radioactive contamination levels in potential wastes so that significant quantities of potential waste materials can either be recycled, sold as scrap, or disposed at lower costs.
Waste Minimization Evaluation System	Waste Minimization Evaluation System (Computer Software) WMIN-100-OL	Demonstration: A prototype software program was used to analyze waste minimization at a solvent degreasing operation at the Y-12 Plant. This application showed areas where the degreasing operations could be improved from a waste minimization perspective.	Develop and demonstrate the effectiveness of the WMES to minimize site wastes and waste disposal costs. The science/technology needs include for example, software development (e.g., programing and process simulation) and expertise capture.	Development and demonstration of the WMES is estimated to require \$ 3-5 million. The savings from implementing the system could be substantial.

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Solidification Macroencapsulation Microencapsulation Chemical Fixation	Cementitious Solidification/Stabilization WSTA-100-OL Polymer-Impregnated Concrete WSTA-101-OL Thermoplastic Encapsulation WSTA-102/103-OL Thermosetting Plastics Encapsulation WSTA-104-OL	Accepted This is an accepted method for stabilizing hazardous and low-level radioactive wastes for disposal. However, the technology (as currently practiced) is more art than science. This method generally results in a 0.5 to 2-fold increase in the volume of the final wasteform for disposal. TTP Match Evolving Technology This is a developmental technology that is developing an alternate wasteform that is less leachable (and thus more acceptable) than cementitious wasteforms. The polymer addition serves to waterproof the final wasteform thus reducing the migration of the immobilized contaminants into the environment. This method is also expected to result in a one to two-fold increase in the final wasteform volume for disposal. Pre-Demonstration The bitumen stabilization process is determined to be at the demonstration level while the polyethylene process is determined to be at the pre-demonstration level of development. Depending upon the wastes being stabilized, thermoplastic stabilization processes result in a net decrease in the final wasteform volume. The technology is not mature and additional research, development, and demonstration (RD&D) is needed to further develop the technology and its acceptability as a stabilization method by the regulators. TTP Match Pre-Demonstration This process is especially suitable for stabilizing spent ion exchange resin beds for disposal. The process does not require high temperatures or dried wastes and normally results in no net increase in the volume of the final wasteform. However, if the method is used to stabilize a net increase in the volume of the final wasteform could result. Additional RD&D on the process could help increase its applicability to stabilizing other wastes.	Though an accepted technology, the use of the technology to meet the site requirements needs to be demonstrated. Also, need to develop better understanding of the immobilization chemistry and mechanisms. Available at all sites. Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at X-10. Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment. Available at all sites. Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	Knowledge of process application, funding, and regulatory approval. In general cementitious stabilization/solidification costs range between \$ 50 to \$ 500 per cubic foot of waste. These costs are very dependent upon the wastes being solidified, the cementitious materials being employed, and the performance criteria for the wasteform. The RD&D effort is estimated to require \$ 5-10 million. The payback could be significant. The RD&D effort is estimated to require \$ 2-5 million. The payback could be significant. The RD&D effort is estimated to require \$ 2-5 million. The payback could be significant.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Contaminated Solid Wastes	Contaminated Concrete Rubble Scrap Asbestos and Transite Other Scrap Bldg. Materials Scrap Iron and Steel Scrap Plastic, Paper, and Cloth Contaminated Clothing and Rags Scrap Combustable Debris Discarded Filters Lab Packs Spent Ion Exchange Media Waste Processing Residuals Other Heterogenous Debris	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Stabilization
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

Management

	Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Solidification (cont.) Macroencapsulation (cont.) Microencapsulation (cont.) Chemical Fixation (cont.)		High-Temperature Crystalline Materials (Ceramic) WSTA-105-OL	Evolving Technology This is a developmental technology which uses high temperatures to immobilize the wastes in a ceramic wasteform. These wasteforms are generally inert and exhibit very low leachability characteristics. Depending upon the waste characteristics, ceramic wasteforms can result in a significant decrease in the volume of the final wasteform which can translate into significant savings in waste disposal costs. TTP Match	Further research, development, and demonstration (RD&D) on the process to develop the technology to deployment.	The RD&D effort is estimated to require \$ 5-10 million. The pay-back could be significant.
		High-Temperature Noncrystalline Materials (Vitrification) WSTA-106-OL	Pre-Demonstration This is an accepted process for the disposal of high-level nuclear wastes; however, its suitability for the disposal of hazardous and low-level radioactive wastes needs to be established. Because of the high processing temperatures, this process results in the decrease of the final wasteform volume. Under normal environmental conditions the final wasteform is inert and non-leachable. TTP Match	Demonstrate the effectiveness of the technology to meet the site requirements. Available at all sites.	The RD&D effort is estimated to require \$ 5-10 million. The pay-back could be significant.

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
define interfaces	Standard systems engineering technologies	Interface working groups need to be formed	None	\$1 million (1992 dollars)
IP-1 in at least excepted packages	Standard	Accepted	None	Not currently estimated
IP in bulk, unpackaged, or in industrial packaging (IP) (IP-1, IP-2, IP-3); ship in IP-2; do not develop IP-3	Low-Specific-Activity materials processing, preparation and packaging WPHT-102-OL	Must evolve to comply with new DOT/NRC regulations	New packaging designs required to satisfy expected new IP-2 packaging requirements	IP-2 packaging development cost \$1 million (1992 dollars)
many alternatives (e.g., manual, mechanical, automated handling, road, rail, water transport)	Standard	Accepted	None	Not currently estimated
IP in Industrial packaging (IP-1, IP-2, IP-3)	Surface Contaminated Objects Processing, Preparation and Packaging WPHT-103-OL	Must evolve to comply with new DOT/NRC regulations	Methods for producing SCO and for satisfying SCO requirements and new IP packaging requirements need to be developed	\$1-2 million (1992 dollars)
many alternatives	Standard	Accepted	None	Not currently estimated
Type A package	Type A Radioactive Material Transport Packages (Multi-Use) WPHT-104-OL	New standardized Type A package designs need to be developed and qualified to meet regulations. Designs must be user friendly and available to a wide variety of users.	An operationally efficient multi-use Type A package, or packages, for radioactive materials needs to be developed.	\$1 million (1992 dollars)
many alternatives	Standard	Accepted	None	Not currently estimated
lightweight containers, package certification	Type B Radioactive Material Packages WPHT-105-OL	Certified package design can be identified from RAMPAC database and Packaging Management Transportation System (PMTS) database which will identify numbers and status of packagings available under development by EM-561.	New package designs may be required	Not currently estimated
many alternatives	Standard	Accepted	None	Not currently estimated
lightweight containers, package certification	Type-A or Type-B Fissile Radioactive Material Packages WPHT-106-OL	Certified package design can be identified from RAMPAC and PMTS databases which will identify numbers and status of packagings available under development by EM-561.	New package designs may be required	Not currently estimated
many alternatives	Standard	Accepted	None	Not currently estimated

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Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Offsite packaging, equivalent safety of offsite packaging	Type A, Type B, Fissile, Strong Tight, IP, Performance Oriented Packaging (POP), and Bulk packaging or packaging equivalent in safety	Accepted	New package designs may be required	Not currently estimated
Many alternatives	Standard	Accepted	None	Not currently estimated
Use package designs approved for radioactive contents	Mixed waste and waste having more than one hazard	Accepted	New package designs may be required	Not currently estimated
Many alternatives	Standard	Accepted	None	Not currently estimated
POP container	Performance Oriented Packaging (POP) Packaging Group (PG) PGI—air, vessel; PGII—rail, highway (if reportable quantity), Bulk—Strong Tight Container WPHT-107-OL	Accepted	New package designs may be required	Not currently estimated
Many alternatives	Standard	Accepted	None	Not currently estimated
PGI & PG II POP container	Friable, white—POP PGIII Friable, blue or brown—POP PGII WPHT-108-OL	Accepted	New package designs may be required	Not currently estimated
Many alternatives	Standard	Accepted	None	Not currently estimated
POP container	RCRA non-bulk: POP PGI, II, III Specification packaging Bulk - Strong Tight Containers WPHT-109-OL	Accepted	New package designs may be required	Not currently estimated
Many alternatives	Standard	Accepted	None	Not currently estimated

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Landfill	Y-12 Plant Industrial Landfill (Tennessee) WDIS-101-OL	Accepted & Operating New landfill is expected to be operational in July 1993. The landfill has a design capacity of 1.5 million cubic feet and a design life of 43 years.	None Available at Y-12.	Need regulatory approval and funding. The wastes disposed in this landfill must meet the waste acceptance criteria (WAC) for the landfill and obtain approval from the facility manager for the disposal of the wastes. Funding would be required for performing waste analyses (to ensure compliance with the landfill WAC) and waste packaging, handling, and transportation (WPH&T) to the landfill. Estimated funding requirements cannot be forecast because they are dependent upon several factors such as waste volumes, tipping fees, analytical requirements, and WPH&T costs.
Landfill	Y-12 Plant Industrial Landfill (Tennessee) WDIS-101-OL	Accepted & Operating New landfill is expected to be operational in July 1993. The landfill has a design capacity of 1.5 million cubic feet and a design life of 43 years.	None Available at Y-12.	Need regulatory approval and funding. The wastes disposed in this landfill must meet the waste acceptance criteria (WAC) for the landfill and obtain approval from the facility manager for the disposal of the wastes. Funding would be required for performing waste analyses (to ensure compliance with the landfill WAC) and waste packaging, handling, and transportation (WPH&T) to the landfill. Estimated funding requirements cannot be forecast because they are dependent upon several factors such as waste volumes, tipping fees, analytical requirements, and WPH&T costs.
Low Level Disposal	Nevada Test Site WDIS-102-OL	Accepted, Not Available This facility has been earmarked as one of the facilities for the disposal of DOE low-level radioactive (RAD) wastes. However the facility is NOT currently available for disposal of Oak Ridge Waste. The Hanford Solid LLW Site is now available. TTP Match	None	Need regulatory approval and funding. The wastes disposed in this landfill must meet the waste acceptance criteria (WAC) for the landfill and obtain approval from the facility manager for the disposal of the wastes. Funding would be required for performing waste analyses (to ensure compliance with the landfill WAC) and waste packaging, handling, and transportation (WPH&T) to the landfill. Estimated funding requirements cannot be forecast because they are dependent upon several factors such as waste volumes, tipping fees, analytical requirements, and WPH&T costs.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Disposal of final residues from D&D, ER, and WM operations	Low-Level Rad Waste	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Disposal
EM Problems - Facility Decontamination and Decommissioning (D&D) - Remedial Action (RA)—Soils, Ground Water and Surface Water - Waste Management (WM)		RCRA Waste	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Disposal

Management

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Underground Disposal	Borehole Disposal WDIS-100-OL	Pre-demonstration, Not Available This is a developmental disposal option that has been endorsed by the International Atomic Energy Agency (IAEA) for the disposal of radioactive wastes. The site for the facility would be determined after evaluating the geohydrology and the resulting environmental impacts of potential sites. One potential site is the Conasauga shale formation that underlies parts of East Tennessee.	Additional research, development, and demonstration (RD&D) is required on the method to determine its environmental, economic, and engineering acceptability. This RD&D effort would include for example, identifying candidate disposal sites, the characteristics of the wastes to be disposed in the boreholes, and evaluating the geohydrology of the sites.	Estimated RD&D cost is \$2-3 million (1992 dollars)
Landfill	ORR Class L-I Low-Level Waste Landfill WDIS-106-OL	Pre-demonstration, Not Available West Chestnut Ridge at Y-12 Plant	Research, development, and demonstration (RD&D) needs to be conducted to determine the environmental acceptability of this disposal option for the low-level radioactive wastes.	Need regulatory approval and funding. The facility is projected to be ready to accept wastes in early 1999. The capital cost for the facility is estimated to be \$90 million (1992 dollars) and the annual operating costs are estimated to be around \$8 million (1992 dollars).
Landfill	Commercial RCRA Landfill Sites (e.g., Chemical Waste Management at Emelle, AL, Envirocare in UT, or U. S. Ecology landfill in NV). WDIS-103-OL	Accepted, Not Available The strictly Resource Conservation and Recovery Act (RCRA) solid wastes from the site will be disposed of in approved commercial landfills provided the wastes meet the landfill's waste acceptance criteria and it is economic. Because the DOE performance objective of "No RAD Added" cannot be demonstrated, a DOE mandated moratorium on shipments to this site is currently in effect.	None	Need regulatory approval and funding. The wastes disposed in this landfill must meet the waste acceptance criteria (WAC) for the landfill and obtain approval from the facility manager for the disposal of the wastes. Funding would be required for performing waste analyses (to ensure compliance with the landfill WAC) and waste packaging, handling, and transportation (WPH&T) to the landfill. Estimated funding requirements cannot be forecast because they are dependent upon several factors such as waste volumes, tipping fees, analytical requirements, and WPH&T costs.
Underground Disposal	Borehole Disposal WDIS-100-OL	Pre-demonstration, Not Available This is a developmental disposal option that has been endorsed by the International Atomic Energy Agency (IAEA) for the disposal of radioactive wastes. The site for the facility would be determined after evaluating the geohydrology and the resulting environmental impacts of potential sites. One potential site is the Conasauga shale formation that underlies parts of East Tennessee.	Additional research, development, and demonstration (RD&D) is required on the method to determine its environmental, economic, and engineering acceptability. This RD&D effort would include for example, identifying candidate disposal sites, the characteristics of the wastes to be disposed in the boreholes, and evaluating the geohydrology of the sites.	Estimated RD&D cost is \$2-3 million (1992 dollars)

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
- Clean Up Legacy Waste - Prevent Future Insult - Develop Environmental Stewardship	Disposal of final residues from D&D, ER, and WM operations	Low-Level Mixed Waste	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Disposal	Land
EM Problems Facility Decontamination and Decommissioning (D&D)					Under
Remedial Action (RA)—Soils, Ground Water and Surface Water		TRU Waste	Refer to Vol. 1, Pt. C, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Waste Disposal	Under Retri
Waste Management (WM)					

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Landfill	Envirocare, Utah Landfill WDIS-104-OL	Accepted, Not Available. Negotiations to allow disposal of Oak Ridge Waste at this site are currently underway.	None	Need regulatory approval and funding. The wastes disposed in this landfill must meet the waste acceptance criteria (WAC) for the landfill and obtain approval from the facility manager for the disposal of the wastes. Funding would be required for performing waste analyses (to ensure compliance with the landfill WAC) and waste packaging, handling, and transportation (WPH&T) to the landfill. Estimated funding requirements cannot be forecast because they are dependent upon several factors such as waste volumes, tipping fees, analytical requirements, and WPH&T costs.
Deep Ground Disposal	Borehole Disposal WDIS-100-OL	Pre-demonstration, Not Available. This is a developmental disposal option that has been endorsed by the International Atomic Energy Agency (IAEA) for the disposal of radioactive wastes. The site for the facility would be determined after evaluating the geohydrology and the resulting environmental impacts of potential sites. One potential site is the Conasauga shale formation that underlies parts of East Tennessee.	Additional research, development, and demonstration (RD&D) is required on the method to determine its environmental, economic, and engineering acceptability. This RD&D effort would include for example, identifying candidate disposal sites, the characteristics of the wastes to be disposed in the boreholes, and evaluating the geohydrology of the sites.	Estimated RD&D cost is \$2-3 million (1992 dollars).
Deep Ground Waste Isolation Facilities	Waste Isolation Pilot Plant (WIPP), New Mexico WDIS-105-OL	Demonstration, Not Available. This facility has been designated by DOE for the disposal of transuranic (TRU) wastes but is not available for Oak Ridge waste. TTP Match	Additional research and evaluations need to be performed to obtain regulatory approval to dispose TRU wastes at the site.	Need regulatory approval for TRU waste disposal and funding. Funding would be required for performing waste analyses and WPH&T to ensure compliance with the WIPP waste acceptance criteria. The estimated funding requirements cannot be forecast because they are dependent upon several factors such as waste volumes, analytical requirements, WPH&T, and disposal costs.

Robotics and Automation

The identification of the technologies required to use remedial action, and waste management at ORNL was these technologies is to provide support for other necessities, decontamination, and dismantlement. Hence, in this section as these "other" decommissioning activities and no attention. For example a robotic platform used to deploy a sensor dismantlement tools.

The robotics/ automation technologies were grouped into three categories: (1) Control, and (3) Sensors; with various sub-groups identified. These technologies were selected for this section on the basis of the following criteria: deployment of tools and sensors, adaptability of automation, waste by reduction or elimination of clothing exchange, and handling redundant tasks.

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for Waste Management

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robotics/ automation in the decommissioning, based upon the premise that the primary purpose of sary activities such as characterization, ction of the diagram the problem areas are identified mpt to differentiate between activities was made was assumed to be equally applicable to deploy

l into three main categories: (1) Mechanical, (2) ified under each of the categories. Technologies ng considerations: speed and economy in the ted equipment to repetitive tasks, ability to minimize equirements, and reliability and efficiency in

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
• Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship	Waste Handling and Packaging Waste Surveillance and Inspection	Robotics/automation (R/A) is a cross-cutting technology that provides support to characterization, decontamination, and dismantlement activities. Specifically support is provided for the following tasks. I. Characterization R/A provides methods of deploying sensors and instruments required for in-situ characterization, monitoring, and surveying as described by the Characterization Data Sheets contained in Vol. 3. R/A provides methods for deploying tools to collect and prepare samples for subsequent analysis in analytical laboratories. These technologies are described in ROBA-57 and -59-OL. R/A provides the technologies required for the automation of analytical laboratories as described in ROBA-55 and -56-OL. II. Decontamination Provides methods of deploying decontamination tools and/or performing tasks in areas sufficiently hazardous to preclude human access. Most of these high hazard areas will be encountered in hot cells or shut-down reactors. R/A will also be required for those tasks that generate secondary environmental hazards, e.g., grinding, carbon dioxide blasting, etc. III. Dismantlement Provides methods of deploying dismantlement tools and/or performing tasks in areas within buildings or structures that are sufficiently hazardous to preclude human access. Similar to the decontamination activities, most of these tasks will be in hot cell or shut-down reactors. IV. Waste Retrieval R/A provides the vehicles, mobile platforms, or excavation systems necessary to retrieve radiologically or chemically hazard wastes or soils from waste fields or impoundments. Mobile platforms suitable for these tasks are described in ROBA-1-OL. V. Waste Sorting and Packaging R/A provides the bridge-mounted robotic systems (ROBA-8-OL), the manipulation systems, (ROBA-16-OL), and the End-of-Arm Tooling (ROBA-23 through -26-OL) required for the sorting and repackaging of RH-TRU waste. VI. Surveillance and Inspection R/A provides the vehicles or mobile platforms (ROBA-1-OL) and sensors (ROBA-43 through -46-OL) required for the periodic surveillance and inspection of waste containers in above-ground storage areas.	Refer to Vol. 1, Pt. A, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Robotics/Automation	Mech
EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					

or Waste Management

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Mechanical—Mobility	E Wheeled/Tracked Vehicle ROBA-1-OL Ranking:* E-5-2 (\$3M;N)	Accepted Efficacy: An essential technology. High probability of being useful for reactors, support buildings, and storage areas. Waste: Possible emissions. Decontamination of system after use. TTP Match	Development: -Improved controls to allow more autonomy of operation. -Improved design for decontamination after use.	-Training of operators in advanced control stations. -Development Costs: \$3.0M
	M Mounted Robotic Platform ROBA-8-OL Ranking:* M-2-1 (\$5M;N)	Accepted Efficacy: High, although number of applications may be limited. Waste: Minimal waste will be generated.	None	-Standardization -Development Costs: \$1.0M
	Long-Arm Deployed Robotic Platforms ROBA-9-OL Ranking:*	Accepted Efficacy: Medium. Accurate positioning may be a problem. Limited applications in WM. Waste: Hydraulic fluid during operation. Decontamination fluids after use.	Development: -Flexible body control. -End-point sensing. -Collision avoidance. -Weight-to-payload ratio reduction.	-Cold test beds -Extensive operator training. -Development Costs: \$5.0M
	E Power Sources for Mobile Platforms ROBA-10-OL Ranking:* E-5-1 (\$0.5M;N)	Accepted Efficacy: An essential technology. Accepted status means high efficacy. Waste: Batteries, and exhaust emissions.	Technology Improvement: - Energy storage capacity - Duty cycle availability - Current capacity/discharge rate - Emission control	- No unusual needs - Development Costs: \$1 to 4M
	E Failure Recovery Systems for Mobile Platforms ROBA-11-OL Ranking:* E-5-1 (\$0.5M;N)	Accepted Efficacy: High. This is an essential technology that is well established. Waste: Little or no waste.	None	- No unusual needs - Development Costs: \$0.5M
	M Transportation Systems for Mobile Platforms ROBA-12-OL Ranking:* M-3-1 (\$0.5M;N)	Accepted for small robotic platforms. Predemonstration for large platforms or unique devices. Efficacy: Low. Waste: No waste. The purpose of the technology is to minimize decontamination waste.	Development: -Light-weight containers for medium and heavy duty mobile platform. -Containers that can be easily decontaminated.	- No unusual needs - Development Costs: \$0.5M
Mechanical—Manipulation	E Data/Signal Transmission ROBA-13-OL Ranking:* E-5-1 (\$1M;N)	Accepted Efficacy: High. An essential technology. Specific application may determine type of system required. Waste: None. TTP Match	None	-Testing in representative environments. -Development Costs: \$1.0M
	E Dexterous Manipulators ROBA-16-OL Ranking:* E-5-1 (\$1M;N)	Demonstration Efficacy: High. An essential technology. Waste: Possible hydraulic fluid during use and decon fluid after use. TTP Match	Development: -Redundant manipulator planning and control. -Modular design. -Nonreplica master/slave operation. -Cooperating and coordinated dual arm control.	-Operator training on nonreplica master controllers. -Development Costs: \$1.0M

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EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

ion for Waste Management

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Mechanical—Manipulation	E Compact, High-Capacity Manipulators ROBA-19-OL Ranking:* E-5-1 (\$1M;N)	Evolving Efficacy: High. Constrained access may require this technology.	Development: -Compact, high-output, electrical motors. -Design/fabrication/testing of compact arms.	-No unusual needs -Development Costs: \$1.0M
	H Precise Programmable Motions ROBA-20-O Ranking:* H-5-1 (\$0.5M;N)	Demonstration Efficacy: High. Particularly useful in analytical laboratory. Waste: None. TTP Match	Improvement: -Standardization of mechanical interfaces.	-No unusual needs -Development Costs: \$0.5M
	H Tool Caddies ROBA-21-OL Ranking:* H-4-1 (\$0.5M;N)	Demonstration Efficacy: High. Will increase efficiency of operations and minimize waste. Waste: Decontamination after use.	None	-No unusual needs -Development Costs: \$0.5M
	M Stabilization/Support Mechanisms or Booms ROBA-22-OL Ranking:* M-3-1 (\$0.5M;N)	Demonstration Efficacy: Medium. Some applications may require secondary support due to deteriorating condition of facility. Waste: Minimal. Some decon waste.	Improvement: -Use of high-strength advanced materials.	-No unusual needs -Development Costs: \$0.5M
Mechanical—End-of-Arm Tooling	E End Effectors/Alternatives ROBA-23-OL Ranking:* E-5-2 (\$1M;N)	Demonstration (Predemonstration for multi-fingered grippers) Efficacy: High. An essential technology. Primary interface with tools. Waste: Minimal. TTP Match	Improvement: -Robotic compatibility of tooling.	-Extensive operator training. -Development Costs: \$1.0M
	M End-Effector Changeout Mechanisms ROBA-24-OL Ranking:* M-3-1 (\$0.5M;N)	Demonstration Efficacy: Medium. Applications may be limited. Waste: Minimal decon waste. TTP Match	None	-Integration and testing with specific robotic systems. -Development Costs: \$0.5M
	H General Gripper/Tool Interface ROBA-25-OL Ranking:* H-4-1 (\$0.5M;N)	Accepted Efficacy: High. Many potential applications for tool/sensor gripping. Waste: Minimal decon waste.	None	-No unusual needs. -Development Costs: \$0.5M
	M Force Limiting/Compliant Mechanisms ROBA-26-OL Ranking:* M-3-1 (\$0.5M;N)	Demonstration Efficacy: Medium. Limited applications in WM. Waste: Minimal	None	-No unusual needs. -Development Costs: \$0.5M
Controls—Algorithms	E Control Modes ROBA-27-OL Ranking:* E-5-N (\$N;N)	Accepted for Teleoperation Demonstration for Preprogramming Predemonstration for other modes Efficacy: High. An essential technology. Type of control mode will depend on application. Waste: None.	Development: -Operator assistance technologies. -Sensor interpretation. -Task planning. Improvement: -Better human-machine interfaces.	-University level research. -Development Costs: \$N

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EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					

for Waste Management

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
rois-Algorithms	E Vehicle/Mobility Driving ROBA-28-OL Ranking:* E-5-1 (\$0.5M;N)	Accepted Efficacy: High. An essential technology. Many potential applications. Waste: None.	Development: -Integration of driving algorithms with human-machine interface. -Fuzzy logic driving algorithms.	-Operator training. -Development Costs: \$0.5M
	H Vehicle/Mobility Navigation ROBA-29-OL Ranking:* H-4-1 (\$0.5M;N)	Demonstration Efficacy: Medium. Few applications in WM. Waste: None. TTP Match	Development: -Path planning with nonholonomic constraints. -Real-time sensor feedback.	-Operator training in Global Positioning Systems. -Development Costs: \$0.5M
	H Manipulation (Joint Control) ROBA-30-OL Ranking:* H-4-1 (\$0.5M;N)	Demonstration Efficacy: Medium. Applications may be limited. Usage assumes desired trajectory is known. Waste: None. TTP Match	Development: -Special purpose control algorithms.	-University level research. -Development Costs: \$0.5M
	H Manipulation (Cartesian Control) ROBA-31-OL Ranking:* H-4-1 (\$1M;N)	Demonstration Efficacy: Medium. Applications limited for WM. Operator interaction is more intuitive than other control schemes. Waste: None.	None	-No unusual needs. -Development Costs: \$1.0M
	H Manipulation (Special Purpose Control) ROBA-32-OL Ranking:* H-4-2 (\$1.5M;N)	Predemonstration Efficacy: Medium. Will lead to higher efficiency and safety. Waste: None. TTP Match	Development: -Advanced testbeds for testing and evaluating candidate algorithms.	-Software development. -Development Costs: \$1.5M
	M Manipulation (Redundancy Control) ROBA-33-OL Ranking:* M-3-2 (\$2M;N)	Predemonstration Efficacy: Medium. Arms with greater than 6 D.O.F. may be required for constrained areas. Waste: None. TTP Match	Development: -Advanced testbeds for testing and evaluating candidate algorithms.	-Software development. -Development Costs: \$2.0M
	M Combined Mobility/Manipulation ROBA-34-OL Ranking:* M-2-2 (\$1M;N)	Evolving Efficacy: Low. Minimal improvements in efficiency could be realized. Waste: None.	Development: -Redundancy resolution. -real-time task planning.	-Software development. -Development costs: \$1.0M
	H Safety (Collision Avoidance) ROBA-35-OL Ranking:* H-4-1 (\$1M;N)	Accepted Efficacy: Medium. An increase in efficiency would be realized and potential damage to equipment minimized. Waste: None. TTP Match	None	-Use of customized sensor sites. -Development Costs: \$1.0M
	H Safety (Load/Rate Limiting) ROBA-35-OL Ranking:* H-3-1 (\$0.5M;N)	Accepted Efficacy: Medium. An increase in efficiency would be realized and potential damage to equipment minimized. Waste: None. TTP Match	Improvement: -Testing of load- and rate-limiting algorithms.	-Software development. -Development Costs: \$0.5M

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EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

tion for Waste Management

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Controls—Algorithms	E Emergency Shutdown ROBA-37 Ranking:* E-4-1 (\$0.5M;N)	Accepted for Teleoperation Predemonstration for automated shutdown. Efficacy: High. An essential technology to prevent catastrophic damage to equipment. Waste: None.	None	Software Development. Development Costs: \$0.5M
Controls—Human/Machine Interface	E Console (Fixed/Mobile/Suitcase) ROBA-38-OL Ranking:* E-5-1 (\$0.5M;N) H Console (Data Handling Methods) ROBA-39-OL Ranking:* H-5-1 (\$1M;N) H Operator Interface (Command Input) ROBA-40-OL Ranking:* H-3-1 (\$0.5M;N) H Operator Interface (Operator Assistance) ROBA-41-OL Ranking:* H-3-2 (\$1.5M;N) E Operator Interface (Status/Alert System) ROBA-42-OL Ranking:* E-5-1 (\$0.5M;N)	Demonstrated for fixed or mobile stations. Evolving for suitcase control stations. Efficacy: High. An essential technology for use of robotics/automation. Waste: None. Evolving Efficacy: Medium for WM activities. The need to process, store, and retrieve data is limited. Waste: None. TTP Match Evolving Efficacy: High. Minimizes human error and increases operational efficiency. Waste: None. TTP Match Demonstration for most functions. Evolving for other functions. Efficacy: High. Will allow most efficient operation of "teleoperated" equipment. Waste: None. TTP Match Demonstration for most functions. Evolving for other functions. Efficacy: High. An essential technology to prevent damage to equipment/tools/sensors. Waste: None. TTP Match	Improvement: -Reliability and capacity of data links requires improvements. Development: -Design of heterogeneous data base management systems. -Integration of heterogeneous data sources. -Data fusion. Development: -Language expansion. -Validation of eye-gaze measures/parameters. -Head tracking Development: -Establish validity and completeness of knowledge bases. -Conflict resolution. -Hybrid artificial intelligence architectures. -Dynamic allocation of functions. Development: -Display navigation. -Sensor/data fusion.	-Improved human-machine interfaces. -Development costs: \$0.5M -Development Costs: \$1.0M -Specialized operator training. -Development Costs: \$0.5M -Extensive operator training. -Development Costs: \$1.5M -Extensive operator training. -Development Costs: \$0.5M
Sensors—Perception	E Visual/Aural Systems ROBA-43-OL Ranking:* E-5-1 (\$1M;N) M Range Finders ROBA-44-OL Ranking:* M-3-2 (\$1.5M;N)	Demonstration for 3-D and HDTV. Predemonstration for directional aural. Efficacy: High. An essential technology for Robotics/Automation. Waste: None. Accepted Efficacy: Medium. Applications are limited. Waste: None. TTP Match	Development: -Sensor fusion. -Increased processing speed. -Advanced visualization. Improvement: -Speed/accuracy improvement.	-No unusual needs. -Development Costs: \$1.0M -No unusual needs. -Development Costs: \$1.5M

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EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)					

for Waste Management

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Sensors—Perception	M Proximity Probes ROBA-45-OL Ranking:* M-2-2 (\$1M;N)	Predemonstration Efficacy: Medium. Alternatives to probes may be more cost effective. Waste: None. TTP Match	Improvement: -Increased range and improved presentation to operator.	-No unusual needs -Development Costs: \$1.0M
	M Force/Torque Sensors ROBA-46-OL Ranking:* M-2-1 (\$0.5M;N)	Demonstration Efficacy: Medium. Applications for WM are very limited. Waste: None. TTP Match	Improvement: -Testing of force sensing systems.	-No unusual needs -Development Costs: \$0.5M
Sensors—Control	E Position/Velocity Sensors ROBA-48-OL Ranking:* E-5-1 (\$0.5M;N)	Accepted Efficacy: High for analytical laboratory applications or sensor sweeps. Waste: None.	None	-No unusual needs -Development Costs: \$0.5M
	H Force/Torque ROBA-50-OL Ranking:* H-3-1 (\$0.5M;N)	Demonstration Efficacy: Medium. Few applications in WM activities. The need for force or torque control to prevent damage is limited. Waste: None. TTP Match	Improvement: -Impulse force resolution. -Stability.	-No unusual needs -Development Costs: \$0.5M
	H Proximity Probes as Control Sensors ROBA-51-OL Ranking:* H-3-1 (\$1M;N)	Accepted for small volumes. Predemonstration for large volumes. Efficacy: Medium. Alternatives to sensors may be more cost effective. Waste: None.	Improvement: -Increased range and better signal quality.	-No unusual needs -Development Costs: \$1.0M
	H Tooling Sensors ROBA-52-OL Ranking:* H-3-1 (\$0.5M;N)	Predemonstration Efficacy: High. This technology is required to prevent damage to tools or sensors. Waste: None. TTP Match	Development: -Development/testing of tactile sensing sensors, force sensors, and proximity sensors.	-Operator training -Development Costs: \$0.5M
Technologies	E Field Hardening ROBA-53-OL Ranking:* E-5-1 (\$0.5M;N)	Demonstration Efficacy: Medium. The primary environmental concern in WM is high radiation fields as described in ROBA-54-OL. Ranking:* The ability to be decontaminated is essential for mechanical devices. Waste: None. TTP Match	None	-Testing of hardened systems. -Development Costs: \$0.5M
	M Radiation Hardening ROBA-54-OL Ranking:* M-3-2 (\$2M;N)	Demonstration Efficacy: High. An essential technology for many WM activities, particularly reactors and hot cells. Waste: None. TTP Match	None	-Extensive radiation testing of existing electronic chips. -Development Cost: \$2.0M

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EM Problems • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM)				

ation for Waste Management

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Other Technologies				
E	Integrated Automated Analytical Laboratory ROBA-55-OL <i>Ranking:*</i> E-5-2 (\$3M;N)	Predemonstration for hardware systems. Evolving for data interpretation. Efficacy: High. High sample loading in analytical laboratories require maximum use of automation. Waste: None. TTP Match	Development: -Development of Standard Laboratory Modules (SLM) for Sample Preparation, Analytical Instruments, and Data Interpretation.	-Extensive testing of SLM's. -EPA approval of SLM. -Development Costs: \$3.0M
E	Information Management for Sample Handling ROBA-56-OL <i>Ranking:*</i> E-5-1 (\$1M;N)	Demonstration Efficacy: High. Waste: None. TTP Match	Development: -Automatic data entry systems. -Improved reliability and auditability.	-No unusual needs. -Development Costs: \$1.0M
E	Sample Collection ROBA-57-OL <i>Ranking:*</i> E-5-1 (\$1.5M;N)	Evolving. Efficacy: Medium. Alternative, but slower methods of sample collection are available and may be more cost effective. Waste: None. TTP Match	Development: -Mobile platforms to deploy and manipulate sample collection tools. -Suitable robotic end-effectors.	-No unusual needs. -Development Costs: \$1.5M
M	Characterization Sensor Integration ROBA-58-OL <i>Ranking:*</i> M-3-2 (\$1M;N)	Demonstration Efficacy: Low. May not be cost effective. Waste: None. TTP Match	Development: -Signal conditioning. -Data/Signal transmission.	-No unusual needs. -Development Costs: \$1.0M
E	Sample Preparation ROBA-59-OL <i>Ranking:*</i> E-5-1 (\$1M;N)	Evolving. Efficacy: Medium. Will minimize work to be performed in analytical laboratory. Waste: Usual amount of waste normally generated in sample preparation operations. TTP Match	None	-Adaptation of current sample preparation tools to robotic devices. -Development Costs: \$1.0M

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