

**Hazardous Waste, Deactivation, Dismantlement,
and Cleanup Workers
Exposure Assessment Feasibility Study
at the Department of Energy Oak Ridge Reservation**

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This background document addresses hazardous waste, deactivation, dismantlement, and clean up worker activities at the Department of Energy (DOE) Oak Ridge Reservation facilities in Oak Ridge, Tennessee. The work was performed by Oak Ridge Associated Universities Center for Epidemiologic Research ORAU/CER, P.O. Box 117, Oak Ridge, TN 37830 under Work Authorization 2695-018 within Contract 200-93-2695 for the National Institute for Occupational Safety and Health (NIOSH). The NIOSH project officers responsible for the management and technical direction of the project were Steven H. Ahrenholz, John J. Cardarelli II, and Tim Taulbee. Assistance with document review and comment was provided by Larry J. Elliott, NIOSH. William G. Tankersley, Charles M. West, and Frederick E. Gray of ORAU/CER were responsible for the discovery, acquisition, and assembly of data into the final report. This document is the major deliverable pertaining to the ORR facilities for Phase I of the Hazardous Waste, Deactivation, Dismantlement, and Cleanup Workers Exposure Assessment Study being conducted by the NIOSH Division of Surveillance, Hazard Evaluations, and Field Studies - Health-Related Energy Research Branch. NIOSH conducts worker health studies at the various DOE sites through a Memorandum of Understanding executed by DOE and the Department of Health and Human Services (DHHS) in 1990 and renewed in 1996. NIOSH is one of the Centers for Disease Control and Prevention within DHHS.

TABLE OF CONTENTS

Section	Page #
List of Tables	iv
List of Figures	v
List of Acronyms	vi
Preface	1
1.0 Summary	3
2.0 Purpose of Project	5
3.0 Methods	6
3.1 Initial project strategy meeting	6
3.2 Efforts to collect additional information	7
3.3 General procedures	8
3.4 Identification, location, and retrieval of pertinent information	8
3.5 Review of collected information	8
3.6 Assemblage of project materials	9
3.7 Worker classification	9
3.8 Reporting	10
4.0 Site Overview	11
4.1 History	11
5.0 Activities	13
5.1 Overview	13
5.2 Sites previously remediated	14
5.3 Activities descriptions (ER and De/Di)	19
5.4 Activities involving waste	28
6.0 Workforce Demographics	37
6.1 General	37
6.2 Current status of M&O workforce	38
6.3 Locating subcontract workers for epidemiologic study	54
7.0 Technologies	55
7.1 Descriptions of major technologies	55
7.2 Tables of technologies	65
8.0 Exposures	93
8.1 Potential exposures	93
8.2 Actual exposures	96
9.0 Site Maps	105
10.0 Contacts	111

11.0	Data Sources and Repositories	119
12.0	References	122
12.1	Work cited	122
12.2	Bibliography	125
13.0	Submitted Materials	134

LIST OF TABLES

Table	Page #
Table 5-1 Completed CERCLA Actions Not Requiring Performance Monitoring	15
Table 5-2 Completed CERCLA Actions Requiring Performance Monitoring	16
Table 5-3 CERCLA Actions Not Fully Implemented or Results from Monitoring Not Available	18
Table 5-4 ORR ER and De/Di Activities Ordered by Average Subactivity Priority Ranking ..	23
Table 5-5 ORR ER and De/Di Activities by Worker Category	24
Table 5-6 ORR WM Activities Ordered by Average Subactivity Priority Ranking	32
Table 5-7 ORR WM Activities by Worker Category	33
Table 6-1 ORR Employment Estimate (Full-time Equivalents) FY 1997-FY 2006	38
Table 6-2 LMES Work Force Report for Central Staff (October 1997)	39
Table 6-3 LMES Work Force Report for EMEF ETTP (October 1997)	41
Table 6-4 LMES Work Force Report for EMEF Y-12 (October 1997)	42
Table 6-5 ORNL Work Force Report (October 31, 1997)	43
Table 6-6 Description of ORR Facilities-Designated Waste Workers	45
Table 6-7 ORR Remediation Past and Current Subcontractors (1995)	46
Table 7-1 Remediation Technologies by Watershed - ORR	65
Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR	67
Table 8-1 Y-12 Employee 1996 Occupation and Dose Information as reported by REMS ...	97
Table 8-2 ORNL Employee 1996 Occupation and Dose Information as Reported by REMS .	98
Table 8-3 ETTP Employees 1996 Occupation and Dose Information as Reported by REMS	99
Table 8-4 Y-12 HWW, CW, and De/Di Worker Employment Group and Dose Information .	100
Table 8-5 ORNL HWW, CW, and De/Di Worker Employment Group and Dose Information	101
Table 8-6 ETTP HWW, CW, and De/Di Worker Employment Group and Dose Information .	102
Table 8-7 ORNL Subcontractors HW, CW, De, and Di Worker Employment Group and Dose Information	103
Table 8-8 Summary of Industrial Hygiene Monitoring of Y-12 HW Employees	104
Table 10-1 Directory of Contacts Providing Information or Data	111

LIST OF FIGURES

Figure	Page #
Figure 9-1 Map of Oak Ridge Operations Office sites	105
Figure 9-2 Map of Oak Ridge Reservation within Oak Ridge and Knoxville areas	106
Figure 9-3 Map of Oak Ridge Reservation National Priority List Sites	107
Figure 9-4 Aerial Drawing of Oak Ridge National Laboratory	108
Figure 9-5 Aerial Drawing of the Y-12 Plant	109
Figure 9-6 Aerial Drawing of East Tennessee Technology Park	110

LIST OF ACRONYMS

ASO	Analytical Services Organization
ATLC	Atomic Trades and Labor Council
BC	Bear Creek
BJC	Bechtel Jacobs Company
BV	Bethel Valley
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CH	Contact-Handled
CW	Cleanup Worker
DeW	Deactivation Worker
D&D	Decontamination and Decommissioning
DHHS	Department of Health and Human Services
DiW	Dismantlement Worker
DNFSB	Defense Nuclear Facility Safety Board
DOE	U.S. Department of Energy
EM	Environmental Management
EMEF	Environmental Management and Enrichment Facilities
EPA	U.S. Environmental Protection Agency
ER	Environment Restoration
ETTP	East Tennessee Technology Park, K-25
FFA	Federal Facility Agreement
FFCA	Federal Facilities Compliance Act
FOIA	Freedom of Information Act
FS	Feasibility Study
HW	Hazardous Waste

HWW	Hazardous Waste Worker
IH	Industrial Hygiene
KAFaD	K-25 Auxiliary Facilities and Demolition
LCB	Life Cycle Baseline
LLLW	Low-Level Liquid Waste
LLW	Low-Level Waste
LMER	Lockheed Martin Energy Research, Incorporated
LMES	Lockheed Martin Energy Systems, Incorporated
M&I	Management and Integration
MLLW	Mixed Low-Level Waste
MOU	Memorandum of Understanding
MSRE	Molten Salt Reactor Experiment
MW	Megawatt
NIOSH	National Institute for Occupational Safety and Health
OCAW	Oil, Chemical, and Atomic Workers
ORAU/CER	Oak Ridge Associated Universities/Center for Epidemiologic Research
ORNL	Oak Ridge National Laboratory, X-10
ORO	Oak Ridge Operations
ORR	Oak Ridge Reservation
PBS	Project Breakdown Structure
PCBs	Polychlorinated Biphenyls
RA	Remedial Action
RCRA	Resource Conservation and Recovery Act
REMS	Radiation Exposure Monitoring System
RH	Remote-Handled
RI	Remedial Investigation

ROD	Record of Decision
RW	Radioactive Waste
S&M	Surveillance and maintenance
SRS	Savannah River Site
SVE	Soil Vapor Extraction
SW	Sanitary Waste
SWSA	Solid Waste Storage Area
TEDE	Total Effective Dose Equivalent
TRU	Transuranic
TSCA	Toxic Substances Control Act
UEFPC	Upper East Fork Poplar Creek
VOCs	Volatile Organic Compounds
WAG	Waste Area Grouping
WOC	White Oak Creek
WOCE	White Oak Creek Embayment

PREFACE

The Department of Health and Human Services (DHHS), subsequent to the implementation of a Memorandum of Understanding (MOU) between the Departments of Energy (DOE) and DHHS, conducts a program of independent occupational and environmental research studies with funding from DOE. Research conducted under this MOU focuses on examination of health effects that may result from past, current, or future DOE operations. The National Institute for Occupational Safety and Health (NIOSH) within the Centers for Disease Control and Prevention, DHHS is charged with the conduct of the occupational health research component of this MOU. This document on the DOE Oak Ridge Reservation (ORR) facilities, including the Y-12 Plant, Oak Ridge National Laboratory (ORNL), and East Tennessee Technology Park (ETTP), represents the site-specific background document prepared for the feasibility phase of the NIOSH project titled Exposure Assessment of Hazardous Waste, Deactivation, Dismantlement, and Cleanup Workers.

The purpose of this document is to assemble information relevant to activities involving hazardous waste workers (HWW), deactivation workers (DeW), dismantlement workers (DiW), and cleanup workers (CW) at the DOE ORR facilities. Four primary objectives addressed include:

- Identification of HWW, DeW, DiW, and CW activities anticipated or in progress from the recent past through the next 5-10 years
- Demographic definition of the workforce performing these activities at the ORR facilities
- Identification of the technologies in use or proposed for use (including considerations regarding health and safety impact upon the workforce)
- Assembly of summary information for potential chemical, mixed, and radiological contaminant exposures that may be encountered during these activities.

The information herein is drawn predominantly from existing DOE and contractor documents or reports. Other source documents may include those assembled for compliance purposes or to define activities dictated by site deactivation, dismantlement, restoration, transition, and cleanup agreements with local, state, and federal authorities, or as mandated by DOE. This assembly of information is to support research hypothesis development in the next phase of this project. It will also provide insight and initial data for study feasibility and planning considerations.

This document is descriptive in nature; the depth and scope of the information assembled provides a midrange presentation of data. Grappling with the needs for substantive information while avoiding premature details and acknowledging changes in data relevance as time elapses influenced both the character and decisions that went into the assembly of the document. The data collection process limited the need for intensive site involvement. The resource documents used for the report, as well as the physical location for the documents, are referenced. Information that could not be obtained or which did not exist in an accessible form is also identified.

The intended application of this document is to provide an overview of HWW, DeW, DiW, and CW activities at the DOE ORR facilities. The information is presented in two formats:

- A textual description
- A tabular presentation

The intent of this approach is to permit disassembly of the document to facilitate combining similar information for different sites, ideally facilitating an assessment of the feasibility of involving multiple sites in a comprehensive research study.

The limitations of this document should be recognized. The changes in organizational structure, workforce composition, and site activities at the DOE sites involving HWWs, DeWs, DiWs, and CWs appear to be increasing in frequency and complexity. This coincides with a compression of the time frame committed to cleaning up sites by DOE, resource reductions, and an increase in the use of autonomous multi-tiered subcontracting. Numerical data are presented as found in the cited references. No verification of summary data provided by the sites or obtained from preexisting documents has been performed. Obstacles that may become substantial regarding exposure characterization of workforces on site include modification of site programs documenting worker exposures; shifts away from a stable, long-term workforce; and changes in the structure of site management. The information presented may also constitute tangential information related to the objectives specified for this phase of the project.

1.0 Summary

Since the signing of an MOU between DOE and DHHS in 1990, NIOSH has had responsibility for management or conduct of analytical health studies of workers at DOE facilities. Unlike most previous DOE-related epidemiologic studies which have focused on past worker exposure from normal facility operations, this report pertains to a feasibility study aimed at identifying and describing records relating to the population of workers at the ORR facilities in Oak Ridge, Tennessee who have been, are currently, or who will be involved with environmental management (EM), including environmental restoration (ER) and waste management (WM) activities.¹ The ORR includes the Y-12 Plant and ETTP managed by Lockheed Martin Energy Systems, Inc. (LMES), and ORNL managed by Lockheed Martin Energy Research, Inc. (LMER). In addition to these operations management organizations, Bechtel Jacobs Corporation (BJC) is the Management and Integration (M&I) contractor for all ER and WM activities at all three facilities. In many cases, accelerated cleanup schedules are planned for DOE sites across the country with the intention of site remediation within the scope of a 10-year period. There is concern that the workers involved in these cleanup activities, who might encounter hazards to which their predecessors (i.e., production workers) were not exposed, may not be traceable upon completion of these tasks. It is this concern that initiated and encouraged this study.

The population of interest for the study included workers directly involved in ER or WM activities, as well as persons providing support, supervision, and monitoring, if these persons are at risk of exposure. For the purpose of the study, NIOSH initially defined the population of interest to include workers involved in HW, D&D* and CW activities. The population of interest included prime contractor workers and subcontractor workers holding various job titles. The focus of the study included recent past (1992 to 1996), present, and proposed future (1997 to 2006) remediation activities, current and proposed technologies, and worker group demographics and occupational exposures.

The first phase of the study was to identify, review, and summarize documentation regarding the study population for use as a foundation upon which further studies may be built. Activities involving workers of interest were identified chiefly from information collected from publicly available documents and from interviews with ORR personnel. A limited amount of data was garnered from documents provided by ORR not normally made available to the public. The same set of resources were used to collect other information relevant to the activities identified. Characteristics of the work force(s) involved in these activities and the technologies presently used or proposed for use in these activities were investigated. Information on the types, quantity, availability, and level of radiation exposure data pertaining to the study population, as well as the location and oversight responsibility of the exposure data, were investigated. A large number of personal contacts were made during the course of this project, and a large number of resources were accessed or identified. A detailed listing of these contacts and references is included as part of this formal document and can be found in Sections 10, 11, and 12.

Due to the physical volume of information identified during this study, and due to limitations on retrieval and reproduction costs, only a fraction of the identified documents are included as part of the physical product of the study. The documents and other materials that are included as products of the study were selected on the basis of their value as primary, example, or rare documents or materials. Efforts were made to provide ample information necessary to physically retrieve any or all of the other identified materials if and when that is deemed useful.

During the course of the study, the partnership agreement between DOE and the DHHS, as described in the December 24, 1990 MOU between the two agencies, served to facilitate communication among the participating parties and the gathering of necessary worker group data for the study.

* The nomenclature relative to D&D workers changed while this report was being prepared. As first used, D&D workers were usually understood to include not only decontamination and decommissioning workers, but also deactivation and dismantlement workers. In an effort to make the nomenclature more precise and more relevant to most DOE facilities, NIOSH redefined these classifications in June 1997. In the revised nomenclature, Deactivation Worker (DeW) includes workers engaged in decontamination, decommissioning, deactivation, and small-scale dismantlement work. Dismantlement Worker (DiW) refers to workers who dismantle, disassemble, or demolish large-scale structures or components and remove the residue from the facility. For accuracy, the D&D designation was maintained whenever it was used in a resource document presented in this report. Otherwise, the DeW and DiW designations were used.

2.0 Purpose of Project

As defined in the NIOSH Work Assignment 2695-018¹, the purpose of this project was to identify, locate, and collect information, subject to availability, on activities and workers involved with waste streams within the DOE ORR facilities. The workers of interest included those described as hazardous waste, deactivation, dismantlement, and cleanup workers. Specifically, the following tasks were prescribed:

1. Identify and catalog HWW, DeW, DiW, and CW activities in progress or anticipated over the next 5-10 years at the ORR facilities.
2. Describe and characterize the HWW, DeW, DiW, and CW populations at the ORR sites.
3. Identify and provide limited descriptions of the major technologies used in the past, in current use, or planned for use in the future in the activities identified in (1), above.
4. Assemble a catalog of exposure information, delineated into chemical, mixed, and radiological types, available at the ORR for the workers identified in (2), above.
5. Construct a catalog of resources and contacts used to collect information for the project.

The amount of information and data identified, collected, or reviewed for this project was immense and widely scattered. In producing the major reports describing the procedures and results of the project, every attempt was made to use the most credible sources; however, because of limitations of time and personnel prescribed by the NIOSH Statement of Work, it was not possible to validate information or data supplied by the study sites or collected from previously published documents.

3.0 Methods

3.1 Initial project strategy meeting

In March, 1997, researchers from Oak Ridge Associated Universities (ORAU), Center for Epidemiologic Research (CER) and the NIOSH project officer met with representatives of the three ORR facilities (Y-12, ORNL, ETPP) to describe the HWW, DeW, DiW, and CW projects and to outline the types and levels of effort anticipated to accomplish the project goals. The meeting lasted approximately three hours and was extremely well organized and implemented. As the last piece of business accomplished at the meeting, plans were made for arranging multiple appointments with appropriate contacts to further discuss project strategies. The following day, a schedule of appointments for meetings of the NIOSH and ORAU/CER representatives with a number of ORR contacts was delivered by fax, and these appointments were attended as scheduled during the next 2 ½ days. Following is a list of persons attending this initial meeting.

Steven Ahrenholz	NIOSH	Technical Advisor
Bill Tankersley	ORAU/CER	Project Manager
Bobby K. Williams	Y-12	Facility Safety
Larry S. Key	LMES	Waste Management
Clarence Kirkpatrick	LMES	Analytical Services Organization ASO)
Russell Rickard	ETTP	Industrial Hygiene (IH)
Jon Pack	Y-12	Dosimetry
Sam Guy	ETTP	Waste Management
Steve Foster	ETTP	EM Dept.
Mickey Sizemore	DOE	EM Support
Dave Barncord	ATLC/ORNL	Union representative
Gerald Watson	LMER	Human Resources
Peery Shaffer	OCAW/ETTP	Union representative
Olga P. Henley	Y-12	Human Resources
Cathy A. Groover	Y-12	IH (Waste Management)
Steven W. Wiley	LMES	Health and Safety Liaison
Michael Harrison	ETTP	Facility Safety
Fred Mynatt	LMES	
George Thoeming	ORO	Classification
Gabe Marciante	ORO	Classification
G. B. Boroughs	ETTP	CICO
Nancy C. Jacobus	LMES	Analytical Services
Linda Hill	ORNL	Liaison
Joe Weaver	ORNL	Liaison
Nick Ingle	ORAU/CER	IH (Hazards Assessment)
Bill Sliski	Y-12	IH (Hazardous Waste Operations and Emergency Response Mgr.)
Wayne Lawless	Y-12	IH

3.2 Efforts to collect additional information

Included in comments from NIOSH following initial review of the draft of this document was a request to collect more specific information on (1) the contaminants of concern for the previously identified subactivities and (2) the number and occupations of the workers involved in the various subactivities. In response to this request, an explicit proposal was made to identify plant personnel most likely to have, or have access to, the requested information and once more submit formal requests for such information. Subsequently, a meeting to request the specified information was held with appropriate representatives from LMES, LMER, and BJC. The meeting was held in December 1998 and was also attended by DOE representatives and by Mr. Larry Elliott of NIOSH.

No single resource was identified for the information sought for the NIOSH study. However, during the meeting BJC representatives announced that BJC had already committed to publishing a Life Cycle Baseline (LCB) document², due to be published in April 1999, that should contain much of the needed information. After considerable discussion of the proposed content of the report, all attendees agreed that the LCB document offered considerable potential benefit for the NIOSH study. In concurrence with Mr. Elliott, a decision was made to delay the NIOSH report on the ORR facilities until the LCB document was available.

The final publication of the LCB document was delayed until June 1, 1999. Due to a combination of factors including organizational changes within BJC, BJC employee vacations, business travel, and administrative delays by BJC due to the company's short tenure on the ORR cleanup project and consequently, its unfamiliarity with the NIOSH/DOE agreement, the document was not available to ORAU/CER until late July 1999.

Once received, the LCB document was reviewed to ascertain what information was contained within that might be useful for the ORR report. The LCB was found to be a very comprehensive document in general and was comprised of the following sections:

1. Guidelines, i.e., guidance on how the LCBs were to be written
2. Spreadsheets showing cost by FY of the various subactivities
3. Subactivities listed in order by overall cost
4. A management summary
5. A summary description of the LCB for each subactivity.

Only Section 5 contained information on contaminants and the workforces. A representative fraction (~10%) of the designated subactivities were studied, of which only one included information on workforce demographics. Of the Toxic Substances Control Act (TSCA) Incineration Operation, the LCB document stated, "A workforce includes 17 operators, 6 instrument mechanics, 2 electricians, and 4 maintenance mechanics" and that "TSCA1 remains the only treatment option in the DOE complex for PCB with rad contamination." The inclusion of such information was a stark exception. Infrequently, a few job titles were mentioned, but no other numbers were found. Occasionally, a major contaminant was listed, usually in the course of describing the processes within the subactivity. No consistent or comprehensive listings of contaminants were found. It is possible that a complete search of the LCB document may have discovered additional information on demographics or contaminants of concern, but time and

cost constraints prohibited such an effort. As a consequence, it was not possible, or practical, to augment the information previously collected with information from the LCB document.

3.3 General procedures

Methods used to complete this work may be categorized into the following activities:

- Project management and primary communications
- Field searching
- Data management.

The actual pathway to a particular fact of information or to a document may be quite complex and involve a number of different activities.

Following is a brief description of the primary steps taken in performing the work resulting in this document and other associated products of this project:

- Activities of significance, undertaken in the performance of the project, were recorded in an electronic log to which all research team members had access.
- One team member was designated to periodically reorganize and edit the log to improve its usefulness and remove redundant information.

3.4 Identification, location, and retrieval of pertinent information

At the beginning of the study, the whereabouts or even the existence of data likely to be relevant to the study were unknown. An initial strategy planning meeting of the research team was held to construct a "wish list" of documents that should provide the information needed for the study and make personnel assignments for various tasks within the project. The necessary tasks were generally divided into three categories:

- Communications with facility oversight personnel and establishment of major new contacts
- Activities at local and remote document repositories aimed at locating and retrieval of hard copy documents.
- Search for and either retrieval or mapping the location of electronic documents.

A list of references and documents used in the development of this report may be found in Section 12.

3.5 Review of collected information

Some documents or materials (maps, graphics, listings, etc.) collected were obviously valuable for the study. Examples of this kind of information include the DOE implemented 10-year plan³, current plant-generated documents listing formally designated WM or ER activities, and tables showing distributions of workers by occupational type. A large amount of other information was identified during personal and phone interviews with contacts identified as having knowledge

pertinent to the study. The relevance and importance of this information ranged from remotely relevant to critically important to understanding the current status of remediation activities at the ORR. A considerable amount of the information discovered was collected for review, or reviewed where resident. A large fraction of the information discovered was not collected because of the sheer volume. Other information was not available for physical collection. As much as feasible, the identity and location of all information judged relevant to the study are provided in Sections 11 and 12 of this report

3.6 Assemblage of project materials

As information was gathered through site visits and telephone contacts, it was organized by the team members utilizing a central log and various tables (activities, technologies, contacts). Each team member would record their activities in the central log as the research was done and information-bearing materials and concepts were gathered. This method of organization proved helpful in eliminating duplication of work among the research team. Hard copy documents were located in a central office area along with notes and bibliographic citations to relevant documents of interest to the project. All team members had access to the organization tools and documents for review during the research process. The report bibliography was compiled from this information collection.

3.7 Worker classification

The worker classification for purposes of this report was prescribed by NIOSH and reported in a revision of the Fernald Report⁴. The following were excerpted from that document and edited to fit the ORR situation.

1. Hazardous Waste Worker (HWW)

That portion of the ORR waged workforce involved with sampling, surveying, containerization, treatment, transportation, storage, disposal, or remediation of hazardous waste (i.e., chemically-contaminated wood, metal, concrete, asphalt, debris, process residues, discarded product, contact waste, etc.). HWWs may also deal with hazardous waste with a radiological component.

2. Cleanup Worker (CW)

Those ORR waged workers who are involved with systems operation and maintenance (treatment, transportation, or storage and disposal of all levels of radioactive waste (RW) generated during day-to-day activities at the ORR facilities). The CW identifies, weighs, samples, surveys, containerizes, stores, and prepares RW for shipment or storage. CWs are usually not associated with hazardous or mixed waste; this is the domain of the HWW.

3. Deactivation Worker (DeW)

Those workers responsible for placing a facility in a safe and stable condition to minimize the long-term cost of a surveillance and maintenance (S&M) program that protects workers, the public, and the environment. Actions include the removal of fuel, draining and/or de-energizing of nonessential systems, removal of stored radioactive, mixed, and hazardous waste materials. Deactivation can also include decontamination activities and small-scale dismantlement of process lines, tanks, and equipment. Decommissioning takes

place after deactivation and includes S&M. If this S&M result in some exposure potential, those persons performing these activities would be included in the deactivation group.

4. Dismantlement Worker (DiW)

Those workers responsible for the dismantlement, disassembly, or demolition and removal of any large-scale structure, systems, or components and of the residue from the facility.

3.8 Reporting

Reports of progress for the study were presented in four forms:

- Monthly reports
- Informal reports
- Draft reports
- Final reports.

Monthly reports were submitted that included recent progress, problems encountered or changes implemented in the project, and budget information. Informal reports, both written and verbal, were submitted on an irregular but frequent basis to the NIOSH Technical Officer. This provided a mechanism for quickly addressing problems or needs encountered during the course of the project. As prescribed in the ORAU/CER Work Plan¹, near the completion of the project, a draft report of the entire project was submitted to the NIOSH Technical Officer for comments. Appropriate changes to the draft report, based on the NIOSH review, were integrated into the draft, resulting in a final report of methods and findings (this document) to be submitted at the completion of the project.

4.0 Site Overview

4.1 History

The three DOE facilities located on the ORR in eastern Tennessee (ORNL, ETTP, Y-12) which are the subjects of this investigation were built as a part of the World War II Manhattan Project. The DOE Oak Ridge Operations Office (ORO) manages and oversees operations at all three sites; however, most day-to-day functions of ORNL, ETTP, and Y-12 have been delegated to DOE site offices which are headed by site office managers. A brief description of each facility and its mission has been included to clarify its role in the DOE complex.

ORNL

Weapons research facilities were established at the site of the ORNL in 1943. The laboratory's original mission was to produce and separate the first gram quantities of plutonium used to produce the atomic bomb. As nuclear weapons development decreased over time, the scope of ORNL's role expanded to include production of isotopes and research in basic and environmental sciences, hazardous and radioactive materials, and RW disposal.

ORNL is one of the nation's largest multidisciplinary and multiprogram laboratories and research facilities. Conducting leading-edge nonweapons research and development is its current primary mission. This includes performing applied research and engineering development for DOE programs in nuclear fusion and fission, energy conservation, fossil fuels, and other energy technologies. In addition, ORNL performs basic scientific research in selected areas of the physical, life, and environmental sciences and contributes time and resources to the national initiative for the improvement of science and mathematics education. Environmental restoration and waste management activities are ongoing. The condition of sites within the facility are continually assessed to determine contamination levels and the best methods for cleanup or containment.

ETTP (K-25 Site)

The Gaseous Diffusion Plant at the K-25 Site was built to supply enriched uranium for nuclear weapons production. Construction at K-25 Site began in 1943 and the K-25 Building was fully operable by August 1945. Additional buildings housing other enrichment process equipment were operable by 1956. The site was used primarily for the production of highly enriched uranium for nuclear weapons through 1964. In response to the national postwar emphasis on nuclear power, plant operations were modified to include the production of commercial-grade, low-enrichment uranium. Because of the declining demand for enriched uranium, the enrichment process was placed on standby in 1985 and shut down permanently in 1987. The site also was a host for centrifuge facilities constructed as part of a program to develop and demonstrate this uranium-enrichment technology. These facilities have also been shut down.

In May 1993, the K-25 Site was chosen to be both the Center for Environmental Technology and the Center for Waste Management. The site's current mission encompasses environmental restoration, waste management, technology development and demonstration, education and training, and technology transfer for the Department of Energy, other agencies, and the public. Another important aspect of the site's mission is planning for industrial reuse of the facilities by other government agencies or private industry. In 1997, the name of the facility was changed to East Tennessee Technology Park to encourage its use by the private sector.

Assessment of the condition and contamination at the facility are in progress to determine the optimal methods of cleanup or containment that will be implemented as funding becomes available. Priorities for these activities are being set by evaluating the risk to the public and environment. Since the former gaseous diffusion facilities are now in safe shutdown condition, full-scale decommissioning of some structures is underway. The focus of initial decommissioning efforts has been demolition of cooling towers and a large powerhouse structure. The facility has been placed on the Environmental Protection Agency (EPA) National Priorities List as a part of the ORR. A Federal Facility Agreement (FFA) signed by DOE, the EPA Region IV, and the State of Tennessee provides a framework for environmental restoration.

Y-12 Plant

The Y-12 Plant is located at the eastern section of the ORR. The plant occupies an area approximately 0.67 mile wide and 3.2 miles long and consists of 531 buildings that cover more than 7,000,000 square feet of space. Y-12 was constructed in 1943 to separate fissionable isotopes of uranium (^{235}U) by the electromagnetic process. Over the years, Y-12 became a highly sophisticated nuclear weapons component manufacturing facility and development engineering organization. The plant receives, stores, and protects uranium and lithium materials and parts; dismantles nuclear weapons components; and serves as a government repository for enriched uranium.

Y-12 has many treatment, storage, or disposal facilities for hazardous and radioactive materials. Included are landfills, incinerators, storage areas, impoundments, and treatment plants which are under investigation to determine remediation requirements. The best methods of remediation are also being considered for the many contaminants present, among which are metals, radionuclides, volatile organic compounds (VOCs), and nitrates.

5.0 Activities

5.1 Overview

In December 1989, the three major ORR facilities (Y-12, ORNL, K-25 now ETTP) and other ORR locations were placed on the EPA National Priority List and specified as actual or potential sources of contamination of groundwater, surface water, and air. That placement dictated that DOE follow the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), usually referred to as the Superfund Act.

Adherence to this act requires that EPA oversee the remediation of these Oak Ridge facilities and sites. This cleanup is and has been regulated by the FFA among DOE, EPA, and the State of Tennessee. The methods of remediation were determined when DOE, through its regular operating contractor for the facilities or other contractors or subcontractors, performs a remedial investigation (RI) and feasibility study (FS), and develops a preferred alternative for remediating the situation in question. This alternative is then offered to the public, EPA, and State of Tennessee for comment. With consideration of these comments, a remedy is selected, and this selection is documented in a Record of Decision (ROD). Once this is accomplished the site can be remediated as and when proposed, if the funding is available.

At the initial overview meeting for this study, held at Oak Ridge in March 1997, it was determined that numerous activities involving CWs, DeWs, and DiWs were ongoing or planned. Fewer activities specifically involving HWWs were identified. Since this meeting, it has been determined that a large number of LMES and subcontractor workers participate in these activities. Activities that fit the model prescribed in the ORAU/CER Work Plan¹ include storage, treatment, and disposal of mixed low-level waste (MLLW); storage, treatment, and disposal of low-level waste (LLW); removal and transfer of contaminated materials; dismantlement and demolition of contaminated structures; and operation of waste processing facilities.

An especially significant finding during the initial collection of information pertains to the functional relationships among the three ORR facilities. While the three facilities are still operated independently, with regards to remediation activities, the three facilities are linked by a formal relationship. This formal relationship is evident by existence of an organizational entity called the Environmental Management and Enrichment Facilities (EMEF). Within this organizational arrangement, the Y-12 Plant and ETTP are much more closely aligned. During the course of this study, we were assisted by two liaison persons, one functioning for ORNL, the other functioning for Y-12 and ETTP.

As prescribed in the ORAU/CER Work Plan¹, the first task within the project was to furnish a catalog and brief description of HWW, DeW, DiW, and CW activities (past, present, and planned for the next 10 years). Providing information on planned or anticipated activities assumed that decisions regarding these activities had been made and documented. However, considerable study of the available information indicated that future activities were difficult to define since the levels of funding for subsequent fiscal years are uncertain. Because funding levels for ER and WM are uncertain, operational information on activities anticipated in the next 5-10 years has been very imprecise and variable. In addition, the degrees of certainty and priority levels of specific activities, already included in established budgets, appear to be continually subject to change such that it may be considered fluid.

The prioritization of remediation activities depends on such factors as public interest, federal and local health agency concern, and scientific urgency. All of these factors are significantly

influenced by federal and local politics, both of which are subsequently influenced by DOE and its contractors as each facility maneuvers for a larger share of remediation activity funding. These remediation activities, of course, are greatly influenced in the public arena when national and local politicians become involved. The situation is even further complicated by the recent interest by the Assistant Secretary of Energy in finishing the bulk of this work within the next 10 years under cost and inflation constraints.

Aside from the uncertainty and fluidness that generally characterize the total DOE environmental management and remediation efforts, from the perspective of this NIOSH study, a number of practical problems exist. Within the last 10 years, three activity organizational structures have been used. Initially, activities were organized or grouped by facility (Y-12, ORNL, ETTP). Subsequently, a system of Waste Area Groupings (WAGs) was established based on physical locations of the remediation sites. Most recently, a reorganization of remediation activities by watershed was established. The later activity organization is logical, based on the fact that much of the contamination is in flowing or dammed waters, and therefore activities contributing to this contamination stream are linked naturally. However, because the literature pertaining to the large number of remediation activities has been published over such a large span of time, the nomenclature associated with the activities is often confusing. Depending on authorship, publication date, and intended audience, DOE and contractor documents naming and describing remediation activities and activities at ORR include considerably different information. In some instances, the differences are interpretable; in other instances, the differences are quite confusing. In this document, the authors adhere to the most current organizational structure for grouping remediation activities, i.e. watersheds. It is noted that the ETTP is a facility, but since it also involves just one watershed, the watershed is also called ETTP by the EM and Di/De personnel in Oak Ridge. It was decided to use the listing of major activities and subactivities identified by ORR in the Accelerating Cleanup: Focus on 2006, Discussion Draft⁵ as the basic or core set of remediation activities to address in this report. This was judged to be the most appropriate list of activities for which to provide the details of interest prescribed by NIOSH for the study. Since this overview document is authored by DOE, the authority of the document will not be affected by the transfer of ER and WM contractor responsibilities from LMER and LMES to BJC. Selected current and future activities are briefly described below in Sections 5.3 and 5.4, then presented in tabular form with other pertinent information.

5.2 Sites previously remediated

It is appropriate to first discuss sites previously remediated. Such CERCLA sites that have been remediated are designated by previously used nomenclature and are listed in DOE/OR/01-1584D-2⁵. Tables 5-1, 5-2, and 5-3, on the following pages, were excerpted from that document and show respectively the sites where:

- all actions are complete,
- most actions are complete but performance monitoring is being performed, or
- RODs or similar documents have been issued but the selected remedy either has not been implemented or the implementation has not been evaluated.

Table 5-1 Completed CERCLA Actions Not Requiring Performance Monitoring

Facility	Activity or Site	Approaches Used	Summary of Performance or Compliance Requirements	Summary of Performance Evaluation	Notes and Recommendations
ETTP	K-1417-A/B Drum Storage Yard	Dewatering; Containerizing; Transport and storage of treated sludge	S&M of access controls pending RCRA closure	Surveillance indicates no need for action	No changes in monitoring requirements
ORNL	WAG 13 Cesium Plots	Removal; Containerization of contaminated soil	S&M of access controls and surface cover	Surveillance indicates no need for action	No changes in S&M program
ORNL	WAG 11 Debris	Removal of surface debris	S&M of access controls and surface cover	Surveillance indicates no need for action	No changes in S&M program
Y-12	Plating Shop	No Further Action required	None	None	None
Y-12	Abandoned Nitric Acid Pipeline	No Further Action required	None	None	None

Table 5-2 Completed CERCLA Actions Requiring Performance Monitoring

Facility	Activity or Site	Approaches Used	Summary of Performance or Compliance Requirements	Summary of Performance Evaluation	Notes and Recommendations
ETTP	K-1070-C/D Sanitary Waste Site 31 (SW31) Seep Collection and Treatment	Collection and treatment of discharge from SW31; Treatment at the ETTP Central Neutralization Facility under an existing National Pollutant Discharge and Elimination System permit	Physical inspection of SW31 to verify that seepage is contained	Surveillance indicates no need for action	No changes in monitoring requirements
ETTP	K-1407 B&C Ponds Residual Soil Contamination	Placement of Soil Cover; Access/Institutional Controls; Semi-annual Monitoring	Physical inspection, semi-annual monitoring of two groundwater wells and one surface water location.	Sampling results do not indicate any significant problem	No changes in monitoring requirements
ORNL	White Oak Creek Embayment (WOCE)	Construction of a sediment retention structure on the WOCE	Short-term monitoring of discharge and sediments for ¹³⁷ Cs); Inspection and maintenance of the Sediment Retention Structure	New layer of relatively clean sediments on bottom of WOCE indicates good short-term effectiveness; Occasional flow over the gabions between storms may provide off-site pathway for fish	Monitor water levels at WOCE; Analyze WOCE sediment cores every five years
ORNL	WAG/5 Seep C Collection and Treatment	Seep collection and treatment system	90% removal of ⁹⁰ Sr from recovered seep water; Monitoring of Melton Branch upstream and downstream of the seep	Facility removed about 99% of in flowing ⁹⁰ Sr; Removed about 15% of ⁹⁰ Sr at WOD; problem with iron oxide precipitate	Remove up-stream and downstream grab sampling; Add new up-stream automatic sampling; Make adjustments to decrease clogging of drums
ORNL	WAG 5 Seep D Collection and Treatment	Seep collection and treatment system	90% removal of ⁹⁰ Sr from recovered seep water; Monitoring of Melton Branch upstream and downstream of the seep	Facility removed about 99% of inflowing ⁹⁰ Sr; Removed 10-12% of ⁹⁰ Sr at WOD	No changes in monitoring
ORNL	WAG 1 Corehole B Plume	Installation of french drain for interception of groundwater; Pumping to ORNL plant treatment system	20-50% reduction in ⁹⁰ Sr discharge, as measured at First Creek weir	Facility removed 20-50% of ⁹⁰ Sr from First Creek; Removed 5-6% of ⁹⁰ Sr at WOD	New sampling point added for captured ground water; Source investigation and another Action Memo under way

Table 5-2 Completed CERCLA Actions Requiring Performance Monitoring

Facility	Activity or Site	Approaches Used	Summary of Performance or Compliance Requirements	Summary of Performance Evaluation	Notes and Recommendations
ORNL	Low-Level Liquid Waste (LLLW) Tank WC-14	Removal of supernatant liquid from Tank WC-14	Routine S&M of Tank WC-14	Inflow of groundwater has increased over the past year; approximately 500 gal. removed Nov 96	Tank will probably be drained and grouted under 1997 Action Memo
ORNL	WAG 6 Environmental Monitoring	Special case: action postponed	Monitoring changes in contaminant flux from WAG; Continuous surface water flow and sampling, groundwater sampling	Need to analyze FY 1996 groundwater and surface water data	Suspend sampling at 8 interior wells and south french drain; Eliminate WAG-specific reporting requirement
Y-12	United Nuclear Landfill	Capping of United Nuclear Company Disposal Site; Monitoring of on-site wells	Physical inspection of landfill cap, monitoring of on-site wells, groundwater contaminant trend evaluation	Groundwater analyses do not indicate any significant problem	Reduce groundwater monitoring from semi-annual to bi-annual
Y-12	Mercury Tanks	Removal of mercury-containing sediments and water from three tanks	Periodic sampling of water and observation of tank sludge levels	Sampling and observations indicate no need for action	Monitoring to be discontinued in 1997 following tank removal
Y-12	Kerr Hollow Quarry	No Further Action	Groundwater and surface water monitoring under RCRA Postclosure permit; CERCLA requires occasional surface water monitoring as best management practice	Groundwater and surface water quality does not exceed regulatory limits	No changes in monitoring requirements

Table 5-3 CERCLA Actions Not Fully Implemented or Results from Monitoring Not Available

Facility	Activity or Site	Approaches Used	Summary of Performance or Compliance Requirements	Summary of Performance Evaluation	Notes and Recommendations
ETTP	Group 1 Auxiliary Facilities	Demolition of five buildings to grade	Not Established	Not Established	Not Established
ORNL	Waste Evaporator Facility	Demolition of above- and below-ground structures at the Waste Evaporator Facility	Not Established	Not Established	Not Established
ORNL	Molten Salt Reactor Experiment (MSRE)	Removal of off-gases, installation of water removal and monitoring system	Not Established	Not Established	Not Established
ORNL	WAG 4 Seeps	Grouting of selected trench areas	Anticipated 35% reduction in ⁹⁰ Sr in seeps within 3 years and 75% reduction within 10 years	Data collection began in October 1996	Not Established
ORNL	3001 Canal	Displace water in canal with grout	One well sampled two times per year	Not Established	Not Established
ORNL	Old Hydrofracture Facility Tanks	Sluice tank contents to Melton Valley Storage Tanks	Not Established	Not Established	Not Established
Y-12	Filled Coal Ash Pond Chestnut Ridge	Improvements to existing dam; Passive treatment of surface water; Access/Institutional controls	Not Established	Not Established	Not Established
Y-12	Spoil Area 1 and SY-200 Yard	Maintain soil covers and institutional controls	Not Established	Not Established	Not Established

5.3 Activity descriptions (ER and De/Di)^{5,7}

During the time the remedial actions (RAs) listed in Section 5.1 were taking place, the strategy for cleaning up a site (now referred to as subactivity) was evaluated on a site-by-site basis. However, it was quickly realized that the completion of all subactivities would take decades and would be extremely costly. Consequently, a broader approach for remediation of the Oak Ridge Sites was sought by looking for a common thread linking the necessary subactivities. Since the rainfall in Tennessee is high (averaging 55 inches per year), surface and groundwater act as a major pathway for movement and distribution of contamination. Because of these facts, five watersheds that drain the three Oak Ridge facilities were selected as the main activities upon which cleanup decisions would be made under the new strategy. Watershed is a term that describes a specific land area from which surface water flows into a system of creeks, streams, and rivers to a common destination. Two watersheds associated with ORNL are the White Oak Creek (WOC) and the Bethel Valley (BV) watersheds. Those associated with Y-12 are the Upper East Fork Poplar Creek (UEFPC) and the Bear Creek (BC) watersheds. The final watershed, the ETPP watershed, takes the name of the facility from which it drains.

This selection of watersheds made it possible to rely on the massive amount of data that existed for these locations, since over the past several years hundreds of studies have been made resulting in the collection of such data. These studies indicate that similarly contaminated areas in these watersheds share common environmental problems and cleanup challenges. Consequently, major activities as listed in the Oak Ridge Site Environmental Restoration and Decontamination and Decommissioning Projects in the Oak Ridge Operations Office Environmental Management Accelerated Cleanup: Focus on 2006 Discussion Draft June 1997⁵ are associated with these watersheds.

Following are descriptions and tabulations of each of these activities excerpted from that document, as well as summary information on the associated subactivities and the number of such subactivities. Contaminants of concern are shown in Table 7.2 of Section 7.0 by subactivity for each of the major activities described here.

Decision draft rankings (low, average, high), as shown in Appendix C "Prioritized Subactivity List" of this document, are shown in Table 5-4 as rough indicators of the relative priorities associated with these subactivities at the time of the Discussion Draft. These priorities were assigned on a risk basis, i.e., the judged increased risk from not performing an subactivity compared with the risk of performing the subactivity. Those subactivities showing the greatest risk reduction were assigned higher priority, i.e., lower numbered rank. Generally, subactivities would be initiated in order of priority ranking, thereby providing the greatest risk reduction for monies spent. This system was used to decide (based on certain funding assumptions) which subactivities would be completed by year 2000, which additional ones could be completed by 2006, and which would have to be done after 2006. The factors considered in these evaluations were (a) public safety and health, (b) site personnel safety and health, (c) environmental protection, (d) compliance, (e) emission impact, and (f) mortgage reduction. Two hundred and seventy-eight of these activities were ranked in this manner. It should be realized that these priorities are fluid and subject to changes between the production of the Discussion Draft and the final report. In addition, progress on these subactivities depends not only on the priorities, but are also directly dependent on the amount of funding available.

OR-42101 Y-12 UPPER EAST FORK POPLAR CREEK REMEDIAL ACTION

The purpose of the Y-12 UEFPC RA grouping of activities is to address environmental hazards that have been identified within the UEFPC watershed (the main Y-12 Plant area) and associated waste disposal sites located to the south of the Y-12 Plant on Chestnut Ridge and to bring the watershed and associated sites into CERCLA compliance. This grouping of activities also includes all the S&M initiatives for all sites in the Y-12 Environmental Restoration listing (includes BC watershed, UEFPC watershed, and sites on Chestnut Ridge).

The Y-12 UEFPC RA grouping of activities has additional importance because of associated off-site groundwater contamination found just east of the Y-12 Plant underneath privately owned industrial businesses. The Y-12 Plant is a source of some of the contamination found off-site. Initial groundwater usage restrictions will be negotiated as studies continue in the watershed ROD project to identify on-site RAs.

OR-42102 Y-12 BEAR CREEK REMEDIAL ACTION

The purpose of the Y-12 BC RA grouping of activities is to address environmental hazards that have been identified within the BC watershed (waste management areas west of the main Y-12 Plant area) and to take the watershed and associated sites through the CERCLA process. Another Project Breakdown Structure (PBS), the Y-12 UEFPC RA grouping of activities (OR-42101) includes all the S&M initiatives for sites in the Y-12 Environmental Restoration listing (includes BC watershed).

OR-43201 ORNL WHITE OAK CREEK REMEDIAL ACTION

All of the surface water at ORNL drains into WOC and then into the Clinch River. The purpose of the WOC RA activity is the environmental restoration of all contaminated areas located in the lower half (Melton Valley) of the WOC watershed. The activity scope includes remediation of contaminated soil, sediment, surface water, groundwater, settling ponds, waste burial grounds, and liquid waste seepage pits and trenches. Innovative technologies will be applied as appropriate to support the RA efforts. Active operating facilities and inactive Di-De facilities are located in the same geographic area but are not considered in the scope of this activity.

OR-43202 ORNL WHITE OAK CREEK D&D

This activity involves 20 contaminated inactive facilities plus the fuel salt associated with the MSRE. These facilities include: (a) MSRE, an 8-megawatt (MW) nuclear reactor fueled with uranium fluoride and other salts which were heated until molten; (b) six auxiliary buildings/facilities associated with MSRE including office building, cooling tower, stack; (c) Homogenous Reactor Experiment, the first aqueous experimental research reactor; (d) six auxiliary facilities associated with the Homogeneous Reactor Experiment including cooling tower, waste evaporator, and decon shed; (e) surface facilities associated with the first hydrofracture waste disposal operations (Old Hydrofracture Facility) at ORNL including mixer cell, injection pump cell, and wellhead cell; and (f) five shielded transfer tanks used to transport high-specific activity radioactive solutions by rail.

OR-43203 ORNL BETHEL VALLEY REMEDIAL ACTION

All of the surface water at ORNL drains into WOC, then into the Clinch River. The purpose of the BV RA activity is the environmental restoration of contaminated areas located in the upper half of the WOC watershed. Innovative technologies will be applied as appropriate to support the RA efforts. Bethel Valley is the location of the main area at ORNL and contains active operating research facilities intermingled with deactivation and dismantlement facilities and areas requiring environmental restoration. The activity scope includes remediation of contaminated soil, sediment, surface water, groundwater, settling ponds, waste burial grounds, and inactive LLLW tanks. Active operating facilities and inactive deactivation and dismantlement facilities are located in the same geographic area, but are not considered in the scope of this activity. Selection of the preferred remedy for the DeW and DiW activities is included in the BV Watershed ROD, which is prepared as part of this PBS. Field activities involving DeW and DiW activities are not included in this PBS but are covered under PBS OR-43204, BV D&D.

OR-43204 ORNL BETHEL VALLEY D&D

This activity involve 27 contaminated facilities including: (a) Metal Recovery Facility, a one-story building with seven above-grade process cells used for the recovery of uranium and other materials from fuel and waste; (b) Fission Product Development Laboratory (FPDL) inactive cells consisting of five cells and the service tunnel, which are inactive portions of the FPDL, used to separate kilocurie quantities of ^{137}Cs , ^{90}Sr , and other isotopes from waste streams from Hanford; (c) Fission Product Pilot Plant, a small building used to extract various isotopes from aqueous fission product waste; (d) Low-Intensity Reactor, a 3-MW early research reactor and associated facilities/buildings; (e) Oak Ridge Graphite Reactor, an air-cooled, graphite-moderated reactor and associated buildings/facilities; (f) High-Level Chemical Development Laboratory, a laboratory and small-scale pilot plant for development studies of reactor-fuel processing; separation and recovery of transuranic (TRU) material, and separation of fission products from aqueous waste; and (g) Oak Ridge Research Reactor, a 30-MW research reactor and associated buildings/facilities.

OR-44301 ETPP REMEDIAL ACTION

The purpose of this activity is to address environmental hazards that have been identified within the ETPP watershed and the waste sites associated with it and to complete the CERCLA activities required for all of these sites. The boundaries of the ETPP watershed are Black Oak Ridge on the north, West Pine Ridge on the south, and Clinch River to the west. The eastern boundary is comprised of Blair Road, Highway 58, and Highway 95. ETPP is located in Roane County in Eastern Tennessee, near the town of Oak Ridge. After World War II, the uranium enrichment operations were continued to supply uranium for nuclear reactors. All enrichment operation stopped in 1985. ETPP has been part of the Oak Ridge Environmental Restoration program since its inception in 1990. Several activities have been scoped and implemented during this time period in order to reduce the hazards remaining from uranium enrichment operations. This PBS describes the scope of the subactivities that will address the remaining contamination to achieve the goals and objectives of the Discussion Draft. This activity also includes all of the S&M requirements for sites included in the RA program.

OR-44302 ETTP PROCESS EQUIPMENT D&D

As it exists, the gaseous diffusion process equipment at ETTP will require long-term, extensive and costly S&M as long as it remains in place; poses progressively increasing risk of release of nuclear and hazardous materials to the environment; could result in nuclear criticality under certain conditions; and is an attractive target for theft of fissionable material remaining in the process. Alternatively, timely deactivation and dismantlement as proposed in the activity will recover metal of enough value to offset activity cost, reduce long-term risks, and avoid cumulative S&M costs expected to total \$300M over the next 10 years.

The gaseous diffusion process equipment at ETTP is no longer needed for enriching uranium for either civilian or defense purposes and has been in cold shutdown for periods of 10 to 30 years. Stakeholders are concerned about the risks posed by progressively deteriorating buildings which house the equipment; about costly maintenance (such as new roofs) which are required in the short-term to adequately contain environmental and health risks; that DOE will walk away and leave an abandoned facility; that valuable materials will not be recovered; and that jobs generated by this activity will not materialize.

This activity will abate risks and stakeholder concerns through several major accomplishments: (a) dismantle the gaseous diffusion process equipment contained in process buildings K-25, K-27, K-29, K-31, and K-33 at ETTP; (b) process the resultant scrap metal in a way which cost-effectively balances recovery of metal values against generation of wastes requiring disposal; (c) disposition primary and secondary materials in a manner acceptable both on-site and at remote locations; (d) protect workers, the public, and the environment during all phases of operations; (e) satisfy the federal, state, and local requirements before, during, and after operations; (f) result in buildings which represent an environmentally stable state conducive to long-term, low-cost S&M; (g) provide opportunities for private sector participation to a diverse set of players having available expertise in this type of work; and (h) provide major reduction in EM mortgage.

OR-44303 ETTP D&D

The purpose of this activity is to address environmental hazards that have been identified within the ETTP watershed and to complete the CERCLA activities required for all of these sites. The boundaries of the ETTP watershed are Black Oak Ridge on the north, West Pine Ridge on the south, and Clinch River to the west. The eastern boundary is comprised of Blair Road, Highway 58, and Highway 95. ETTP is located in Roane County in Eastern Tennessee, near the town of Oak Ridge. ETTP was the first site at which uranium was enriched for use in an atomic bomb. After World War II, the uranium enrichment operations were continued to supply uranium for nuclear reactors. All enrichment operation stopped in 1985. ETTP has been part of the Oak Ridge Environmental Restoration program since its inception in 1990. Several activities have been scoped and implemented during this time period in order to reduce the hazards remaining from uranium enrichment operations. This PBS describes the scope of the subactivities that will address the remaining contamination to achieve the goals and objectives of the Discussion Draft.

The following table is a listing of ORR ER and De/Di activity titles and descriptions tabulated according to average priority of the inclusive subactivities.

Table 5-4 ORR ER and De/Di Activities Ordered by Average Subactivity Priority Ranking

Activity	Total Subactivities	No. Subactivities by Facility and Watershed					Subactivity Priority Ranking		
		ETTP	ORNL		Y-12		Low	High	Avg
		ETTP	BV	WOC	BC	UEFPC			
OR-44302	2	2					87	86	87
OR-42102	7				7		253	4	103
OR-43203	9		9				275	2	138
OR-43201	19			19			242	3	143
OR-44301	21	21					270	10	157
OR-43202	6			6			273	8	185
OR-42101	21					21	277	11	197
OR-44303	13	13					268	88	207
OR-43204	7		7				258	211	232

The following table is a listing of ORO ER and De/Di activity titles and description according to worker category.

Table 5-5 ORR ER and De/Di Activities by Worker Category

Contractor Code	Worker Category ^a	Contact(s) or Reference	Activities Title and Brief Description	Exposure Type ^b	Driver ^{8c}	Time Line	Duration (Years)	Workers per Activity
LMES (Y-12)	HWW/CW	4, 6	42101: UEFPC grouping of activities addresses environmental hazards that have been identified within the UEFPC watershed (the main Y-12 Plant area) and associated waste sites to the south of the Y-12 Plant on Chestnut Ridge.	C,R,M	CERCLA RCRA DOE Orders	1989 - 2006	18	N/A
LMES (Y-12)	HWW/CW	4, 6	42102: BCk grouping of activities addresses environmental hazards that have been identified within the BC watershed (waste management areas west of the main Y-12 Plant area).	C,R,M	CERCLA RCRA DOE Orders	1989 - 2006	18	N/A
LMER (ORNL)	HWW/CW	4, 6	43201: All of the surface water at ORNL drains into WOC and then into the Clinch River. This activity is the environmental restoration of all contaminated areas located in the lower half (Melton Valley) of the WOC watershed.	C,R,M	CERCLA RCRA DNFSB AEA State DOE Orders	1989 - 2006	18	N/A

^aCW = Cleanup Worker; DeW= Deactivation Worker; DiW= Dismantlement Worker; HWW = Hazardous Waste Worker

^bC = Chemical; M = Mixed; R = Radiological

^cCERCLA = Comprehensive Environmental Response, Compensation, and Liability Act; RCRA = Resource Conservation and Recovery Act; DNFSB= Defense Nuclear Facility Safety Board; AEA= Atomic Energy Agency; FFA = Federal Facility Agreement

Table 5-5 ORR ER and De/Di Activities by Worker Category

Contractor Code	Worker Category ^a	Contact(s) or Reference	Activities Title and Brief Description	Exposure Type ^b	Driver ^{bc}	Time Line	Duration (Years)	Workers per Activity
LMER (ORNL)	DeW/DiW	4, 6	43202: WOC This activity contains 20 contaminated inactive facilities plus the fuel salt associated with the MSRE.	C,R,M	CERCLA RCRA AEA State DOE Orders	1989 - 2006	18	N/A
LMER (ORNL)	HWW/CW	4, 6	43203: BV All surface water at ORNL drains into WOC, then into the Clinch River. The purpose of this activity is the environmental restoration of contaminated areas in the upper half of WOC watershed. Innovative technologies will be applied as appropriate to support remediation efforts.	C,R,M	CERCLA RCRA AEA State DOE Orders	1989 - 2006	18	N/A

^aCW = Cleanup Worker; DeW= Deactivation Worker; DiW= Dismantlement Worker; HWW = Hazardous Waste Worker

^bC = Chemical; M = Mixed; R = Radiological

^cCERCLA = Comprehensive Environmental Response, Compensation, and Liability Act; RCRA = Resource Conservation and Recovery Act; DNFSB= Defense Nuclear Facility Safety Board; AEA= Atomic Energy Agency; FFA = Federal Facility Agreement

Table 5-5 ORR ER and De/DI Activities by Worker Category

Contractor Code	Worker Category ^a	Contact(s) or Reference	Activities Title and Brief Description	Exposure Type ^b	Driver ^{9c}	Time Line	Duration (Years)	Workers per Activity
LMER (ORNL)	DeW/DiW	4, 6	43204: BV D&D activity includes the decontamination or decommissioning of 27 contaminated facilities including (1) a Metal Recovery Facility, (2) a Fission Products Development Laboratory, (3) a Fission Product Pilot Plant, (4) a Low-Intensity Reactor, (5) the Oak Ridge Graphite Reactor, (6) the High-Level Chemical Development Laboratory, and (7) the Oak Ridge Research Reactor.	C,R,M	CERCLA RCRA AEA State DOE Orders	1989 - 2006	18	N/A
LMES (ETTP)	HWW	4, 6	44301: ETTP Remedial Action addresses environmental hazards that have been identified within the ETTP watershed and the waste sites associated with it, and to complete the CERCLA activities required for all of these sites.	C,R,M	CERCLA RCRA AEA State DOE Orders	1989 - 2006	18	N/A

^aCW = Cleanup Worker; DeW= Deactivation Worker; DiW= Dismantlement Worker; HWW = Hazardous Waste Worker

^bC = Chemical; M = Mixed; R = Radiological

^cCERCLA = Comprehensive Environmental Response, Compensation, and Liability Act; RCRA = Resource Conservation and Recovery Act; DNFSB= Defense Nuclear Facility Safety Board; AEA= Atomic Energy Agency; FFA = Federal Facility Agreement

Table 5-5 ORR ER and De/Di Activities by Worker Category

Contractor Code	Worker Category ^a	Contact(s) or Reference	Activities Title and Brief Description	Exposure Type ^b	Driver ^{bc}	Time Line	Duration (Years)	Workers per Activity
LMES (ETTP)	DeW/DiW	4, 6	44302: ETTP Process Equipment D&D activity will recover metal values to offset activity cost, reduce long-term risks, and avoid cumulative S&M costs expected to total \$300M over the next 10 years. This activity will abate risks through dismantlement of gaseous diffusion process equipment contained in process buildings K-25, K-27, K-29, K-31, and K-33 which will result in buildings in environmentally stable states conducive to long-term, low-cost S&M.	C,R,M	CERCLA RCRA DNFSB AEA State DOE Orders	1989 - 2006	18	N/A
LMES (ETTP)	DeW/DiW	4, 6	44303: ETTP D&D addresses environmental hazards that have been identified within the ETTP watershed and completes the CERCLA activities required for these sites. The boundaries of the ETTP watershed are Black Oak Ridge on the north, West Pine Ridge on the south, Clinch River to the west.	C,R,M	CERCLA RCRA AEA State DOE Orders	1989 - 2006	18	N/A

^aCW = Cleanup Worker; DeW= Deactivation Worker; DiW= Dismantlement Worker; HWW = Hazardous Waste Worker

^bC = Chemical; M = Mixed; R = Radiological

^cCERCLA = Comprehensive Environmental Response, Compensation, and Liability Act; RCRA = Resource Conservation and Recovery Act; DNFSB= Defense Nuclear Facility Safety Board; AEA= Atomic Energy Agency; FFA = Federal Facility Agreement

5.4 Activities involving waste

In addition to the activities listed in the previous section which relate to environmental restoration, deactivation, and dismantlement, there are a number of waste management activities associated with this cleanup. It is interesting to note that an attachment to the ORR Priority List shows that of the funds requested for fiscal year 1999, 74 percent is for remediation while only 24 percent is for waste management.⁹ These activities are classified by the type of waste involved and the type of activity involved with this waste (i.e., treatment, storage, and disposal). Under this classification, the subactivity/activities are listed by watershed which are in turn associated with facilities. These activities are listed in the Accelerated Cleanup: Focus on 2006 Discussion Draft referenced above. Table 5-6 below was excerpted from that draft. The number of subactivities associated with each facility and the low, high, and average decision draft ranks are shown as a rough indication of the priorities that these activities were afforded in the Discussion Draft. As noted above, these priorities are subject to change and the accomplishments on the subactivities are highly dependent on the funding level.

Following is a list and a tabulation of ORR waste activities and a table of general information about the subactivities within each major activity and their priorities. Contaminants of concern are shown in Table 7.2 of Section 7.0 by subactivity for each major activity.

OR-38101 MIXED LOW-LEVEL WASTE STORAGE

The purpose of this activity is to support the achievement and maintenance of compliance with the requirements of the State of Tennessee Commissioner's Order Site Treatment Plan under the Federal Facilities Compliance Act (FFCA) of 1992 signed on September 25, 1995. This activity provides for the storage of mixed low-level waste (MLLW) at the three DOE-ORO sites on the Oak Ridge Reservation-ETTP, ORNL, and the Y-12 Plant. In addition to supporting the actions to meet the enforceable milestones and targets specified by the Commissioner's Order, MLLW must be stored in compliance with the requirements specified in the RCRA and the TSCA.

The scope of this activity includes storage of MLLW on the ORR until the treatment and disposal of 30,988 cubic meters of MLLW in inventory is completed and the time is reached when MLLW is stored with the sole purpose of accumulating sufficient quantities to facilitate treatment, storage, or disposal. The MLLW streams included in this scope are: wastewater, aqueous waste, incinerable liquids, incinerable solids, non-incinerable solids, inorganic solids and sludges, special waste, and treatment process residues.

OR-38102 MIXED LOW-LEVEL WASTE TREATMENT

The purpose of this activity is to achieve and maintain compliance with the requirements of the State of Tennessee Commissioner's Order Site Treatment Plan under the FFCA of 1992 signed on September 25, 1995, and the PCB FFCA signed on December 16, 1997. This activity provides for the storage of MLLW at the three DOE-ORO sites on the ORR - ETTP, ORNL, and the Y-12 Plant. In addition to the enforceable milestones and targets specified by the Commissioner's Order and the ORR-PCB-FFCA, MLLW must be managed in compliance with the requirements specified in the RCRA and TSCA.

The scope of this activity includes the treatment of 17,304 cubic meters of MLLW in inventory and to reach a point when MLLW is stored with the sole purpose of accumulating sufficient quantities to facilitate treatment, storage, or disposal. The MLLW streams included in this scope are: wastewater, aqueous waste, incinerable liquids, incinerable solids, non-incinerable solids, inorganic solids and sludges, special waste, and treatment process residues. This activity also includes treatment of ongoing waste generated and treated in existing on-site facilities.

This activity involves the treatment of MLLW on the ORR. Facilities utilized to accomplish the goal of reaching the steady-state by the end of Fiscal Year (FY) 2008 include on-site facilities such as the TSCA Incinerator, Central Neutralization Facility, West End Treatment Facility, as well as commercial treatment and disposal. In addition, other technologies such as polymer filtration, mercury removal from mixed waste solids, mercury recovery from liquid mixed waste, rotary flow filtration, and self-assembled monolayers on ordered mesoporous supports are considered pending funding and technological considerations.

OR-38103 MIXED LOW-LEVEL WASTE DISPOSAL

The purpose of this activity is to achieve and maintain compliance with the requirements of the State of Tennessee Commissioner's Order Site Treatment Plan under the FFCA of 1992 signed on September 25, 1995. This activity provides for the disposal of MLLW at the three DOE-ORO sites on the ORR-ETTP, ORNL, and the Y-12 Plant. In addition to the enforceable milestones and targets specified by the Commissioner's Order, MLLW must be managed in compliance with the requirements specified in RCRA and TSCA.

The scope of this activity includes disposal of MLLW in inventory and to reach a point when MLLW is stored with the sole purpose of accumulating sufficient quantities to facilitate treatment, storage, or disposal. The MLLW streams included in this scope are: wastewater, aqueous waste, incinerable liquids, incinerable solids, non-incinerable solids, inorganic solids and sludges, special waste, and treatment process residues.

OR-38104 LOW-LEVEL WASTE STORAGE

The purpose of this activity is to support achieving and maintaining an end-state (steady-state) condition in the management of LLW on the ORR consistent with the objectives of the Discussion Draft and the requirements of DOE Order 5820.2A. This activity provides for the storage and treatment, storage, and disposal support of LLW at the three DOE ORO sites on the ORR-ETTP, ORNL, and the Y-12 Plant.

The scope of this activity includes the storage of LLW in inventory and new waste to reach a point when LLW is stored with the sole purpose of accumulating sufficient quantities and in a manner to facilitate treatment, disposal, and maximize storage efficiency. The LLW streams included in this scope are: wastewater, containerized inventories of LLW liquids, dry active waste, radioactive scrap metal, process residues, and special waste (includes special-case waste). Capabilities utilized to accomplish the goal of reaching the steady-state by the end of FY 2008 include the storage facilities at the three ORR sites-ETTP, ORNL, and the Y-12 Plant.

OR-38105 LOW-LEVEL WASTE TREATMENT

The purpose of this activity is to support achieving and maintaining an end-state (steady-state) condition in the management of LLW being readied for treatment on the ORR, consistent with the objectives of the Discussion Draft and the requirements of DOE Order 5820.2A. This activity provides for the treatment of LLW generated at the three DOE ORO sites on the ORR-ETTP, ORNL, and the Y-12 Plant.

The scope of this activity includes the storage of 28,547 cubic meters of LLW in inventory and 3,200 cubic meters per year of new waste to reach a point when LLW is stored with the sole purpose of accumulating sufficient quantities and in a manner to facilitate treatment. The LLW streams included in this scope are: wastewater, containerized inventories of LLW liquids, dry active waste, radioactive scrap metal, process residues, and special waste (includes special-case waste). This activity involves the treatment of LLW generated on the ORR. Capabilities utilized to accomplish the goal of reaching the steady-state by the end of FY 1999 include on-site compaction facilities, wastewater treatment facilities such as the Process Waste Treatment Complex, the LLLW Evaporator, and commercial treatment services which include compaction, incineration, and metal melting for recycling.

OR-38106 LOW-LEVEL WASTE DISPOSAL

The purpose of this activity is to support achieving and maintaining an end-state (steady-state) condition in the management of LLW on the ORR consistent with the objectives of the Discussion Draft and the requirements of DOE Order 5820.2A. This activity provides for the disposal of LLW generated at the three DOE ORO sites on the ORR-ETTP, ORNL, and the Y-12 Plant.

The scope of this activity includes the disposal of 31,311 cubic meters of LLW in inventory and new waste to reach a point when LLW is stored with the sole purpose of accumulating sufficient quantities to facilitate disposal. The LLW streams included in this scope are: wastewater, containerized inventories of LLW liquids, dry active waste, radioactive scrap metal, process residues, and special waste (includes special-case waste). This activity involves the disposal of LLW generated on the ORR. Capabilities utilized to accomplish the goal of reaching the steady-state by the end of FY 2010 include on-site disposal facilities such as the Interim Waste Management Facility and commercial disposal services.

OR-38107 TRU WASTE STORAGE

The purpose of this activity is safe and compliant storage of remote-handled (RH) and contact-handled (CH) TRU waste (solid debris) prior to processing for disposal at the Waste Isolation Pilot Plant.

Two TRU waste streams comprise this activity: CH-TRU solids and RH-TRU solids. The scope of this activity is the safe and compliant storage of these waste streams. The CH-TRU solids are contained in drums (30-, 33-, 79-, and 110-gallon) which are stored in RCRA-permitted storage buildings. The RH-TRU solids are contained in concrete cast canisters and are stored in bunkers which are RCRA permitted. The following technology including associated cost savings has been incorporated into this activity baseline: enhanced nondestructive assay of TRU waste.

OR-38108 TRU WASTE TREATMENT

The purpose of this activity is to process, certify, and ship approximately 2,300 cubic meters (over the 10-year period) of TRU wastes to the Waste Isolation Pilot Plant or the Nevada Test Site.

Three TRU waste streams comprise this activity: CH-TRU solids, RH-TRU solids, and RH-TRU sludges. The state of Tennessee has designated treatment and disposal of these wastes as their number one environmental priority. This activity will, through subcontract with the private sector, treat and repackage TRU waste in accordance with RCRA requirements and the waste acceptance criteria for shipment to the Waste Isolation Pilot Plant or the Nevada Test Site.

OR-38109 HAZARDOUS DISPOSAL

Hazardous waste management activities performed by Oak Ridge are primarily driven by environmental laws and regulations external to the DOE system. The current Oak Ridge hazardous waste management system provides for proper treatment (possibly including recycling), storage, and disposal of liquids, chemicals, and solids defined as toxic or hazardous. Hazardous waste is defined in 40 Code of Federal Regulations 161.3. TSCA waste is defined in 40 CFR 761.

This activity includes the storage, treatment, and disposal of RCRA, TSCA, and other wastes deemed hazardous (by Tennessee) which cannot be disposed of in on-site or off-site landfills. Costs to manage the program (contract administration, administrative activities driven by the regulations, etc.) are included in the activity. Other activities provided for in the budget include waste certifications, no-rad-added, and waste tracking.

OR-38901 BROAD SPECTRUM MLLW TREATMENT

The purpose of this activity is to award a MLLW treatment contract for a broad spectrum of mixed waste that is available to all DOE sites.

The scope of this activity is to retrieve waste from the generating site, treat the waste, and transport it to the disposal site with potential to treat 30,000 cubic meters of MLLW from all other DOE sites under this procurement. Currently, there are roughly 5,300 cubic meters in about 80 separate waste streams on the ORR that will be included in this action. Many other DOE sites have similar waste streams in storage, and some sites continue to generate MLLW. Budget authority in the PBS allows award of contract(s) with sufficiently large commitments to encourage vendors to enter the mixed waste treatment market. The remaining additional budget authority and the budget outlay is being requested as part of the annual appropriations from Oak Ridge for mixed waste treatment and all other participating DOE sites during the period covered by this Discussion Draft.

The following table is a listing of ORR Waste Management activity titles and descriptions tabulated according to the average priority of the subactivities.

Table 5-6 ORR WM Activities Ordered by Average Subactivity Priority Ranking

Activity	Total Subactivities	No. Subactivities by Facility and Watershed					Subactivity Priority Ranking		
		ETTP	ORNL		Y-12		Low	High	Avg
		ETTP	BV	WOC	BC	UEFPC			
OR-38103	9	5	1			3	173	7	35
OR-38108	12		12				66	45	52
OR-38901	6	2	1			3	55	50	52
OR-38102	28	16	1			11	209	14	76
OR-38107	6	1	5				92	65	78
OR-38109	6	3	2			1	95	89	92
OR-38105	21	4	14			3	213	61	93
OR-38101	10	4	3			3	129	13	94
OR-38104	9	4	3			2	145	33	113
OR-38106	7	4	2			1	176	149	170

OR-48101 OFF-SITE REMEDIAL ACTION describes a group of activities involving areas and facilities contaminated by DOE-ORR operations but downgradient from and/or outside of DOE property. This grouping also includes two reservation-wide initiatives (Footprint Reduction/Site Evaluations and ORR Integrated Water Quality Program).

The following table gives information relative to the location and priority rankings of the involved subactivities.

Total Subactivities	OFF-SITE	ORR-WIDE	Lowest Priority	Highest Priority	Average Priority
10	8	2	272	40	165

The following table is a listing of ORR waste activity titles and descriptions tabulated according to worker category.

Table 5-7 ORR WM Activities by Worker Category

Contractor Code	Worker Category ^a	Contact(s) or Reference	Activities Title and Brief Description	Exposure Type ^b	Driver ^c	Time Line	Duration (Years)	Workers per Activity
ORR (Y-12, ORNL, ETP)	HWW/CW	4, 6	38101: MLLW activity is to support the achievement and maintenance of compliance with the requirements of the State of Tennessee Commissioner's Order Site Treatment Plan under the FFCA of 1992. This activity provides for the storage of MLLW at the three DOE-Oak Ridge Operations Office (DOE-ORO) sites.	C,R,M	RCRA TSCA FFA	1989 - 2006	18	N/A
ORR (Y-12, ORNL, ETP)	HWW/CW	4, 6	38102: MLLW activity achieves and maintains compliance with the requirements of the State of Tennessee Commissioner's Order Site Treatment Plan. The scope of this activity includes the treatment of 17,304 cubic meters of MLLW.	C,R,M	RCRA TSCA	1989 - 2006	18	N/A
ORR (Y-12, ORNL, ETP)	HWW/CW	4, 6	38103: MLLW activity achieves and maintains compliance with the requirements of the State of Tennessee Commissioner's Order Site Treatment Plan under the FFCA of 1992. This activity provides for the disposal of MLLW at the three DOE-ORO sites.	C,R,M	RCRA TSCA FFA	1989 - 2006	18	N/A

^aCW = Cleanup Worker; DeW= Deactivation Worker; DiW= Dismantlement Worker; HWW = Hazardous Waste Worker

^bC = Chemical; M = Mixed; R = Radiological

^cCERCLA = Comprehensive Environmental Response, Compensation, and Liability Act; RCRA = Resource Conservation and Recovery Act; DNFSB= Defense Nuclear Facility Safety Board; AEA= Atomic Energy Agency; Toxic Substances Control Act (TSCA); FFA = Federal Facility Agreement

Table 5-7 ORR WM Activities by Worker Category

Contractor Code	Worker Category ^a	Contact(s) or Reference	Activities Title and Brief Description	Exposure Type ^b	Driver ^c	Time Line	Duration (Years)	Workers per Activity
ORR (Y-12, ORNL, ETPP)	HWW/CW	4, 6	38104: LLW activity supports achieving and maintaining an end-state (steady-state) condition in the management of LLW on the ORR and includes the storage of LLW in inventory and new waste to reach a point when LLW is stored with the sole purpose of accumulating sufficient quantities to facilitate treatment, disposal, and maximize storage efficiency.	R	DOE Order 5820.2A	1989 - 2006	18	N/A
ORR (Y-12, ORNL, ETPP)	HWW/CW	4, 6	38105: LLW activity supports achieving and maintaining an end-state (steady-state) condition in the management of LLW on the ORR for treatment, consistent with the requirements of DOE Order 5820.2A. The scope of this activity includes the storage of 28,547 cubic meters of LLW in inventory and 3,200 cubic meters per year of new waste to reach a point when LLW is stored with the sole purpose of accumulating sufficient quantities and in a manner to facilitate treatment.	R	DOE Order 5820.2A	1989 - 2006	18	N/A

^aCW = Cleanup Worker; DeW= Deactivation Worker; DiW= Dismantlement Worker; HWW = Hazardous Waste Worker

^bC = Chemical; M = Mixed; R = Radiological

^cCERCLA = Comprehensive Environmental Response, Compensation, and Liability Act; RCRA = Resource Conservation and Recovery Act; DNFSB= Defense Nuclear Facility Safety Board; AEA= Atomic Energy Agency; Toxic Substances Control Act (TSCA); FFA = Federal Facility Agreement

Table 5-7 ORR WM Activities by Worker Category

Contractor Code	Worker Category ^a	Contact(s) or Reference	Activities Title and Brief Description	Exposure Type ^b	Driver ^c	Time Line	Duration (Years)	Workers per Activity
ORR (Y-12, ORNL, ETPP)	HWW/CW	4, 6	38106: LLW Disposal supports achieving and maintaining an end-state (steady-state) condition in the management of LLW on the ORR consistent with requirements of DOE Order 5820.2A. The scope of this activity includes the disposal of 31,311 cubic meters of LLW in inventory and new waste to reach a point when LLW is stored with the sole purpose of accumulating sufficient quantities to facilitate disposal.	R	DOE Order 5820.2A	1989 - 2006	18	N/A
ORR (ORNL, ETPP)	HWW/CW	4, 6	38107: TRU Waste Storage involves the safe and compliant storage of RH-TRU and CH-TRU waste prior to processing for disposal at the Waste Isolation Pilot Plant.	R	RCRA	1989 - 2006	18	N/A
ORR (ORNL)	HWW/CW	4, 6	38108: TRU Waste Treatment activity includes processing, certifying, and shipping approximately 2,300 cubic meters (over the 10-year period) of TRU wastes to the Waste Isolation Pilot Plant or the Nevada Test Site. Three TRU waste streams comprise this activity: CH-TRU solids, RH-TRU solids, and RH-TRU sludges.	R	RCRA	1989 - 2006	18	N/A

^aCW = Cleanup Worker; DeW= Deactivation Worker; DiW= Dismantlement Worker; HWW = Hazardous Waste Worker

^bC = Chemical; M = Mixed; R = Radiological

^cCERCLA = Comprehensive Environmental Response, Compensation, and Liability Act; RCRA = Resource Conservation and Recovery Act; DNFSB= Defense Nuclear Facility Safety Board; AEA= Atomic Energy Agency; Toxic Substances Control Act (TSCA); FFA = Federal Facility Agreement

Table 5-7 ORR WM Activities by Worker Category

Contractor Code	Worker Category ^a	Contact(s) or Reference	Activities Title and Brief Description	Exposure Type ^b	Driver ^c	Time Line	Duration (Years)	Workers per Activity
ORR (Y-12, ORNL, ETPP)	HWW/CW	4, 6	38109: Hazardous Waste Disposal activities performed by Oak Ridge are primarily driven by environmental laws and regulations external to the DOE system. This activity includes the storage, treatment, and disposal of RCRA, TSCA, and other wastes deemed hazardous (by Tennessee) and which cannot be disposed in on-site or off-site landfills.	C,R,M	RCRA TSCA	1989 - 2006	18	N/A
ORR (Y-12, ORNL, ETPP)	HWW/CW	4, 6	38901: Broad Spectrum MLLW activity retrieves waste from the generating site, treats the waste, and transports it to the disposal site. Currently, there are roughly 5,300 cubic meters in about 80 separate waste streams on the ORR that will be included.	C,R,M	RCRA	1989 - 2006	18	N/A
ORR (Off-site)	HWW/CW/ DeW	4, 6	48101: Off-Site Remedial Action describes a group of activities involving areas and facilities contaminated by DOE-ORR operations but downgradient from and/or outside of DOE property. This grouping also includes two reservation-wide initiatives (Footprint Reduction/Site Evaluations and ORR Integrated Water Quality Program).	C,R,M	CERCLA	1989-2006	18	N/A

6.0 Workforce Demographics

6.1 General

The DOE ORR facilities have undergone dramatic changes in function during the last 20 years and particularly during the last 10 years. These changes reflect similarly dramatic changes in technology and national priorities, and most recently, the intense focus on remediation activities. From the activities associated with nuclear weapons production and research for which the ORR facilities were designed and in which the facilities engaged for more than 50 years, the majority of current activities at the ORR facilities are directed toward stabilization and storage of nuclear processing materials, deactivation of nuclear processing equipment, disassembly of nuclear weapons, and remediation of environmental contamination. According to all resources used in this study, the changes in activities at these facilities, from nuclear materials production and research to nuclear materials and equipment management and environmental restoration, will continue for many years. To be expected, these changes in facility functionality have required commensurate changes in characteristics and size of the work forces involved. The number of workers and the types of workers required to perform designated activities at ORR are in a state of significant and frequent change due to changes in skills requirements resulting from the dramatic changes in the activities prescribed for the ORR facilities by DOE. The term designated by DOE for this change in character and size of the workforce is "restructuring."

A characterization of the population of workers at the ORR is made complicated by the fact that much of the work on many of the activities is, or will be, performed by subcontracted workers, the number of which is likely to be increased in coming years. One of the goals prescribed by NIOSH for the present study was to identify workers at the ORR by job title or other industry designation and determine the number of such workers by remediation activity. While a number of subcontractors performing work at the ORR have been identified, a characterization and accounting of their workers performing HWW, DeW and DiW, and CW activities have not been possible to date. Repeated attempts have been made to directly contact subcontractors but without success. This is not to imply that this information is not available, however. Discussions with LMES and BJC representatives have convinced the ORAU/CER research team that with additional effort and precise queries regarding specific activities of interest, data on types and numbers of workers involved in subcontracted activities can be collected. Considerable information has been gathered in efforts to understand the quite complex business relationships that exist among LMES, LMER, BJC and the many subcontractors who perform much of the work at ORR. A thorough comprehension of these business relationships will be necessary in order to determine if the appropriate populations can be adequately determined so that relevant data can be retrieved and meaningful health studies made.

One additional factor pertains to the problems encountered when attempting to collect demographic information on ORR subcontractor populations. Subcontracts may be let to subcontractors directly by the prime contractor (LMES, LMER, or BJC) or through a major subcontractor such as M. K. Ferguson. Activity characteristics that determine which method is used for subcontracting include, but are not limited to, activity size, type, and complexity.

Lengthy and detailed discussions about demographics of subcontractor populations were conducted with senior management, procurement, and health and safety personnel at ORR. An overall consistent impression was given that subcontractor personnel record-keeping was considered a responsibility of the subcontractor. A possible exception to this concept may be record-keeping for radiation monitoring which is still chiefly performed by the prime contractor or a separate subcontractor.

6.2 Current status of M&O workforce

The remarkable changes in operations at the ORR over the last 10-15 years have resulted in equally remarkable changes in the associated workforce. While periodic reductions in force have been necessary in response to change in weapons and research priorities, within the last five years ORR has seen a reduction in force of more than 5000 employees. Further reductions in the prime contractor's work force were anticipated as a result of the transition to an M&I management structure, beginning in 1998, and most of the impacted contractor employees left the payroll by the end of FY 1998. Table 6-1 shows the number of federal and contractor employees for FY 1997 through FY 2006. This estimated reduction is necessary to realign the work force to reduce spending by several \$100M. Reductions in force will be accomplished through voluntary and involuntary terminations. It is anticipated that many of the same workers previously employed by LMES and LMER in environmental restoration or waste management will be employed by one of the many M&I subcontractors.

Since the recent selection of BJC as the M & I contractor for all remediation projects at the ORR, a few meetings were held with BJC personnel in the Summer of 1999 relative to final efforts to obtain information from the LCB study (Section 3.2).

Table 6-1 ORR Employment Estimate (Full-Time Equivalents) FY 1997-FY 2006^s

Field Office	1997-2006 Totals	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
DOE-ORO Federal FTEs [*]	1,369	145	136	136	136	136	136	136	136	136	136
ORR M&I FTEs [*]	18,600	3,300	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700

* Full-time equivalent

In addition to changes in workforce, many procedures, processes, and services are being evaluated for reduction of time and improvement in quality. Make-or-buy studies are being performed for many service functions to determine if savings can be achieved by outsourcing. Plans are already in place to privatize some service functions.

During the prescribed changes in facility management and the associated changes in work forces, DOE is dedicated to adhering to the plan established during the planning process. When activities are determined to be off schedule or over budget, activity management techniques are in place to initiate appropriate actions to correct deviations from the plan. Performance metrics are also being monitored to ensure that the outcomes of the individual activities meet the EM program goals. These metrics include number of sites remediated, progress toward goals, and volume of waste stored, treated, and disposed.

The following tables (6-2 through 6-5) present the administrative breakdown, by payroll category, for employees at the central staff and the three ORR facilities as of October, 1997. Generally, these categories are not related to HWW, DeW, DiW, and CW activities, however, most of the workers involved in these activities would likely be hourly employees.

In addition, knowledgeable personnel at the ORR facilities identified employees engaged in cleanup, HW, De/Di or support activities and these individuals' job titles. A summary of the information garnered is shown in Table 6-6.

Table 6-2 LMES Work Force Report for Central Staff (October 1997)¹⁰

Job Code	Job Description	Number
Business Mgmt. & Admin.		
C052	Property & Materials Mgmt.	127
C060	LMES Business Services	110
C062	Office of the Controller	65
C064	Procurement	104
C080	Business Management & Admin.	15
C094	Energy Systems Contracts	10
C095	Business Systems	16
	Subtotal	447
Central Services		
C068	Auditing	24
C090	Executive Offices - Dept 7110	7
C090	Executive Offices - Dept 7111 Public Affairs	2
C090	Executive Offices - Dept 6271 Tech Transfer	0
C090	Executive Offices - Dept 7130 Recreation	4
C091	ES Human Resources	145
C092	Office of General Counsel	17
	Subtotal	199

Table 6-2 LMES Work Force Report for Central Staff (October 1997)¹⁰

Job Code	Job Description	Number
Private Enterprise		
C004	ASO Analytical Support	0
C010	ASO Admin.	0
C063	Information Technology Services	428
C065	ASO Analytical Laboratories	252
C067	ASO Compliance & Quality	3
C069	Engineering	588
C070	Information Management Services	198
C079	Engineering & Construction	3
C083	ASO Customer Services	5
	Subtotal	1477
Protective Services Organization		
C051	Protective Services Organization	776
Reindustrialization		
CO15	Reindustrialization	12
Supporting Operations & Compliance		
C061	Office of Quality Assurance	4
C085	Compliance	6
C093	Environmental Compliance	0
	Subtotal	10
Technology Partnerships		
D077	Haz. Waste Remed. Actions	80
C086	DSRD Software Engineering	103
D088	Data Systems R & D	76
	Subtotal	259
	Total	2404

Table 6-3 LMES Work Force Report for EMEF ETTP (October 1997)¹⁰

Job Code	Job Description	Number
K005	Technical	36
K007	Maintenance	316
K008	Data Systems Development & Maint	9
K009	Site Management	9
K0013	Enrichment Facility Support	7
K0015	Site Infrastructure	98
K0016	Health and Safety	0
K0017	ES Waste Management Organization	0
K0019	Management Systems	23
K0021	Program Planning & Integration	43
K0026	Environmental Compliance	0
K027	Business Management	73
K029	Landlord Programs Organization	0
K031	Project Execution	52
K041	Y-12 Waste Management	197
K044	Environmental Restoration Waste Management Administration	7
K045	ETTP Operations	226
K046	Environmental Tech. Development	0
K047	Waste Mgmt. & Remedial Action	20
K054	Management Planning & Analysis	12
K087	Environmental Restoration	0
	Total	1125

Table 6-4 LMES Work Force Report for EMEF Y-12 (October 1997)¹⁰

Job Code	Job Description	Number
Y001	Disassembly and Storage	168
Y002	Nuclear Operations	2
Y003	General Manufacturing	130
Y005	Resumption Operations	19
Y012	ES Safety & Health	30
Y012	Safety & Health	58
Y015	Development	161
Y016	Technology Services	49
Y017	Membrane Technologies	16
Y018	Special Materials	71
Y022	National Security Program Office	58
Y024	Depleted Uranium Operations	215
Y032	Y-12 Co-op	0
Y035	Facilities Management	1034
Y036	Business and Finance	66
Y037	Enriched Uranium Operation	308
Y040	Y-12 Site Management Services	61
Y053	Site Shift Operations & Emer. Prep.	0
Y055	Product Certification	122
Y056	Radiological Control	49
Y056	Radiological Control	128
Y057	Organization Improvement Programs	3
Y058	Plant Managers	31
Y059	Health Center	23
Y064	Facility Safety	18
Y066	Environmental Compliance	41
Y066	HSE - Environmental Compliance	65
Y068	Criticality Safety	39
Y081	Defense Programs and Engrg. Serv.	107
C082	ES Safety & Health	18
C089	Quality Services	0
K089	Quality Services	39
Y089	Quality Services	141
	Total	3270

Table 6-5 ORNL Work Force Report (October 31, 1997)¹¹

Division	Regular Payroll				Temporary Payroll				Guests (Non-Payroll)			
	Hr ^a	Wk ^b	Mo ^c	Total	>12 Mos	<12 Mos	Part-Time	Total	Citiz	Non-Citiz	Total Guests	Grand Total
Ctr. Computational Sciences	0	3	12	15	5	0	0	20	7	1	8	28
Central Management Offices	0	51	100	151	1	1	2	155	75	7	82	237
Chemical Technology	11	90	157	258	10	0	15	283	92	29	121	404
Chem & Anal. Sciences	0	21	96	117	11	0	4	132	107	39	146	278
Comp. Physics & Engr.	0	23	130	153	8	0	2	163	32	5	37	200
Computing Info & Networking	0	45	79	124	0	0	4	128	19	0	19	147
Computer Science & Math	0	12	60	72	4	0	2	78	16	6	22	100
Energy	0	40	111	151	6	0	7	164	119	16	135	299
Engineering Technology	0	43	174	217	3	0	6	226	36	4	40	266
Environmental Sciences	0	47	104	151	10	0	9	170	129	23	152	322
Fusion Energy	0	12	51	63	1	0	3	67	8	6	14	81
Inst. & Ctrls. (R&D)	0	29	119	148	8	2	7	165	25	2	27	192
Life Sciences	21	66	142	229	13	0	21	263	164	54	218	481
Metals & Ceramics	4	75	152	231	13	1	7	252	288	117	405	657
Physics	0	20	49	69	9	0	6	84	118	103	221	305
Research Reactors	25	22	86	133	0	0	1	134	11	0	11	145
Robotics & Process Systems	0	15	51	66	1	0	2	69	17	5	22	91
Solid State	0	7	45	52	20	0	4	76	147	191	338	414
SUBTOTAL	61	621	1718	2400	123	4	102	2629	1410	608	2018	4647
Administrative Services	42	21	12	75	0	0	0	75	3	0	3	78
Eng. & Construction Mgmt.	0	2	28	30	0	0	0	30	17	6	23	53
Finance & Budget	2	14	64	80	1	0	4	85	0	0	0	85
Health	1	14	10	25	0	0	2	27	3	0	3	30
Human Resources	15	15	16	46	0	2	13	61	8	0	8	69
Inst. & Controls (Services)	87	37	21	145	0	0	0	145	1	0	1	146

Table 6-5 ORNL Work Force Report (October 31, 1997)¹¹

Division	Regular Payroll				Temporary Payroll				Guests (Non-Payroll)			
	Hr ^a	Wk ^b	Mo ^c	Total	>12 Mos	<12 Mos	Part-Time	Total	Citiz	Non-Citiz	Total Guests	Grand Total
Ofc. of Laboratory Protection	0	12	20	32	0	0	0	32	0	0	0	32
Ofc. of Sci. & Technol. Part.	0	6	4	10	0	0	2	12	4	0	4	16
Ofc. of Env. Comp. & Doc.	0	23	40	63	0	0	3	66	7	0	7	73
Ofc. Oper. Read. & Fac. Saf.	0	4	19	23	1	0	0	24	3	0	3	27
Ofc. of Radiation Prot.	0	102	48	150	0	0	1	151	28	0	28	179
Ofc. of Safety & Hlth. Prot.	3	23	54	80	0	0	7	87	10	0	10	97
Ofc. of Quality Prog. & Insp	0	28	40	68	0	0	1	69	2	0	2	71
Ofc. of Univ. & Sci. Educ.	0	2	4	6	0	0	0	6	0	0	0	6
Plant & Equipment	613	30	149	792	1	1	1	795	13	0	13	808
Technology Transfer	0	6	6	12	1	0	0	13	2	0	2	15
Waste Mgmt. & Rem. Action	37	28	63	128	0	0	3	131	39	3	42	173
SUBTOTAL	800	367	598	1765	4	3	37	1809	140	9	149	1958
ASO Analytical Laboratories	0	2	1	3	0	0	0	3	0	0	0	3
Computing & Tele. Services	0	27	23	50	0	1	3	54	0	0	0	54
Central Engineering	0	0	16	16	0	0	0	16	20	0	20	36
ES Protective Services Org.	69	5	14	88	0	0	0	88	0	0	0	88
Information Mgmt. Svcs. Org.	0	25	34	59	1	0	5	65	0	0	0	65
Office of the Controller	0	5	3	8	0	0	0	8	0	0	0	8
LMES Business Services	0	8	3	11	0	0	0	11	0	0	0	11
Procurement	0	0	0	0	0	0	0	0	0	0	0	0
ES Waste Mgmt.&Rem.Action	0	3	17	20	0	0	0	20	0	0	0	20
Grand Total	930	1063	2427	4420	128	8	147	4703	1570	617	2187	6890

Table 6-6 Description of ORR Facilities-Designated Waste Workers^a

Category	Contractor	No. Workers	Industry Profile	Top Five Job Titles	No. Workers	Primary Activity Titles
HWW	LMES/Y-12	157	Solid and liquid hazardous and mixed waste treatment, storage and disposal workers	1. Chemical operator 2. Laborer 3. Engineer 4. TSCA operator 5. Supervisor	35 28 27 21 20	Solid, hazardous, and mixed waste treatment, storage, disposal, transportation, and systems maintenance
HWW	LMES/ETTP	375	Solid and liquid hazardous and mixed waste treatment, storage, disposal, and remediation workers	1.Operator 2.Maintenance mechanic 3. Instrument mechanic 4.Engineer 5. Power operator	115 63 50 16 7	Solid and liquid hazardous and mixed waste treatment, storage, disposal, transportation, systems maintenance, and remediation
De/Di	LMES/ETTP	25	DeW and DiW	1. Engineer 2. Supervisor 3. Technical assistant 4. Facility specialist	11 10 3 1	Manage and support DeW and DiW operations
Support	LMES/ETTP	124	Support CW and De/Di workers	1. Ground service worker 2. Bldg service worker 3. Carpenter 4. Refrig. mechanic 5. Laundry washer	38 32 20 8 6	These workers support the CW and De/Di and work in the facilities where this work is performed.
HWW	LMER/ORNL	222	Solid and liquid hazardous and mixed waste treatment, storage, disposal, and remediation workers	1. Engineer 2. Miscellaneous 3. Administrative support 4. Managers/Admin. 5. Misc. repair	NA	Solid and liquid hazardous and mixed waste treatment, storage, disposal, transportation, systems maintenance, and remediation
HWW	Subcontract /ORNL	39	Furnish ER craftsmen/laborers	NA	NA	Remediation work

The FFA requires publication of a progress report each quarter. Included within the prescribed report is a listing of the identities and task assignments of each of the DOE contractors performing work under the FFA. The following table presents a selected list of subcontractors and their assignments as reported in the July-September, 1995 ORR FFA Quarterly Report grouped by work location within the ORR. Subcontractors included in the list were selected on the basis of (1) likelihood of their employees to be physically

involved in remediation activities that could result in exposures and (2) likelihood of their generating and/or maintaining data or information pertinent to the remediation activities of interest in this project.

Table 6-7 ORR Remediation Past and Current Subcontractors (1995)¹²

Facility/Contractor	Service(s) Performed
Oak Ridge Y-12 Plant	
Advanced Sciences, Inc. (ASI)	Provides laboratory and field support.
Army Corps of Engineers	Hydro-acoustic study of the Clinch River arm of Watts Bar Reservoir to determine water depth and the distribution, thickness, and type of bottom sediments.
ATI	Project Management Plans for UEFPC OU 1; Conduct of Operations compliance support for multiple programs.
Automated Sciences Group (ASG)	Management support, collection, analysis, and interpretation of biota, water, and sediment samples. Management assistance for the Clinch River ER Program.
Battelle/Pacific Northwest Laboratories (PNL)	Provides support for water, sediment, and contaminant modeling tasks.
CDM Federal	Development of an RI Work Plan for UEFPC OU 1. Development of a Union Valley Interim Study Remedial Site Evaluation for UEFPC OU 1.
Colorado State University	Consulting concerning the DNAPLs in the Bear Creek Burial Ground. [Closed]
The Earth Technology Corporation	Development of the RI Plans. Sub-subcontractors include Singleton Labs and A.L. Clark for drilling, IT Corporation for analytical support, H&R Technical for data management and health and safety support. [Closed]
Foster Wheeler Environmental Corporation	Design prime contractor, LEFPC.
Geraghty & Miller, Inc.	Support in preparation of all post closure permit applications and preparation of the Bear Creek Valley OU 4 RI Plan
Highland Drilling Company	Characterization well drilling.

Table 6-7 ORR Remediation Past and Current Subcontractors (1995)¹²

Facility/Contractor	Service(s) Performed
Jacobs Engineering (DOE prime contractor)	Prepares the decision documents (FS and ROD) and other documents, Proposed Plans, RODs, Environmental Assessments, Environmental Impact Statements, documents for interim actions, and cost estimates associated with these documents. Technical support for RIs, assessments, and investigations for off-site locations; remedial action verification, DOE, and Energy Systems community relations activities, requirements associated with the Administrative Record; and risk assessments. PP/ROD prime contractor LEFPC OU.
JAYCOR	Provides support of data management activities and document maintenance in the production of risk assessment documents for the Clinch River ER Program.
Midwest Technical, Inc.	Provides support of data management activities and document maintenance in the production of risk assessment documents for the Clinch River ER Program.
MK-Ferguson of Oak Ridge Company	Baseline planning support for ORAU. Construction contractor, LEFPC OU.
ORAU	Provides radio analytical support for Phase 1 of the RI.
Oak Ridge Institute for Science and Energy	Provides risk assessment and contaminant transport modeling support.
PAI	Technical support for UEFPC RMPE project development.
Queen's University	The use of alcohol flooding to remediate sites contaminated by DNAPL; progress report submitted 5/31/94.
SAIC	Field sampling in Bear Creek Valley, development of an RI report for Bear Creek Valley OU 2 and Bear Creek Valley OU, data management support, support for ER strategic plan development, and field mobilization. Provides support in the compilation of data packages, validation and verification of data packages, and analytical services coordination for Clinch River. Support Preparation of ROD for LEFPC OU.
SENES, Oak Ridge	Provides support for human health risk assessment.
SONSUB	Subcontract for the closure of Kerr Hollow Quarry. [Closed]
Southern Illinois University	Provides assistance in biological data collection and sample design.

Table 6-7 ORR Remediation Past and Current Subcontractors (1995)¹²

Facility/Contractor	Service(s) Performed
Tennessee Valley Authority (via interagency agreement)	Support for: (1) sedimentation range cross sections; (2) aerial photography and topographic mapping; (3) numerical modeling of water, sediment, and contaminant transport; (4) sampling and analysis of water and sediments; (5) review of TVA sediment-disturbing activities; (6) sampling and contaminant analysis of fish; (7) sediment and water toxicity studies; and (9) benthic macro invertebrate community study at monitoring stations within the Clinch River and Poplar Creek. <i>[Tasks 1, 2, 5 closed]</i>
University of California-Davis	Provides quantitative histopathological analysis of target organs of fish.
University of Kansas	Support of geophysical studies concerning DNAPL migration. <i>[Closed]</i>
University of Tennessee	Hydrogeological support planned for RMPE as subcontractor to PAI. Provides assistance in data collection; data compilation; database development and management; development of procedures and maintenance/coordination of training; coordination of the Clinch River/WAG2 document management center with the other DMCs in Energy Systems Oak Ridge; study of pollutant material transport, distribution, and characterization; and program management.
University of Waterloo	Consultant concerning the DNAPLs in the Bear Creek Burial Ground and PCB experiments. <i>[Closed]</i>
Oak Ridge National Laboratory	
Advanced Systems Technology	Waste characterization processing and transportation assistance.
ATI	Structural integrity assessments for active LLLW tanks.
Automated Sciences Group	Biological data analysis, support for management, and analysis and interpretation of biological data from laboratory and field studies.
Battelle Pacific Northwest Laboratory	Design and fabrication services for an <i>in situ</i> vitrification off-gas hood and filtration system.
Bechtel National, Inc. (Team members also include CH2M Hill; PEER; ERC, Inc.; and IT Corporation)	RI activities for WAGs 1, 5, 6, and 10. Assessments will also be conducted of the inactive tanks as required by the FFA.
CDM Federal Programs	Preparation of a regulatory review and sampling and analysis plan for the WAG 6 performance monitoring activity.
ChemRad Inc.	Walkover survey. <i>[Closed]</i>

Table 6-7 ORR Remediation Past and Current Subcontractors (1995)¹²

Facility/Contractor	Service(s) Performed
Colorado Logging COLOG	Logging and ambient and stress testing of wells at WAG 5.
Dr. David Daniel	Assistance in the analysis of surface water.
EDGE, Inc.	Groundwater monitoring of wells.
Environmental Consulting Engineers	Preparation of remediation and post remediation monitoring plans for WAG 6 and monitoring in WAG 2 and WAG 5 removal action investigation.
ERC, Edge	Geotechnical tests.
ETE Consulting Engineers	Survey Services
Foster Wheeler	Remedial design activities
Geotek Drilling	Drilling services.
Gilbert Commonwealth	Assistance with preparing cost account plans and project documentation such as project management plans, health and safety plans, waste management plans, current year work plans, and configuration control support documents. Valve replacement for active LLLW tanks.
Harco	Cathodic protection for active LLLW tanks.
IT Corp.	Final closure certification on the 3001 Storage Canal RCRA Interim Closure. [Closed]
Jacobs ER Team	Preparation of integrated RCRA/CERCLA/National Environmental Policy Act (NEPA) decision documents, including FSs, Proposed Plans, RODs, EAs, Environmental Impact Statements, documents for interim actions, and cost estimates associated with these documents. Provision of technical support for the performance of RIs, assessments and investigations of off-site locations, and remedial action verification; support for DOE and Energy Systems community relations activities; and support for the adherence to requirements associated with the Administrative Record and performance of risk assessments.
JAYCOR	Sampling and analysis support for benthic macro invertebrate samples from WOC and its tributaries (no longer supporting benthic macro invertebrate samples).
JBF Associates	Technical Advisory Group support and appraisal of the Underground Storage Tank Program.
Kansas Geological Survey	Collection of seismic reflection data for WAG 10.

Table 6-7 ORR Remediation Past and Current Subcontractors (1995)¹²

Facility/Contractor	Service(s) Performed
Knoxville College	Data base support and technical support for sample collections.
Lockheed	Analytical services.
Midwest Technical, Inc.	Assistance in budgeting, planning, and cost tracking and provision of laboratory and field technical support.
MK-Ferguson of Oak Ridge Company	Construction management. Valve replacement/cathodic protection for active low-level RW tanks.
North Carolina State University	Assistance in biological monitoring and abatement tasks.
Northern Arizona University	Technical direction for surveillance and maintenance and WAG 5 cryogenic.
ORAU	Field services coordination.
OGDEN	Geotechnical services as required to support the remedial design architect-engineer and the Performance Assessment Program.
Performance Development Corporation	Technical and administrative support for active low-level RW tanks.
Radian	Preparation of environmental assessments and CERCLA decision documents. [Closed]
SAIC	Monitoring coordination, performance assessments and hydrologic modeling for the WAG 6 Performance Assessment Program.
Scientific Ecology Group (SEG)	Field demonstration on waste stabilization in burial trenches.
Southwest Research	Outside laboratory services.
Temp Systems	Assistance with administrative functions and surface water monitoring.
Tennessee Valley Authority Interagency Agreement	Technical supervision of FY 1992 drilling activities, including drilling three core holes and instrumenting them with multipoint measuring systems (Westbay systems) and selecting monitoring intervals using core data, geophysical logs, and flowmeter data via the agreement.
TMA Eberline	Outside laboratory analytical services.
University of California	Assistance in biological monitoring and abatement tasks.

Table 6-7 ORR Remediation Past and Current Subcontractors (1995)¹²

Facility/Contractor	Service(s) Performed
University of Tennessee	Assistance in performing data collection; data compilation; development of performance criteria, maintenance programs, and quality assurance plans; and oversight of surface water monitoring station upgrade activities.
U.S. Geological Service	Assistance in performing surface water monitoring.
Vista Research, Inc.	LLLW tank system leak testing methodology development.
Oak Ridge ETTP	
Adams Craft Hertz Walker	Site surveying (for the Pond Waste Management Project).
Battelle, Columbus Laboratories	Preparation of a simplified environmental assessment (for the Pond Waste Management Project).
Brooks Rand Laboratory	Mercury speciation analyses.
CDM Federal Programs	Preliminary Assessment/Site Inspection and RCRA Facility Investigation Work Plan preparation
Chemrad Tennessee Corporation	Ultrasonic Ranging and Data System support.
CompuChem Laboratories	Chemical/radiological analyses.
Dennis Weiter Assoc.	Study of available filter press operations (for the Pond Waste Management Project).
ESE Consulting Engineers	Surveying.
Geraghty and Miller	Technical support (for the ETTP Site Groundwater Protection Program). [Closed]
Highland Drilling	Characterization well drilling and drilling services for the ETTP Site Groundwater Protection Program. [Closed]
HSW Environmental Consultants, Inc.	Technical support (for the ETTP Site Groundwater Protection Program).
Jacobs ER Team	Preparation of integrated RCRA/CERCLA/NEPA decision documents, including FSs, Proposed Plans, RODs, EAs, Environmental Impact Statements, documents for interim actions, and cost estimates associated with these documents. Provision of technical support for the performance of RIs, assessments and investigations of off-site locations, and remedial action verification; support for DOE and Energy Systems community relations activities; and support for the adherence to requirements associated with the Administrative Record and performance for risk assessments.

Table 6-7 ORR Remediation Past and Current Subcontractors (1995)¹²

Facility/Contractor	Service(s) Performed
Labat-Anderson	Assistance for Radian Corporation in the environmental assessment of the K-1407-B and -C Ponds. <i>[Closed]</i>
Lockwood Greene	On-site project engineering support and Title II design (for the Pond Waste Management Project). <i>[Closed]</i>
SAIC	RI subcontract services for the K-770 and K-1070 OUs.
Tenerra	Technical consulting and assistance in conduct of operations (for the Pond Waste Management Project). <i>[Closed]</i>
University of Tennessee, Industrial Engineering Department	Assistance in planning for storage layout and warehousing (for the Pond Waste Management Project). <i>[Closed]</i>
Oak Ridge Reservation Boundary Areas	
Advanced Sciences, Inc. (ASI)	Laboratory and field support.
Analytical Projects Office at Martin Marietta Energy Systems, Oak Ridge	Processing of all contracts for the analysis of samples collected. The analytical Projects Office and Energy Systems Procurement determine which labs will perform analyses.
Army Corps of Engineers	Hydroacoustic study of the Clinch River arm of WBR to determine the water depth and the distribution, thickness, and type of bottom sediments.
Automated Sciences Group (ASG)	Support for various tasks in the management, collection, analysis, and interpretation of biota, water, and sediment samples. Also, provides program management assistance for the Clinch River ER Program.
Battelle/Pacific Northwest Laboratories (PNL)	Support for water, sediment, and contaminant modeling tasks.
Foster Wheeler Environmental Corporation	Baseline planning support for ORAU. Design and estimating services as a prime contractor for LEFPC.
Gilbert/Commonwealth	Scheduling for LEFPC.

Table 6-7 ORR Remediation Past and Current Subcontractors (1995)¹²

Facility/Contractor	Service(s) Performed
Jacobs ER Team	Preparation of RCRA/CERCLA/NEPA documents. Provision of technical support for RIs, assessments and investigations of off-site locations, and remedial action verification; support for DOE and Energy Systems community relations activities; and support for the adherence to requirements associated with the Administrative Record and performance for risk assessments. Prepares the decision documents (FS and ROD) in support of the new LWBR OU. Is the prime contractor for the Proposed Plan and ROD for LEFPC.
JAYCOR	Data management activities and document maintenance in the production of risk assessment documents for the Clinch River ER Program.
Midwest Technical, Inc.	Support of data management activities and document maintenance in the production of risk assessment documents for the Clinch River ER Program.
MK-Ferguson	Baseline planning support for ORAU. Construction contractor for LEFPC.
ORAU	Radio analytical support for Phase 1 of the RI.
Oak Ridge institute for Science and Energy	Risk assessment and contaminant transport modeling support.
Science Applications International Corporation (SAIC)	Support in the compilation of data packages; validation and verification of data packages; and coordination of analytical services. Provides support preparation of ROD for LEFPC.
SENES, Oak Ridge	Support for human health risk assessments.
Southern Illinois University	Assistance in biological data collection and sample design.
Tennessee Valley Authority (via an interagency agreement)	Support for: (1) cross sections of sedimentation ranges; (2) aerial photography and topography; (3) modeling of water, sediment, and contaminant transport; (4) sampling and analysis of water and sediment; (5) review of TVA sediment-disturbing activities; (6) sampling and contaminant analysis of fish; (7) sediment and water toxicity studies; and (8) benthic macro invertebrate community study of monitoring stations within the Clinch River and Poplar Creek. <i>[Tasks 1, 2, and 5 are closed]</i>
University of California-Davis	Quantitative histopathological analysis of target organs of fish.
University of Tennessee	Assistance in data collection; data compilation; data base development and management; development of procedures and maintenance/coordination of training; coordination of the Clinch River/WAG 2 document management center with the other DMCs at Energy Systems in Oak Ridge; study of pollutant material transport, distribution, and characterization; and program management.

6.3 Locating subcontract workers for epidemiologic study

During the conduct of this study, ORR contacts repeatedly confirmed that a large portion (up to 93 percent) of remediation activities have been, and will be, performed by subcontract workers. The preferred procedure calls for virtually all aspects of a subcontracted activity to be within the responsibility of the primary subcontractor. In addition to performing the physical activities prescribed within the subcontract, these aspects include, but are not limited to, hiring of workers, assuring that workers meet required certifications, performing required monitoring of workers, management of required monitoring records, and submission of required occupational reports to appropriate agencies. An exception to this protocol is the monitoring of subcontractor workers for radiation or radioactive material exposure or dose. BCJ has hired a subcontractor to perform these duties and is requiring all other subcontractors to use this service. Considering these facts, the pathway necessarily followed to identify subcontract workers would be the following:

1. Identify remediation activity of interest. Information about completed, ongoing, and planned remediation activities can be collected from public documents, Internet sites, or this report.
2. Identify contract number of the activity of interest from LMES, LMER, or BJC managers in deactivation and dismantlement or WM departments. If possible, at this time also identify the activity subcontract representative. The subcontract representative for each activity should be familiar with almost all aspects of the activity including approval of completed work.
3. Identify the primary subcontractor(s) for the activity of interest from the appropriate procurement department. Typically, all contracts are issued through the contractor procurement department, and this is the location of records containing contract titles, numbers, and dates; and contractor names.
4. Contact primary subcontractor(s) to identify employees performing work specified in activity of interest. At this time the primary subcontractor(s) should also be asked to identify any other subcontractors that participated in the activity of interest.
5. If additional subcontractors are identified by the primary subcontractor, steps (4) and (5) should be iteratively repeated until all subcontract workers have been identified.

7.0 Technologies

Although we found many references to new and innovative technologies which may be developed or pursued, pending funding availability, it is interesting to note that technology development is so low on their priority list that ORO has not requested any funding for such development in fiscal year 1999⁹. A majority of the information about technologies applied at the ORR was found in a four-volume set, titled *Oak Ridge National Laboratory Technology Logic Diagram* (TLD), developed as a decision-support tool that relates environmental restoration and waste management problems to existing or potential technologies that can remediate these problems. The TLD consists of *Part A, Characterization and Decontamination*¹³, *Part B, Dismantlement and Remedial Action*¹⁴, *Part C, Robotics/Automation and Waste Management*¹⁵, and *Indexes*.

7.1 Descriptions of major technologies

Brief descriptions of the major technologies presently employed and planned for future use in remediation activities are presented below. The descriptions are directly relevant to the activities at the ORR, however, it should be noted that in many cases the actual procedures followed are modified for a particular activity.

Activated Carbon¹⁴

Activated carbon is used as a high surface area or permeability material in liquid-phase adsorption to selectively adsorb organic contaminants from aqueous streams, using the principles of physical adsorption and chemisorption. Liquid-phase adsorption works on the principle that the concentration of certain organics will be higher on the surfaces of certain solids than in the bulk-liquid phase. Physical adsorption occurs between the dissolved compound and the surface because of weak atomic and molecular forces such as Van der Waal forces. Chemisorption involves a chemical reaction between the compound and the surface of the solid. Granular activated carbon is, by far, the most commonly used adsorbent column system and is often regenerated. Contaminated water is passed through the column until the key contaminant is detected at some predetermined level in the effluent. This is an accepted, well developed technology, applicable for many different waste contaminants. Size of the exchange system, flow rate, and adsorption material are dependent on the contaminant to be removed. Only minor strategic problems are associated with the technology, such as having a regeneration facility or disposal means for the used carbon and having a means of conveying groundwater or surface water to the treatment facility.

Air Stripping^{14,16}

Air stripping is a full-scale technology in which VOCs are separated from groundwater by greatly increasing the surface area of the contaminated water exposed to air. This process is generally conducted in a packed tower or an aeration tank. Packed tower air strippers include a spray nozzle at the top of the tower to distribute contaminated water over the packing in the column, a fan to force air countercurrent to the water flow, and a sump at the bottom of the tower to collect decontaminated water. Aeration tanks involve the injection of air creating an air lift pumping system due to the density gradient. This causes the groundwater with entrained air bubbles to rise and separate volatile contaminants from dissolved to vapor phase. Groundwater is recirculated through the stripping well until remediation goals are met.

Air stripping is used to separate VOCs from water. It is ineffective for inorganic contaminants. Henry's law constant is used to determine whether air stripping will be effective. (Generally, organic compounds with constants greater than 0.01 atmospheres - m³/mol are considered amenable to stripping). Some compounds that have been successfully separated from water using air stripping include chloroethane, trichloroethylene, dichloroethylene, and perchloroethylene.

Asphalt Capping^{14,17,18}

Asphalt capping results in physical containment and vertical isolation of solid contaminants or hazardous material. This is a well accepted, industrial technology that is relatively inexpensive and may provide normal access and use of site. This technology does not provide complete entombment of waste and does not protect from horizontal migration of contaminants by groundwater. No other disadvantages are noted.

Bioremediation^{15,16,19,20,21,22,23,24}

Bioremediation, or bioreclamation, uses microorganisms such as bacteria, fungi and yeast, or their extracts, to dissolve and/or degrade organic contaminants such as oil, gasoline, detergents, polychlorinated hydrocarbons, pesticides, and gases or inorganic contaminants in soil and water, and render them harmless. Bioremediation is most efficient as a polishing step used in conjunction with some other type of treatment that results in trace amounts of toxic pollutants in large volumes of soils or industrial effluents. To optimize the bioremediation process, variables such as temperature, pH, dissolved oxygen concentration, nutrient concentration, redox potential, and rate of mixing are controlled.

A major advantage of bioremediation is that the cost is roughly one-third to one-half of conventional chemical and physical remediation technologies, and it is faster than many other methods. In addition, because treatment is *in situ*, the risk of worker exposure is reduced significantly. However, microbial activity can be inhibited by factors such as high concentrations of heavy metals, the presence of toxic organic substances such as chlorine and inorganic salts, and the formation of toxic byproducts.

Capping (Low permeability cover, Kaolin, and Geosynthetic)^{17,18}

Cap closure technology utilizes a variety of material from low permeability soil to geosynthetic covers, all designed to stabilize the waste and stop infiltration of rainwater. Once the waste has been stabilized, if the area (usually a basin or ditch) still contains hazardous material, it will be topped with a cap.

Depending on the amounts of hazardous waste left, caps may just be nothing more than a backfilling of earth, a low permeability cover, or some highly impervious material to help prevent groundwater from moving through the hazardous substances. Two types of capping widely used are the Kaolin clay cover and the Geosynthetic cap. The traditional Kaolin clay cover layers a foundation layer of 2 feet of native soil, two 1 foot rock areas which serves as a gas vent and drainage layer and sandwiches a 2 feet Kaolin clay barrier that protects the waste from surface water. These layers are covered with soil and grass or with other materials depending on the planned usage. The use of the Geosynthetic cap reduces the thickness of a like cap by about 4 feet since it is 1 inch thick and takes the place of the two rock layers and the Kaolin clay.

Capping (pits/trenches)¹⁴

Capping of pits and trenches entails placing hydraulic barriers over, around, and/or under a zone of contaminated shallow ground to protect against leaching and advection of contaminants by movement of water. In addition to protection of waste from infiltration of precipitation and percolation of groundwater, barriers also can address intrusion by plant roots and burrowing animals, including humans, for periods dictated either by contaminant risk duration or by attention span of regulatory responsibility. This is a mature technology that isolates contaminant(s) against entry and exit. Use of flexible membrane liner depends on lack of differential subsidence between the waste pit/trench and the surrounding soil. Currently, site infiltration covers have design limitations much shorter than the time required for containment of some contaminants (fission products and TRU radioisotopes). Most restrictively, the TRU radioisotopes would require containment for thousands of years before significant decay would eliminate the need for continued containment. Capping does not insure against lateral migration of contaminant(s) from groundwater leaching over long periods, although such techniques as cutoff walls and drains might address this need in the short-term (30 years).

Compaction (Dynamic Compaction)¹⁴

Dynamic compaction involves mechanical pounding of solid waste areas such as trenches and pits containing waste in drums, plastic bags, wooden crates, cardboard boxes, etc. Compaction is a simple, well-demonstrated technology that can effectively stabilize a wide range of waste forms. The pounding not only stabilizes the waste but also produces instantaneous data on the effectiveness of the compaction (i.e., quality control is established on a crater-by-crater basis). Dynamic compaction is most effective for LLW buried within 30 feet of the surface. Advantages associated with the technology include minimizing worker exposure, dramatic reduction of waste volume, and increased waste stability. The technology is restricted by equipment limitations (crane and tamper sizes). Also, there are environmental risks related to collapse and release of fluid-filled drums. If groundwater transport is present and many fluid filled drums exist, then dynamic compaction is not a good choice.

Cryogenic Barriers¹⁴

Cryogenic barriers provide containment of subsurface chemical and nuclear wastes using barriers composed of a frozen layer of native geologic materials. A geologic layer is frozen via freeze pipes installed at an angle that reach below the area of contamination or down to the impermeable layer below the site. The layer between the two arrays of piping is frozen and serves as the barrier to prevent movement of contaminants and water into or out of the area that has been isolated. This type of barrier can serve as an effective alternative to using slurry walls, grout curtains, or steel sheet barriers. It is useful for areas with many buried devices, structures, or equipment. It is also useful in areas where generation of hazards from excavation might be difficult to control. Cryogenic barriers are typically useful only for temporary containment, but may be used for longer periods when justified by costs of other methods.

Cutoff Walls¹⁴

Cutoff walls are used for temporary hydrologic isolation. Nonporous interlocking sheets (usually steel) are driven into ground to refusal or rock (30-40 feet maximum depth). This technology is well accepted, commercially available, and relatively inexpensive. Cutoff walls usually do not provide a perfect water barrier since leaking occurs at joints; if no confining layer exists, water

will also migrate underneath. For these reasons, cutoff walls are usually only used for temporary isolation.

Decontamination¹³

Decontamination involves a large number of technologies ranging from very simple procedures to highly technical processes. Examples include brushing, washing, steaming, grinding, blasting, dissolving, extraction, and electrical migration. Many of these technologies are common industrial procedures requiring little special training or equipment. Additional controls may be required to protect decontamination workers from spray or dust generated. Often, decontamination of facilities, equipment, or materials may be more costly than disposal.

Demolition (Conventional)¹⁴

Conventional demolition involves destruction of concrete and other structural materials using wrecking balls and hydraulic or pneumatic hammers. This is an accepted, mature technology requiring commonly available equipment and requiring little specialized training. During demolition, a large amount of dust is often generated and it is usually impractical to contain. Also, any reinforcing steel encountered has to be cut by other means.

Dewatering¹⁵

(See Evaporation and Filtration)

Dismantlement¹⁴

Dismantlement includes a variety of disassembly activities for the purpose of removing contaminated structures, parts, or materials, in some cases separating these from uncontaminated structures, parts, or materials. Salvage of uncontaminated structures, parts, or materials may be possible. Dismantlement activities may present high potential for exposures to contaminants as well as potential for physical injury. Dismantlement may result in reclamation of valuable equipment or materials, but also may be more costly than total disposal.

Diversion Ditches with Downgrade Leachate Collection Ditches⁵

Diversion ditches, combined with downgrade leachate collection ditches, make possible redirection and relocation of contaminants for subsequent appropriate removal, treatment, or disposal. This is an accepted, simple industrial technology that can remarkably improve accessibility and isolation of contaminants. This technology does not eliminate the need for subsequent remediation of original contaminant pathway(s) and actually may increase the total volume of waste requiring remediation.

Downgradient French Drains¹⁴

Downgradient french drains are narrow, vertical trenches filled with porous backfill. Waste water intercepted by the drain is gravity drained if the terrain allows, or pumped from sumps located at low points in the drain and transferred to appropriate locations for storage, treatment, or disposal. This is an accepted, cost-effective, and commercially available technology that has been used successfully at ORNL. A disadvantage is that cost-effective construction of French drains is limited to rippable materials i.e., soil and rock which can be excavated without blasting, jack-hammering, etc.

Equipment Removal (Conventional Disassembly)¹⁴

Conventional disassembly includes sawing with toothed or abrasive blades or severing with edged tools (chisels) and dismantling by removing fasteners. Cutting can be done in air or under a liquid, using power or hand tools. This is a common and accepted technology requiring inexpensive equipment and little specialized training, and there is little danger of equipment contamination. Adaption of the technology for use by remote manipulation will be required for certain equipment and facilities.

Evaporation¹⁵

Evaporation is the partial or complete removal of liquid from a solution or liquid mixture, resulting in concentration of solutes or particulates and reduction in volume. Evaporation may be by natural vapor pressure or by evaporation devices. The technology is an accepted, easily implemented technology applicable to many waste streams for sludge dewatering or as a pretreatment to decrease quantities of material for final treatment. Solar evaporation is the simplest implementation and has much lower capital and operating costs. However, applicability of solar evaporation may depend on availability of land and time requirements. Disadvantages of the technology include scale formation on heating tubes, thermal degradation or coking of organics, and its applicability only when initial solute concentrations are high (>10,000 ppm).

Excavation^{14,18}

Excavation results in removing and relocating contaminant(s). In some cases when this removal leaves a depression or a ditch, it will be backfilled with available uncontaminated soil. This is an accepted technology using commercially available equipment such as clamshells and backhoes. In some cases it may be necessary to control airborne emissions, and further treatment of removed soil/sediment may be required. Development of remotely controlled equipment and controls to limit emissions is underway.

Extraction Wells⁵

Extraction wells provide physical access for removal of contaminated liquids for subsequent transfer to appropriate treatment system(s). This is a simple, mature technology resulting in capture of plumes and mitigation of contaminant migration. Use of this technology does not result in complete elimination of contamination.

Filtration¹⁵

Filtration is a generic technology for physical removal of solid particulates from liquid or gaseous streams, often using a porous medium. This waste management operation includes various forms of solids separation such as decantation, centrifugation, gravity separation, sedimentation, cake filtration, bag house and high efficiency particulate air (HEPA) filtration, and electrostatic precipitation. The technology may be used for removal of inorganics, organics, and particulates from various liquid and gaseous effluent streams generated in DeW and DiW activities, remedial action, and other site waste processing operations. Filtration is a mature, commercially available technology with many filter media available. Because filtration often enables the discharge of large volume waste streams (by removing the contaminants), the payback for use of the technology often is quite significant compared with the cost of alternatives.

Hydrofracture Grouting¹⁴

Hydrofracture grouting involves polymer injection to fill cracks in host rock at the edge of a contaminant plume. Polyurethane has superior mechanical properties that allow good control over grout migration into rock mass. Setup times can be varied from seconds to several minutes, and both large and fine rock fissures are effectively grouted. This is a well accepted technology that results in good sealing of waste. An additional benefit is reestablishment of rock tensile strength. Some grouting materials are subject to deterioration by ultraviolet light, and grout setting may be affected by very saline groundwater. The need exists to evaluate the influence of radioisotopes on the long-term mechanical properties of cured polyurethane.

Incineration^{13,14}

Incineration is used to remediate soils contaminated with hazardous waste. Incinerators operating at temperatures of 870°C to 1200°C are used to volatilize and combust with oxygen, halogenated and other refractory organics. Incineration technology offers the advantage of being able to dispose of waste contaminated with dioxins and polychlorinated biphenyls (PCBs) which are extremely difficult, if not impossible, to dispose of in other ways. These incinerators can be used to meet the 99.9999% efficiency requirements for PCBs and dioxins. Some disadvantages of the technology are: (1) there is a limited number of incinerators licensed to burn dioxins and PCBs, (2) there are feed and material handling requirements that impact applicability and cost, (3) some contaminants cause operational problems, (4) volatile heavy metals (Cd, Pb, Hg, and As) exit the combustion unit with the flue gases and require gas cleaning systems for removal. Incinerator off-gas requires treatment by an air pollution control system to remove particulates and neutralize and remove acid gases.

In Situ Vitrification (see Vitrification)

Institutional Controls

If contamination cannot be stabilized or remediated satisfactorily with regards to decontamination or timeliness, the contaminated equipment, material, area, or facility may be fenced off, or entry otherwise controlled, or other administrative actions taken that will minimize the possibility that harm will be done to people or to the environment. Simple and relatively inexpensive to implement, these controls may have to be continued indefinitely and may be costly. The public usually opposes use of such controls.

Interception Trenches⁵

Trenches filled with reactive media are used to capture contaminant plumes and mitigate contaminant migration. This is a simple, mature technology resulting in lessening and possibly elimination of further downgrade contamination. Further remediation or disposal of contaminated reactive media may be necessary.

Ion Exchange^{14,15}

Ion exchange is a volume and toxicity reduction technology to remove ionic species, principally inorganics, from aqueous waste streams. Ion exchange is based on the use of specifically formulated resins and natural inorganic materials having an "exchangeable" ion bound to the resin with a weak ionic bond. If the electrochemical potential of the ion to be recovered (contaminant) is greater than that of the exchangeable ion, the exchange ion goes into solution

and the ionic contaminant binds to the resin. The decontamination takes place by passing the contaminated liquid through a series of columns containing the ion-exchange medium designed to trap and retain the ionic contaminants(s). Typically, four operations are carried out in a complete ion exchange cycle: service, backwash, regeneration, and rinse. Laboratory-scale performance tests can usually provide data for resin selection, estimates of resin loading and regeneration requirements, and other needed parameters for column design. This technology is a common, fully developed, and well accepted technology, applicable for many different separations. Applications may be very contaminant-specific, and appropriate exchange media may not be available for particular contaminants.

Jet Grouting^{14,18}

Jet grouting involves the injection of various grouting agents into soil/waste matrices that result in forming a soil/waste/grout monolith that has a natural analog of a long-lived material. The grouting material cements the waste in place, thus encapsulating the waste in a cemented block that is impervious to water migration. The technique can also be used as an intermediate stage to solidify waste to prevent future aerosolization of contaminants, should retrieval be necessary. This technology has the potential to significantly reduce worker exposure.

Jet grouting technology that is capable of isolating waste material from the natural environment has several advantages. The technology can stabilize a variety of DOE and Superfund sites; is compatible with complex mixtures of various contaminants; isolates and encapsulates buried materials containing radioactive and other hazardous waste; is applicable to various waste forms and surrounding materials, and isolation of buried structures such as waste storage tanks; and has a natural analog, both in formation and longevity.

Magnetic Seed Filtration^{25,26}

Magnetic seed (or seeding) filtration is a technology under development for enhanced removal of magnetic and non-magnetic particulates from liquids. The process involves the addition of a small amount of magnetic seed particles (such as naturally occurring iron oxide) to a waste suspension, followed by treatment with a magnetic filter. Non-magnetic and weakly magnetic particles are made to undergo nonhomogeneous flocculation with the seed particles, forming flocs of high magnetic susceptibility that are readily removed by a conventional high-gradient magnetic filter. The technology is applicable to a wide range of liquid wastes, including groundwater, process waters, and tank supernatants. At this point, the technology is at the bench-scale stage of development; laboratory studies and fundamental modeling are currently being employed to determine the capabilities of the process.

Neutralization¹⁵

Neutralization consists of appropriate treatment of acidic and caustic wastes with base or acid, respectively, to reduce corrosivity, often resulting in precipitation of hazardous contaminants. Precipitates subsequently can be filtered and removed from the treated waste prior to either further treatment or disposal. This technology is an accepted, highly effective, and economical industrial practice, not requiring specialized devices for implementation. Neutralization often results in a drastic reduction of hazardous waste volume. No significant disadvantages are noted.

Plume Migration Retardation⁵

Plume migration retardation involves the use of low-volume pumps in existing or new wells to extract liquid from a plume to retard further migration of the plume. This technology is usually employed to quickly diminish or stop further spread of contaminants. This is a simple, commercially available technology that may provide valuable contaminant control, but does not eliminate contamination.

Pressure Grouting (see Jet Grouting)^{5,14,18}

Pressure grouting involves high pressure pumping of grout into or under a waste area to form a grout seal. This technology has been used successfully in Europe and at ORNL to form bottom seals. Grout formulations are needed to allow increase in percent mixing of injected grout with *in situ* materials, while improving the volume of grout mixed in place.

Slurry Walls¹⁴

Slurry walls are narrow, vertical excavations that are backfilled with a slurry while excavation is in progress, thereby preventing collapse of the sidewalls during excavation and producing a barrier to groundwater flow. The slurry is generally a bentonite, bentonite/clay, or bentonite/Portland cement mixture. For the slurry wall to be effective, a confining layer must be present in which to key the wall. The technology could be combined with other technologies in new or unique applications which would not depend on confining layers to be effective. This is an accepted, commercially available technology that has been used on environmental activities at the Portsmouth Gaseous Diffusion Plant. At Oak Ridge, the fractured and solution-featured bedrock lacks a confining layer or aquiclude and thus, may not be suited for slurry wall use.

Smelting¹⁵

Smelting is a pyrometallurgical process consisting of heating contaminated scrap metal in a furnace with various fluxes (such as limestone and coke) to high temperatures (700-2000°C) in the presence of reducing gases to yield molten metal and a slag or dross. Organic contaminants are destroyed during smelting and nonvolatile inorganic and radioactive species are (hopefully) removed with the slag. The slag can be further processed (if necessary) and disposed while the metal is cooled, cast in molds, and recycled (if radioactive contamination is within regulatory limits). Smelting is an old, well recognized and accepted industrial technology. Applicability for treatment of RWs has not been fully demonstrated for some metals.

Soil Vapor Extraction^{14,16,27,28}

Soil vapor extraction (SVE), also called *in situ* air stripping or enhanced volatilization, removes VOCs from a soil matrix. A network of wells with perforated well screens potentially extending into the groundwater is packed with gravel and sealed at the top with bentonite. A vacuum extraction unit induces a flow of air from the subsurface into extraction wells connected to a surface collection manifold. This technology is commercially available and has been demonstrated to be quite efficient (50% VOCs typically removed in the first 10 percent of the operating time). Extraction times are dependent on porosity, permeability, and the hydraulic conductivity of the soils being treated. Information on contaminant volatility, vapor pressure, and Henry's Law constants (adsorption coefficient) are required to estimate air flow rates and treatment times.

Soil Washing^{14,16}

Soil washing is a water-based process for scrubbing soils *ex situ* to remove contaminants. The process removes contaminants from soils in one of two ways: (1) by dissolving or suspending them in the wash solution which is later treated by conventional wastewater treatment methods or (2) by concentrating them into a smaller volume of soil through particle size separation, gravity separation, and scrubbing.

Soil washing systems incorporating the most removal techniques offer the greatest promise for application to soils contaminated with a wide variety of heavy metals, radionuclides, and organic contaminants. Washing processes that separate the fine clay and silt particles from the coarser sand and gravel soil particles effectively separate and concentrate the contaminants into a smaller volume of soil that can be further treated or disposed of. Gravity separation is effective for removing high or low specific gravity particles such as heavy metal-containing compounds.

At the present time, soil washing is used extensively in Europe but has had limited use in the United States. It is most commonly used in combination with bioremediation, incineration, and solidification/stabilization. Depending on the process used, the washing agent and soil fines are residuals that require further treatment.

The target contaminant groups for soil washing are semi-volatile organic compounds, fuels, and inorganics. The technology can be used on selected VOCs and pesticides. The technology offers the potential for recovery of metals and can clean a wide range of organic and inorganic contaminants from coarse-grained soils.

Supercompaction¹⁵

Supercompaction is an effective mechanical volume reduction process distinguished from ordinary compaction by the force applied by the compression device (>1000 tons). This technology is commonly used by the nuclear power industry to reduce the volume of waste prior to storage and disposal. Supercompaction can be used on wastes that are not normally considered compatible such as pipes, valves, motors, and certain construction materials. This is an accepted, robust, and reliable technology that can result in an increase of storage capacity of about 66%. There are essentially no secondary wastes generated except for some liquid bleeding for site-specific applications.

Vitrification^{14,16,29,30,31,32,33}

Vitrification is the process of converting hazardous waste (liquid or solid) into a glass and crystalline product by melting it with electrical energy. *In situ* vitrification is performed subsurface, where the contamination resides. Four electrodes are inserted to the required depth in the ground at the corners of the site to be treated. An electrical current is initiated causing the frit and adjacent soil to fuse and form a melt. The molten zone slowly expands throughout the treatment zone where the electrodes have been placed. Nonvolatile wastes and metals are incorporated in the melt and VOCs are pyrolysed. The pyrolysed products migrate to the surface of the melt and combust in the presence of air. These gasses are collected and treated by an offgas treatment system. Currently, this technology applies to wastes at soil depths of up to 19 feet.

Remote vitrification is performed in much the same way except the material to be vitrified is transferred to a location other than where it originally existed. Vitrification of radioactive liquid

waste usually occurs through one of two processes: (1) a two-stage process based on rotary calciner/metallic melter; and (2) a liquid-fed ceramic melter process. In both processes the result is a containable glass-like solid.

The advantages of vitrification include its simplicity and its ability to treat many types of waste. The nonleachable glass waste product allows for safer handling and cheaper land disposal of the waste due to waste volume reductions. The technology is particularly applicable to soils and sediments which present significant hazards to workers from direct contact during handling. The major disadvantage of the technology is the volatilization of some materials during heating.

Waste Relocation^{13,14,15}

Relocation of waste to other facilities for storage, treatment, or disposal is frequently necessary to achieve prescribed remediation goals. This procedure involves a number of quite common activities including packaging, loading, and transporting. Transferring hazardous waste to an area less likely to present potential exposure to humans is often a cost-effective measure that can also provide significant benefits of time saving. In some cases, waste relocation may be the only means of reducing potential exposures or meeting regulatory requirements for particular wastes. The chief disadvantage of this technology is that it is a temporary measure only, and subsequent decontamination, treatment, or permanent disposal still remains to be done.

Well Plugging and Abandonment¹⁴

Well plugging and abandonment involves the use of rig-mounted drilling units to conventionally plug and abandon well bores, leaving the casing in place. Cement plugs are placed above (and below if applicable) injection zones to isolate the zones from any aquifers. The plugs are inside and outside the casing string. The technology is well accepted and allows for selection of several plugging techniques based on geology of formation and physical condition of casing. Heavy shielding or remotely operated drilling equipment may be required to prevent worker exposure, and equipment may become contaminated requiring use of a toxic substance disposal facility for decontamination of drilling fluids and equipment.

7.2 Tables of technologies

Table 7-1 presents a summary list of technologies in use or planned for use in remediation activities in each watershed. Details of the technologies are presented in Table 7-2.

Table 7-1 Remediation Technologies by Watershed - ORR^{5,15,16,17,18}

ORNL Bethel Valley	ORNL White Oak Creek	Y-12 Bear Creek	Y-12 Upper East Fork Poplar Creek	ETTP
Incineration			Incineration	Incineration
Neutralization			Neutralization	Neutralization
Filtration			Filtration	Filtration
Evaporation			Evaporation	Evaporation
Ion Exchange			Ion Exchange	Ion Exchange
Activated Carbon				Activated Carbon
Jet Grouting	Jet Grouting		Jet Grouting	Jet Grouting
	Hydrofracture Grouting			
	Pressure Grouting			
Compaction (Dynamic Compaction)			Compaction (Dynamic Compaction)	Compaction (Dynamic Compaction)
Supercompaction			Supercompaction	Supercompaction
Smelting			Smelting	Smelting
Magnetic Seed Filtration				
Waste Relocation	Waste Relocation		Waste Relocation	Waste Relocation
Capping (pits/trenches)	Capping (pits/trenches)	Capping (pits/trenches)	Capping (pits/trenches)	Capping (pits/trenches)
Slurry Walls				
Downgradient French Drains	Downgradient French Drains			Downgradient French Drains
Excavation	Excavation	Excavation	Excavation	Excavation
Soil Washing				

Table 7-1 Remediation Technologies by Watershed - ORR^{5,15,16,17,18}

ORNL Bethel Valley	ORNL White Oak Creek	Y-12 Bear Creek	Y-12 Upper East Fork Poplar Creek	ETTP
Plume Migration Retardation				
Decontamination	Decontamination			Decontamination
Equipment Removal (Conventional Disassembly)				Equipment Removal (Conventional Disassembly)
Dismantlement	Dismantlement			Dismantlement
Demolition (Conventional)				Demolition (Conventional)
			Bioremediation	
	Cutoff Walls			
	Cryogenic Barriers			
	<i>In Situ</i> Vitrification			
	Well Plugging and Abandonment			
		Extraction Wells	Extraction Wells	
		Interception Trenches		
		Diversion Ditches with Downgrade Leachate Collection Ditches		
			Institutional Controls	Institutional Controls
			Air stripping	
				Soil Vapor Extraction

The following table presents a more detailed tabulation of technologies listed by subactivity within major activity. Also included are major contaminants targeted, potential for exposure, advantages, and disadvantages of each technology.

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ETTP	HWW/CW	ETTP LLW Treatment	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc	<u>Activated Carbon</u> is used as a high surface area or permeability material in liquid -phase adsorption to selectively adsorb organic contaminants from aqueous streams, using the principles of physical adsorption and chemisorption.	Low	An accepted, well developed technology applicable for many different waste contaminants.	Size of system, flow rate, and adsorption material dependent on contaminant to be removed.
ETTP	HWW/CW	K-1410 Old Neutralization Pit and K-1131 Neutralization Pile	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc, Ni	<u>Capping (pits/trenches)</u> entails placing hydraulic barriers over, around, and/or over a zone of contaminated shallow ground to protect against leaching and advection of contaminants by movement of water.	Low	Mature technology that isolates contaminant against entry and exit.	Use of flexible membrane liner depends on lack of differential subsidence between waste pit/trench and surrounding soil. Infiltration covers have design limitations much shorter than time required for containment of some contaminants (fission products and TRU radioisotopes). Technology does not insure against lateral migration of contaminant from groundwater leaching over long periods
		K-1070-A Contaminated Burial Ground					

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ETTP	HWW/CW	ETTP LLW Treatment	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc	<u>Compaction (Dynamic Compaction)</u> involves mechanical pounding of solid waste areas such as trenches and pits containing waste in drums, plastic bags, wooden crates, cardboard boxes, etc.	Low	A simple, well-demonstrated technology that minimizes worker exposure, dramatically reduces waste volume, and increases waste stability.	Restricted by equipment limitations (crane and tamper sizes).
ETTP	DeW	K-1417/1419 RCRA Closure	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc	<u>Decontamination</u> involves a large number of technologies ranging from very simple procedures to highly technical processes. Examples include brushing, washing, steaming, grinding, blasting, dissolving, extraction, and electrical migration.	Low	Many technologies used for decontamination are common industrial procedures requiring little special training or equipment.	Additional controls may be required to protect workers from spray or dust generated. May be more costly than disposal
	DeW	Process Equipment D&D (K-25 and K-27)					
	DeW	Process Equipment D&D (K-29, K-31, and K-33)					
	DeW	Centrifuge Facilities Decontamination					
ETTP	DeW	K-1417/1419 RCRA Closure	Chromate, Zn, Phosphate	<u>Demolition (Conventional)</u> involves destruction of concrete and other structural materials using wrecking balls and hydraulic or pneumatic hammers.	Low	An accepted, mature technology requiring commonly available equipment.	Impractical to contain dust, and reinforcing steel has to be cut by other means.
		Powerhouse Demolition	²³⁴ U, ²³⁵ U, ²³⁸ U				
		ETTP Cooling Towers Demolition	Chromate, Zn, Phosphate				
		K-25 Auxiliary Facilities and Demolition (KAFaD) Group I Building Demolition	²³⁴ U, ²³⁵ U, ²³⁸ U				
		KAFaD Group II Building Demolition	²³⁴ U, ²³⁵ U, ²³⁸ U				
		KAFaD Group III Building Demolition	²³⁴ U, ²³⁵ U, ²³⁸ U				

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
		KAFaD Group IV Building Demolition	²³⁴ U, ²³⁵ U, ²³⁸ U				
		K-1420 Demolition	²³⁴ U, ²³⁵ U, ²³⁸ U				
		K-25, K-27, and K-29 Demolition	²³⁴ U, ²³⁵ U, ²³⁸ U Ni, ⁹⁹ Tc				
ETTP	HWW/CW	K-1413 Soils and Groundwater	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc, Ni	<u>Downgradient French Drains</u> are narrow, vertical trenches filled with porous backfill. Waste water intercepted by the drain is gravity drained to appropriate locations for storage, treatment, or disposal.	Low	An accepted, cost-effective, and commercially available technology.	Difficult and costly to implement in hard rock.
	K-1070-C/D and Mitchell Branch Plumes						
	K-1400 French Drain Plume						
	K-1070-A Contaminated Burial Ground						
ETTP	DeW	K-1417/1419 RCRA Closure	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc, Ni	<u>Equipment Removal (Conventional Disassembly)</u> includes sawing with tooth or abrasive blades and dismantling by removing fasteners. Cutting can be done in air or under a liquid, using power or hand tools.	Low	An accepted technology requiring inexpensive equipment., and there is little danger of equipment contamination.	Adaption for use by remote manipulation will be required for certain equipment and facilities.
ETTP	HWW/CW	ETTP LLW Treatment	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U	<u>Evaporation</u> is the partial or complete removal of liquid from a solution or liquid mixture, resulting in concentration of solutes or particulates and reduction in volume. Evaporation may be by natural vapor pressure or by evaporation devices.	Low	An accepted, easily implemented technology.	Applicability may depend on availability of land and time requirements.

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ETTP	HWW/CW	ETTP MLLW Treatment	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U	Filtration is a generic technology for physical removal of solid particulates from liquid or gaseous streams, often using a porous medium.	Medium	A mature, commercially available technology with many filter media available.	None noted
		ETTP LLW Treatment			Low		
ETTP	HWW/CW	ETTP LLW Treatment	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc	Jet Grouting is the injection or mixing of various materials with contaminated soil or sediment resulting in solidification and stabilization of contaminant.	Low	Accepted, relatively inexpensive, and successful technology requiring commercially available materials and equipment.	Some leaching may still occur. Some wastes not compatible with grouting materials, and special formulations for certain wastes may be required. Special equipment for injection of grout may be required for waste tanks.
ETTP	HWW/CW	K-1070-C/D G-pit and Contaminated Pad	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc, Ni	In Situ Vitrification is the process of converting, in place, hazardous waste (soils and sediments) into a glass and crystalline product by melting it with electrical energy. Currently, this technology applies to wastes at soil depths of up to 19 feet.	Low	Simplicity: Ability to treat many types of waste; allows safer handling and cheaper land disposal of waste. Particularly applicable to soils and sediments which present significant hazards to workers from direct contact during handling.	Volatilization of some materials during heating.

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ETTP	HWW/CW	ETTP LLW Treatment	PCBs, Radioactive and Chemical toxicants	<u>Incineration</u> is the thermal destruction of hazardous wastes in the presence of adequate oxygen for combustion.	Medium	Organic contaminants are permanently destroyed by high-temperature oxidation and volume reduced.	Residual ash may contain heavy metals and toxic products of incomplete combustion.
		ETTP MLLW Treatment	PCBs, Radioactive and Chemical toxicants		Low		
		Compliant Storage	PCBs, Radioactive and Chemical toxicants		Low		
ETTP	HWW/CW	K-901A Holding Pond	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc, Ni	<u>Institutional Controls</u> controls entry to minimize possibility that persons will be exposed.	Low	Simple and inexpensive to initiate.	It may have to be continued indefinitely. Public usually opposes.
		K-1007 P1 Pond					
		Scrap Metal					
ETTP	HWW/CW	ETTP LLW Treatment	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc	<u>Ion Exchange</u> removes ionic contaminants from aqueous solutions and liquids containing ionic radioactive and/or hazardous species by passing the contaminated liquid through a series of columns containing an ion-exchange medium designed to trap and retain the ionic contaminants(s). Media are specially treated organic resins or inorganic material.	Low	A common, accepted technology applicable for many different separations.	Appropriate exchange media may not be available for particular contaminants.

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ETTP	HWW/CW	ETTP MLLW Treatment	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U	<u>Neutralization</u> consists of appropriate treatment of acidic and caustic wastes with base or acid, respectively, to reduce corrosivity, often resulting in precipitation of hazardous contaminants.	Medium	An accepted, effective, economic industrial practice, not requiring specialized devices, often drastically reducing volume of hazardous waste	None noted
ETTP	HWW/CW	ETTP LLW Treatment	²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc, Ni	<u>Smelting</u> is a pyrometallurgical process consisting of heating contaminated scrap metal in a furnace with various fluxes (such as limestone and coke) to high temperatures (700-2000C) in the presence of reducing gases to yield molten metal and a slag or dross. Organic contaminants are destroyed during smelting and nonvolatile inorganic and radioactive species are (hopefully) removed with the slag. The slag can be further processed and disposed while the metal is cooled, cast in molds, and recycled.	Low	An accepted, well recognized industrial technology.	Applicability for treatment of RWs has not been fully demonstrated.
ETTP	HWW/CW	K-1413 Soils and Groundwater	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc, Ni	<u>Excavation</u> is the mechanical removal of soils and sediments using common equipment such as clamshells and backhoes.	Low	Accepted technology using commercially available equipment.	None noted
		K-1401 Acid Line					
		ETTP Site Wide Soil Remediation					
		K-1410 Old Neutralization Pit and K-1131 Neutralization Pile					

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ETTP	HWW/CW	K-1413 Soils and Groundwater	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc, Ni	<u>Soil Vapor Extraction</u> (also called <i>in situ</i> air stripping or enhanced volatilization) removes VOCs from a soil matrix. A network of wells with perforated well screens potentially extending into groundwater are packed with gravel and sealed at the top with bentonite. A vacuum extraction unit induces a flow of air from the subsurface into extraction wells connected to a surface collection manifold.	Low	Is commercially available and has been demonstrated to be quite efficient (50% VOCs typically removed in first 10 percent operating time).	Extraction time dependent on porosity, permeability, and hydraulic conductivity of soil. Information on contaminant volatility, vapor pressure, and Henry's Law constants (adsorption coefficient) required to estimate air flow rate and treatment time.
		K-1070-C/D and Mitchell Branch Plumes					
		K-1401 Acid Line					
		K-1420 Contaminated Groundwater					
		K-27/29 Groundwater Source Control					
ETTP	HWW/CW	ETTP LLW Treatment	²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc	<u>Supercompaction</u> is an effective mechanical volume reduction process distinguished from ordinary compaction by the force applied by the press (>1000 tons). This technology is commonly used on wastes that are not normally considered compatible such as pipes, valves, motors, and certain construction materials.	Low	An accepted, robust, and reliable technology that can result in an increase of storage capacity of about 66%.	Some additional waste generated by drum bleeding.

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ETTP	HWW/CW	K-1401 Acid Line	Nitrates/Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ⁹⁹ Tc, Ni Chromate, Zn, Phosphate	<u>Waste Relocation</u> to other facilities for storage, treatment, or disposal.	Low	Cost-effective technology that can provide significant benefits of time.	Temporary measure.
		K-1420 Contaminated Groundwater					
		K-1400 French Drain Plume					
		K-27/29 Groundwater Source Control					
		K-1417/1419 RCRA Closure					
		Compliant Storage					
		Unstabilized Pond Waste Treatment, Storage, and Disposal					
		Stabilized Pond Waste Disposal					
		Legacy Container Disposition Initiative					
		Powerhouse Demolition					
		ETTP Cooling Towers Demolition					

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ORNL BV	HWW/CW	BV LLW Treatment	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	Activated Carbon is used as a high surface area or permeability material in liquid -phase adsorption to selectively adsorb organic contaminants from aqueous streams, using the principles of physical adsorption and chemisorption.	Low	An accepted, well developed technology applicable for many different waste contaminants.	Size of system, flow rate, and adsorption material dependent on contaminant to be removed.
ORNL BV	HWW	Solid Waste Storage Area 1 (SWSA 1) Remediation	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	Capping (pits/trenches) entails placing hydraulic barriers over, around, and/or over a zone of contaminated shallow ground to protect against leaching and advection of contaminants by movement of water.	Low	Mature technology that isolates contaminant against entry and exit.	Use of flexible membrane liner depends on lack of differential subsidence between waste pit/trench and surrounding soil. Site infiltration covers have design limitations much shorter than time required for containment of some contaminants (fission products and TRU radioisotopes). Technology does not insure against lateral migration of contaminant from groundwater leaching over long periods.
		SWSA 3 Remediation					

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ORNL BV	HWW/CW	BV LLW Treatment	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U ²³⁸ U, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Compaction (Dynamic Compaction)</u> involves mechanical pounding of solid waste areas such as trenches and pits containing waste in drums, plastic bags, wooden crates, cardboard boxes, etc.	Low	A simple, well-demonstrated technology that minimizes worker exposure, dramatically reduces waste volume, and increases waste stability.	Restricted by equipment limitations (crane and tamper sizes).
ORNL BV	DiW	Metal Recovery Facility	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U ²³⁸ U, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Demolition (Conventional)</u> involves destruction of concrete and other structural materials using wrecking balls and hydraulic or pneumatic hammers.	Low	An accepted, mature technology requiring commonly available equipment.	Impractical to contain dust, and reinforcing steel has to be cut by other means.
		High-Level Chemical Development Laboratory					
ORNL BV	DiW	Fission Product Pilot Plant	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U ²³⁸ U, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Dismantlement</u> includes a variety of disassembly activities for the purpose of removing contaminated structures, parts, or materials, in some cases separating these from uncontaminated structures, parts, or materials.	Medium	Salvage of uncontaminated structures, parts, or materials may be possible.	May present high potential for exposures. May be more costly than total disposal.
		Low Intensity Test Reactor			Low		
		Oak Ridge Research Reactor			Low		
ORNL BV	HWW	SWSA 1 Remediation	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U ²³⁸ U, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Downgradient French Drains</u> are narrow, vertical trenches filled with porous backfill. Waste water intercepted by the drain is gravity drained to appropriate locations for storage, treatment, or disposal.	Low	An accepted, cost-effective, and commercially available technology.	Difficult and costly to implement in hard rock.
ORNL BV	DeW	Fission Product Development Laboratory Inactive Cells	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U ²³⁸ U, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Equipment Removal (Conventional Disassembly)</u> includes sawing with tooth or abrasive blades and dismantling by removing fasteners. Cutting can be done in air or under a liquid, using power or hand tools.	Low	An accepted technology requiring inexpensive equipment., and there is little danger of equipment contamination.	Adaption for use by remote manipulation will be required for certain equipment and facilities.
		Fission Product Pilot Plant			Medium		
		Low Intensity Test Reactor			Low		

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
		Oak Ridge Graphite Reactor					
		High-Level Chemical Development Laboratory					
ORNL BV	HWW/CW	BV LLW Treatment	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Evaporation</u> is the partial or complete removal of liquid from a solution or liquid mixture, resulting in concentration of solutes or particulates and reduction in volume. Evaporation may be by natural vapor pressure or by evaporation devices.	Low	An accepted, easily implemented technology.	Applicability may depend on availability of land and time requirements. Scale formation on heating tubes; thermal degradation or coking of organics; and applicable only when initial solute concentrations are high (>10,000 ppm).
		Treatment of TRU Waste	²³⁸ Pu, ²⁴¹ Am				
ORNL BV	HWW	BV Contaminated Soils	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Excavation</u> results in removing and relocating contaminant(s). In some cases when this removal leaves a depression or a ditch, it will be backfilled with available uncontaminated soil.	Low	Accepted technology using commercially available equipment.	Need for control of airborne emissions Further treatment of removed soil/sediment may be required.
ORNL BV	HWW	BV MLLW Treatment	Pb, Hg, PCBs, ²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr, PCBs	<u>Filtration</u> is a generic technology for physical removal of solid particulates from liquid or gaseous streams, often using a porous medium.	Low	A mature, commercially available technology with many filter media available.	None noted
	HWW/CW	BV LLW Treatment	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr, PCBs				

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ORNL BV	HWW/CW	BV LLW Treatment	^{232}U , ^{233}U , ^{234}U , ^{235}U , ^{238}U , ^{238}Pu , ^{239}Pu , ^{241}Pu , ^{137}Cs , ^{60}Co , ^{90}Sr	<u>Jet Grouting</u> is the injection or mixing of various materials with contaminated soil or sediment resulting in solidification and stabilization of contaminant.	Low	Accepted, relatively inexpensive, and successful technology requiring commercially available materials and equipment.	Some leaching may still occur. Some wastes not compatible with grouting materials, and special formulations for certain wastes may be required. Special equipment for injection of grout may be required for waste tanks.
		ORNL Main Plant Inactive Tanks					
		Gunite and Associated Tanks					
		BV Contaminated Soils					
		Corehole 8 Plume Source					
		SWSA 3 Remediation					
		Low Intensity Test Reactor					
		Oak Ridge Research Reactor					
ORNL BV	HWW	BV MLLW Treatment	Pb , Hg , PCBs , ^{232}U , ^{233}U , ^{234}U , ^{235}U , ^{238}U , ^{238}Pu , ^{239}Pu , ^{241}Pu , ^{137}Cs , ^{60}Co , ^{90}Sr	<u>Incineration</u> is the thermal destruction of hazardous wastes in the presence of adequate oxygen for combustion.	Low	Organic contaminants are permanently destroyed by high-temperature oxidation and volume is reduced.	Residual ash may contain heavy metals and toxic products of incomplete combustion.
	CW	BV LLW Treatment					

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ORNL BV	HWW/CW	BV LLW Treatment	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Ion Exchange</u> removes ionic contaminants from aqueous solutions and liquids containing ionic radioactive and/or hazardous species by passing the contaminated liquid through a series of columns containing an ion-exchange medium designed to trap and retain the ionic contaminants(s). Media are specially treated organic resins or inorganic material.	Low	A common, accepted technology applicable for many different separations.	Appropriate exchange media may not be available for particular contaminants.
ORNL BV	HWW	Bench-scale demonstrations only	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Magnetic Seed Filtration</u> is a technology under development for enhanced removal of magnetic and non-magnetic particulates from liquids. The process involves the addition of a small amount of magnetic seed particles to a waste suspension, followed by treatment with a magnetic filter. Non-magnetic and weakly magnetic particles form flocs of high magnetic susceptibility that are readily removed by a conventional high-gradient magnetic filter.	Low	The technology is applicable to a wide range of liquid wastes, including groundwater, process waters, and tank supernatants.	None noted.
ORNL BV	HWW	BV MLLW Treatment	Pb, Hg, PCBs, ²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Neutralization</u> consists of appropriate treatment of acidic and caustic wastes with base or acid, respectively, to reduce corrosivity, often resulting in precipitation of hazardous contaminants.	Low	An accepted, effective, economic industrial practice, not requiring specialized devices, and often drastically reducing volume of hazardous waste	None noted

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ORNL BV	HWW/CW	Corehole * Plume Source	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Plume Migration Retardation</u> involves the use of low-volume pumps in existing or new wells to extract water from a plume to retard further migration of the plume.	Low	A simple, commercially available technology.	Diminishes but does not eliminate contamination.
ORNL BV	HWW/CW	SWSA 1 Remediation	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Slurry Walls</u> are narrow, vertical excavations that are backfilled with a slurry while excavation is in progress, thereby preventing collapse of the sidewalls during excavation and producing a barrier to groundwater flow.	Low	This is an accepted, commercially available technology.	A confining layer must be present in which to key the slurry wall.
ORNL BV	HWW/CW	BV Contaminated Soils	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Soil Washing</u> removes contaminants from soils in one of two ways: 1) by dissolving or suspending them in the wash solution (which is later treated by conventional wastewater treatment methods) or 2) by concentrating them into a smaller volume of soil.	Low	Offers the potential for metal recovery and can clean a wide range of organic and inorganic contaminants from coarse-grained soils.	Not suitable for heavy-textured soils containing variety of radionuclides, heavy metals, or organic contaminants.
ORNL BV	HWW/CW	BV LLW Treatment	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Smelting</u> is a pyrometallurgical process consisting of heating contaminated scrap metal in a furnace with various fluxes (such as limestone and coke) to high temperatures (700-2000C) in the presence of reducing gases to yield molten metal and a slag or dross. Organic contaminants are destroyed during smelting and nonvolatile inorganic and radioactive species are (hopefully) removed with the slag. The slag can be further processed and disposed while the metal is cooled, cast in molds, and recycled.	Low	An accepted, well recognized industrial technology.	Applicability for treatment of RWs has not been fully demonstrated.

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ORNL BV	HWW/CW	BV LLW Treatment	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Supercompaction</u> is an effective mechanical volume reduction process distinguished from ordinary compaction by the force applied by the press (>1000 tons).	Low	An accepted, robust, and reliable technology that can result in an increase of storage capacity of about 66%.	Some additional waste generated by drum bleeding.
ORNL BV	HWW/CW	Gunite and Associated Tan	²³² U, ²³³ U, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³⁹ Pu, ²⁴¹ Pu, ¹³⁷ Cs, ⁶⁰ Co, ⁹⁰ Sr	<u>Waste Relocation</u> to other facilities for storage, treatment, or disposal.	Low	Cost-effective technology that can provide significant benefits of time saved.	Temporary measure only.
		ORNL Main Plant Surface Impoundments					
		Metal Recovery Facility					
		Fission Product Development Laboratory Inactive Cells					
		Fission Product Pilot Plant					
		Low Intensity Test Reactor					
		Oak Ridge Graphite React					
		High-Level Chemical Development Laboratory					
Oak Ridge Research Reactor							

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ORNL WOC	HWW/CW	SWSA 4 Remediation	^{238}Pu , ^{239}Pu , ^{241}Pu , ^{234}U , ^{235}U , ^{238}U	Capping (pits/trenches) entails placing hydraulic barriers over, around, and/or over a zone of contaminated shallow ground to protect against leaching and advection of contaminants by movement of water.	Low	Mature technology that isolates contaminant against entry and exit.	Use of flexible membrane liner depends on lack of differential subsidence between waste pit/trench and surrounding soil. Site infiltration covers have design limitations much shorter than time required for containment of some contaminants (fission products and TRU radioisotopes). Technology does not insure against lateral migration of contaminant from groundwater leaching over long periods.
		SWSA 5 North and South Remediation					
		Pits and Trenches Secondary Sources					
		SWSA 6 Remediation					
ORNL WOC	HWW/CW	ORNL Remediation Technology Demonstration	^{238}Pu , ^{239}Pu , ^{241}Pu , ^{234}U , ^{235}U , ^{238}U	Cryogenic Barriers provide containment of subsurface chemical and nuclear wastes using barriers composed of a frozen layer of native geologic materials. Geologic layer is frozen via freeze pipes installed at an angle to frost line depths.	Low	Useful for areas with many buried devices, structures, or equipment. Also useful in areas where generation of hazards from excavation might be difficult to control.	Typically useful only for temporary containment, but may be used for longer periods when justified by costs of other methods.

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ORNL WOC	HWW/CW	SWSA 5 North and South Remediation	^{238}Pu , ^{239}Pu , ^{241}Pu ^{234}U , ^{235}U , ^{238}U	<u>Cutoff Walls</u> are used to temporary hydrologic isolation. Non-porous interlocking sheets (usually steel) are driven into ground to refusal or rock.	Low	This technology is well accepted, commercially available, and relatively inexpensive.	Does not provide perfect water barrier since leaking occurs at joints, and if no confining layer exists, water will migrate underneath.
		SWSA 6 Remediation					
ORNL WOC	DIW	MSRE D&D	^{238}Pu , ^{239}Pu , ^{241}Pu ^{234}U , ^{235}U , ^{238}U	<u>Demolition (Conventional)</u> involves destruction of concrete and other structural materials using wrecking balls and hydraulic or pneumatic hammers.	Low	An accepted, mature technology requiring commonly available.	Impractical to contain dust, and reinforcing steel has to be cut by other means.
ORNL WOC	DIW	Homogeneous Reactor Experiment	^{238}Pu , ^{239}Pu , ^{241}Pu , ^{234}U , ^{235}U , ^{238}U	<u>Dismantlement</u> includes a variety of disassembly activities for the purpose of removing contaminated structures, parts, or materials, in some cases separating these from uncontaminated structures, parts, or materials.	Medium	Salvage of uncontaminated structures, parts, or materials may be possible.	May present high potential for exposures. May be more costly than total disposal.
		Old Hydrofracture Facility			Low		
		Shielded Transfer Tanks					
ORNL WOC	HWW/CW	SWSA 4 Remediation	^{238}Pu , ^{239}Pu , ^{241}Pu ^{234}U , ^{235}U , ^{238}U	<u>Downgradient French Drains</u> are narrow, vertical trenches filled with porous backfill. Waste water intercepted by the drain is gravity drained to appropriate locations for storage, treatment, or disposal.	Low	An accepted, cost-effective, and commercially available technology.	Difficult and costly to implement in hard rock.
		SWSA 5 North and South Remediation					
ORNL WOC	HWW/CW	WOC Remediation	^{238}Pu , ^{239}Pu , ^{241}Pu , ^{234}U , ^{235}U , ^{238}U	<u>Excavation</u> results in removing and relocating contaminant(s). In some cases when this removal leaves a depression or a ditch, it will be backfilled with available uncontaminated soil.	Low	Accepted technology using commercially available equipment.	Need for control of airborne emissions
		Melton Valley Contaminated Soils					Further treatment of removed soil/sediment may be required.
		High Flux Isotope Reactor Collection Basins					

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ORNL WOC	HWW/CW	WOC Remediation	²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ²³⁴ U, ²³⁵ U, ²³⁸ U	Jet Grouting is the injection or mixing of various materials with contaminated soil or sediment resulting in solidification and stabilization of contaminant.	Low	Accepted, relatively inexpensive, and successful technology requiring commercially available materials and equipment.	Some leaching may still occur. Some wastes not compatible with grouting materials. Special formulations for certain wastes may be required. Special equipment for injection of grout may be required for waste tanks.
		Melton Valley Contaminated Soils					
		SWSA 4 Seep Control					
		SWSA 4 Remediation					
		Old Hydrofracture Facility Pond					
		Process Waste Sludge Basin					
	CW	Pits and Trenches Secondary Sources					
		Homogeneous Reactor Experiment/MSRE Inactive Tanks					
DiW	Homogeneous Reactor Experiment						
	MSRE D&D						
ORNL WOC	HWW/CW	Hydrofracture Injection/Monitoring Wells	²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ²³⁴ U, ²³⁵ U, ²³⁸ U	Hydrofracture Grouting involves polymer injection to fill cracks in host rock at the edge of a contaminant plume.	Low	An accepted technology that results in good sealing of waste. Also used to reestablish rock tensile strength	Grouting material subject to deterioration by ultraviolet light. Grout setting may also be affected by very saline groundwater,

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ORNL WOC	HWW/CW	LLLW Disposal Pits and Trenches	²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ²³⁴ U, ²³⁵ U, ²³⁸ U	<u>In Situ Vitrification</u> is the process of converting, in place, hazardous waste (soils and sediments) into a glass and crystalline product by melting it with electrical energy. Currently, this technology applies to wastes at soil depths of up to 19 feet.	Low	Simplicity: Ability to treat many types of waste; allows safer handling and cheaper land disposal of waste. Particularly applicable to soils and sediments which present significant hazards to workers from direct contact during handling.	Volatilization of some materials during heating.
	CW	Homogeneous Reactor Experiment Pond					
ORNL WOC	HWW/CW	Hydrofracture Injection/Monitoring Wells	²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ²³⁴ U, ²³⁵ U, ²³⁸ U	<u>Pressure Grouting</u> involves high pressure pumping of grout into or under a waste area to form a grout seal.	Low	Has been used successfully in Europe and at ORNL to form bottom seals.	Grout formulations needed to allow increase in percent mixing of injected grout with <i>in situ</i> materials, while improving volume of grout mixed in place.
ORNL WOC	HWW/CW	Old Hydrofracture Facility Tanks	²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ²³⁴ U, ²³⁵ U, ²³⁸ U	<u>Waste Relocation</u> to other facilities for storage, treatment, or disposal.	Low	Cost-effective technology that can provide significant benefits of time savings.	Temporary measure.
		High Flux Isotope Reactor Collection Basins					
		MSRE Fuel Salt Removal					
	CW	Homogeneous Reactor Experiment					
	HWW/CW	Old Hydrofracture Facility					
Shielded Transfer Tanks							

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
ORNL WOC	HWW/CW	Old Hydrofracture Facility	²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Pu, ²³⁴ U, ²³⁵ U, ²³⁸ U	<u>Well Plugging and Abandonment</u> involves use of rig-mounted drilling unit to conventionally plug and abandon well bores, leaving casing in place. Cement plugs are placed above (and below if applicable) injection zones to isolate the zones from any aquifers.	Low	Technology is well accepted and allows for selection of plugging technique based on geology of formation and physical condition of casing.	Heavy shielding may be required to prevent worker exposure, and equipment may become contaminated requiring use of a toxic substance disposal facility for decontamination.

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
Y-12 BC	HWW/CW	White Wing Scrap Yard	²³⁴ U, ²³⁵ U, ²³⁸ U, Hg, PCBs	<u>Asphalt Capping</u> results in physical containment and isolation of solid contaminants or hazardous material.	Low	Accepted technology that may provide normal access and use of site.	None noted
Y-12 BC	HWW/CW	BC Valley Boneyard/Burnyard	²³⁴ U, ²³⁵ U, ²³⁸ U, Hg	<u>Capping (pits/trenches)</u> entails placing hydraulic barriers over, around, and/or over a zone of contaminated shallow ground to protect against leaching and advection of contaminants by movement of water.	Low	Mature technology that isolates contaminant against entry and exit.	Use of flexible membrane liner depends on lack of differential subsidence between waste pit/trench and surrounding soil. Site infiltration covers have design limitations much shorter than time required for containment of some contaminants (fission products and TRU radioisotopes). Technology does not insure against lateral migration of contaminant from groundwater leaching over long periods.
		BC Valley Burial Grounds					
Y-12 BC	HWW/CW	BC Valley Burial Grounds	²³⁴ U, ²³⁵ U, ²³⁸ U, Hg	<u>Diversion Ditches with Downgrade Leachate Collection Ditches</u> make possible redirection and relocation of contaminants for subsequent appropriate removal, treatment, or disposal.	Low	Accepted, simple technology that can remarkably improve accessibility and isolation of contaminant.	Does not eliminate need for subsequent remediation of original contaminant pathway(s).
Y-12 BC	HWW/CW	BC Valley Groundwater Remediation	Nitrates, Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁶ Th, ²³² Th	<u>Extraction Wells</u> provide physical access for removal of contaminated liquids for subsequent transfer to appropriate treatment system(s).	Low	Mature technology resulting in capture of plumes and mitigation of contaminant migration.	Does not result in complete elimination of contamination.

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
Y-12 BC	HWW/CW	BC Valley Tributary Interception	Nitrates, Nitrites, ²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁸ Th, ²³² Th	<u>Interception Trenches</u> with reactive media capture contaminant plumes and mitigate contaminant migration.	Low	Mature technology resulting in lessening and possibly elimination of further downgrade contamination.	Further remediation or disposal of reactive media may be necessary.
Y-12 BC	HWW/CW	BC Valley Boneyard/Burnyard	²³⁴ U, ²³⁵ U, ²³⁸ U, Hg	<u>Excavation</u> is the mechanical removal of soils and sediments using common equipment such as clamshells and backhoes.	Low	Accepted technology using commercially available equipment.	None noted
		BC Valley Floodplain and Sediments					
Y-12 UEFPC	HWW/CW	Y-12 UEFPC LLW Treatment UEFPC	²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁸ Th, ²³² Th	<u>Activated Carbon</u> is used as a high surface area or permeability material in liquid -phase adsorption to selectively adsorb organic contaminants from aqueous streams, using the principles of physical adsorption and chemisorption.	Low	An accepted, well developed technology applicable for many different waste contaminants.	Size of system, flow rate, and adsorption material dependent on contaminant to be removed.
		Hydraulic Isolation and Groundwater Treatment					
Y-12 UEFPC	HWW/CW	Reduction of Hg in Plant Effluents	Hg, organics	<u>Air stripping</u> is a full-scale technology in which VOCs are separated from groundwater by greatly increasing the surface area of the contaminated water exposed to air. This process is generally conducted in a packed tower or an aeration tank.	Low	None noted.	Ineffective for most inorganic contaminants.
		UEFPC Hydraulic Isolation and Groundwater Treatment					
Y-12 UEFPC	HWW/CW	UEFPC Underground Storage Tank Legacy Remediation	²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁸ Th, ²³² Th	<u>Bioremediation</u> uses microorganisms such as bacteria, fungi and yeast, or their extracts, to dissolve and/or degrade organic contaminants such as oil, gasoline, detergents, polychlorinated hydrocarbons, pesticides, and gases or inorganic contaminants in soil and water, and render them harmless.	Low	Cost is roughly one-third to one-half of conventional chemical and physical remediation technologies and the risk worker exposure is significantly reduced.	Microbial activity can be inhibited by factors such as high concentrations of heavy metals. Formation of toxic byproducts.

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
Y-12 UEFPC	HWW/CW	UEFPC Soil Remediation	²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁸ Th, ²³² Th, Hg	<u>Capping (pits/trenches)</u> entails placing hydraulic barriers over, around, and/or over a zone of contaminated shallow ground to protect against leaching and advection of contaminants by movement of water.	Low	Mature technology that isolates contaminant against entry and exit.	Use of flexible membrane liner depends on lack of differential subsidence between waste pit/trench and surrounding soil. Site infiltration covers have design limitations much shorter than time required for containment of some contaminants (fission products and TRU radioisotopes). Technology does not insure against lateral migration of contaminant from groundwater leaching over long periods.
Y-12 UEFPC	HWW/CW	Y-12 UEFPC LLW Treatment	²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁸ Th, ²³² Th	<u>Compaction (Dynamic Compaction)</u> involves mechanical pounding of solid waste areas such as trenches and pits containing waste in drums, plastic bags, wooden crates, cardboard boxes, etc.	Low	A simple, well-demonstrated technology that minimizes worker exposure, dramatically reduces waste volume, and increases waste stability.	Restricted by equipment limitations (crane and tamper sizes).

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
Y-12 UEFC	HWW/CW	Y-12 UEFC LLW Treatment	²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁸ Th, ²³² Th	<u>Evaporation</u> is the partial or complete removal of liquid from a solution or liquid mixture, resulting in concentration of solutes or particulates and reduction in volume. Evaporation may be by natural vapor pressure or by evaporation devices.	Low	An accepted, easily implemented technology.	Applicability may depend on availability of land and time requirements.
Y-12 UEFC	HWW/CW	UEFC East End Dense Nonaqueous-Phase Liquid Plume	Carbon tetrachloride	<u>Extraction Wells</u> provide physical access for removal of contaminated liquids for subsequent transfer to appropriate treatment system(s).	Low	Mature technology resulting in capture of plumes and mitigation of contaminant migration.	Does not result in complete elimination of contamination.
Y-12 UEFC	HWW/CW	Y-12 UEFC MLLW Treatment	²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁸ Th, ²³² Th, PCBs, Hg, Be	Filtration is a generic technology for physical removal of solid particulates from liquid or gaseous streams, often using a porous medium.	Medium	A mature, commercially available technology with many filter media available.	None noted
		Y-12 UEFC LLW Treatment			Low		
		UEFC Hydraulic Isolation and Groundwater Treatment					
Y-12 UEFC	HWW/CW	Y-12 UEFC LLW Treatment	²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁸ Th, ²³² Th	<u>Jet Grouting</u> is the injection or mixing of various materials with contaminated soil or sediment resulting in solidification and stabilization of contaminant.	Low	Accepted, relatively inexpensive, and successful technology requiring commercially available materials and equipment.	Some leaching may still occur. Some wastes not compatible with grouting materials, and special formulations for certain wastes may be required. Special equipment for injection of grout may be required for waste tanks.

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
Y-12 UEFPC	HWW/CW	Y-12 UEFPC MLLW Treatment	²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁸ Th, ²³² Th, PCBs, Hg, Be	<u>Incineration</u> is the thermal destruction of hazardous wastes in the presence of adequate oxygen for combustion.	Medium	Organic contaminants are permanently destroyed by high-temperature oxidation and volume is reduced.	Residual ash may contain heavy metals and toxic products of incomplete combustion.
Y-12 UEFPC	HWW/CW	Rogers Quarry/Lower McCoy Branch	Nitrates, Nitrites, numerous chemical disposed here	<u>Institutional Controls</u> involves the use of administrative and physical restrictions to limit access to a waste site to minimize the possibility that persons will be exposed.	Low	Simple and inexpensive to implement.	May have to be continued indefinitely. Public usually opposes.
Y-12 UEFPC	HWW/CW	Y-12 UEFPC LLW Treatment	²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁸ Th, ²³² Th	<u>Ion Exchange</u> removes ionic contaminants from aqueous solutions and liquids containing ionic radioactive and/or hazardous species by passing the contaminated liquid through a series of columns containing an ion-exchange medium designed to trap and retain the ionic contaminants(s). Media are specially treated organic resins or inorganic material.	Low	A common, accepted technology applicable for many different separations.	Appropriate exchange media may not be available for particular contaminants.
Y-12 UEFPC	HWW/CW	Y-12 UEFPC MLLW Treatment	²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁸ Th, ²³² Th, PCBs, Hg, Be	<u>Neutralization</u> consists of appropriate treatment of acidic and caustic wastes with base or acid, respectively, to reduce corrosivity, often resulting in precipitation of hazardous contaminants.	Medium	An accepted, effective, economic industrial practice, not requiring specialized devices, and often drastically reducing volume of hazardous waste	None noted

Table 7-2 Past, Present, and Proposed Future Technologies for Use at ORR^{5,15,16,17,18}

Major Activity	Category	Subactivity Title	Contaminants	Technology and Description	Exposure Potential	Advantages	Disadvantages
Y-12 UEFPC	HWW/CW	Y-12 UEFPC LLW Treatment	²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁶ Th, ²³² Th	<u>Smelting</u> is a pyrometallurgical process consisting of heating contaminated scrap metal in a furnace with various fluxes (such as limestone and coke) to high temperatures (700-2000C) in the presence of reducing gases to yield molten metal and a slag or dross. Organic contaminants are destroyed during smelting and nonvolatile inorganic and radioactive species are (hopefully) removed with the slag. The slag can be further processed and disposed while the metal is cooled, cast in molds, and recycled.	Low	An accepted, well recognized industrial technology.	Applicability for treatment of RWs has not been fully demonstrated.
Y-12 UEFPC	HWW/CW	UEFPC Soil Remediation	²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁶ Th, ²³² Th, Hg	<u>Excavation</u> is the mechanical removal of soils and sediments using common equipment such as clamshells and backhoes.	Low	Accepted technology using commercially available equipment.	None noted
Y-12 UEFPC	HWW/CW	Y-12 UEFPC LLW Treatment	²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁶ Th, ²³² Th	<u>Supercompaction</u> is an effective mechanical volume reduction process distinguished from ordinary compaction by the force applied by the press (>1000 tons). This technology is commonly used on wastes that are not normally considered compatible such as pipes, valves, motors, and certain construction materials.	Low	An accepted, robust, and reliable technology that can result in an increase of storage capacity of about 66%.	Some additional waste generated by drum bleeding.
Y-12 UEFPC	HWW/CW	UEFPC Sumps	²³⁴ U, ²³⁵ U, ²³⁸ U, ²²⁶ Th, ²³² Th, Hg, Be	<u>Waste Removal and Transfer</u> describes the use of common methods (packaging, loading, transporting) to relocate waste for storage or treatment.	Low	Simple to accomplish and can result in savings of time and eliminate need for construction of new treatment facilities.	Does not usually result in elimination of waste.
	UEFPC Storm Sewer						
	UEFPC coal Pile Trench and Beta-4 Security Pits						

8.0 Exposures

8.1 Potential exposures

During the 50+ years of operations of the ORR facilities, a large number of materials have been used or produced. In addition to common materials used in a wide range of industrial and laboratory processes, and because of the unique mission(s) of these facilities, many uncommon elements, alloys, and chemical solutions also have been used. Even though thousands of soil, water, and solids samples have been collected and analyzed, a complete inventory of contaminants for each remediation subactivity is not readily available. Below are listings of contaminants that are known to be present at sites identified for remediation at Y-12, ORNL, and ETP. Precise quantities of each contaminant are not known. However, for many of the listed contaminants, the concentrations have been determined to be greater than established environmental compliance levels.

Y-12

The Y-12 Plant has been a production facility for atomic and/or nuclear bomb components since the mid-1940s. The main radioisotopes used in this project were the naturally occurring uranium isotopes, ^{238}U , ^{235}U , and ^{234}U . Normal and depleted uranium were processed along with varying levels of uranium enriched in the ^{235}U and ^{234}U isotopes. Natural thorium including ^{232}Th and ^{228}Th was also processed in large quantities. Nonradioactive isotopes used or handled in great quantities were mercury, beryllium, nitrates, and nitrites. Consequently, much of the hazard involved with the remediation of this facility would involve these materials. However, many other materials used or handled in Y-12 were found in the analyses of soil, liquid, or waste inventory sampling done to evaluate chemicals of concern associated with the remediation of Y-12 Plant watersheds and are listed below:

Bear Creek Watershed³⁴

Acetone	Cu	Perchloroethylene
Al	1,1-Dichloroethane)	Phthalates
Sb	1,2-Dichloroethane	Ag
As	1,1-DCA	1,1,1-TCA
Ba	Ethylbenzene	^{99}Tc
Benzene	Pb	Trichloroethane
B	Li	Trichloroethylene
Cd	Mo	Trace metals
^{137}Cs	^{237}Np	V
Chloroethane	Ni	Vinyl chloride
Chloroform	Oils	VOCs
Cr	PAHs	Xylene
^{60}Co	PCBs	Zn

Upper East Fork Poplar Creek Watershed³⁵

Contaminants of concern for current industrial workers

As	Dibenz (a,h) anthracene	²²⁶ Ra
Benzo (B) fluoranthene	3,3'-Dichlorobenzidine	Vinyl chloride
Cd	Indeno (1,2,3-cd)pyrene	
¹³⁷ Cs	PCBs	

ORNL

ORNL has been a National Laboratory since its inception doing research on reactors and other nuclear projects that would benefit the war or defense efforts. Consequently, the radioisotopes most likely to be hazards during environmental cleanup are uranium isotopes, not only those that are naturally occurring (²³⁸U, ²³⁵U, ²³⁴U), but also ²³³U and ²³²U, which are associated with breeder reactors, and the ²³⁸Pu, ²³⁹Pu, ²⁴¹Pu, other TRUs, and the longer-lived fission or activation products such as ¹³⁷Cs, ⁶⁰Co, ⁹⁰Sr, and ⁹⁹Tc associated with reactors,. Tritium is also a contaminant of concern. In addition, many nonradioactive materials and a few other radioisotopes which could be of exposure concern for the two watersheds associated with ORNL are listed below.

Bethel Valley Watershed³⁶

Cd	Fuel-derived Hydrocarbons	PCBs
Chlordane	Pb	Solvents
Cr	Hg	Trichloroethylene
Cu	Mo	²³² Th
^{15x} Eu	Ni	Zn

White Oak Creek Watershed³⁶

Cr	Mo	¹⁰⁶ Ru
Cu	Ni	Trichloroethylene
^{15x} Eu	Nitrates	VOCs
Pb	Other radionuclides	Zn
Hg	PCBs	

ETTP³⁷

ETTP was a uranium gaseous diffusion plant for most of its production history. It also served as a production plant for the nickel barrier material used in the uranium gaseous diffusion separation process. Consequently, nickel, ²³⁸U, ²³⁵U, ²³⁴U, and the fluorine that was combined with uranium would be the contaminants of most concern in its cleanup. Listed below are many nonradioactive materials and other radioisotopes known to be present in the ETTP watershed and of possible concern in the cleanup of ETTP.

ETTP Watershed

Acetone	Diesel fuel	Hg
Acids	Fluorocarbon Oil	PCB-contaminated oils
Asbestos	Gasoline	²³⁹ Pu
Ethyl alcohol	Au	Se
Ethylene glycol	Kerosene	S
Sb	Heavy Metals	Sulfuric acid
Benzene	Pb	⁹⁹ Tc
Be	Mn	Tetraethyl lead
B	Methyl chloride	²³² Th
Cd	Mineral Oil	Ti
Carbon tetrachloride	²³⁷ Np	Toluene tetrachloride
Chromate	Organics	Trichloroethane
Chromic acid	Organic degreasers	Trichloroethylene
Cr	Perchloroethylene	VOCs
Cu	Phosphate	Xylene
Dichloride	Resins	Zn

ORO

Contaminants of concern for community residents

Acetone	Cr	Pyridine
Acetonitrile	1,1-Dichloroethene	²²⁶ Ra
Acrylonitrile	Dichloropropane	⁹⁰ Sr
Ag	Dinitrophenol	⁹⁹ Tc
²⁴¹ Am	Dimethylbenzene	1,1,2,2-Tetrachloroethane
Ammonia	Di-n-octylphthalate	²²⁸ Th
Sb	Ethylbenzene	²³² Th
As	Fluoride	Toluene
Ba	Mn	Trans-1,2 Dichloroethene
Benzene	Hg	1,1,1-Trichloroethane
Be	Methyl mercury	Trichloroethene
B	Methyl parathion	Trichloroethylene
2-Butanone	4-Methyl-2-Pentanone	Tritium
Cd	Methylene chloride	²³⁴ U
Carbon disulfide	Mo	²³⁵ U
Carbon tetrachloride	²³⁷ Np	²³⁸ U
¹³⁷ Cs	Ni	V
Chloroform	Nitrate	Vinyl acetate
Chloromethane	Nitrite	Vinyl chloride
⁶⁰ Co	N-Nitrosodimethylamine	Zn

8.2 Actual exposures

The tables on the following pages show the distribution or worker classification for the last five years along with radiation dosimetry information. Job assignment and radiation dose information were available from the Radiation Exposure Monitoring System (REMS) residing on the Internet at <<http://rems.eh.doe.gov>>. Unfortunately, all employees for each ORR facility were identified under a single Facility Type Code, i.e., Fuel/Uranium Enrichment for ETP, Research General for ORNL, and Weapons Fabrication and Testing for Y-12. Had the ORR facilities classified their waste workers as Waste Processing/Management, the personnel listing would have been grouped more similarly to the grouping reported for the Savannah River Site (SRS)³⁸. The information from the REMS system for the ORR facilities is shown below in Tables 8-1 through 8-3. Two facts regarding the REMS data should be of much interest to NIOSH. First, only 45 DOE occupational categories are provided by REMS into which the ORR facilities must "force fit" the much larger number of actual jobs at each facility. Secondly, the dose information on individual employees resides within the REMS data base and would be available to NIOSH for epidemiologic studies. If the employees of interest can be identified by social security number, this may well be the best and most convenient source of radiation exposure information.

For each facility, a listing of waste workers was developed based on available information and with assistance from facility representatives. These workers were identified to the Radiation Safety Organizations at the ORR facilities who provided summary radiation dose information for these employees for the last five years. Generally, all prime contractor employees and some subcontractor employees were monitored for external exposure; a number of these employees also were monitored for internal exposures. The number of employees monitored for external and internal radiation exposure, the number with positive total effective dose equivalents (TEDEs), and the average and maximum TEDE for each year is presented in Tables 8-4 through 8-7 below.

Information on chemical exposures for these groups of employees could possibly be obtained by linking the employee IDs with chemical monitoring data bases, if they exist. This was done at the Y-12 Plant, and the resulting list of chemical or physical exposures for which these Y-12 waste workers were monitored is listed in Table 8-8.

Table 8-1 Y-12 Employees 1996 Occupational and Dose Information as Reported by REMS^a

Occ Code	Occupation	Employing Organization	Total Monitored	No. With Measured Dose	Average Measured Dose (mrem)
450	Admin. Support and Clerical	LMES (Y-12)	908	31	41
260	Doctors and Nurses	LMES (Y-12)	98	1	2
643	Electricians	LMES (Y-12)	405	19	17
160	Engineers	LMES (Y-12)	1,366	45	18
370	Engineering Technicians	LMES (Y-12)	119	11	23
512	Firefighters	LMES (Y-12)	76	2	35
360	Health Technicians	LMES (Y-12)	217	14	16
110	Managers - Administrators	LMES (Y-12)	1,717	83	22
200	Misc. Professionals	LMES (Y-12)	734	19	15
660	Misc. Repair/Construction	LMES (Y-12)	1,030	79	15
390	Misc. Technicians	LMES (Y-12)	232	10	9
990	Miscellaneous	LMES (Y-12)	424	31	55
690	Operators, Plant/System/Utility	LMES (Y-12)	839	152	17
380	Science Technicians	LMES (Y-12)	165	6	21
170	Scientist	LMES (Y-12)	214	7	9
513	Security Guards	LMES (Y-12)	495	12	10
350	Technicians	LMES (Y-12)	120	0	0
	All	LMES (Y-12)	9,411	522	21

^a Radiation Exposure Monitoring System

Table 8-2 ORNL Employees 1996 Occupational and Dose Information as Reported by REMS^a

Occ Code	Occupation	Employing Organization	Total Monitored	No. With Measured Dose	Average Measured Dose (mrem)
450	Electricians	LMER (ORNL)	265	33	62
260	Misc. Repair/Construction	LMER (ORNL)	482	88	84
643	Admin. Support and Clerical	LMER (ORNL)	991	19	113
160	Managers - Administrators	LMER (ORNL)	949	54	100
370	Miscellaneous	LMER (ORNL)	1,112	72	72
512	Operators, Plant/System/Utility	LMER (ORNL)	259	54	109
360	Doctors and Nurses	LMER (ORNL)	109	7	51
110	Engineers	LMER (ORNL)	1,343	89	89
200	Misc. Professionals	LMER (ORNL)	511	37	66
660	Scientists	LMER (ORNL)	15	1	11
390	Firefighters	LMER (ORNL)	31	0	0
990	Security Guards	LMER (ORNL)	77	3	25
690	Engineering Technicians	LMER (ORNL)	228	43	252
380	Health Technicians	LMER (ORNL)	204	53	121
170	Misc. Technicians	LMER (ORNL)	119	18	45
513	Science Technicians	LMER (ORNL)	85	15	197
350	Technicians	LMER (ORNL)	66	0	0
	All	LMER (ORNL)	7,266	597	101

^a Radiation Exposure Monitoring System

Table 8-3 ETPP Employee 1996 Occupation and Dose Information as Reported by REMS^a

Occ Code	Occupation	Employing Organization	Total Monitored	No. With Measured Dose	Average Measured Dose (mrem)
450	Adm. Support and Clerical	LMES (ETTP)	606	3	18
260	Doctors and Nurses	LMES (ETTP)	27	1	16
643	Electricians	LMES (ETTP)	179	2	22
160	Engineers	LMES (ETTP)	563	5	21
370	Engineering Technicians	LMES (ETTP)	48	0	0
512	Firefighters	LMES (ETTP)	19	0	0
360	Health Technicians	LMES (ETTP)	64	0	0
110	Managers - Administrators	LMES (ETTP)	987	11	22
200	Misc. Professionals	LMES (ETTP)	591	3	9
660	Misc. Repair/Construction	LMES (ETTP)	271	14	9
390	Misc. Technicians	LMES (ETTP)	56	2	12
990	Miscellaneous	LMES (ETTP)	166	1	1
690	Operators, Plant/System/Utility	LMES (ETTP)	339	27	14
380	Science Technicians	LMES (ETTP)	113	3	19
170	Scientists	LMES (ETTP)	73	1	13
513	Security Guards	LMES (ETTP)	79	0	0
350	Technicians	LMES (ETTP)	69	0	0
	All	LMES (ETTP)	4,258	75	15

^a Radiation Exposure Monitoring System

Table 8-4 Y-12 HWW, CW, and De/Di Worker Employment Group and Dose Information - 1997

Employment Group	Year	No. of Employees Monitored			TEDE (mrem)	
		External	Internal	Positive TEDE	Avg	Max
WM and De/Di	1992	N/A	N/A	N/A	N/A	N/A
	1993	168	103	20	1.2	76.0
	1994	180	83	19	0.4	17.0
	1995	184	99	37	0.9	33.0
	1996	190	99	12	0.6	31.0
ER	1992	N/A	N/A	N/A	N/A	N/A
	1993	2	2	1	0.5	1.0
	1994	6	2	1	0.2	1.0
	1995	13	0	0	0.0	0.0
	1996	15	0	0	0.0	0.0

Table 8-5 ORNL HWW, CW, and De/Di Worker Employment Group and Dose Information - 1997

Employment Group	Year	No. of Employees Monitored			TEDE (mrem)	
		External	Internal	Positive TEDE	Avg	Max
Hourly	1992	38	36		21.4	205
	1993	38	38		28.3	152
	1994	39	39		23.8	221
	1995	37	37		15.6	101
	1996	41	40		20.0	123
Monthly	1992	76	36		2.8	42
	1993	90	46		7.8	226
	1994	96	42		9.7	229
	1995	112	47		5.5	152
	1996	129	43		4.1	115
Weekly Technical	1992	11	4		1.0	11
	1993	12	4		8.5	102
	1994	13	4		21.2	260
	1995	16	6		1.7	18
	1996	18	6		0.7	12
Weekly Clerical	1992	26	1		0	0
	1993	31	1		0	0
	1994	28	1		1.3	23
	1995	31	2		0.6	18
	1996	34	1		0.8	28

Table 8-6 ETPP HWW, CW, and De/Di Worker Employment Group and Dose Information - 1997

Employment Group	Year	No. of Employees Monitored			TEDE (mrem)	
		External	Internal	Positive TEDE	Avg	Max
De/Di	1992	10	5	3	11.1	50
	1993	9	0	0	0	0
	1994	9	4	0	0	0
	1995	11	2	1	1.2	1.1
	1996	12	8	1	13	13
ER	1992	354	263	224	15.2	122
	1993	354	227	23	1.0	66
	1994	356	295	19	0.5	69
	1995	363	79	4	0.4	121
	1996	362	236	17	0.8	65
Support	1992	122	679	56	10.8	189
	1993	118	81	2	0.2	15
	1994	121	88	5	0.4	26
	1995	122	76	1	0.0	.1
	1996	122	58	5	0.5	49
De/Di&ER	1992	9	4	3	6.9	31
	1993	12	5	1	0.5	6
	1994	13	9	0	0	0
	1995	13	7	0	0	0
	1996	13	7	0	0	0

Table 8-7 ORNL Subcontractors HWW, CW, De/Di Worker Employment Group and Dose Information - 1996

Employment Group	Year	No. of Employees Monitored			TEDE (mrem)	
		External	Internal	Positive TEDE	Avg	Max
Jacobs Engineering Group	1992	3	2		0	0
	1993	6	0		0	0
	1994	15	2		0	0
	1995	18	3		0	0
	1996	2	0		0	0
Bechtel	1992	41	39		1.2	21
	1993	66	3		4.4	39
	1994	71	48		10.7	274
	1995	30	28		5.5	45
	1996	17	0		0	0
Bechtel National Incorporated	1992	29	25		0.8	23
	1993	20	0		2.0	21
	1994	19	8		0	0
	1995	3	2		13.3	24
	1996	2	0		0	0
Science Applications Incorporated	1992	2	0		0	0
	1993	18	1		0.1	2
	1994	19	5		0	0
	1995	23	4		0	0
	1996	1	0		0	0
Analysas	1992	0	0		NA	NA
	1993	18	0		0	0
	1994	21	1		0	0
	1995	19	2		0.1	2
	1996	14	0		0	0
Pacific Western Technology	1992	11	1		0	0
	1993	22	0		0	0
	1994	21	0		0	0
	1995	22	2		0	0
	1996	1	0		0	0

Table 8-8 Summary of Industrial Hygiene Monitoring of Y-12 HW Employees

Contaminant	No. Of Employees
4,4' -Methylenedianiline	1
Acetone	2
Asbestos	5
Beryllium & Compounds, as Be	3
Cadmium Dusts and Salts, as Cd	1
Carbon Monoxide	1
Carbon Tetrachloride	1
Chromium Metal	1
Cobalt, Elemental & Inorganic Compounds, as Co	2
Iron Oxide Fume (Fe ₂ O ₃), as Fe	1
Lead, Inorganic Dusts & Fumes, as Pb	2
Lead Metal	1
Lithium Hydride	7
Mercury Metal	8
Mercury, all forms except Alkyl Vapor, as Hg	7
Mercury, with Creatinine	5
Methyl Chloroform	3
Methylene Chloride	1
Methylene Bisphenyl Isocyanate (MDI)	2
Naphtha, Coal Tar Pitch Volatiles as Benzene Solubles	2
Nickel, Insoluble Compounds, as Ni	2
Nitric Acid	4
Noise	49
Nuisance Particulates (PNOC) - Respirable Fraction	4
Nuisance Particulates (PNOC) - Total Dust	8
Polychlorinated Biphenyls	1
Protooporphyrin	1
Silica, Crystalline-Quartz	1
Sodium Hydroxide	1
Sulfuric Acid	2
Tetrachloroethylene	3
Toluene	1
Trichloroethylene	1
Uranium Metal	3
Xylene	3
Zinc Oxide Dust	1

9.0 Site maps

The ORR, occupying more than 35,000 acres near Oak Ridge, Tennessee, is composed of three primary sites ; the Y-12 Plant, ETTP, and ORNL. These sites are operated by private industry under the oversight of the Oak Ridge Operations Office. For environmental restoration purposes, the ORR has been divided into five areas defined by natural watersheds. The Y-12 Plant and ORNL are primarily associated with two watersheds each, while all of the ETTP area is within a single watershed.

Figure 9-1 Map of Oak Ridge Operations Office sites

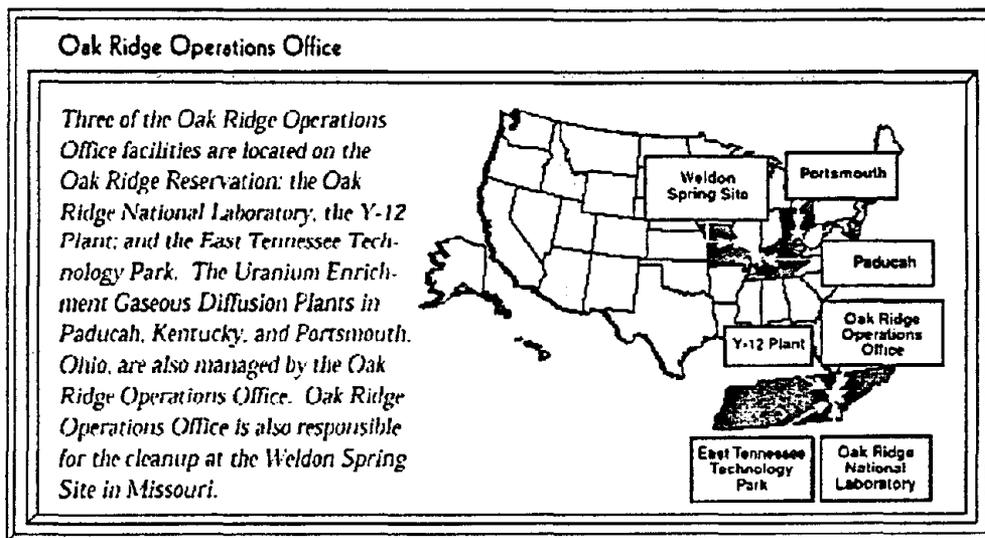
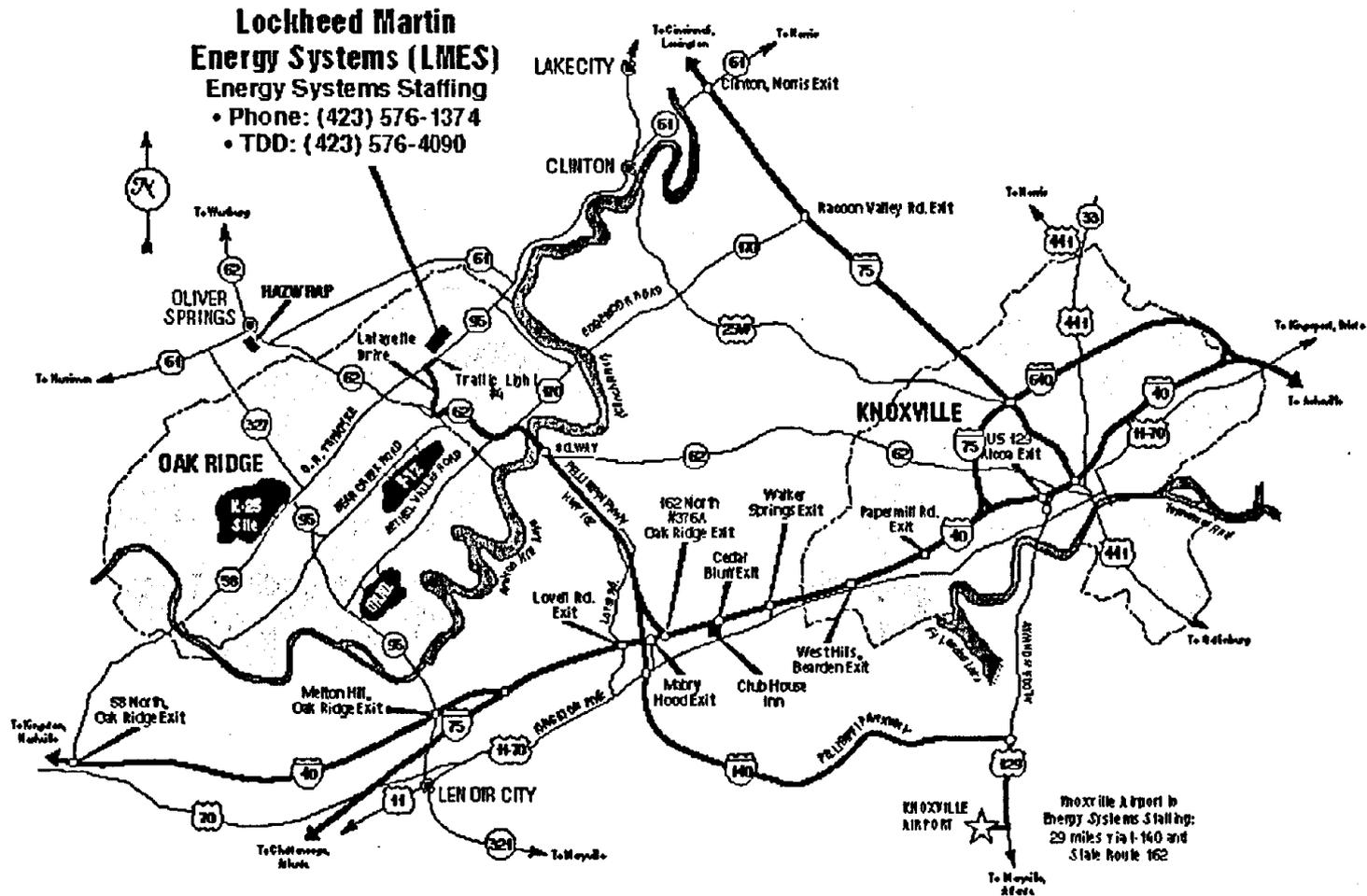


Figure 9-2 Map of Oak Ridge Reservation within Oak Ridge and Knoxville areas



V.GA94-2700

Figure 9-3 Map of Oak Ridge Reservation National Priority List Sites

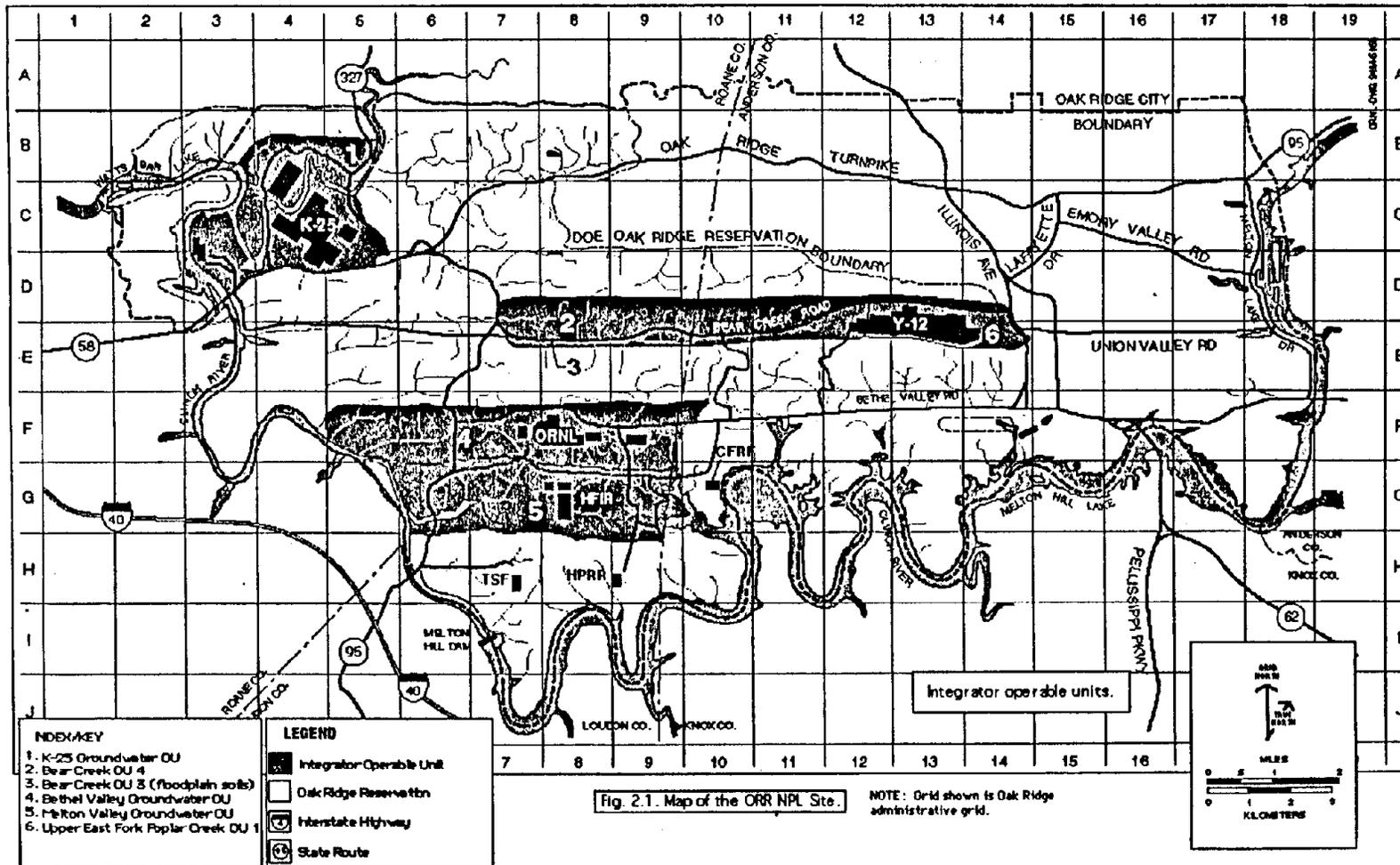


Fig. 2.1. Map of the ORR NPL Sites.

Figure 9-4 Aerial Drawing of Oak Ridge National Laboratory

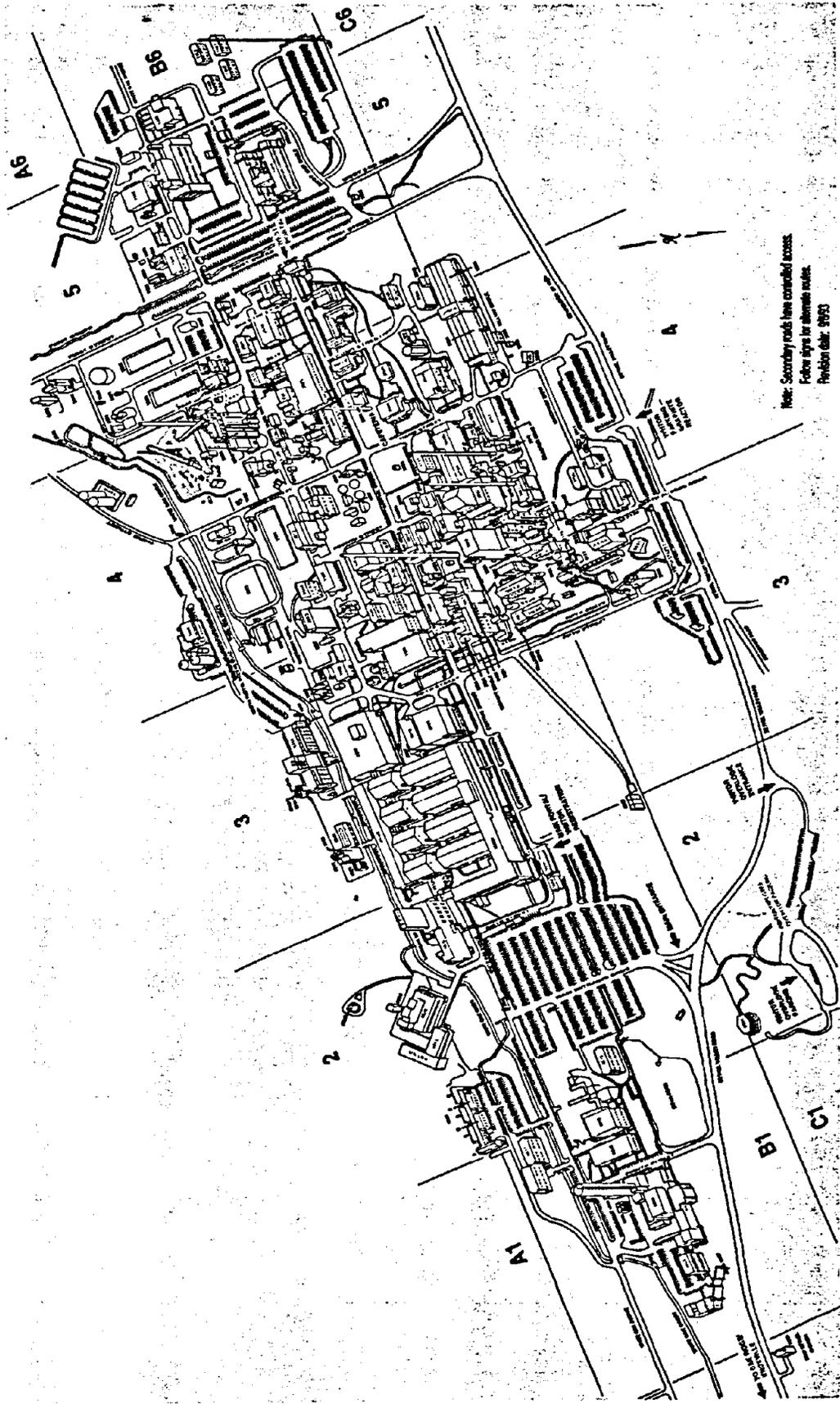
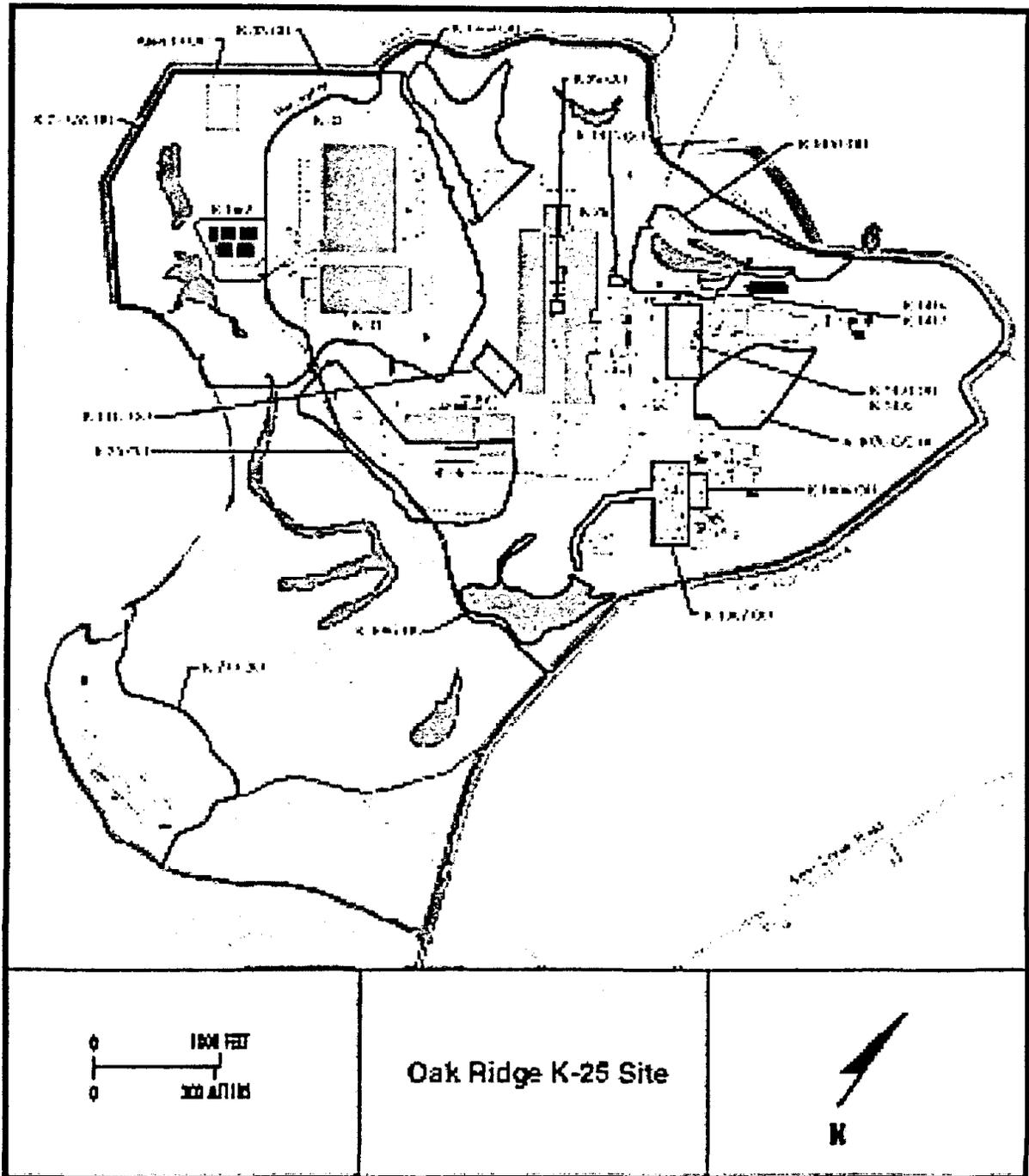


Figure 9-6 Aerial Drawing of East Tennessee Technology Park



10.0 Contacts

Table 10-1 Directory of Contacts Providing Information or Data

Contact	Organization and Addresses	Telephone No.	Facsimile No.	Area of Expertise
Mike Ambrose	ETTP, Bldg K1550-W Room 008 Oak Ridge, TN 37830	423-576-6213	423-576-6714	ETTP environmental compliance
Karen Andrews	EMEF Document Management Center K-25, Bldg 1002, Oak Ridge, TN 37830 xke@ornl.gov	423-241-6112	423-241-6111	Y-12 and ETTP records and reports
Cindy Bailey	Y-12, Information Mgmt Services Audit Response Center, Bldg 9711-5 Oak Ridge, TN 37830, bcw@ornl.gov	423-574-5941	423-576-2946	Y-12 document control
Mary Bales	Remedial Action Program Information Center (RAPIC), 138 Mitchell Road, Oak Ridge, TN 37830, RAPIC@ornl.gov	423-576-6500	423-576-6547	Remedial activities documents maintenance
Bonnie Basher, Director	ORHASP, Nashville, bash101w@wonder.cdc.gov bbasher@mail.state.tn.us	615-532-2212	615-741-3857	ORR plant records associated with ChemRisk Study
Gary Bodenstein	DOE-ORO, Environmental Restoration, 2115 IRC	423-576-9429		ORR environmental restoration
Rhonda Bogard	9711-1, Y-12 bogardrs@ornl.gov	423-574-3539	423-574-1770	Radiological control personnel monitoring for Y-12 and ETTP
Pat Boggess	ETTP K1024	423-576-6240		S&M activities at ETTP
Challise Broughton (Replacement for Mickey Sizemore)	DOE-ORO, Federal Office Building Rm 2222	423-576-2655		ORR technical support and projects coordination

Table 10-1 Directory of Contacts Providing Information or Data

Contact	Organization and Addresses	Telephone No.	Facsimile No.	Area of Expertise
Vickie Brumback	ETTP K1330 Oak Ridge, TN 37830	423/576-8453		Y-12 environmental restoration program
Eleanor Cole, Administrative Assistant	Local Oversight Committee, 761 Emory Valley Road, Oak Ridge, TN 37839 locinc@aol.com	423-483-1333	423-482-6572	ORR waste remediation and management activities stakeholders documents
Jackie Corpering	Y-12 Plant Records, Bldg 9711-5, Room 106 Oak Ridge, TN 37830, juc@ornl.gov	423-574-2949	423-574-0673	Y-12 records management
Rana Dole, Librarian	ORAU/EHSD Library, M.S. 49 P.O. Box 117, Oak Ridge, TN 37830 doler@orau.gov	423-576-3490	423-576-3194	ORR documents search and retrieval
Lola Estes	RAPIC, 138 Mitchell Road Oak Ridge, TN 37830, RAPIC@ornl.gov	423-576-6500	423-576-6547	Remedial activities documents maintenance
Amy Fitzgerald, Executive Director (replaced by Susan L. Gawarecki)	Local Oversight Committee 761 Emory Valley Road, Oak Ridge, TN 37830 loc@icx.net	423-483-1333	423-482-6572	ORR waste remediation and management activities stakeholders documents
Robert Gee	ETTP K-1650, Oak Ridge, TN 37830, xrf@ornl.gov	423-576-5707	423-574-9939	Knowledge of ETTP operations
Ann Glenn	ETTP, Information Mgmt Serv, K1002, Oak Ridge, TN 37830 G16@ornl.gov	423-574-2960	423-241-6111	ETTP records and reports
Patty Goddard	ETTP, K1330, Oak Ridge, TN 37830	423-576-3692		ETTD environmental restoration program

Table 10-1 Directory of Contacts Providing Information or Data

Contact	Organization and Addresses	Telephone No.	Facsimile No.	Area of Expertise
Debbie Gray	Safety and Health Evaluation and Support Team, ORNL, 2256C Oak Ridge, TN 37830 g71@ornl.gov	423-576-4353	423-241-5161	Subcontractor health and safety programs
Mary Ellen Haddox	Office of Science and Technology Information, Oak Ridge, TN 37830 mary_ellen_haddox@ccmail.osti.gov	423-694-4186	423-576-2865	Information dissemination
David R. Hamrin	ORNL Information Officer, 4500N, Oak Ridge, TN 37830 hamrindb@ornl.gov	423-574-6752	423-241-3685	Technologies documents
Mike Harrison	Facility Safety, ETPP, K1001, Oak Ridge, TN 37830	423/576-4562	423-241-2640	ETPP remedial action activities and contaminants
Sara Hayden	Y-12 Information Management Services Room 108, 9711-5 Plant Procedures and Micrographics Oak Ridge, TN 37830, haydensk@ornl.gov	423-574-0099	423-574-0673	Y-12 plant procedures
Marianne Heiskell, Coordination Director	Oak Ridge Environmental Management Program, Department of Energy, Oak Ridge, TN 37830 heiskellmn@oro.doe.gov	423-576-0314	423-241-5712	ORO waste remediation and management
Suzanne Herron	ORNL 7078B, Oak Ridge, TN 37830	423-574-7877		S&M of D&D and RA sites before and after work begins.
Sheri Hester, Librarian	ORAU/ETD Library, MS 15 P.O. Box 117, Oak Ridge, TN 37830 hesters@orau.gov	423-576-2011	423-241-3851	ORR documents search and retrieval

Table 10-1 Directory of Contacts Providing Information or Data

Contact	Organization and Addresses	Telephone No.	Facsimile No.	Area of Expertise
Linda Hill	Energy Systems, ORNL, Envir Compl & Doc, 130MIT, Room 0004, MS 6282 Oak Ridge, TN 37830, hilllf@ornl.gov	423-241-5834	423-576-6616	Health studies coordination
Robert Ihle	Safety and Health Evaluation and Support Team, ORNL, 2652C, Oak Ridge, TN 37830 ihle@ornl.gov	423-576-5064	423-241-5161	ORNL safety and health
Carol Johnson	Y-12 Human Resources, 9704-2, Oak Ridge, TN 37830	423-574-4428		Y-12 and ETTP work force statistics
Cleveland Jones, Director Human Resources/ETTP	ETTP, Human Resrc, Bldg 1001, Room B152, MS 7119 Oak Ridge, TN 37380, dbj@ornl.gov	423-574-8317	423-574-6368	Employment history data
Tim Joseph	ORNL, 4500N, Oak Ridge, TN 37830	423-576-1582		
Linda Kaiser	ETTP K1330, Oak Ridge, TN 37830	423-576-8349		ORNL environmental restoration
Martha Knowles	Jacobs Engineering 125 Broadway Avenue Oak Ridge, TN 37830 mknowles@goldsword.com	423-241-4582	423-574-1405	ORR records and reports
Jerry Kuhaida, Deputy Director Waste Management	Environmental Restoration Program, ORNL, 7078A, Oak Ridge, TN 37830	423-576-5506	423-574-5969	Entire ORR remedial action and waste management programs
Lowell Langford, Records Manager	Office of Scientific and Technical Information 1916-T1, Bldg 0164, Oak Ridge, TN 37830 lowell.langford@ccmail.osti.gov	423-576-4372	423-576-2865	Y-12, ETTP, and ORNL technical documents

Table 10-1 Directory of Contacts Providing Information or Data

Contact	Organization and Addresses	Telephone No.	Facsimile No.	Area of Expertise
Donna Lawson	Y-12 Information Mgmt Services, 9711-5, Room 109, Central Files, Weapons Services Documents and Document Accountability, Oak Ridge, TN 37830 qdl@ornl.gov	423-574-9664	423-574-0673	Classified information analysis
Kathy Marciante	DOE Oak Ridge Operations Records Vault Information Resources, Federal Building, Room B122, Oak Ridge, TN 37830 marciantecs@oro.doe.gov	423-576-0944	423-576-7298	DOE records and classification issues
C.R. Martin	Y-12, Document Management Center, 9115, Room 140, Oak Ridge, TN 37830 martin@ornl.gov	423-574-0076	423-574-0673	Y-12 records and reports
Melanie May	ETTP, K1200, Oak Ridge, TN 37830 maymp@ornl.gov	423-576-6350	423-574-1644	
Craig Money	BJC, 900 TCB Oak Ridge, TN 37830	423-241-9300		Procurement for LMES and LMER sites
Bryant L. (Dell) Morgan, Engineer	ORNL, 1000, Oak Ridge, TN 37830 bxm@ornl.gov	423-574-6430	423-576-2893	ORNL safety and health
Tim E. Myrick, Director	Office of Environmental Programs ORNL 1000, Oak Ridge, TN 37830	423-241-4597	423/576-1100	ORNL waste treatment program
Park Owens, Manager	RAPIC, 138 Mitchell Road, Oak Ridge, TN 37830, RAPIC@ornl.gov	423-576-6500	423-576-6547	Remedial activities documents maintenance
Shelia Perry	Public Reading Room, 2001 Administration Road, Oak Ridge, TN 37830	423-241-4780	423-574-3521	Records and reports
Walter Perry	Oak Ridge Environmental Management, 201 Administration Road, Oak Ridge, TN 37830, perrywn@oro.doe.gov	423-574-3612	423-576-0085	Community relations

Table 10-1 Directory of Contacts Providing Information or Data

Contact	Organization and Addresses	Telephone No.	Facsimile No.	Area of Expertise
J. E. Powell	Y-12, Document Management Center, 9115, Room 140, Oak Ridge, TN 37830 env@cosmail3.ctd.ornl.gov	423-574-1514	423-574-0673	Environmental compliance
Diane Rayer	Public Environmental Information Center Harrison, OH	513-648-7496	513-648-7490	Records management
Remedial Action Program Information Center	RAPIC, 138 Mitchell Road, Oak Ridge, TN 37830, RAPIC@ornl.gov	423-576-6500	423-576-6547	Comprehensive searches, environmental restoration topics
Betty K. Robinette	LMES, Info Mgmt Services, 800 Turnpike, Room 0009, Mail Stop 8250 Oak Ridge, TN 37830, bkr@ornl.gov robinettebk@ornl.gov	423-576-5694	423-576-1277	Records management
Amy Rothrock, DOE Freedom of Information Act (FOIA) Officer	Public Reading Room, 2001 Administration Road, Oak Ridge, TN 37830, rothrockal@oro.doe.gov	423-241-4780 423-576-1216	423-576-1556	FOIA request processing
Greg Rowland	Safety and Health Evaluation and Support Team, ORNL, 2652C, Oak Ridge, TN 37830 dr9@ornl.gov	423-576-6445	423-241-5160	ORNL IH
Peggy Sands, Receptionist	Information Resource Center, 105 Broadway Oak Ridge, TN 37830	423-241-4582	423-574-1405	ORR records and reports
Bill Saury, Manager	Information Resource Center, 105 Broadway Avenue, Oak Ridge, TN 37830 saurywm@oro.doe.gov	423-241-2998	423-574-1405	CERCLA records and reports
Tom Scanlan	ORNL, 4007, Oak Ridge, TN 37830, tex@ornl.gov	423-574-4562	423-576-3515	ORNL waste management

Table 10-1 Directory of Contacts Providing Information or Data

Contact	Organization and Addresses	Telephone No.	Facsimile No.	Area of Expertise
Mike Shelton, Deputy Manager	ETTP Hazardous Waste-Operations Division, K1400, Oak Ridge, TN 37830, ems@ornl.gov	423-576-1895	423-574-9571	ETTP hazardous waste operations
Andrejs Simanis, Manager	Radiological Control, ETTP, K-1020 Oak Ridge, TN 37830	423-574-9086		Radiological control monitoring program
Steve Sims	ORNL 4500S Oak Ridge, TN 37830	423-574-6692		ORNL health physics data
Lisa Snapp	Y-12, HSE&A, 9711-1, Room 0024, MS 8105 Oak Ridge, TN 37830, l8q@ornl.gov	423-576-4567	423-574-1770	Y-12 radiological control, internal dosimetry
Mark Sollenberger Project/Program Manager	Y-12 Plant, Environmental Restoration, 9204-1, Room 0001 MS 8053, Oak Ridge, TN 37830 sollenbergml@ornl.gov	423-576-5573	423-241-3013	Y-12 environmental restoration
Jimmie Stone, Deputy Director	Hazardous Waste Operations, Y-12 Plant 9624 Oak Ridge, TN 37830	423-574-6911		Y-12 WM, DeW and DiW activity
Paul Tarrant, Records Custodian	Information Resource Center, 105 Broadway Oak Ridge, TN 37830	423-241-4582	423-576-1405	ORO environmental restoration documents
Jacque Van Audenhove	TN Dept of Environment and Conservation DOE Oversight Office, 761 Emory Valley Road Oak Ridge, TN 37830, jvanaudenhove@mail.state.tn.us	423-481-0995	423-482-1835	ORO environmental restoration
Joe Weaver	ORNL, Envir Compl & Doc 130MIT, Room 0005, MS 6282 Oak Ridge, TN 37830, j53@ornl.gov	423-241-3339	423-576-2105	Chief liaison person for ORNL
Allen White	Safety and Health Evaluation and Support Team, ORNL, 2652C Oak Ridge, TN 37830	423-574-1482		Subcontractor health and safety programs

Table 10-1 Directory of Contacts Providing Information or Data

Contact	Organization and Addresses	Telephone No.	Facsimile No.	Area of Expertise
Margaret Whitehead	Safety and Health Evaluation and Support Team, ORNL, 2652C Oak Ridge, TN 37830 s8a@ornl.gov	423-576-7059	423-241-5161	General liaison, safety and health
Stanley Whittenbarger, Safety Specialist	Safety and Health Evaluation and Support Team, ORNL, 2652C Oak Ridge, TN 37830 s5w@ornl.gov	423-574-0254	423-241-5161	Construction safety
Steve Wyatt	DOE Oak Ridge Operations Office, AM Public Information, Federal Building, Room 2067 Oak Ridge, TN 37830, wyattsl@oro.doe.gov	423-576-0888	423-576-1665	Public information on ORR waste remediation activities
Steve Wiley	Y-12, 9106, Room 41 Oak Ridge, TN 37830 wileysw@cosmail2.ctd.ornl.gov@smtp	423-576-0263	423-576-7310	Chief liaison for all project interactions for Y-12 and ETP

11.0 Data Sources and Repositories

(1) DOE PUBLIC READING ROOM

LOCATION: Federal Building, Oak Ridge, TN

HOURS OF OPERATION: 8:00 - 11:30 a.m. and 12:00 - 4:30 p.m. Monday-Friday

MANAGER: Amy Rothrock

ATTENDANT: Sheila Perry

COLLECTION: Documents are obtained from FOIA requests, DOE, and site documents provided for public use. The documents collection includes Human Radiation Studies, epidemiology studies by ChemRisk, and documents from Martin Marietta Energy Systems and Oak Ridge Operations Office. The collection includes the following variety of documents: proposed site treatment plans, contracts, Programmatic Environmental Impact Statements, Tiger Team Reports, DOE Orders, DOE Labor Standard Reports, and Daily Operation Reports. Indexes are available for the collection. A computer is available to the public to search the indexes.

(2) INFORMATION RESOURCE CENTER

LOCATION: 105 Broadway, Oak Ridge, TN

HOURS OF OPERATION: 7:30 - 5:30 p.m. Monday - Friday

ATTENDANT: Peggy Sands

COLLECTION: This facility is established by law and maintains technical documents, remedial investigations, reports, records of decision, and site evaluations on the three Oak Ridge sites. Documents are supplied from DOE and Martin Marietta Energy Systems. Documents are kept in closed files; patrons may review a document prior to requesting copies. Copying costs for each 14-day period are as follows: 0-399 pages--no charge; 400 pages--\$15.00 plus 5 cents for each additional page. Paper indexes are located in the reception area; they are updated periodically.

(3) REMEDIAL ACTION PROGRAM INFORMATION CENTER

LOCATION: 138 Mitchell Road, Oak Ridge, TN 37830-7918

PHONE: (423) 576-6500

MANAGER: Park T. Owen

COLLECTION: RAPIC's long-term mission is to provide comprehensive information services to all programs under the auspices of U.S. DOE Office of Environmental Restoration. The objectives of the program are to (1) provide a focal point for collecting, analyzing, abstracting and indexing, and archiving information related to ER program interests; (2) develop computerized information resources; (3) respond to requests for information assistance from program participants; and (4) facilitate information transfer initiatives as directed by program sponsors. RAPIC is a comprehensive information broker and archivist for the DOE environmental restoration community. Specific information activities include: (1) maintaining a computerized bibliographic database of technical literature; (2) publishing an annual bibliography of documents identified as pertinent to the environmental restoration programs; (3) providing copies of requested documents or assisting in locating documents not currently available from RAPIC; (4) performing manual and computerized searches of the technical literature upon request; and (5) maintaining a database of individuals involved with environmental restoration work.

(4) DOCUMENT MANAGEMENT CENTER

LOCATION: Y-12 Plant, Building 9115, Room 140

MANAGERS: C.R. Martin; J.E. Powell

CONTACT: Steve Wiley, (423) 576-0263

COLLECTION: Contains some very old environmental documents and some environmental restoration and subcontractor documents. As documents are generated from the Environmental Management Group, they are given a document number and added to the collection. There is a computer system for searching the collection and a hard copy list is available. The collection is in the process of being scanned for optical disk technology storage.

(5) EMEF DOCUMENT MANAGEMENT CENTER

LOCATION: Building 1002, East Tennessee Technology Park (K-25 Site)

MANAGER: Karen Andrews, 241-6112

CONTACT: Steve Wiley, (423) 576-0263

COLLECTION: The EMEF Document Management Center is the site for environmental management and environmental restoration documents (many of the old environmental restoration documents are located here). The center contains approximately 40,000 active documents which are individually managed; 2,000 boxes of special collections are located at the center and managed at the box level; approximately 15,000 cu ft of inactive records are located at the site records center. Work is underway to merge other document centers with this facility. Approximately 400 documents are added to the collection per month. The active documents are indexed on the Documentum data base. Generally, there is no charge for copies of documents.

12.0 References

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13.0 Submitted Materials

A total of 239 documents were collected and/or reviewed for this project. The documents include journal articles, technical reports, book excerpts, and information from the internet. Many of the documents are specific to one site (SRS or ORR) and appear only in the bibliography of one report. Other documents, however, are more general and were used to produce both reports.

A linkage tool (reference table) was developed to identify all the reference documents and show how they were used in the project. The table lists the references for all project documents in alphabetical order. The table shows (a) the site(s) to which the reference applies; (b) how the references are used in the report(s): as a general source of information (bibliography) or as a specific citation within the report(s) (work cited); and (c) whether the document is included in the shipment of documents to NIOSH. Documents cited in the report(s) are indicated in the table along with the citation number. Labels appear on the cited documents identifying the citation number(s) used.

A total of 152 documents (4 cubic feet) have been shipped to NIOSH. The documents are arranged in the record boxes in the same alphabetical arrangement as listed in the reference table. The documents were shipped in official record boxes as prescribed in the approved work plan.