Energy Systems Environmental Restoration Program

Work Plan for the Oak Ridge Reservation
Ecological Monitoring and Assessment Program

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Date Issued—August 1994

Prepared by
Environmental Sciences Division
Oak Ridge National Laboratory
ESD Publication 4315

Prepared for
U.S. Department of Energy
Office of Environmental Restoration and Waste Management
under budget and reporting code EU 20

MARTIN MARIETTA ENERGY SYSTEMS, INC.
managing the
Oak Ridge K-25 Site, Oak Ridge National Laboratory, Oak Ridge Y-12 Plant,
and Environmental Restoration and Waste Management activities at the
Paducah, Kentucky, and Piketon, Ohio, Gaseous Diffusion Plants
under contract DE-AC05-84OR21400
for the U.S. Department of Energy

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CONTENTS

FIGURES	v
TABLES	vii
ABBREVIATIONS AND ACRONYMS	ix
EXECUTIVE SUMMARY	xi
1. INTRODUCTION	1
2. BACKGROUND	2
2.1 DESCRIPTION OF THE OAK RIDGE RESERVATION	2
2.2 CONCEPTUAL FRAMEWORK	4
2.3 REVIEW OF EXISTING INFORMATION	10
2.3.1 Monitoring in Aquatic Systems	10
2.3.2 Ecological Information for the Terrestrial System	22
2.3.3 ORR-Wide Contaminants of Potential Concern	25
2.3.4 Contaminants in Terrestrial Biota	36
2.4 INTERFACES WITH OTHER PLANNED OR EXISTING PROGRAMS	45
2.4.1 Biological Monitoring and Abatement Programs	45
2.4.2 Rare Plant Surveys	45
2.4.3 Wetlands Surveys	45
2.4.4 Endangered Animals Surveys	45
2.4.5 Managed Deer Hunts	46
2.4.6 Remedial Investigations on Source and Aquatic Integrator Operable Units	46
2.4.7 Clinch River Environmental Restoration Program	46
2.4.8 Monitoring by the Natural Resource Trustees	46
3. WORK PLAN	47
3.1 DATA QUALITY OBJECTIVES	47
3.2 DATA GAPS	49
3.3 SPECIFIC TASKS	53
3.3.1 Habitat Mapping and Analysis	53
3.3.2 Ecological Risk Assessment	64
3.3.3 Preliminary Field Sampling and Analysis Plan	66
3.4 PROJECT ORGANIZATION AND MANAGEMENT PLAN	69
3.5 QUALITY ASSURANCE/QUALITY CONTROL	69
3.6 GENERAL HEALTH AND SAFETY REQUIREMENTS	69
4. REFERENCES	70

APPENDIX A: FACILITATOR'S SUMMARY OF DATA QUALITY OBJECTIVES MEETINGS	A-1
APPENDIX B: FIGURES FOR SUMMARY OF AQUATIC MONITORING PROGRAMS	B-1
APPENDIX C: TERRESTRIAL ANIMAL SPECIES ON THE OAK RIDGE RESERVATION	C-1
APPENDIX D: PUBLICATIONS RELATED TO CONTAMINATION IN TERRESTIRAL BIOTA ON THE OAK RIDGE RESERVATION ...	D-1

FIGURES

1	Oak Ridge Reservation and surrounding areas	3
2	Conceptual model of the transport of contaminants among the different classes of operable units	5
3	Generic conceptual model for contaminant transport and exposure on a source operable unit	6
4	Generic conceptual for contaminant transport and exposure on an aquatic integrator operable unit	7
5	Generic conceptual model for contaminant transport and exposure on the terrestrial integrator	8
6	Generic conceptual model for contaminant transport and exposure in the aquatic biota component of source and aquatic integrator operable units	9
7	Oak Ridge Reservation and surrounding areas. September 1984. Projection: UTM	24
8	Oak Ridge Reservation and surrounding areas, totalling ~188,000 ha. April 13, 1994. Projection: TSP	55
9	Oak Ridge Reservation and surrounding areas. April 13 1994. Projection: TSP	56
10	Oak Ridge Reservation operable units. April 13, 1994	57

TABLES

1	Summary of Existing Biological Monitoring Programs	10
2	Summary of Biological Monitoring Program tasks	11
3	Number of dead fish collected in daily surveys of East Fork Poplar Creek between Bear Creek Road and North-South pipes	15
4	Technical assistance provided by BMAP staff to the K-25 Site, 1986-1992	18
5	Changes from 1986 to 1993 in average concentrations of PCBs and fraction of channel catfish exceeding the Food and Drug Administration limit	22
6	Changes from 1986 to 1993 in average concentrations of PCBs and fraction of channel catfish exceeding the Food and Drug Administration limit	25
7	Evaluation of Contaminants Observed at the Oak Ridge Reservation for Determination of Reservation-wide COPCs	27
8	Contaminants in terrestrial biota on the Oak Ridge Reservation	37
9	Problem statements and decisions for the Oak Ridge Reservation ecological monitoring and assessment program	47
10	Assessment endpoints for an ecological risk assessment of the Oak Ridge Reservation	48
11	Measurement endpoints for an ecological risk assessment of the Oak Ridge Reservation	48
12	Data Gaps Identified for Reservation-Scale Ecological Assessment Endpoint Species and Communities	51
13	Land use/land cover categories and descriptions	58
14	Preliminary estimates of area and relative percent cover by category for the Oak Ridge Reservation and the ~188,000-ha subscene	58
15	Preliminary estimates of area and relative percent cover by category within Oak Ridge Reservation operable units	59

ABBREVIATIONS AND ACRONYMS

ATSDR	Agency for Toxic Substances and Disease Registry
BCK	Bear Creek kilometer
BMAP	Biological Monitoring and Abatement Program
BSCP	Background Soils Characterization Project
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	contaminant of potential concern
CRK	Clinch River kilometer
DOE	U.S. Department of Energy
DNA	deoxyribonucleic acid
DQO	data quality objectives
EFK	East Fork Poplar Creek kilometer
EFPC	East Fork Poplar Creek
EIS	Environmental Impact Statement
EMAP	Ecological Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
EPT	ephemeroptera, plecoptera, and tricoptera
ER	environmental restoration
ERD	Environmental Restoration Division
FB/BB	Freel's Bend/Bull Bluff
FCAP	Filled Coal Ash Pond
FDA	U.S. Department of Agriculture Food and Drug Administration
FFA	Federal Facilities Agreement
FFK	Fifth Creek kilometer
FS	feasibility study
FWS	U.S. Fish and Wildlife Service
GIS	geographic information system
GPS	global positioning system
GRASS	Geographic Resource Analysis Support System
HSDB	Hazardous Substances Database
HSI	Habitat Suitability Index
INM	in need of management
KCP	Kansas City Plant
LC ₅₀	lowest concentration at which 50% mortality occurs
LD ₅₀	lowest dose at which 50% mortality occurs
LOAEL	lowest observed adverse effects level
MHR	Melton Hill Reservoir
MIK	Mitchell Branch kilometer
NAD	North American Datum
NEPA	National Environmental Policy Act
NOAEL	no observed adverse effects level
NPDES	National Pollutant Discharge Elimination System
NRDA	natural resource damage assessment
NS	not sampled
NT	North Tributary
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OU	operable unit
PAH	polycyclic aromatic hydrocarbon

PCB	polychlorinated biphenyl
PCK	Poplar Creek kilometer
PGDP	Paducah Gaseous Diffusion Plant
PORTS	Portsmouth Gaseous Diffusion Plant
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
SD	storm drain
STP	sewage treatment plant
SVOC	semi-volatile organic compound
T&E	threatened and endangered
TDEC	Tennessee Department of Environment and Conservation
TM	Landsat Thematic Mapper
TSP	Tennessee State Plane
TVA	Tennessee Valley Authority
TWRA	Tennessee Wildlife Resources Agency
USA CERL	U.S. Army Corps of Engineers Research Laboratory
USGS	U.S. Geological Survey
UT	University of Tennessee
VOC	volatile organic compound
WAG	waste area grouping
WCK	White Oak Creek kilometer
WOC	White Oak Creek
WOL	White Oak Lake

EXECUTIVE SUMMARY

This plan describes an approach for developing an ecological monitoring and assessment program (EMAP) for the U.S. Department of Energy's (DOE's) Oak Ridge Reservation (ORR). Such a program is required to assess existing ecological risks, to predict changes in those ecological risks from proposed remedial actions, and to monitor the effectiveness of remedial actions in reducing ecological risks. Ecological risk assessments must be based on Reservation-level data for those widespread or wide-ranging plant and animal species (including state- and federally-listed threatened and endangered species) that occupy the entire ORR. In recognition of this need, Region IV of the U.S. Environmental Protection Agency (EPA) has specifically requested that DOE develop a Reservation-wide monitoring and assessment program. The approach described herein was developed in a series of meetings among DOE, EPA, and the Tennessee Department of Environment and Conservation who are the three parties to the Federal Facilities Agreement (FFA) that governs environmental restoration activities on the ORR.

The current strategy distinguishes four types of potentially contaminated areas: (1) source operable units (OUs), which may contain waste disposal areas, (2) groundwater aquifers that are potentially contaminated by source OUs, (3) aquatic integrator OUs which are streams and associated floodplains that drain source OUs, and (4) the terrestrial integrator, which encompasses the Reservation.

Source OUs may contain sources of contamination that potentially impact local plant and animal populations and communities that are restricted to the areal extent of the OU. Such local impacts must be assessed for each OU. However, these source OUs also contribute to risks within the aquatic OUs and within the Reservation-wide terrestrial ecosystem. Therefore, remedial investigations at source OUs must provide data necessary to support ecological risk assessments at the larger scales.

Existing data from historical research and monitoring activities are summarized in this report. For purposes of this project, the FFA parties agreed that existing data and ongoing programs were sufficient for aquatic monitoring. Therefore, this project does not include additional aquatic monitoring.

In terrestrial ecosystems three conclusions emerge from the existing data. First, a wide range of contaminants have been found in a wide range of wildlife and vegetation. This conclusion must be tempered with the realization that, in most cases, researchers were looking for contamination that was expected to bioaccumulate in areas that were known to be contaminated. Nevertheless, the important point is that biota in contaminated areas are accumulating that contamination.

A second noteworthy feature of the historical data is that contaminated animals with large home ranges (e.g., Canada geese, deer, kingfishers, and wild turkeys) have been collected at locations outside the boundaries of existing OUs.

Finally, although the ecological significance of this widespread contamination is unclear at this time, there is evidence—from a modeling study, from the ecological risk assessments for two OUs, and from preliminary evaluation of a year-long mink trapping program—that some wildlife species, in some areas of the ORR, are suffering adverse effects from existing contamination.

Based on this existing information as well as conceptual models of the terrestrial ecosystems, 53 wildlife species were selected as assessment endpoints for this project. These endpoints include all of the 32 state- or federally-listed threatened, endangered, or in-need-of-management species that are known or suspected to inhabit the ORR.

Contaminants of potential concern have been identified for all OUs and for the ORR as a whole. Using these contaminants and the 53 assessment endpoints, a preliminary ecological risk assessment will be performed in FY 1995. Results of this risk assessment will be used to prioritize additional work as well as to guide data collection on individual OUs.

In order to assess ecological risks to widely distributed species, the habitat requirements of the species must be known and the distribution of habitats on the ORR—especially within source and aquatic integrator OUs—must be determined. Preliminary habitat mapping activities have been completed and are presented in this plan. Habitat requirements of endpoint species will be determined from reviews of existing literature during FY 1995. The result of this activity will be the ability to map the likely distribution of endpoint species within contaminated areas. This information is essential to assess the exposure of endpoint species to contaminants.

At the same time that habitat requirements are being determined for endpoint species, the toxicity of contaminants of potential concern to those endpoints will also be determined, to the extent possible, from the scientific literature. Knowledge of the toxicity of each contaminant to each endpoint is needed to relate exposure to effects.

This program will be closely coordinated with ongoing programs that obtain related data. For example, information from ongoing surveys of wetlands, rare plants, and threatened and endangered wildlife species will be incorporated into the assessment activities of this project. Aerial survey data from the Oak Ridge Environmental Base Mapping and Imagery Project will be used to update habitat maps produced by this project.

Although the principal effort in FY 1995 will be to gather existing information and conduct a preliminary ecological risk assessment, some field data collection will proceed. Just as background contaminant levels have been determined for the various soil types on the ORR, similar background information is needed for biota in order to determine whether contaminant concentrations measured in biota on source OUs represent an increased exposure to the organisms beyond what they would receive in uncontaminated areas. Samples of earthworms, vegetation, and small mammals will be collected from the same areas as were used for the background soil characterization project. Analyses of these samples will be deferred until FY 1996. In addition regular surveys of roadkilled animals will be made to obtain opportunistic samples of organisms that could not otherwise be sampled. Analyses of these samples will also be deferred to FY 1996.

1. INTRODUCTION

The purpose of this plan is to describe an approach for developing an ecological monitoring and assessment program for the U.S. Department of Energy's (DOE's) Oak Ridge Reservation (ORR). Such a program is required to assess existing ecological risks, to predict changes in those ecological risks from proposed remedial actions, and to monitor the effectiveness of remedial actions in reducing ecological risks. This document sets out the basic framework for the ecological monitoring and assessment program and defines the specific tasks to be completed in FY 1995. However, these proposed tasks will provide information that will lead to the need for revisions to this program plan. Accordingly, future revisions of this document will be issued as new information dictates.

The principal regulatory impetus for a Reservation-wide ecological monitoring and assessment program derives from the Federal Facilities Agreement (FFA) that governs implementation of environmental restoration (ER) activities on the Reservation. This agreement integrates the provisions of the Resource Conservation and Recovery Act (RCRA) with those of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and requires that ER activities be based upon human health and ecological risk assessments. As described in Section 2.2 of this plan, ecological risk assessments must be based on Reservation-level data. In recognition of this need, Region IV of the U.S. Environmental Protection Agency (EPA) has specifically requested that DOE develop a Reservation-wide program (Brown 1993).

In addition to the FFA, at least two other major environmental regulations require ORR-level data in order to support assessment activities. The National Environmental Policy Act (NEPA) requires consideration of cumulative impacts of major federally funded actions. The cumulative impacts of the many individual unit-level remedial actions on the ORR ecosystem cannot be evaluated without reservation-level information.

The Natural Resource Damage Assessment (NRDA) provisions in CERCLA require DOE to pay for restoration of natural resource services injured by facility-related contaminants. Since most of the ecological resources (e.g., forests, rare habitats, fish, and wildlife) are distributed across the Reservation, accurate assessment of injuries and potential DOE liabilities requires Reservation-level information.

Finally, DOE environmental restoration policy is now moving away from a contaminant-removal strategy and toward a land-use strategy. There is a DOE initiative to evaluate future initiatives. Potential land uses of the ORR cannot be effectively evaluated without reservation-wide data.

Given the above regulatory impetus and the need for information to support decisions to be made by the FFA parties [i.e., DOE, EPA Region IV, and the Tennessee Department of Environment and Conservation (TDEC)], the program described in this plan was developed based on a series of discussions among those parties. This process, collectively called the Data Quality Objectives (DQO) process, is described in Sect. 3.1 and Appendix A. Results of the DQO process were a set of problem statements, decisions, decision rules, and inputs. This plan has been developed to provide those inputs.

2. BACKGROUND

This chapter presents background information. A brief description of the Reservation is followed by conceptual models that describe the pertinent processes operating in the terrestrial ecosystems. Existing data concerning contaminants of potential concern and measured contamination in aquatic and terrestrial biota is reviewed. A brief description of related programs is provided to demonstrate that this program will take full advantage of all available data and will not duplicate any ongoing or planned activities.

2.1 DESCRIPTION OF THE OAK RIDGE RESERVATION

The ORR (Fig. 1) covers ~14,000 ha (~35,000 acres) in Anderson and Roane counties. The ORR is bounded on the south and west by the Clinch River. The residential/commercial portion of the city of Oak Ridge borders the ORR to the north and east.

Since the early 1940s, the Oak Ridge Reservation has been owned by a succession of federal government agencies beginning with the Manhattan Project through the present U.S. Department of Energy. Originally, the ORR covered a much larger area, including all of the present city of Oak Ridge.

Three major DOE facilities are located on the ORR. Oak Ridge National Laboratory is a multiple-mission research facility. The K-25 Site, formerly the Oak Ridge Gaseous Diffusion Plant, now houses Environmental Restoration and Waste Management programs, laboratory, engineering, and administrative personnel. The Y-12 Plant is part of the DOE's nuclear weapons complex and also houses the Center for Manufacturing Technology. Most of the ORR outside these major facilities is part of the Oak Ridge National Environmental Research Park.

In addition to the major DOE facilities, the University of Tennessee (UT) operates two facilities, the UT Arboretum and the Comparative Animal Research Laboratory in the eastern portion of the ORR. Private companies operate industries along a strip of Oak Ridge City land adjacent to Bear Creek Road west of State Highway 95. A large tract of land on the west end of the ORR is owned by the Tennessee Valley Authority (TVA).

The ORR is a component of the Southern Appalachian Man and Biosphere Reserve and a wildlife management area of the Tennessee Wildlife Resources Agency (TWRA). The ORR also contains registered state natural areas.

Operation of the DOE facilities over the past 50 years has resulted in intentional and inadvertent release of contaminants to all ambient media. The nature of these facilities has been such that a wide variety of contaminants have been released. Results of biological monitoring studies over the past 30 years have shown that many of these contaminants—especially radioisotopes—have accumulated in terrestrial and aquatic biota (see Sect. 2.3). Areas where contaminants have been released or have accumulated following release have been identified, and operable units (OUs) have been established for remedial actions.

Figure 1. Oak Ridge Reservation and surrounding areas.

- Major Roads
- Water Features
- Operable Units
- Reservation Boundary

2.2 CONCEPTUAL FRAMEWORK

The conceptual strategy for ecological risk assessment on the ORR, which was developed by the FFA parties through a DQO process, is described in a separate document (Suter et al. 1994). The purpose of the strategy is to permit the completion of adequate ecological risk assessment on individual OUs while ensuring that all ecological resources on the ORR that are exposed to contaminants are assessed. The strategy distinguishes four types of potentially contaminated areas: (1) source OUs, which may contain waste disposal areas, (2) groundwater aquifers that are potentially contaminated by source OUs, (3) aquatic integrator OUs which are streams and associated floodplains that drain source OUs, and (4) the terrestrial integrator, which encompasses the Reservation.

Generic conceptual models for these OUs are presented graphically in Figures 2–6. Figure 2 shows the flows of contaminants among the four classes of OUs. Figures 3–5 show the contaminant flows into, within, and out of the source OUs, aquatic integrator OUs, and terrestrial integrator. Finally Figure 6 shows the equivalent flows within the aquatic biota compartment of the source and aquatic integrator OUs. Each compartment of these models has been described in terms of its content, inputs, and outputs by Suter et al. (1994).

The implementation of the ORR strategy for ecological risk assessment depends on the exchange of information among the OUs. As part of the remedial investigation (RI), each OU is responsible for characterizing: risks to the ecological endpoints that are associated with the OU (i.e., occur on the OU and have a scale appropriate to the OU), contributions to contaminant inputs to “downstream” integrator OUs, and risks resulting from contaminant inputs from “upstream” OUs. In order to perform those characterizations, each OU needs estimates of: fluxes of contaminants from “upstream” OUs, and ecological risks resulting from its contributions to downstream OUs. The needed data would be generated if each OU characterized sources that occurred within the OU, exposures to all endpoint biota on the OU (whether associated with the OU or with a larger scale integrator OU), responses of endpoint biota associated with the OU, and fluxes of contaminants off the OU and into integrator OUs.

All of these OU types have been previously recognized except the terrestrial integrator. The creation of the terrestrial integrator is a result of the recognition by the FFA parties that some ecological endpoints were not being appropriately assessed. Those were the highly mobile animals that move among the OUs and the rest of the reservation, feeding, drinking, and resting in various locations. Effects on these wide-ranging animals can not be attributed to one OU, but without a terrestrial integrator, there would be no mechanism to assess the combined effects of the multiple OUs. In addition, the terrestrial integrator provides a means of assessing the ecological risks associated with habitat destruction during remediation by identifying the habitat types destroyed, the importance of the habitat loss to endpoint species and communities, and the significance of the particular area destroyed (e.g., as a habitat corridor). Finally, the terrestrial integrator provides a means of interpreting the significance of effects on individual OUs in an ecosystem context. The sampling, analysis, and assessment activities for the terrestrial integrator will be carried out by the ORR EMAP.

Fig. 2. Conceptual model of the transport of contaminants among the different classes of operable units

Fig. 3. Generic conceptual model for contaminant transport and exposure on a source operable unit.

Fig. 4. Generic conceptual model for contaminant transport and exposure on an aquatic integrator operable unit.

Fig. 5. Generic conceptual model for contaminant transport and exposure on the terrestrial integrator operable unit.

Fig. 6. Generic conceptual model for contaminant transport and exposure in the aquatic biota component of source and aquatic integrator operable units.

2.3 REVIEW OF EXISTING INFORMATION

2.3.1 Monitoring in Aquatic Systems

The FFA parties agreed during the DQO process that existing monitoring programs for aquatic systems were adequate to provide input for their future decisions. This section supports that agreement by presenting a summary of available data from aquatic monitoring programs and a description of those programs. To make this section more readable, the 45 figures have been moved to Appendix B.

2.3.1.1 Overview

Five biological monitoring programs have been implemented over the past 10 years on the major watersheds of the ORR, including Bear Creek, East Fork Poplar Creek (EFPC), White Oak Creek (WOC), Mitchell Branch, and McCoy Branch (Table 1). The five programs can be separated into two groups, which reflect different missions and funding sources. One group consists of the three Biological Monitoring and Abatement Programs (BMAPs), one for each of the three DOE facilities on the Reservation. These three programs are mandated by the permits issued under the National Pollutant Discharge Elimination System (NPDES), with funding provided by the environmental compliance organization at each facility. The remaining two biological monitoring programs are not required by the NPDES permit, but were initially implemented at the request of Y-12 Plant staff. Currently, the information obtained from these programs is used to document the effectiveness of remedial actions and support ecological risk assessments under CERCLA. Funding for one (McCoy Branch), and eventually the other (Bear Creek), is provided by the Environmental Restoration Program.

Table 1. Summary of Existing Biological Monitoring Programs

Facility	Program ^b	Receiving Stream(s)	Date Monitoring Initiated
Y-12 Plant	ER	Bear Creek	May 1984
Y-12 Plant	NPDES	East Fork Poplar Creek	May 1985
ORNL	ER	White Oak Creek Watershed	August 1985
		Clinch River	
ORNL	NPDES	White Oak Creek Watershed	April 1986 ^c
		Clinch River	
K-25 Site	NPDES	Mitchell Branch	August 1986
Y-12 Plant	ER	McCoy Branch	April 1989

^a ORNL = Oak Ridge National Laboratory

^b ER = Environmental Restoration; NPDES = National Pollutant Discharge Elimination System.

^c The two programs at ORNL were combined into a single comprehensive biological monitoring program in April 1986.

Although the programs have different origins, they share a common set of objectives. These are to (1) determine if the NPDES effluent limits protect the uses of the receiving stream (e.g., growth and propagation of fish and aquatic life), as recognized by the TDEC; (2) assess the ecological impacts of plant operations and identify causes/sources of impact, including the significance of nonpoint sources; and (3) monitor ecological recovery and assess the effectiveness of remedial actions. The biological monitoring programs also share a common set of tasks (Table 2), although there are some differences due to both programmatic needs and site suitability.

Table 2. Summary of Biological Monitoring Program tasks

	NPDES Programs			ER Programs	
	ORNL	Y-12 Plant	K-25 Site	Bear Creek	McCoy Branch
Ambient Toxicity Testing	x	x	x	x	x
Bioaccumulation Monitoring					
Aquatic	x	x	x	x	x
Terrestrial	x	x ^a	x ^a		
Biomarker Studies	x	x	x	x	x
Instream Monitoring					
Benthic invertebrates	x	x	x	x	x
Fish	x	x	x	x	x
Periphyton	x	x			

^a Added in 1993–1994

The requirement for biological monitoring in the NPDES permits that were issued in 1984–1986 to each facility was based on the fact that the receiving streams did not meet ambient water quality criteria. There was insufficient information on facility effluents, and high capital costs impacted alternative approaches to compliance. Consequently, a biological monitoring approach was selected to provide (1) an alternative mechanism for compliance based upon protection of the classified uses of the receiving stream, and (2) a framework for establishing interim, less restrictive effluent limits.

All of the biological monitoring programs are designed to assess ecological effects at the watershed level; that is, sites were located above and below known or potential contaminant sources and on various tributaries, as appropriate (Fig. B.1). Many of the ORR streams are used as reference sites (Fig. B.1). However, because all of the larger streams on the Reservation receive industrial discharges, suitable large streams for use as reference sites could only be found off site (Fig. B.2). The use of multiple reference sites provides a broad range of values for selected ecological variables that can be compared to values obtained for the on-site receiving streams. The significance of including multiple reference sites is illustrated in Fig. B.3, which shows the range in biomass and taxonomic richness of the benthic macroinvertebrate communities across 17 sites.

The biological monitoring programs have several other unique attributes. They consist of characterization and investigative phases, in addition to routine monitoring. They also utilize detailed, written procedures to assure quality. Finally, they can provide data for many related activities, such as ecological risk assessments under CERCLA and major project assessments under NEPA [e.g., ORNL Advanced Neutron Source Environmental Impact Statement (EIS), Complex 21 Programmatic EIS].

In addition, the ORR biological monitoring programs combine conventional monitoring procedures and innovative state-of-the-art techniques to assess impacts. New, more sensitive techniques that were developed to measure the effects of contaminant exposure include measures of the structural integrity of deoxyribonucleic acid (DNA), which has been proposed as a biological parameter for detecting environmental genotoxicity on the basis that carcinogenic or mutagenic chemicals will cause deleterious modifications to DNA in living organisms. Measurement of strand breaks in the DNA of redbreast sunfish is a component in the Y-12 Plant BMAP for EFPC. The integrity of DNA in fish collected just below New Hope Pond in 1987 and 1988 was low (i.e., high number of

strand breaks) but increased in 1989-1991 when values were similar to those observed in redbreast sunfish from Hinds Creek, a minimally impacted, off-site reference stream (Fig. B.4). This decrease in the number of DNA strand breaks in EFPC was associated with the closure of New Hope Pond, which was initiated in November 1988. Correlation, however, does not imply causality, and other remedial actions at the Y-12 Plant during this period may have been responsible for the observed reduction in genotoxic stress.

Another new monitoring technique developed and tested by BMAP was an in situ toxicity test with the endemic fingernail clam, *Sphaerium fabale*. Clams were collected from a local reference stream (Beaver Creek), placed in small, screened plexiglass containers, and put into EFPC and several reference streams, including the source stream. Survival, growth, and reproduction were assessed at 3-week intervals for the duration of the test. The results of clam reproduction in 1990 and 1991 are shown in Figs. 5 and 6, respectively. This test provides a more accurate and sensitive measure of the effects of chronic exposure to contaminants than more traditional laboratory toxicity tests.

The ORR biological monitoring programs also include some unique applications of conventional monitoring techniques. For example, caged Asiatic clams are typically used to monitor contaminants but are used in BMAP not only to monitor the bioaccumulation of organics but also to identify contaminant sources. The 7-day, "mini-chronic" toxicity tests with fathead minnow larvae and *Ceriodaphnia* were developed primarily to evaluate the toxicity of plant effluents. In the ORR biological monitoring programs, these tests are used to evaluate the toxicity of receiving streams. It was this application of an effluent test to ambient waters that resulted in the identification of (1) residual chlorine as the primary toxicant in streams that receive point-source discharges from the three DOE facilities and (2) nickel as one of possibly several toxic metals in Bear Creek.

Major findings of each of the five biological monitoring programs are presented below. In addition, the monitoring of contaminants that accumulate in aquatic biota, which is a component of each program, is discussed separately in the concluding section of the report. In this manner, the contaminant data from individual programs are integrated within a Reservation-wide framework.

2.3.1.2 Bear Creek

A review of the existing literature provided evidence of significant ecological impacts on aquatic biota in Bear Creek more than 20 years ago. A zone of acute toxicity in 1974 extended at least 2 km below the S-3 acid waste disposal ponds, which are situated in the headwaters of Bear Creek at the west end of the Y-12 Plant. Mortality was 100% in 24-h in situ fish bioassays conducted just above and 500 m below the oil landfarm. In addition, no benthic invertebrates were found at sites above and below the oil landfarm (~1 km downstream of the S-3 ponds). This toxicity was probably related to low pH/high metals due to seepage from S-3 ponds (Fig. B.7).

Biological sampling was initiated in 1984 at a series of sites between the headwaters at Bear Creek kilometer (BCK) 12.36 and BCK 3.25, which is located downstream of Highway 95 (Figs. B.8 and B.9). Highlights of this monitoring program are summarized below.

Neutralization and denitrification of the S-3 ponds occurred in 1983-1984 and resulted in a rapid improvement in surface water quality. All discharges to the ponds had been terminated by March 1984. The pH of upper Bear Creek increased and the solubility (and

toxicity) of many metals decreased. The zone of acute toxicity was reduced from several kilometers to about 500 m and fish abundance increased substantially at BCK 11.83, about 0.75 km below the ponds (Fig. B.10). However, the reach of Bear Creek immediately downstream of the ponds remained toxic until fall 1989, when a dramatic increase in fish abundance was observed at BCK 12.36 (Fig. B.11). Recovery of the fish community was associated with closure of the ponds in 1989. Concentrations of dissolved constituents in upper Bear Creek continued to decline (Fig. B.12), and a resident fish community was finally established in the headwaters.

This recovery is especially significant because it recently included a substantial increase in the abundance of the Tennessee dace, *Phoxinus tennesseensis*, in upper Bear Creek (Fig. B.11). This species comprised 20% of the fish population at BCK 12.36 in spring 1993 compared with only 1-8% during 1989-1992. The Tennessee dace is listed in need of management by the Tennessee Wildlife Resources Commission and endangered by the state of Virginia. It is a pollution-intolerant species that currently inhabits only 45 sites in East Tennessee, and its state wide distribution is concentrated on the Cherokee National Forest in Polk County and the ORR (Fig. B.13). This species has a relatively short life span (2-3 years) and low fecundity; therefore, it depends upon successful reproduction at least once every two years. Large spawning aggregations (as many as 100 individuals) utilize clean gravel nests prepared by other species. Consequently, siltation from erosion and runoff at construction sites must be minimized. Moreover, because these aggregations can require substantial movement of many fish over long distances, any reduction in stream flow that is associated with remedial action should be avoided.

Further recovery of the fish community (e.g., an increase in species richness) in Bear Creek upstream of the Route 95 bridge will be limited by the weir at the NPDES monitoring station just upstream of the bridge. This weir is a barrier to upstream fish movement, and explains, in part, why no significant changes in fish species richness similar to those observed in East Fork Poplar Creek have occurred in the middle reaches of Bear Creek.

Although significant recovery of the fish community has occurred in upper Bear Creek in 1985 at BCK 11.83 and in 1989 at BCK 12.36, recovery of the benthic macroinvertebrate community has been substantially slower. Very little recovery occurred during the initial phase of the monitoring programs (1984-1987, Fig. B.14); the apparent increase in taxonomic richness in Bear Creek during this period was also observed at the reference sites and can largely be attributed to a change in analytical laboratories and an increase in sample processing efficiency. However, an actual increase in richness was observed in upper Bear Creek between 1988 and 1990 (Fig. B.15), although densities of more sensitive taxa, such as those in the orders Ephemeroptera, Plecoptera, and Tricoptera (which are often combined and expressed as EPT) remain much lower at the upstream sites compared to BCK 3.25 or the reference sites. Adverse impacts on the benthic macroinvertebrate community remain evident over an 8-km reach of Bear Creek between the S-3 ponds and Route 95.

In the past, the S-3 ponds have had the greatest ecological impact on Bear Creek. They continue to adversely affect biota in Bear Creek, while impacts of the oil landfarm and burial grounds have been relatively minor. Downstream improvement in the benthic macroinvertebrate community seems to be associated with dilution provided by several tributaries and springs. Further ecological recovery will be linked to additional improvements in surface water quality just below the S-3 ponds because groundwater contamination is still present in this area. A pump-and-treat alternative could have

significant ecological impacts because biota in Bear Creek above the SS5 spring at BCK 9.40 are habitat-limited due to intermittent stream flow (Fig. B.16), and habitat will be substantially reduced if treated groundwater is discharged to EFPC and not returned to Bear Creek. The Tennessee dace may be especially vulnerable to such reductions in habitat, as discussed previously.

2.3.1.3 East Fork Poplar Creek

The Y-12 Plant BMAP was implemented in EFPC in May 1985. This program was developed to meet the requirements of the Y-12 Plant NPDES permit that was issued on May 24, 1985. Sampling sites were located between East Fork Poplar Creek kilometer (EFK) 24.4 at the Y-12 Plant and EFK 2.1 just below the confluence with Bear Creek (Fig. B.17). Implementation of a modified BMAP for EFPC is dependent upon issuance of the renewed NPDES permit, a draft of which was submitted for public comment in February 1994.

Results of BMAP have provided evidence of ecological recovery in EFPC. A 10-fold increase in fish abundance occurred at EFK 23.4 in 1986 (Fig. B.18), which was not observed in two reference streams (Fig. B.19). Although this change was not associated with any obvious improvements in water quality, another increase in population abundance in 1989 occurred just after the draining of New Hope Pond and filling of Lake Reality in November 1988.

Benthic macroinvertebrate communities near the Y-12 Plant (sites EFK 24.4 and EFK 23.4) showed no evidence of recovery prior to 1989. Both quantitative sampling of riffles in 1985-1988 (Fig. B.20) and in situ toxicity tests with fingernail clams in 1988 (Fig. B.21) indicated that a significant adverse impact existed. Recovery of the benthic community with distance from the Y-12 Plant suggests that water quality gradually improves downstream. However, the similarity of the downstream gradient of increasing taxonomic richness in each of the first three years (Fig. B.19) suggests that no substantial improvements in water quality occurred in EFPC during this time period.

Some recovery occurred below Lake Reality (EFK 23.4) after 1989. An increase in survival and growth of fingernail clams was observed from 1988 to 1990 (Fig. B.21). Moreover, qualitative assessments indicated that the abundance of filter-feeders, including the Asiatic clam and caddisfly species, increased during the same time period.

The first evidence of recovery above Lake Reality was obtained in early 1993 and was associated with the recent completion of two dechlorination projects. Dechlorination units were placed in operation at the North-South pipes in November 1992 and at outfall 21 below station AS-8 in December 1992 (Fig. B.22). Prior to this time, chlorine was the primary toxicant in this reach of stream. An increase in survival of snails (2-week exposures) at the North-South pipes (Fig. B.23) provides evidence of this recovery. Also, the number of dead fish collected in daily surveys that were conducted to monitor a chronic fish kill in upper EFPC decreased following dechlorination (Table 3), while fish abundance in upper EFPC has been increasing. For example, fish densities at EFK 24.4 in March increased from 0.8 fish/m² in 1991 to 5.6 fish/m² in 1994 (M. G. Ryon unpubl. data).

The evidence of recovery is strong because it is based on trends observed at both the molecular/biochemical level (e.g., DNA integrity, as discussed previously) and the community level (e.g., fish species richness) of biological organization. In upper EFPC, the number of fish species has increased at EFK 23.4 (just below Lake Reality) and at EFK

18.2, which is located just downstream of most commercial development in Oak Ridge (Fig. B.24). The increase at EFK 24.4 above Lake Reality reflects removal of a barrier (New Hope Pond) to upstream fish movement in 1988 and is not a direct response to remedial actions at the Y-12 Plant. The number of fish species in Brushy Fork, an off-site reference stream north of Oak Ridge, has remained relatively stable, as expected, over the same time period. The fluctuations in fish species richness at this site probably reflect seasonal changes associated with localized spawning movements.

Table 3. Number of dead fish collected in daily surveys of East Fork Poplar Creek between Bear Creek Road and North-South pipes^a

	1991		1992/1993	
	Avg. no. per day ^b	No. days	Avg. no. per day ^b	No. days
December	3.9	15	1.1	17
January/February	3.1	21	1.1	23

^a Surveys were not conducted on weekends or holidays.

^b Excluding fish kills of January 15, 1992 (probable cause: aluminum nitrate); December 27, 1992 (probable cause: runoff from a urea storage area); and January 19, 1993 (probable cause: germicidal detergent in outfall 21).

The increase in the number of species comprising the fish community in lower EFPC (Fig. B.25) was greater than that observed upstream. Longitudinal gradients in fish species richness in streams have been well documented and probably reflect the greater habitat heterogeneity found downstream (e.g., increase in number and depth of pools with increase in flow/drainage area). Although gradients in total fish species are expected, gradients in sensitive species are not. For example, a greater proportion of the community in lower EFPC consists of pollution-intolerant species, although the proportion is less than that of the two reference streams (Fig. B.26). The increase in fish species in both upper and lower EFPC is probably not a response to a single remedial action, but may be associated with several remedial actions, such as construction of new wastewater treatment facilities at the Y-12 Plant between 1985 and 1989 and closure of New Hope Pond in 1988. Also, there has been a substantial decline in the mercury loading to EFPC (Fig. B.27) and a decline in the concentration of total mercury in water at the outfall of Lake Reality (Fig. B.28).

Although the results of BMAP have documented ecological recovery in EFPC, they also indicate that recovery of the fish and macroinvertebrate communities is not complete. Both communities in upper EFPC are dominated by pollution-tolerant species, and total species richness in EFPC is below that of reference streams. Values of the most sensitive indices at downstream sites are ~75% of reference stream values. Further recovery of EFPC will be dependent upon remedial actions within the Y-12 Plant, including a reduction in aqueous mercury concentrations, lower water temperature, fewer inadvertent discharges/spills, and restoration of physical habitat. However, point-source discharges are not the only factor controlling recovery of lower EFPC in the future. Nonpoint source pollution occurs in the watershed (e.g., nutrient enrichment from agricultural runoff; siltation from residential construction), and possible remedial actions in the floodplain could destroy aquatic habitats.

2.3.1.4 White Oak Creek and Tributaries

The ORNL BMAP for White Oak Creek and tributaries and the Clinch River was implemented in 1986. This program was developed to meet the requirements of the ORNL NPDES permit that was issued on April 1, 1986. This permit has not been renewed, but a draft version has been prepared, and negotiations are continuing. The ORNL BMAP sampling sites are shown in Fig. B.29 and the significant results are summarized below. In 91 ambient toxicity tests conducted with *Ceriodaphnia* in 1992, none indicated toxicity. These tests are conducted routinely on water from 15 sites on 5 streams in WOC watershed. However, 7-day tests with the snail *Elimia*, a species sensitive to residual chlorine, indicated that WOC in the main plant area and lower First Creek are toxic; possibly due to chlorine. Moreover, survival of Japanese medaka in embryo-larval toxicity tests was reduced in WOC in the main plant area and downstream. Results of the ambient toxicity tests with these more sensitive species are supported by the results of the benthic macroinvertebrate sampling, which has documented the presence of adverse effects on the more sensitive indicator species (i.e., EPT taxa) throughout WOC.

With a few exceptions, trends in fish species richness and abundance have not changed significantly since 1986. The exceptions include lower Fifth Creek, lower Melton Branch, and a mid-reach site on WOC. The number of fish collected in lower Fifth Creek increased gradually since 1989; before then, no fish were collected at Fifth Creek kilometer (FFK) 0.2. This recovery is probably associated with reactor shutdowns in 1987 and the elimination of significant sources of residual chlorine to the stream. Fish abundance increased in lower Melton Branch following the shutdown of the High Flux Isotope Reactor in November 1986. Since the reactor was returned to continuous operation in May 1990, the ecological impact of operation has been substantially less than that observed prior to the shutdown. Fish abundance also increased substantially at White Oak Creek kilometer (WCK) 3.9 in the main plant area. Densities have increased steadily since spring 1989 when no fish were collected at the site (Fig. B.18). This recovery is associated temporally with completion of the Nonradiological Wastewater Treatment Facility in March 1990 and elimination of seven major outfalls to WOC and Melton Branch. Finally, stability (or absence of improvement) in fish species richness in WOC and other tributaries could be attributed to the presence of weirs, which are barriers to upstream movement and can isolate the fish populations at some sites.

Recovery of the benthic macroinvertebrate communities was observed in lower Fifth Creek and lower Melton Branch, also (Figs. B.30 and B.31, respectively). Whereas no difference was observed between the headwater reference site and two downstream sites on Melton Branch, taxonomic richness at FFK 0.2 remains substantially lower than that at the upstream reference site. With the exception of WCK 3.9, trends at the other sites on WOC and two tributaries (First Creek and Northwest Tributary) show no evidence of recovery during the five-year period of record (1987-1991). At WCK 3.9, taxonomic richness increased substantially in 1990 and 1991, but the more sensitive parameter (EPT richness) at FFK 0.2 was substantially lower than that of WCK 6.8, the upstream reference site (Fig. B.32).

Finally, when various indicators (biomarkers) of contaminated-related stress were measured in redbreast sunfish from WOC below Lagoon Road (Fig. B.29) and compared with those measured in the same species from three off site reference streams, the results of the integrated evaluation indicated an improvement in fish health in both 1990 and 1991 over that observed in 1989. Using a canonical discriminant analysis, however, the integrated response of WOC fish could be clearly distinguished from that of the reference

fish. Thus, while fish health in WOC has improved, it remains below that of redbreast sunfish from uncontaminated reference streams. For example, levels of liver detoxification enzymes, which are used as an indicator of exposure and possible effects of various organics [e.g., hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides], are significantly higher in fish from WOC compared to those from the three reference streams (Fig. B.33).

2.3.1.5 Mitchell Branch

The K-25 Site BMAP was implemented in August 1986 and revised under the renewed NPDES permit that was issued on October 1, 1992. The sampling sites are shown in Figs. B.34 and B.35, and the significant results are summarized below.

The major toxicant in the mid-reaches of Mitchell Branch was chlorine prior to 1991, but evidence of chronic toxicity (low *Ceriodaphnia* reproduction) has been observed in the dechlorinated effluent from storm drain (SD) 170, SD180, and SD190 (Fig. B.35). The revised BMAP includes more frequent monitoring of storm drains.

The overall health of the redbreast sunfish population in lower Mitchell Branch is impaired, as evidenced by elevated levels of liver detoxification enzymes, liver histopathology, and gill and liver dysfunction. The revised plan includes specific bioindicators (or biomarkers) and additional sampling sites on Poplar Creek above and below the K-25 Site.

Some recovery of the fish community in Mitchell Branch was observed below SD170, SD180, SD190 in fall 1991 (Fig. B.18). This response was associated with dechlorination of these storm drains in May 1991. Although fish abundance increased, no sensitive (i.e., pollution-intolerant) species were collected. The benthic macroinvertebrate community in Mitchell Branch is significantly impacted compared to the upstream reference site. The greatest impact occurs just below SD170, and some improvement occurs with distance downstream. Because differences in the benthic macroinvertebrate and fish communities between some adjacent sampling sites were minimal, the revised plan eliminates two sites while continuing the sampling at the other three.

In addition to conducting routine monitoring and implementing studies to investigate potential sources of toxicants that impact biota, BMAP staff are involved in numerous technical support activities, including fish kill investigations, ecological evaluations, and NPDES-related assessments. Although these activities are summarized only for the K-25 Site (Table 4), similar and often more extensive technical support is also provided to ORNL and Y-12 Plant.

Table 4. Technical assistance provided by BMAP staff to the K-25 Site, 1986-1992

<i>I. FISH KILL INVESTIGATIONS</i>		
1. Mitchell Branch November 24, 1987: 2 fish Cause: Unknown	2. K-1515C Pond December 14, 1988-January 13, 1989: ~300 fish Cause: Discharge of chlorinated water during filter backwash operations at Water Treatment Plant	3. Other observed fish deaths K-1007B pond March 1987, April 1987, June 1987, March 1989, June 1989, March 1990, May 1990, March 1992
November 1, 1988: 79 fish Cause: Discharge of chlorinated cooling water during operation of AVLIS test facility	November 27, 1989-January 15, 1990: 175 fish Cause: Discharge of chlorinated cooling water due to control cablewater during filter backwash failure on primary cooling system operations at Water Treatment Plant	K-901A pond April 1989
November 4, 1990: 549 fish Cause: Discharge of chlorinated cooling water due to control cablewater during filter backwash failure on primary cooling system operations at AVLIS test facility		
August 29, 1992: 6 fish Cause: Pesticide (pyrethrin) spill in SD 180		
<i>II. ECOLOGICAL EVALUATIONS</i>		
1. New Projects • Blair Road bridge (1985) • TSCA incinerator (1988-1989) • Production Waste Storage Facility (1990) • Storm drain dechlorinators (1990-1991) • CNF pipeline to Clinch River (1992-1993)	2. Spills • Lithium hydroxide-hypothetical (4/85) • Diesel fuel (2/87) • Sludge/fly ash (7/88)	3. Construction Activities • Stoner Road culvert replacement (2/87) • Drum Yard erosion/runoff (3/87) • K-1515C pond weir/dewatering (3/89) • Removal of streamside vegetation (7/90) • Beaver dams in K-901A (11/88, 3/92)
<i>III. NPDES PERMIT ACTIVITIES</i>		
1. Assessment of Cause(s) of Permit Exceedances • Al, COD, DO at K-1007B • DO at K-901A	2. Assistance with Permit Renewal • Strategy development • Review/recommendations	

2.3.1.6 McCoy Branch

As part of the RCRA Facility Investigation for the Filled-Coal Ash Pond, a biological monitoring program was implemented in January 1989 to characterize the ecological impacts on McCoy Branch and to monitor the effectiveness of remedial actions.

The impact period began in 1955, when a coal ash slurry from the Y-12 Steam Plant was pumped and discharged to an impoundment on McCoy Branch, a small headwater stream on the south slope of Chestnut Ridge. After the pond filled in 1965, the slurry was discharged to Rogers Quarry via McCoy Branch for the next 25 years.

Results obtained from the quantitative sampling of benthic invertebrates showed that a substantial improvement had occurred during the first year of monitoring (1989; Fig. B.36). The assessment is based on the number of species (or taxa) comprising three groups of aquatic insects that are relatively intolerant of pollution. No fish are present in McCoy Branch between the filled coal ash pond and Rogers Quarry, which is a barrier to fish movement and prevents recolonization of this reach of stream. Consequently, a study was initiated in 1993 to evaluate the reintroduction of the banded sculpin (*Cottus carolinae*), a common inhabitant of spring-fed, headwater streams on the ORR.

The ecological recovery of McCoy Branch was associated with several significant remedial actions, including (1) conversion from coal to natural gas in several boilers at the Y-12 Steam Plant in 1989–1990, (2) completion of a pipeline in November 1989 that eliminated the use of McCoy Branch to transport the ash slurry to the quarry, and (3) cessation of fly ash disposal in Rogers Quarry in 1990. These actions resulted in a significant decrease in arsenic and selenium to levels after 1989 that are well below the EPA water quality criteria for protection of aquatic life (Figs. B.37 and B.38, respectively).

To assess changes in trace element concentrations in fish following elimination of fly ash discharge to Rogers Quarry, largemouth bass were sampled from the quarry in 1990, 1991, and 1992 and analyzed for trace elements. Concentrations of arsenic in fish remained unchanged over that period averaging 0.27 $\mu\text{g/g}$ wet wt, more than a factor of ten higher than arsenic concentrations (<0.025 $\mu\text{g/g}$) in bass from nearby Lambert Quarry, a reference site for the study. Selenium concentrations in bass also changed little, averaging 3.0, 3.3, and 2.2 $\mu\text{g/g}$ in 1990, 1991, and 1992, respectively, versus 0.71 $\mu\text{g/g}$ in Lambert Quarry. Despite the elimination of trace element inputs, arsenic and selenium concentrations in bass have remained elevated above background levels.

The mean mercury concentration in bass collected from Rogers Quarry in July 1990 (0.02 $\mu\text{g/g}$) was the lowest observed in fish from any site in east Tennessee in monitoring conducted since 1985 for the BMAPs. Selenium is known to reduce the aquatic toxicity of mercury, and researchers have observed that excess selenium in the diet and exposure water acts to reduce the bioaccumulation of mercury. In Sweden, selenium has been intentionally added to mercury-contaminated lakes in efforts to reduce mercury contamination in fish, with generally successful results. Mean mercury concentrations in Rogers Quarry bass have increased each year since the original sampling in 1990, to 0.05 $\mu\text{g/g}$ in 1991 and 0.11 $\mu\text{g/g}$ in 1992. These levels are still quite low and typical of background concentrations in this species. The results suggest that accumulated body burdens of selenium have little impact on mercury bioaccumulation, but the presence of elevated concentrations of selenium in food and/or water is capable of reducing mercury bioaccumulation in some waters in this region. Finally, bass from Lambert Quarry contained relatively high concentrations of mercury, averaging 0.93 $\mu\text{g/g}$, but currently it is not known if this level represents contamination of the quarry or is typical for such systems in this geographical region.

2.3.1.7 Monitoring Mercury and PCBs in Fish

The BMAPs mandated by the NPDES permits at the Y-12 Plant, ORNL, and the K-25 Site each contain tasks to monitor the accumulation of contaminants in the biota of receiving waters. The primary objectives of the contaminant accumulation studies are to (1) identify substances that accumulate to undesirable levels in biota as a result of discharges from DOE facilities, (2) determine the significance of those discharges relative to other sources in

determining contaminant concentrations in biota in receiving waters, and (3) provide a baseline measure of biotic contamination to use in evaluating the effectiveness of any future remedial actions.

The non-radiological contaminants of most concern in biota are mercury and PCBs. Elevated concentrations (relative to local reference sites) of mercury and PCBs in biota are associated with discharges at all three facilities. Since 1985, concentrations of these substances in sunfish have been monitored at sites in EFPC downstream of the Y-12 Plant (Fig. B.39). In 1992/1993, sunfish did not exhibit a decrease in mercury concentrations with distance below Lake Reality, a change from the trend observed in previous years. Mean mercury concentrations in sunfish from all sites between Lake Reality at EFK 23.7 and EFK 6.3 were similar; only the site upstream of Lake Reality (EFK 24.8) was substantially different. The two to three-fold higher concentrations in sunfish above Lake Reality suggests that Y-12 Plant discharges continue to be an important source of mercury to fish in the upper reaches of EFPC.

Mean concentrations of mercury at specific sites have not exhibited an increasing or decreasing trend relative to concentrations observed in the mid-1980s except at EFK 23.4, the site nearest the Y-12 Plant (Fig. B.40). Lower mercury concentrations were observed in redbreast sunfish (*Lepomis auritus*) at EFK 23.4 in 1989–1992 than were typical of the 1985–1988 period (Fig. B.41). The average mercury concentration in edible fish tissue decreased by almost 50% at EFK 23.4 on upper EFPC just below Lake Reality and now is below the U.S. Department of Agriculture Food and Drug Administration (FDA) action level of 1 ppm. This decrease in mercury in fish tissue was associated with (1) closure of New Hope Pond in November 1988 and (2) a decrease in mercury in water from 1989–1992 that was associated with remedial actions implemented in the Reduction of Mercury in Plant Effluents Program. Mercury concentrations are lower in fish at EFK 23.4 than in fish at the next site downstream. The reduction in fish tissue levels of mercury at only EFK 23.4 and none of the downstream sites may reflect a time lag associated with retention of methylmercury in stream biota, so changes at the downstream sites may occur more slowly.

A pattern of decreasing concentrations with distance downstream is apparent for PCBs in redbreast sunfish in EFPC (Fig. B.42). As a result of colonization of Lake Reality and EFPC upstream of Lake Reality following its construction, it was possible to obtain sunfish from sites upstream from EFK 23.4. Redbreast sunfish from EFPC above Lake Reality and bluegill from Lake Reality contained PCB concentrations in December 1992 substantially higher than those observed in fish from other EFPC sites (Fig. B.42). The high concentrations in fish at sites in upper EFPC indicate the importance of the industrialized portion of the Y-12 Plant as a source in relation to contaminated sediment and soil downstream of Lake Reality. PCB concentrations found in EFPC sunfish in 1992/1993 fell within the range observed in previous years (Fig. B.43).

Bluegill (*Lepomis macrochirus*) and other sunfish collected in 1992/1993 again showed the presence of multiple sources of mercury and PCB contamination (Figs. B.39 and B.42) on the ORR. Elevated concentrations of mercury were clearly evident in fish from EFPC, Poplar Creek, Bear Creek, Mitchell Branch, and WOC. The highest mean concentrations continued to be in fish from EFPC and Bear Creek. Overall, mean mercury concentrations in fish in 1992/1993 on the ORR were similar to those observed in 1991.

Mean PCB concentrations in sunfish were elevated in WOC, EFPC, Bear Creek, lower Poplar Creek, and Mitchell Branch (Fig. B.42). The highest PCB concentrations

were found in sunfish from Mitchell Branch (kilometer 0.6), Bear Creek (BCK 4.5), and upper EFPC (EFK 24.8, EFK 23.7). Mean PCB concentrations in sunfish from most WOC sites have decreased significantly over the 1987–1993 period. With the exception of BCK 4.5, mean PCB concentrations in sunfish at other sites on the ORR in 1992/1993 remained similar to concentrations observed in previous years.

Monitoring contaminant accumulation in aquatic biota of Bear Creek involves the collection of fish at BCK 4.5, which is located at the NPDES station near Route 95 and about 5 km downstream of the burial grounds, and at BCK 0.6, which is located near the confluence with EFPC. The data from BCK 4.5 (Fig. B.44, top) are mean values based on four fish per sampling date compared with eight fish per date at BCK 0.6 (Fig. B.44, bottom). Suitable fish were difficult to find at BCK 4.5 and had to be collected over a longer reach of stream, thus contributing to a greater variability among replicates. This information must be considered in evaluating the significance of the mean value for December 1992. The decrease in PCB concentrations in edible fish tissue observed in 1991 and 1992 at BCK 0.6 was associated with (1) closure of oil retention ponds on North Tributary (NT) 6 and 7 in the Y-12 Plant burial grounds and (2) removal of sediment and closure of NT7 between Oil Retention Pond 1 and Bear Creek.

Sunfish serve as good indicators of PCB contamination, particularly in small streams close to specific sources, but they do not accumulate PCBs to the extent that longer-lived, larger, fattier fish such as catfish (*Ictalurus punctatus*) and carp (*Cyprinus carpio*) do. Channel catfish have been found to contain PCBs approaching the FDA limit (2 µg/g) in several reservoirs in East Tennessee, including Watts Bar Reservoir (TVA 1985). As a result of the Oak Ridge Task Force finding that PCB concentrations exceeded the FDA limit in all channel catfish collected in WOC embayment in 1984, annual PCB monitoring in this species was initiated in 1986. Routine collection sites are shown in Fig. B.45; sites were selected to provide the ability to distinguish the relative importance of PCB sources in the WOC and Poplar Creek drainages in contributing to PCB concentrations in Clinch River catfish.

The site-to site pattern of PCB concentrations in channel catfish in 1993 was similar to the pattern observed previously (Table 5). WOC embayment continues to yield both the highest mean PCB concentrations (average over all years = 2.6 µg/g) and the largest fraction of catfish exceeding the FDA limit. Mean PCB concentrations have generally remained around 0.9 µg/g at the Clinch River sites and approximately 0.5 µg/g in Melton Hill Reservoir (MHR). With the exception of the mean PCB concentrations in catfish from WCK 0.3, mean PCB concentrations over time at each site yield little indication of a consistent increasing or decreasing trend.

Channel catfish from WCK 0.3 contained substantially higher PCB concentrations than those in catfish collected from this site in previous years. Only four individuals were obtained from WCK 0.3 in 1993, probably due to the construction of a sediment retention structure in 1991 that has prevented catfish movement into or out of the watershed. The higher PCB concentrations may be a result of capturing fish that have been exposed to PCBs in WOC for a longer period of time than fish collected previously. With the construction of the retention structure in 1991, the likelihood of anglers fishing near the mouth of WOC and catching a catfish that has accumulated high concentrations of PCBs in WOC embayment and then moved back to the river has substantially decreased. Continued monitoring of channel catfish will help to evaluate the long-term effect of the sediment retention structure on PCB contamination in Clinch River biota.

Table 5. Changes from 1986 to 1993 in average concentrations of PCBs and fraction of channel catfish exceeding the Food and Drug Administration limit^a

Site	1986	1987	1988	1989	1990	1991	1992	1993
<i>PCBs</i>								
WCK 0.3	1.30	1.59	0.96	1.54	3.56	3.60	3.29	8.40
CRK 32.2	1.01	1.61	0.58	1.20	0.31	1.38	0.36	0.67
MHR	0.46	0.81	0.52	0.28	0.41	0.29	0.34	0.62
PCK 6.9	NS	NS	0.71	1.07	0.92	0.68	0.54	0.92
CRK 15.0	NS	NS	0.50	0.79	0.88	1.08	1.27	0.63
<i>Fraction over FDA limit</i>								
WCK 0.3	3/12	2/8	2/8	4/8	4/8	6/8	5/8	4/4
CRK 32.2	0/8	2/8	1/8	1/8	0/8	1/8	0/8	0/8
MHR	0/6	1/7	0/10	0/8	0/8	0/8	0/8	0/8
PCK 6.9	NS	NS	0/8	1/8	1/8	0/8	0/8	0/8
CRK 15.0	NS	NS	0/9	1/8	1/8	1/8	2/8	0/8

^a All values reported in µg/g wet weight. Food and Drug Administration action level is 2 µg/g for PCBs. WCK = White Oak Creek kilometer, CRK = Clinch River kilometer, PCK = Poplar Creek kilometer, MHR = Melton Hill Reservoir, NS = not sampled.

2.3.1.8 Monitoring Organic Contaminants in Asiatic Clams

From 1985 to 1993, organic contaminant concentrations in stream biota were monitored near DOE Oak Ridge facilities. One of the primary objectives of the monitoring effort was to detect spatial and temporal changes in biotic contamination to evaluate the effectiveness of pollution abatement activities. Asiatic clams (*Corbicula fluminea*) were the bioindicator of choice for monitoring most organic contaminants, because clams can accumulate organic pollutants that are rapidly metabolized by fish. Asiatic clams taken from an uncontaminated reference stream were placed in cages for 4-week exposures in the receiving streams on an annual basis. Clam monitoring has detected PAHs in upper EFPC and a localized source of chlordane in WOC, while annual follow-up monitoring tracked a steady decrease in the level of chlordane contamination. The use of clams to resolve spatial differences in PCB contamination was found to be limited in the presence of sublethal concentrations of residual chlorine; therefore, the use of resident fish was preferred for monitoring PCBs under those exposure conditions. Annual monitoring of resident sunfish from White Oak Creek, a stream receiving discharges from the Oak Ridge National Laboratory, showed a significant decrease in PCB concentration over a 5-year period at all five sites monitored. Overall, the long-term, concurrent monitoring of resident fish and transplanted Asiatic clams was effective in identifying and evaluating changes in organic contaminant bioaccumulation downstream of the DOE facilities.

2.3.2 Ecological Information for the Terrestrial System

The ORR lies in the Ridge and Valley physiographic area. This area is characterized by elongated ridges and broad-to-narrow valleys. On the ORR, the ridges and valleys run northeast to southwest.

The hydrologic system on the ORR is controlled regionally by the Clinch River. Climate of the area is temperate with hot, humid summers and moderate winters. Average annual rainfall is 136 cm, and this rainfall is typically spread evenly throughout the year.

Geologically, the area is characterized by three principal rock groups: Conasauga shales, Knox dolomite, and Chickamauga limestone. Soils in the area are either residual soils developed in place from weathered rock or partially sorted colluvial and alluvial soils.

The original forests on the ORR were extensively cleared, and the land was cultivated or partially cleared and used for rough pasture by settlers in the area. Except on very steep slopes, most of the forest had been cut for timber or cleared for agriculture by the time the federal government acquired the land in 1942. With the end of cultivation in 1942, fields have developed into forest either through natural succession or through planting of pines.

The ORR is home to a wide diversity of plant species. The most recent published number of species is 983 (Cunningham et al. 1993). However, rare plant surveys subsequent to that publication suggest that the number is in excess of 1000 (P. D. Parr, ORNL, personal communication, to T. L. Ashwood, 1994).

Plant communities on the ORR are characteristic of those found in the intermountain regions of Appalachia. The dominant association on the ORR is oak-hickory forest, which is most widely distributed on ridges and dry slopes.

Northern hardwoods are found in coves along the ridge system. Common overstory species in these coves are tulip-poplar (*Liriodendron tulipifera*), beech (*Fagus grandifolia*), and sugar maple (*Acer saccharum*). White pine (*Pinus strobus*) also occurs in these coves. Cove areas grade into floodplains in lower slope positions where more flood-tolerant species such as box elder (*Acer negundo*), elm (*Ulmus spp.*), sycamore (*Platanus occidentalis*), and green ash (*Fraxinus pennsylvanica*) become abundant (Cunningham et al. 1993).

Small cedar barrens are common on the ORR. These drought-tolerant plant communities occur on shallow, limestone soils. Cedar barrens are habitat for several species of rare plants.

A survey of wetlands on the ORR was conducted in 1990 (Cunningham and Pounds 1991). At that time 90 wetlands were identified. Additional surveys since that time have identified additional wetlands. Wetland types included emergent communities in shallow embayments on reservoirs, emergent and aquatic communities in ponds, forested wetland on low ground along major streams, and wet meadows and marshes associated with streams and seeps (Cunningham and Pounds 1991).

Types and distribution of habitats on the Oak Ridge Reservation and surrounding areas are summarized in a land use/land cover map derived from remotely sensed data (Fig. 7). This map was developed by Chatfield and Graham (unpubl. data) from Landsat Thematic Mapper (TM) and SPOT satellite images generated in September 1984. The map delineates nine land use/land cover categories: water, low density urban, high density urban, open pasture and grass, agricultural fields and bare ground, hardwood forest, mixed hardwood-pine forest, natural pine forest, and pine plantations. The map is in raster format with 30 meter pixels and covers an area of 187,508 hectares (Chatfield and Graham, unpubl. data). An error matrix was produced which quantifies the map's accuracy; overall accuracy for the 1984 map is 80%.

FIGURE 7. Oak Ridge Reservation and surrounding areas. September, 1984. Projection: UTM. From Chatfield and Graham (unpublished data).

Area and relative percent cover for each land use class were estimated for the ORR, the area surrounding ORR, and both areas combined (Table 6). The percentage of land cover identified as forest or urban was greater on the ORR than in the surrounding area, while the area identified as agricultural or open fields was less (Table 6).

Table 6. 1984 Land use/land cover map analysis. Area and relative percent cover by class for Oak Ridge Reservation and surrounding areas^a

Category	Reservation		Study Area Subscene ^b		Total Study Area	
	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Water	683.0	4.8	10018.1	7.0	10701.1	6.8
Ag. fields/ bare ground	292.2	2.1	13014.2	9.1	13306.4	8.4
Open fields/ grasses	1965.1	13.8	45523.7	31.7	47488.8	30.1
Pine plantation	249.7	1.8	1007.1	<1.0	1256.8	<1.0
Mature pine	2075.9	14.6	13233.1	9.2	15308.9	9.7
Hardwood-pine mix	3167.3	22.2	19725.7	13.8	22892.9	14.5
Hardwoods	4723.9	33.2	37287.9	26.0	42011.8	26.6
Low density urban	731.2	5.1	2671.9	1.9	3403.0	2.2
High density urban	358.2	2.5	996.6	<1.0	1354.8	<1.0
TOTAL	14246.3	9.0	143478.1	91.0	157724.4	100.0

^a After Chatfield and Graham (unpubl. data).

^b Without Oak Ridge Reservation.

Given the diversity of plants and habitat types, the ORR supports a wide variety of wildlife species. A list of amphibians, reptiles, birds, and mammals on the ORR has been compiled from various published sources and personal observations (Appendix C). The list includes animals that have been identified on the ORR as well as some animals not confirmed but who are present in the Ridge and Valley region and for whom adequate habitat exists on the ORR. This list includes more than 35 species that are listed by either the Tennessee Wildlife Resources Commission or the U.S. Fish and Wildlife Service (FWS) as threatened, endangered, or in need of management.

2.3.3 ORR-Wide Contaminants of Potential Concern

Although numerous contaminants have been observed at source OUs on the Oak Ridge Reservation, many of these contaminants possess characteristics that make it unlikely that they will present a risk beyond the scale of the source operable unit. Some of these characteristics include high volatility, rapid environmental degradation, low persistence, low environmental mobility, low bioavailability, and low bioaccumulation potential. These characteristics act to limit the area potentially affected by these contaminants to the source OU where they occur and its immediate surroundings. In the ORR environmental monitoring and assessment plan, because our emphasis is on wide-ranging species, contaminants that are persistent, mobile, and that may enter food webs and bioaccumulate are the primary concern. This list was developed to identify those contaminants present at the reservation that may be accumulated by wide-ranging species (and therefore may present risks to these species) so that monitoring efforts may be focused on these contaminants.

While all contaminants identified as contaminants of potential concern (COPCs) will be assessed as part of the ORR-wide ecological risk assessment, only those that are persistent, enter food webs, or bioaccumulate will be monitored as part of the ORR-wide plan. The purpose of this list is to focus the finite analytical resources on those contaminants that are most likely to be taken up by and observed in wide-ranging, mobile species. Data on media concentrations of non-persistent, non-bioaccumulative contaminants will be provided to the ORR-wide program by each separate source OU program (for use in the ORR-wide ecological risk assessment).

This list of ORR-wide COPCs is not intended to be static. It is expected that this list will be updated, with contaminants added or deleted, as new information becomes available. If, following completion of each annual screening assessment (Sect. 3.3.2.2), a contaminant is found not to present an ecological risk, it will be recommended for removal from the ORR-wide COPCs list. Conversely, if new contaminants, known to bioaccumulate, are identified by source OU RI programs, they will be recommended for addition to the list. A list of contaminants recommended for addition to or deletion from the ORR-wide COPCs list will be submitted annually to the FFA parties for approval.

2.3.3.1 Approach

The initial list of inorganic and organic contaminants was obtained from the list of COPCs identified in Ross et al. (1992). Classified contaminants, not currently included in this list, will be considered as information and security constraints permit. Additional contaminants identified through current work at source OUs or as residues in previous biota sampling (Sect. 2.3.4.) were added to the list. Literature concerning the chemical characteristics, environmental fate and transport was evaluated for each contaminant. A weight-of-evidence approach was employed in determining which contaminants to retain as reservation-wide COPCs and which to exclude. In general, contaminants with one or more of the following characteristics were excluded as reservation-wide COPCs: high volatility, rapid environmental degradation, low persistence, and low bioavailability. Conversely, the following characteristics were used to identify contaminants to be retained: high persistence, high bioavailability, slow degradation, and high potential for bioaccumulation. A list of contaminants identified on the reservation, factors considered in evaluating their large scale significance, and whether or not they should be retained as reservation-wide COPCs is presented in Table 7.

2.3.3.2 Results

Using the methodology described above, a total of 134 contaminants were identified (Table 7). Of these contaminants, environmental fate and transport information was available for all but six (4-chloro-4,4-difluoro 2-butanone, methyl propenyl benzene, 1,1-oxybis(2,1-ethanedioxy)bi butane, 2,5-hexanedione, 1-methylpentyl hydroperoxide, and 9-octadecenamide). Because the distribution of these contaminants is limited [(five are priority 4 and one is priority 3 (Table 7)], and no environmental fate and transport information was found, they were not retained as reservation-wide COPCs. If future sampling at source OUs should indicate a wider distribution, or data should become available to suggest they bioaccumulate, they will be added to the list of ORR-wide COPCs.

Table 7. Evaluation of contaminants observed at the Oak Ridge Reservation for determination of Reservation-wide contaminants of potential concern^a

Contaminant	Priority ^b	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References (Complete references in Sect. 4)
<i>Inorganics (includes organic and inorganic forms)</i>				
Aluminum	2	A ubiquitous element; While soluble Al may be toxic, toxicity of insoluble Al is low. Most Al in environment is in relatively insoluble forms and biologically unavailable; may become available under conditions of low pH (<4.5).	NO	Adriano 1986; Lindsay 1979; Storer and Nelson 1968
Antimony	1	Not appreciably taken up by plants; low potential for bioaccumulation but highly toxic	NO	ATSDR 1992a
Arsenic	1	Bioaccumulates in biota, present in coal ash	YES	Eisler 1988a
Barium	1	Not very mobile in most soils, however may bioaccumulate somewhat	YES	ATSDR 1992b
Beryllium	1	Little potential for bioaccumulation; released at Y-12	NO	ATSDR 1988b
Boron	1	Bioaccumulates in biota	YES	Eisler 1990a
Cadmium	1	Bioaccumulates in biota, released at Y-12	YES	Eisler 1985a
Calcium	4	A ubiquitous element and essential nutrient, Ca deficiency is more likely to be a problem than excess. Toxic effects unlikely.	NO	Robbins 1993
Chlorine		While Cl may be toxic in aquatic systems, it is a ubiquitous element and essential nutrient.	NO	EPA 1988; Robbins 1993
Chromium	1	May bioaccumulate in biota, released in cooling towers	YES	Eisler 1986a
Cobalt	3	May be mobile in soils; may bioaccumulate	YES	ATSDR 1992e
Copper	2	Essential element; even at high doses, toxic effects unlikely	NO	ATSDR 1990b
Cyanide	1	CN has low persistence, rapid environmental and metabolic degradation, and does not biomagnify or cycle in biota.	NO	Eisler 1991
Fluorine	4	F accumulates in biota, low toxicity	YES	Henny and Burke 1990
Iron	4	A ubiquitous element and essential nutrient, Fe deficiency more likely to be a problem than excess. Toxic effects unlikely.	NO	Elinder and Piscator 1979

Table 7. (continued)

Contaminant	Priority ^b	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References (Complete references in Sect. 4)
<i>Inorganics (includes organic and inorganic forms)</i>				
Lead	1	Pb may be take up by plants and transferred to other biota	YES	Eisler 1988b; Blus et al. 1991
Lithium	2	Released at Y-12; animals exposed to high levels may accumulate Li	YES	Venugopal and Luckey 1978.
Magnesium	4	A ubiquitous element and essential nutrient, Mg deficiency is more likely to be a problem than excess. Toxic effects unlikely.	NO	NAS 1980
Manganese	1	Potential for bioaccumulation	YES	ATSDR 1992h
Mercury	1	Bioaccumulates in biota, released by Y-12 and X-10	YES	Eisler 1987a
Molybdenum	1	Bioaccumulates in biota	YES	Eisler 1989c
Nickel	1	May bioaccumulate in biota, released at Y-12	YES	ATSDR 1988c
Niobium	2	Low toxicity; does not bioaccumulate	NO	Venugopal and Luckey 1978.
Potassium	4	A ubiquitous element and essential nutrient, K deficiency is more likely to be a problem than excess. Toxic effects unlikely.	NO	Robbins 1993
Selenium	1	Bioaccumulates in biota, present in coal ash	YES	Eisler 1985b
Silver	1	Rare element; while low potential for bioaccumulation, observed in ducks from White Oak Lake; released from photo laboratories	YES	ATSDR 1990h
Sodium	4	A ubiquitous element and essential nutrient - Na deficiency more likely to be a problem than excess. Toxic effects unlikely.	NO	Robbins 1993
Strontium	3	Sr (including radiostrontium) is taken up by plants and accumulates in bones.	YES	NAS 1980
Thallium	1	Taken up by plants from soil; bioaccumulates in biota	YES	ATSDR 1992j
Thorium	4	Little uptake by plants; low potential for bioaccumulation	NO	ATSDR 1990i
Tin	2	While inorganic Sn is generally not bioavailable, organotin compounds may be generated in aquatic systems. Organotin compounds bioaccumulate and are more toxic.	YES	Eisler 1989a
Titanium	2	Low toxicity; poorly absorbed in the alimentary tract	NO	NAS 1980

Table 7. (continued)

Contaminant	Priority ^b	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References (Complete references in Sect. 4)
<i>Inorganics (includes organic and inorganic forms)</i>				
Vanadium	1	While V consumed by animals is rapidly excreted, some plants may bioaccumulate. Associated with petroleum.	YES	ATSDR 1992k
Zinc	1	Essential nutrient; bioaccumulates in biota	YES	ATSDR 1989j
Zirconium	2	Low toxicity; low solubility; low uptake through gastrointestinal tract	NO	Ganrot 1986
<i>Radionuclides</i>				
Americium		Taken up by both plants and animals	YES	Garton 1981
Cesium		Cs-137 accumulates in biota and may be transferred up food chains	YES	Straney et al. 1975; Kalas et al. 1994
Curium		Taken up by both plants and animals	YES	Garton 1981
Cobalt	3	May be mobile in soils; may bioaccumulate	YES	ATSDR 1992e
Plutonium		Taken up by both plants and animals	YES	Garton 1981
Strontium	3	Sr (including radiostrontium) is taken up by plants and accumulates in bones	YES	NAS 1980
Technetium		Taken up by plants	YES	Garton et al. 1986
Uranium	2	Bioaccumulation low due to low assimilation efficiency, released by all facilities on Reservation	YES	ATSDR 1990j
<i>Volatile Organics</i>				
Acetone	4	Highly volatile; low potential for bioaccumulation	NO	ATSDR 1992m
Benzene	3	Highly volatile; low potential for bioaccumulation	NO	ATSDR 1993a
2-Butanone	4	Highly volatile; low potential for bioaccumulation	NO	ATSDR 1992c
4-chloro- 4,4-difluoro 2-Butanone	4		NO	

Table 7. (continued)

Contaminant	Priority ^b	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References (Complete references in Sect. 4)
<i>Volatile Organics</i>				
Carbon disulfide	4	Highly volatile; low potential for bioaccumulation	NO	ATSDR 1992d
Carbon tetrachloride	1	Highly volatile; low potential for bioaccumulation	NO	ATSDR 1989b
Chlorobenzene	4	Highly volatile; rapidly biodegraded in soil	NO	ATSDR 1990a
Chloroethane	2	Highly volatile and highly soluble in water; expected to be biodegraded in both soil and water	NO	ATSDR 1989c
Chloroform	1	Highly volatile; low potential for bioaccumulation	NO	ATSDR 1993b
Decane	4	Highly volatile; rapidly biodegraded	NO	Verschuereen 1983
Dichloro difluoromethane	2	Highly volatile; low toxicity	NO	Verschuereen 1983
1,1-Dichloroethane	3	Highly volatile; low potential for bioaccumulation	NO	ATSDR 1990d
1,1-Dichloroethene	3	Highly volatile; low potential for bioaccumulation	NO	ATSDR 1989e
1,2-Dichloroethane	4	Highly volatile	NO	ATSDR 1989d
1,2-Dichloroethene (cis,trans)	1	Highly volatile; low potential for bioaccumulation	NO	ATSDR 1990e
1,3-Dichloropropene	2	Highly volatile; environmental fate and transport poorly known	NO	ATSDR 1992f
Ethanol		Highly volatile; low toxicity	NO	Verschuereen 1983
Ethyl benzene	3	Highly volatile; low potential for bioaccumulation	NO	ATSDR 1990f
Ethyl dimethyl benzen	4	Highly volatile	NO	Chao et al. 1983
Ethenyl methyl benzene	4	Volatile; low potential for bioaccumulation	NO	EPA 1987
Ethyl methyl benzene	4	Volatile	NO	Daubert and Danner 1985

Table 7. (continued)

Contaminant	Priority ^b	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References (Complete references in Sect. 4)
<i>Volatile Organics</i>				
Methyl propenyl benzene	4		NO	
Methyl propyl benzene	4	Highly volatile	NO	Chao et al. 1983
Gasoline		A complex mixture of mostly volatile hydrocarbons with little potential for bioaccumulation; some constituents, such as PAHs, may bioaccumulate and are addressed separately	NO	ATSDR 1993j
Hexane	4	Highly volatile; rapid photo-degradation	NO	Verschueren 1983
2-Hexanone	3	Highly volatile and highly soluble in water; not predicted to be lipophilic or bioaccumulate	NO	ATSDR 1992g
Methylene chloride	2	Highly volatile; low potential for bioaccumulation	NO	ATSDR 1993c
4-Methyl 2-pentanone	3	Highly volatile; low toxicity	NO	Verschueren 1983
Nonane	4	Volatile; moderate biodegradation	NO	Verschueren 1983
3-Octanone	4	Highly volatile; low toxicity	NO	Verschueren 1983
2-Propanol		Highly volatile; low toxicity	NO	Verschueren 1983
1,1,2,2-Tetrachloroethane	4	highly volatile; low potential for bioaccumulation	NO	ATSDR 1989h
1,1,1-Trichloroethane	1	Highly volatile; low potential for bioaccumulation	NO	ATSDR 1993i
Tetrachloroethene	1	Highly volatile; short residence in surface water and soil	NO	ATSDR 1993d
Toluene	3	Highly volatile; lipophilic; bioaccumulation limited due to rapid metabolism	NO	ATSDR 1993f
1,1,2-Trichloroethane	3	Highly volatile; low potential for bioaccumulation	NO	ATSDR 1989i
Trichloroethene	1	Highly volatile; rapid degradation in aquatic systems, slower in soil and groundwater	NO	ATSDR 1993e

Table 7. (continued)

Contaminant	Priority ^b	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References (Complete references in Sect. 4)
<i>Volatile Organics</i>				
Trichlorofluoromethane	2	Volatile; low toxicity	NO	Verschueren 1983
Trimethyl benzene	4	Highly volatile; rapidly degraded	NO	Verschueren 1983
Xylene	3	Highly volatile; low potential for bioaccumulation; rapidly oxidized in higher animals	NO	ATSDR 1990k
<i>Semi-volatile Organics</i>				
Benzidine	2	Not readily biodegraded or bioaccumulated; depending on pH, may be strongly adsorbed to soil particles and strongly bound to soil organic matter	NO	ATSDR 1989a
Benzoic acid	4	Low toxicity; rapidly biodegraded	NO	Verschueren 1983
Benzyl alcohol	4	Low volatility, readily leaches through soil	NO	HSDB 1994a
Bis(2-ethylhexyl) phthalate	2	Bioaccumulates in lower trophic levels; rapidly metabolized in mammals; widely used, reported in many substrates (soil, plants, animals), presence may be result of ubiquitous environmental contamination or contamination through sample handling.	NO	Peakall 1975
1,1-oxybis (2,1-ethanedioxy)bi Butane	4			
Dibenzofuran	4	Low volatility, may bioaccumulate	YES	HSDB 1994b
Diethyl Phthalate	4	Widely used, reported in many substrates (soil, plants, animals), presence may be result of ubiquitous environmental contamination or contamination through sample handling; readily biodegraded	NO	Peakall 1975; ATSDR 1993g
Di-n-butyl phthalate	2	Widely used, reported in many substrates (soil, plants, animals), presence may be result of ubiquitous environmental contamination or contamination through sample handling; rapidly degraded by soil microorganisms	NO	Peakall 1975; ATSDR 1990c
Di-n-octyl phthalate	2	Widely used, reported in many substrates (soil, plants, animals), presence may be result of ubiquitous environmental contamination or contamination through sample handling	NO	Peakall 1975;
4,6-Dinitro-ortho-cresol	2	Fate, degradation, and transport poorly known; may bioaccumulate	YES	ATSDR 1993h

Table 7. (continued)

Contaminant	Priority ^b	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References (Complete references in Sect. 4)
<i>Semi-volatile Organics</i>				
Ethylene glycol		Does not bioaccumulate; rapidly biodegraded	NO	ATSDR 1993k
Freon-113	4	Highly volatile; low toxicity	NO	Sax and Lewis 1987
Freon-123	4	Highly volatile	NO	HSDB 1994c
2,5-Hexanedione	3		NO	
1-Methylpentyl Hydroperoxide	4		NO	
Methyl cyclopentane	4	Highly volatile	NO	Boublik et al. 1984
2-Methylphenol	4	Low volatility but rapid biodegradation in soil	NO	Tabak et al. 1964
4-Nitrophenol	2	Low volatility; may bioaccumulate in plants and animals; moderately persistent	YES	ATSDR 1992i
N-Nitroso-di- phenylamine	3	Low soil mobility, low persistence, low bioaccumulation	NO	ATSDR 1988d
N-Nitroso-di-n- propylamine	4	Not persistent; readily photo- and biodegraded; bioaccumulation potential predicted to be low	NO	ATSDR 1989f
9-Octadecenamide	4			
1-Pentanol	4	Volatile, degraded in soil, low potential for bioaccumulation	NO	Verschueren 1983; HSDB 1994d
Phenol	4	Does not bioaccumulate; readily biodegraded	NO	ATSDR 1989g
Vinyl acetate	4	Highly volatile; low potential for bioaccumulation; readily biodegraded	NO	ATSDR 1992l
Vinyl chloride	2	Highly volatile; low potential for bioaccumulation	NO	ATSDR 1988e
<i>Polycyclic Aromatic Hydrocarbons (associated with coal, asphalt, heavy oils, etc.)</i>				
Acenaphelene	4	Both lipophilic and persistent	YES	Eisler 1987b
Anthracene	2	Both lipophilic and persistent	YES	Eisler 1987b

Table 7. (continued)

Contaminant	Priority ^b	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References (Complete references in Sect. 4)
<i>Polycyclic Aromatic Hydrocarbons (associated with coal, asphalt, heavy oils, etc.)</i>				
Benzo(a)anthracene	1	Both lipophilic and persistent	YES	Eisler 1987b
Benzo(b)fluoranthene	3	Both lipophilic and persistent	YES	Eisler 1987b
Benzo(k)fluoranthene	3	Both lipophilic and persistent	YES	Eisler 1987b
Benzo(g,h,i)perylene	4	Both lipophilic and persistent	YES	Eisler 1987b
Benzo(a)pyrene	3	Both lipophilic and persistent	YES	Eisler 1987b
Chrysene	1	Both lipophilic and persistent	YES	Eisler 1987b
Dimethylnaphthalene	4	Both lipophilic and persistent	YES	Eisler 1987b
Fluoranthene	2	Both lipophilic and persistent	YES	Eisler 1987b
Indeno(1,2,3-c,d)pyrene	4	Both lipophilic and persistent	YES	Eisler 1987b
1-Methylnaphthalene	4	Both lipophilic and persistent	YES	Eisler 1987b
2-Methylnaphthalene	4	Both lipophilic and persistent	YES	Eisler 1987b
Naphthalene	3	Both lipophilic and persistent	YES	ATSDR 1990g, Eisler 1987b
Phenanthrene	2	Both lipophilic and persistent	YES	Eisler 1987b
Pyrene	2	Both lipophilic and persistent	YES	Eisler 1987b

Table 7. (continued)

Contaminant	Priority ^b	Factors Considered in Evaluation	Retained	References
		(Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)		(Complete references in Sect. 4)
<i>PCB's, Pesticides (and metabolites), and Related Compounds</i>				
PCB's (mixed isomers)	2	Lipophilic, persistent, bioaccumulate, and released by all facilities	YES	Eisler 1986b
Aldrin		Lipophilic, persistent, and bioaccumulate	YES	
BHC (mixed isomers)	4	Lipophilic, persistent, and bioaccumulate	YES	
gamma BHC (Lindane)		Lipophilic, persistent, and bioaccumulate	YES	
Chlordane	2	Lipophilic, persistent, bioaccumulate, released at X-10	YES	Eisler 1990b
DDT	2	Lipophilic, persistent, and bioaccumulate	YES	
Dieldrin		Lipophilic, persistent, and bioaccumulate	YES	
Dioxons, Chlorinated Dibenzofurans		persistent, and bioaccumulate	YES ^c	Eisler 1986c
Heptachlor	4	Lipophilic, persistent, and bioaccumulate	YES	
Pentachlorophenol		While PCP is readily degraded in the environment, it rapidly accumulates in biota. Released in cooling towers.	YES	Eisler 1989b

^a Boldface type indicates contaminants selected for further evaluation as contaminants of potential concern (COPCs). All references are listed in Sect. 4.

^b Priority according to Ross et al. 1992.

1 = human health COPC offsite and at 2 or more ORR OU's;

2 = human health COPC offsite and at least 1 ORR OU;

3 = human health COPC at 2 or more ORR OU's but not offsite;

4 = human health COPC at only one ORR OU but not offsite;

^c It is suggested that the occurrence of these compounds should be evaluated on an OU by OU basis. If found, surveys should be expanded to the entire reservation. In addition, because these compounds may be detected at very low concentrations, and may be detected in most or all samples considered, it is important to establish a local, background concentration level for comparison, so that contaminated sites may be identified.

Of the contaminants for which environmental fate and transport information was available, 57 were retained as ORR-wide COPCs. These included 20 of 35 inorganics, 8 of 8 radionuclides, 0 of 40 volatile organic compounds (VOCs), 4 of 25 semivolatile organic compounds (SVOCs), 15 of 16 PAHs, and 10 of 10 pesticides, PCBs, or related compounds.

With the exception of radionuclides, biotic samples collected as part of the ORR-wide monitoring and assessment program will be analyzed for the listed contaminants, as appropriate. For example, while inorganic contaminants accumulate in fur and feathers, organic contaminants do not. Therefore it is inappropriate to do analyses for organic contaminants on fur or feather samples. In the case of radionuclides, gross alpha, gross beta, and gamma emitters will be measured. Only if these values exceed background concentration values as determined by background sampling (see Section 3.3.3.1) will analyses for specific bioaccumulative radionuclides listed in Table 7 be performed.

Special consideration will also be given to dioxins and chlorinated dibenzofurans. The occurrence of these compounds will be evaluated on an OU by OU basis, so that potential sources may be identified. If found, surveys will be expanded to the entire reservation. In addition, because these compounds may be detected at very low concentrations, and may be detected in most or all samples considered, it is important to establish a local, background concentration level for comparison, so that contaminated sites may be identified.

2.3.4 Contaminants in Terrestrial Biota

Beginning in 1960 several ecological researchers have measured contaminants in biota on the ORR. A bibliography of research publications concerning contamination in ORR biota is contained in Appendix D. Table 8 presents a summary of results from the studies conducted after the mid-1970s. Studies conducted prior to this time have not been included in the summary because (1) contaminant data from earlier periods is unlikely to be the same as current contaminant levels and (2) general conclusions drawn from the post-1975 studies would not be substantially altered by including earlier studies.

One conclusion that can be drawn from the studies summarized in Table 8 is that a wide range of contaminants have been found in a wide range of wildlife and vegetation. However, this conclusion must be tempered with the realization that, in most cases, researchers were looking for contamination that was expected to bioaccumulate in areas that were known to be contaminated. Nevertheless, the important point is that biota in contaminated areas are accumulating that contamination.

A second noteworthy feature of the historical data is that mobile animals with large home ranges (e.g., Canada geese, deer, kingfishers, and wild turkeys) are contaminated, and contaminated individuals of those species have been collected at locations outside the boundaries of existing OUs.

Whereas the ecological significance of this widespread contamination is unclear at this time, there is evidence—from a modeling study (MacIntosh et al. 1992), from the ecological risk assessments for Chestnut Ridge OU 2 and East Fork Poplar Creek, and from preliminary evaluation of a year-long mink trapping program—that some wildlife species in some areas of the ORR are suffering adverse effects from existing contamination.

Table 8. Contaminants in terrestrial biota on the Oak Ridge Reservation

Common Name ^a	Trophic Position ^b	Sample Location ^c	Date(s)	Analyte	Tissue	Value ^d	Units	Reference (Complete references are in Appendix D)
Gadwall	AqH1	K-901A	1991	¹³⁷ Cs	Muscle	30.1	pCi/g	Blaylock et al. (1992b)
Mallard Duck	AqH2	WOL	1989	Ag	Muscle	2.4	µg/g	Blaylock et al. (1994)
Mallard Duck	AqH2	WOL	1989	⁶⁰ Co	Muscle	1.7	pCi/g	Blaylock et al. (1991)
Mallard Duck	AqH2	WOL	1989	¹³⁷ Cs	Muscle	9.6	pCi/g	Blaylock et al. (1994)
Mallard Duck	AqH2	WOL	1989	Hg	Muscle	0.05	µg/g	Blaylock et al. (1994)
Mallard Duck	AqH2	WOL	1989	Se	Muscle	2.1	µg/g	Blaylock et al. (1994)
Mallard Duck	AqH2	WOL	1989	⁹⁰ Sr	Bone	9.2	pCi/g	Blaylock et al. (1991)
Canada Goose	LH1	WOL	1990	⁶⁰ Co	Muscle	0.02	pCi/g	Blaylock et al. (1991)
Canada Goose	LH1	3513 Pond	1988	¹³⁷ Cs	Muscle	32.1*	pCi/g	Waters and Blaylock (1994)
Canada Goose	LH1	3524 Pond	1989	¹³⁷ Cs	Muscle	4,054.1	pCi/g	Blaylock et al. (1994)
Canada Goose	LH1	ORNL STP	1989	¹³⁷ Cs	Muscle	2.1*	pCi/g	Blaylock et al. (1994)
Canada Goose	LH1	WOL	1990	¹³⁷ Cs	Muscle	3.3	pCi/g	Blaylock et al. (1991)
Canada Goose	LH1	Y-12	1991	¹³⁷ Cs	Muscle	0.2	pCi/g	Blaylock et al. (1992b)
Canada Goose	LH1	Swan Pond	1991	¹³⁷ Cs	Muscle	0.04	pCi/g	Blaylock et al. (1992b)
Canada Goose	LH1	3524 Pond	1992	¹³⁷ Cs	Muscle	4.3*	pCi/g	Blaylock (1993)
Canada Goose	LH1	K-25	1992	¹³⁷ Cs	Muscle	<1	pCi/g	Blaylock (1993)
Canada Goose	LH1	ORNL	1992	¹³⁷ Cs	Muscle	<1	pCi/g	Blaylock (1993)
Canada Goose	LH1	Clinch R.	1993	¹³⁷ Cs	Muscle	0.1	pCi/g	Blaylock et al. (1994)
Canada Goose	LH1	3524 Pond	1989	⁹⁰ Sr	Bone	648.6	pCi/g	Blaylock et al. (1994)
Canada Goose	LH1	ORNL STP	1989	⁹⁰ Sr	Bone	61.0*	pCi/g	Blaylock et al. (1994)
Wild Turkey	LH2	Melton Br.	1991	Gross beta	Bone	**		Ashwood et al. (1992b)
American Coot	LO1	WOL	1991	⁶⁰ Co	Muscle	0.1	pCi/g	Blaylock et al. (1992b)
American Coot	LO1	WOL	1991	¹³⁷ Cs	Muscle	6.8	pCi/g	Blaylock et al. (1992b)

Table 8. (continued)

Common Name ^a	Trophic Position ^b	Sample Location ^c	Date(s)	Analyte	Tissue	Value ^d	Units	Reference (Complete references are in Appendix D)
Great Blue Heron	P1	Poplar Cr.	1991-93	Hg	Feathers	1.4*	µg/g	Halbrook (unpubl. data)
Great Blue Heron	P1	Poplar Cr.	1991-93	PCBs	Egg	1.7*	µg/g	Halbrook (unpubl. data)
Kingfisher	P2	Lake Reality	1993	Cd	Kidney	4.	µg/g	Ashwood et al. (1994)
Kingfisher	P2	4505	1993	Cd	Kidney	1.5	µg/g	Ashwood et al. (1994)
Kingfisher	P2	EFPC	1993	Cd	Kidney	0.4	µg/g	Ashwood et al. (1994)
Kingfisher	P2	WOL	1991	⁶⁰ Co	Liver	3.	pCi/g	Blaylock et al. (1992b)
Kingfisher	P2	WOL	1991	¹³⁷ Cs	Muscle	568.	pCi/g	Blaylock et al. (1992b)
Kingfisher	P2	Lake Reality	1993	¹³⁷ Cs	Whole Body	<2	pCi/g	Ashwood et al. (1994)
Kingfisher	P2	4505	1993	¹³⁷ Cs	Whole Body	13,690.	pCi/g	Ashwood et al. (1994)
Kingfisher	P2	4505	1993	¹³⁷ Cs	Muscle	151.	pCi/g	Ashwood et al. (1994)
Kingfisher	P2	EFPC	1993	¹³⁷ Cs	Muscle	3.	pCi/g	Ashwood et al. (1994)
Kingfisher	P2	Lake Reality	1993	Hg	Feathers	13.9	µg/g	Ashwood et al. (1994)
Kingfisher	P2	Lake Reality	1993	Hg	Kidney	8.7	µg/g	Ashwood et al. (1994)
Kingfisher	P2	4505	1993	Hg	Feathers	2.7	µg/g	Ashwood et al. (1994)
Kingfisher	P2	4505	1993	Hg	Kidney	26.8	µg/g	Ashwood et al. (1994)
Kingfisher	P2	EFPC	1993	Hg	Feathers	4.6	µg/g	Ashwood et al. (1994)
Kingfisher	P2	EFPC	1993	Hg	Kidney	1.5	µg/g	Ashwood et al. (1994)
Kingfisher	P2	Lake Reality	1993	Pb	Feathers	2.7	µg/g	Ashwood et al. (1994)
Kingfisher	P2	4505	1993	Pb	Feathers	4.9	µg/g	Ashwood et al. (1994)
Kingfisher	P2	EFPC	1993	Pb	Feathers	1.9	µg/g	Ashwood et al. (1994)
Kingfisher	P2	Lake Reality	1993	Se	Feathers	5.4	µg/g	Ashwood et al. (1994)
Kingfisher	P2	4505	1993	Se	Feathers	7.3	µg/g	Ashwood et al. (1994)
Kingfisher	P2	EFPC	1993	Se	Feathers	5.6	µg/g	Ashwood et al. (1994)
Short-tailed Shrew	GI1	FCAP	1993	As	Whole body	0.2	µg/g	Baron et al. (unpubl. data)
Short-tailed Shrew	GI1	Walker Br.	1993	As	Whole body	0.06	µg/g	Baron et al. (unpubl. data)
Short-tailed Shrew	GI1	FCAP	1993	Cd	Whole body	0.07	µg/g	Baron et al. (unpubl. data)
Short-tailed Shrew	GI1	Walker Br.	1993	Cd	Whole body	0.07	µg/g	Baron et al. (unpubl. data)

Table 8. (continued)

Common Name ^a	Trophic Position ^b	Sample Location ^c	Date(s)	Analyte	Tissue	Value ^d	Units	Reference (Complete references are in Appendix D)
Short-tailed Shrew	GI1	FCAP	1993	Cr	Whole body	0.8	µg/g	Baron et al. (unpubl. data)
Short-tailed Shrew	GI1	Walker Br.	1993	Cr	Whole body	3.7	µg/g	Baron et al. (unpubl. data)
Short-tailed Shrew	GI1	EFPC	1986-87	Hg	Kidney	38.8*	µg/g	Talmage and Walton (1993)
Short-tailed Shrew	GI1	EFK 17.4	1987	Hg	Kidney	47.2*	µg/g	Talmage et al. (1992)
Short-tailed Shrew	GI1	SWSA 4	1987	Hg	Kidney	0.9*	µg/g	Talmage et al. (1992)
Short-tailed Shrew	GI1	FCAP	1993	Hg	Whole body	0.5	µg/g	Baron et al. (unpubl. data)
Short-tailed Shrew	GI1	Walker Br.	1993	Hg	Whole body	0.3	µg/g	Baron et al. (unpubl. data)
Short-tailed Shrew	GI1	FCAP	1993	Pb	Whole body	0.7	µg/g	Baron et al. (unpubl. data)
Short-tailed Shrew	GI1	Walker Br.	1993	Pb	Whole body	1.5	µg/g	Baron et al. (unpubl. data)
Short-tailed Shrew	GI1	FCAP	1993	Se	Whole body	2.3	µg/g	Baron et al. (unpubl. data)
Short-tailed Shrew	GI1	Walker Br.	1993	Se	Whole body	1.2	µg/g	Baron et al. (unpubl. data)
Short-tailed Shrew	GI1	SWSA 4	1987	⁹⁰ Sr	Bone	634.5*	pCi/g	Talmage et al. (1992)
Short-tailed Shrew	GI1	EFK 17.4	1987	⁹⁰ Sr	Bone	<11	pCi/g	Talmage et al. (1992)
Short-tailed Shrew	GI1	WOC	1974-75	¹³⁷ Cs	Whole Body	107.4	pCi/g	Van Voris and Dahlman (1976)
White-tailed Deer	LH3	ORR	1986	Cd	Hair	8.	µg/g	Tasca (1988)
White-tailed Deer	LH3	ORR	1986	Hg	Hair	17.	µg/g	Tasca (1988)
White-tailed Deer	LH3	ORR	1986	Pb	Hair	87.6	µg/g	Tasca (1988)
Eastern Cottontail	LH4	WOC	1975	¹³⁷ Cs	Whole Body	22.8	pCi/g	Van Voris and Dahlman (1976)
Opossum	LO2	WOC	1975	¹³⁷ Cs	Whole Body	92.7	pCi/g	Van Voris and Dahlman (1976)
Raccoon	LO3	WOC	1975	¹³⁷ Cs	Whole Body	19.6	pCi/g	Van Voris and Dahlman (1976)
Raccoon	LO3	WOC	1991-93	⁶⁰ Co	Hair	3.4	pCi/g	Ashwood et al. (1993)
Raccoon	LO3	EFPC	1991-93	⁶⁰ Co	Hair	<0.2	pCi/g	Ashwood et al. (1993)
Raccoon	LO3	FB/BB	1991-93	⁶⁰ Co	Hair	<0.3	pCi/g	Ashwood et al. (1993)
Raccoon	LO3	WOC	1991-93	¹³⁷ Cs	Hair	80.	pCi/g	Ashwood et al. (1994)
Raccoon	LO3	EFPC	1991-93	¹³⁷ Cs	Hair	0.3	pCi/g	Ashwood et al. (1993)

Table 8. (continued)

Common Name ^a	Trophic Position ^b	Sample Location ^c	Date(s)	Analyte	Tissue	Value ^d	Units	Reference (Complete references are in Appendix D)
Raccoon	LO3	FB/BB	1991-93	¹³⁷ Cs	Hair	<0.3	pCi/g	Ashwood et al. (1993)
Raccoon	LO3	WOC	1991-93	Hg	Hair	10.6	µg/g	Ashwood et al. (1993)
Raccoon	LO3	FB/BB	1991-93	Hg	Hair	1.1	µg/g	Ashwood et al. (1993)
Raccoon	LO3	WOC	1991-93	Pb	Hair	2.2	µg/g	Ashwood et al. (1993)
Raccoon	LO3	FB/BB	1991-93	Pb	Hair	1.5	µg/g	Ashwood et al. (1993)
Eastern Harvest Mouse	SH1	FCAP	1993	As	Whole body	0.2	µg/g	Baron et al. (unpubl. data)
Eastern Harvest Mouse	SH1	FCAP	1993	Cd	Whole body	0.07	µg/g	Baron et al. (unpubl. data)
Eastern Harvest Mouse	SH1	FCAP	1993	Cr	Whole body	1.2	µg/g	Baron et al. (unpubl. data)
Eastern Harvest Mouse	SH1	FCAP	1993	Hg	Whole body	0.1	µg/g	Baron et al. (unpubl. data)
Eastern Harvest Mouse	SH1	FCAP	1993	Pb	Whole body	10.3	µg/g	Baron et al. (unpubl. data)
Eastern Harvest Mouse	SH1	FCAP	1993	Se	Whole body	3.4	µg/g	Baron et al. (unpubl. data)
Eastern Harvest Mouse	SH1	SWSA 4	1987	⁹⁰ Sr	Bone	1930*	pCi/g	Talmage et al. (1992)
Eastern Harvest Mouse	SH1	WCK 3.4	1987	⁹⁰ Sr	Bone	24.3	pCi/g	Talmage et al. (1992)
Pine Vole	SH2	WOC	1974	¹³⁷ Cs	Whole Body	34.2	pCi/g	Van Voris and Dahlman (1976)
Pine Vole	SH2	FCAP	1993	As	Whole Body	0.1	µg/g	Baron et al. (unpubl. data)
Pine Vole	SH2	FCAP	1993	Cd	Whole Body	0.02	µg/g	Baron et al. (unpubl. data)
Pine Vole	SH2	FCAP	1993	Cr	Whole Body	1.5	µg/g	Baron et al. (unpubl. data)
Pine Vole	SH2	FCAP	1993	Hg	Whole Body	0.01	µg/g	Baron et al. (unpubl. data)
Pine Vole	SH2	FCAP	1993	Pb	Whole Body	0.5	µg/g	Baron et al. (unpubl. data)
Pine Vole	SH2	FCAP	1993	Se	Whole Body	0.6	µg/g	Baron et al. (unpubl. data)
Golden Mouse	SH3	WOC	1974-75	¹³⁷ Cs	Whole Body	12.4	pCi/g	Van Voris and Dahlman (1976)
Cotton rat	SO1	EFK 17.4	1987	Hg	Kidney	1.9	µg/g	Talmage et al. (1992)
Cotton rat	SO1	WCK 3.4	1987	Hg	Kidney	0.5*	µg/g	Talmage et al. (1992)
Cotton rat	SO1	SWSA 4	1987	Hg	Kidney	0.1	µg/g	Talmage et al. (1992)
Cotton Rat	SO1	SWSA 4	1987	⁹⁰ Sr	Bone	715.5*	pCi/g	Talmage et al. (1992)
Cotton Rat	SO1	WCK 3.4	1987	⁹⁰ Sr	Bone	558.9*	pCi/g	Talmage et al. (1992)

Table 8. (continued)

Common Name ^a	Trophic Position ^b	Sample Location ^c	Date(s)	Analyte	Tissue	Value ^d	Units	Reference (Complete references are in Appendix D)
Cotton Rat	SO1	K-25	1976	Cr	Hair	4.4*	µg/g	Taylor and Parr (1978)
Cotton Rat	SO1	K-25	1976	Cr	Bone	0.5*	µg/g	Taylor and Parr (1978)
Cotton Rat	SO1	3513 Pond	1978	²³³ U	Carcass	36,000.	pCi/g	Garten (1981)
Cotton Rat	SO1	3513 Pond	1978	²³⁸ U	Carcass	25,000.	pCi/g	Garten (1981)
Cotton Rat	SO1	3513 Pond	1977	²³⁹ Pu	Carcass	71,000.	pCi/g	Garten (1981)
Cotton Rat	SO1	3513 Pond	1977	²⁴¹ Am	Carcass	61,000.	pCi/g	Garten (1981)
Cotton Rat	SO1	3513 Pond	1977	²⁴⁴ Cm	Carcass	67,000.	pCi/g	Garten (1981)
Rice Rat	SO2	WOC	1974-75	¹³⁷ Cs	Whole Body	37.3	pCi/g	Van Voris and Dahlman (1976)
White-footed Mouse	SO3	EFPC	1986-87	Hg	Kidney	1.2*	µg/g	Talmage and Walton (1993)
White-footed Mouse	SO3	EFK 17.4	1987	Hg	Kidney	1.5*	µg/g	Talmage et al. (1992)
White-footed Mouse	SO3	WCK 3.4	1987	Hg	Kidney	0.3	µg/g	Talmage et al. (1992)
White-footed Mouse	SO3	WCK 2.7	1987	Hg	Kidney	0.4*	µg/g	Talmage et al. (1992)
White-footed Mouse	SO3	WCK 2.1	1987	Hg	Kidney	0.2*	µg/g	Talmage et al. (1992)
White-footed Mouse	SO3	SWSA 4	1987	Hg	Kidney	0.5*	µg/g	Talmage et al. (1992)
White-footed Mouse	SO3	SWSA 4	1987	PCB 1254	Liver	0.2	µg/g	Talmage et al. (1992)
White-footed Mouse	SO3	WCK 2.1	1987	PCB 1254	Liver	<0.05	µg/g	Talmage et al. (1992)
White-footed Mouse	SO3	SWSA 5	1987	PCB 1260	Liver	0.1	µg/g	Talmage et al. (1992)
White-footed Mouse	SO3	WCK 2.2	1987	PCB 1260	Liver	2.1	µg/g	Talmage et al. (1992)
White-footed Mouse	SO3	EFK 17.4	1987	⁹⁰ Sr	Bone	<1.1	pCi/g	Talmage et al. (1992)
White-footed Mouse	SO3	SWSA 4	1987	⁹⁰ Sr	Bone	342.9*	pCi/g	Talmage et al. (1992)
White-footed Mouse	SO3	WCK 3.4	1987	⁹⁰ Sr	Bone	16.2	pCi/g	Talmage et al. (1992)
White-footed Mouse	SO3	WCK 2.7	1987	⁹⁰ Sr	Bone	43.2*	pCi/g	Talmage et al. (1992)
White-footed Mouse	SO3	WCK 2.1	1987	⁹⁰ Sr	Bone	43.2*	pCi/g	Talmage et al. (1992)
White-footed Mouse	SO3	WOC	1974-75	¹³⁷ Cs	Whole Body	79.5	pCi/g	Van Voris and Dahlman (1976)

Table 8. (continued)

Common Name ^a	Trophic Position ^b	Sample Location ^c	Date(s)	Analyte	Tissue	Value ^d	Units	Reference (Complete references are in Appendix D)
White-footed Mouse	SO3	FCAP	1993	As	Whole body	0.4	µg/g	Baron et al. (unpubl. data)
White-footed Mouse	SO3	Walker Br.	1993	As	Whole body	0.06	µg/g	Baron et al. (unpubl. data)
White-footed Mouse	SO3	FCAP	1993	Cd	Whole body	0.05	µg/g	Baron et al. (unpubl. data)
White-footed Mouse	SO3	Walker Br.	1993	Cd	Whole body	0.03	µg/g	Baron et al. (unpubl. data)
White-footed Mouse	SO3	FCAP	1993	Cr	Whole body	2.3	µg/g	Baron et al. (unpubl. data)
White-footed Mouse	SO3	Walker Br.	1993	Cr	Whole body	3.8	µg/g	Baron et al. (unpubl. data)
White-footed Mouse	SO3	FCAP	1993	Hg	Whole body	0.06	µg/g	Baron et al. (unpubl. data)
White-footed Mouse	SO3	Walker Br.	1993	Hg	Whole body	0.03	µg/g	Baron et al. (unpubl. data)
White-footed Mouse	SO3	FCAP	1993	Pb	Whole body	1.5	µg/g	Baron et al. (unpubl. data)
White-footed Mouse	SO3	Walker Br.	1993	Pb	Whole body	0.7	µg/g	Baron et al. (unpubl. data)
White-footed Mouse	SO3	FCAP	1993	Se	Whole body	5.6	µg/g	Baron et al. (unpubl. data)
White-footed Mouse	SO3	Walker Br.	1993	Se	Whole body	0.3	µg/g	Baron et al. (unpubl. data)
Pond Slider	AqH3	WOL	1988	⁶⁰ Co	Muscle	<0.1	pCi/g	Meyers-Schöne and Walton (1994b,c)
Pond Slider	AqH3	Bearden Cr.	1988	⁶⁰ Co	Muscle	<0.1	pCi/g	Meyers-Schöne and Walton (1994b,c)
Pond Slider	AqH3	WOL	1988	¹³⁷ Cs	Muscle	13,554.	pCi/g	Meyers-Schöne and Walton (1994b,c)
Pond Slider	AqH3	Bearden Cr.	1988	¹³⁷ Cs	Muscle	0.4	pCi/g	Meyers-Schöne and Walton (1994b,c)
Pond Slider	AqH3	WOL	1990	PCB 1260	Muscle	0.5	µg/g	Ashwood et al. (1991)
Pond Slider	AqH3	WOL	1988	⁹⁰ Sr	Shell	109,890.	pCi/g	Meyers-Schöne and Walton (1994b,c)
Pond Slider	AqH3	Bearden Cr.	1988	⁹⁰ Sr	Shell	31.9	pCi/g	Meyers-Schöne and Walton (1994b,c)
Snapping Turtle	LC1	WOL	1988	⁶⁰ Co	Muscle	<0.1	pCi/g	Meyers-Schöne and Walton (1994b,c)
Snapping Turtle	LC1	Bearden Cr.	1988	⁶⁰ Co	Muscle	<0.1	pCi/g	Meyers-Schöne and Walton (1994b,c)
Snapping Turtle	LC1	WOL	1988	¹³⁷ Cs	Muscle	37.0	pCi/g	Meyers-Schöne and Walton (1994b,c)
Snapping Turtle	LC1	Bearden Cr.	1988	¹³⁷ Cs	Muscle	<0.1	pCi/g	Meyers-Schöne and Walton (1994b,c)
Snapping Turtle	LC1	WOL	1988	Hg	Kidney	1.1	µg/g	Meyers-Schöne and Walton (1994b,c)

Table 8. (continued)

Common Name ^a	Trophic Position ^b	Sample Location ^c	Date(s)	Analyte	Tissue	Value ^d	Units	Reference (Complete references are in Appendix D)
Snapping Turtle	LC1	Bearden Cr.	1988	Hg	Kidney	4.4	µg/g	Meyers-Schöne and Walton (1994b,c)
Snapping Turtle	LC1	WOL	1990	PCB 1260	Muscle	0.6	µg/g	Ashwood et al. (1991)
Snapping Turtle	LC1	WOL	1988	⁹⁰ Sr	Shell	1,242.	pCi/g	Meyers-Schöne and Walton (1994b,c)
Snapping Turtle	LC1	Bearden Cr.	1988	⁹⁰ Sr	Shell	4.8	pCi/g	Meyers-Schöne and Walton (1994b,c)
Eulalia	UPL1	ORNL WAG 7	1984	⁹⁹ Tc	Leaves	18532*	pCi/g	Garten et al. (1986)
Eulalia	UPL1	FCAP	1992	As	Leaves	1.3	µg/g	Baron et al. (unpubl. data)
Eulalia	UPL1	FCAP	1992	Se	Leaves	1.8	µg/g	Baron et al. (unpubl. data)
Goldenrod	UPL2	ORNL WAG 7	1984	⁹⁹ Tc	Leaves	310*	pCi/g	Garten et al. (1986)
Honeysuckle	UPL3	ORNL WAG 5	1986	⁹⁰ Sr	Twigs	39,000,000.	pCi/g	Garten and Lomax (1987)
Honeysuckle	UPL3	ORNL WAG 4	1986	⁹⁰ Sr	Twigs	21,000,000.	pCi/g	Garten and Lomax (1987)
Honeysuckle	UPL3	WOC	1974-75	¹³⁷ Cs	Twigs	182.4	pCi/g	Van Voris and Dahlman (1976)
Honeysuckle	UPL3	FCAP	1992	As	Twigs	<1.0	µg/g	Baron et al. (unpubl. data)
Honeysuckle	UPL3	FCAP	1992	Se	Twigs	3.1	µg/g	Baron et al. (unpubl. data)
Boxelder	UPL4	WOC	1978	²³⁴ U	Leaves	45,900.	pCi/g	Garten (1980)
Boxelder	UPL4	WOC	1978	²³⁸ U	Leaves	33,800.	pCi/g	Garten (1980)
Boxelder	UPL4	WOC	1978	²³⁹ Pu	Leaves	32,000.	pCi/g	Garten (1980)
Boxelder	UPL4	WOC	1978	²⁴¹ Am	Leaves	13,500.	pCi/g	Garten (1980)
Boxelder	UPL4	WOC	1978	²⁴⁴ Cm	Leaves	9,000.	pCi/g	Garten (1980)
Boxelder	UPL4	FCAP	1992	As	Leaves	1.5	µg/g	Baron et al. (unpubl. data)
Boxelder	UPL4	FCAP	1992	Se	Leaves	12.6	µg/g	Baron et al. (unpubl. data)
Cottonwood	UPL5	FCAP	1992	As	Leaves	1.9	µg/g	Baron et al. (unpubl. data)
Cottonwood	UPL5	FCAP	1992	Se	Leaves	97.	µg/g	Baron et al. (unpubl. data)
Red Maple	UPL6	ORNL WAG 7	1984	⁹⁹ Tc	Wood	1027*	pCi/g	Garten et al. (1986)
Red Maple	UPL6	FCAP	1992	As	Leaves	3.8	µg/g	Baron et al. (unpubl. data)
Red Maple	UPL6	FCAP	1992	Se	Leaves	8.5	µg/g	Baron et al. (unpubl. data)

Table 8. (continued)

Common Name ^a	Trophic Position ^b	Sample Location ^c	Date(s)	Analyte	Tissue	Value ^d	Units	Reference (Complete references are in Appendix D)
Sycamore	UPL7	FCAP	1992	As	Leaves	2.2	µg/g	Baron et al. (unpubl. data)
Sycamore	UPL7	FCAP	1992	Se	Leaves	22.5	µg/g	Baron et al. (unpubl. data)
Willow	UPL8	FCAP	1992	As	Leaves	3.1	µg/g	Baron et al. (unpubl. data)
Willow	UPL8	FCAP	1992	Se	Leaves	43.	µg/g	Baron et al. (unpubl. data)
Eastern Red Cedar	UPL9	FCAP	1992	As	Leaves	<1.0	µg/g	Baron et al. (unpubl. data)
Eastern Red Cedar	UPL9	FCAP	1992	Se		2.9	µg/g	Baron et al. (unpubl. data)
Loblolly Pine	UPL10	ORNL WAG 5	1986	³ H	Cores	6,500.	pCi/g	Amano et al. (1987)
Eleocharis	FPL1	3513 Pond	1978	²³³ U	Leaves	288,000.	pCi/g	Garten (1981)
Eleocharis	FPL1	3513 Pond	1978	²³⁸ U	Leaves	86,000.	pCi/g	Garten (1981)
Eleocharis	FPL1	3513 Pond	1978	²³⁹ Pu	Leaves	1,311,000.	pCi/g	Garten (1981)
Eleocharis	FPL1	3513 Pond	1978	²⁴¹ Am	Leaves	496,000.	pCi/g	Garten (1981)
Eleocharis	FPL1	3513 Pond	1977	²⁴⁴ Cm	Leaves	820,000.	pCi/g	Garten (1981)

^a Scientific names are listed in Appendix C.

^b AqH = aquatic herbivore; AqI = aquatic invertebrate feeder; ArI = arboreal invertebrate feeder; FI = flying insectivore; GI = ground invertebrate feeder; LC = predators and scavengers with Reservation-wide population; LH = herbivore with Reservation-wide population; LO = omnivore with Reservation-wide population; SH = herbivore with areally-restricted population; SO = omnivore with areally-restricted population; UPL = upland plant; FPL = floodplain/wetland plant.

^c EFPC = East Fork Poplar Creek; FB/BB = Freel's Bend/Bull Bluff; FCAP = Filled Coal Ash Pond; ORNL = Oak Ridge National Laboratory; ORR = Oak Ridge Reservation; STP = Sewage Treatment Plant; WAG = Waste Area Grouping; WCK = White Oak Creek kilometer; WOC = White Oak Lake; WOL = White Oak Lake.

^d Values given are maximum of all samples, except for values followed by *, which are means. ** Three turkeys were sampled for gross beta in bones. One turkey's bone contained gross beta at >50% above background.

2.4 INTERFACES WITH OTHER PLANNED OR EXISTING PROGRAMS

There are a number of ongoing or planned programs that will provide data that are useful to this project. For the most part, those programs are being implemented by members of the Environmental Sciences Division at ORNL. Virtually all ecological monitoring of aquatic systems on the ORR is conducted by staff assigned to the Biological Monitoring and Abatement Programs described in Sect. 2.3.1. All monitoring of biota in the terrestrial ecosystem is conducted or supervised by BMAP staff or by staff who work closely with the ORR Area Manager (the Area Manager is an ESD staff member with responsibility for activities on the ORR outside of the individual plant boundaries). Thus, the conducting of ecological monitoring activities on the ORR is focused in a small group of individuals who are also closely associated with this project.

The following paragraphs briefly describe those ongoing and planned activities that are expected to produce information relevant to this project. Interfaces with this project are also described.

2.4.1 Biological Monitoring and Abatement Programs

These programs have been described in Sect. 2.3.1. At present the terrestrial components of the ORNL and K-25 Site BMAPs consist of raccoon and waterfowl (e.g., Canada geese) monitoring. This project is managed by staff in the same organizational group as the staff who conduct the BMAP projects.

2.4.2 Rare Plant Surveys

The rare plant survey program is described by Cunningham et al. (1993). Funding was provided through the Environmental Restoration Program in 1993 to survey the entire ORR. All existing OUs have been surveyed. Surveys of the rest of the ORR are scheduled to be complete at the end of FY 1995.

The rare plant surveys are conducted by staff and subcontractors assigned to the Oak Ridge National Environmental Park Manager, and the surveys are conducted in close coordination with the ORR Area Manager. The Area Manager is one of the individuals who will have technical oversight of this project, so communication between the two programs will be facilitated.

2.4.3 Wetlands Surveys

Wetlands resources on the ORR have been described by Cunningham and Pounds (1991). A programmatic survey of wetlands is ongoing. The wetlands surveys are conducted by staff and subcontractors assigned to the Oak Ridge National Environmental Park Manager, and the surveys are conducted in close coordination with the ORR Area Manager. The Area Manager is one of the individuals who will have technical oversight of this project, so communication between the two programs will be facilitated.

2.4.4 Endangered Animals Surveys

Parr and Evans (1992) have prepared a wildlife management plan for the ORR. The environmental Restoration Program funded a comprehensive endangered animals survey that is being conducted in FY 1994 and FY 1995. This survey is being conducted by staff and subcontractors assigned to the Oak Ridge National Environmental Park Manager, and

the surveys are conducted in close coordination with the ORR Area Manager. The Area Manager is one of the individuals who will have technical oversight of this project, so communication between the two programs will be facilitated.

2.4.5 Managed Deer Hunts

The TWRA manages deer hunts on the ORR each year. As part of these hunts, each deer must be checked for gross beta radiation and ^{137}Cs before the hunter can remove it from the ORR. Data from these deer surveys are available for ecological risk assessment. It is likely that the preliminary ecological risk assessment to be conducted in FY 1995 (Sect. 3.3.2) will identify a need for additional contaminant data from the hunter-killed deer.

2.4.6 Remedial Investigations on Source and Aquatic Integrator Operable Units

As described in Sect. 2.2, data from source OUs will be necessary to provide a basis for assessing the impacts of those OUs on wide-ranging animals. The need for these data will be communicated directly to the affected OU managers by staff from this project. Furthermore, the need for this data will be addressed in the DQO sessions for these OUs.

2.4.7 Clinch River Environmental Restoration Program

Certain data being collected in support of the RI for the Clinch River will be of value for the ecological risk assessment of the ORR. The ecological risk assessment staff assigned to this project are in communication with the staff collecting data for the Clinch River RI.

2.4.8 Monitoring by the Natural Resource Trustees

The natural resource trustees for the ORR are implementing a program to assess natural resource damages. Because of a perceived need to keep those efforts independent of other DOE activities, it is unclear whether data from the natural resource trustees will be available to this project.

3. WORK PLAN

3.1 DATA QUALITY OBJECTIVES

As discussed in Sect. 1, this plan was developed to meet specific objectives identified in a formal data quality objectives process. The reason for this approach was to focus project activities on those tasks that were needed to support decisions to be made by the FFA parties.

The DQO process usually involves seven steps: (1) problem statement, (2) decision identification, (3) development of decision rules, (4) establishment of boundaries, (5) identification of inputs to the decision, (6) determination of uncertainty constraints, and (7) optimization of the sampling design. Because of the nature of this project, the FFA parties agreed that determining uncertainty constraints and optimizing sampling design could not be accomplished until further information is available. Therefore the process proceeded only through the first five steps.

For this project, the DQO process was implemented in three meetings, beginning in January 1994 and concluding in May 1994. The facilitator's summary of the last two meetings is included in Appendix A. No formal summary of the first meeting was documented.

Problem statements and decisions are presented in Table 9. Tables 10 and 11 identify the assessment and measurement endpoints that are considered to be inputs to the decisions.

Table 9. Problem statements and decisions for the Oak Ridge Reservation ecological monitoring and assessment program

Problem 1:	Given the previous data, it is important to determine if contamination has resulted in ecological impacts on terrestrial and aquatic species and to determine the extent of the impacts across the ORR.
Problem 2:	Assess the ecological system to the appropriate level required to allow evaluation of impacts of potential activities.
Problem 3:	Once data has been gathered for problems 1 and 2, the effectiveness of remedial action (or no action in selected cases) must be evaluated.
Decision 1:	Determine whether there is an unacceptable ecological impact.
Decision 2:	Determine whether interim actions are necessary due to the ecological impact.
Decision 3:	If an ecological impact exists, the "major" contributing sources to the problem and appropriate remedies must be identified, evaluated, and properly implemented.

The primary boundary for this project is the Reservation boundary. Each OU will address the ecological system within its boundaries. Data from each OU will be used to assess the impacts on wide-ranging species. Boundaries may be habitat or species specific. After mapping the habitat (see Sect. 3.3.1), boundaries may need to be reassessed.

Table 10. Assessment endpoints for an ecological risk assessment of the Oak Ridge Reservation

Group or trophic position ^a	Species or community ^b
Upland plants	Distribution and abundance of plant community types and threatened or endangered plant species.
Aquatic herbivores	Cumberland slider and Mallard duck.
Piscivores	River otter, bald eagle, osprey, double-crested cormorant, black-crowned night heron, mink, great blue heron, and belted kingfisher.
Aquatic invertebrate feeders	Hellbender, leopard frog, and pied-billed grebe.
Flying insectivores	Gray bat, Indiana bat, eastern small-footed bat, Rafinesque's big-eared bat, and rough-winged swallow.
Ground invertebrate feeders	Long-tailed shrew, masked shrew, smokey shrew, southeastern shrew, six-line racerunner, slender glass snake, Tennessee cave salamander, green salamander, American woodcock, European starling, and American toad.
Arboreal insectivores	Quality and availability of habitat.
Large omnivores	muskrat, raccoon, and wood duck.
Large herbivores	Grasshopper sparrow, Henslow's sparrow, lark sparrow, vesper sparrow, white-tailed deer, wild turkey, Canada goose, and groundhog.
Predators and scavengers	Golden eagle, northern harrier, Cooper's hawk, red-shouldered hawk, sharp-shinned hawk, barn owl, black vulture, eastern cougar, northern pine snake, red fox, snapping turtle, and black rat snake.

^a For a description of each category see Sect. 2.2.

^b Species in boldface are listed as threatened, endangered, or in need of management by the Tennessee Wildlife Resources Agency or the U.S. Fish and Wildlife Service. Scientific names of all animals are listed in Appendix C.

Table 11. Measurement endpoints for an ecological risk assessment of the Oak Ridge Reservation

Group or trophic position ^a	Species or community ^b
Upland plants	Distribution and abundance of plant community types and threatened or endangered plant species.
Aquatic herbivores	Pond slider and Mallard duck.
Piscivores	Great blue heron, belted kingfisher, and northern water snake.
Aquatic invertebrate feeders	Leopard frog, and pied-billed grebe.
Flying insectivores	Rough-winged swallow and common bats.

Table 11. (continued)

Group or trophic position ^a	Species or community ^b
Ground invertebrate feeders	Short-tailed shrew, American woodcock, European starling, and American toad.
Arboreal insectivores	Quality and availability of habitat.
Large omnivores	muskrat, raccoon, and wood duck.
Large herbivores	White-tailed deer, wild turkey, Canada goose, and groundhog.
Predators and scavengers	Red fox, snapping turtle, and black rat snake.

^a For a description of each category see Sect. 2.2.

^b Scientific names of all animals are listed in Appendix C.

Three decision rules were agreed upon:

1. A significant impact has occurred if there is a >20% reduction in abundance or production of an endpoint species (Tables 9 and 10).
2. A significant impact has occurred if there is a >20% reduction in species richness or abundance in an endpoint community (Tables 9 and 10).
3. A significant impact has occurred if there is a >20% reduction in survival, growth, or reproduction of organisms in a toxicity test that is representative of an endpoint species or community.

For species listed by the State of Tennessee or the FWS, the 20% degradation criteria is not acceptable. Any toxic effect on a listed species is considered a significant impact.

Wetlands are also considered separately from the above criteria. No net loss of wetland functions is permitted.

3.2 DATA GAPS

Data needed to evaluate ecological risk at the reservation scale may be broken into two categories: population-related parameters and exposure-related parameters. Population-related parameters are measures that can be used to describe the health of populations of endpoint species. These parameters include:

- abundance (numbers of individuals of an endpoint species on the ORR)
- demographics (age and sex distributions and measures of reproduction of an endpoint species on the ORR)
- distribution (spatial arrangement of individuals of endpoint species on the ORR)
- home range (area where individual resides [in ha.])
- feeding range (area where individual forages [in ha.])

- local habitat preference (type and frequency of use of habitats available on the ORR)
- local food habits (type and frequency of use of foods available on the ORR)

Exposure-related parameters serve to identify the magnitude of contaminant exposure that individuals and populations of endpoint species are experiencing on the reservation. These parameters include:

- contaminant concentrations in food, water, and soil
- contaminant body burdens
- bioindicators of contaminant exposure
- proportion and magnitude of contamination within preferred habitats
- proportion of time spent in contaminated habitats

Comparison of these data needs to the existing data described in Section 2.3. defines the data gaps that need to be filled so that a reservation-wide ecological risk assessment may be performed. The specific data gaps for each assessment endpoint species or community identified in Section 3.1. are outlined below.

While some data exists with which to assess ecological risks to ORR-wide endpoints, much information is lacking. For example, ORR-specific population data are only available for three assessment endpoints: upland plants, mallard duck, and white-tailed deer. Available data consists of abundance, distribution, and habitat preference (for mallards only). Other population-related data gaps, such as home and feeding ranges and food and habitat preferences of endpoint species, will be filled using published observations or values from other locations within the range of the species. If published data are not available or if the habits of the endpoint species are so variable that observations from other locations may not be representative of those on the ORR, specific studies will be undertaken to collect the needed data. The need for specific studies will be addressed in future updates of the work plan for this program.

In the case of contaminants-related data, while more data are available, many data gaps exist. The most abundant contaminants related data consist of contaminant concentrations in food, water, or soil. These data are available for many endpoint species (Table 12). However, because data are available only for those operable units for which RI/feasibility study (FS) programs have been initiated and RI/FS programs have not been initiated at all operable units, existing data are not sufficient to definitively evaluate risk to ORR-wide populations. Of the other types of contaminants-related data, body burden data are available for six groups or species (upland plants, raccoon, white-tailed deer, wild turkey, Canada geese, and snapping turtle), bioindicator data exists for only one species (snapping turtle), and no information is available for any endpoint concerning the portion of habitat that is contaminated or the proportion of time spent in contaminated habitat.

Additional data on food, water and soil contaminant levels for areas on the reservation but outside source OUs (i.e. background data) will be collected as part of this program, as will data for OUs where the RI/FS data collection is scheduled too distantly in the future. Collection of background data will be performed as part of this program and is outlined in Section 3.3.3. The need for collection of contaminants data from source OUs will be addressed in future updates of the work plan for this program.

Table 12. Data Gaps Identified for Reservation-Scale Ecological Assessment Endpoint Species and Communities

Trophic group	Endpoint species or community	Exposure-related data gaps ^a				
		Contaminant Concentration in food, water, or soil	Contaminant body burden	Bioindicators of contaminant exposure	Proportion of Proportion of habitat contaminated	Time in contaminated habitat
Upland Plants	Upland plants	SD ^b	SD	NA ^c		NA
Aquatic herbivores	Mallard	SD				
	Cumberland slider	SD				
Piscivores	Mink	SD				
	River otter	SD				
	Great blue heron	SD				
	Belted kingfisher	SD				
	Bald eagle	SD				
	Osprey	SD				
	Double-crested cormorant	SD				
	black-crowned night heron	SD				
Aquatic invertebrate feeders	Pied-billed grebe					
	Leopard frog					
	Hellbender					
Flying insectivores	Rough-winged swallow					
	Gray bat					
	Indiana bat					
	Eastern small-footed bat					
	Rafinesque's big-eared bat					
Ground invertebrate feeders	American woodcock	SD				
	American Robin	SD				
	American toad	SD				
	Six-line racerunner	SD				
	Slender glass snake	SD				
	Tennessee cave salamander	SD				
	Green salamander	SD				
	Long-tailed shrew	SD				
	Masked shrew	SD				
	Smokey shrew	SD				
	Southeastern shrew	SD				
Arboreal insectivores	NA					
Large omnivores	Raccoon	SD	SD			
	Wood duck	SD				
	Muskrat	SD				

Table 12. (continued)

Trophic group	Endpoint species or community	Exposure-related data gaps ^a				
		Contaminant Concentration in food, water, or soil	Contaminant body burden	Bioindicators of contaminant exposure	Proportion of habitat contaminated	Time in contaminated habitat
Large herbivores	White-tailed deer	SD	SD			
	Wild turkey	SD	SD			
	Canada goose	SD	SD			
	Groundhog	SD				
	Grasshopper sparrow					
	Henslow's sparrow					
	Lark sparrow					
	Vesper sparrow					
Predators and Scavengers	Golden eagle	SD				
	Northern harrier	SD				
	Cooper's hawk	SD				
	Red-shouldered hawk	SD				
	Sharp-shinned hawk	SD				
	Barn owl	SD				
	Black vulture	SD				
	Cougar	SD				
	Red fox	SD				
	Snapping turtle	SD	SD	SD		
	Black rat snake	SD				
	Northern pine snake	SD				

^a Empty cells indicate that no data exist for that parameter and endpoint species

^b SD = Some data are available, but are inadequate to assess risk to the reservation-wide population.

^c Not Applicable

Abundance, demographics, and distribution of wildlife are related to the abundance, diversity, and distribution of habitat. By identifying the habitats available on the reservation and the habitat requirements of endpoint species, models to estimate the distribution and abundance of populations of endpoint species, similar to the Habitat Suitability Indices (HSIs) of the FWS, may be developed. Assessment of available habitat on the ORR will use existing maps (see Section 2.3.2.) and new analyses to be performed as part of this program (see Section 3.3.1.). Extensive literature reviews (see Section 3.3.1.) will be performed for each endpoint species to identify critical habitat parameters that may be used to predict the presence and abundance of endpoint species in each particular habitat. Insufficient information may be available to estimate abundance and distribution of some endpoint species by habitat alone. Therefore, specific studies will be undertaken to collect the needed data. The need for specific studies will be addressed in future updates of the work plan for this program.

To evaluate the proportion of habitat contaminated, habitat maps (Sect. 2.3.2. and 3.3.1.) will be compared to the areas of known contamination (source and aquatic integrator OUs). The proportions of various habitat types observed within these contaminated areas will serve as estimates of the proportion of that habitat that is contaminated. The proportion of an endpoint species habitat that is contaminated will be

determined by comparing this information to the habitat use information for each endpoint species.

Finally, while efforts will be made to address and fill all data gaps, this may not be possible due to practical limitations. For example, methods may be lacking to accurately census populations of some species, appropriate biomarkers for all species/contaminant combinations may not be available, contaminant analyses in all species may be inordinately expensive, etc. Because a weight-of-evidence approach will be used in this assessment (Sect. 2.2 and 3.3.2.), all data listed above and in Table 12 are not necessary to adequately assess risk. However, with a more complete the data set (particularly one that includes site-specific data) for each endpoint species, fewer uncertainties are associated with ecological risk assessment.

3.3 SPECIFIC TASKS

3.3.1 Habitat Mapping and Analysis

Abundance and diversity of terrestrial endpoint species on the ORR is integrally related to the availability, quality, and distribution of habitat. Many endpoint species are likely to be associated only with particular habitat types that supply their specific food, water, or cover requirements. For example, as piscivores, mink and kingfisher require riparian or other water-associated habitats, while woodpeckers and warblers, as arboreal insectivores, require upland forest. Other endpoint species need a mixture of different habitat types to meet their specific life history requirements.

To evaluate how contamination and remedial actions taken to alleviate that contamination may influence populations of endpoint species, information on the types, availability, and distribution of habitats on the ORR are needed. In addition, life history information (e.g., food habits, home ranges, habitat requirements, etc.) is needed for all endpoint species so that impacts associated with specific habitats may be related to specific endpoint species. To fulfill these needs, remotely sensed data will be used to generate an updated land use/land cover map for the ORR and surrounding areas, the amount and proportion of habitat that occurs on source OUs will be determined, and literature reviews will be performed to develop life history profiles for all endpoint species.

3.3.1.1 Generation of Updated Land Use/Land Cover Map

The updated land use/land cover map for the ORR was developed using remotely sensed data which provides information over a larger geographic extent, and at less expense, than data collected in the field. Available options for acquisition of remotely sensed data include aerial photography, aerial sensors, and satellite-borne sensors. Satellite systems offer several advantages over other data acquisition options. For instance, digital data gathered by satellite sensors are easily processed, analyzed and stored; areas can be covered on a regular basis for change detection; and the stability of satellite platforms reduces distortion in the final image (as compared to airborne platforms) (ERDAS 1994).

TM 5 satellite imagery was used to create the land use/land cover map for the ORR and surrounding areas. TM images consist of seven spectral bands spanning the visible, infrared, and thermal-infrared wavelengths; these bands are particularly useful for environmental applications such as vegetation type and health determination, soil moisture, snow and cloud differentiation, and rock type discrimination (ERDAS 1994). Data are

stored in digital format as a grid of pixel values for each band (Lillesand and Kiefer 1987). Each TM image pixel represents the average reflectance over a ground area of 30×30 m.

The image used to create the ORR land use/land cover map was taken from satellite path 19/row 35 on April 13, 1994 at approximately 9:00 am Eastern Standard Time. A Spring image was selected to maximize the physiological differences between evergreen and deciduous vegetation types; the April 13 date was chosen for its low (<10%) cloud cover.

The 100×100-km image is georeferenced to United States Geological Survey (USGS) ground control points and terrain corrected using a USGS 1:24,000 digital elevation model. The image is resampled to the standard ORR map projection [i.e. Tennessee State Plane (TSP) zone 5301, North American Datum 83] with 25×25-m pixels. The study area subscene is nearly 189,000 ha in size, with an approximate center point of 35:49:40 west, longitude and 84:17:22 north, latitude. The ORR boundary encompasses an area of 14,252 ha (King et al. 1994) (Fig. 8).

Classification is the process of assigning the pixels of a continuous image to discrete categories. Classification can be supervised, in which the analyst is directly involved in the pattern recognition process, or unsupervised, in which the analyst specifies parameters but pattern recognition is largely computer-automated (ERDAS 1994). Supervised classification is preferable when relatively few classes need to be identified, there are training sites that can be verified with ground truth data, or when distinct, homogeneous regions can be identified in the image. The current project meets these specifications.

A supervised classification was performed using ERDAS IMAGINE 8.1 software (ERDAS 1994) (Fig. 9). The 125 training sites used in the supervised classification were derived from ground observations and large scale (approximately 1:6000) aerial photographs. Ten land use/land cover classes were mapped (Table 13); this classification scheme was slightly modified from the Anderson classification system (Anderson et al. 1976) to emphasize vegetation differences and de-emphasize urban areas. Non-forest categories represent Anderson level-one classification, while forest categories represent Anderson level-two classification. Areas of cloud and cloud shadow were not used in analyses.

Preliminary analysis of the composition and distribution of habitats on the ORR were performed. Geographic Resource Analysis Support System (GRASS) geographic information system (GIS) software (USA CERL 1991) was used to estimate total area and relative percent cover for each land use/land cover class within the study area and within the ORR boundary (Table 14). A preliminary evaluation of the total area and relative percent cover for each land use/land cover class was also performed for operable units within the ORR (Fig. 10; Table 15). The accuracy of these estimates, however, can not be assessed until the land use/land cover map accuracy has been evaluated.

Scale

5 0 Kilometers

Legend

Class_Names	Class_Names	Class_Names	Class_Names
pine plant.	hi dens. urb.	bare soil	cult.ag. field
water	lo dens. urban	deciduous	dead grass/slash
no data	mat. pine	hard-pine mix

FIGURE 8. Oak Ridge Reservation and surrounding areas, totalling ~ 188,000 ha. April 13, 1994.
Projection: TSP.

FIGURE 9. Oak Ridge Reservation and surrounding areas. April 13, 1994. Projection: TSP.

Figure 10. Oak Ridge Reservation operable units. April 13, 1994.

Scale
1 : 109880.03

- Major Roads
- ~ Water Features
- Operable Units
- Reservation Boundary

Table 13. Land use/land cover categories and descriptions^a

Category	Description
Water	Lakes, rivers, quarry ponds, ponds, and streams of a size to be seen in a 25×25-m pixel.
Bare Soil	Plowed field, areas where vegetation has been removed (at least temporarily).
Dry grasses/slash	Old fields and maintained power line corridors where low vegetation has not begun spring growth; deforested areas where dead vegetation has not been removed from the surface.
Agricultural fields/ pastures in cultivation	Cropped or grassy fields with vigorous spring growth.
Pine Plantations	Areas of pine trees (usually loblolly pine) which are row planted, are of the same age, and are generally younger than 25 years (in 1994).
Mature Pine	Areas dominated by mature pine forest, with trees generally older than 25 years (in 1994) and having an uneven canopy.
Pine-Hardwood Mix	Areas of nearly even mixture of hardwood and pine trees.
Hardwoods (Decid.)	Areas dominated by deciduous forest, with species generally including oak, maple, and poplar.
Low Density Urban	Residential, buildings mixed with grasses and trees.
High Density Urban	Industrial, heavy commercial building areas.

^a Based on Chatfield and Graham (unpubl. data).

Table 14. Preliminary estimates of area and relative percent cover by category for the Oak Ridge Reservation and the 188,000-ha subscene

Category	Reservation		Study Area Subscene	
	Area (ha)	Percentage	Area (ha)	Percentage
Water	733.0	5.4	10081.9	5.6
Bare soil	46.0	<1.0	324.6	<1.0
Dry grasses/slash	2413.0	17.9	32830.3	18.2
Agriculture/ pasture	323.8	2.4	25923.4	14.7
Pine plantation	269.8	2.0	1000.2	<1.0
Mature pine	664.6	4.9	7706.7	4.3
Pine-hardwood Mix	3735.4	27.7	35848.9	19.9
Hardwood (decid.)	3779.3	28.0	34814.2	19.3
Low density urban	841.9	6.3	26688.6	14.8
High density urban	668.3	5.0	5153.5	2.9

Table 15. Preliminary estimates of area and relative percent cover by category within Oak Ridge Reservation operable units

Category	Area (ha)	Percentage
Water	18.6	1.4
Bare soil	2.0	<1.0
Dry grasses/slash	440.4	27.1
Agriculture/ pasture	66.5	4.1
Pine plantation	22.7	1.4
Mature pine	56.8	3.5
Pine-hardwood Mix	288.1	17.7
Hardwood (decid.)	269.3	16.5
Low density urban	275.6	16.9
High density urban	187.9	11.5

Land use/land cover map accuracy assessment

Map accuracy is affected by a host of factors, including location of source map boundary lines, sensor resolution, mapped cell size, and subjective interpretation of spectral signatures. Although the influence of each factor is difficult to quantify, existing methods may estimate overall map accuracy. Error matrices are an industry standard for assessing and displaying accuracy statistics.

An error matrix for the ORR map will be produced by selecting random test sites from the map, making ground observations of the actual land cover at those sites, and comparing actual cover with mapped cover types. Test sites will be selected using a stratified-random sampling method; this method prevents the number of samples falling into the land use/land cover categories from being proportional to the size of the class (Chatfield and Graham, unpubl. data). A minimum of 50 cells will be selected from each map class and compared to ground observations (Hay 1979; Chatfield and Graham, unpubl. data). More cells may be selected from classes with spectral signatures which are easily confused, such as Mature Pine and Pine-Hardwood Mix.

Ground observations will be provided by 0.5 m resolution orthophotographs and by field work using a global positioning system (GPS). Twenty-five percent of the test sites will be visited in the field by the image interpreter, where a GPS will be used to pinpoint test site locations and the cover type at the site will be recorded. Seventy-five percent of the test sites will be observed by comparison with Oak Ridge Environmental Base Mapping and Imagery Project orthophotographs. These orthophotographs are well suited for ground verification because of their fine resolution, georectification, and the fact that they were taken less than a week apart from the image date.

Simple statistical analysis will yield a matrix of accuracy statements (i.e., percent correctly classified) for each land use/land cover class. Chatfield and Graham (unpubl. data) produced an ORR land use/land cover map for 1984 (Fig. 7) with an overall map accuracy of 80%. If the 1994 map falls below this accuracy level, improvements will be made to the classification method. Potential strategies include utilizing unsupervised classification to minimize error in subjective signature interpretation; spectral band ratioing to minimize shadowing effects; and merging images from different time periods to maximize physiological differences between vegetation types.

The completed 1994 map will be compared to the 1984 map to determine temporal change in area and pattern of land use/land cover classes for the ORR as a whole and within each OU. For this comparison, the 1984 map will be reinterpreted using the same methodology as was used for the 1994 map. This reinterpretation is necessary in order to minimize errors which result from different interpretation strategies. The 1984 and 1994 maps will be archived in suitable formats for integration with existing databases and the Oak Ridge Environmental Information System.

Initial comparisons of the 1984 and 1994 maps indicate apparent differences in land use/land cover. For example, on the 1984 map, the Clinch River Breeder Reactor Site is classified as predominantly high and low density urban cover (Fig. 7, Location A). In the 1994 coverage, this area is predominantly dead grass and slash, with only a small portion classified as urban (Fig. 10, Location A). In the 1984 coverage, the predominant cover in the Freel's Bend area was agricultural fields/bare ground (Fig. 7, Location B), while in 1994, this area was classified as cultivated agricultural fields or dead grass/slash (Fig. 10, Location B). These differences may be partially attributed to differing classification methods. An unsupervised classification procedure was used for the 1984 image, in which land use groupings were generated by computer, according to preset pattern recognition parameters. This may have resulted in the misclassification of some areas (particularly in the case of the Clinch River Breeder Reactor Site). In contrast, the land use classes in the 1994 map were assigned by supervised classification process (see above). By combining ground observations with a priori knowledge of the number and type of land use classes to be mapped (derived from the 1984 map, aerial photographs, and ground observations), the likelihood of erroneous classification of locations is reduced.

Apparent differences in land use patterns observed between 1984 and 1994 may also be attributed to seasonal differences in vegetation observed in images generated at different times of the year. The 1984 image was taken in fall while the 1994 image was taken in spring. Because the 1984 image was taken post-harvest in the fall, bare ground and agricultural fields (that had been harvested or disked under) could not be differentiated. In contrast, in the 1994 image, differences between bare ground, agricultural fields, and dead grass/slash were very evident due to the flush of spring growth. The effects of different seasons are clearly displayed in the Freel's Bend area. Additional differences resulted due to the different number of classes and class definitions used in 1994 (11) as compared to 1984 (9).

To reduce the variation in land use classification that may be attributed solely to seasonal differences between satellite observations, only spring or fall images will be selected for future remapping of the ORR. The existing spring and fall images will make future multitemporal analysis possible. In multitemporal analyses, images generated at different times of year are used to maximize detection of differences between vegetation types and to increase discrimination between habitats of differing species composition.

Spatial analyses and change detection

Land use/land cover patterns in 1984 and 1994 will be analyzed by computing indices that describe both overall landscape pattern and that of each habitat type. Analyses will be conducted separately for each operable unit, as well as for the entire Reservation; other meaningful subdivisions of the Reservation can also be selected for analysis, as necessary. Analyses will be done by using the SPAN program (Turner 1990a, 1990b) and FRAGSTATS (McGarigal and Marks 1993). Both programs are written in FORTRAN and

can be linked to map layers stored in the GRASS geographic information system (GIS) (USA CERL 1991).

The proportion of the landscape area, p , occupied by each habitat type will be calculated. Nearest neighbor probabilities, $q_{i,j}$, which represent the probability of cells of land use type i being adjacent to cells of land use type j , will be calculated by dividing the number of cells of type i that are adjacent to type j by the total number of cells of type i . The $q_{i,j}$ values will be used in the contagion index described below, and the $q_{i,j}$ also used as a fine-scale measure of the degree of clumping in any habitat type.

Two overall landscape indices adapted from O'Neill et al. (1988) will be calculated. The first index, D , is a measure of dominance, calculated as the deviation from the maximum possible landscape or habitat diversity:

$$D = \frac{H_{\max} + \sum_{i=1}^m (P_i) \log(P_i)}{H_{\max}} \quad (1)$$

where m = number of land use types observed on the map, P_i is the proportion of the landscape in land use i and $H_{\max} = \log(m)$, the maximum diversity when all land uses are present in equal proportions. Values of D approaching one indicate a landscape that is dominated by one or a few land uses, and lower values nearing zero indicate a landscape with land uses represented in approximately equal proportions.

The second overall index, C , measures contagion, or the adjacency of habitat types (O'Neill et al. 1988, Li and Reynolds 1993). The index is calculated from an adjacency matrix, Q , in which $q_{i,j}$ is the proportion of cells of type i that are adjacent to cells of type j , such that:

$$C = \frac{K_{\max} + \sum_{i=1}^m \sum_{j=1}^m (q_{i,j}) \log(q_{i,j})}{K_{\max}} \quad (2)$$

where $K_{\max} = 2m \log(m)$ and is the absolute value of the summation of $(q_{i,j}) \log(q_{i,j})$ when all possible adjacencies between habitat types occur with equal probabilities. The index C will be zero when the pattern is dispersed and all possible adjacencies occur with equal probability. Values of C approaching 1 indicate a landscape with a clumped pattern of habitats.

The remaining metrics are computed separately for each habitat category. For each habitat type, every patch in the landscape map is identified and its area and perimeter recorded. A patch is defined as contiguous, adjacent (horizontally or vertically) cells of the same habitat; diagonal cells are not considered to be contiguous. The total number of patches, arithmetic mean patch size, area-weighted mean patch size, size of the largest patch, and number of single-cell patches will be recorded for each habitat type. The arithmetic mean patch size is calculated by simple division of the summation of the patch sizes, S_i , by the number of patches, N_i . The area-weighted mean patch size was computed by dividing the summation of the squared patch sizes, S_i^2 , by S_i . Finally, an edge-to-area ratio will be computed for each habitat type by dividing the total number of edges by the number of grid cells of that habitat.

These analyses will be conducted on the reinterpreted 1984 image and the 1994 image to describe habitat changes on the ORR during the past decade. In addition, a change map can be developed by overlaying the 1994 image on the 1984 image and identifying grid cells that differ in their land use/land cover classification between years. This analysis will capture more fine-scale transitions; for example, simple comparison of percentages might not detect loss of pine plantation in some areas of the Reservation but gain in other areas, whereas a change map would detect these transitions.

Changes in the abundance and spatial distribution of the major vegetation communities will be monitored in the future at regular time intervals. A five-year remapping interval is proposed, unless land use/land cover changes are observed to be occurring rapidly or in habitats of particular interest. If so, a more frequent remapping interval will be considered.

Survey of habitats on operable units

Endpoint species on the ORR will receive contaminant exposure by using Operable Units (both source and aquatic integrator) to meet life history requirements (e.g. obtaining food, water, or shelter on the OU). The amount of use that an operable unit receives by endpoint species is expected to be proportional to the amount and type of habitat present on the OU. OUs with little or no suitable habitat are likely to receive minimal use (and therefore present a minimal risk to endpoint species) while those with extensive suitable habitat are likely to receive considerable use (and present a greater risk to endpoint species). This information will serve to aid the prioritization of source OUs for the implementation of RI/FS activities. To evaluate the potential use that endpoint species may make of OUs, the amount and types of habitat present on OUs must be determined.

Extent and arrangement of habitat types on OUs will be estimated by overlaying the map of OUs on the 1994 habitat map. Spatial extent of each habitat type will be computed as area (ha) and percent of each OU by using standard algorithms available within the geographic information system. In addition, spatial characteristics about habitat distribution (e.g., patch size, number of patches, connectivity, etc.) can be computed by using algorithms such as SPAN (Turner 1990) or FRAGSTATS (McGarigal and Marks 1993).

A preliminary evaluation of habitat in all OUs on the ORR was performed for this plan (see Table 15 and in Fig. 10). These analyses are preliminary and have not been verified. However, these analyses indicate that about 28% of total area within OUs on the ORR is classified as urban (both high and low density), 31.2% grass or pasture, and 39.1% forested (all types combined).

Long-term use of land use/land cover mapping data

The land use/land cover mapping data will form the basis for the future development of species-specific models for use in the assessment of risks to endpoint species from both contamination and remedial actions. Conducting a full set of experimental and field studies to understand species' responses to the variety of reservation-wide changes in habitat quantity or quality that may occur is both extremely difficult and costly. Therefore, to evaluate potential impacts that contamination and remedial actions may have on endpoint species, species-specific models will be developed. Stochastic simulations (of potential ORR-wide habitat changes) with a model can be replicated many times and the results summarized statistically, thereby providing an estimate of the range of potential effects. Modeling allows the manager to explore the implications and risks associated with events

for which landscape-level experiments are not feasible. Spatially explicit population models consider both species-habitat relationships and the arrangement of the habitats in space and time, going far beyond simple comparisons of suitable and unsuitable habitat. Thus, these models can address questions of fragmentation, isolation, habitat shape, and patch size, providing the manager with a tool to determine not only what types of habitats are needed but also how these habitats should be arranged across the landscape. Furthermore, potential effects of no management, alternative management strategies, land use changes, or natural events can be examined. The visualizations that typically accompany spatially explicit models also permit managers to “see” the effects of alternative management strategies on populations of interest. As changes in the abundance and spatial distribution of the major vegetation communities are described by using TM imagery on the Reservation, the dynamics of selected species will be simulated by using spatially explicit modeling integrated with the GIS data base.

Evaluating the risk posed to habitats and species by ER activities or land use changed is expressed as the probability of an undesired outcome. These probabilities are estimated by Monte Carlo simulations of the models under particular scenarios. The frequency distribution of outputs are then used to estimate the risk of an undesirable outcome, such as losing critical habitat for a protected species. “Risk maps” in which the probability of an event occurring (e.g., a disturbance or land cover change) is depicted for each grid cell of a map can also be generated for the Reservation. The probability of change (or loss) of a given species on each grid cell (or patch) across the reservation under different scenarios of management of land-use change would be depicted. Adequacy and availability of existing data, data needs, and endpoint species for which to produce spatially explicit models will be addressed in future revisions to this work plan.

3.3.1.2 Life History Profiles for Endpoint Species

The primary purpose of the analysis and mapping of habitat on the reservation is to evaluate the quantity and quality of available habitat for endpoint species on the reservation. However, each species requires different suitable habitat, based on its own life history requirements. Thus to develop models that may be used to estimate the abundance of endpoint species using habitat variables, a thorough knowledge of the habitat requirements and life history parameters of all assessment endpoint species is needed. Additionally, to accurately estimate contaminant exposure and to evaluate risk to these species, information concerning home and feeding ranges and food and habitat preferences is needed. Habitat and life history information is also needed for measurement endpoint species, so that their similarity (and therefore appropriateness) to the assessment endpoints may be evaluated. To this end, life history profiles for all endpoint species identified in Section 2.2 and Tables 10 and 11 will be developed.

Life history profiles will be developed by performing literature searches using Biological Abstracts, the Wildlife Review, and manual searching using existing publications. Recently published reports will be obtained by searching the Current Contents database. For some species (e.g. some T&E or INM species), little information may be available. In these cases attempts will be made to contact researchers working with these species so that unpublished information may be obtained.

Information for each life history profile includes

- physical description of organism (size, body weight, etc.),
- range (geographic area where the species occurs),

- abundance and density in different locations within its range,
- demographics (sex ratios, reproductive rates, longevity, annual mortality rates, etc.),
- migratory behavior,
- home or feeding range size and characteristics,
- distances traveled to forage,
- food habits (dietary preferences, food, soil, water consumption rates, etc.),
- interspecies interactions (competitors, predators, etc. and their influence), and
- habitat requirements (broken down by type of use, such as feeding, reproduction, etc. Emphasis will be placed on identifying critical habitat attributes that may be used to determine the presence, proportion of activity, or abundance of the endpoint species in a particular habitat.).

3.3.2 Ecological Risk Assessment

The ORR EMAP will serve two risk assessment purposes. First, it will provide the means to assess the ecological implications of contaminant exposures on individual source and aquatic integrator OUs. Individual OUs must characterize the sources of exposure to animals with large ranges by analyzing food items, soil, and water for COPCs. The ORR EMAP will provide the information necessary to estimate the actual exposure of large animals to contaminants on the OU including habitat use, diet, soil and water consumption, background exposure. Similarly, for the FS, the individual OUs will characterize the habitat destruction associated with remedial options and the ORR EMAP will provide information on the amount of the habitat on the ORR, any special status of the habitat, and use of the habitat by endpoint species and communities.

Second, the ORR EMAP will assess the risks to the terrestrial due to the combined effects of contaminants and habitat disturbances. This activity will serve to indicate the risks to the reservation-scale ecological endpoints and, by integrating ecological risks across the reservation, will provide a basis for ultimately determining that remediation has been successful. Such a determination must occur before the ORR can be removed from the National Priority List.

3.3.2.1 Screening-Level Ecological Risk Assessment

The first purpose, assessing large-scale risks of contaminants and physical disturbances on individual OUs, will be served by making the results of the tasks described in this plan available for RI and FS analyses. In addition, the ORR EMAP staff will be available to advise and assist in those assessments.

The second purpose, assessing the integrated risks of contaminants and ER activities to the ecological endpoints will be served by performing a screening assessment for those endpoints. This assessment will compile existing information concerning the endpoint populations and communities and their exposure to current contamination and to habitat loss associated with prior or ongoing remedial actions. It will address the following issues: which of the ecological assessment endpoints are significantly at risk, which of the COPCs are significantly contributing to ecological risks (i.e., which COPCs require more detailed investigation), and which of the OUs is significantly contributing to ecological risks? Results of this assessment will serve as the first summary of ecological risks on the scale of the ORR and will update and refine the data gaps analysis presented in Sect. 3.2. The first

reservation-scale screening ecological risk assessment will be submitted by August 31, 1995.

All risk assessments must have endpoints. The assessment endpoints are the actual valued entities to be assessed and protected. For ecological risk assessments of the ORR, the assessment endpoint populations and communities and the group within the conceptual model that they represent are summarized in Table 10. The endpoints are described quantitatively and in greater detail by Suter et al. (1994).

All risk assessments will be conducted in a manner consistent with published direction and guidance from EPA (EPA 1989a, EPA 1989b, Risk Assessment Forum 1992), and guidance from staff of EPA Region IV, and the Tennessee Department of Environment and Conservation. In particular, ecological risk assessments for the ORR will be based on weight-of-evidence. That is, rather than relying on theoretical models and standard laboratory toxicity values, the ecological risk assessments will be based on knowledge of the state of the ORR ecosystems, and the actual toxicity of the media that occur on the ORR. This approach is described in more detail by Suter et al. (1994).

3.3.2.2 Contamination and Toxicological Profiles for Endpoint Species

To adequately evaluate the significance of contaminant body burdens and contaminant exposures (and potential effects) estimated for endpoint species at the ORR, observations at the ORR must be compared to those from other locations. To facilitate these comparisons, contamination and toxicological profiles will be developed for each endpoint species.

Contamination and toxicological profiles will be developed by performing literature searches using Biological Abstracts, the Wildlife Review, the PolTox (Pollution and Toxicology) database, and manual searching using existing publications. Recently published reports will be obtained by searching the Current Contents database. For many species, little or no information may be available. In these cases the profile will use data from related species (if available), with the assumption that toxicity will be comparable between these related species.

Each contamination and toxicological profile will consider the following classes of contaminants: inorganics, radionuclides, volatile organics, semivolatile organics, organochlorines (including PCBs, dioxins, and related compounds), and PAHs. Pesticides other than organochlorines will not be considered because they are not currently COPCs on the ORR. If they should become COPCs, the profiles will be updated so that they are addressed. Each profile will include information on body burdens, bioindicators of exposure, toxicity threshold levels (e.g., LD₅₀, LC₅₀, LOAEL, NOAEL, etc.)*, direct and indirect effects associated with exposure, and exposure and effect modifying factors (i.e. if exposure to multiple contaminants produce synergistic or antagonistic effects).

* LD₅₀ = lowest dose at which 50% mortality occurs; LC₅₀ = lowest concentration at which 50% mortality occurs; LOAEL = lowest observed adverse effects level; NOAEL = no observed adverse effects level.

3.3.3 Preliminary Field Sampling and Analysis Plan

3.3.3.1 Analyte Residues in Terrestrial Biota: Background Values

Justification

Measures of contaminant concentrations in food resources are required to estimate contaminant exposure experienced by terrestrial endpoint species, both at the source OU and ORR-wide levels (see Section 3.2). Data from uncontaminated areas are needed to determine if the contaminant levels observed in food items indicate anthropogenic contamination or naturally occurring analyte concentrations. Analyte concentrations in endpoint food resources from source OUs that exceed those from uncontaminated reference areas are indicative of contamination. To provide background analyte concentrations in food resources for endpoint species, for use in risk assessments at both the source OU and ORR-wide levels, biota samples will be collected and analyte concentrations determined. In FY 1995, sampling will focus on small mammals, earthworms, and vegetation. Additional data on other food resources may be added in future updates to this plan if the life history profiles for endpoint species (see Section 3.3.2) indicate significant data gaps.

Analytes to be considered

Samples will be collected in FY 1995 and stored at -20° C until early FY 1996 when funding is available for analysis.

To differentiate between naturally occurring levels and anthropogenic concentrations, residue analysis will only be performed for those analytes that may occur naturally. The presence of all VOCs, SVOCs, PAHs, PCBs, pesticides, and related compounds in the environment is a result of human activities and is assumed to indicate anthropogenic contamination. Therefore no true background value can be established for these compounds and they will not be analyzed for.

Background residue analyses will be restricted to inorganic elements and radionuclides. Metals include Ag, Al, As, Ba, Be, B, Cd, Co, Cr, Cu, F, Hg, Li, Mo, Ni, Pb, Sb, Se, Sr, Tl, V, Zn, and Zr. Radionuclide analyses will include gross alpha, gross beta, and gamma emitting isotopes. Background data on gross alpha and gross beta concentrations will be used for screening surveys of source OU biota in the following manner: if samples from source OUs have gross alpha, or gross beta that exceed those from the background samples, analyses for the specific radionuclides responsible will be performed. If gross alpha and gross beta concentrations in source OU samples do not exceed background, no further radionuclide analyses are needed.

Sampling locations

Background biota samples will be collected so that they are as comparable to the background soils data (Watkins et al. 1993) as possible. The Background Soils Characterization Project (BSCP) evaluated analyte concentrations in soils from 72 locations on the ORR—12 locations in each of 6 geologic formations on the ORR (Chapultepec, Chickamauga-Bethel Valley, Chickamauga-K-25, Copper Ridge, Dismal Gap, and Nolichucky). Analyses of inorganic and radionuclide analytes were performed on four composite samples (each consisting of soil from three randomly selected locations within each formation) per formation. The BSCP found that, while there were significant differences in analyte concentrations in soils from different formations, in general, there

were no significant differences in analyte concentrations in soils from different locations within the same formation (Watkins et al. 1993).

Because differences in soil analyte concentrations were observed between but not within each formation, background biota sampling will be focused on each formation, with only one area being sampled per formation. While soil samples were collected from multiple habitat types, for continuity and comparability, all biota samples (from all formations) will be collected from one habitat type. Mixed hardwood forest was chosen as a representative habitat type because it is common throughout the ORR (Figs. 7-9) and occurs in all six soil formations sampled by the BSCP. Within each soil formation, all sites sampled by the BSCP at which mixed hardwood forest habitat occurred will be identified. One of these sites will be randomly selected as the location for the biota sampling. In future updates to this plan, background biota data may be collected at additional habitat types (e.g. old field, pine-hardwood, pine, etc.), if the preliminary ecological risk assessments (Sect. 3.3.2) suggest that this is a data gap.

Small mammal sampling

Background analyte concentrations will be determined for rodents (mice and voles) and shrews.

Shrews will be sampled using pitfall traps and drift fences (Call 1986). Four 100-m transects will be established in each of the six sampling areas. Each transect will consist of 21 pitfall traps (plastic containers, 0.5–1 L in size, buried in the ground so that their tops are flush with the surface) located about 10 m apart and arranged in a zig-zag pattern. Drift fence (wire mesh approximately 20 cm high and buried approximately 4 cm into the ground) will run between adjacent pitfall traps.

After installation of the pitfall traps, they will be covered with small boards for about 10 days to allow for resident animals to become accustomed to their presence (Call 1986). After this 10 day period, the boards will be removed and each area will be sampled for 10 days. Traps will be checked each morning. A maximum of five short-tailed shrews will be collected from each area and retained for residue analyses. All other small mammals will be released immediately following recording of trapping observations.

Rodents (mice and voles) will be collected using snap-traps. Fifty traps will be placed in each of the six sampling areas in five parallel transects of ten traps each. Transects and traps within transects will be 10 m apart. Traps will be operated in each area for a maximum of five nights (Kirkland 1982) or until five rodents are collected. Traps will be baited with oats and peanut butter and will be checked daily.

Age, sex, body measurements (weight, tail length, head/body length), and species of all small mammals (rodents and shrews) collected will be recorded. Whole-body samples will be washed with a non-ionic shampoo to remove external contamination and thoroughly rinsed with deionized water. Samples will be stored at -20 °C in a locked freezer.

Earthworm sampling

Earthworms will be collected using a mustard solution (Gunn 1992) as an expellant as described by Bechtel (1994). This technique is non-intrusive, minimizes personnel exposure to contaminants, and is not as labor intensive as hand-sorting. Three sampling sites, approximately 30 m apart will be established in each of the six sampling areas. All

worms collected from each sampling site will be combined into one composite sample (for a total of three from each area). Samples will be taken by forcing a 50-cm-by-50-cm stainless steel frame approximately 10 cm into the soil. Approximately 3–6 L of a mustard and water suspension will then be slowly applied to the soil surface within the frame using a watering can (to obtain even spread and minimal ponding). Surfacing earthworms will be collected using forceps until no additional worms emerge from the soil (approximately 20 to 25 minutes). Multiple locations will be sampled at each sampling site until a total of approximately 200 g (wet weight) of worms are collected from each sampling site.

Upon collection, each worm will be rinsed in the field with deionized water (to remove soil and expellant), placed in a sealed petri dish, and set in a cooler. It is essential that all worms be kept moist, intact, alive, and handled at a minimum. Parameters recorded for each earthworm will include: sample location, sample site, date collected, species, wet weight (to be measured in the laboratory), presence of clitellum (girdle), and general physical condition including overt signs of lesions or other abnormalities. In addition, a running total of earthworms collected since the time expellant was added (in 2-min intervals) should be recorded.

All worms will be maintained in the lab for 3 days to allow voiding of intestinal tract contents (depuration). Depurate (intestinal tract contents) collected from the earthworms will be composited by each of the five sample sites per area. Samples will be stored at -20 °C in a locked freezer.

Vegetation sampling

Vegetation will be collected at five sampling sites in each of the six sampling areas. These sampling sites will coincide with those used for earthworm sampling. At each site, two vegetation samples (approximately 200 g each) will be collected from one species of deciduous tree and one species of ground cover (grass or herbaceous vegetation). (Sampling and analysis of seeds and fruits may be added in future revisions of this plan.) The same species of tree and of ground cover will be collected at each site. These species will be chosen on the basis of being representative of a large proportion of the vegetation on source and aquatic integrator OUs. Ground cover will be sampled by compositing both leaves and stems at each sampling point. The plant species from which samples were collected will be recorded for all sample types.

Plant samples will be gently rinsed with deionized water to remove external contamination, air dried, and stored at -20 °C in a locked freezer.

3.3.3.2 Reservation-Wide Wildlife Presence and Distribution Survey

Information on the actual presence and distribution of assessment and measurement endpoint species is important to characterize the magnitude of potential contaminant effects. In addition, such information, when coupled with measurements of contaminant body burdens, provides a baseline against which future effects of remedial actions can be measured.

One cost-effective method of obtaining general presence and distribution information and collecting samples is to conduct a survey of roadkilled animals on the ORR highways. An *ad hoc* roadkill survey has been conducted each year since 1990. This task will formalize that survey and take advantage of the dataset already available.

The survey will be conducted from August through November. This period corresponds with the period of dispersal for many mammal species, the fall migratory period for neotropical migrant bird species, and the pre-winter foraging period for many resident animals of all classes.

The survey will be conducted by driving the following roads three times each week during the survey period: Bethel Valley Road, State Highway 95, State Highway 58, and Scarboro Road. The entire length of these roads within the ORR will be surveyed each day. Experience from the *ad hoc* survey has shown that a driving speed of 35–40 mph is sufficiently slow to allow an experienced observer to spot all roadkills on the shoulders and lanes of the roads.

At each new specimen, the observer stops, identifies the animal to species, and records the location, species, condition, age class, and other observations. For specimens of endpoint species that are in sufficiently good shape, samples of appropriate organs will be collected and frozen for future analyses. Results of such future analyses may be used to provide baseline information on the distribution of contaminant concentrations within ORR populations of endpoint species and to monitor changes in contaminant concentrations over time.

3.4 PROJECT ORGANIZATION AND MANAGEMENT PLAN

The project will be managed by a project manager who receives technical oversight from a technical review committee. The technical review committee is composed of senior technical staff from relevant disciplines within the Environmental Sciences Division, including the ORR Area Manager. Each project task will be conducted by a principal investigator.

3.5 QUALITY ASSURANCE/QUALITY CONTROL

Project implementation will be in accordance with quality assurance provisions of DOE order 5700.6c "Quality Assurance" and with the Environmental Restoration Quality Program Plan (ERD 1993). During the first year of the project, a quality assurance plan will be prepared. All field activities will be conducted in accordance with approved procedures. All activities that involve handling of vertebrate animals will be approved by the ORNL Animal Care and Use Committee.

3.6 GENERAL HEALTH AND SAFETY REQUIREMENTS

The Environmental Restoration Program has established a health and safety program to provide a safe workplace for all employees, subcontractors, visitors, and guests (ERD 1991). Each project conducted for the Environmental Restoration Program must develop a health and safety plan that describes task specific procedures to be followed during project activities. Such a plan will be prepared and approved during the first year of the project—prior to implementation of any significant field activities.

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APPENDIX A

**FACILITATOR'S SUMMARY* OF DATA QUALITY
OBJECTIVES MEETINGS**

* Attachments to the facilitator's summary that duplicate material presented elsewhere in the report have been omitted from this appendix.

**AGREEMENTS AND ACTION ITEMS OF DQO TEAM
OAK RIDGE RESERVATION ECOLOGICAL RISK ASSESSMENT
APRIL 14, 1994**

DRAFT FOR FFA PARTY REVIEW

May 5, 1994

AGREEMENTS AND ACTION ITEMS OF DQO TEAM
OAK RIDGE RESERVATION ECOLOGICAL RISK ASSESSMENT
APRIL 14, 1994
(DRAFT FOR FFA PARTY REVIEW)

1.0 MEETING PURPOSE

A meeting was held on April 14, 1994 to initiate the development of data quality objectives (DQOs) and strategies for the Oak Ridge Reservation (ORR) ecological risk assessment program. The problems (objectives), decisions, a portion of the inputs, decision criteria and limits of error were discussed and general agreements were made.

2.0 ATTENDEES

A list of attendees can be found in Attachment A. Representatives of EPA Region IV, TDEC, DOE-ORO and Martin Marietta attended. The meeting was facilitated by Mitzi Miller of EQM. During the introductions the team members outlined the following objectives:

- gain background of the problem
- identify ecological assessment endpoints
- identify the study and decisional boundaries
- determine how decisions will be made
- identify the data needed
- obtain the data from a previous meeting and summarize existing data
- provide the information for generation of a plan for ecological monitoring by August
- determine how ecological monitoring will address CERCLA issues
- identify any analytical data generation and validation needs

3.0 USING THE DATA QUALITY OBJECTIVE PROCESS

Mitzi Miller provided a general summary of the Data Quality Objectives (DQO) process and how it is to be used. Most team members were familiar with the process. The process will address each of the issues identified by the attendees and described in the introduction.

4.0 BACKGROUND AND EXISTING DATA

Tom Ashwood provided a summary of the existing terrestrial contamination data collected from reviews of 150 publications over the last twenty years. Attachment B includes the summary information presented. Dr. Ashwood emphasized that this represented most of the information available. He also indicated that the only animals which had enough data to allow trending were deer and geese. The first page of Attachment B provides the species or groups monitored, the area in which the animal was found, the organ or tissue monitored, the contaminants measured, concentration of

the contaminant and the background concentration where available.

The second page summarizes the white-tailed deer hunt information. The graph shows the percentage of deer confiscated based on gross beta determinations which exceeded criteria. The gross beta measurements are based on one minute counts of a leg bone. Contamination exists if the result in gross beta counts are greater than 50% above background. The graph indicates that confiscations reached a high of ~6% in 1987 and decreased to between 1 and 2% from 1990 to 1993.

The locations of the contaminated deer when killed were plotted and no patterns emerged. Two theories for the decline in the percent confiscated/contaminated are presented below.

- The high percentage occurred during a four year draught. During the draught, the deer may have ventured further from their normal travel areas in search of food.
- Hunting is not allowed in areas of known contamination on the ORR. Early hunts during the high contamination years may have resulted in killing deer which normally ventured through contaminated areas. As a result of the decreased deer population, deer may be roaming less. Contaminated deer may be staying closer to areas of contamination and are not in the hunted areas.

In addition to screening for beta emitters, the livers of the deer have been screened for cesium-137. No deer have been confiscated based on the elevated levels of cesium-137.

The last page of Attachment B contains statements based on ecological risk assessments of two areas on the Oak Ridge Reservation.

In conclusion, previous data indicate that sites on the ORR have contamination which may impact the terrestrial biota. Previous data indicate that species which have been monitored have shown some type contamination in some individuals.

Similar data are available for aquatic biota from the BMAP program. It was not summarized at this meeting because many of the team members are familiar with the information from BMAP.

3.0 DEVELOPMENT OF DQOs

3.1 Problems/Objectives

A draft list of potential problems from Attachment C were

considered, modified and prioritized.

Problem #1

Given the previous data, it is important to determine if contamination has resulted in ecological impacts on terrestrial and aquatic species and to determine the extent of the impacts across the ORR. If ecological impact occurs, identification of the potential sources of contamination causing the impact should be determined. The group acknowledged that due to synergistic effects, the transience of many species and multiple locations of the same contaminant in the ORR, specific source identification will be difficult. If potential sources are found, the goal is to determine what actions are required to mitigate the ecological impact.

Problem #2

The draft problem #2 was replaced by problems 2 and 3. The team agreed that the problem #2 of Appendix C should be addressed in the feasibility study (FS) for each source operable unit (OU).

The new problem #2 is to assess the ecological system to appropriate level required to allow evaluation of impacts of potential activities.

Problem # 3

Once data has been gathered for problems 1 and 2, a determination of the effectiveness of remedial action^s (or no action is select cases) must be evaluated. ~~If the remedial action results in an adverse ecological impact, alternate strategies may be chosen.~~

3.2 Decisions

Draft decision statements are presented in Appendix C. Draft decision statements #2, 3, 4, and 6 were felt to belong in the site specific ecological RI plans. Draft decision #5 was felt to be a Tennessee Wildlife Resource (TWRA) ??A, issue and not a CERCLA issue. This project deals primarily with CERCLA issues.

The following decisions were agreed upon:

1. Determine whether there is an unacceptable ecological impact.
2. Determine whether interim actions are necessary due to the ecological impact.
3. If an ecological impact exists, the "major" contributing sources to the problem and appropriate remedies must be identified, evaluated and appropriately implemented.

3.3 Inputs

For each problem and decision, the inputs must be listed which will allow a solution to the problem and decisions to be made. Inputs developed for the ORR Ecological Risk Assessment and agreements reached concerning these are as follows:

Input #1 - Programmatic Ecological Strategy

Several programmatic data inputs were addressed. DOE and Energy Systems expressed concern that multiple programs have needs for ecological data. The concern is that one document should integrate many of the data needs. Region IV and TDEC indicated that their data needs were those of CERCLA which invokes applicable and relevant action levels from other EPA programs.

Agreement #1

It was agreed by all parties that non-CERCLA data needs from other programs can be addressed in the ORR ecological planning document. However, these data needs MUST be clearly identified as not being part of CERCLA requirements. These data needs may be included in appendices in the document. This will allow DOE to address biological monitoring across programs and to include these needs in the ORR global work plan discussed in Action Item #3 below.

A second programmatic issue raised by Region IV was the need for one programmatic document which presents the overall conceptual model, guidance in ORR decision strategy, and how the data and decisions from each OU will be integrated for an overall ORR ecological risk assessment. DOE could use this plan to integrate the various programs across the ORR. The following actions and agreements were made to allow appropriate programmatic guidance.

Agreement #2

An ecological risk management program plan will be issued to all program and OU managers and team members. Each RI will address data needs and decision requirements identified in the program document. Some data is needed which is not OU specific. These data needs and decisions which apply to the entire ORR will be identified in a separate work plan which will be applied to the reservation wide data needs. In order to accomplish this strategy, the following action items, dates and responsible parties were agreed upon.

Action Item #1

An existing programmatic document will be updated to include the conceptual model, the terrestrial data needs, and the data endpoints or decision criteria from a program perspective. This

will be updated by Environmental Sciences Division, team member Glenn Suter. A draft of the updated program document will be completed by August 1994. The document will be distributed to appropriate OU staff and managers and DOE staff by Mildred Ferre.

Action Item #2

Operating instruction language in the Federal Facilities Agreement (FFA) for the ORR should be updated to reflect the implementation of the ecological risk assessment program document and the relationship between the ecological program document and the work plans for each OU. This wording will be generated by Mildred Ferre of DOE by the next meeting.

Action Item #3

A work plan outlining the data needs applicable to the ORR on a global basis will be generated by Energy Systems Environmental Sciences Division. Tom Ashwood is responsible for generation of a draft of this document by August 31, 1994. More detailed information as to specific data inputs will be discussed later in this section of the meeting minutes.

Input #2 - Conceptual Models

Attachment D provides the conceptual models presented by Glenn Suter of Environmental Sciences Division. Dr. Suter's first model provides the inputs and outputs of the terrestrial ecological system and includes the relationship between the small scale OU specific and large scale ORR inputs and outputs. One modification made by the group was to divide the herbivorous, vermivorous, and omnivorous wildlife into small and large categories. The ORR reservation wide inputs would include the large herbivorous, vermivorous, and omnivorous wildlife while each OU would include the small wildlife.

Three models respectively outlining the terrestrial, aquatic, and wetland impacts of physical disturbances from potential remedial actions were presented.

These models will be used in the programmatic documents to explain the relationships between the inputs and outputs from each OU and the reservation wide data needs.

Action Item #4 - Conceptual Models in the ORR Program Document

Dr. Suter will include the models and provide a discussion of each model in the programmatic ecological document addressed in Action Item #3.

1

Input #3 - Entity, Societal, and Sensitivity Criteria

The following criteria will be used to determine the species to examine in both global and OU specific studies. The general goal in species selection for monitoring is to consider the most sensitive receptors relative to the contaminants.

The entity selection criteria include Sensitivity (i.e. sensitivity to specific contaminants per various exposure pathways) and Biological Importance (nutrient cycling, energy flow, and keystone species status). The EPA Framework for Ecological Risk Assessment also considers "Policy Goals and Societal Importance" as a selection criterion. Societal importance includes the importance of various species to the ecological system and population impacts of each species.

Agreement #3

It was agreed that societal issues can be used as a selection criteria provided that selection criteria also include biological importance and sensitivity.

3.4 Boundaries

The ORR ecological boundaries include the integration of each OU. The primary boundary is the Oak Ridge Reservation DOE boundary. Further consideration may be given to species which travel outside the reservation and their effect on the ecological system of the general region.

Each OU will address the ecological system with respect to the OU specific boundaries and area, with input to the integration across the reservation.

These boundaries are flexible meaning that if contamination exists a specific OU or the reservation, a larger boundary may be used to assess ecological risk.

3.5 Decision Criteria

In order to determine when enough data has been collected and to assess when a detrimental effect has occurred, criteria describing an impact must be identified. One important agreement was reached with respect to decision criteria:

Agreement #4

The team agreed that an impact would occur based on the 20% degradation rule listed below. An impact occurs when:

- a greater than 20% reduction in abundance or production of an endpoint population occurs.
- a greater than 20% reduction in species richness or abundance of an endpoint community occurs.
- a greater than 20% reduction in survival growth or reproduction of organisms in a toxicity test that are representative of an endpoint species or communities occur.

Any toxic effect on Threatened and Endangered Species individuals is considered a significant impact.

Since laws dictate special criteria for wetlands, the above rules do not apply to wetlands. No net loss of wetlands functions is allowed. Wetland ecological functionality includes habitat, hydrology, and nutrient cycle.

Dr. Suter has developed a white paper describing the degradation criteria.

Action Item #5

Dr. Suter will provide to Mildred Ferre a copy of the paper for distribution to the team by May 13, 1994. The team will review the criteria for discussion at the next meeting.

3.6 Limits of Decision Error

The team agreed that quantitating the limits of decision error is very difficult due to the many unquantified uncertainties. These include frequency of trapping species, uncertain estimates of population on the reservation, lack of variance estimates in analytical measurements on tissue, and risk assessment error. The group agreed that each potential source of error would be identified and discussed. Discussions may be qualitative in nature. This discussion will serve to make all readers aware of the uncertainty in ecological risk assessments.

4.0 INFORMATION NEEDS FOR FURTHER APPLICATION OF DQO PROCESS

In order to assess any specific DQOs for the ORR global sampling and ecological characterization effort, TDEC and Region IV indicated a need to see more summaries of existing data. Energy Systems indicated that little information beyond that presented exists for terrestrial data but more detail and assessment of the existing data could be documented.

TDEC and Region IV were also interested in the recommendations from the technical team prior to continuing the DQO process. This resulted in the following action items:

Action Item #6

A summary of the terrestrial and aquatic (BMAP) data will be provided. This will include:

- trend analysis for deer and geese studies,
- general lists of species monitored and contaminants

Lists of potential contaminants of concern will be provided. These will be based on known contaminants identified at the OU level, fate and transport, exposure pathways, toxicological effects, and bioaccumulation.

Lists of potential species to monitor will be provided based on data gaps from existing information. Species will be sorted as to herbivores, omnivorous, vermivores and carnivores. Species selection rational will be presented. Gaps in aquatic data will also be provided.

An update of the conceptual model will be provided per Action Item #4. A schedule for accomplishing the proposed monitoring strategy will be identified.

The information will be provided to the team by May 13, 1994. Tom Ashwood will coordinate generating the information. Mildred Ferre will distribute the information.

Action Items #7

Meeting minutes will be completed by Mitzi Miller, reviewed by Environmental Sciences and DOE and distributed for final review by the team by May 13, 1994. The final review will be completed at the next meeting.

5.0 FUTURE MEETING

A meeting is planned to complete the DQOs for the ORR work plan. This meeting will be held in Oak Ridge on May 20, 1994 beginning at 8:30 am. The location will be determined by Mildred Ferre. The agenda includes:

- Review of past meeting minutes, agreements and status of action items.
- Presentation of the revised conceptual models, existing data, data gaps, data needs, and rational for sampling various species.
- Agreement as to the inputs for making decisions based on the programmatic decision criteria.

- Agreement as to any specific decision criteria, sampling plans and schedules.

6.0 LIST OF ATTACHMENTS

Attachment A - Attendees
Attachment B - Context and Terrestrial Data Summary
Attachment C - Draft Problem and Decision Statements
Attachment D - Conceptual Models
Attachment E - Concurrence Record

Attachment A - Attendees

Name	Organization	Phone/Fax
Larry Barnthouse	ESD/ORNL	574-7393
Glenn Suter	ESD/ORNL	574-7306
Tom Mattis	Jacobs	220-4850
Brad Sample	ESD/ORNL	241-3933
Jim Loar	ESD/ORNL	574-7323
David Carden	DOE ERD	576-9262
Mildred Ferre'	DOE ERD	576-8018
Victor Weeks	EPA Region IV	404-347-3016
Lynn Wellman	EPA Region IV	404-347-1586
Tom Ashwood	ESD/ORNL	574-7542
Jeffery Parr	DQP/ER/MMES	241-4882
Eric Diebert	TDEC	481-0163
Jean Ottinger	TDEC	481-0163
Doug McCoy	TDEC	481-0163
Mitzi Miller	EQM	927-3102

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**AGREEMENTS AND ACTION ITEMS OF DQO TEAM
OAK RIDGE RESERVATION ECOLOGICAL RISK ASSESSMENT
MAY 20, 1994**

Completion of Steps 1-5 of the DQO Process

DRAFT FOR FFA PARTIES REVIEW

AGREEMENTS AND ACTION ITEMS OF DQO TEAM
OAK RIDGE RESERVATION ECOLOGICAL RISK ASSESSMENT
MAY 20, 1994
Completion of Steps 1-5 of the DQO Process

DRAFT FOR FFA PARTY REVIEW

1.0 MEETING PURPOSE

In the previous meeting, the problems, decisions, a portion of the inputs, and select decision criteria were agreed upon for the Oak Ridge Reservation (ORR) ecological characterization and monitoring program. The planned focus of the current meeting was to agree upon the inputs (terrestrial data collection needs), the decision criteria (rules), and limits of error.

The facilitator stressed the need to proceed through the limits of error and design optimization in order to assess the resources versus benefits of the data collection effort. The group, however, decided not to proceed through the limits of error at the present time. Discussions at the current meeting thus proceeded only through step five of the DQO Process - "Decision Rules".

NOTE: To ensure that resources can be effectively balanced with decision criteria, it is critical that limits of uncertainty be established and an understanding developed for the magnitude of sampling error that can exist in an ecological risk estimate. The FFA parties should revisit this step in the process at a later date.

2.0 REVIEW OF PREVIOUS MEETING MINUTES

The team discussed the agreements and action item from the previous April 14, 1994 meeting. These has been previously submitted to EPA and TDEC for review. Comments were as follows:

Section 3.1 Problems/Objectives

The three problems were reviewed. Problems 1 and 2 remain per the meeting of April 14, 1994. Problem 3 was edited by removing the last sentence. The revised Problem #3 is as follows:

Revised Problem #3:

"Once data has been gathered for problems 1 and 2, a determination of the effectiveness of remedial action (or no action in select cases) must be evaluated."

Section 3.2 Decisions

There were no comments on this section of the document.

Section 3.3 Inputs

There were no comments on this section of the document.

Section 3.4 Boundaries

The team edited the following boundary condition to include an additional condition. The following is to be added as a fourth paragraph in section 3.4:

"Boundaries of evaluation may be habitat or species specific. After mapping, the habitat the boundaries may need to be reassessed. It is likely that habitat surveys will be needed in order to assess boundaries."

Section 3.5 Decision Criteria

Agreement #4 from the April 14, 1994 meeting was modified to ensure that species "of special concern" were protected. Species of Special Concern include those to which a 20% degradation may not be tolerable due to the unique sensitivity of the species (e.g. limited range, lower reproductivity, etc.). The definition of an impact and thus Agreement #4 was modified as follows:

"The team agreed that an impact would occur based on the 20% reduction in abundance rules listed below. An impact occurs when:

- a greater than 20% reduction in abundance or production of an endpoint population occurs.
- a greater than 20% reduction in species richness or abundance of an endpoint community occurs.
- a greater than 20% reduction in survival growth or reproduction of organisms in a toxicity test that are representative of an endpoint species or communities occur.

NOTE: For Species of Special Concern, the 20 degradation definition as noted above may not be tolerable. A Species of Special Concern is one that due to it's sensitivity (e.g. limited range, lower reproductivity, etc.) must be treated with special concern.

Any toxic effect on Threatened and Endangered Species individuals is considered a significant impact.

Since laws dictate special criteria for wetlands, the above rules do not apply to wetlands. No net loss of wetlands function is allowed in wetlands. Wetland ecological functionality includes habitat, hydrology, and nutrient cycle."

3.0 ADDITIONAL INPUT INFORMATION

Additional input information was generated by ORNL Environmental Science staff and presented by three scientists of ORNL. The information presented included the data provided to the team previous to the meeting with some revisions as presented here.

3.1 Assessment and Measurement Endpoints and Conceptual Models

Attachment A was presented by Dr. Glenn Suter and provides the summary of the decision rules/criteria in the form of Assessment and Measurement Endpoints per pages A-4 and A-5.

Attachment A Figures 1-5 provide a conceptual models of the various pathways within and between OUs via groundwater, surface water and soils. The air pathway was not considered. The air exposure path is believed to be the least contributor to risk.

3.2 Summary of Terrestrial Data

Attachment B includes the summary of terrestrial data and animal species present on the ORR and was presented by Dr. Tom Ashwood. The shaded species on the summary are cross referenced to the shaded species on the overall list of ORR species. A map was presented which outlined locations of any major sample collections and the concentrations reported in the tissue. The maps were engineering drawing size and copies were provided for USEPA and TDEC.

A table listing the habitats and rarity status of plants listed by state or federal agencies which occur on the ORR is also part of Attachment B.

3.3 Preliminary Reservation-Scale Ecological Assessment and Measurement Endpoint Species or Community

Attachments C-1, C-3 respectively present the initial listing of groups and species for assessment and measurement endpoints as presented by Dr. Suter. Attachment C-2 provides the rationale for selection of the assessment endpoint species. Data gaps related to the measurement endpoints indicate that there is little if any data on reptiles and amphibians. Significant data gaps exist related to general population and habitat information.

The Measurement Endpoint Species and Communities may not actually be sampled, but the plants and animals eaten by the species in question may be examined to determine the effect of contaminants on their food source. Surrogate species may be used instead of those listed. It should be noted that no coyotes or birds were listed as potential measurement endpoint species under the group predators and scavengers. These species cover large ranges and it was felt that sampling time and effort was best spent on species

more easily found on the reservation.

It was further pointed out that the body burden is not necessarily tied to the measurement endpoint. All species listed in the measurement endpoint table will not necessarily be sampled. Some will be assessed based on their available food sources, some will be assessed based on modeling contaminants measured from each OU and will be extrapolated over the entire ORR.

Agreement #1

It was generally agreed that Attachments C-1 and C-3 serve as a starting point for terrestrial data gathering for both the ORR and each OU. However, further cost assessment and detailed specification of each species and the method of assessment or measurement will be defined in the work plan due in August of 1994 as agreed upon in the April 1994 meeting.

3.4 Contaminants of Potential Concern (COPCs) for the ORR Environmental Monitoring and Assessment

Attachment D-1 presents the rationale and list of COPCs presented by Dr. Brad Sample. These COPCs are those proposed for monitoring in terrestrial species. It must be clearly understood that more COPCs may be included in water and soil monitoring than those listed for ecological monitoring. This is due to the fate and transport between the environment and the species. As an example many of the volatile organics are too volatile to bioaccumulate in animal tissue and therefore are not recommended as COPCs in tissue. These compounds are being assessed in soil and groundwater in the OUs due to human health effects. The focus was to examine fate and transport in tissue based on published data regarding the contaminants in question. Attachment D-2 presents the summary of the key COPCs.

Agreement #2

The general list of COPCs will be the starting point for the work plan for ecological risk assessment and for specific OU ecological risk assessment. It was agreed that silver must be added to the metals COPC list. It was further agreed that action levels for gross alpha and beta may be used to trigger isotope-specific analyses.

Plausible scenarios for use of radiological screening include:

- Samples will only be analyzed for specific alpha emitting radionuclides (e.g. uranium and transuranic isotopes) if gross alpha concentrations exceed predetermined screening levels. The work plan will identify the screening levels

and will include an iterative procedure for determining which specific analytes will be analyzed and in what order

- Samples will be analyzed for strontium-90 if gross beta concentrations exceed predetermined screening levels identified in the work plan.
- Technetium-99 will only become an analyte if the preliminary screening risk assessment identifies a need for its analysis.
- Samples will be scanned for gamma emitting radionuclides - primarily cobalt-60 and cesium-137.

Action Item #1

Dr. Tom Ashwood agreed to take the action to meet with analytical laboratory radiochemists and those who established the ORNL Deer Monitoring program to discuss the feasibility of establishing action levels for total alpha and beta which would be sufficiently above background and which would trigger isotopic analyses.

Agreement #3

Dioxins and furan analyses were discussed. Rather than monitor each species, it was agreed to examine fish in specific watershed areas likely to have dioxin contamination. If significant dioxin levels are found in these fish, the fish eating species may be examined for dioxins and furans. Significant concentration levels were not defined by the group. It was further pointed out that a preliminary EPA ecological report indicated that little uptake of dioxins and furans had been found in terrestrial species.

When asked the levels of detection of COPCs which were deemed significant, the reply was that the toxicity levels for each species were significant. The general discussion indicated that the levels currently being monitored for human health were sufficiently low with the exception of thallium.

Agreement #4 and Unassigned Action Item #2

It was generally agreed that the toxicity level for thallium was lower than current monitoring levels in soil and water. An action must be taken to determine how low to measure thallium in terrestrial species. Further verification that other COPCs are being measured at levels which are sufficiently low for ecological risk assessment should be

performed.

4.0 LIMITS OF DECISION ERROR

The group agreed that there are large error windows on all the ecological risk assessment results. The group decided not to estimate the goals for the limits of decision error at this time.

WARNING: Without an analysis of the uncertainty associated with ecological measurements and development of limits for acceptable levels of uncertainty, it will be very difficult to assure that the proposed work plan will be sufficient to meet the decisional needs of the FFA Parties. By successfully going through DQO steps One to Five, we can now be assured that we will be getting THE RIGHT TYPE OF DATA, however, the other side of the coin must also be addressed, i.e GETTING THE RIGHT QUANTITY OF DATA. Without the establishment of error tolerances, we cannot readily balance resources and effort with measurement uncertainty.

5.0 PROJECT MANAGEMENT

Some concern was expressed by TDEC as to the management mechanism which would assure effective communication of the ORR ecological risk assessment and the respective OU assessments. It was pointed out that the same staff, Drs. Suter, Ashwood and Sample would be the focal point for both the ORR and OU specific assessments. Additionally, Dr. Wilson McGinn will be the focal person for all risk assessment on a reservation wide basis.

Mildred Ferre' presented the proposed FFA wording which outlines the management strategy and agreement between the DOE, EPA and TDEC as shown in Attachment E.

Action Item # 3

Mildred Ferre' indicated that she will be presenting the new FFA wording and the strategy generated from these meetings to the Environmental Restoration Program Managers on or prior to the June 24, 1994 meeting with EPA Region 4 and TDEC. She agreed to be the focal point for obtaining summary information related to the status of ecological risk assessment from each of the OUs in progress. This information will be provided to EPA Region 4 and TDEC. She will be supported in this effort by Drs. Ashwood, Suter, and Sample.

Attachment F provides the list of attendees.

ENVIRONMENTAL RESTORATION RISK ASSESSMENT INITIATION, IMPLEMENTATION, AND INTERACTION OPERATING INSTRUCTIONS

The following delineates the Federal Facility Agreement (FFA) operating instructions to ensure active communications and consistent development and application of risk assessment methodologies and techniques at all sites or areas under the Environmental Restoration Division responsibility.

POLICIES:

1. It is the policy of DOE-OR/ERD that Martin Marietta Energy Systems, through its Environmental Restoration Division, will serve as the integrating contractor for all Environmental Restoration technical issues. As such, Energy Systems is the lead DOE contractor for human health and ecological risk assessment.
2. It is the policy of the DOE-ORO/ERD that all risk assessment activities be conducted consistent with guidelines provided by the Environmental Protection Agency (EPA) and the Agency for Toxic Substances and Disease Registry (ATSDR) and best scientific judgement.
3. It is the policy of DOE-ORO/ERD that all risk assessment activities within their purview shall be centralized through the Energy Systems/ERD Risk Assessment Coordinator (RAC). The primary role of the RAC is to provide technical expertise and support in the area of risk assessment to: (i) the Energy Systems/ERD Director of Technical Integration, and (ii) the Energy Systems/ERD Site Program Managers or their counterparts (for work managed by contractors other than Energy Systems), and to interface with the DOE-ORO/ERD Technical Coordinator. A Central Risk Assessment Council (CRAC) of experts and site risk assessment team leaders will support the RAC in pursuit of these objectives.
4. It is the policy of DOE-ORO/ERD that integrator operable unit risk assessments be coordinated closely with the source operable unit risk assessments to ensure that source impacts to the integrator are adequately defined. For example, the reservation-wide risk assessment being managed by the Energy Systems Environmental Sciences Division must develop formal interfaces with each site operable unit risk assessment program to ensure that data regarding contaminants that may impact reservation ranging species are collected. The need for information on an integrator unit basis must be considered when establishing the priorities for initiation of source operable unit remedial investigations.
5. It is the policy of DOE-ORO/ERD that integrator operable units be evaluated using a baseline risk assessment approach only in cases where remedial actions,

other than continued institutional controls, are presently feasible. For cases in which the upstream or input source operable units are supplying a continuing and significant contribution of contaminants to a given integrator exposure pathway, screening level risk assessments will be conducted and updated periodically through input from routine environmental monitoring. If specific areas are identified in integrator operable units where significant risk reductions can be effectively achieved, these may become candidates for accelerated remedial actions or removal actions in which baseline risk assessments may be needed.

RESPONSIBILITIES:

1. DOE-ORO/ERD Director approves policies and procedures pertaining to conducting risk assessments within the DOE-ORO/ERD.
2. The DOE-ORO/ERD Technical Coordinator is responsible for:
 - a. liaising among the RAC/CRAC, risk assessment contractors/subcontractors, and regulatory agencies;
 - b. ensuring procedures and policies identified herein are duly executed by appropriate personnel;
 - c. representing risk assessment resource needs in budget, manpower, and scheduling to appropriate management attention.
3. The Energy System ERD Director ensures implementation of policies and procedures affecting Energy Systems Environmental Restoration Program which have been approved by the Director of DOE-OR/ERD.
4. The Energy Systems/ERD Director of Technical Integration is responsible for:
 - a. implementing the procedures and policies for participants in the ORO/ERD;
 - b. obtaining and identifying staff as necessary to execute Energy Systems responsibilities and assignments required by risk assessment activities.
 - c. coordination of Energy Systems resource requirements (financial, manpower, etc.) to carry out needed risk assessment consistent with regulatory obligations;
5. The Energy Systems ERD RAC is responsible for:

- a. directing the activities of the CRAC by coordinating appropriate support from a variety of expert sources for accomplishing ERD risk assessment activities;
 - b. recommending schedules to the Site Program Managers and to DOE Primer Contractor Project Managers for the required performance of risk assessment in site projects;
 - c. risk assessment results, recommendations, project status reports, and periodic updates to Site Program Managers on a regular and/or as-needed basis;
 - d. ensuring the (i) ERD risk assessment policies and approaches are current and in accordance with the latest EPA and ATSDR recommendations, (ii) the most recent risk assessment information and data, (iii) communicating these policies and requirements to all risk assessment staff;
 - e. using the Risk Assessment Guidance for Superfund: Vol. 1 and 2 and the Health Assessment Manual: Format, Guidelines, and Methodology as reference manuals, conducting appropriate risk model comparisons, validations, sensitivity analyses, and uncertainty analyses to ensure the most scientifically defensible risk assessment methodologies are available to the ERD.
6. The Energy Systems/ERD CRAC, in support of the RAC:
- a. will provide advice and guidance on appropriate risk assessment methodology and procedure;
 - b. develop appropriate methods, procedures, models, and/or data needed to fulfill Site Programs' risk assessment needs;
 - c. provide appropriate review of site programs' risk assessment implementation to ensure consistent application and interpretation of risk assessment guidance and methodology;
 - d. support ERD risk assessment needs through the research and development of critical risk assessment data gaps;

7. Energy Systems/ERD Site Program Managers are responsible for:
 - a. ensuring implementation of risk assessment policies and procedures set by the RAC and approved by the DOE-ORO/ERD Energy Systems Environmental Restoration Technical Integration Director;
 - b. ensuring that risk assessment is maintained as an integral part of project activities throughout;
 - c. ensuring integration of risk assessment in site projects at their onset;
 - d. ensuring that appropriate CRAC personnel involved, either directly or in advisory roles, in the risk assessment activities conducted in site projects;

Attachment F - Attendees

Name	Organization	Phone/Fax	4/14	5/20
Larry Barnthouse	ESD/ORNL	574-7393	x	
Glenn Suter	ESD/ORNL	574-7306	x	x
Tom Mattis	Jacobs	220-4850	x	
Brad Sample	ESD/ORNL	241-3933	x	x
Jim Loar	ESD/ORNL	574-7323	x	x
David Carden	DOE ERD	576-9262	x	x
Mildred Ferre'	DOE ERD	576-8018	x	x
Victor Weeks	EPA Region IV	404-347-3016	x	x
Lynn Wellman	EPA Region IV	404-347-1586	x	x
Tom Ashwood	ESD/ORNL	574-7542	x	x
Jeffery Parr	DQP/ER/MMES	241-4882	x	
Eric Diebert	TDEC	481-0163	x	x
Jean Ottinger	TDEC	481-0163	x	x
Doug McCoy	TDEC	481-0163	x	x
Mitzi Miller	EQM	927-3102	x	x
Dawn Miller	ORNL-ER	576-3989		x
Mark Tardiff	ORNL-ER	574-4055		x
Ana Gonzalez	TDEC/DOE-O	481-0163		x

APPENDIX B

**FIGURES FOR SUMMARY OF AQUATIC MONITORING
PROGRAMS**

B-3

Fig. B.1. Map of the Oak Ridge Reservation showing the location of biological monitoring sites.

Fig. B.2. Location of offsite reference streams used in the Oak Ridge Reservation biological monitoring programs.

REFERENCE SITES

TAXON RICHNESS

YEAR 3

Aug 1986-Jul 1987

Number of taxa
per Sample

Circle Size Corresponds
to Biomass (wet wt)
per Sample

Values are Means for
Quarterly Samples:
Oct., Jan., Apr., Jul

Fig. B.3. Comparisons of benthic macroinvertebrate richness and biomass at 17 reference sites. The Clear Creek and Hinds Creek sites at the bottom of the figure are outside the map boundaries.

Fig. B.4. Temporal trends in DNA integrity in redbreast sunfish determined by an alkaline unwinding assay to estimate the number of DNA breaks. The EFPC site was located just downstream of the Y-12 Plant and Hinds Creek was used as the offsite reference stream.

CUMULATIVE NUMBER OF OFFSPRING, 1990

Fig. B.5 Results of an *in situ* toxicity test conducted in 1990 with fingernail clams (*Sphaerium fabale*) at two sites on East Fork Poplar Creek (EFK) downstream of the Y-12 Plant and two offsite reference streams, Brushy Fork (BFK) and Beaver Creek (BVK).

Fig. B.6 Results of an in situ toxicity test conducted in 1991 with fingernail clams (*Sphaerium fabale*) at two sites on East Fork Poplar Creek (EFK) downstream of the Y-12 Plant and four offsite reference streams, Brushy Fork (BFK), Bull Run (BRK), Beaver Creek (BVK), and Hinds Creek (HCK).

Fig. B.7. Changes in pH with increasing distance below the S-3 ponds in 1974-1975 and 1981-1982.

Fig. B.8. Map of upper Bear Creek showing the location of the biological sampling sites (•) in relation to various waste disposal areas. The sampling sites range from BCK 12.36 to BCK 9.40.

ORNL-DWG 85-11050

Fig. B.9. Map of lower Bear Creek showing the location of biological sampling sites BCK 7.87 to BCK 3.25.

Fig. B.10 Total fish densities at two monitoring sites in the headwaters of Bear Creek, May 1984–April 1992.

ORNL-DWG 94M-1108

Fig. B.11. Total fish and Tennessee dace densities in upper Bear Creek at BCK 12.36, May 1984–April 1993.

Fig. B.12. Change in total dissolved solids in headwaters of Bear Creek just below S-3 ponds.

Fig. B.13. Distribution of the Tennessee dace (*Phoxinus tennesseensis*).

Fig. B.14. Taxonomic richness of benthic macroinvertebrates in Bear Creek. Mean values were calculated for each of three years between May 1984 and April 1987.

Fig. B.15 Mean total richness of benthic macroinvertebrates at three sites in the middle to upper reaches of Bear Creek.

Fig. B.16 Comparison of total daily precipitation and the frequency of occurrence of zero flow in Bear Creek, 1985–1987. Sampling dates are indicated by open circles (zero flow) and closed circles (flow > 0.02 L/s). Precipitation was measured at a rain gage located near BCK 10.6 in the Bear Creek Burial Grounds. Total precipitation at the NOAA Oak Ridge site for the period May through October is shown in parentheses as percent of normal.

Fig. B.17. Map of East Fork Poplar Creek showing the location of the seven biological monitoring sites and the reference site on Brushy Fork (BFK) north of Oak Ridge.

Fig. B.18. Changes in fish population abundance in four streams on the Oak Ridge Reservation. EFK = East Fork Poplar Creek; BFK = Bear Creek; WCK = White Oak Creek; MIK = Mitchell Branch.

Fig. B.19. Changes in fish population abundance in two reference streams, the headwaters of White Oak Creek (WCK) above ORNL and Brushy Fork (BFK) north of Oak Ridge.

Fig. B.20. Mean annual taxonomic richness of benthic macroinvertebrates in East Fork Poplar and two reference streams, Brushy Fork (BFK) and Hinds Creek (HCK).

IN SITU TOXICITY TESTS WITH
FINGERNAIL CLAM (*SPHAERIUM FABALE*)

1988

1989

1990

Fig. B.21 Survival and growth of fingernail clams in screened, plexiglass containers placed in East Fork Poplar Creek (EFK) and several reference streams, including Brushy Fork (BFK), Hinds Creek (HCK), and Bull Run (BRK).

ORNL DWG 94M-1028R3

B-24

Fig. B.22. Map of upper East Fork Poplar Creek at the Y-12 Plant. N/S = North-South pipes; AS8 = Area Source Study Site 8; NHP-i/NHP-o = New Hope Pond inlet/outlet; LR = Lake Reality. NHP was drained in November 1988 and capped in 1989.

Fig. B.23. Snail survival in East Fork Poplar Creek (EFPC) before and after dechlorination. Survival was zero at the North-South pipes (NSP) before dechlorination and $\geq 90\%$ after dechlorination. An uncontaminated tributary of EFPC was used as the reference site.

Fig. B.24. Fish species richness in upper East Fork Poplar Creek (EFK) and a reference stream (BFK), May 1985–March 1993.

ORNL-DWG 94M-1111

Fig. B.25. Fish species richness in lower East Fork Poplar Creek (EFK) and a reference stream (BFK), May 1985–March 1993.

Fig. B.26. Number of pollutant-tolerant and pollution-intolerant fishes in East Fork Poplar Creek (EFK) and two reference streams, Hinds Creek (HCK) and Brushy Fork (BFK).

Fig. B.27. Mercury loading to East Fork Poplar Creek at the Y-12 Plant boundary.

B-30

Fig. B.28. Decrease in total mercury concentration in East Fork Poplar Creek just below Lake Reality, 1989–1992.

ORNL-DWG 91M-14155

Fig. B.29, Location of biological monitoring sites and liquid and solid radioactive waste disposal areas in White Oak Creek watershed.

Fig. B.30. Mean total richness (number of taxa/sample) and mean EPT (Ephemeroptera, Plecoptera, and Trichoptera) richness (number of EPT taxa/sample) of the benthic macroinvertebrate community in Fifth Creek during the April sampling periods of 1987–1991. Standard error (± 1 SE) of the mean for each parameter is represented by the vertical bars. Results of ANOVA site comparisons are given above the symbols (ns = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; **** = $p < 0.0001$). FFK = Fifth Creek kilometer.

Fig. B.31 Mean total richness (number of taxa/sample) and mean EPT (Ephemeroptera, Plecoptera, and Trichoptera) richness (number of EPT taxa/sample) of the benthic macroinvertebrate community in Melton Branch during the April sampling periods of 1987–1991. Standard error (± 1 SE) of the mean for each parameter is represented by the vertical bars. Results of ANOVA site comparisons are given above the symbols (ns = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; **** = $p < 0.0001$). MEK = Melton Branch kilometer.

Fig. B.32 Mean total richness (number of taxa/sample) and mean EPT (Ephemeroptera, Plecoptera, and Trichoptera) richness (number of EPT taxa/sample) of the benthic macroinvertebrate community in White Oak Creek during the April sampling periods of 1987–1991. Standard error (± 1 SE) of the mean for each parameter is represented by the vertical bars. Results of ANOVA site comparisons are given above the symbols (ns = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; **** = $p < 0.0001$). WCK = White Oak Creek kilometer.

Fig. B.33. Relative differences in the mean response of three detoxification enzymes for male redbreast sunfish from each of three reference streams compared to White Oak Creek (WOC), summer 1991. Values above (or below) the zero line indicate that the response for fish from each of the reference streams was higher (or lower), respectively, than that for fish from WOC. Asterisks indicate those values that were significantly different ($\alpha = 0.05$) from WOC. EROD = 7-ethoxyresorufin O-deethylase; P450 = cytochrome P450; NADPH = NADPH-cytochrome c reductase.

Fig. B.34. Drawing of the Oak Ridge K-25 Site area showing the location of sampling sites on Poplar Creek. The drawing of the area delineated as "detail map" is Fig 35.

Fig. B.35 Detail drawing of the biological sampling locations on Mitchell Branch. CRERP = Clinch River Environmental Restoration Program; MIK = Mitchell Branch kilometer; PCK = Poplar Creek kilometer.

Fig. B.36. Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa in upper McCoy Branch above and below Rogers Quarry, 1989-1993. MCK = McCoy Branch kilometer, which indicates the distance above the confluence with the Clinch River (MCK 2.03 and MCK 1.40 are located above and below Rogers Quarry, respectively). WCK 6.80 is located on White Oak Creek north of Bethel Valley Road and approximately 6 km west of McCoy Branch.

ORNL-DWG 94M-1109

Fig. B.37. Average monthly arsenic concentrations in the outfall of Rogers Quarry, January 1986–July 1993. The EPA national ambient water quality criterion for protection of freshwater aquatic life to chronic exposure of arsenic is 0.19 mg/L.

Fig. B.38 Average monthly selenium concentrations in the outfall of Rogers Quarry, January 1986–July 1993.

Fig. B.39. Average concentrations ($\pm$ SE) of mercury ($\mu\text{g/g}$, wet weight) in sunfish collected from November 1992 through March 1993 at sites on the ORR. Fish are redbreast sunfish (*Lepomis auritus*) at MIK 0.6, EFK sites (bottom values where two appear) and WCK 2.9; rock bass (*Ambloplites rupestris*) at BCK sites; and bluegill (*L. macrochirus*) at the remaining sites.

Fig. B.40. Average concentrations of mercury in redbreast sunfish ($n=8$) collected at sites in East Fork Poplar Creek, 1984-1993. The 1984 data are from the Oak Ridge Task Force study (TVA 1985).

Fig. B.41. Mercury in redbreast sunfish from East Fork Poplar Creek, before and after New Hope Pond closure (November 1988).

Fig. B.42. Average concentrations ($\pm$ SE) of PCBs ($\mu\text{g/g}$, wet weight) in sunfish collected from November 1992 through March 1993 at sites on the ORR. Fish are redbreast sunfish (*Lepomis auritus*) at MIK 0.6, EFK sites (bottom values where two appear) and WCK 2.9; rock bass (*Ambloplites rupestris*) at BCK sites; and bluegill (*L. macrochirus*) at the remaining sites.

Fig. B.43. Average concentrations of PCBs in redbreast sunfish (n=8) collected at sites in East Fork Poplar Creek, 1985-1993.

Fig. B.44 Mean PCB concentrations in rockbass from Bear Creek near the old NPDES weir (BCK 4.5) and near EFPC (BCK 0.6). Closure of oil retention ponds on NT6 and NT7 was completed in April 1990.

Fig. B.45. Location of sites on the ORR where channel catfish were collected for PCB analysis in August/November 1993.

APPENDIX C
TERRESTRIAL ANIMAL SPECIES ON THE OAK RIDGE RESERVATION

Terrestrial^a animal species on the Oak Ridge Reservation

Common Name	Trophic Category ^b	Status ^c
<i>Birds</i>		
Gadwall (<i>Anas strepera</i>)	AqH	
Common Gallinule (<i>Gallinula chloropus</i>)	AqH	
Mallard (<i>Anas platyrhynchos</i>)	AqH	
Pintail (<i>Anas acuta</i>)	AqH	
Tundra Swan (<i>Cygnus columbianus</i>)	AqH	
Blue-Winged Teal (<i>Anas discors</i>)	AqH	
American Widgeon (<i>Anas americana</i>)	AqH	
Bufflehead (<i>Bucephala albeola</i>)	AqI	
Black Duck (<i>Anas rubripes</i>)	AqI	
Ruddy Duck (<i>Oxyura jamaicensis</i>)	AqI	
Common Goldeneye (<i>Bucephala clangula</i>)	AqI	
Pied-Billed Grebe (<i>Podilymbus podiceps</i>)	AqI	
Lesser Scaup (<i>Aythya affinis</i>)	AqI	
Green-Winged Teal (<i>Anas crecca</i>)	AqI	
Black Tern (<i>Chlidonias niger</i>)	AqI	
Carolina Chickadee (<i>Parus carolinensis</i>)	ArI	
Brown Creeper (<i>Certhia americana</i>)	ArI	
Yellow-Billed Cuckoo (<i>Coccyzus americanus</i>)	ArI	
Yellow-Shafted Flicker (<i>Colaptes auratus</i>)	ArI	
Golden-Crowned Kinglet (<i>Regulus satrapa</i>)	ArI	
Ruby-Crowned Kinglet (<i>Regulus calendula</i>)	ArI	
Red-Breasted Nuthatch (<i>Sitta canadensis</i>)	ArI	
White-Breasted Nuthatch (<i>Sitta carolinensis</i>)	ArI	
Baltimore Oriole (<i>Icterus galbula</i>)	ArI	
Orchard Oriole (<i>Icterus spurius</i>)	ArI	
American Redstart (<i>Setophaga ruticilla</i>)	ArI	
Yellow-Bellied Sapsucker (<i>Sphyrapicus varius</i>)	ArI	INM
Scarlet Tanager (<i>Piranga olivacea</i>)	ArI	
Summer Tanager (<i>Piranga rubra</i>)	ArI	
Tufted Titmouse (<i>Parus bicolor</i>)	ArI	
Red-Eyed Vireo (<i>Vireo olivaceus</i>)	ArI	
Solitary Vireo (<i>Vireo solitarius</i>)	ArI	
White-Eyed Vireo (<i>Vireo griseus</i>)	ArI	
Yellow-Throated Vireo (<i>Vireo flavifrons</i>)	ArI	
Bay-Breasted Warbler (<i>Dendroica castanea</i>)	ArI	
Black and White Warbler (<i>Mniotilta varia</i>)	ArI	
Black-Throated Green Warbler (<i>Dendroica virens</i>)	ArI	
Blackburnian Warbler (<i>Dendroica fusca</i>)	ArI	
Blackpoll Warbler (<i>Dendroica striata</i>)	ArI	
Blue-Winged Warbler (<i>Vermivora pinus</i>)	ArI	
Cape May Warbler (<i>Dendroica tigrina</i>)	ArI	
Cerulean Warbler (<i>Dendroica cerulea</i>)	ArI	
Chestnut-Sided Warbler (<i>Dendroica pensylvanica</i>)	ArI	
Hooded Warbler (<i>Wilsonia citrina</i>)	ArI	
Magnolia Warbler (<i>Dendroica magnolia</i>)	ArI	

Terrestrial^a animal species on the Oak Ridge Reservation

Common Name	Trophic Category ^b	Status ^c
<i>Birds (cont.)</i>		
Myrtle Warbler (<i>Dendroica coronata</i>)	ArI	
Parula Warbler (<i>Parula americana</i>)	ArI	
Pine Warbler (<i>Dendroica pinus</i>)	ArI	
Prairie Warbler (<i>Dendroica discolor</i>)	ArI	
Prothonotary Warbler (<i>Protonotaria citrea</i>)	ArI	
Tennessee Warbler (<i>Vermivora peregrina</i>)	ArI	
Worm-Eating Warbler (<i>Helminthos vermivorus</i>)	ArI	
Yellow Warbler (<i>Dendroica petechia</i>)	ArI	
Yellow-Throated Warbler (<i>Dendroica dominica</i>)	ArI	
Downy Woodpecker (<i>Picoides pubescens</i>)	ArI	
Hairy Woodpecker (<i>Picoides villosus</i>)	ArI	
Pileated Woodpecker (<i>Dryocopus pileatus</i>)	ArI	
Red-Bellied Woodpecker (<i>Melanerpes carolinus</i>)	ArI	
Red-Headed Woodpecker (<i>Melanerpes erythrocephalus</i>)	ArI	INM
Yellowthroat (<i>Geothlypis trichas</i>)	ArI	
Eastern Bluebird (<i>Sialia sialis</i>)	FI	
Chuck-Will's-Widow (<i>Caprimulgus carolinensis</i>)	FI	
Acadian Flycatcher (<i>Empidonax virescens</i>)	FI	
Great Crested Flycatcher (<i>Myiarchus crinitus</i>)	FI	
Least Flycatcher (<i>Empidonax minimus</i>)	FI	
Blue-Gray Gnatcatcher (<i>Poliophtila caerulea</i>)	FI	
Eastern Kingbird (<i>Tyrannus tyrannus</i>)	FI	
Purple Martin (<i>Progne subis</i>)	FI	
Common Nighthawk (<i>Chordeiles minor</i>)	FI	
Eastern Phoebe (<i>Sayornis phoebe</i>)	FI	
Bank Swallow (<i>Riparia riparia</i>)	FI	
Barn Swallow (<i>Hirundo rustica</i>)	FI	
Cliff Swallow (<i>Hirundo pyrrhonota</i>)	FI	
Rough-Winged Swallow (<i>Stelgidopteryx serripennis</i>)	FI	
Chimney Swift (<i>Chaetura pelagica</i>)	FI	
Whip-Poor-Will (<i>Caprimulgus vociferus</i>)	FI	
Eastern Wood-pewee (<i>Contopus virens</i>)	FI	
Red-Winged Blackbird (<i>Agelaius phoeniceus</i>)	GI	
Catbird (<i>Dumetella carolinensis</i>)	GI	
Brown-Headed Cowbird (<i>Molothrus ater</i>)	GI	
Cattle Egret (<i>Bubulcus ibis</i>)	GI	
Common Egret (<i>Casmerodius albus</i>)	GI	
Killdeer (<i>Charadrius vociferus</i>)	GI	
Horned Lark (<i>Eremophila alpestris</i>)	GI	
Eastern Meadowlark (<i>Sturnella magna</i>)	GI	
Mockingbird (<i>Mimus polyglottos</i>)	GI	
Ovenbird (<i>Seiurus aurocapillus</i>)	GI	
American Robin (<i>Turdus migratorius</i>)	GI	
Spotted Sandpiper (<i>Actitis macularia</i>)	GI	
Common Snipe (<i>Gallinago gallinago</i>)	GI	

Terrestrial^a animal species on the Oak Ridge Reservation

Common Name	Trophic Category ^b	Status ^c
<i>Birds (cont.)</i>		
Starling (<i>Sturnus vulgaris</i>)	GI	
Brown Thrasher (<i>Toxostoma rufum</i>)	GI	
Gray-Cheeked Thrush (<i>Catharus minimus</i>)	GI	
Hermit Thrush (<i>Catharus guttatus</i>)	GI	
Louisiana Water Thrush	GI	
Swainson's Thrush (<i>Catharus ustulatus</i>)	GI	
Wood Thrush (<i>Hylocichla mustelina</i>)	GI	
Kentucky Warbler (<i>Oporornis formosus</i>)	GI	
Swainson's Warbler (<i>Limnothlypis swainsonii</i>)	GI	
American Woodcock (<i>Scolopax minor</i>)	GI	
Bewick's Wren (<i>Thryomanes bewickii</i>)	GI	
Carolina Wren (<i>Thryothorus ludovicianus</i>)	GI	
House Wren (<i>Troglodytes aedon</i>)	GI	
Winter Wren (<i>Troglodytes troglodytes</i>)	GI	
Golden Eagle (<i>Aquila chrysaetos</i>)	LC	SE
Northern Harrier (<i>Circus cyaneus</i>)	LC	ST
Broad-Winged Hawk (<i>Buteo platypterus</i>)	LC	
Cooper's Hawk (<i>Accipiter cooperii</i>)	LC	ST
Red-Shouldered Hawk (<i>Buteo lineatus</i>)	LC	INM
Red-Tailed Hawk (<i>Buteo jamaicensis</i>)	LC	
Sharp-Shinned Hawk (<i>Accipiter striatus</i>)	LC	ST
Sparrow Hawk (<i>Falco sparverius</i>)	LC	
Barn Owl (<i>Tyto alba</i>)	LC	INM
Barred Owl (<i>Strix varia</i>)	LC	
Great Horned Owl (<i>Bubo virginianus</i>)	LC	
Screech Owl (<i>Otus asio</i>)	LC	
Loggerhead Shrike (<i>Lanius ludovicianus</i>)	LC	
Black Vulture (<i>Coragyps atratus</i>)	LC	INM
Turkey Vulture (<i>Cathartes aura</i>)	LC	
Bobwhite (<i>Colinus virginianus</i>)	LH	
Red Crossbill (<i>Loxia curvirostra</i>)	LH	
Mourning Dove (<i>Zenaida macroura</i>)	LH	
Rock Dove (<i>Columba livia</i>)	LH	
Purple Finch (<i>Carpodacus purpureus</i>)	LH	
American Goldfinch (<i>Carduelis tristis</i>)	LH	
Canada Goose (<i>Branta canadensis</i>)	LH	
Ruffed Grouse (<i>Bonasa umbellus</i>)	LH	
Ruby-Throated Hummingbird (<i>Archilochus colubris</i>)	LH	
Slate-Colored Junco (<i>Junco hyemalis</i>)	LH	
Pine Siskin (<i>Carduelis pinus</i>)	LH	
Bachman's Sparrow (<i>Aimophila aestivalis</i>)	LH	
Chipping Sparrow (<i>Spizella passerina</i>)	LH	
Field Sparrow (<i>Spizella pusilla</i>)	LH	
Fox Sparrow (<i>Passerella iliaca</i>)	LH	
Grasshopper Sparrow (<i>Ammodramus savannarum</i>)	LH	ST

Terrestrial^a animal species on the Oak Ridge Reservation

Common Name	Trophic Category ^b	Status ^c
<i>Birds (cont.)</i>		
Henslow's Sparrow (<i>Ammodramus henslowii</i>)	LH	FC
House Sparrow (<i>Passer domesticus</i>)	LH	
Lark Sparrow (<i>Chondestes grammacus</i>)	LH	INM
Song Sparrow (<i>Melospiza melodia</i>)	LH	
Swamp Sparrow (<i>Melospiza georgiana</i>)	LH	
Vesper Sparrow (<i>Pooecetes gramineus</i>)	LH	INM
White-Throated Sparrow (<i>Zonotrichia albicollis</i>)	LH	
Wild Turkey (<i>Meleagris gallopavo</i>)	LH	
Cedar Waxwing (<i>Bombycilla cedrorum</i>)	LH	
Indigo Bunting (<i>Passerina cyanea</i>)	LO	
Canvasback (<i>Aythya valisineria</i>)	LO	
Cardinal (<i>Cardinalis cardinalis</i>)	LO	
Yellow-Breasted Chat (<i>Icteria virens</i>)	LO	
American Coot (<i>Fulica americana</i>)	LO	
Common Crow (<i>Corvus brachyrhynchos</i>)	LO	
Ring-Necked Duck (<i>Aythya collaris</i>)	LO	
Wood Duck (<i>Aix sponsa</i>)	LO	
Common Grackle (<i>Quiscalus quiscula</i>)	LO	
Blue Grosbeak (<i>Guiraca caerulea</i>)	LO	
Evening Grosbeak (<i>Coccothraustes vespertinus</i>)	LO	
Rose-Breasted Grosbeak (<i>Pheucticus ludovicianus</i>)	LO	
Blue Jay (<i>Cyanocitta cristata</i>)	LO	
Redhead (<i>Aythya americana</i>)	LO	
Rufous-Sided Towhee (<i>Pipilo erythrophthalmus</i>)	LO	
Bald Eagle (<i>Haliaeetus leucocephalus</i>)	P	SE, FE
Double-Crested Cormorant (<i>Phalacrocorax auritus</i>)	P	INM
Bonaparte's Gull (<i>Larus philadelphia</i>)	P	
Herring Gull (<i>Larus argentatus</i>)	P	
Ring-Billed Gull (<i>Larus delawarensis</i>)	P	
Black-Crowned Night Heron (<i>Nycticorax nycticorax</i>)	P	INM
Great Blue Heron (<i>Ardea herodias</i>)	P	
Green Heron (<i>Butorides striatus</i>)	P	
Belted Kingfisher (<i>Ceryle alcyon</i>)	P	
Common Loon (<i>Gavia immer</i>)	P	
Common Merganser (<i>Mergus merganser</i>)	P	
Hooded Merganser (<i>Lophodytes cucullatus</i>)	P	
Red-Breasted Merganser (<i>Mergus serrator</i>)	P	
Osprey (<i>Pandion haliaetus</i>)	P	SE
<i>Mammals</i>		
Big Brown Bat (<i>Eptesicus fuscus</i>)	FI	
Eastern Small-Footed Bat (	FI	FC, INM
Evening Bat (<i>Nycticeius humeralis</i>)	FI	
Gray Bat	FI	FE, SE

Terrestrial^a animal species on the Oak Ridge Reservation

Common Name	Trophic Category ^b	Status ^c
<i>Mammals (cont.)</i>		
Hoary Bat (<i>Lasiurus cinereus</i>)	FI	
Indiana Bat	FI	FE, SE
Little Brown Bat	FI	
Rafinesque's Big-Eared Bat	FI	FC, INM
Red Bat (<i>Lasiurus borealis</i>)	FI	
Silver-Haired Bat (<i>Lasionycteris noctivagans</i>)	FI	
Keen's Myotis (<i>Myotis keeni</i>)	FI	
Eastern Pipistrelle (<i>Pipistrellus subflavus</i>)	FI	
Eastern Mole (<i>Scalopus aquaticus</i>)	GI	
Least Shrew (<i>Cryptotis parva</i>)	GI	
Long-Tailed Shrew (<i>Sorex dispar</i>)	GI	FC, INM
Masked Shrew (<i>Sorex cinereus</i>)	GI	INM
Short-Tailed Shrew (<i>Blarina brevicauda</i>)	GI	
Smokey Shrew (<i>Sorex fumeus</i>)	GI	INM
Southeastern Shrew (<i>Sorex longirostris</i>)	GI	INM
Spotted Skunk (<i>Spilogale putorius</i>)	GI	
Striped Skunk (<i>Mephitis mephitis</i>)	GI	
Bobcat (<i>Lynx rufus</i>)	LC	
Cougar^d (<i>Felis concolor</i>)	LC	FE
Feral Cat	LC	
Coyote (<i>Canis latrans</i>)	LC	
Feral Dog (<i>Canis familiaris</i>)	LC	
Red Fox (<i>Vulpes fulva</i>)	LC	
Long-Tailed Weasel (<i>Mustela frenata</i>)	LC	
Beaver (<i>Castor canadensis</i>)	LH	
Eastern Chipmunk (<i>Tamias striatus</i>)	LH	
Eastern Cottontail (<i>Sylvilagus floridanus</i>)	LH	
Gray Squirrel (<i>Sciurus carolinensis</i>)	LH	
Groundhog (<i>Marmota monax</i>)	LH	
Southern Flying Squirrel (<i>Glaucomys volans</i>)	LH	
White-Tailed Deer (<i>Odocoileus virginianus</i>)	LH	
Gray Fox (<i>Urocyon cinereoargenteus</i>)	LO	
Muskrat (<i>Ondatra zibethica</i>)	LO	
Opossum (<i>Didelphis marsupialis</i>)	LO	
Raccoon (<i>Procyon lotor</i>)	LO	
Mink (<i>Mustela vison</i>)	P	
River Otter^e (<i>Lutra canadensis</i>)	P	ST
Southern Bog Lemming (<i>Synaptomys cooperi</i>)	SH	INM
Deer Mouse (<i>Peromyscus maniculatus</i>)	SH	
Eastern Harvest Mouse (<i>Reithrodontomys humulis</i>)	SH	
Golden Mouse (<i>Peromyscus nuttalli</i>)	SH	
House Mouse (<i>Mus musculus</i>)	SH	
Meadow Jumping Mouse (<i>Zapus hudsonius</i>)	SH	INM
Woodland Jumping Mouse (<i>Napaeozapus insignis</i>)	SH	INM
Meadow Vole (<i>Microtus pennsylvanicus</i>)	SH	

Terrestrial^a animal species on the Oak Ridge Reservation

Common Name	Trophic Category ^b	Status ^c
<i>Mammals (cont.)</i>		
Pine Vole (<i>Pitymys pinetorum</i>)	SH	
White-Footed Mouse (<i>Peromyscus leucopus</i>)	SO	
Hispid Cotton Rat (<i>Sigmodon hispidus</i>)	SO	
Rice Rat (<i>Oryzomys palustris</i>)	SO	
Norway Rat (<i>Rattus norvegicus</i>)	SO	
<i>Amphibians and Reptiles</i>		
Pond Slider (<i>Chrysemys scripta</i>)	AqH	
Cumberland Slider	AqH	INM
Yellow-Bellied Turtle (<i>Chrysemys scripta scripta</i>)	AqH	
Bronze Frog (<i>Rana clamitans clamitans</i>)	AqI	
Bullfrog (<i>Rana catesbeiana</i>)	AqI	
Leopard Frog (<i>Rana utricularia</i>)	AqI	
Northern Cricket Frog (<i>Acris crepitans crepitans</i>)	AqI	
Pickerel Frog (<i>Rana palustris</i>)	AqI	
Wood Frog (<i>Rana sylvatica</i>)	AqI	
Hellbender (<i>Cryptobranchus alleganiensis</i>)	AqI	FC, INM
Mudpuppy (<i>Necturus maculosus</i>)	AqI	
Northern Red Salamander (<i>Pseudotriton ruber ruber</i>)	AqI	
Spring Salamander (<i>Gyrinophilus porphyriticus</i>)	AqI	
Three-Lined Salamander (<i>Eurycea longicauda guttolineata</i>)	AqI	
Map Turtle (<i>Graptemys geographica</i>)	AqI	
Gray Tree Frog (<i>Hyla versicolor</i>)	ArI	
Spring Peeper Frog (<i>Hyla crucifer</i>)	ArI	
Upland Chorus Frog (<i>Pseudacris triseriata feriarum</i>)	ArI	
Fence Lizard (<i>Sceloporus undulatus</i>)	ArI	
Green Anole (<i>Anolis carolinensis carolinensis</i>)	ArI	
Rough Green Snake (<i>Opheodrys aestivus</i>)	ArI	
Broadhead Skink (<i>Eumeces laticeps</i>)	GI	
Five-Lined Skink (<i>Eumeces fasciatus</i>)	GI	
Ground Skink (<i>Scincella lateralis</i>)	GI	
Six-Lined Racer (<i>Cnemidophorus sexlineatus</i>)	GI	INM
Slender Glass Lizard (<i>Ophisaurus attenuatus</i>)	GI	INM
Tennessee Cave Salamander (<i>Gyrinophilus pallescens</i>)	GI	FC, ST
Green Salamander (<i>Aneides aeneus</i>)	GI	FC, INM
Red-Backed Salamander (<i>Plethodon cinereus cinereus</i>)	GI	
Slimy Salamander (<i>Plethodon glutinosus glutinosus</i>)	GI	
Spotted Salamander (<i>Ambystoma maculatum</i>)	GI	
Brown Snake (<i>Storeria dekayi</i>)	GI	
Eastern Crowned Snake (<i>Tantilla coronata</i>)	GI	
Eastern Worm Snake (<i>Carphophis amoenus amoenus</i>)	GI	
Northern Ringneck Snake (<i>Diadophis punctatus edwardsi</i>)	GI	
Red-Bellied Snake (<i>Storeria occipitomaculata</i>)	GI	
American Toad (<i>Bufo americanus</i>)	GI	

Terrestrial^a animal species on the Oak Ridge Reservation

Common Name	Trophic Category ^b	Status ^c
<i>Amphibians and Reptiles (cont.)</i>		
Eastern Marrow-Mouthed Toad (<i>Gastrophryne carolinensis</i>)	GI	
Eastern Spadefoot Toad (<i>Scaphiopus holbrooki holbrooki</i>)	GI	
Fowler's Toad (<i>Bufo woodhousei fowleri</i>)	GI	
Black King Snake (<i>Lampropeltis getulus</i>)	LC	
Black Rat Snake (<i>Elaphe obsoleta obsoleta</i>)	LC	
Corn Snake (<i>Elaphe guttata guttata</i>)	LC	
Eastern Hognose Snake (<i>Heterodon platyrhinos</i>)	LC	
Eastern Milk Snake (<i>Lampropeltis triangulum triangulum</i>)	LC	
Garter Snake (<i>Thamnophis sirtalis</i>)	LC	
Mole Snake (<i>Lampropeltis calligaster rhombomaculata</i>)	LC	
Northern Black Racer (<i>Coluber constrictor constrictor</i>)	LC	
Northern Copperhead (<i>Agkistrodon contortrix mokasen</i>)	LC	
Northern Pine Snake (<i>Pituophis melanoleucus</i>)	LC	FC, ST
Scarlet Snake (<i>Cemophora coccinea</i>)	LC	
Timber Rattlesnake (<i>Crotalus horridus horridus</i>)	LC	
Eastern Spiny Softshell Turtle (<i>Trionyx spiniferus spiniferus</i>)	LC	
Snapping Turtle (<i>Chelydra serpentina</i>)	LC	
Stinkpot Turtle (<i>Sternotherus odoratus</i>)	LC	
Striped-Neck Musk Turtle (<i>Sternotherus minor peltifer</i>)	LC	
Eastern Box Turtle (<i>Terrapene carolina carolina</i>)	LO	
Eastern Painted Turtle (<i>Chrysemys picta picta</i>)	LO	
Northern Water Snake (<i>Natrix sipedon sipedon</i>)	P	
Queen Snake (<i>Natrix septemvittata</i>)	P	

^a Includes water associated animals capable of moving on land.

^b AqI = aquatic invertebrate feeder; ArI = arboreal invertebrate feeder; FI = flying insectivore; GI = ground invertebrate feeder; LC = predators and scavengers with ORR-wide populations; LH = herbivores with ORR-wide populations; LO = omnivores with ORR-wide populations; P = piscivores; SH = herbivores with populations restricted to source OU-scale; SO = omnivores with populations restricted to source OU-scale.

^c FC = candidate for federal listing; FE = federally listed as endangered; INM = state listed as in need of management; SE = state listed as endangered; ST = state listed as threatened.

^d Reported sightings, but probably does not occur on a regular basis.

^e Not yet sighted on the ORR, but introduced to area streams, and suitable habitat exists on the ORR.

APPENDIX D

**PUBLICATIONS RELATED TO CONTAMINATION IN
TERRESTRIAL BIOTA ON THE
OAK RIDGE RESERVATION**

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- Ashwood, T. L., C. L. Landrum, and S. M. Ratnayeke. 1993. Assessment of contaminants in the terrestrial environment. Chap. 7 In T. L. Ashwood (ed.) Seventh annual report on the ORNL biological monitoring and abatement program. Draft ORNL/TM. Oak Ridge National Laboratory.
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