ES/ER/TM-33/R2

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ENVIRONMENTAL RESTORATION PROGRAM

Approach and Strategy for Performing Ecological Risk Assessments for the U.S. Department of Energy's Oak Ridge Reservation: 1995 Revision

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Approach and Strategy for Performing Ecological Risk Assessments for the U.S. Department of Energy's Oak Ridge Reservation: 1995 Revision

G. W. Suter II
B. E. Sample
D. S. Jones
T. L. Ashwood
J. M. Loar

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Prepared by the
Environmental Restoration Risk Assessment Program
Lockheed Martin Energy Systems, Inc.
Oak Ridge, Tennessee 37831

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PREFACE

This technical memorandum provides guidance for planning and performing ecological risk assessments (ERAs) on the Oak Ridge Reservation (ORR). This work was performed under Work Breakdown Structure 1.4.12.2.3.04.07.02 (Activity Data Sheet 8304) and meets an Environmental Restoration Program milestone for FY 95. The strategy discussed in this report is consistent with the overall strategy for site management and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) compliance developed for the ORR and relevant U.S. Environmental Protection Agency documents and guidance. The general approach and strategy presented herein was developed for the ORR, but it could be applicable to other complex CERCLA sites that possess significant ecological resources.

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ACRONYMS

BMAP	Biological Monitoring and Assessment Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPEC	Chemicals of Potential Ecological Concern
DOE	U.S. Department of Energy
DQO	Data Quality Objectives
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
FFA	Federal Facilities Agreement
INM	in need of management
LOEC	lowest-observed-effects-concentration
NAWQC	National Ambient Water Quality Criteria
NPL	National Priorities List
NRDA	Natural Resource Damage Assessment
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OU	operable unit
PCB	polychlorinated biphenyls
PRG	Preliminary Remediation Goal
RAG	Remedial Action Goal
RGO	Remedial Goal Option
RI/FS	Remedial Investigation/Feasibility Study
ROD	record of decision
SERA	Screening Ecological Risk Assessment
T&E	threatened and endangered
TIE	toxicity identification and evaluation
WAG	waste area grouping

EXECUTIVE SUMMARY

The purpose of this document is to provide guidance for planning and performing ecological risk assessments (ERAs) on the Oak Ridge Reservation (ORR). It is the third such document prepared for this purpose. The first ecorisk strategy document described the ERA process and presented a tiered approach to ERAs appropriate to complex sites. The first revision was necessitated by the considerable progress that has been made by the parties to the Federal Facilities Agreement (FFA) for the ORR in resolving specific issues relating to ERAs as a result of a series of data quality objectives (DQOs) meetings. The tiered approach to ERAs as recommended in the first document was implemented, generic conceptual models were developed, and a general approach for developing ecological assessment endpoints and measurement endpoints was agreed upon.

Although ecological risks are equal in regulatory importance to human health risks, formal procedures for ERAs are relatively poorly developed. The EPA has a framework for guidance on ERAs but no agency guidelines for its implementation. The EPA's risk assessment guidance manual for ERAs addresses only procedures and general philosophy. EPA is developing new guidance for ERAs under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), but the current draft is still undergoing modifications and corrections.

This report will provide specific guidance and promote the use of consistent approaches for ERAs at individual sites on the ORR. The strategy discussed in this report is consistent with the overall strategy for site management and CERCLA compliance developed for the ORR and relevant EPA documents and guidance. The general approach and strategy presented herein was developed for the ORR, but it could be applicable to other complex CERCLA sites that possess significant ecological resources.

1. PURPOSE

The purpose of this document is to provide guidance for planning and performing ecological risk assessments (ERAs) on the Oak Ridge Reservation (ORR). It is the third such document prepared for this purpose. The first ecorisk strategy document described the ERA process and presented a tiered approach to ERAs appropriate to complex sites (Suter et al. 1992). The first revision was necessitated by the considerable progress that has been made by the parties to the Federal Facilities Agreement (FFA) for the ORR in resolving specific issues relating to ERA as a result of a series of data quality objectives (DQOs) meetings (Suter et al. 1994). The tiered approach to ERAs as recommended in the first document (Suter et al. 1992) was implemented, generic conceptual models were developed, and a general approach for developing ecological assessment endpoints and measurement endpoints was agreed upon.

This revision is necessitated by comments from the U.S. Environmental Protection Agency's (EPA's) Region IV and the Tennessee Department of Environment and Conservation (TDEC) which clarified and modified the positions taken during the DQO process. In particular, support for the collection of data that would support ERAs for all OUs on the ORR have been withdrawn. Therefore, the work plan developed to fill the reservation-wide data needs identified in the DQO process has also been withdrawn (Ashwood et al. 1994), and portions that are still relevant have been incorporated into this document.

Although ecological risks are equal in regulatory importance to human health risks (Reilly 1990, SAB 1990), formal procedures for ERAs are relatively poorly developed. The EPA has a framework for guidance on ERAs (Risk Assessment Forum 1992) but no agency guidelines for its implementation. The EPA's risk assessment guidance manual for ERAs (EPA 1989) addresses only procedures and general philosophy. EPA is developing new guidance for ERAs under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), but the current draft is still undergoing modifications and corrections (EPA 1994). This report will provide specific guidance and promote the use of consistent approaches for ERAs at individual sites on the ORR. The strategy discussed in this report is consistent with the overall strategy for site management and CERCLA compliance developed for the ORR (Environmental Restoration Division 1992), with relevant EPA documents (EPA 1989, Warren-Hicks et al. 1989, Risk Assessment Forum 1992), and with draft EPA guidance (personal communication among M. D. Sprenger, G. W. Suter II, and L. W. Barnthouse). The general approach and strategy presented herein was developed for the ORR, but it could be applicable to other complex CERCLA sites that possess significant ecological resources.

The reader should be aware that this guidance is complex and lengthy because it attempts to cover all the reasonable contingencies (for ERAs on the ORR) that were considered to be potentially important to the FFA parties. For example, the conceptual models include all potentially significant types of sources, routes of exposure, and receptors. Similarly, the assessment endpoints include all species that are of special concern to the FFA parties as well as species that may be particularly sensitive to particular contaminants. When applying the guidance to particular assessments, these models and lists serve as a starting point from which the problem formulation for the assessment is carried out. The means for adapting this generic guidance to particular assessments is discussed in the individual chapters of this technical memorandum.

Four appendixes are provided to support this strategy document. Appendix A presents lists of vertebrate species present on the ORR and in Watts Bar reservoir and plant and invertebrate species of status [federal- and state-listed threatened, endangered, and in-need-of-management (INM) species]. Appendix B describes programs other than the Environmental Restoration Program that are developing ecological data for the ORR which are useful for CERCLA assessments. Appendix C summarizes existing aquatic ecological and ecotoxicological information for the ORR, and Appendix D presents equivalent terrestrial ecological information.

2. SCOPE

2.1 PHYSICAL SCOPE

Because the entire ORR is on the National Priorities List (NPL), the scope of CERCLA activities on the ORR includes the entire reservation and areas outside the reservation boundaries contaminated by ORR releases including portions of the Melton Hill and Watts Bar Reservoirs. The ORR is not uniformly contaminated and cannot be investigated and remediated all at once. Therefore, the ORR was divided into operable units (OUs)—areas that contain wastes in proximity to each other in a locality with (ideally) common physical and hydrological characteristics. The OUs are described in the ORR site management plan (ERD 1994).

Division of the ORR into OUs was not a sufficient solution to the problem of providing an appropriate spatial organization to CERCLA activities because the spatial dynamics of contaminants on the site were not recognized. Contaminants deposited in sites now designated as OUs have moved in leachate into the groundwater and in runoff and leachate into surface waters where they have mixed with contaminants from other sources. In addition, the plant and animal populations of the ORR extend across areas that encompass multiple OUs, and individual organisms may feed on one OU, drink from another, and rest on a third. As a result, four classes of OUs are now recognized: source OUs, aquatic integrator OUs, groundwater OUs, and the terrestrial integrator OU.

The nature of these classes of OUs and the relationships among them are discussed in the following text. In general, each ERA for each OU must address the ecological values that are distinct to that OU. However, the Remedial Investigation/Feasibility Study (RI/FS) for each OU must also characterize its ongoing contributions to risks on other OUs. These risks are due to fluxes of contaminants out of the OU (e.g., leachate or emergent mayflies), use of an OU by animals that are not distinct to that OU (e.g., deer grazing on a waste disposal site), or physical disturbances that extend off the site (e.g., deposition of silt or construction of facilities for the remedial action off the site).

2.1.1 Source Operable Units

Source OUs are sites where wastes were directly deposited. These are the conventional waste sites—areas with trenches, tanks, pits, and drums of waste and areas where wastes have been spilled. Because these source OUs are highly modified systems, they often have low ecological value; some of them are entirely industrialized. Most of the waste burial grounds are vegetated, but the vegetation is maintained as a mowed lawn to prevent erosion while minimizing use of the sites by native plants and animals that might disturb, mobilize, take up, and transport the wastes.

The intensity of effort devoted to ERAs for a source OU should depend on its current character and its assumed future use. A paved OU would have negligible ecological value and would normally require a minimal ERA. A waste pond or sump may be treated as a waste source to be removed or destroyed or as a receptor ecosystem to be remediated. Waste ponds and sumps support aquatic biota, but toxicological risks to that community may not be assessed for the RI because destruction or removal of the wastes would destroy the community. However, organisms that drink from the pond or consume aquatic organisms would be the appropriate endpoint species because they might benefit from removal of a source of toxic exposure. Sites maintained as large lawns may support a distinct plant community (the lawn) and the associated soil heterotrophic community and herbivorous and predatory arthropods characteristic of such plant communities. In such a situation, the ERA for the site would address the toxicity of the soil to plants and soil heterotrophs. Wider ranging organisms that occasionally use the site could not be assessed in the RI for the OU because neither their exposure nor their response could be associated with a single OU. However, the sources of exposure of these animals must be characterized. These considerations may be sources of discussion during the DQO process. In particular, Region IV has called for assessment of risks to aquatic communities in waste sumps and ponds unless wildlife are expected to be more sensitive.

Some ecological expertise must be applied to evaluating these artificial communities. For example, the low-level waste burial grounds at Oak Ridge National Laboratory (ORNL) are frequently mowed so they do not support small mammals except around the edges where adjoining natural vegetation supplies cover (Talmage and Walton 1990). However, other waste sites such as those in Bear Creek OU-1 are seldom mowed, so it is likely that they support small mammal populations.

The appropriate assumptions concerning future states of the source OUs are not well-defined at this time. A land use plan for the reservation, which would help to define future use scenarios, is being developed. Under such a plan, many if not all of these sites are likely to remain industrial. However, loss of institutional control has been a standard scenario for CERCLA baseline risk assessments. Under a loss of institutional control scenario, or under any land use plan that calls for reversion of a source OU to a natural state, natural succession must be assumed leading to establishment on most sites of a deciduous forest. Such scenarios would have more exposure pathways and receptors than the current baseline case; they might include establishment of threatened and endangered (T&E) species on the site that are not currently present. Appropriate future scenarios for individual source OUs must be determined during the DQO process.

Some source OUs are too large and diverse to be assessed and remediated as a unit. In those cases, the OU may be divided into subunits. Although these divisions are likely to be based primarily on the types of wastes present and the manner of their disposal, such divisions should also take ecological differences in the site into consideration. For example, boundaries between distinctly different vegetation types may serve as bounds of subunits.

2.1.2 Aquatic Integrator Operable Units

Aquatic integrator OUs are streams and their associated floodplains. The aquatic integrator OUs include White Oak Creek, Bear Creek, upper and lower East Fork Poplar Creek, Poplar Creek, and upper and lower McCoy Branch. In addition, the Clinch River and lower Watts Bar Reservoir are aquatic integrator OUs for the entire reservation. These OUs receive contaminants from all of the source OUs in their watersheds; incorporate them into sediments, floodplain soils, and biota; and pass them along to the next aquatic integrator OU downstream.

The aquatic integrator OUs generally have much greater ecological value than the source OUs. They support stream communities and, except in reaches that are channelized, riparian communities that are diverse and provide ecosystem services such as hydrologic regulation. Although the inventories of contaminants are greater in most source OUs, aquatic integrator OUs are likely to be more susceptible to contaminants than the communities of source OUs because the contaminants are in the surface environment including surface waters and because of the greater diversity and of biota and routes of exposure. Future land use scenarios may change exposures in some portions of integrator OUs. For example, White Oak Creek through the grounds of ORNL is channelized and riprapped. If it were assumed that ORNL will be removed and no new industrial or residential development is allowed to replace it, then the stream would eventually develop a natural channel and riparian community leading to a more diverse and abundant aquatic community.

In general, aquatic integrator OUs should not be assessed as single units because they are large and vary significantly in their structure and degree of contamination. Rather, they must be divided into reaches. The reaches should be delimited in such a way that they form distinct and reasonably uniform units for assessment and remediation:

- Sources of contamination should be used as bounds on reaches. Examples include contaminated tributaries and sets of seeps associated with drainage from a source OU.

- Tributaries that provide sufficient input to significantly change the hydrology or basic water quality (e.g., pH or hardness) of a stream should serve as bounds of reaches.

- Physical structures that divide a stream, particularly if they limit the movement of animals or trap contaminated sediments, should be used as bounds of reaches. Examples include dams, weirs, and some culverts.

- Changes in land use should be used to delimit reaches. Clearly, ecological risks are different where floodplains have commercial or agricultural land uses than where they are forested.

- Reaches should not be so finely divided that they do not constitute ecological units. Reaches that are too short will contain fish or small mammals that cannot be clearly associated with the reach.

2.1.3 Groundwater Operable Units

Groundwater aquifers have received contaminants by direct deposition, in leachate from source OUs, and from losing reaches of contaminated streams. The groundwater OUs are aquifers that receive contaminants from multiple sources. Groundwater OUs have not been subject to ERAs because microbes and invertebrates that make up groundwater communities are not protected in the United States.

2.1.4 Terrestrial Integrator Operable Unit

Most of the ORR lies outside the contaminated sites, streams, and rivers that were originally designated as OUs. However, regulatory and ecological concerns are not limited to such sites. Wildlife and plant populations extend across the reservation, and individual animals visit and use multiple OUs. In addition, the values associated with wetlands and other communities result from their spatial extent and distribution and not just their occurrence on individual contaminated OUs. Therefore, it was necessary to create a terrestrial integrator OU encompassing the entire reservation and addressing risks to those widely distributed populations and communities.

Although the terrestrial integrator OU is not a unit scheduled for remediation under the FFA, assessment of risks to reservation-wide ecological resources in a reservation-wide assessment was determined by the FFA parties to be a cost-effective way to address those endpoints for all of the designated OUs. The reservation-wide assessments use existing data from the source and aquatic integrator OUs and other sources such as the Biological Monitoring and Assessment Program

(BMAP). They address the concerns of TDEC and DOE for the combined effects of multiple contaminant sources on wide-ranging species while avoiding the concern of Region IV that wide-ranging and societally valued species may not be sensitive if assessed on an OU-by-OU basis. A preliminary reservation-wide assessment has been produced (Sample et al. 1995) and will be updated in future years to incorporate data that are generated by the individual OUs and data from the BMAP and other programs that become available. The results of these assessments will be used in the RIs for individual OUs.

2.2 ADMINISTRATIVE AND REGULATORY SCOPE

Ecological risk assessors must be involved in all stages of the CERCLA investigation and remediation process. That process is diagramed in Fig. 1 and is briefly discussed in the following paragraphs.

2.2.1 Site Characterization

Before an ERA can be performed, it is necessary to have a basic understanding of the nature and extent of contamination, potential routes of exposure, and ecological resources present at the site. This involves a site visit and accumulation of information pertaining to the state and history of the site. Site characterization involves describing the physical characteristics of the site (e.g., topography, geology, hydrology, etc.) and the types and extent of plant and animal communities present. Previous actions taken at the site that have affected the environment, such as capping of landfills, should also be described. Data collected during the site characterization should be used to perform a preliminary screening ERA in preparation for the DQO process.

2.2.2 DQO Process

The DQO process was developed as a means of focusing sampling and analysis activities at CERCLA sites on the needs of the decision makers. The strategy presented in this document is a result of a series of DQO meetings conducted in 1994 by the FFA parties. DQO meetings should be held for all OUs as well. These meetings should focus on reducing the generic conceptual models, endpoint lists, and data needs presented here to those that are pertinent to the individual OU and then determine exactly how much and what types of data are needed.

2.2.3 Screening Assessment and the RI Work Plan

The RI work plan explains how DOE will implement the decisions made during the DQO process concerning the scope and activities of the RI. A screening ERA is included in the RI work plan to provide a technical justification for the scope of ecological sampling, analysis, and assessment activities. Screening assessments serve to summarize the existing information (both biotic and abiotic) about a site in terms of risk. That is, they screen contaminants into categories of chemicals of potential ecological concern (COPECs) and chemicals that may be ignored. Similarly, screening assessments partition routes of exposure and receptors into those that require further assessment and those that may be ignored. In this way, a screening assessment provides the basis for the conceptual model and identifies data gaps to be filled by sampling and analysis. In addition, a screening assessment may identify risks that require early remedial actions.

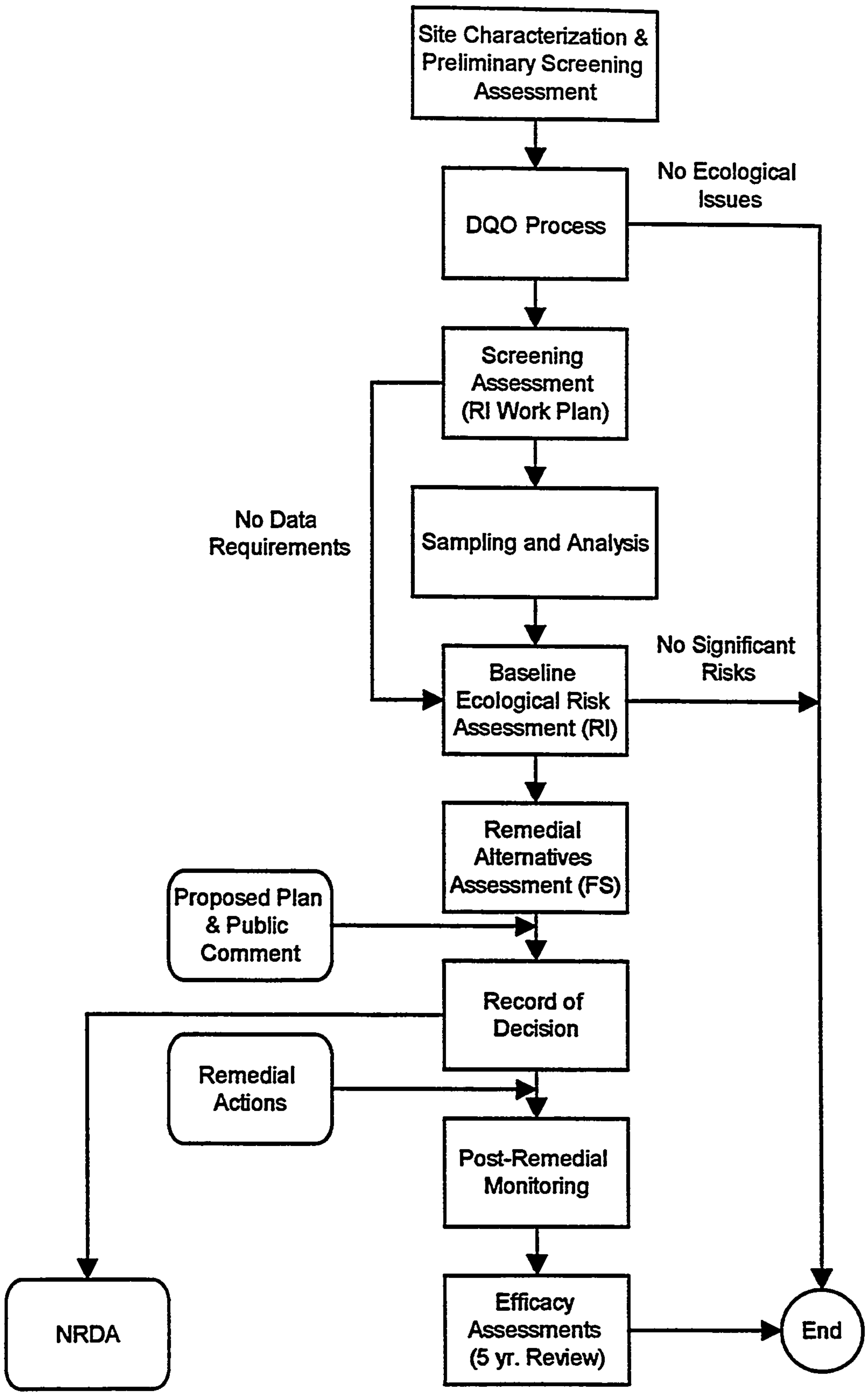

Fig. 1. Ecological risk assessment in the RI/FS process.

Questions that drive a screening assessment include: (1) Which media (water, sediment, soil, etc.) are contaminated such that they may be toxic?; (2) What chemicals are involved (Which chemicals are COPECs)?; (3) What are the concentrations and spatial and temporal distributions of these chemicals?; (4) What routes of transport may cause additional contamination in the future?; and (5) What organisms are expected to be significantly exposed to the chemicals? Answering these questions works to define the bounds of the problem to be assessed.

Because screening assessments use existing information, they may be performed relatively rapidly. Their primary purpose is to eliminate all nonexistent or clearly insignificant hazards. Only those chemicals that obviously pose no hazard are excluded in these assessments. Screening assessments should therefore be conservative and as broad as is reasonably possible so that no potential hazards are overlooked. Guidance for screening ERAs is provided by Suter (1995).

In addition to preparing the screening assessment, ecological risk assessors participate in the preparation of the RI work plan including summarization of existing ecological information about the site and data gaps identified through the screening assessment. The primary purpose of the RI work plan, however, is to outline the approach and methods that will be used to collect data needed to fill these data gaps. The RI work plan presents a plan for obtaining the data needed for the baseline assessment and a plan for using that data to assess ecological risks. The ecological risk assessor must ensure that the proposed activities will in fact fill the needs of the assessment by consulting with the authors of the sampling and analysis sections and by including a plan for performing the baseline ERA using that data set.

If the OU is poorly characterized by existing data, the RI may be carried out in phases. That is, a Phase 1 sampling and analysis program may be defined and carried out which provides the basis for planning a more focused second phase. This requires that the results of the Phase 1 studies be used to conduct a screening assessment which is used to identify the data gaps that must be filled in Phase 2 [see Cook et al. (1993) for an example].

2.2.4 Baseline Ecological Risk Assessment

In contrast to the screening assessment which defines the scope of the baseline assessment, the baseline assessment uses new and existing data to evaluate the risk of leaving the site unremediated. The purposes of the baseline assessment are to determine (1) if significant ecological effects are occurring at the site, (2) the causes of these effects, (3) the source of the causal agents, and (4) the potential future risks from leaving the system unremediated. The baseline assessment provides the ecological basis for determining the need for remediation.

Because the baseline assessment focuses on a smaller number of chemicals and species than the screening assessment, it can provide a higher level of characterization of toxicity to the species and communities at the site. In the baseline ERA, a weight-of-evidence approach is employed to determine if and to what degree ecological effects are occurring or may occur (Chapter 8).

2.2.5 Remedial Alternatives Assessment

A part of the FS for a CERCLA site is an assessment of the degree to which each alternative provides "overall protection of human health and the environment." For the no action alternative and for those alternatives that limit human access to and use of the site, the risks are those identified in the baseline ERA. Other remedial alternatives involve some reduction of site contamination or of exposure to contaminants but at a cost of risks due to physical disturbances. These remedial risks include destruction of the biotic communities on the site and on uncontaminated sites for borrow pits, land fills, roads, laydown areas, parking lots, etc. The remedial ERA must consider these direct effects, secondary effects such as erosion and habitat fragmentation, and the expected rate and degree of recovery of the disturbed areas given the site management and expected land uses. The importance of assessing remedial risks is demonstrated by the record of decison (ROD) for Lower East Fork Poplar Creek in which contaminant levels that are estimated to constitute a significant risk to shrews and wrens, but not humans, were left in place because the potential remedial actions would result in destruction of riparian forests and wetlands. That is, the remedial risks exceeded the baseline risks.

2.2.6 Efficacy Assessment

ERAs are performed after completion of remedial actions for two purposes. First, if the remedial actions leave contaminants in place rather than removing or destroying them, DOE is required under CERCLA to monitor the remediated site, and, every 5 years, assess the efficacy of the remedial actions in terms of the protection of human health and the environment, until unrestricted use of the site is possible. This monitoring and assessment activity is specified in the ROD for the OU. Second, DOE, for its own planning and site-stewardship needs, must determine whether the remedial actions in concert with other management activities have sufficiently reduced risks to ORR environmental resources. Both of these assessment goals require collection of data to characterize the post-remedial condition and estimation of levels of effects rather than simply screening chemicals.

2.2.7 Natural Resource Damage Assessment

The Natural Resource Damage Assessment (NRDA) provisions of CERCLA require that the residual injuries be assessed so that the natural resource trustees can be compensated for lost natural resource services. Because DOE is a natural resource trustee for the ORR, it is required to participate in the NRDA along with co-trustees. To be more efficient and ensure that remedial actions are taken which avoid excessive payments of natural resource damages, it has been recommended that NRDA be integrated with the rest of the CERCLA process (DOE 1991). Therefore, results of the RI/FS are important input to the NRDA, and selection of assessment endpoints which are also "natural resource services" could save assessment costs and damage payments. While this integration is logical and would be cost-effective, it is complicated by the fact that EPA is excluded from participation in NRDA activities. Therefore, NRDA is not explicitly addressed in EPA's DQO process or in RI/FS-related documents that are reviewed by the EPA.

3. CONCEPTUAL MODELS

3.1 GENERIC CONCEPTUAL MODELS OF BASELINE ECOLOGICAL RISKS

The generic conceptual models described in this chapter are provided to illustrate the relationships among the ecological components of the various OUs on the ORR and serve as bases for developing specific conceptual models for particular OUs. The OU-specific models are expected to be simpler than these generic models because individual OUs are unlikely to contain all of the compartments and pathways and not all of those that are present are likely to be significantly exposed or be sensitive to that exposure. The basic conceptual model for the CERCLA baseline ERA is presented in Fig. 2 which depicts the movement of contaminants from the source OUs to the groundwater OUs and the terrestrial and aquatic integrator OUs and the exchange of contaminants between the integrator OUs. Fluxes from the groundwater and integrator OUs to source OUs are assumed to be negligible. Contaminant fluxes, exposure, and accumulation within the four types of OUs are discussed in the following text.

The compartments of the model are described in this section in terms of their composition, input, and output. The compartments are composed of groups of taxa that have similar routes of exposure due to their common trophic habits. These trophic groups are not necessarily similar in their sensitivity to contaminant exposures because they may include species from different taxonomic classes. Examples of species assigned to each compartment are presented in the following discussion. In addition, vertebrate species occurring on the ORR or in the Clinch River/Watts Bar Reservoir are listed in Appendix A with the compartment to which they are assigned.

A number of decisions must be made in developing conceptual models. The following list applies to this set of decisions.

- These models are based on the transfer of contaminants and resulting exposures and not on secondary effects such as reduced predator abundance due to loss of prey.
- Recycling of contaminants within an OU is not depicted when it does not increase the number of receptors or routes of exposure. For example, the return of contaminants to the contaminated soil when an herbivore dies on a source OU is not shown.
- "Large" refers to the range of an organism rather than its body size. For example, a vole may be a small herbivore in that the range of a population of voles may be confined primarily to a single OU, but a bird of approximately the same weight, such as a robin, would be categorized as a large soil invertebrate feeder because the high mobility of robins ensures that the range of a robin population will be much larger than a source OU.
- Atmospheric routes of exposure are not included. None are believed to be significant on the ORR, but if evidence is obtained indicating that such routes may be significant at an OU, they should be added.
- Parasites are not included.

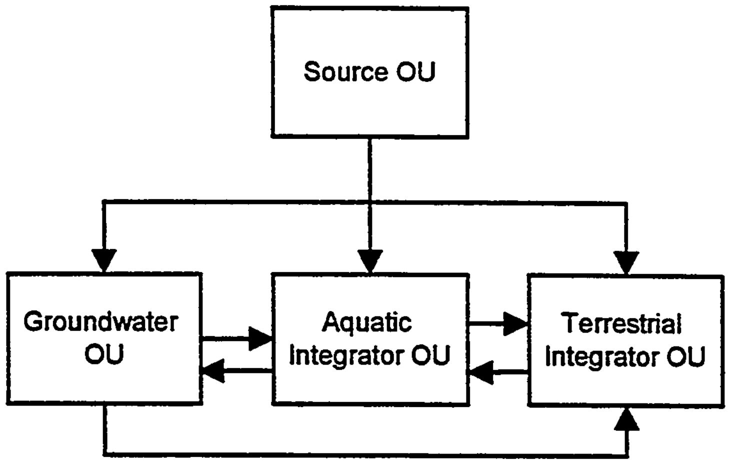

Fig. 2. Contaminant transfers among operable units.

- Physical effects of waste disposal such as paving or erosion of disturbed soils are not included.

In the diagrams, rectangles represent components of the depicted OU, rounded rectangles represent inputs from other OUs, and circles represent other OUs that receive output from the depicted OU. Rectangles with heavy borders represent compartments containing potential assessment endpoint species or communities.

These generic conceptual models provide a basis for deriving site-specific conceptual models. In general, the site-specific models will be less complex because some sources, routes of exposure, or classes of receptors do not occur on the site or could not be credibly associated with a significant risk. For example, many source OUs do not have surface water so a whole branch of the model can be pruned off. Similarly, if a screening assessment has shown that no chemicals occur at potentially phytotoxic concentrations, then plants could be eliminated as endpoint receptors and would be retained only as contributors to wildlife exposures.

3.1.1 Source OU Conceptual Model

The generic conceptual model for contaminant fluxes in source OUs is presented in Fig. 3.

Contaminant Sources

Composition—These are the trenches, pits, sumps, tanks, spill sites, and other facilities in which wastes were deposited in the source OU.

Input—It is assumed in this generic conceptual model that wastes are no longer being added, so there is no input. However, if wastes are still being disposed of in the source OU, they must be included in the model.

Output—Waste components enter the soil by direct deposition or by migration out of containers. Wastes enter aqueous systems by leaching into groundwater or the solution or particulate phases of runoff.

Surface Soil

Composition—Surface soil is the biologically active upper layer of the soil on the source OU including the litter layer (A_O horizon). The depth of this compartment varies among sites. This compartment contains contaminants associated with mineral soil, pore water, organic matter, and microbiota. For purposes of this model, contaminants in pits, trenches, etc., that are contacted by plant roots or animals are considered functionally to be contaminated soil.

Input—Waste components enter the soil from the contaminant sources by direct deposition or by migration out of containers.

Output—Soil contaminants enter aqueous systems by leaching into groundwater, by dissolving in runoff, or by being carried with eroded soil. Soil contaminants enter terrestrial plants by root uptake and by leaf uptake following volatilization. They may also be deposited on plants as particles. Soil contaminants enter animals by direct ingestion either incidentally or deliberately. They also enter animals and microbes by absorption from the pore water.

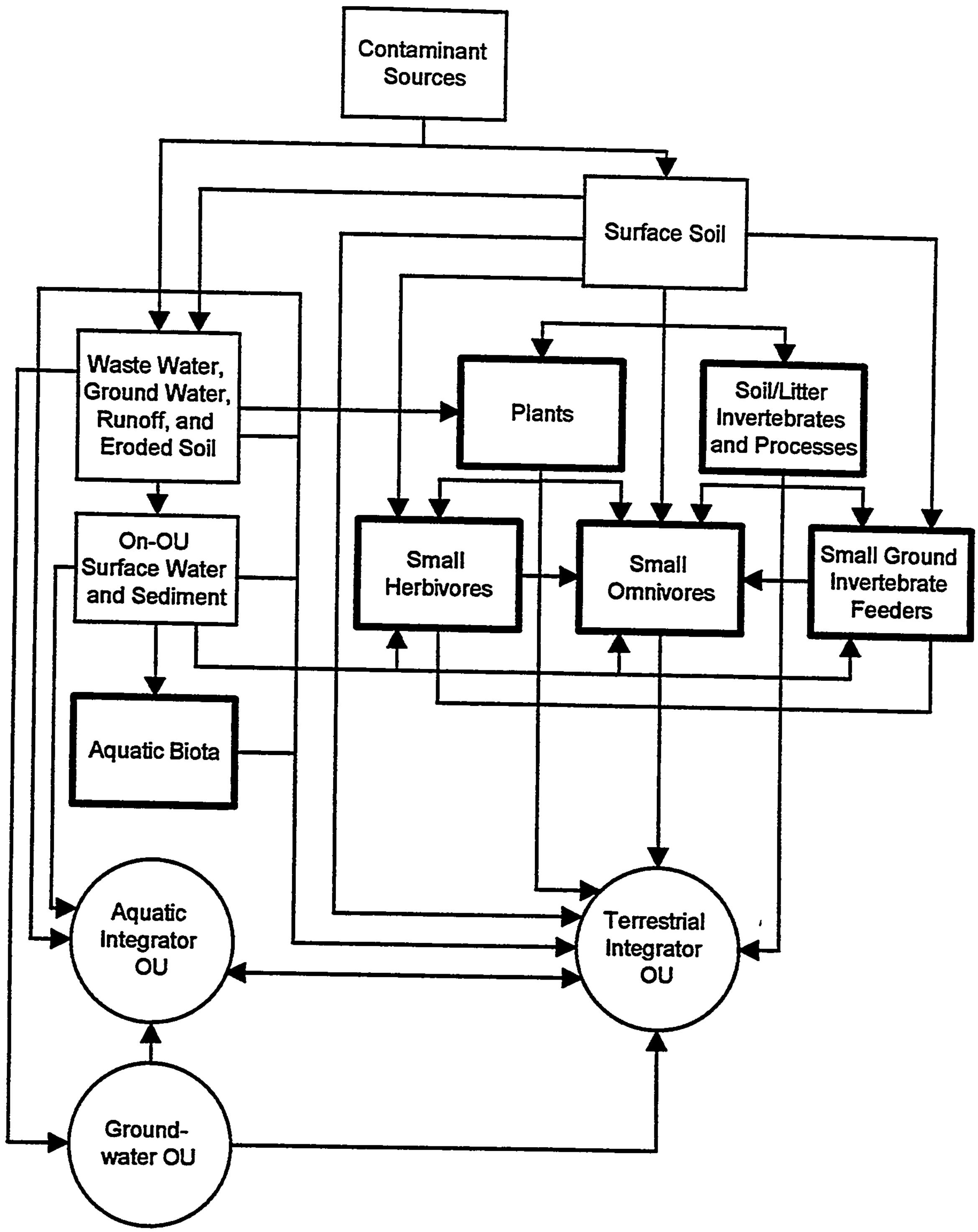

Fig. 3. Transfer of contaminants through a source OU and into integrator OUs.

Groundwater, Runoff, and Eroded Soil

Composition—This compartment represents the contaminants that are in flux in an aqueous phase. It includes all groundwater, surface runoff water, and contaminated soil carried in runoff.

Input—Waste components enter aqueous systems by dissolution into groundwater (leaching) or into runoff. Contaminated soil enters by erosion.

Output—Wastes in aqueous phases may be carried to on-site water bodies or to aquatic or groundwater integrator OUs. Plants may take up contaminants in shallow groundwater.

On an-OU Surface Water and Sediments

Composition—Some source OUs contain streams or ponds that are distinct to the source OU and are not part of an aquatic integrator OU. These water bodies include ponds that are "waters of the state" which have been contaminated. However, the inclusion of sumps or ponds for aqueous wastes is a subject of disagreement among the FFA parties which must be settled on an OU-by-OU basis. They may be treated as sources to be remediated or as ecosystems to be protected.

Input—These waters receive contaminants in groundwater seeps or springs, runoff, and eroded soil. In addition, some surface waters have received direct discharges of wastes.

Output—Contaminants in on-OU surface waters and sediments are taken up by any aquatic biota that inhabit them and may be consumed by animals inhabiting the source OU or coming in from the terrestrial integrator. In addition, they may be transported to water and sediments in the aquatic integrator OU.

Aquatic Biota

Composition—This compartment represents the plants, invertebrates, and vertebrates inhabiting the on-OU surface waters. This compartment is described in more detail in Subsect. 3.1.5.

Input—The aquatic biota take up contaminants from water and sediments.

Output—Fish and macroinvertebrates are consumed by piscivores, aquatic invertebrate feeders, and omnivores, and emergent aquatic insects are consumed by flying insectivores. All of these are from the terrestrial integrator OU.

Plants

Composition—This compartment includes terrestrial vascular plants.

Input—Uptake from soil through roots and leaves (leaf uptake includes deposition of contaminated soil and uptake of contaminants volatilized from soil) and from groundwater through roots.

Output—Plants are consumed by herbivores and omnivores. Some of these are not resident on the site and are assessed in the terrestrial integrator OU.

Soil/Litter Invertebrates and Processes

Composition—This compartment includes the heterotrophic invertebrates and microbes that inhabit the soil and litter layers. It does not include soil herbivores. This compartment is commonly represented by earthworms.

Input—Contaminants are taken up by consumption of soil and litter and by absorption from the soil pore water.

Output—Soil invertebrates are consumed by animals that feed primarily on them such as shrews and woodcock and by omnivores such as *Peromyscus*. If there is suitable habitat on the source OU that is sufficiently extensive, these animals may have distinct populations on the source OU. Otherwise, they are part of the terrestrial integrator OU.

Small Herbivores

Composition—Small herbivores include those terrestrial herbivores that are sufficiently small or have sufficiently low mobility to have distinct populations on the OU. The most abundant and ecologically important are insects. However, some vertebrate herbivores such as voles may be included.

Input—Contaminant input includes consumption of contaminated plants and water and incidental consumption of soil.

Output—Contaminant output is consumption by small ground invertebrate feeders and small omnivores on the OU and by flying insectivores, large ground invertebrates feeders, arboreal insectivores (if the OU is wooded), large omnivores, and carnivores from the terrestrial integrator OU.

Small Omnivores

Composition—Small omnivores include those terrestrial omnivores that are sufficiently small or have sufficiently low mobility to have distinct populations on the OU. Examples potentially include *Peromyscus* spp.

Input—Contaminant input includes consumption of contaminated plants, herbivores, soil invertebrates, and water and incidental consumption of soil.

Output—Contaminant output is consumption by large omnivores and carnivores from the terrestrial integrator OU.

Small Ground Invertebrate Feeders

Composition—Small ground invertebrate feeders include those species that feed on soil and litter invertebrates including herbivores that feed on roots and low vegetation and are sufficiently small or have sufficiently low mobility to have distinct populations on the OU. Potential examples include shrews, terrestrial salamanders, lycosid spiders, and centipedes.

Input—Contaminant input includes consumption of contaminated soil invertebrates and water, incidental consumption of soil, and, for amphibians, dermal absorption.

Output—Contaminant output is consumption by small omnivores on the OU and by large omnivores and carnivores from the terrestrial integrator OU.

3.1.2 Aquatic Integrator OU Conceptual Model

The generic conceptual model for contaminant fluxes in aquatic integrator OUs is presented in Fig. 4. These OUs are streams that receive wastes from source OUs plus their floodplains and associated biota. The aquatic biota compartment is elaborated in Fig. 5.

Wastes Deposited In-OU

Composition—Although hazardous wastes were seldom deliberately deposited in streams or floodplains, the practice is not unknown. This compartment includes wastes disposed of in the aquatic integrator OU either directly or in liquid wastes retained in settling basins. An example is the contaminants deposited in the intermediate pond on White Oak Creek [Waste Area Grouping 2 (WAG 2)].

Input—It is assumed that hazardous wastes are no longer being deposited in the aquatic integrator OUs. All input are from outside the OU in source OUs, point sources (i.e., NPDES sources), or nonpoint sources (e.g., landscaping chemicals).

Output—These wastes directly contaminate the floodplain soils and contaminate water through leachate, runoff, and eroded soil.

Stream, Pond, and Wetland Water

Composition—This compartment includes all persistent surface water in the OU including not only the stream, but also vernal pools, wetlands, and other surface water that persists for sufficient duration to support a community of aquatic macrobiota.

Input—The input to this compartment includes contaminants in runoff from source OUs and in groundwater either from shallow groundwater coming directly off an adjoining source OU or less directly from a groundwater OU. Contaminants may also come from wastes deposited in the aquatic integrator OU.

Output—Surface water contaminants are taken up by the aquatic biota, become sorbed to sediments and floodplain soils, and are consumed by animals inhabiting the aquatic integrator OU or the terrestrial integrator OU.

Stream, Pond, and Wetland Sediments

Composition—This compartment includes all sediments underlying persistent surface water in the OU.

Input—Sediment contaminants come from soil eroded from Source OUs and contaminated floodplain soils and from contaminated surface water and groundwater.

Output—Sediment contaminants are desorbed to the surface water, taken up by aquatic biota, and deposited on the floodplain.

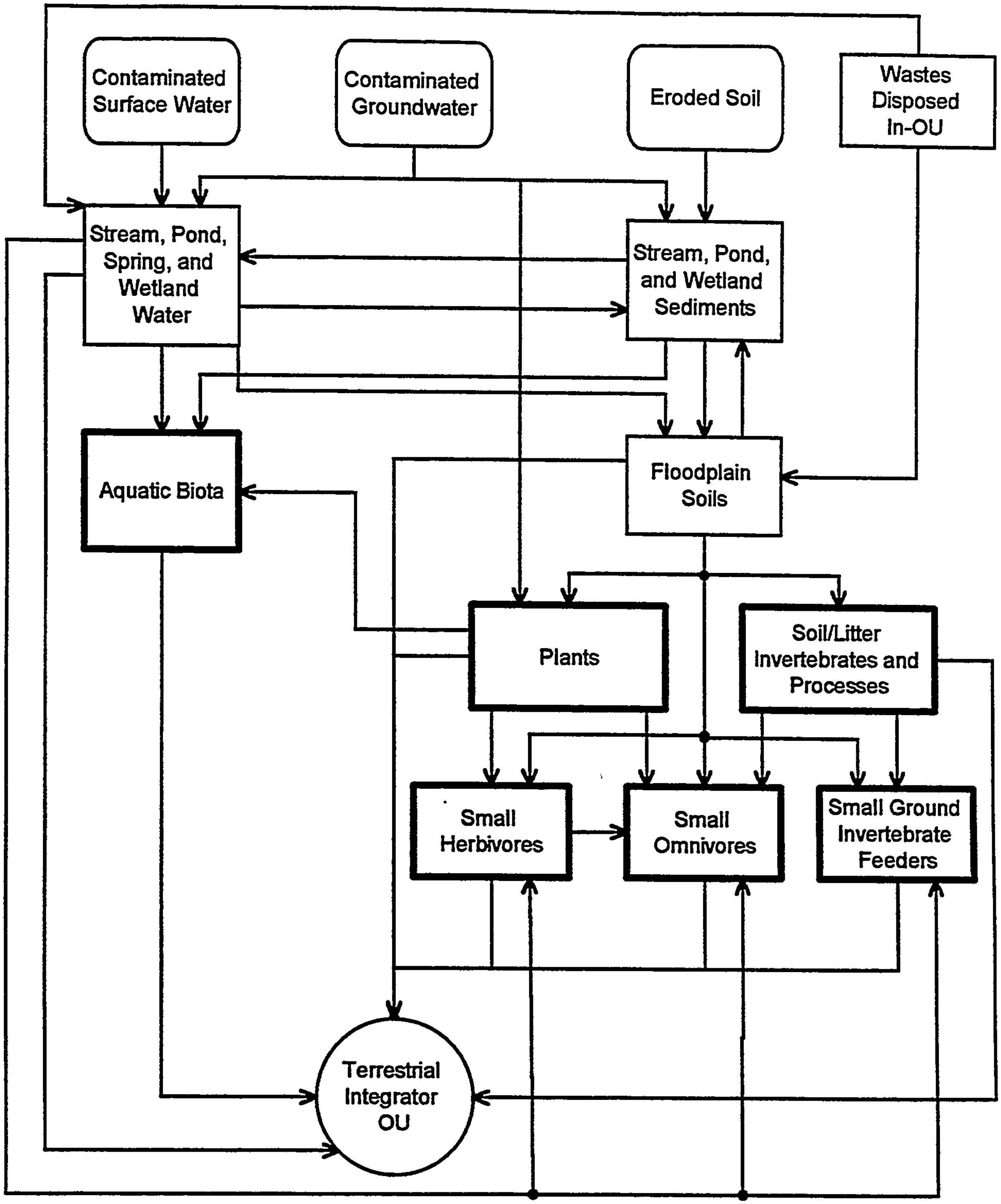

Fig. 4. Transfer of contaminants into and through an aquatic integrator OU.

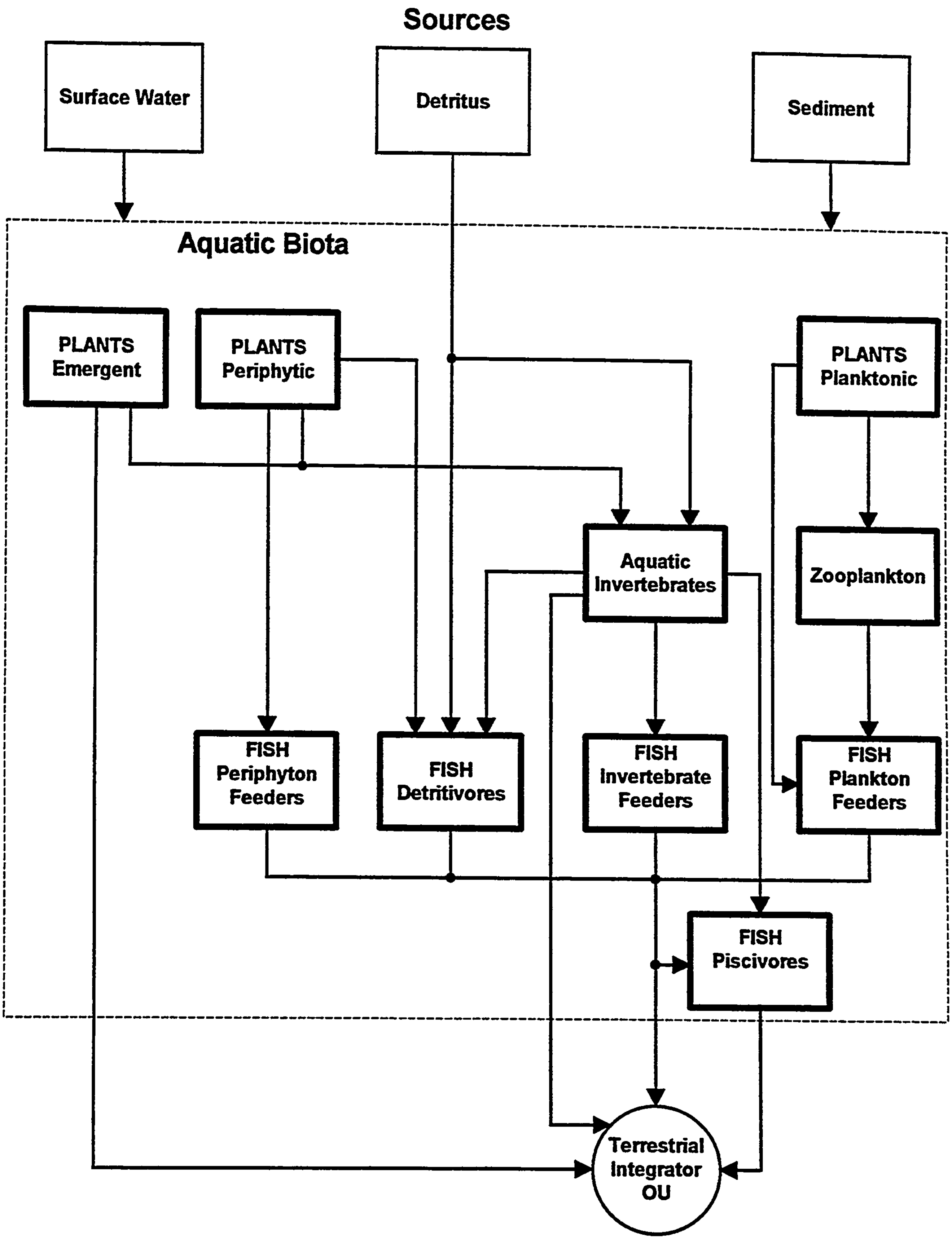

Fig. 5. Transfer of contaminants into and through the aquatic biota.

Aquatic Biota

Composition—This compartment represents the plants, invertebrates, and vertebrates inhabiting the on-OU surface waters. This compartment is described in more detail in Subsect. 3.1.5.

Input—The aquatic biota take up contaminants from water and sediments.

Output—Fish and macroinvertebrates are consumed by piscivores, aquatic invertebrate feeders, and omnivores, and emergent aquatic insects are consumed by flying insectivores. All of these are from the terrestrial integrator OU.

Floodplain Soil

Composition—Surface soil is the biologically active upper layer of the soil on the floodplain including the litter layer (A_O horizon). The depth of contaminated surface soil in floodplains is quite variable because of the dynamics of deposition and erosion.

Input—Waste components enter the soil from the surface water and sediments during flooding or the soils may be contaminated by past waste disposal in the floodplain.

Output—Soil contaminants enter aqueous systems from floodplain soils by leaching into groundwater, by dissolving in runoff, or by being carried with eroded soil. Soil contaminants enter terrestrial plants by root uptake and by leaf uptake following volatilization. Soil contaminants enter animals by direct ingestion either incidentally or deliberately. They also enter animals and microbes by absorption from the pore water.

Plants

Composition—This compartment includes terrestrial vascular plants.

Input—Uptake from soil through roots and leaves (leaf uptake includes deposition of contaminated soil and uptake of contaminants volatilized from soil) and from groundwater through roots.

Output—Plants are consumed by herbivores and omnivores. Some of these are not resident on the site, and are assessed in the terrestrial integrator OU.

Soil/Litter Invertebrates and Processes

Composition—This compartment includes the heterotrophic invertebrates and microbes that inhabit the soil and litter layers. It does not include soil herbivores. This compartment is commonly represented by earthworms.

Input—Contaminants are taken up by consumption of soil and litter and by absorption from the soil pore water.

Output—Soil invertebrates are consumed by animals that feed primarily on them such as shrews and by small omnivores such as *Peromyscus* on the OU and by flying insectivores and large ground invertebrates feeders from the terrestrial integrator OU.

Small Herbivores

Composition—Small herbivores include those terrestrial herbivores that are sufficiently small or have sufficiently low mobility to have distinct populations on the OU. The most abundant and ecologically important are insects. However, some vertebrate herbivores such as voles may be included.

Input—Contaminant input includes consumption of contaminated plants and water and incidental consumption of soil.

Output—Contaminant output is consumption by small ground invertebrate feeders and small omnivores on the OU and by flying insectivores, large ground invertebrates feeders, arboreal insectivores (if the OU is wooded), large omnivores, and carnivores from the terrestrial integrator OU.

Small Omnivores

Composition—Small omnivores include those terrestrial omnivores that are sufficiently small or have sufficiently low mobility to have distinct populations on the OU. Examples include *Peromyscus* spp.

Input—Contaminant input includes consumption of contaminated plants, herbivores, soil invertebrates, and water and incidental consumption of soil.

Output—Contaminant output is consumption by large omnivores and carnivores from the terrestrial integrator OU.

Small Soil Invertebrate Feeders

Composition—Small soil invertebrate feeders include those species that are sufficiently small or have sufficiently low mobility to have distinct populations on the OU. Examples include shrews, terrestrial salamanders, and centipedes.

Input—Contaminant input includes consumption of contaminated soil invertebrates and water and incidental consumption of soil.

Output—Contaminant output is consumption by small omnivores on the OU and by large omnivores and carnivores from the terrestrial integrator OU.

3.1.3 Groundwater OU Conceptual Model

The generic conceptual model for contaminant fluxes in the groundwater integrator OUs is presented in Fig. 6.

Groundwater

Composition—This compartment consists of contaminated water that occurs in underground aquifers.

Input—Input to this compartment consists of leachates from wastes or contaminated soils.

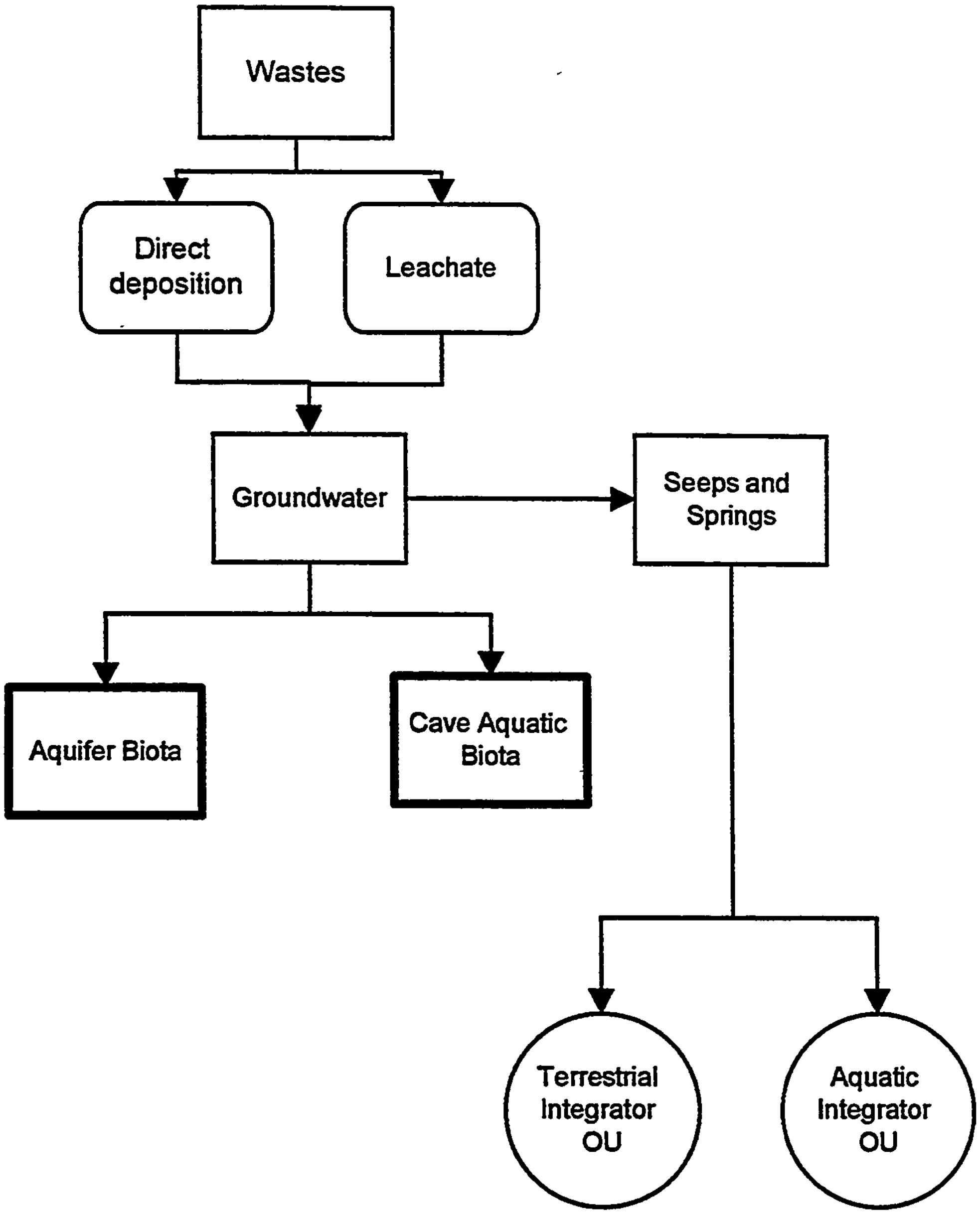

Fig. 6. Transfer of contaminants into and through a groundwater integrator OU.

Output—Contaminant output includes uptake of contaminants by aquifer microbes and invertebrates and by the aquatic biota of caves. It also includes output through seeps and springs to aquatic and terrestrial integrator OUs.

Aquifer Biota

Composition—This compartment includes the invertebrates and microbes that inhabit aquifers. This compartment is not usually considered in ERAs in the U.S., although the contaminant degradation performed by this community may be important to ultimate site remediation.

Input—Contaminants are taken up by absorption from the groundwater.

Output—It is assumed there is no output from this community.

Cave Aquatic Biota

Composition—This compartment includes the vertebrates, invertebrates, and microbes that inhabit cave waters. This compartment is not usually considered in ERAs in the U.S., except when threatened or endangered species are present. Although caves occur on the ORR, it is not clear what species may actually occur in those caves.

Input—Contaminants are taken up by absorption from the groundwater or through food webs within this compartment. If bats or other surface-feeding species use the caves, they may also serve as an input route. However, the occurrence of such transfers is purely speculative for the ORR.

Output—It is assumed there is no significant output from this community.

3.1.4 Terrestrial Integrator OU Conceptual Model

The generic conceptual model for contaminant fluxes into the terrestrial integrator OUs is presented in Fig. 7. It is assumed there are no contaminant sources in this OU. This figure does not depict contaminant transfers among compartments in the OU. The primary source of contaminants to all compartments is assumed to be contaminants on the source and aquatic integrator OUs. If preliminary assessments suggest there may be significant transfers of contaminants within this OU (e.g., consumption of deer by coyotes or addition of contaminants to soil by defecation), then a model of such internal dynamics of the terrestrial integrator OU will be developed.

Upland Plants

Composition—This compartment consists of vascular plants in areas outside source or aquatic integrator OUs.

Input—Upland plants take up contaminants from shallow groundwater that has become contaminated by leachates.

Output—Upland plants are consumed by herbivores and omnivores and may add contaminants to uncontaminated surface soil in litter fall.

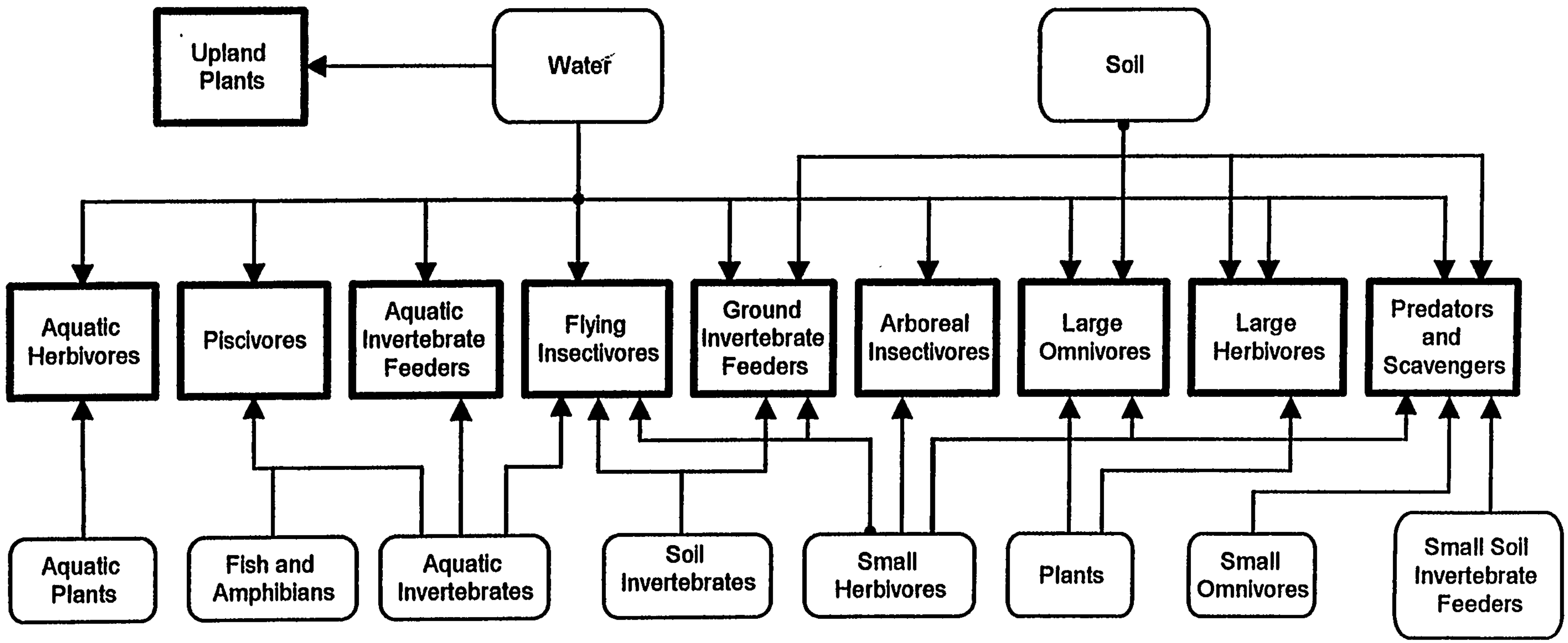

Fig. 7. Transfer of contaminants from source and aquatic integrator OUs to the terrestrial integrator OU.

Aquatic Herbivores

Composition—This compartment consists of wildlife that consume primarily aquatic plants. Examples include dabbling ducks such as widgeon and gadwall and herbivorous turtles such as pond sliders.

Input—Contaminants are taken up by consumption of aquatic plants and water.

Output—It is assumed that there is no output from this trophic group except decomposition because it would not form a significant component of the diet of any carnivore or scavenger.

Piscivores

Composition—This compartment consists of wildlife that consume primarily fish. Examples include kingfishers, herons, and mink.

Input—Contaminants are taken up by consumption of aquatic biota (fish, amphibians, and aquatic invertebrates) and water.

Output—It is assumed there is no output from this trophic group except decomposition because it would not form a significant component of the diet of any carnivore or scavenger

Aquatic Invertebrate Feeders

Composition—This compartment consists of wildlife that consume primarily aquatic invertebrates. Examples include water fowl such as ruddy duck and pied-billed grebe.

Input—Contaminants are taken up by consumption of aquatic invertebrates and water.

Output—It is assumed that there is no output from this trophic group except decomposition because it would not form a significant component of the diet of any carnivore or scavenger

Flying Insectivores

Composition—This compartment consists of wildlife that consume primarily flying invertebrates. This group is separated from other insectivores primarily because they may consume significant quantities of aquatic insects which would result in different exposure levels from consumption of terrestrial insects. Examples include bats, swallows, and flycatchers.

Input—Contaminants are taken up by consumption of aquatic and terrestrial flying insects and water.

Output—It is assumed there is no output from this trophic group except decomposition because it would not form a significant component of the diet of any carnivore or scavenger. However, bats may act as a route for transferring contaminants to cave ecosystems.

Ground Invertebrate Feeders

Composition—This compartment consists of wildlife that forage on the ground and consume primarily invertebrates. This group consumes soil and litter invertebrates such as earthworms and isopods as well as herbivorous invertebrates that feed on herbaceous vegetation and roots. Examples include robins, woodcock, towhee, skunks, shrews, and toads.

Input—Contaminants are taken up by consumption of herbivorous and soil/litter invertebrates and water and incidental consumption of soil.

Output—Output to this compartment is consumption by predators and scavengers and decomposition.

Arboreal Insectivores

Composition—This compartment consists of wildlife that consume primarily invertebrates that feed on trees. This group is separated from other insectivores primarily because they may consume invertebrates from an almost entirely herbivorous food web and do not consume significant amounts of soil which would result in different exposure levels from consumption of ground-level invertebrates. Examples include vireos, most warblers, and woodpeckers.

Input—Contaminants are taken up by consumption of arboreal invertebrates and water.

Output—Output to this compartment is consumption by predators and scavengers and decomposition.

Large Omnivores

Composition—This compartment consists of wildlife that consume a variety of plant and animal material from terrestrial or aquatic systems. Examples include crows, raccoons, grey fox, and muskrats.

Input—Contaminants are taken up by consumption of plants, animals, and water and incidental consumption of soil.

Output—Output to this compartment is consumption by predators and scavengers and decomposition.

Large Herbivores

Composition—This compartment consists of wildlife that consume primarily plant material from terrestrial systems. Examples include deer, rabbits, and wild turkeys.

Input—Contaminants are taken up by consumption of plants and water and incidental or deliberate consumption of soil.

Output—Output to this compartment is consumption by predators and scavengers and decomposition.

Predators and Scavengers

Composition—This compartment consists of wildlife that consume animal flesh material through predation or scavenging. Examples include weasels, bobcats, hawks, and vultures.

Input—Contaminants are taken up by consumption of animals and water and incidental consumption of soil.

Output—It is assumed there is no output from this trophic group except decomposition because it would not form a significant component of the diet of any carnivore or scavenger.

3.1.5 Aquatic Biota Conceptual Model

The generic conceptual model for contaminant fluxes in the aquatic biota compartment is presented in Fig. 5. This model is an elaboration of the aquatic biota compartment in the conceptual models for source OUs and aquatic integrator OUs. Although aquatic plants, invertebrates, and fish are assessed as a community, they are subdivided in the conceptual model because exposure is dependent on habitat and trophic category. A species list of fishes that identifies their trophic categories is presented in Appendix A, Table A.2. Contaminant fluxes among abiotic compartments (i.e., desorption of sediment contaminants to the surface water) are represented in the conceptual models of the OUs.

Surface Water

Composition—This compartment includes all persistent surface water in the OU which is capable of supporting aquatic macrobiota. This may include streams, ponds, vernal pools and wetlands but not waste sumps or waste ponds when they are treated as sources rather than receptor ecosystems.

Input—The input to this compartment includes contaminants in runoff and groundwater.

Output—Surface water contaminants are taken up by the aquatic biota. Outputs to abiotic and terrestrial biotic compartments are addressed at the OU level.

Sediment

Composition—This compartment includes all sediments underlying persistent surface water in the source or integrator OU.

Input—The input to this compartment includes contaminants in eroded soil, surface water, and groundwater.

Output—Sediment contaminants are taken up by aquatic biota. Outputs to abiotic compartments are addressed at the OU level.

Detritus

Composition—This compartment represents the nonliving organic matter in the aquatic system.

Input—The primary input is contaminants in allochthanous material from upstream source OUs and riparian communities. Contaminants may be recycled through the decomposition of contaminated aquatic biota resident within the aquatic system.

Output—Contaminants in detritus are taken up through consumption by aquatic biota.

Plants—Emergent

Composition—This compartment represents the vascular aquatic plants rooted in the soft sediments of depositional zones. These plants extend into or above the water column.

Input—Emergent plants take up contaminants from the surface water and sediment.

Output—Emergent plants are consumed by aquatic invertebrates and terrestrial herbivores, such as the pond slider turtle.

Plants—Periphytic

Composition—This compartment represents aquatic vegetation attached to benthic hard substrates in erosional zones (i.e., rocks and submerged logs). These are primarily monocellular and non-vascular assemblages including attached algae, bacteria, and fungi.

Input—The primary contaminant input is from surface water. Uptake from soft sediments is limited by erosion.

Output—Consumers of periphyton include aquatic invertebrates, fish, and terrestrial herbivores.

Plants—Planktonic and Floating

Composition—This compartment represents all unattached vegetation, including simple and vascular plants, suspended in the water column or on the surface. Examples include algae and duckweed.

Input—Planktonic and floating plants take up contaminants from the water column but not from the sediment.

Output—Planktonic and floating plants are consumed by planktonic animals, fish, and terrestrial herbivores.

Zooplankton

Composition—This compartment includes the invertebrates inhabiting the open water zone of slow moving bodies of water. The primary representatives of this group are crustaceans, which may include daphnids, and rotifers.

Input—Planktonic animals take up contaminants from the water and through consumption of phytoplankton.

Output—Contaminant output from this compartment is consumption by planktivorous fish.

Aquatic Invertebrates

Composition—This compartment represents all invertebrates for which the principal habitat of the aquatic life stage is the benthic, or sediment, zone. Potential examples are aquatic insects (including mayflies, stoneflies, and caddisflies which are collectively known as EPT) and crustaceans such as amphipods, isopods, and crayfish.

Input—Benthic invertebrates take up contaminants from the water and sediment and through consumption of detrital and plant material.

Output—Contaminant output to the aquatic system is consumption by fish. Output to the terrestrial integrator OU includes consumption of aquatic life stages by water fowl and consumption of terrestrial life stages by flying insectivores.

Fish—Periphyton Feeders

Composition—This compartment represents fish which primarily consume attached vegetation. Examples include the stoneroller.

Input—Contaminants are taken up from water and sediment and through consumption of periphyton.

Output—Output is consumption by piscivorous fish and wildlife.

Fish—Detritivores

Composition—This compartment includes fish which consume dead organic matter. Fish in this compartment may intentionally or incidentally consume varying amounts of periphyton and benthic invertebrates. Examples include the carp, spotted sucker, and Tennessee Dace.

Input—Contaminants s are taken up from water and sediment and through consumption of detritus, benthic invertebrates, and periphyton.

Output—Output is consumption by piscivorous fish and wildlife.

Fish—Invertebrate Feeders

Composition—This compartment represents fish which primarily consume aquatic invertebrates. Examples include the bluegill, skipjack herring, and blacknose dace.

Input—Contaminants are taken up from water and sediment and through consumption of invertebrates.

Output—Output is consumption by piscivorous fish and wildlife.

Fish—Plankton Feeders

Composition—This compartment represents fish which primarily consume phytoplankton and zooplankton. Examples include the paddle fish.

Input—Contaminants are taken up from water and sediment and through consumption of plankton.

Output—Output is consumption by piscivorous fish and wildlife.

Fish—Piscivores

Composition—This compartment includes fish which consume other fish and invertebrates. Examples include bass, crappie, and channel catfish.

Input—Contaminants are taken up from water and sediment and through consumption of fish and aquatic invertebrates.

Output—Output is consumption by piscivorous wildlife.

3.2 ADDITIONAL CONCEPTUAL MODELS FOR FEASIBILITY STUDIES

Feasibility studies require assessment of the risks associated with remedial alternatives. For no-action alternatives or alternatives that take no action to remediate ecological risks (e.g., fences, fishing advisories, land use controls), the conceptual models for the baseline risk assessments are applicable. However, the remedial alternatives that involve removal, isolation, or treatment of soil or sediment require disturbance not only of the contaminated areas but also of uncontaminated areas used for roads, structures, laydown areas, borrow pits, landfills, treatment facilities, etc. Generic conceptual models for these activities are presented in Figs. 8–10. These conceptual models for physical disturbance differ from those for chemicals in that the flows are flows of causal influences rather than flows of chemicals. Additionally, the receptors are defined much more broadly because the consequences of physical disturbances tend to be less discriminatory than those of chemicals. These conceptual models of physical disturbance were presented during the DQO meetings for the ORR ecological assessment and were modified in response to comments. However, they were not developed further. They are presented herein as a basis for developing future ERAs for feasibility studies.

Some confusion exists about the role of the ERA in the FS. For human health risk assessments, it is typically assumed that the remedial actions have no significant risks. Therefore, the FS tends to focus on the effectiveness of the alternatives in terms of reducing exposure to and risks from the waste materials. However, remedial actions often destroy all but the most mobile members of the nonhuman biota of a site, diminish or destroy the habitat quality of the site for some time, and destroy organisms and habitat in areas used for support facilities, landfills, etc. Therefore, to determine whether the ecological risks posed by the contaminants are greater than the risks posed by the remedial alternatives, it is necessary to perform an ecological assessment for the FS that is equivalent in rigor and specificity to the baseline ERA in the RI. This point is illustrated by the development of the proposed plan and ROD for Lower East Fork Poplar Creek. Although the Remedial Action Goal (RAG) for ecological risks was lower than that for human health risks, only areas that exceed the human health RAG will be remediated. That is because it was agreed by the FFA parties that remediation of areas with mercury concentrations below the human health RAG would eliminate a toxic risk to shrews and wrens but would cause a greater net ecological risk due to destruction of wetlands, riparian forest, and associated organisms.

Some individuals are reluctant to call the assessments of ecological risks of remediation an ERA, because they associate the term ERA with assessments of risks from contaminants. However, EPA has made it clear that risks from physical stressors should also be assessed using the ERA framework (EPA 1992). Therefore, both because of the need for risk balancing and based on EPA policy, the ecological assessment of the remedial alternatives in the FS should be treated as an ERA.

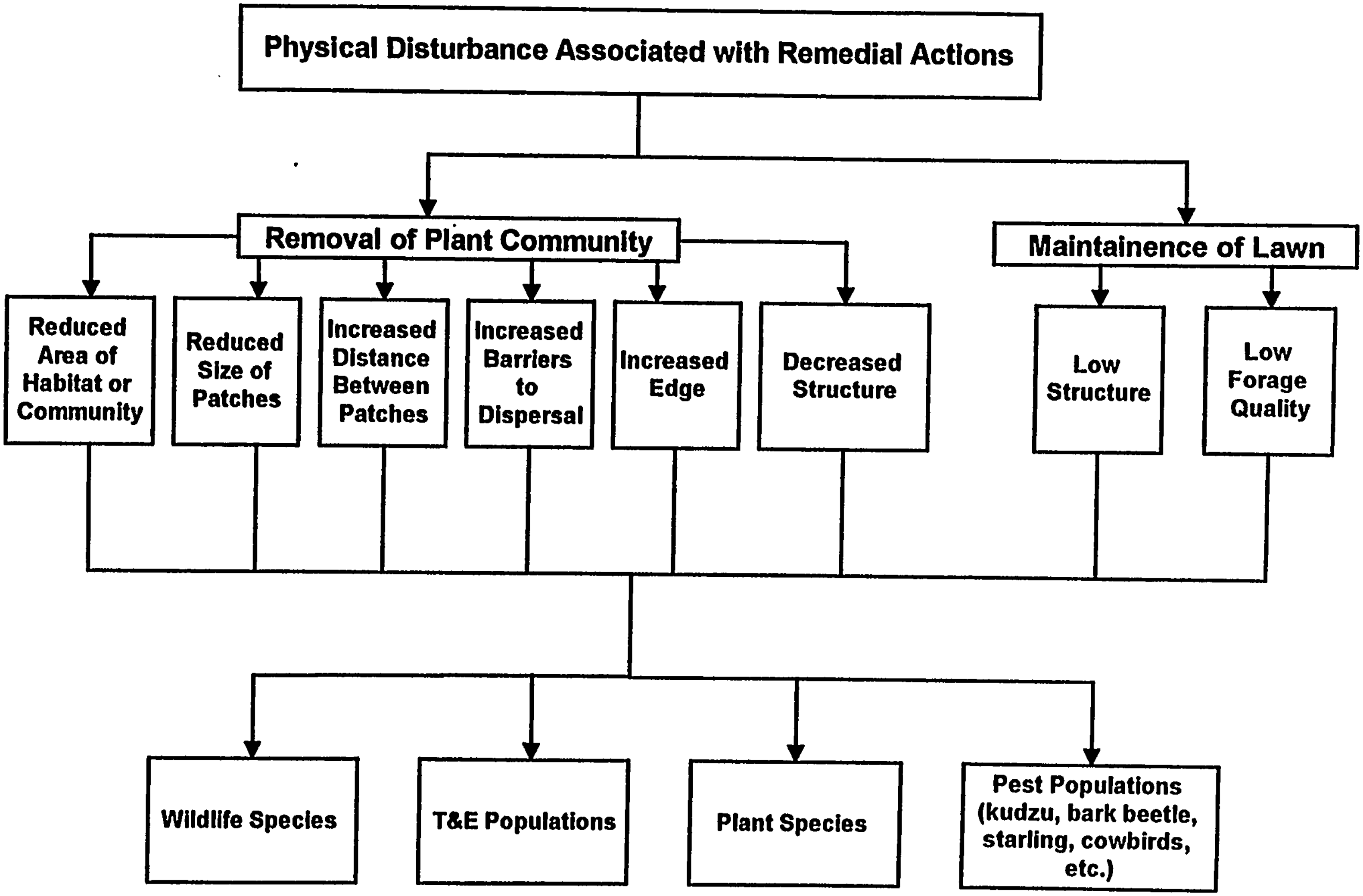

Fig. 8. Generic conceptual model of the effects of physical disturbance on terrestrial eosystems.

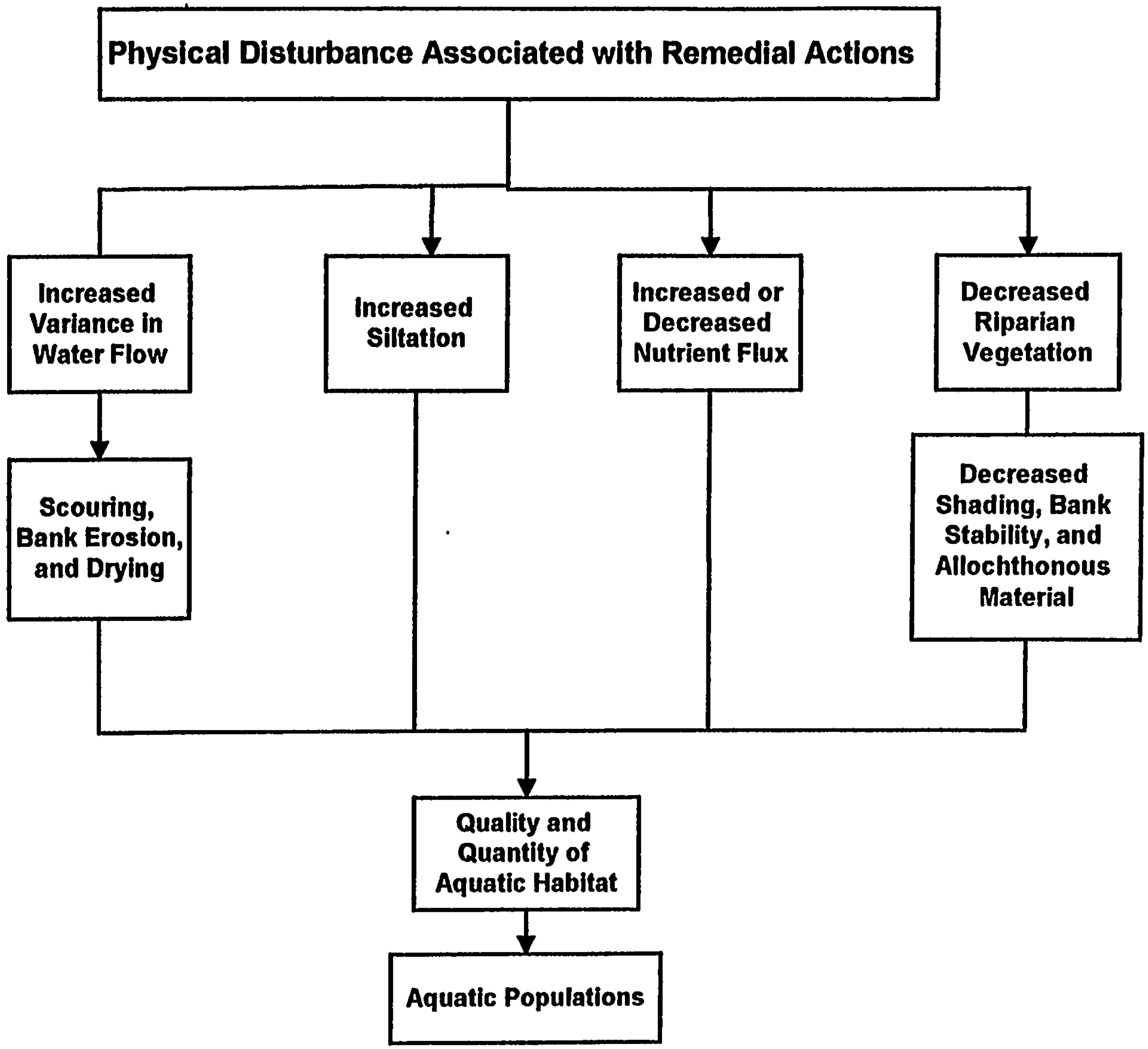

Fig. 9. Generic conceptual model of effects of physical disturbance on aquatic ecosystems.

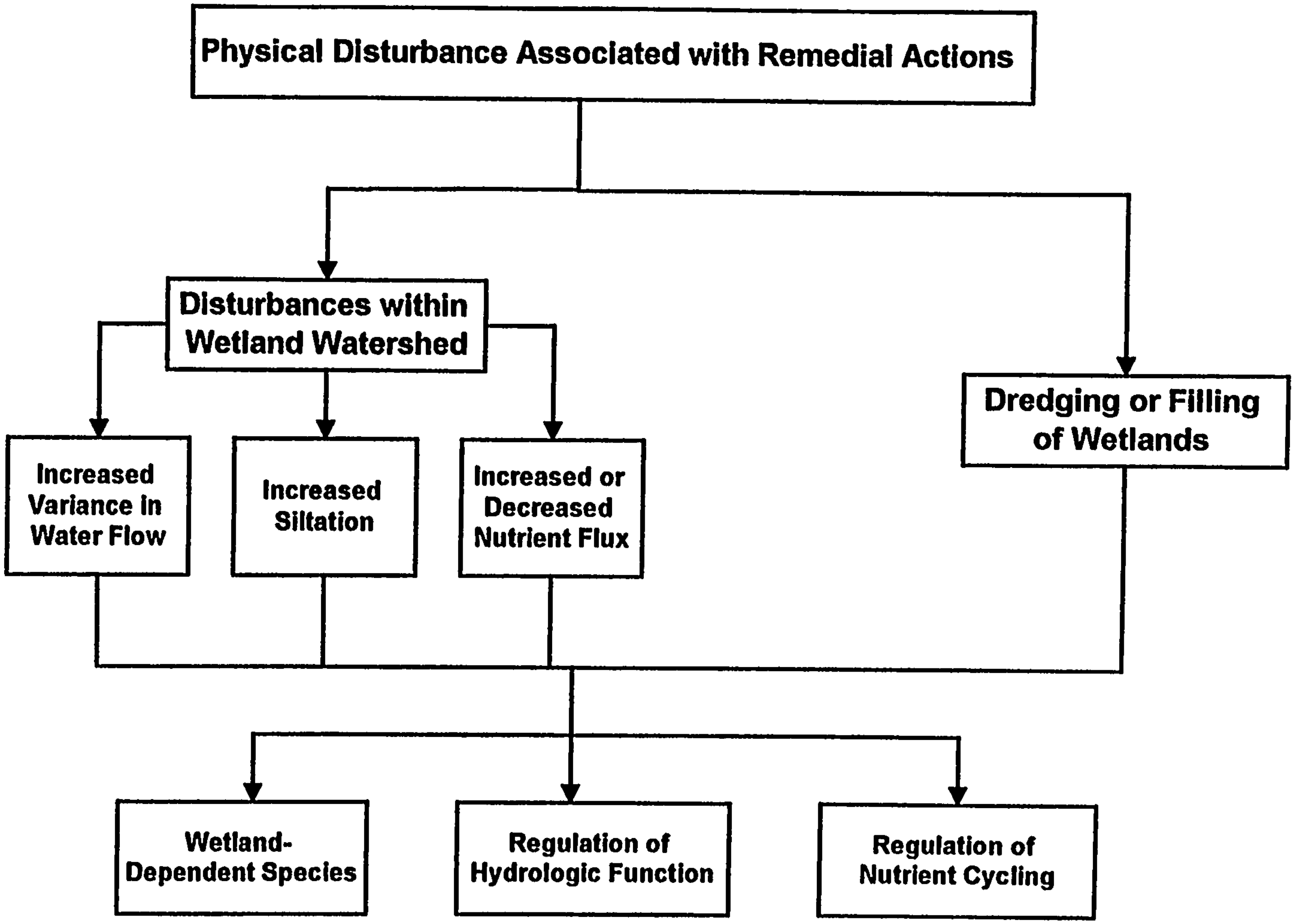

Fig. 10. Generic conceptual model of effects of physical disturbance on wetlands.

4. ECOLOGICAL ENDPOINTS

The problem formulation phase of an ERA must identify both the assessment endpoints, which are explicit statements of the characteristics of the environment that are to be protected, and the measurement endpoints, which are quantitative summaries of a measurement or series of measurements related to effects on an assessment endpoint (Suter 1989, Risk Assessment Forum 1992). Although endpoints must be derived for each OU, the following generic approach to selecting endpoints has been agreed-upon by the FFA parties for the ORR.

4.1 SELECTING ASSESSMENT ENDPOINTS

The assessment endpoints are explicit statements of the environmental values to be protected. Ecological assessment endpoints consist of an entity, a property of that entity, and a degree of change in the entity that should be detected with some confidence. These are referred to as endpoint entities, endpoint properties, and endpoint effects levels, respectively.

4.1.1 Selection of Endpoint Entities

As agreed by the FFA parties for the ORR, the criteria for selection of the entities are those recommended by the EPA (Risk Assessment Forum 1992), plus considerations of scale and practical considerations.

Susceptibility—Assessment endpoints should be susceptible to the contaminants at the site in that they are potentially exposed and are sensitive to the toxic effects of the contaminants. EPA Region IV considers this to be the most important criterion.

Ecological Relevance—Ecological relevance has been defined as being important to other components of the natural environment, particularly higher levels of organization. Region IV has provided specific illustrative criteria (importance in energy flow and mineral or nutrient cycling or acting as keystone species), but they allow other criteria for ecological relevance as appropriate.

Appropriate Scale—Ecological assessment endpoints should have a scale appropriate to the site being assessed to be clearly associated with the site. In particular, organisms that are wide-ranging relative to the scale of an OU should not be used as ecological assessment endpoints for that OU because their contamination or responses could not be clearly associated with the site.

Practical Considerations—Some potential assessment endpoints are impractical because there are not good techniques available to assess risks to them. For example, there are little available toxicity data to assess effects of contaminants on lizards, no standard toxicity tests for any reptile are available, and lizards may be difficult to survey. Therefore, lizards may have a lower priority than other better known taxa. This criterion should be given consideration only after the other criteria are evaluated. If, for example, lizards are included because of evidence of particular sensitivity or policy goals and societal values (e.g., presence of an endangered lizard species), then some means should be found to deal with the practical difficulties.

Policy Goals and Societal Values—"Societal concerns can range from protection of endangered or commercially or recreationally important species to preservation of ecosystem attributes for functional reasons (e.g., flood water retention by wetlands) or aesthetic reasons" (Risk

Assessment Forum 1992). However, Region IV does not agree with the EPA's Risk Assessment Forum, DOE, and TDEC on this point, arguing that protection of T&E species is a legal matter and is "representative of the agency's commitment to the maintenance of biodiversity" that should not be considered to be related to policy goals and societal values (personal communication from V. L. Weeks to W. Nelson Lingle). However, it is not clear in what sense "the agency's commitment to the maintenance of biodiversity" is not a policy goal. It is also not clear whether agency commitments are another basis for selecting assessment endpoints distinct from policy goals and societal values and, if not, how agency commitments are to be treated. Therefore, DOE will continue to consider T&E species and other species and ecosystems of special concern as assessment endpoints to fulfill its obligations and to be in compliance with the wishes of TDEC. Additionally, the preferences of the FFA parties as expressed in DQO meetings or other situations can constitute policy goals that must be considered in selecting assessment endpoints.

4.1.2 Selection of Endpoint Properties

The appropriate properties of the entities selected by these criteria depend on the level of organization of the entity and the criteria that led to their selection. These general properties should be selected from, modified, or supplemented for OU-specific assessments if appropriate based on properties of the COPECs, the modes of exposure, and the receptors. However, care should be taken to avoid excessive specificity. For example, dichlorodiphenyltrichloroethane (DDT) and some other compounds cause thinning of avian egg shells which reduces reproductive success. In that case, the measurement endpoint is the concentration of the chemical that causes sufficient thinning to reduce reproductive success and the assessment endpoint is individual reproduction or population production. This is because shell thickness is not ecologically or societally important *per se*, but it is important as a measure of a particular mode of action by which individual reproduction or population production may be reduced.

Organism Level—In general, protection of individual organisms is appropriate only for T&E species. For those species, individual survivorship or reproductive capacity are appropriate endpoint properties.

Population Level—In general, the appropriate endpoint properties for populations of endpoint species are abundance and production.

Community Level—In general, the appropriate endpoint properties for endpoint communities are species richness and abundance. The measure of abundance will vary among communities. For example, the abundance of the fish community is determined as numbers of all component species, whereas herbaceous plant community abundance may be expressed as biomass per unit area.

Ecosystem Level—Some ecosystems such as wetlands are valued for their properties as ecosystems rather than their composition as communities. Specifically protected properties of wetlands are provisional habitat for wetland dependent species, hydrological regulation, and retention or recycling of nutrients. No other endpoint ecosystem types have been identified. However, some components of ecosystems are clearly ecologically relevant for their role in ecosystem processes but not for their population or community properties. The soil heterotrophic community is a prominent example. Properties of the soil biota that might be endpoint properties include rates of carbon and nitrogen mineralization and rates of transformation of nitrogen and sulfur.

4.1.3 Selection of Levels of Effect on Properties of Endpoint Entities

The levels of effects on endpoint properties that should be detected and may constitute grounds for remedial action have not been specified on a national basis for ERAs as they have been for human health risk assessment. Therefore, they have been inferred on the basis of analysis of EPA and Tennessee regulatory practice (Suter et al. 1992). The clearest ecological criteria for regulation in the U.S. are those developed for the regulation of aqueous effluent under the National Pollution Discharge Elimination System (NPDES). NPDES permitting may be based on any of three types of evidence: water quality criteria, effluent toxicity tests, and biological surveys, and the use of each of these implies that a 20% reduction in ecological parameters is *de minimis*.

1. The Chronic National Ambient Water Quality Criteria (NAWQC) for Protection of Aquatic Life are based on thresholds for statistically significant effects on individual responses of fish and aquatic invertebrates. Those thresholds correspond to approximately 25% reductions in the parameters of fish chronic tests (Suter et al. 1987). Because of the compounding of individual responses across life stages, the chronic NAWQC frequently correspond to much more than 20% effects on a continuously-exposed fish population (Barnthouse et al. 1990). Therefore, while the EPA did not intend to design the NAWQC to correspond to a 20% effect or any other particular level of effect, the consequence of the procedure used to derive the NAWQC is to specify a concentration that, in chronic exposures, results in effects that are greater than 20% on average.

2. The subchronic tests used to regulate effluent based on their toxicity cannot reliably detect reductions of less than 20% in the test endpoints (Anderson and Norberg-King 1991). Once again, this is a consequence of the manner in which EPA regulates effluents rather than a conscious policy decision.

3. Twenty percent is the approximate detection limit of field measurement techniques used in regulating aqueous contaminants based on bioassessment. For example, the community metrics for an exposed benthic macroinvertebrate community must be reduced by more than 20% relative to the best communities within the ecoregion to be considered even slightly impaired in the EPA's rapid bioassessment procedure (Plafkin et al. 1989). Measures for other taxa that are more difficult to sample may be even less sensitive. For example, the number of fish species and individuals must be reduced by 33% to receive less than the top score in the EPA's rapid bioassessment procedure for fish (Plafkin et al. 1989). Once again, this is a consequence of the manner in which the EPA regulates effluents rather than a conscious policy decision.

The 20% level is also consistent with practice in assessments of terrestrial effects. The lowest-observed-effects-concentration (LOEC) for dietary tests of avian reproduction (the most important chronic test endpoint for ecological assessment of terrestrial effects of pesticides and arguably the most applicable test for waste sites) corresponds to approximately a 20% effect on individual response parameters (Office of Pesticide Programs 1982).

Therefore, an effects level for ecological assessment endpoints lower than 20% is generally acceptable based on current EPA regulatory practice and could not be reliably confirmed by field studies. Therefore, it *is de minimis in practice*. To allay concerns about the use of the 20% effects level of protection, statistically significant levels of effects should be considered as well. Because conventional statistical significance levels nearly always correspond to biological effects levels greater than 20%, statistical significance will relatively seldom be an issue in interpreting a particular set of ecological effects data. When using both types of significance criteria, any significant effects should be identified as either biologically significant (>20% effect) or statistically significant (<5% chance the difference from control or reference is due to chance).

Some exceptions apply to the use of a 20% level of effect or of statistical significance to define ecological assessment endpoints. T&E species are protected from any adverse effects; therefore, neither a 20% effect nor a statistically significant effect can be considered acceptable. Wetlands are protected from any net loss, so a 20% reduction could not be considered acceptable for ecosystems that are so classified. At particular sites there may be other species, communities, or ecosystems that have exceptional importance and therefore require greater protection than is afforded by the 20% level or statistical significance. These exceptions must be identified on a site-by-site basis.

The 20% criterion should not necessarily be assumed to apply to modeled levels of effects as opposed to the measured levels of effects discussed previously. In particular, Region IV has requested that the proportion of members of a wildlife population that is estimated to be affected be reported rather than simply reporting whether the proportion exceeds 20% or not. Since that proportion is based on modeling rather than measurement of population abundance, the limitations on measurements that provide the basis for the 20% criterion are not directly applicable. However, Region IV has indicated that the threshold for significant reductions in wildlife populations would not be greater than 20%.

The use of this or any other percent reduction in a population or community requires definition of the area where the reduction occurs. The criterion is stated in terms of the natural units, population, and community, but populations and communities are often difficult to define and delimit. If the limits are set too narrowly, the results will be meaningless (e.g., treating a 5 m^2 plot within a 5 hectare field as a community). On an the other hand, if the bounds are too broad, significant effects will be diluted to apparent insignificance (e.g., treating all the short-tailed shrews on the reservation as a single population). The following points are provided as guidance, but each case requires individual consideration.

- Plant communities should be defined using commonly applied categories. Calculations of proportional losses should be based on the area of a distinct occurrence of the community type (e.g., a floodplain hardwood forest on an individual stream or an individual cedar barren) rather than the total area of the community type on the reservation.

- Wetlands should be defined using the U.S. Army Corps of Engineers manual (1987).

- Fish and other aquatic communities in streams and rivers should be defined by reach. These reaches should have been defined during the development of the RI work plan, but there may need to be some modification of the reaches during the risk characterization to ensure that they are still logical units, given the increased understanding of the system. See Sect. 2.1.2 for criteria for delimiting reaches.

- For colonial animals such as great blue herons, each colony should be treated as a population.

- For animals that have small ranges relative to the size of plant communities (e.g., mice and shrews), the bounds of the animal population may be assumed to correspond to the bounds of the plant community. This suggestion is based on the assumption that the plant communities have habitat qualities that are sufficiently different to support distinct populations, and that they are large enough to support a population. The reasonableness of these assumptions should be determined in each case.

4.2 SELECTING MEASUREMENT ENDPOINTS

Measurement endpoints are "measurable ecological characteristics that are related to the valued characteristic chosen as the assessment endpoint. Measurement endpoints are often expressed as the statistical or arithmetic summaries of the observations that comprise the measurement" (Risk Assessment Forum 1992). Multiple measurement endpoints may exist for a particular assessment endpoint. For example, if the assessment endpoint is a 20% reduction in the species richness or abundance of a fish community, then measurement endpoints would include not only results of fish surveys expressed as densities of fish by species, but also LC50s and other test endpoints for toxicity tests with fish.

To specify the measurement endpoints during the DQO process, it is necessary to provide generic definitions that correspond to the generic definitions of assessment endpoints. These definitions are generically applicable but they should be selected, modified, or supplemented on an OU-specific basis as appropriate given properties of the specific COPECs, modes of exposure, and receptors at the site.

Organism level—Any effect on survivorship, growth or fecundity in a toxicity test of surrogate species for a threatened or endangered species. Any observed death or morbidity of individuals of a threatened or endangered species, or any detectable reduction in the abundance or production of an exposed population of a threatened or endangered species relative to reference populations.

Population level—a 20% effect on survivorship, growth or fecundity in a toxicity test of surrogate species for an endpoint species. a 20% reduction in the abundance or production of an exposed endpoint population relative to reference populations.

Community level—a 20% effect on survivorship, growth or fecundity in a toxicity test of surrogate species for an endpoint community. a 20% reduction in the species richness or abundance of an exposed endpoint community relative to reference communities.

Ecosystem level—a 20% effect on survivorship, growth or fecundity in a toxicity test of surrogate species for an endpoint ecosystem or a 20% or greater reduction in functions of a surrogate ecosystem in a microcosm toxicity test. a 20% reduction in an ecosystem function or a change in 20% of the area of an endpoint ecosystem that is indicative of loss of function. Any net loss of wetlands.

4.3 ECOLOGICAL ASSESSMENT ENDPOINTS FOR THE ORR

The following categories of organisms have been identified by the conceptual model as potential contaminant receptors that occur on the ORR but are not associated with individual source OUs or aquatic integrator OUs. These categories correspond to the compartments in the conceptual model for the terrestrial integrator OU, and they are defined in the conceptual model. This section reviews them in terms of the criteria for selection of assessment endpoints and suggests which species, community, or ecosystem properties are appropriate. Species selected as assessment endpoint species were chosen either because they are common and representative of others within their category or they are species of status (state or federal threatened or endangered or in-need-of-management species or candidate species). The selected species and communities are summarized in Table 1 in terms of the receptor groups in the conceptual models. a subset of these species which may be sampled or surveyed is presented in Table 2.

It must be re-emphasized that these species are not all to be sampled, analyzed, counted, or modeled at each OU where they might occur. Rather, the FFA parties determined them to be species that potentially meet the criteria for being endpoint species on the ORR because of their potential susceptibility or their special status or because they may serve as surrogates for species with special status. Species were selected to represent each of the potentially significant routes of exposure identified in the conceptual models. In addition, because the sensitivity of organisms to various toxic chemicals varies among taxa depending on the mode of action of the chemical, species from the various taxa that may experience a particular route of exposure are included. These species should be considered when selecting assessment and measurement endpoint species for an OU.

An example may serve to clarify the use of this species list. Nine species are listed as piscivores. Birds and mammals are sufficiently different in their sensitivities that one of each should be selected. However, a total of seven bird species is left. The osprey might be selected as the surrogate for this group because it is likely to be the most sensitive. In addition, because osprey are almost entirely piscivorous, they feed on relatively large fish which will tend to have higher concentrations of chemicals that are slowly accumulated such as polychlorinated biphenyls (PCBs), they are falconiforms which tend to be more sensitive to some chemicals than the other avian families represented in the list, and they are a Tennessee endangered species so they are protected from effects on individuals. If there are no significant risks to osprey, there should be no significant risks to other avian piscivores. If there are significant risks to osprey, then their special status should be sufficient to prompt remediation. However, if the need for remediation is still questionable, the risks to the other six avian piscivores could be calculated to determine the extent of the risks.

Many species that use the ORR are migratory and are present and potentially exposed to contaminants on the reservation for only a portion of the year. To assess risks to these species, a representative resident species within the same category will be assessed. Because residents may receive year-round exposures, the risk they experience is likely to be substantially greater than that experienced by an ecologically similar migratory species. If it is determined that resident species are not at risk from contaminant exposure, it will be assumed that ecologically similar migratory species are also not at risk. If significant risks are identified for the representative resident species, risks to ecologically similar migrants should be addressed using time-weighted exposure estimates based on the length of time they are resident at the ORR.

4.3.1 Plants (Upland, Wetland, and Floodplain)

Level of Organization

In general, the most appropriate level of organization at which to address upland plants is the plant community. There is no technical basis for distinguishing the responses of one plant species from another within a community and no policy basis to prefer one species over another. However, there are differences among communities in terms of ecological relevance, policy goals, and societal values. For T&E species, it is appropriate to assess effects on both individuals and populations.

Table 1. Reservation-scale ecological assessment endpoint species and communities for ecological risk assessment

Group	Species or Community (species in bold are state or federal T&E or candidate species)
Upland Plants	distribution and abundance of plant community types and T&E plant species
Aquatic Herbivores	Mallard duck and **cumberland slider**
Piscivores	mink, **river otter**, great blue heron, belted kingfisher, **bald eagle, osprey, double-crested cormorant, and black-crowned night heron.**
Aquatic Invertebrate Feeders	pied-billed grebe, leopard frog, and **hellbender.**
Flying Insectivores	rough-winged swallows, **gray bat, Indiana bat, eastern small footed bat, and Rafinesque's big-eared bat.**
Ground Invertebrate Feeders	American woodcock, European starling, American toad, **long-tailed shrew, masked shrew, smokey shrew, southeastern shrew, six-line racerunner, slender glass snake, Tennessee cave salamander and green salamander.**
Arboreal Insectivores	Because arboreal insectivores have low susceptibility to contamination, contaminant risks to these species will not be specifically assessed. Impacts to arboreal insectivores that may occur as a result of remediation-induced habitat alteration will be assessed by monitoring the quality and availability of habitat required by these species.
Large Omnivores	raccoons, wood duck, and muskrat
Large Herbivores	white-tailed deer, wild turkey, Canada goose, groundhog, **grasshopper sparrow, Henslow's sparrow, lark sparrow, and vesper sparrow**
Predators and Scavengers	**golden eagle, northern harrier, Cooper's hawk, red-shouldered hawk, sharp-shinned hawk, barn owl, black vulture, cougar**, red fox, snapping turtle, black rat snake, and **northern pine snake**

Table 2. Reservation-scale measurement endpoint species and communities for ecological risk assessment

Group	Species or Community
Upland Plants	distribution and abundance of plant community types and T&E plant species
Aquatic Herbivores	Mallard duck and pond slider
Piscivores	great blue heron, belted kingfisher, northern watersnake
Aquatic Invertebrate Feeders	pied-billed grebe, leopard frog
Flying Insectivores	rough-winged swallows, common bats (e.g., little brown or big brown bat).
Ground Invertebrate Feeders	Short-tailed shrew, European starling, American toad
Arboreal Insectivores	quality and availability of habitat required by these species will be monitored
Large Omnivores	raccoons, wood duck, and muskrat
Large Herbivores	white-tailed deer, wild turkey, Canada goose, and groundhog
Predators and Scavengers	red fox, snapping turtle, and black rat snake

Susceptibility

The susceptibility of upland plants to chemicals is not well defined relative to animals. Region IV believes that plants are "not particularly useful in terms of the assessment" because they are not generally sensitive to contaminants on the ORR (personal communication from V. L. Weeks to W. Nelson Lingle). However, there are distinctly different patterns of sensitivity between plants and animals. For example, boron in soil and ozone in air are much more toxic to plants than animals. In addition, plant communities are highly susceptible to physical disturbances.

Policy Goals and Societal Values

Although none of the FFA parties has expressed a particular policy concerning protection of plant communities, their societal values are manifest. In addition, 17 plant species of special concern are currently known to occur on the ORR.

Ecological Relevance

Because they are the primary producers, upland plant communities are of obvious ecological relevance.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to upland plant communities. However, many source and aquatic integrator OUs have distinct plant communities that may also be assessed at that scale.

Practical Considerations

Although the available data for toxicity of industrial chemicals to terrestrial plants is sparse and of erratic quality, plants are easily surveyed and soil toxicity tests are available.

Conclusions and Recommendations

Data concerning the distribution and abundance of plant community types are being collected as part of the reservation-wide program (Washington-Allen et al. 1995), and T&E plants are being mapped by the National Environmental Research Park staff (Appendix B). Chemical concentrations in plants should be measured by the OUs, unless there is reason to believe that the contaminants on the site will not be taken up by plants. These data will be used to assess contaminant exposure to vegetation-consuming wildlife. If contamination is found outside a designated OU (e.g., radionuclide-contaminated trees) or vegetation sampling by an OU is not scheduled until some future date, plant chemical burden data should be collected.

4.3.2 Aquatic Herbivores

Level of Organization

The appropriate level of organization for an assessment of aquatic herbivorous wildlife is the population. There is no distinct aquatic herbivore community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

These species are not known to be particularly sensitive to toxic chemicals. However, any wildlife feeding on aquatic biota are likely to be highly exposed and therefore susceptible.

Policy Goals and Societal Values

Most avian aquatic herbivores are protected and have societal value because they are migratory game species. One of the two turtles (e.g., Cumberland slider) is listed as a state INM species.

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to aquatic herbivores.

Practical Considerations

- Abundance of avian aquatic herbivores on the reservation has been monitored for the past several years as part of the ongoing waterfowl monitoring program. This survey provides baseline data and may be used to evaluate temporal trends.
- Individuals of some migratory avian aquatic herbivore species are year-round residents while others are transient. Differential exposures to these groups produces varying levels of risk. Assessment of contribution of ORR to total contaminant-related risk experienced by migrants and their populations is problematic.
- Toxicological data for turtles are limited or lacking.

Conclusions and Recommendations

Mallard duck and Cumberland slider should be retained as assessment endpoints. Toxicological data for turtles should be developed.

4.3.3 Piscivores

Level of Organization

The appropriate level of organization for an assessment endpoint for piscivorous wildlife is the population. There is no distinct piscivore community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

Piscivores are likely to be highly susceptible to chemicals because of the bioaccumulation and biomagnification that occurs in aquatic food webs and because of the sensitivity of mink to various chemicals including two that occur on the reservation: mercury and PCBs.

Policy Goals and Societal Values

Avian piscivores are conspicuous and aesthetically appealing so they have high societal value. Mink, and possibly future otters, have both commercial value and aesthetic value. In addition, four avian species (bald eagle, osprey, double-crested cormorant, and black-crowned night heron) and one mammal (river otter) are state or federal T&E or INM species.

Ecological Relevance

These species are not known to have any particular importance to the structure or function of the ecosystem of the reservation.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to piscivores.

Practical Considerations

- Population surveys of some species (e.g., mink, black-crowned night heron) may be difficult to perform. Populations of great blue herons are relatively easy to survey due to their colonial nesting behavior.

- Abundance of some avian piscivores (e.g., fish-eating ducks) on the reservation has been monitored for the past several years as part of the ongoing waterfowl monitoring program. This survey provides baseline data and may be used to evaluate temporal trends for these species.

- Some species (i.e., bald eagle) are transient on the ORR. Assessment of the ORR's contribution to total contaminant-related risk experienced by migrants and their populations is problematic.

Conclusions and Recommendations

The following should be retained as endpoint species: mink, river otter, great blue heron, belted kingfisher, bald eagle, osprey, double-crested cormorant, and black-crowned night heron.

4.3.4 Aquatic Invertebrate Feeders

Level of Organization

The appropriate level of organization for an assessment endpoint for aquatic invertebrate feeders is the population. There is no distinct aquatic invertebrate feeder community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

These species are not known to be particularly sensitive to toxic chemicals. However, any wildlife feeding on aquatic biota are likely to be highly exposed and therefore susceptible.

Policy Goals and Societal Values

Most avian aquatic invertebrate feeders are protected and have particular societal value because they are migratory game species. One of the 12 amphibians or reptiles (i.e., hellbender) is listed as a candidate for protection under the federal Endangered Species Act and is a state INM species.

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to aquatic invertebrate feeders.

Practical Considerations

- Abundance of avian aquatic invertebrate feeders on the reservation has been monitored for the past several years as part of the ongoing waterfowl monitoring program. This survey provides baseline data and may be used to evaluate temporal trends.

- Population surveys of some species (e.g., amphibians) may be difficult to perform.

- Toxicological data for amphibians and reptiles are limited or lacking.

- Some species (i.e., waterfowl) are migratory. Assessment of contribution of ORR to total contaminant-related risk experienced by migrants and their populations is problematic.

Conclusions and Recommendations

The following should be retained as endpoint species: pied-billed grebe, leopard frog, and hellbender. Toxicological data for amphibians and reptiles should be developed.

4.3.5 Flying Insectivores

Level of Organization

The appropriate level of organization for an assessment endpoint for flying insectivores is the population. There is no distinct flying insectivore community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

Many flying insectivores (bats and swallows in particular) forage extensively on emergent aquatic insects. Because they consume large volumes of insects, they are exposed and susceptible to contaminants from aquatic biota.

Policy Goals and Societal Values

Avian flying insectivores are conspicuous and aesthetically appealing so they have high societal value. Several bats potentially present on the ORR are either state and federal endangered species (e.g., gray and Indiana bats) or are state INM and candidates for protection under the federal Endangered Species Act (e.g., eastern small footed bat, Rafinesque's big-eared bat).

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit. An exception may be the role of bats in cave communities. Use of caves on the ORR by bats is unknown.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to flying insectivores.

Practical Considerations

- It is not known if T&E bat species are actually resident on the ORR.
- Population surveys of some species (e.g., bats) may be difficult to perform.

Conclusions and Recommendations

The following should be retained as endpoint species: rough-winged swallows, gray bat, Indiana bat, eastern small-footed bat, and Rafinesque's big-eared bat. a bat survey should be performed to document the occurrence of T&E bat species. Studies of common, non-T&E bat species (e.g., little brown or big brown bats) should be used to assess risks to T&E bat species.

4.3.6 Ground Invertebrate Feeders

Level of Organization

The appropriate level of organization for an assessment endpoint for ground invertebrate feeders is the population. There is no distinct ground invertebrate feeder community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

Many ground invertebrate feeders consume large volumes of invertebrates; therefore, they are highly exposed and susceptible to chemicals bioaccumulated by ground invertebrates. In addition, shrews, amphibians, and reptiles burrow and are in close physical contact with soil and may take up chemicals directly through ingestion or dermal contact.

Policy Goals and Societal Values

Avian ground invertebrate feeders are conspicuous and aesthetically appealing so they have high societal value. In addition, some are migratory and/or game species. Four shrews (long-tailed, masked, smokey, and southeastern), two lizards (six-line racerunner, slender glass snake), and two salamanders (Tennessee cave salamander and green salamander) are species of status (state T&E or INM or candidates for federal listing).

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

Excluding birds, many ground invertebrate feeders have limited home ranges. However, the reservation provides the most appropriate scale for assessment of risks to populations of ground invertebrate feeders.

Practical Considerations

- Population surveys of some species (e.g., amphibians, reptiles, shrews) may be difficult to perform.

- Toxicological data for amphibians and reptiles are limited or lacking.

- Some species (i.e., birds) are migratory. Assessment of the ORR's contribution to total contaminant-related risk experienced by migrants and their populations is problematic.

Conclusions and Recommendations

The following should be retained as endpoint species: American woodcock, European starlings, American toads, long-tailed shrew, masked shrew, smokey shrew, southeastern shrew, six-line racerunner, slender glass snake, Tennessee cave salamander and green salamander. Toxicological data for amphibians and reptiles should be developed.

4.3.7 Arboreal Insectivores

Level of Organization

The appropriate level of organization for an assessment of arboreal insectivores is the population. There is no distinct arboreal insectivore community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

While arboreal insectivores are not likely to be highly exposed, sensitive, or susceptible to contamination, they may be greatly impacted by habitat alterations resulting from remediation.

Policy Goals and Societal Values

Avian arboreal insectivores are conspicuous and aesthetically appealing so they have high societal value. In addition, most are migratory species and two (red-headed woodpecker, yellow-bellied sapsucker) are state INM species.

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to arboreal insectivores.

Practical Considerations

- Population surveys of some species (e.g., amphibians and reptiles) may be difficult to perform.

- Toxicological data for amphibians and reptiles are limited or lacking.

- Some species (i.e., birds) are migratory. Assessment of the ORR's contribution to total contaminant-related risk experienced by migrants and their populations is problematic.

Conclusions and Recommendations

Because arboreal insectivores have low susceptibility to contamination and have no particular ecological relevance, chemical risks to these species will not be specifically assessed. Impacts to arboreal insectivores that may occur as a result of remediation-induced habitat alteration will be assessed by monitoring the quality and availability of habitat required by these species.

4.3.8 Large Omnivores

Level of Organization

The appropriate level of organization for an assessment of large omnivores is the population. There is no distinct large omnivore community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

While there are no data to suggest that they are particularly sensitive to chemicals, many large omnivores feed extensively on aquatic biota (ducks, raccoons, muskrat) or on soil/litter biota (grackles, opossum, raccoon) that may bioaccumulate chemicals.

Policy Goals and Societal Values

Avian large omnivores are conspicuous and aesthetically appealing so they have high societal value. In addition, most are migratory species. Raccoons and muskrats are valued as furbearers. Raccoons are also a game species.

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to large omnivores.

Practical Considerations

- Population surveys of some species (e.g., turtles) may be difficult to perform.
- Toxicological data for reptiles are limited or lacking.
- Some species (i.e., birds) are migratory. Assessment of the ORR's contribution to total contaminant-related risk experienced by migrants and their populations is problematic.

Conclusions and Recommendations

The following should be retained as endpoint species: raccoons and wood duck. Because muskrats forage almost exclusively on aquatic biota (and may therefore bioaccumulate chemicals) and constitute a substantial portion of the diet of mink, muskrats are also included.

4.3.9 Large Herbivores

Level of Organization

The appropriate level of organization for an assessment of large herbivores is the population. There is no distinct large herbivore community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

With few exceptions (e.g., consumption of coal ash from the FCAP by deer, groundhogs burrowing in contaminated soils), large herbivores are not highly exposed or highly susceptible to contamination.

Policy Goals and Societal Values

Most mammalian large herbivores are valued game species or furbearers and therefore have high societal value. Avian large herbivores are conspicuous and aesthetically appealing so they have high societal value. In addition, many are migratory, and a few are game species. Four sparrows (grasshopper, Henslow's, lark, and vesper) are species of status (state T&E or INM species or candidates for federal listing).

Ecological Relevance

In general, these species are not known to play any particularly significant role in the ecosystems that they inhabit. However, deer populations at high densities may significantly modify plant communities.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to large herbivores.

Practical Considerations

- Some species (i.e., birds) are migratory. Assessment of the ORR's contribution of ORR to total contaminant-related risk experienced by migrants and their populations is problematic.

- Harvesting of deer, trapping of turkey for restocking, and ongoing surveys of Canada goose abundance on the ORR provide an opportunity for monitoring these species.

Conclusions and Recommendations

The following should be retained as endpoint species: white-tailed deer, wild turkey, Canada goose, groundhogs, grasshopper sparrow, Henslow's sparrow, lark sparrow, and vesper sparrow.

4.3.10 Predators and Scavengers

Level of Organization

The appropriate level of organization for an assessment of predators and scavengers is the population. There is no distinct predator and scavenger community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

Predators and scavengers may be susceptible to contamination because they are at the top of the food web and spatially integrate chemicals bioaccumulated by lower trophic levels.

Policy Goals and Societal Values

Avian predators and scavengers are conspicuous and generally aesthetically appealing so they have high societal value. In addition, many are migratory species. While most mammalian predators are not conspicuous, the status of their populations is a concern to the public. Several predator and scavenger species are also species of status (state or federal T&E or INM species or candidates for federal listing). These include golden eagle, northern harrier, Cooper's hawk, red-shouldered hawk, sharp-shinned hawk, barn owl, black vulture, cougar, and the northern pine snake.

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

The reservation provides the appropriate scale for assessment of risks to predators and scavengers.

Practical Considerations

- Most predators and scavengers are extremely wide-ranging with diffuse populations. Locating sufficient individuals to assess their populations may be difficult.
- Some species (i.e., birds) are migratory. Assessment of the ORR's contribution to total contaminant-related risk experienced by migrants and their populations is problematic.
- Toxicological data for reptiles are limited or lacking.

Conclusions and Recommendations

The following should be retained as endpoint species: golden eagle, northern harrier, Cooper's hawk, red-shouldered hawk, sharp-shinned hawk, barn owl, black vulture, cougar, red fox, snapping turtle, black rat snake, and the northern pine snake. Toxicological data for reptiles should be developed.

4.4 ECOLOGICAL ASSESSMENT ENDPOINTS FOR SOURCE AND AQUATIC INTEGRATOR OUS

Both source OUs and aquatic integrator OUs have relatively limited scales that restrict the choice of assessment endpoints to those organisms having restricted ranges because of their small size, immobility, or restriction to streams or ponds. The process of selecting endpoint species and communities is described in the following text and the results are summarized in Table 3.

4.4.1 Fish

Level of Organization

The appropriate level of organization for an assessment of fish is the community. Fish are sampled as a community, and, in the absence of a sport or commercial fishery on the ORR, no particular populations are more valued than others.

Table 3. Generic measurement endpoint species and communities for source and aquatic integrator OUs

Group	Species or Community
Plants	distribution and abundance of plant community types and T&E plant species
Soil/Litter Invertebrates and Processes	earthworms
Ground Invertebrate Feeders	short-tailed shrew, American toad
Small Omnivores	white-footed mouse
Small Herbivores	none
Fish	species richness and abundance of the fish community
Benthic Invertebrates	species richness and abundance of the invertebrate community
Aquatic Plants	none

Susceptibility

Fish are susceptible to aqueous contamination because they are intimately exposed to water, integrate effects on lower trophic levels, and assimilate chemicals bioaccumulated by lower trophic levels from both water and sediments.

Policy Goals and Societal Values

Fish are aesthetically appealing, and fish communities have long been used as endpoints for regulation of aqueous contamination.

Ecological Relevance

Fish may play an important role in energy and nutrient dynamics in streams.

Appropriate Scale

Stream or river reaches are the appropriate scale at which to assess effects on fish.

Practical Considerations

- Methods for sampling fish are well established.
- Baseline data sets are available for fish communities in most contaminated streams and several reference streams.
- Toxicity tests for effects of ambient waters are well established.
- Baseline data sets are available for toxicity of waters from most contaminated streams and several reference streams.
- Toxicological data for fish are relatively abundant.

Conclusions and Recommendations

The species richness and abundance of fish communities should be used as an assessment endpoint at all sites where fish are present.

4.4.2 Benthic Invertebrates

Level of Organization

The appropriate level of organization for an assessment of benthic invertebrates is the community. Benthic invertebrates are sampled as a community, and no particular populations are more valued than others.

Susceptibility

Benthic invertebrates are susceptible to aqueous contamination because they are intimately exposed to water (epibenthic and riffle species) or sediment (benthic infauna) and because some members are inherently sensitive to many chemicals.

Policy Goals and Societal Values

Benthic invertebrate communities have little inherent societal value, but, because of their ecological importance and relative ease of quantitative characterization, they have long been used as endpoints for regulation of aqueous contamination.

Ecological Relevance

Benthic invertebrates play an important role in energy and nutrient dynamics in streams.

Appropriate Scale

Stream or river reaches are the appropriate scale at which to assess effects on benthic invertebrates.

Practical Considerations

- Methods for sampling benthic invertebrates are well established.
- Baseline data sets are available for benthic invertebrate communities in most contaminated streams and several reference streams.
- Toxicity tests for effects of ambient waters and sediments are well established.
- Baseline data sets are available for toxicity of waters from most contaminated streams and several reference streams.
- Toxicological data for benthic invertebrates are rare relative to fish and planktonic invertebrates.
- Benthic invertebrates are present in streams that are too small or intermittent to support fish.

Conclusions and Recommendations

The species richness and abundance of benthic invertebrate communities should be used as an assessment endpoint at all sites where fish are present.

4.4.3 Aquatic Plants

Level of Organization

The appropriate level of organization for an assessment of aquatic plants is the community. In streams, the plant communities are entirely or primarily in the form of periphyton which is sampled as a community.

Susceptibility

Periphyton is not, in general, particularly susceptible to the contaminants released by waste sites. However, some algal species are particularly sensitive to some aqueous contaminants such as copper.

Policy Goals and Societal Values

In general, algae in streams or lakes is considered to be unaesthetic when it is perceptible. Algal effects are seldom the basis for regulation of aqueous contaminants and have not been included in the EPA's stream bioassessment procedure (Plafkin et al. 1989).

Ecological Relevance

Aquatic plants, along with allochthanous material, form the basis of aquatic ecosystems.

Appropriate Scale

Stream or river reaches are the appropriate scale at which to assess effects on aquatic plants.

Practical Considerations

- Methods for sampling periphyton are well established.
- Baseline data sets are available for periphyton communities in many contaminated streams and reference streams.
- Toxicity tests for effects of ambient waters are not established and have not been performed on the ORR.
- Periphyton community characteristics are highly sensitive to light, nutrient levels, and grazing levels, which tends to mask any effects of contaminants.
- Toxicological data for aquatic algae are relatively abundant.

Conclusions and Recommendations

Aquatic plants are not good assessment endpoints for streams and ponds relative to fish and benthic invertebrates. However, where data concerning aquatic plants are available, they should be analyzed for evidence of toxic or other effects that may help to interpret risks to fish and benthic invertebrates.

4.4.4 Soil/Litter Invertebrates and Processes

Level of Organization

An appropriate level of organization for an assessment of the soil community is the entire community, because the primary value of this community is its functional role in decomposition and nutrient recycling. However, the EPA has focused on earthworms as representatives of this community, so the entire earthworm fauna (Order *Opisthopora*, Class *Oligochaeta*) is also an appropriate level of organization.

Susceptibility

The soil community is highly exposed to contaminants. The inherent sensitivity of soil processes to chemicals is low, but the sensitivity of particular taxa including earthworms is largely unknown.

Policy Goals and Societal Values

Earthworms are becoming a standard ecological assessment endpoint for the EPA's regulation of contaminants in soils.

Ecological Relevance

The soil community plays a critical role in terrestrial energy and nutrient dynamics.

Appropriate Scale

Because of their small size and relative immobility, soil communities and earthworms can be assessed on the scale of small subunits of OUs.

Practical Considerations

- Methods for sampling earthworms are available, but earthworm taxonomy is relatively difficult, and guidance for interpreting earthworm field data is not available.
- Toxicity tests for earthworms are relatively well established.
- Baseline data sets are not available for toxicity or earthworm abundance in ORR soils.
- Toxicological data for earthworms or soil communities are relatively rare.

Conclusions and Recommendations

The abundance and production of earthworms constitute an appropriate assessment endpoint.

4.4.5 Ground Invertebrate Feeders

Level of Organization

The appropriate level of organization for an assessment endpoint for ground invertebrate feeders is the population. There is no distinct ground invertebrate feeder community, and toxicity estimates are species-specific for wildlife. For T&E species, it is appropriate to assess effects on both individuals and populations.

Susceptibility

Many ground invertebrate feeders consume large volumes of invertebrates; therefore, they are highly exposed and susceptible to chemicals bioaccumulated by ground invertebrates. In addition, shrews, amphibians, and reptiles burrow and are in close physical contact with soil and may take up chemicals directly through ingestion or dermal contact. However, methods for assessing risks from dermal contact are lacking.

Policy Goals and Societal Values

Four shrews (long-tailed, masked, smokey, and southeastern), two lizards (six-line racerunner, slender glass snake), and two salamanders (Tennessee cave salamander and green salamander) are species of status (state T&E or INM or candidates for federal listing).

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

Excluding birds, many ground invertebrate feeders have limited home ranges. Individual OUs provide an appropriate scale for assessment of risks to populations of ground invertebrate feeders if they are found on the OU in significant numbers and have sufficiently low mobility to be associated with the site.

Practical Considerations

- Population surveys of some species (e.g., amphibians, reptiles, shrews) may be difficult to perform.
- Toxicological data for insectivorous mammals, amphibians, and reptiles are limited or lacking.
- Toxicity testing methods for these organisms are poorly developed.

Conclusions and Recommendations

Short-tailed shrews or any more common shrew species should be used as a representative endpoint species for this group.

4.4.6 Small Omnivores

Level of Organization

The appropriate level of organization for an assessment endpoint for small omnivores is the population. There is no small omnivore community, and toxicity estimates are species-specific for wildlife.

Susceptibility

Small omnivorous mammals (e.g., *Peromyscus* spp.) are more exposed to chemicals than herbivores, possibly because of their consumption of ground invertebrates (Talmadge and Walton 1990). In addition, small omnivores burrow and are in close physical contact with soil and may take up chemicals directly through ingestion or dermal contact.

Policy Goals and Societal Values

None of these species has particular societal value or association with policy goals. However, where the EPA has been the lead agency for CERCLA sites, they have routinely used small mammals, including small omnivores, as endpoint species.

Ecological Relevance

Although these species are the most abundant mammalian group on most of the ORR, they are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

Many small omnivores have limited home ranges. Individual OUs provide an appropriate scale for assessment of risks to populations of ground invertebrate feeders if they are found on the OU in significant numbers and have sufficiently low mobility to be associated with the site.

Practical Considerations

- Population surveys of some species are easily performed but the highly variable demographics of these rodents makes interpretation difficult.

- Toxicological data for rodents are abundant.

- Toxicity testing methods for these organisms are well developed.

Conclusions and Recommendations

Peromyscus species should be used as a representative endpoint species for this group.

4.4.7 Small Herbivores

Level of Organization

The appropriate level of organization for an assessment endpoint for small herbivores is the population. There is no distinct small herbivore community, and toxicity estimates are species-specific for wildlife.

Susceptibility

Small herbivorous mammals (e.g., *Microtus* spp.) are less exposed to chemicals than insectivores or omnivores (Talmadge and Walton 1990).

Policy Goals and Societal Values

None of these species has particular societal value or association with policy goals. However, where the EPA has been the lead agency for CERCLA sites, they have routinely used small mammals, including small herbivores, as endpoint species.

Ecological Relevance

These species are not known to play any particularly significant role in the ecosystems that they inhabit.

Appropriate Scale

Many small herbivores have limited home ranges. Individual OUs provide an appropriate scale for assessment of risks to populations of small herbivores if they are found on the OU in significant numbers and have sufficiently low mobility to be associated with the site.

Practical Considerations

- Population surveys of some species are easily performed but the highly variable demographics of these rodents makes interpretation difficult.

- Toxicological data for rodents are abundant.

Conclusions and Recommendations

No endpoint species are recommended for this group.

5. DATA NEEDS AND RESPONSIBILITIES

As part of the 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.

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. For example, the RI for a source OU like the WAG 5 low-level waste burial grounds at ORNL:

- characterized contamination on the OU,
- characterized exposure of endpoint biota associated with the contaminated areas (earthworms and terrestrial plants) and their resulting risks,
- characterized exposure to contaminants on the site of biota associated with the terrestrial integrator OU that use the site but are not associated with the site (e.g., deer and wild turkeys) by characterizing contamination of plants and invertebrates on the OU that are consumed by wildlife from off the OU, and
- characterized contaminant fluxes off the OU in leachates to the Melton Valley Groundwater OU and in seeps and springs to WAG 2 which includes Melton Branch and White Oak Creek (Bechtel 1988, Ashwood and Suter 1993).

Baseline ERAs are not complete without characterization of the risks to the integrator OUs to which it contributes contaminants because remedial decisions should be made on the basis of total risk. However, the capacity to perform such risk characterizations is limited by the availability of data and analyses for the downstream OUs. In the case of WAG 5, risks to WAG 2, the aquatic integrator OU, had not been assessed (a Phase 1 baseline ERA is scheduled for 1996) so BMAP reports and data collected for the WAG 5 RI were used to characterize risks to WAG 2 *ad hoc*. Risks to wide-ranging species associated with the reservation-wide OU were not assessed in the WAG 5 RI; however, as directed by the FFA parties, they were deferred to the reservation-wide ERAs. The first reservation-wide ERA is now available (Sample et al. 1995), and it and its successors should be used to characterize the contribution of source and aquatic integrator OUs to risks to wide-ranging species in all future BERAs.

6. SPECIFIC DATA NEEDS

Data needs for ERAs are defined for each OU during the DQO process. The DQO process for individual OUs tends to focus on the problems associated with that OU and the decisions that are necessitated by those problems. However, the ERA strategy for the ORR requires that each OU consider what data it needs from other OUs and what data it must supply to other OUs to which it is functionally linked. This section discusses data needs for each OU in terms of measurements that should be performed for a particular compartment in each OU, given prescribed conditions. These needs are implicit in the generic conceptual models. Like those models, they must be adapted to the individual OUs and should be considered as starting points for the ecorisk portions of DQO workshops.

For all media, chemical analyses should include chemicals of potential ecological concern identified in prior screening assessments (Suter 1995). In the absence of an adequate screening assessment, the analyses should include all chemicals that may occur in the OU. Given the incomplete records of waste disposal on most ORR sites, it is often necessary to perform some "full suite" analyses.

For all OUs, data collection must include habitat analyses. Each habitat analysis should include enough information to not only characterize the type of habitat present but to also allow inferences concerning the populations and communities that would be expected to be present and the approximate levels of the endpoint properties.

6.1 SOURCE OUs

Soil Contaminants

Contaminants in the rooting zone of the soil must be characterized. In areas with only herbaceous vegetation, the preponderance of root biomass is likely to be in the top 10–20 cm. If trees are present or may be present in the future, a deep rooting zone down to approximately 3 m should be characterized and assessed separately. In addition, soil particle size distribution, pH, organic matter content, cation exchange capacity, and macronutrient content (N, P, K) should be determined.

Plants

The plant communities of all OUs should be identified and characterized in terms of their structure, major species, and any species of special concern. This characterization need not include a complete species list.

If herbivorous or omnivorous animals are endpoint species for the OU or if such animals from off the OU make significant use of the OU for grazing and if the possibility of toxic levels of chemicals in plants cannot be excluded by a screening assessment based on soil concentrations, the concentrations of chemicals in plants should be determined. For species that are resident on the OU, the sampling design should be based on defining the mean concentration with some specified confidence within an area equal to the range of the least widely ranging endpoint species. If the only endpoint herbivores or omnivores are from off the OU, the sampling should be based on defining the mean concentration for the OU with some specified confidence.

Phytotoxicity tests should be performed on the soil if (1) toxicity to plants is suspected based on a screening assessment, (2) the soil is contaminated but either the soil contamination data or the phytotoxicity data are insufficient to perform a reliable screening assessment, or (3) phytotoxicity is suspected based on the condition of plants on the OU. Plant samples or soil samples for toxicity tests should be collected from sites where soil has been chemically analyzed, or analyses should be performed *ad hoc*.

Soil/Litter Invertebrates

Earthworms are surrogate organisms for all soil invertebrates and are a route of transport of soil contaminants to wildlife. If a screening assessment has not eliminated bioaccumulation of chemicals by soil invertebrates as a hazard, earthworms should be sampled from areas with contaminated soils and analyzed for COPCs that may bioaccumulate. Earthworm toxicity tests should be performed on the soil if (1) toxicity to earthworms is suspected based on a screening assessment, (2) the soil is contaminated, but either the soil contamination data or the oligochaete toxicity data are insufficient to perform a reliable screening assessment, or (3) toxicity is suspected based on the abundance of worms on the OU. Earthworm samples or soil samples for toxicity tests should be collected from sites where soil has been chemically analyzed, or analyses should be performed *ad hoc*.

Small Herbivores, Omnivores, and Soil Invertebrate Feeders

This category includes small mammals, reptiles, and amphibians. Because of the poor habitat quality, these organisms do not occur in significant numbers on many OUs, and mammals are more likely to be present in significant numbers than are reptiles or amphibians.

If the site provides significant habitat for these organisms in areas that have significant soil contamination, small mammals should be sampled and analyzed. The analyses should be performed on whole animals unless toxic effects of particular COPCs can be related to concentrations in specific organs. In such cases, the organ and the remainder of the carcass should be analyzed separately. All captured animals should be counted, aged, sexed, and weighed. However, only selected measurement endpoint species should be chemically analyzed.

Water

If potentially contaminated surface water occurs on the OU, its contamination must be characterized. This should include ponds, wetlands with standing water, streams that are not part of an aquatic integrator OU, and seeps or springs. Water analyses for ERAs should include the dissolved-phase analyses for metals as specified by the EPA Office of Water (Prothro 1993, 59 FR 44678, and 60 FR 22229) and whole water (i.e., unfiltered) analysis as specified by Region IV. Dissolved phase analyses are recommended by the Office of Water because the particulate metals have negligible bioavailability to aquatic life. Region IV wants the particulate phase metals included to make assessments of risks to aquatic life more conservative. Organic chemicals should be analyzed in whole water because organic contaminants are assumed to not be significantly associated with the particulate phase. Basic water chemistry should be characterized including pH and hardness.

Aquatic Community

Most source OUs do not possess distinct aquatic communities that require assessment. Most surface water on source OUs is waste water in sumps or waste ponds. Even when these support aquatic life, they are not communities to be protected, but rather sources to be remediated. However, if there are ponds, wetlands, or other surface waters on the site that are not simply waste repositories but may have been contaminated by wastes, they must be characterized. In other words, risks to waters of the state must be assessed but not risks to waste waters. Water bodies on waste sites are so diverse that it is not possible to generalize about data needs. However, the data needs for the aquatic communities in aquatic integrator OUs (discussed in the following text) should be consulted.

6.2 AQUATIC INTEGRATOR OUs

Soil, plants, soil/litter invertebrates, and small herbivores, omnivores, and ground invertebrate feeders should be characterized as described previously for source OUs. The principal difference from source OUs is that the abundance and diversity of animals is likely to be higher on the floodplains of aquatic integrator OUs.

Water

If potentially contaminated surface water occurs on the OU, its contamination must be characterized. In addition to the stream that defines the aquatic integrator OU, this characterization should include ponds, wetlands with standing water, and any seeps or springs not characterized by the source OU. Water analyses for ERAs should include the dissolved-phase analyses for metals as specified by the EPA Office of Water (Prothro 1993) and the total analysis as specified by Region IV. Organic chemicals should be analyzed in whole water. Basic water chemistry should be characterized including pH and hardness. If chemical analyses or other information suggest that the water may be toxic, aqueous toxicity tests should be performed. If significant toxicity is found, follow-up tests should be conducted to determine the cause and the degree to which the source (e.g., a seep or spring) must be diminished to eliminate the toxicity.

Sediment

Sediment should be sampled and analyzed from deposition areas of streams and ponds. The analyses of chemicals should include both whole sediment and pore water. Basic physical/chemical properties of the sediment including pH, organic carbon content, and texture should also be determined. For ERAs, analysis and toxicity testing can be limited to biologically active surface sediments ($\approx$10 cm). If sediments are sufficiently contaminated to suggest possible toxicity, toxicity tests of the sediment should be performed.

Benthic Invertebrates

Two distinct communities of benthic invertebrates occur in the streams of the aquatic integrator OUs: riffle communities and pool communities. The riffle communities occur in areas with rapid water flow and stony substrates, so they are exposed to chemicals in the surface water. Because of this, they have been monitored by the BMAP to determine effects of water pollution. If there are COPECs in the water, the BMAP sampling program should be examined to determine if contaminated reaches and suitable reference reaches are being sampled and characterized.

The benthic invertebrates of pools are an endpoint community for these OUs because they are associated with the deposited sediments that may be contaminated and may require remediation. This community is not being characterized by the BMAP program. If sediments are known to be significantly contaminated or if particle associated COPCs occur in the OU, this community should be sampled and characterized in each contaminated reach and at reference sites. The sediment samples for characterization of this community should be taken in areas sampled for sediment analysis concurrently if possible or at least in the same season and year.

Benthic invertebrates may be sampled for chemical analysis if they may be a significant source of exposure to fish or flying invertebrate feeders. This will be the case if 1) fish are known to be significantly contaminated with a bioaccumulative COPC (e.g., PCBs or mercury) or 2) concentrations of a bioaccumulative COPCs in water or sediment are sufficient to suggest that invertebrates may receive toxic concentrations. In some cases, it may be difficult to obtain a sufficient mass of invertebrates for analysis without unreasonable effort and damage to the community being sampled.

Fishes

Although fish communities include multiple trophic groups, they are sampled and characterized as a community by electrofishing or net. This characterization is being performed by BMAP in most contaminated streams on the ORR and by the CRRI and TVA in the Clinch River/Watts Bar Reservoir. If there are COPECs in the water, the fish sampling programs should be examined to determine if contaminated reaches and suitable reference reaches are being sampled and the communities characterized. This community characterization should include counts by species, size of fish, and observations of gross pathologies and deformities as described in the BMAP procedures.

Most fish analyses have been performed on fillets of game species. For ERAs, analyses should be performed on whole fish and fish species that are likely to be highly exposed or are likely to be major prey species of piscivorous wildlife. When the species analyzed for human health risk assessments fit those criteria, enough carcasses should be analyzed along with the fillets to establish a fillet to whole body ratio for the species.

In addition to the community characterization and chemical analyses, certain organismal and suborganismal properties termed biomarkers or bioindicators are measured by BMAP and other programs. Some of these may be diagnostic of exposure to or effects of particular chemicals. Others may be indicative of the health of individual fish. During the DQO process, the utility of these biomarkers and bioindicators should be considered and a decision made as to the need to extend these measurements to reaches where they are not measured.

Aquatic Plants

Where aquatic herbivores are present (i.e., mallards or pond sliders) or significant habitat for aquatic herbivores is present and COPCs are present that may accumulate in aquatic plants, aquatic plants should be sampled and analyzed.

6.3 GROUNDWATER OUs

If groundwater directly enters surface water in seeps or springs or cave waters that support multicellular organisms, the concentrations of chemicals of potential ecological concern should be determined including dissolved phase analyses of metals as specified by the EPA Office of Water

(Prothro 1993) and the total analysis as specified by Region IV, and aquatic toxicity tests should be performed.

6.4 TERRESTRIAL INTEGRATOR OUs

Although a small set of sampling and analysis activities was originally included by the FFA parties in the monitoring and assessment program for the ORR (Ashwood et al. 1994), those activities were canceled. Therefore, there are no plans to gather data specifically for the terrestrial integrator OU. All data for the reservation-wide ecological risk assessments will come from data collected by source and aquatic integrator OUs and other environmental programs on the ORR. Any data that are needed by the source and aquatic integrator OUs to assess their contributions to the risks to reservation-scale endpoint populations and communities must be included in sampling and analysis plans for that OU. In particular, all OU activities that collect plants, earthworms, or small mammals for analysis must also collect and analyze materials from clean reference sites because no background has been established for these organisms. Experience at WAG 5 and K-901 has shown that plants and animals collected from the periphery of an OU may be contaminated, so sampling that is limited to the OU is likely to be inadequate.

7. RISK CHARACTERIZATION

Risk characterization combines information concerning exposure to chemicals with information concerning effects of chemicals to estimate risks. Risk characterization for ERAs is performed by weight of evidence (Risk Assessment Forum 1992). That is, rather than simply modeling risks, ecological risk assessors examine all available data from chemical analyses, toxicity tests, biological surveys, and bioindicators to estimate the likelihood that significant effects are occurring or will occur and describe the nature, magnitude, and extent of effects on the designated assessment endpoints. This section describes the approach for estimating risks based on individual lines of evidence and then combining them through a process of weighing the evidence.

7.1 SINGLE CHEMICAL TOXICITY

This line of evidence uses analyses of individual chemicals in individual media to estimate exposure and uses literature values for effects of individual chemicals to estimate effects (Fig. 11). They are combined in two steps. First, the chemicals are screened against ecotoxicological benchmarks and against background exposures to determine which are COPECs. This may have been done previously in screening assessments for earlier phases in the remedial process such as the RI work plan, but it should be repeated for each new assessment.

For those chemicals that are retained by the screening (the COPECs), exposures must be compared to the full toxicity profile of the chemical to characterize risk. For example, the distribution of concentrations in water would be compared to the distribution of concentrations of thresholds for chronic toxicity across fish species and across prey species, the nature of the chronic effects would be described, and the exposure durations needed to achieve effects in the laboratory would be compared to temporal dynamics of concentrations in the field. Characteristics of the chemicals that are relevant to risks are also examined such as the influence of metal speciation on toxicity, tendency of the chemical to accumulate in prey species, etc.

The result of risk characterization for this line of evidence should be statements about:

- are toxic concentrations of chemicals present,
- what effects do these concentrations cause in the laboratory or at well-studied sites,
- how extensive are toxic concentrations,
- how frequent are toxic concentrations,
- are they associated with identifiable sources or chemicals,
- how much must the source be diminished to eliminate toxicity,
- how confident are you concerning your answers?

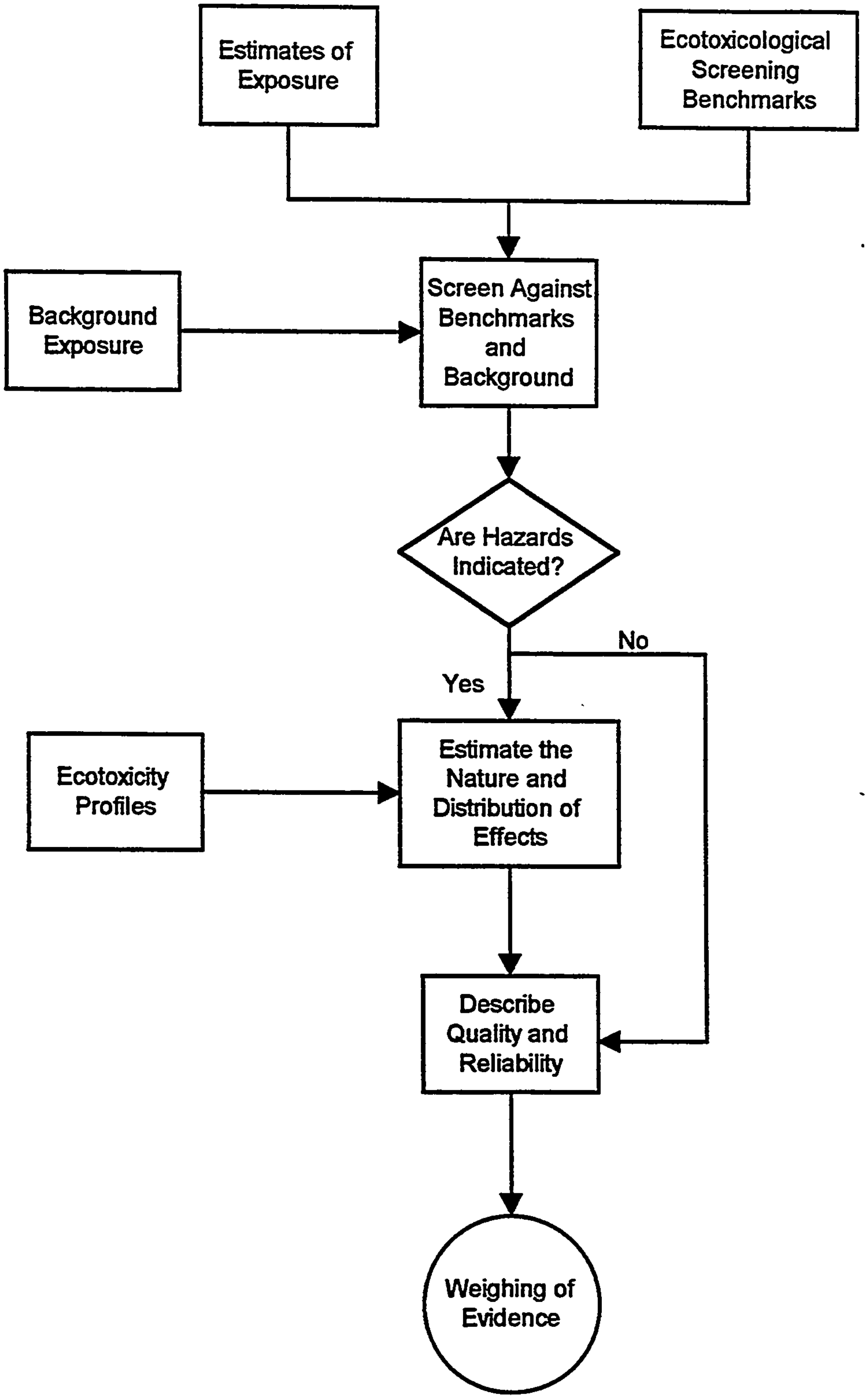

Fig. 11. Risk characterization based on chemical analyses and single chemical toxicity.

7.2 AMBIENT MEDIA TOXICITY TESTS

Risk characterization for this line of evidence begins by determining whether the tests show significant toxicity (Fig. 12).

- If no significant toxicity was found, the risk characterization consists of determining the likelihood that the result constitutes a false negative. False negatives could result from not collecting samples from the most contaminated sites or at the times with the highest contaminant levels, handling the samples in a way that reduced toxicity, or using tests that are not sufficiently sensitive to detect effects that would cause significant injuries to populations or communities in the field.

- If significant toxicity occurs in the tests, the risk characterization should describe the nature and magnitude of the effects and the consistency of effects among tests conducted with different species in the same medium.

- Toxicity tests may produce ambiguous results in some cases due to poor performance of organisms in control media (e.g., due to diseases, background contamination, inappropriate reference or control media, or poor performance of the test protocol). In such cases, expert judgement by the assessor in consultation with the individuals who performed the test should be used to arrive at an interpretation of the test results.

If significant toxicity is found at any site, then the relationship of toxicity to exposure must be characterized. The first way to do this is to examine the relationship of toxicity to concentrations of chemicals in the media. The manner in which this is done will depend on the amount of data available. If numerous toxicity tests are available, the frequency of tests showing toxic effects could be defined as a function of concentrations of one or more COPCs. An alternative and potentially complementary approach is to determine the relationship between the occurrence of toxicity and sources of contaminants (e.g., springs, seeps, tributaries, spills) or of diluents (i.e., relatively clean water or sediments). Finally, when sources of toxic water have been identified, and tests have been performed on dilution series of those waters, the transport and fate of toxicity can be modeled like that of individual chemicals (DiToro et al. 1991). Such models of toxicity can be used to explain ecological degradation observed in streams and apportion causation among sources.

The result of risk characterization for this line of evidence should be questions such as:

- Is toxicity occurring?

- How severe is it?

- How extensive is it?

- How frequent is it?

- is it associated with identifiable sources or contaminants?

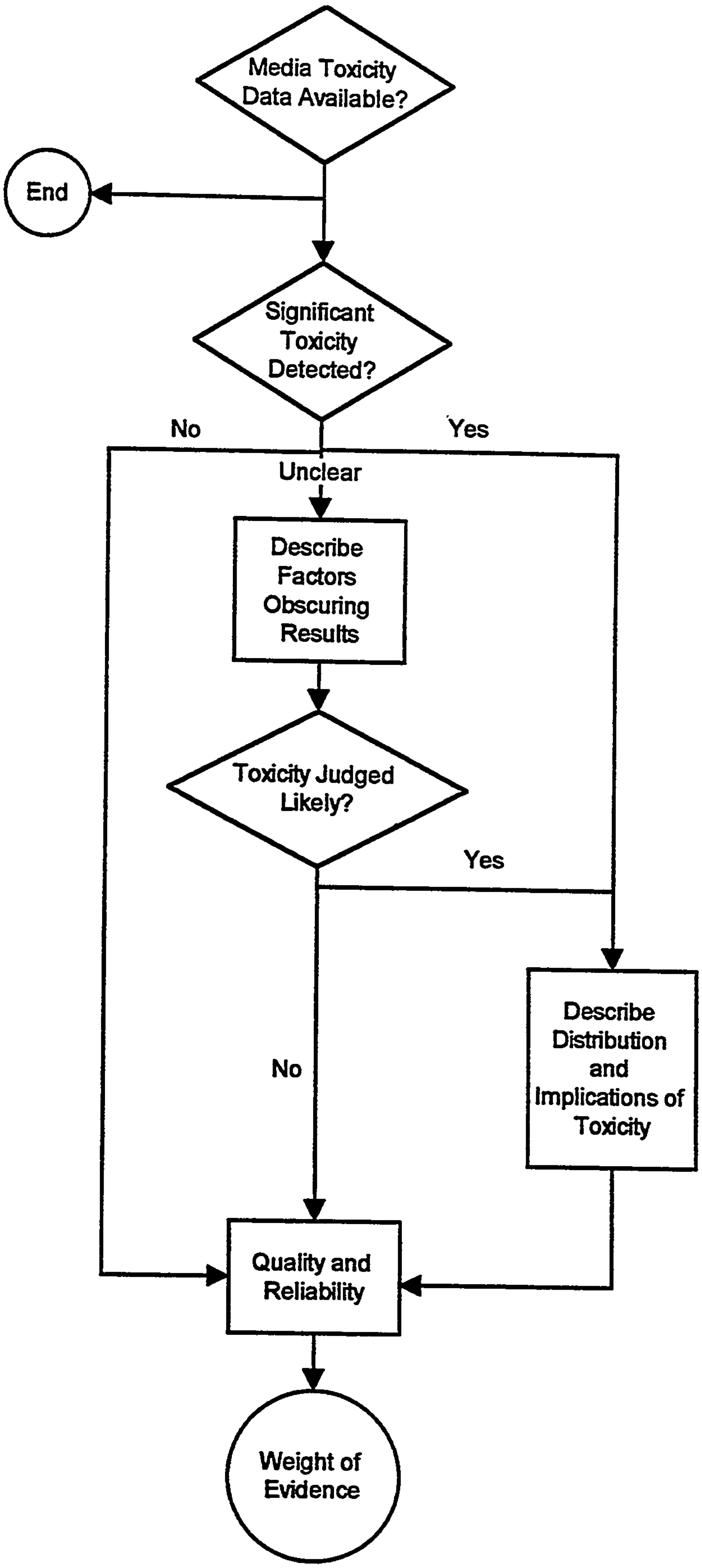

Fig. 12. Risk characterization based on toxicity testing of ambient media.

- how much must the source be diminished to eliminate unacceptable toxicity?
- how confident are you concerning your answers?

7.3 BIOLOGICAL SURVEYS

If biological survey data are available for an endpoint species or community, then the first question to be answered is whether the data suggest that significant effects are occurring (Fig. 13). For some groups, notably fish and benthic invertebrates, there are abundant data from reference streams for comparison. For most other endpoint groups, references must be established *ad hoc* and the lack of temporal or spatial replication may make inference tenuous. For some taxa such as most birds, survey data are not useful for estimating risks from wastes because mobility, territoriality, or other factors obscure demographic effects.

Care must be taken to consider the sensitivity of field survey data to toxic effects relative to other lines of evidence. Some biological surveys are very sensitive (e.g., surveys of nesting success of colonial nesting birds or electrofishing surveys of wadeable streams), others are moderately sensitive (e.g., benthic macroinvertebrates), and still others are insensitive (e.g., fish community surveys in large reservoirs and small mammal surveys). However, even relatively insensitive surveys may be quite useful in assessments. For example, if the concentrations of chemicals suggest that a medium should be highly toxic but toxicity tests of the medium find no toxicity, then even a relatively insensitive survey that found a community that was not highly modified would tend to confirm that the chemical analyses were misleading and the toxicity test data were correct (e.g., the chemical was not in a bioavailable form or consisted of a less toxic species). Conversely, a highly modified community in the absence of high levels of analyzed chemicals would suggest that combined toxic effects, toxic levels of unanalyzed contaminants, or episodic contamination had occurred. However, field surveys interpreted in isolation without supporting data could be misleading, particularly if the absence of statistically significant differences were interpreted as an absence of effects.

If biological survey data are consistent with significant reductions in abundance, production, or diversity, associations of apparent effects with causal factors must be examined. First, the distribution of apparent effects in space and time must be compared to the distribution of sources or of contaminants. Second, the distribution of apparent effects must be compared to the distribution of habitat factors that are likely to affect the organisms in question such as stream structure and flow. Finally, the natural variability of the endpoint populations and communities and the accuracy of the survey methods must be examined to estimate the likelihood that the apparent effects are due to chance.

The result of risk characterization for this line of evidence should be questions such as:

- Are the endpoint ecological properties significantly reduced?
- How much are they reduced?
- How extensively?
- Is the reduction associated with identifiable sources of contaminants?
- Is the reduction associated with identifiable habitat variables?

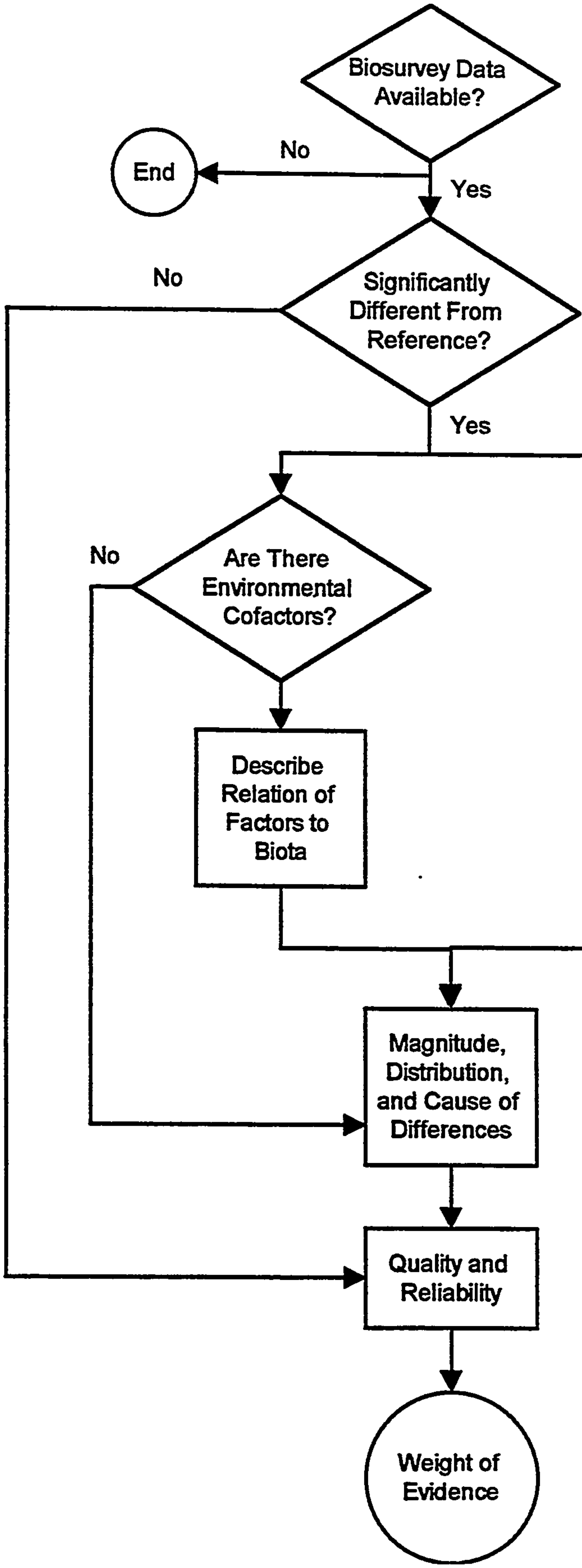

Fig. 13. Risk characterization based on biological survey data.

- What is the most likely cause of the apparent reduction?
- How confident are you concerning your answers?

7.4 BIOINDICATORS

Biological indicators are seldom useful for estimating risks by themselves, but they can be used to support other lines of inference. The inference begins by asking if the levels of the bioindicators significantly differ from those at reference sites (Fig. 14). If they do, then it is necessary to determine whether they are diagnostic or at least characteristic of any of the COPCs or of any of the habitat factors that are thought to affect the endpoint biota. If the bioindicators are characteristic of contaminant exposures, then the distribution and frequency of elevated levels must be compared to the distributions and concentrations of contaminants. Finally, to the extent that the bioindicators are known to be related to overt effects such as reductions in growth, fecundity, or mortality, the implications of the observed bioindicator levels for populations or communities should be estimated.

The result of risk characterization for this line of evidence should be questions such as:

- Are bioindicator levels significantly elevated?
- What are the implications for populations or communities?
- How extensive are the effects?
- Are they spatially or temporally associated with identifiable sources of contaminants?
- Are they spatially or temporally associated with identifiable habitat variables?
- Are they diagnostic or characteristic of a contaminant or a habitat variable?
- What is the most likely cause of the observed levels?
- How confident are you concerning your answers?

7.5 WEIGHT OF EVIDENCE

The weighing of evidence begins by summarizing the available lines of evidence for each endpoint (Fig. 15). The tabular format presented in Table 4 is recommended. The lines of evidence are listed, and a symbol is assigned for each: + if the evidence is consistent with significant effects on the endpoint, - if it is inconsistent with significant effects, and ± if it is too ambiguous to assign to either category. The last column presents a short summary of the results of the risk characterization for that line of evidence. If indirect effects are part of the conceptual model, they should be summarized in their own line of the table. For example, effects on the fish community could be due entirely or in part to toxicity to invertebrate prey species. The last line of the table presents the weight-of-evidence-based conclusion concerning whether significant effects are occurring and a brief statement concerning the basis for the conclusion. This conclusion is not based simply on the relative number of + or - signs. The "weight" component of weight of evidence is the relative credibility and reliability of the conclusions of the various lines of evidence.

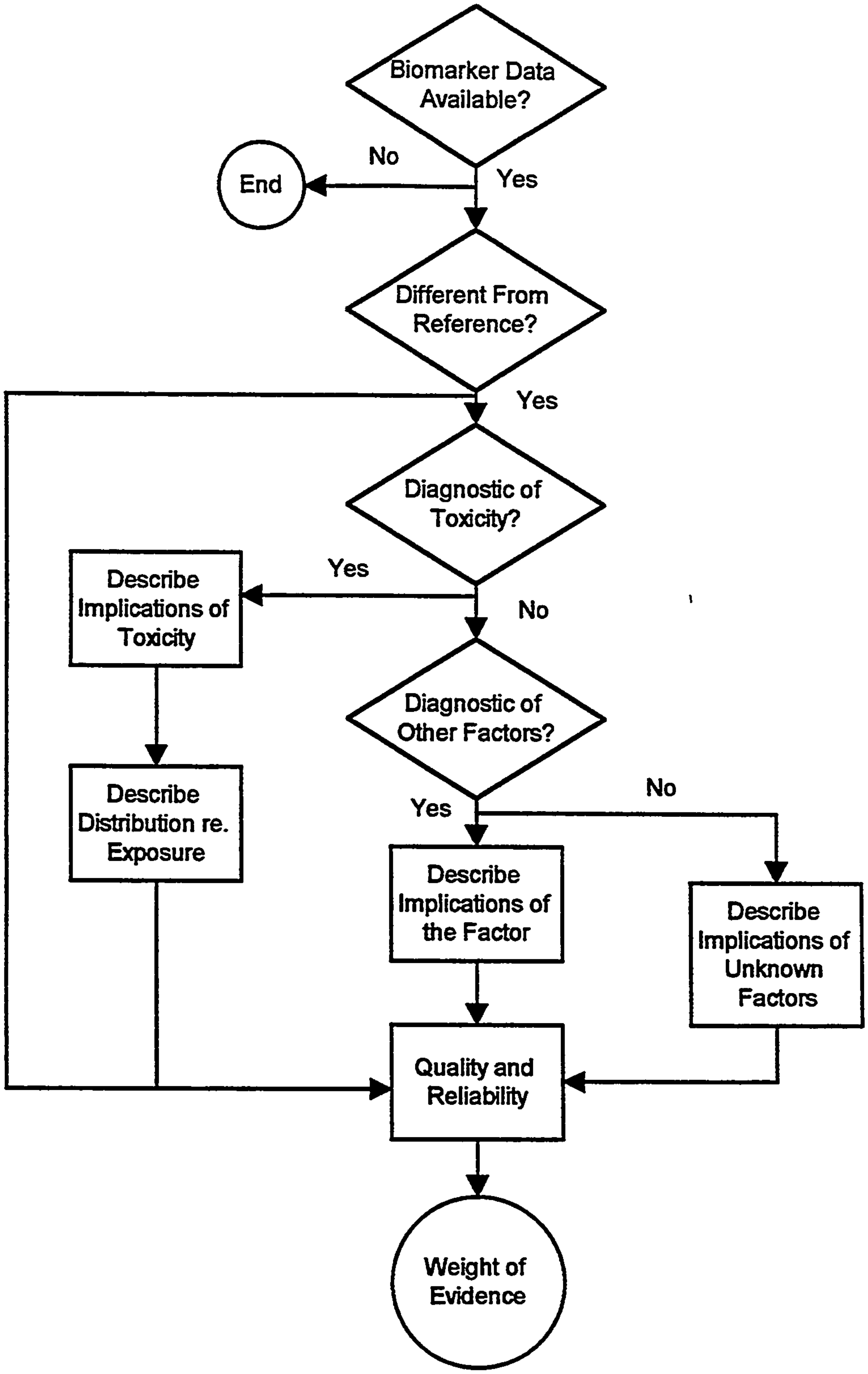

Fig. 14. Risk characterization based on biomarker data.

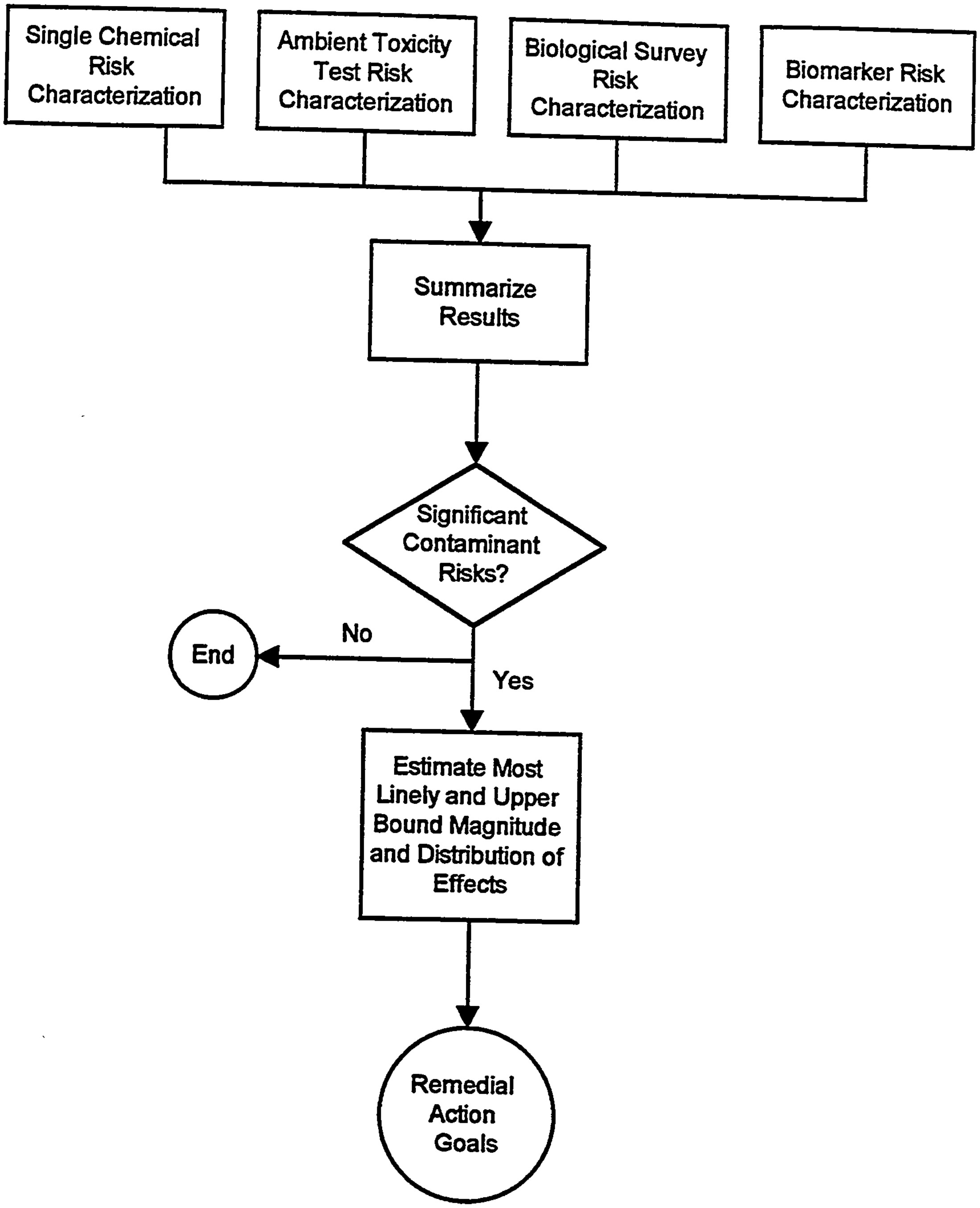

Fig. 15. Risk characterization based on weighing of multiple lines of evidence.

Table 4. Example of a table summarizing the risk characterization for the fish community in a stream at a waste site

Evidence	Result[a]	Explanation
Biological Surveys	-	Fish community productivity and species richness are both high in reaches 2 and 3. Effluents apparently improve community quality.
Toxicity Tests	±	High lethality to fathead minnow larvae in a test at Site 3.3, but variability is too high for standard statistical significance.
Media Analyses	+	Only zinc is believed to be potentially toxic in water and only to highly sensitive species.
Weight-of-Evidence	-	Reaches 2 & 3 support a clearly high quality fish community. Other evidence which suggests toxic risks is much weaker.

a + indicates that the evidence is consistent with the occurrence of the endpoint effect.
- indicates that the evidence is inconsistent with the occurrence of the endpoint effect.
± indicates that the evidence is too ambiguous to interpret.

In general, the weighing of evidence is best accomplished by beginning with the line of evidence that most directly bears on the actual risks. That is, begin with the risk characterization based on biological survey data, if available. If, for example, the fish community is depauperate downstream of a source, look to the risk characterization based on toxicity data to see if it indicates that aqueous toxicity is responsible. Look to the bioindicators to see if the fish populations still present bear signs of suborganismal effects. Finally, look to the risk characterization based on analysis of media to determine what chemicals are likely to be responsible for any observed effects or toxicity. This process clearly relies on expert judgement, but that judgement should be presented as clearly as possible to the stakeholders.

If no significant effects are believed to be occurring, the assessment of that particular endpoint ends. However, if significant effects are occurring they must be characterized. That is, the nature, magnitude, and extent of the effects must be estimated. This estimation may also be based on multiple lines of evidence. That is, different lines of evidence may agree in indicating that a significant effect is occurring but may disagree about its magnitude or extent. In general, the estimates will be based on the best evidence—the evidence that provides the clearest and most accurate estimate of effects.

7.6 FUTURE RISKS

Baseline ERAs for the ORR focus primarily on current risks. However, future baseline risks should be characterized when:

- contaminant exposures are expected to increase in the future (e.g., a contaminated ground water plume will intersect a stream),
- biological succession is expected to increase risks (e.g., a forest will replace a lawn), or
- significant recovery is expected to occur in the near term without remedial actions (i.e., the expense and ecological damage associated with remedial actions may not be justified).

Although these future baseline risks cannot be characterized by measuring effects or by testing future media, all lines of evidence that are useful for estimating current risks may be extended to them. As in human health risk assessments, risk models derived by epidemiological methods can be applied to future conditions and even applied to different sites. For example, if concentrations are expected to change in the future, the exposure-response relationship derived from biosurvey data (e.g., a relationship between contaminant concentration and fish abundance) may supply a better estimate of future effects than a concentration-response relationship derived from laboratory test data. Results of toxicity tests of currently contaminated media may also be used to estimate future effects. The utility of the various risk models depends on their reliability (as suggested by the weight-of-evidence analysis) and their relevance to the future conditions.

7.7 UNCERTAINTIES

Uncertainties should have been identified in the risk characterizations for each line of evidence, but the risk characterization should also include a summary of uncertainties and their implications. The Risk Assessment Forum (1992) indicates that this discussion should include uncertainties due to the conceptual model formulation, incompleteness of information, stochasticity (natural variability), and error. Results of quantitative uncertainty analyses should be presented, but it is important to remember that such analyses do not include all uncertainties. In particular, while it is possible to quantitatively estimate the uncertainty associated with a single line of evidence, it is not possible to quantify the total uncertainty associated with a conclusion reached by weighing multiple lines of evidence.

It is important to summarize the implications of the listed uncertainties. This summary should include:

- the credible maximum and minimum levels of effects,
- endpoints that were not addressed,
- routes of exposure or indirect modes of action that were not addressed, and
- conditions that were not addressed (e.g., storm events).

7.8 REMEDIAL GOAL OPTIONS

Remedial goal options (RGOs) are concentrations of contaminants in media or equivalent criteria that could be used to guide remediation by setting goals which, if achieved, would eliminate any identified significant risks. The PRGs are used by the FFA parties as a basis for negotiating the RAGs for the ROD. One basis for developing RGOs is the PRGs which are standard potential clean-up levels. PRGs include the NAWQC, sediment quality criteria, and other concentrations that are equivalently protective. Because of site-specific factors, PRGs may be over- or under-protective. Therefore, they can be replaced by values that are more appropriate to the site based on the weight of evidence.

In some cases, concentrations are not the only possible RGOs. It may be that the RI identifies a medium as toxic without clearly identifying the causal contaminant. This may be because of inadequate data or because none of the chemicals identified in the medium is at a concentration that is toxic by itself. In such cases, an appropriate RGO could be a direction to remediate all toxic areas. Alternatively, an RGO may be to perform a toxicity identification and evaluation (TIE) and remediate the chemicals that are identified by the TIE to be causing the toxicity.

As the word "option" in the phrase suggests, RGOs may be multiple. If the best basis for remediation is unclear, the assessors may provide a set of numbers or numbers and criteria from which the FFA parties could select or derive the RAGs. For example, RGOs for water might include (1) the chronic NAWQC for the chemical that is believed to cause significant toxic effects on an endpoint community, (2) a threshold for toxicity of that chemical in a toxicity test such as EPA's *subchronic Ceriodaphnia* test, and (3) the option of performing a TIE to determine the RAG.

8. RELATIONSHIP TO HUMAN HEALTH RISK ASSESSMENT

Because the EPA now places equal emphasis on assessing the potential impacts of hazardous waste sites on human health and the environment, human health assessments and ecological assessments will be performed concurrently at DOE-OR ER. Some information and data are likely to be relevant for assessing both human and environmental threats. Common data needs will be identified during project scoping and sampling plans will be developed in such a way as to avoid duplication of efforts. It is imperative that human health and ecological risk assessors coordinate their activities and communicate throughout the whole process so that all relevant data are accessible to all parties concerned.

Common data needs for human and ecological risk assessments will be determined by the individual characteristics of the site and by the scale of the assessments. In general, the following data are likely to be useful for both human health and ecological risk assessments. Differences between ecological and human health effects data needs are noted in parentheses.

a) Chemical concentrations in media including:
   - Soils/sediments (concentrations in the pore water will be required for ERAs)
   - Surface water (concentrations of dissolved forms of chemicals will be required for ERAs)
   - Groundwater
   - Air
   - Biota, including fish (whole body concentrations will be required for ERAs), geese, deer, (plus food for endpoint species not consumed by humans, such as mice)

b) Chemical inventories

c) Operational history and current practices at the site

d) Factors affecting fate and transport of chemicals. For example:
   - Physical parameters, e.g., hydrogeologic setting, soil properties, topography
   - Bioaccumulation factors, particularly for exposure pathways involving indirect exposures to humans via the food chain

e) Background concentration data

All of these factors will be considered as possible common data needs during project scoping.

In some cases, ecological assessments may require samples to be analyzed in a specific way. The list presented previously notes that sediment pore water concentrations are required for ERAs. In addition, minimum required detection limits may be lower for ecological concerns than for human health concerns in some cases. Chemicals that pose a greater ecological than human health risk will need to be analyzed with more precision than would otherwise be required. Certain water quality parameters, such as pH, hardness, and oxygen levels, are also more important for ecological assessments.

The fact that ecological and human health risk assessments have common data needs will be considered during the prioritization of sites for risk assessments. For example, a site of low ecological priority would not normally require an immediate environmental evaluation. If, however, the site is of immediate concern for human health reasons, ecological risks should also be assessed immediately. This is because the analysis of remedial action alternatives must consider both ecological and human health impacts from those alternatives.

When the assessment of risks is completed and remedial action goals are developed, ecological risks must be compared to human health risks to determine which will drive the selection of remedial options. At this point, apparent discrepancies in results will require explanation. Some of these discrepancies will be due to differences in the assessment approaches, and others will be due to unexpectedly greater sensitivities of nonhuman receptors.

8.1 WHY HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT APPROACHES DIFFER

The strategy for ERAs described in this document is more complex than that for human health risk assessment and is fundamentally different in its inferential approach. The greater complexity is largely due to the large number of species and the diversity of routes of exposure that must be considered in ERAs. However, the difference in inferential approach and part of the greater complexity is due to the fact that ERAs for waste sites are based on epidemiological approaches while human health risk assessments for the waste sites are based on modelling. This discrepancy raises the question, why not just model ecological risks as well? The reasons are as follows.

- Epidemiological approaches, when they are feasible, are fundamentally more reliable than modelling, because they address real responses of real receptors. Human health risk assessments are based on epidemiology when possible, but epidemiology is (fortunately) not feasible for the ORR because there are no observable effects in human populations.

- Ecological epidemiology is feasible in practice, because nonhuman organisms are on the OUs and are, in some cases, experiencing observable exposures and effects.

- Ecological epidemiology is feasible in principle because the levels of effects that are deemed to be significant by the regulators and DOE are observable in many populations and communities.

- Because of the assumptions that must be made to model risks, the uncertainties in model-generated risk estimates are large. These uncertainties can be accepted in practice by human health assessors because the effects are not observable. However, it is common for modelled ecological risks to be manifestly incorrect because the predicted effects are not occurring or effects are observed where they are not predicted. Therefore, it is incumbent to use an epidemiological approach to avoid mistakes and embarrassment.

- Because of the great value placed on human life, remedial actions may be taken on the basis of highly uncertain estimates of hypothetical risks. However, because of the lesser value placed on nonhuman organisms and natural ecosystems, decision makers are somewhat reluctant to spend millions of dollars to remediate highly uncertain ecological risks. Therefore, if ERAs are to be useful they must be compelling.

- Inferences concerning the reality and causation of epidemiological phenomena cannot be made on the basis of epidemiological evidence alone. A concordance between the uncontrolled epidemiological observations and controlled studies such as toxicity tests must be demonstrated (Adams 1963, Woodman and Cowling 1987, Suter 1990, Suter 1993).

- Because biological surveys and ecological toxicity tests are inexpensive relative to chemical analyses and provide more direct evidence concerning ecological risks, they are highly cost effective.

- Even in those cases when ecological epidemiology is not feasible, the process of determining that to be the case is instructive and aids the interpretation of modelled risks. For example, if contaminants on an OU would cause reproductive failure in robins feeding on that OU, counting robins would not reveal that effect because the number of breeding pairs is limited by territory size, and the loss of production on the OU would be easily replaced by birds produced elsewhere. That suggests not only that estimating robin density would not indicate the effects on robins but also that the effects that the hypothesized effect (i.e., reduced reproduction on the OU) would not be significant at the population level.

The epidemiological approach also is not directly applicable to potential future risks because future conditions cannot be observed. For example, a contaminated groundwater plume may be predicted to reach surface water in the future. However, the set of assessment tools available to the ecological assessor is greater than that available to the human health risk assessor. For example, samples of the contaminated groundwater can be subject to toxicity testing both full-strength and in a dilution series using the surface water with which it would be mixed in the future as diluent. In addition, if the future risk simply involves expansion of the contaminated area, then studies of the current risks can be used in the prediction of future risks.

8.2 WHY ECOLOGICAL ENDPOINTS MAY BE MORE SENSITIVE THAN HUMANS

It is commonly assumed by the public and by some individuals involved in site remediation that protection of human health will also result in protection of nonhuman organisms. For this reason, when ecological risks, but not human risks, are estimated to be significant, the apparent discrepancy should be explained. Despite the greater degree of protection afforded humans, nonhuman organisms are often at greater risk for a variety of reasons (Suter 1993). When this greater sensitivity is found, it must be explained. Types of explanations include the following:

- Modes of exposure that do not occur in humans such as respiration of water, consumption of sediment, or drinking from waste sumps.

- Quantitatively greater exposure such as a diet of 100% local fish.

- Inherently greater sensitivity of particular taxa of nonhuman organisms.

- Secondary effects such as loss of primary production.

8.3 SCALE IN HUMAN HEALTH AND ECOLOGICAL RISK

The issue of scale is treated differently in human health and ecological risk assessment. Because human health risks are estimated for hypothetical individuals, they can be calculated for the points in space at which samples are collected. For example, risks from contaminants in the water of White Oak Creek are calculated at an integration point, the weir of the dam, where an individual is assumed to collect his 2 liters of drinking water every day for 30 years. However, the endpoints for ERAs (except for those involving T&E species) are population or community level. Therefore, it is not possible to estimate ecological risks at a specific point, except as a screening technique. For example, one would estimate risks to the fish community in the reaches of White Oak Creek, not at a point at the end of the creek. Similarly for assessments of contaminated soils, the human health assessment may assume that a human lives for 30 years on a small site, but the ERA must acknowledge that vertebrate animal populations have large ranges.

This difference means that the data will be averaged differently and the results will not be point-to-point comparable. However, such comparability is not required by regulations or guidance and is not necessary for risk assessments to be useful. Rather, both human health and ERAs must produce defensible estimates of risks to their respective endpoints.

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Appendix A

VERTEBRATE ANIMAL SPECIES AND THREATENED, ENDANGERED OR IN-NEED-OF-MANAGEMENT INVERTEBRATE AND PLANT SPECIES OF THE OAK RIDGE RESERVATION AND WATTS BAR RESERVOIR

Table A.1. Terrestrial[a] animal species on the Oak Ridge Reservation

Common Name	Trophic Category[b]	Special Status[c]
	Birds	
Gadwall	AqH	
Common Gallinule	AqH	
Mallard	AqH	
Pintail	AqH	
Tundra Swan	AqH	
Blue-Winged Teal	AqH	
American Widgeon	AqH	
Bufflehead	AqI	
Black Duck	AqI	
Ruddy Duck	AqI	
Common Goldeneye	AqI	
Pied-Billed Grebe	AqI	
Lesser Scaup	AqI	
Green-Winged Teal	AqI	
Black Tern	AqI	
Carolina Chickadee	ArI	
Brown Creeper	ArI	
Yellow-Billed Cuckoo	ArI	
Yellow-Shafted Flicker	ArI	
Golden-Crowned Kinglet	ArI	
Ruby-Crowned Kinglet	ArI	
Red-Breasted Nuthatch	ArI	
White-Breasted Nuthatch	ArI	
Baltimore Oriole	ArI	
Orchard Oriole	ArI	
American Redstart	ArI	
Yellow-Bellied Sapsucker	**ArI**	**INM**
Scarlet Tanager	ArI	
Summer Tanager	ArI	
Tufted Titmouse	ArI	
Red-Eyed Vireo	ArI	
Solitary Vireo	ArI	

[a]Include water associated animals capable of moving on land.
[b]AqH = aquatic herbivore; 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.

Table A.1. (continued)

Common Name	Trophic Category[b]	Special Status[c]
	Birds (cont.)	
White-Eyed Vireo	ArI	
Yellow-Throated Vireo	ArI	
Bay-Breasted Warbler	ArI	
Black and White Warbler	ArI	
Black-Throated Green Warbler	ArI	
Blackburnian Warbler	ArI	
Blackpoll Warbler	ArI	
Blue-Winged Warbler	ArI	
Cape May Warbler	ArI	
Cerulean Warbler	ArI	
Chestnut-Sided Warbler	ArI	
Hooded Warbler	ArI	
Magnolia Warbler	ArI	
Myrtle Warbler	ArI	
Parula Warbler	ArI	
Pine Warbler	ArI	
Prairie Warbler	ArI	
Prothonotary Warbler	ArI	
Tennessee Warbler	ArI	
Worm-Eating Warbler	ArI	
Yellow Warbler	ArI	
Yellow-Throated Warbler	ArI	
Downy Woodpecker	ArI	
Hairy Woodpecker	ArI	
Pileated Woodpecker	ArI	
Red-Bellied Woodpecker	ArI	
Red-Headed Woodpecker	**ArI**	**INM**
Yellowthroat	ArI	
Eastern Bluebird	FI	
Chuck-Will's-Widow	FI	
Acadian Flycatcher	FI	
Great Crested Flycatcher	FI	
Least Flycatcher	FI	
Blue-Gray Gnatcatcher	FI	
Eastern Kingbird	FI	
Purple Martin	FI	
Common Nighthawk	FI	
Eastern Phoebe	FI	

Table A.1. (continued)

Common Name	Trophic Category[b]	Special Status[c]
Birds (cont.)		
Bank Swallow	FI	
Barn Swallow	FI	
Cliff Swallow	FI	
Rough-Winged Swallow	FI	
Chimney Swift	FI	
Whip-Poor-Will	FI	
Eastern Wood-pewee	FI	
Red-Winged Blackbird	GI	
Catbird	GI	
Brown-Headed Cowbird	GI	
Cattle Egret	GI	
Common Egret	GI	
Killdeer	GI	
Horned Lark	GI	
Eastern Meadowlark	GI	
Mockingbird	GI	
Ovenbird	GI	
American Robin	GI	
Spotted Sandpiper	GI	
Common Snipe	GI	
Starling	GI	
Brown Thrasher	GI	
Gray-Cheeked Thrush	GI	
Hermit Thrush	GI	
Louisiana Water Thrush	GI	
Swainson's Thrush	GI	
Wood Thrush	GI	
Kentucky Warbler	GI	
Swainson's Warbler	GI	
American Woodcock	GI	
Bewick's Wren	**GI**	**ST**
Carolina Wren	GI	
House Wren	GI	
Winter Wren	GI	
Golden Eagle	**LC**	**SE**
Northern Harrier	**LC**	**ST**
Broad-Winged Hawk	LC	

Table A.1. (continued)

Common Name	Trophic Category[b]	Special Status
	Birds (cont.)	
Cooper's Hawk	**LC**	**ST**
Red-Shouldered Hawk	**LC**	**INM**
Red-Tailed Hawk	LC	
Sharp-Shinned Hawk	**LC**	**ST**
Sparrow Hawk	LC	
Barn Owl	LC	INM
Barred Owl	LC	
Great Horned Owl	LC	
Screech Owl	LC	
Loggerhead Shrike	LC	
Black Vulture	**LC**	**INM**
Turkey Vulture	LC	
Bobwhite	LH	
Red Crossbill	LH	
Mourning Dove	LH	
Rock Dove	LH	
Purple Finch	LH	
American Goldfinch	LH	
Canada Goose	LH	
Ruffed Grouse	LH	
Ruby-Throated Hummingbird	LH	
Slate-Colored Junco	LH	
Pine Siskin	LH	
Bachman's Sparrow	LH	
Chipping Sparrow	LH	
Field Sparrow	LH	
Fox Sparrow	LH	
Grasshopper Sparrow	**LH**	**ST**
Henslow's Sparrow	**LH**	**FC**
House Sparrow	LH	
Lark Sparrow	**LH**	**INM**
Song Sparrow	LH	
Swamp Sparrow	LH	
Vesper Sparrow	**LH**	**INM**
White-Throated Sparrow	LH	
Wild Turkey	LH	
Cedar Waxwing	LH	
Indigo Bunting	LO	

Table A.1. (continued)

Common Name	Trophic Category[b]	Special Status[c]
	Birds (cont.)	
Canvasback	LO	
Cardinal	LO	
Yellow-Breasted Chat	LO	
American Coot	LO	
Common Crow	LO	
Ring-Necked Duck	LO	
Wood Duck	LO	
Common Grackle	LO	
Blue Grosbeak	LO	
Evening Grosbeak	LO	
Rose-Breasted Grosbeak	LO	
Blue Jay	LO	
Redhead	LO	
Rufous-Sided Towhee	LO	
Double-Crested Cormorant	**P**	**INM**
Bonaparte's Gull	P	
Herring Gull	P	
Ring-Billed Gull	P	
Black-Crowned Night Heron	**P**	**INM**
Great Blue Heron	P	
Green Heron	P	
Belted Kingfisher	P	
Common Loon	P	
Common Merganser	P	
Hooded Merganser	P	
Red-Breasted Merganser	P	
Bald Eagle	**P**	**SE, FE**
Osprey	**P**	**SE**
	Mammals	
Big Brown Bat	FI	
Eastern Small-Footed Bat	**FI**	**FC, INM**
Evening Bat	FI	
Gray Bat	**FI**	**FE, SE**
Hoary Bat	FI	
Indiana Bat	**FI**	**FE, SE**
Little Brown Bat	FI	

Table A.1. (continued)

Common Name	Trophic Category[b]	Special Status[c]
	Mammals (cont.)	
Rafinesque's Big-Eared Bat	**FI**	**FC, INM**
Red Bat	FI	
Silver-Haired Bat	FI	
Keen's Myotis	FI	
Eastern Pipistrelle	FI	
Eastern Mole	GI	
Least Shrew	GI	
Long-Tailed Shrew	**GI**	**FC, INM**
Masked Shrew	**GI**	**INM**
Short-Tailed Shrew	GI	
Smokey Shrew	GI	INM
Southeastern Shrew	GI	INM
Spotted Skunk	GI	
Stripped Skunk	GI	
Bobcat	LC	
Feral Cat	LC	
Cougar[d]	**LC**	**FE**
Coyote	LC	
Feral Dog	LC	
Red Fox	LC	
Mink	P	
River Otter[e]	**P**	**ST**
Long-Tailed Weasel	LC	
Beaver	LH	
Eastern Chipmunk	LH	
Eastern Cottontail	LH	
White-Tailed Deer	LH	
Gray Squirrel	LH	
Groundhog	LH	
Southern Flying Squirrel	LH	
Woodchuck	LH	
Gray Fox	LO	
Muskrat	LO	
Opossum	LO	
Raccoon	LO	

[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.

Table A.1. (continued)

Common Name	Trophic Category[b]	Special Status[c]
	Mammals (cont'd)	
Southern Bog Lemming	**SH**	**INM**
Eastern Harvest Mouse	SH	
Meadow Vole	SH	
Pine Vole	SH	
White-Footed Mouse	SO	
Deer Mouse	SO	
Golden Mouse	SO	
Hispid Cotton Rat	SO	
Rice Rat	SO	
Meadow Jumping Mouse	**SO**	**INM**
Woodland Jumping Mouse	**SO**	**INM**
House Mouse	SO	
Norway Rat	SO	
Eastern Woodrat	**SO**	**INM**
	Amphibians and Reptiles	
Pond Slider	AqH	
Cumberland Slider	AqH	INM
Yellow-Bellied Turtle	AqH	
Bronze Frog	AqI	
Bullfrog	AqI	
Leopard Frog	AqI	
Northern Cricket Frog	AqI	
Pickerel Frog	AqI	
Wood Frog	AqI	
Hellbender	**AqI**	**FC, INM**
Mudpuppy	AqI	
Northern Red Salamander	AqI	
Spring Salamander	AqI	
Three-Lined Salamander	AqI	
Map Turtle	AqI	
Gray Tree Frog	ArI	
Spring Peeper Frog	ArI	
Upland Chorus Frog	ArI	
Fence Lizard	ArI	
Green Anole	**ArI**	**INM**
Rough Green Snake	ArI	
Broadhead Skink	GI	
Five-Lined Skink	GI	

Table A.1. (continued)

Common Name	Trophic Category[b]	Special Status[c]
Amphibians and Reptiles (cont.)		
Ground Skink	GI	
Six-Line Racerunner	**GI**	**INM**
Slender Glass Lizard	**GI**	**INM**
Tennessee Cave Salamander	**GI**	**FC, ST**
Green Salmander	**GI**	**FC, INM**
Red-Backed Salamander	GI	
Slimy Salamander	GI	
Spotted Salamander	GI	
Brown Snake	GI	
Eastern Crowned Snake	GI	
Eastern Worm Snake	GI	
Northern Ringneck Snake	GI	
Red-Bellied Snake	GI	
American-Toad	GI	
Eastern Marrow-Mouthed Toad	GI	
Eastern Spadefoot Toad	GI	
Fowler's Toad	GI	
Black King Snake	LC	
Black Rat Snake	LC	
Corn Snake	LC	
Eastern Hognose Snake	LC	
Eastern Milk Snake	LC	
Garter Snake	LC	
Mole Snake	LC	
Northern Black Racer	LC	
Northern Copperhead	LC	
Northern Pine Snake	**LC**	**FC, ST**
Scarlet Snake	LC	
Timber Rattlesnake	LC	
Eastern Spiny Softshell Turtle	LC	
Snapping Turtle	LC	
Stinkpot Turtle	LC	
Striped-Neck Musk Turtle	LC	
Eastern Box Turtle	LO	
Eastern Painted Turtle	LO	
Northern Water Snake	P	
Queen Snake	P	

Table A.2. Fish species associated[a] with the Oak Ridge Reservation

Common Name	Trophic Catagory[b]	Special Status[c]
Gizzard shad	Dtr	
Goldfish	Dtr	
Carp	Dtr	
Tennessee dace	**Dtr**	**INM**
Bluntnose minnow	Dtr	
Fathead minnow	Dtr	
River carpsucker	Dtr	
Quillback	Dtr	
White sucker	Dtr	
Spotted sucker	Dtr	
Black bullhead	Dtr	
Yellow bullhead	Dtr	
Skipjack herring	Inv	
Mooneye	Inv	
Rosefin Shiner	Inv	
Emerald shiner	Inv	
Striped shiner	Inv	
Spotfin shiner	Inv	
Blacknose dace	Inv	
Creek chub	Inv	
Biqeye chub	Inv	
Northern hog sucker	Inv	
Smallmouth buffalo	Inv	
Silver redhorse	Inv	
Black redhorse	Inv	
Golden redhorse	Inv	
Blue catfish	Inv	
Mosquitofish	Inv	
Brook stickleback	Inv	
Redbreast sunfish	Inv	
Green sunfish	Inv	
Warmouth	Inv	
Bluegill	Inv	
Longear sunfish	Inv	
Redear sunfish	Inv	
Greenside darter	Inv	

Table A.2. (continued)

Common Name	Trophic Catagory[b]	Special Status[c]
Black darter	Inv	
Stripetail darter	Inv	
Snubnose darter	Inv	
Logperch	Inv	
Banded sculpin	Inv	
Stoneroller	Peri	
Grass carp	Peri	
Paddlefish	Plnk	
Threadfin shad	Plnk	
Golden shiner	Plnk	
Black buffalo	Plnk	
Brook silverside	Plnk	
Chestnut lamprey	Psc	
Spotted gar	Psc	
Longnose gar	Psc	
Northern Pike	Psc	
Channel catfish	Psc	
Flathead catfish	Psc	
White bass	Psc	
Yellow bass	Psc	
Striped bass	Psc	
Rock bass	Psc	
Smallmouth bass	Psc	
Spotted bass	Psc	
Largemouth bass	Psc	
White crappie	Psc	
Yellow perch	Psc	
Sauger	Psc	
Freshwater drum	Psc	

[a] Species from waters on the ORR and in the Clinch River, as identified in Ryon, M.G., and J. M. Loar. 1988. A checklist of fishes on the Department of Energy Oak Ridge Reservation. J. Tenn. Acad. Sci. 63 (4): 97-102.

[b] Dtr = Detritivores; Inv = invertebrate feeders; Peri = periphyton feeders; Plnk = plankton feeders; Psc = Piscivores.

[c] INM = state listed as in need of management.

Table A.3. Threatened, endangered and in-need-of-management plants on the Oak Ridge Reservation.[a]

Species	Common name	Habitat on ORR	Status[b]
Aureolaria patula	Spreading false-foxglove	River bluff	C1, T
Carex gravida	Gravid sedge	Varied	S
Carex oxylepis var pubescens	Hairy sharp-scaled sedge	Rich low woods, wetland	S
Cimicifuga rubifolia	Appalachian bugbane	River slope	C2, T
Collinsonia verticillata	Whorled horse-balm	Moist mature woods	none*
Cypripedium acaule	Pink lady-slipper	Dry to rich woods	E*
Delphinium exaltatum	Tall larkspur	Barrens and woods	C2, E
Diervilla lonicera	Northern bush-honeysuckle	River bluff	T
Draba ramosissima	Branching whitlow-grass	Limestone cliff	S
Elodea nuttallii	Nuttall waterweed	Pond, embayment	S
Fothergilla major	Mountain witch-alder	Woods	T
Hydrastis canadensis	Golden seal	Rich woods	T
Juglans cinerea	Butternut	Slope near stream	C2, T
Juncus brachycephalus	Small-head rush	Wetland	S
Lilium canadense	Canada lily	Moist woods	T
Liparis loeselii	Fen orchid	Forested wetland	E
Panax quinquifolius	Ginseng	Rich woods	3C, T
Platanthera flava var *herbiola*		Tuberculed rein-orchid	Forested wetland, T
Platanthera peramoena	Purple fringeless orchid	Wet meadow	3C, T
Rhynchospora colorata	White-topped sedge	Rocky edge of pond	S
Ruellia purshiana	Pursh's Wild-Petunia	Dry, open woods	S
Saxifraga careyana	Carey saxifrage	River bluff, sink hole	3C, S
Scirpus fluviatilis	River bulrush	Wetland	S
Spiranthes lucida	Shining ladies'-tresses	Wetland	T
Spiranthes ovalis	Lesser ladies'-tresses	Moist to dry woods	S

[a] This list updates the list in: Pounds, L.R., P.D. Parr, and M.G. Ryon. 1993. Resource Management Plan for the Oak Ridge Reservation, Volume 30: Oak Ridge National Environmental Research Park Natural Areas and Reference Areas- Oak Ridge Reservation Environmentally Sensitive Sites Containing Special Plants, Animals, and Communities. ORNL/NERP-8. This list includes five new species but excludes *Lilium michiganense* because it is believed to have been extirpated from the ORR by the impoundment at Melton Hill.

[b] Status codes:

C1	Candidate for federal listing. Proposed listing considered likely.
C2	Candidate for federal listing. More information needed to determine status.
C3	Taxa no longer considered for federal listing. Subcategories indicate reasons.
3C	Taxa more widespread or abundant than previously thought, or taxa not subject to immediate threat.
E	Endangered in Tennessee.
E*	Endangered in Tennessee due to commercial exploitation.
T	Threatened in Tennessee.
S	Special Concern in Tennessee.
none*	No status currently, but high state rank (Tennessee Natural Heritage Program) and under evaluation for state listing.

Table A.4. Threatened, Endangered and In-Need-of-Management Invertebrates of the Oak Ridge Reservation.[a]

Common Name	Scientific Name	Status[b]
Pink mucket[c]	*Lampsilis abrupta*	FE and SE
Alabama lampmussel	*Lampsilis virescens*	FE and SE
Fine-rayed pigtoe	*Fusconaia cuneolus*	FE and SE
Shiny pigtoe	*Fusconaia cor*	FE and SE
Spiny riversnail	*Io fluvialis*	FC and SSC

[a] These are the only invertebrate species listed by DOE and Conservation, Division of Natural Heritage, State of Tennessee, that are known to have occurred on the site (i.e., ORR and the Clinch River/Watts Bar system). However, there have been no surveys for rare invertebrates on the ORR. Rare aquatic arthropod species may not be identified by the routine surveys that have been conducted on the ORR because of the need to collect and carefully identify specific life stages (e.g., adult emergent insects) and because potential habitat for some species has not been sampled.

[b] FE = Federally listed as endangered.
SE = State listed as Threatened
SE = State listed as Endangered
SSC= State listed as Special Concern
FC = Federal Candidate for listing as Threatened or Endangered.

[c] This is the only species that has been found recently on the site. It was found by the TVA at Clinch River Mile 19, but it is identified by them as *L. orbiculata orbiculata*. All of the listed species are riverine species, and the species other than the pink mucket may well be locally extinct.

Appendix B
INTERFACES AMONG PROGRAMS

B. INTERFACES AMONG PROGRAMS

There are a number of ongoing or planned programs that will provide data that are useful to ecological risk assessments. 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 Appendix C or the Clinch River Environmental Restoration Program. 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).

The following paragraphs briefly describe those ongoing and planned activities that are expected to produce information relevant to ecological risk assessments.

Biological Monitoring and Abatement Programs

These programs are described in Appendix C. At present the terrestrial components of the ORNL and K-25 Site BMAPs consist of raccoon and waterfowl (e.g., Canada goose) monitoring.

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.

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.

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.

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 137Cs before the hunter can remove it from the ORR. Data from these deer surveys are available for ecological risk assessment.

Remedial Investigations on Source and Aquatic Integrator Operable Units

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 addressed in the DQO sessions for these OUs.

Clinch River Environmental Restoration Program

Certain data collected in support of the RI for the Clinch River will be of value for the ecological risk assessment of the ORR. These include the great blue heron breeding surveys; the fish community surveys in Poplar Creek, the Clinch River, and Lower Watts Bar Reservoir; the benthic invertebrate community surveys; and the analyses of emergent aquatic insects.

Appendix C

REVIEW OF EXISTING INFORMATION ON AQUATIC ECOSYSTEMS OF THE OAK RIDGE RESERVATION

C. REVIEW OF EXISTING INFORMATION ON AQUATIC ECOSYSTEMS OF THE OAK RIDGE RESERVATION

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 appendix 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 the end of the appendix.

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 C.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 C.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 Clinch River	August 1985
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] 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 C.2), although there are some differences due to both programmatic needs and site suitability.

Table C.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. C.1). Many of the ORR streams are used as reference sites (Fig. C.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. C.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. C.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. C.4). This decrease in the number of DNA strands 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. C.5 and C.6, respectively. Using the cumulative number of offspring obtained over a 24-month period as a measure of reproductive success, the results showed substantially lower reproduction at EFK 23.4 compared to EFK 13.8. Moreover, clam reproduction at EFK 13.8 was similar to that of at least one of the reference sites in each year. 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.

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 form S-3 ponds (Fig. C.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. C.8 and C.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. C.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. C.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. C.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. C.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. C.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, a reduction in stream flow would have a negative impact.

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. C.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. C.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. C.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.

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. C.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. C.18), which was not observed in two reference streams (Fig. C.19). This increase was due in large part to increases in the populations of stonerollers and striped shiners. 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. C.20) and in situ toxicity tests with fingernail clams in 1988 (Fig. C.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. C.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. C.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. C.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. C.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 C.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/m^2 in 1991 to 5.6 fish/m^2 in 1994 (M. G. Ryon unpubl. data).

Table C.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 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. C.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.

The increase in the number of species comprising the fish community in lower EFPC (Fig. C.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. C.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. C.27) and a decline in the concentration of total mercury in water at the outfall of Lake Reality (Fig. C.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. Also impacting recovery will be the flow management program that will bring cold water from the Clinch river to upper EFPC. 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, raw sewage), and possible remedial actions in the floodplain could destroy aquatic habitats.

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. C.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. C.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. C.30 and C.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. C.32).

Finally, when various indicators (biomarkers) of contaminated-related stress were measured in redbreast sunfish from WOC below Lagoon Road (Fig. C.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. C.33).

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. In early 1995, DOE sought and received approval of substantial additional modifications to the K-25 BMAP. Sampling sites are shown in Figs. C.34 and C.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. C.35). The revised BMAP includes less frequent monitoring of storm drains and use of only Ceriodaphnia. Toxicity monitoring in Poplar Creek and the Clinch River has been eliminated.

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 eliminates fish health assessment in 1995 but proposes reinstatement of these tests in 1996.

Some recovery of the fish community in Mitchell Branch was observed below SD170, SD180, SD190 in fall 1991 (Fig. C.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 instream community studies in 1995 but considers them at a reduced number of sites in 1996.

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 C.4), similar and often more extensive technical support is also provided to ORNL and Y-12 Plant.

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

I. FISH KILL INVESTIGATIONS

1. Mitchell Branch November 24, 1987: 2 fish Cause: Unknown November 1, 1988: 79 fish Cause: Discharge of chlorinated cooling water during operation of AVLIS test facility November 4, 1990: 549 fish Cause: Discharge of chlorinated cooling water due to control cable failure on primary cooling system of AVLIS test facility August 29, 1992: 6 fish Cause: Pesticide (pyrethrin) spill in SD 180	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 November 27, 1989–January 15, 1990: 175 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 K-901A pond April 1989

II. ECOLOGICAL EVALUATIONS

1. New Projects o Blair Road bridge (1985) o TSCA incinerator (1988-1989) o Production Waste Storage Facility (1990) o Storm drain dechlorinators (1990-1991) o CNF pipeline to Clinch River (1992-1993)	2. Spills o Lithium hydroxide-hypothetical (4/85) o Diesel fuel (2/87) o Sludge/fly ash (7/88)	3. Construction Activities o Stoner Road culvert replacement (2/87) o Drum Yard erosion/runoff (3/87) o K-1515C pond weir/dewatering (3/89) o Removal of streamside vegetation (7/90) o Beaver dams in K-901A (11/88, 3/92)

III. NPDES PERMIT ACTIVITIES

1. Assessment of Cause(s) of Permit Exceedances	2. Assistance with Permit Renewal
○ Al, COD, DO at K-1007B	○ Strategy development
○ DO at K-901A	○ Review/recommendations

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. C.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. C.37 and C.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 µg/g wet wt, more than a factor of ten higher than arsenic concentrations (<0.025 µg/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 µg/g in 1990, 1991, and 1992, respectively, versus 0.71 µg/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 µg/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 µg/g in 1991 and 0.11 µg/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 μg/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.

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. C.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. C.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. C.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. C.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. C.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. C.43).

Bluegill (Lepomis macrochirus) and other sunfish collected in 1992/1993 again showed the presence of multiple sources of mercury and PCB contamination (Figs. C.39 and C.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. C.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. C.44, top) are mean values based on four fish per sampling date compared with eight fish per date at BCK 0.6 (Fig. C.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. C.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 C.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.

Table C.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
				PCBs				
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
				Fraction over FDA limit				
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.

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.

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.

ORNL-DWG 87-18882

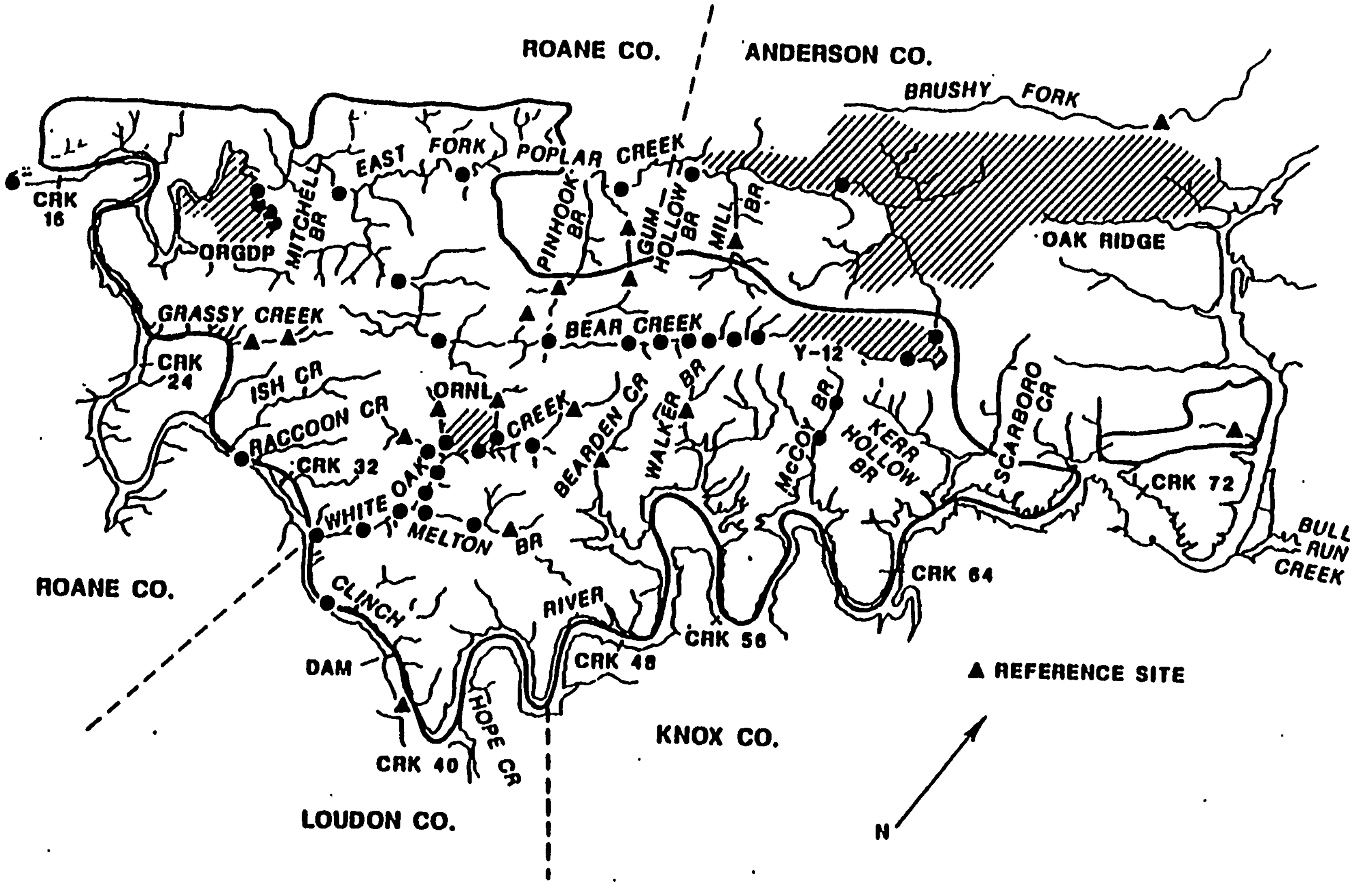

Fig. C.1. Map of the Oak Ridge Reservation showing the location of biological monitoring sites. Sampling sites downstream of facility discharges are shown as circles. Sampling sites that are not affected by facility discharges are reference sites and designated by triangles.

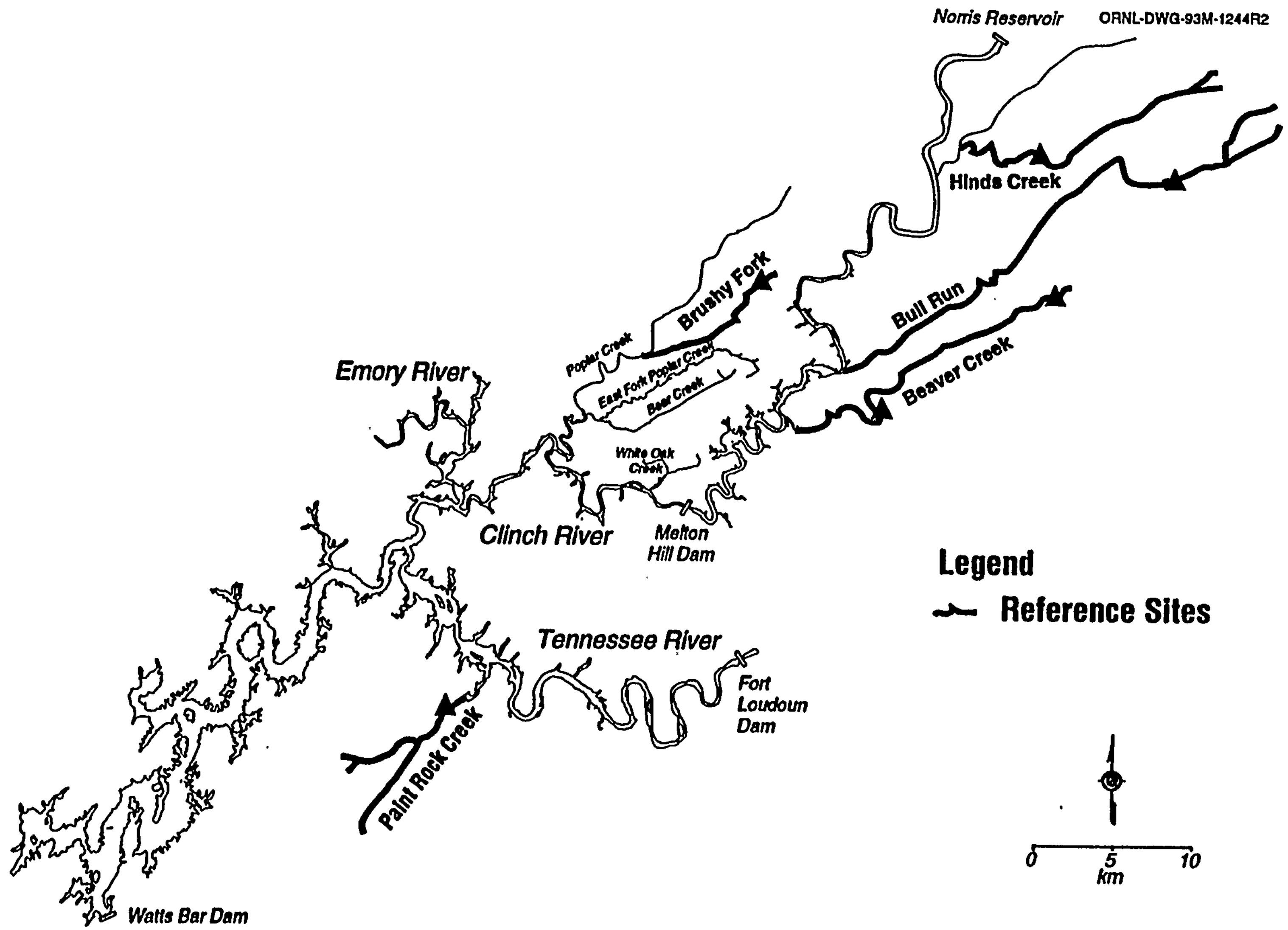

Fig. C.2. Location of offsite reference streams used in the Oak Ridge Reservation biological monitoring programs. Approximate location of sampling sites is designated by triangles.

ORNL-DWG 91 10650

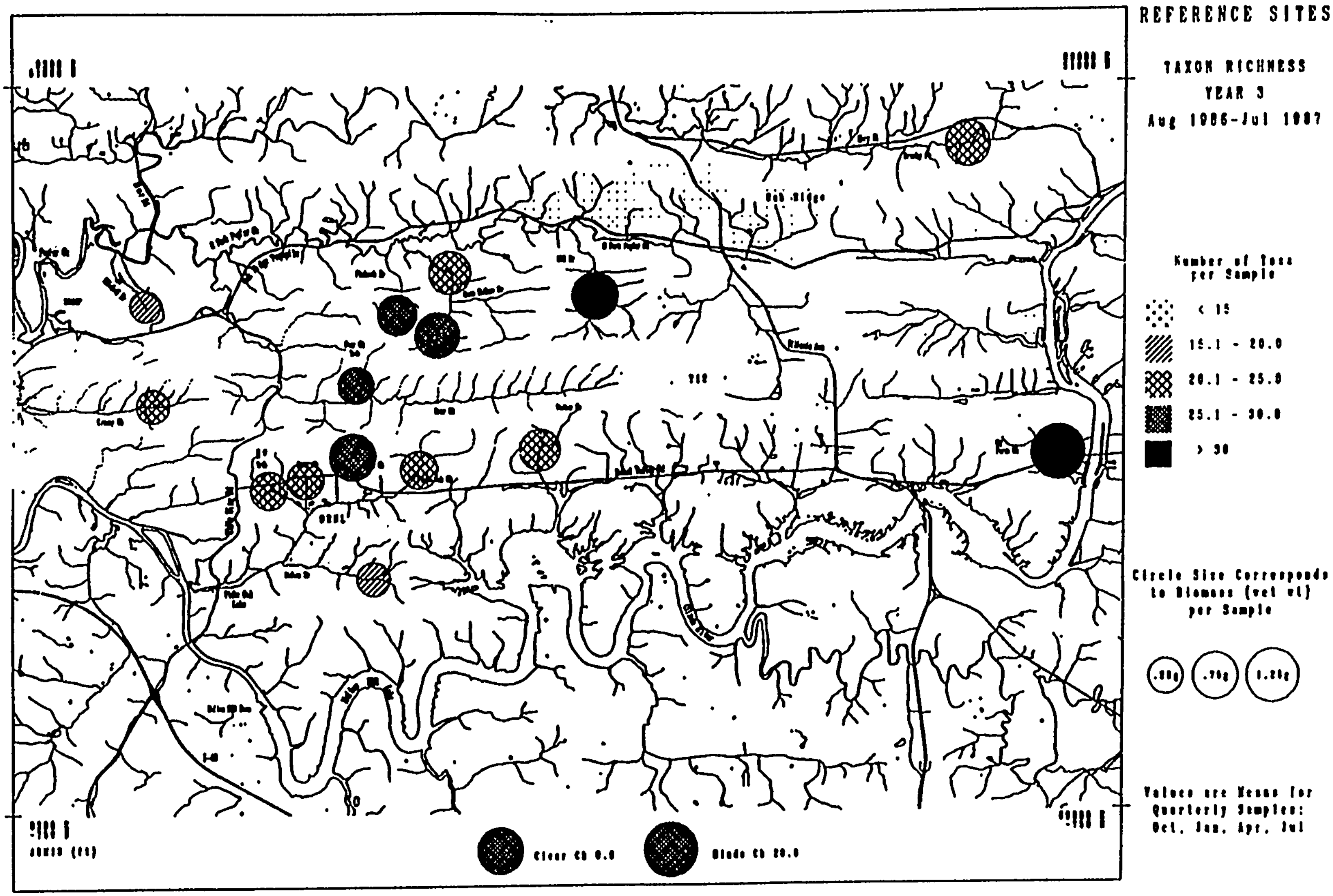

Fig. C.3. Comparisons of benthic macroinvertebrate richness and biomass at 17 reference sites. The Clear Creek and Hinds Creek sites at the bottom of the figure are outside the map boundaries.

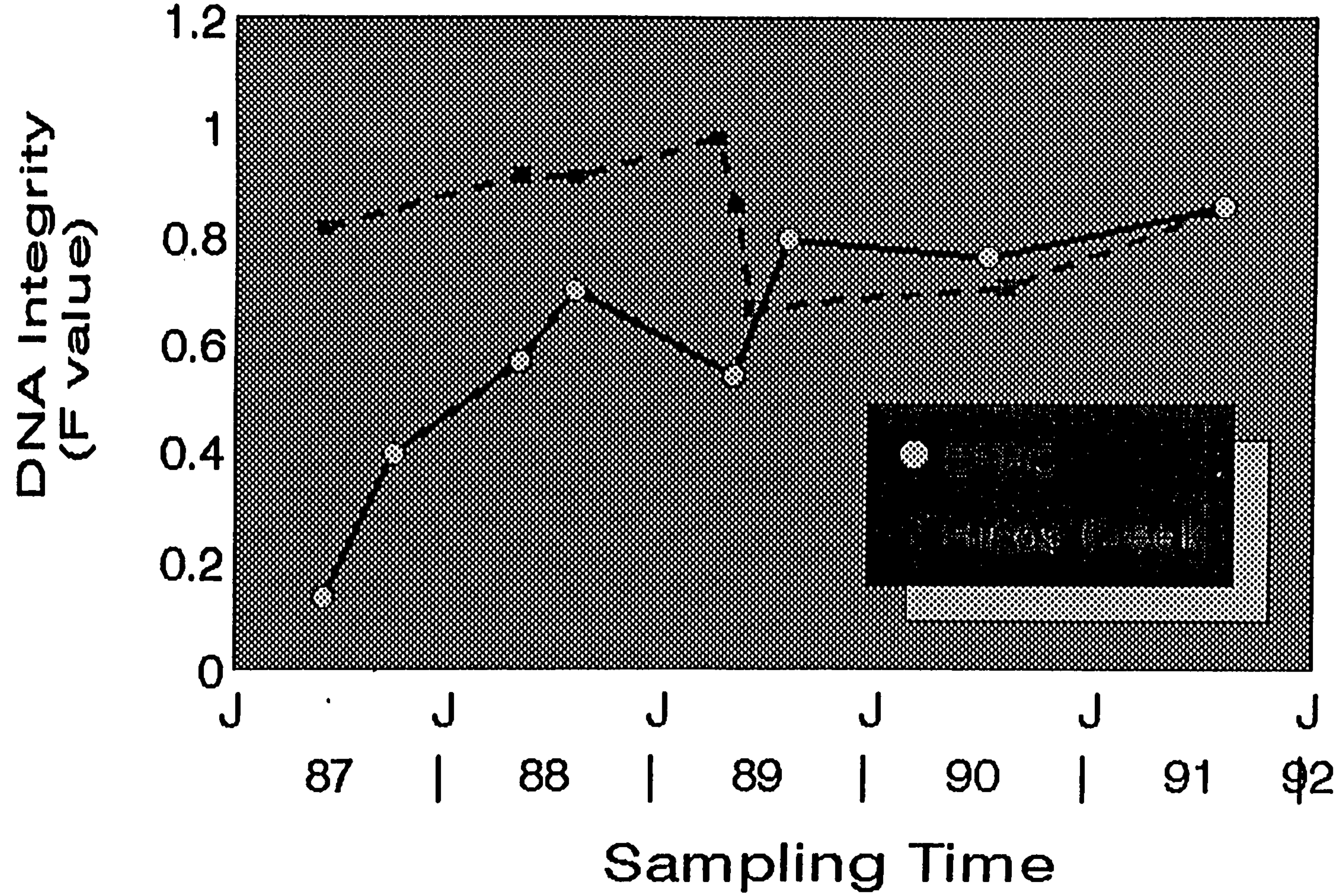

Fig. C.4. Temporal trends in DNA integrity in redbreast sunfish determined by an alkaline unwinding assay to estimate the number of DNA breaks. The EFPC site was located just downstream of the Y-12 Plant and Hinds Creek was used as the offsite reference stream.

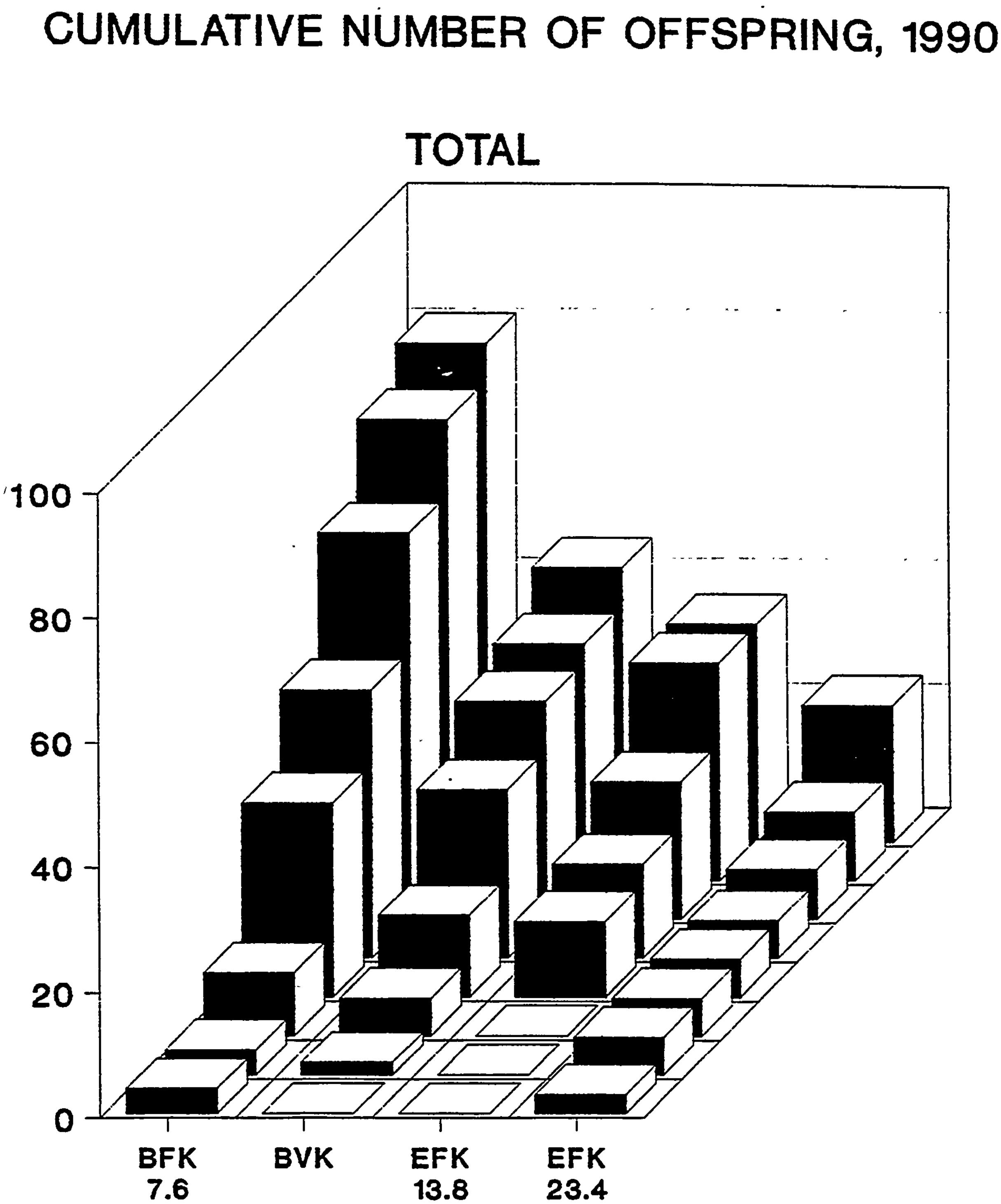

Fig. C.5. Results of an in situ toxicity test conducted in 1990 with fingernail clams (*Sphaerium fabale*) at two sites on East Fork Poplar Creek (EFK) downstream of the Y-12 Plant and two offsite reference streams, Brushy Fork (BFK) and Beaver Creek (BVK). The cumulative number of offspring is shown on the y-axis, and time (in 3-week intervals) is shown on the z-axis.

ORNL-DWG 94M-1105

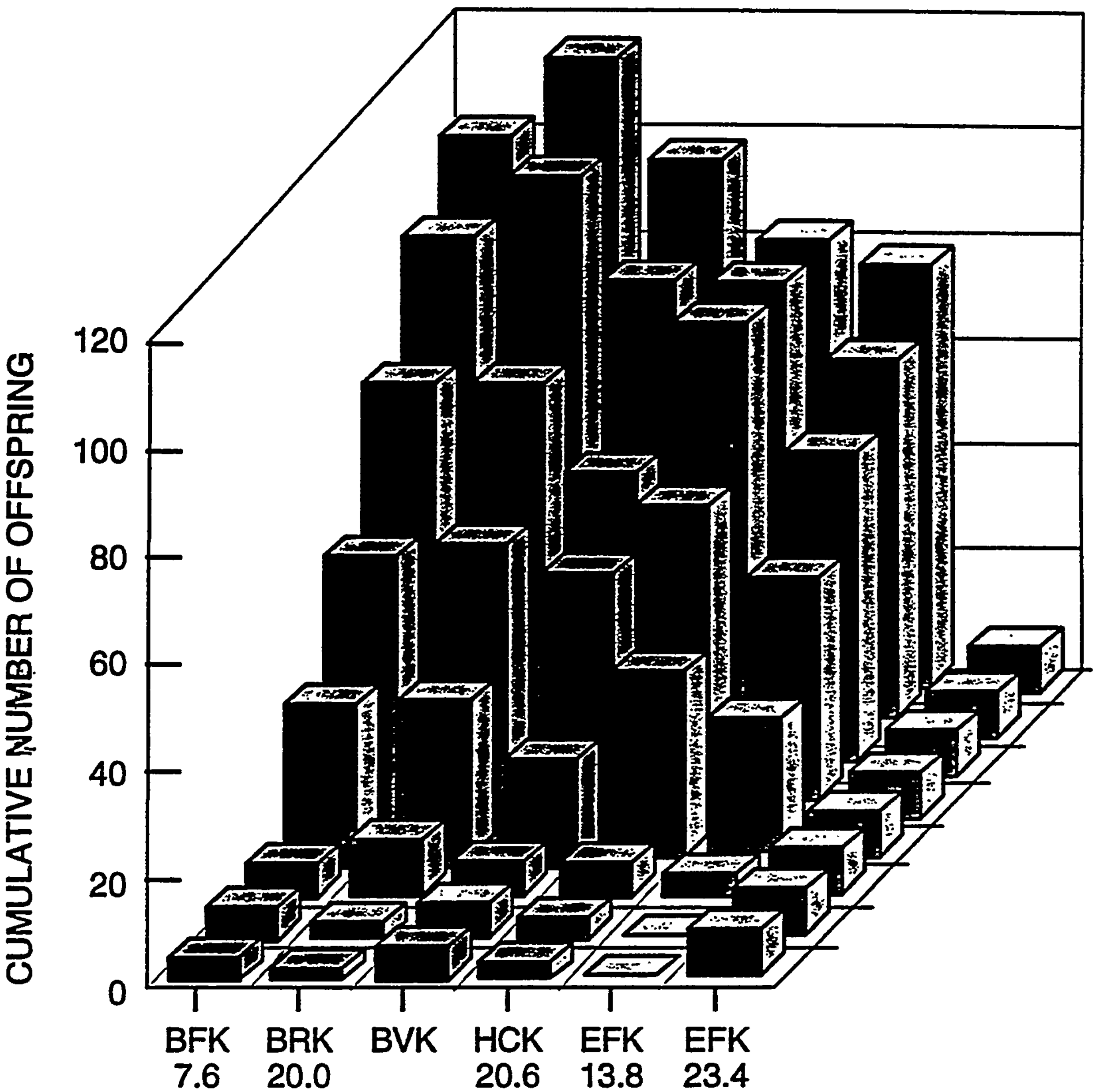

Fig. C.6. Results of an in situ toxicity test conducted in 1991 with fingernail clams (*Sphaerium fabale*) at two sites on East Fork Poplar Creek (EFK) downstream of the Y-12 Plant and four offsite reference streams, Brushy Fork (BFK), Bull Run (BRK), Beaver Creek (BVK), and Hinds Creek (HCK). Time (in 3-week intervals) is shown on the z-axis.

ORNL–DWG 86–9318

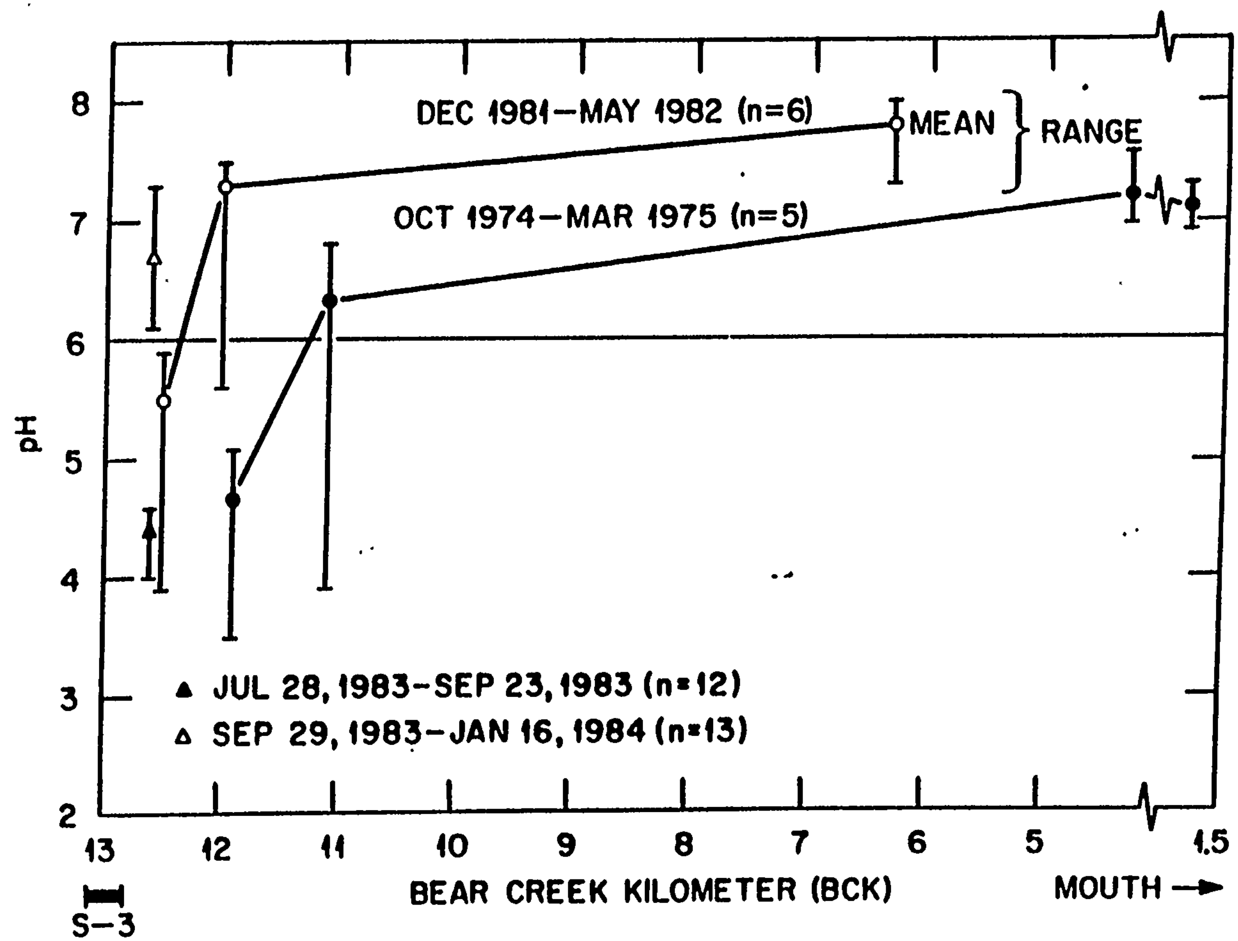

Fig. C.7. Changes in pH with increasing distance below the S-3 ponds in 1974–1975 and 1981–1982.

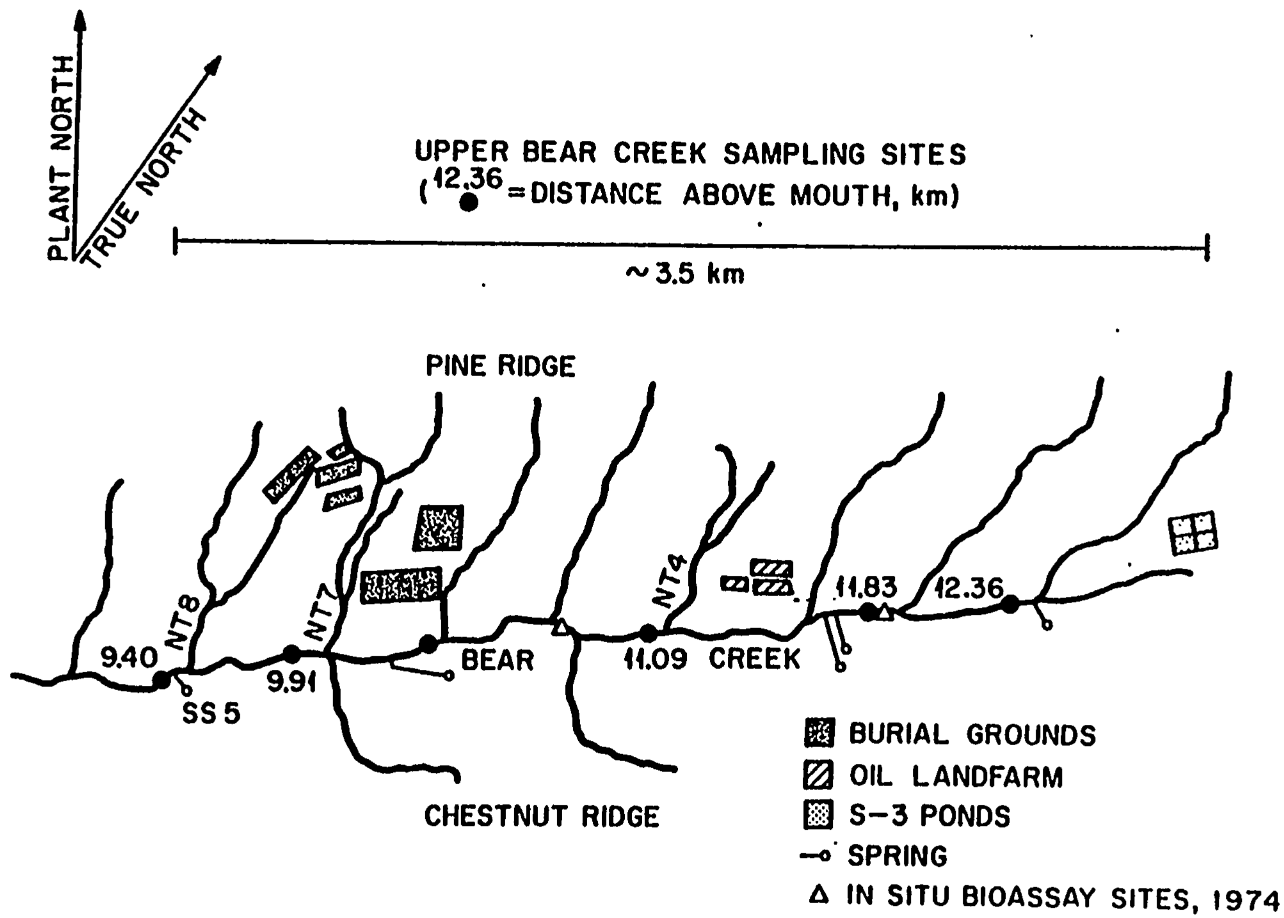

Fig. C.8. Map of upper Bear Creek showing the location of the biological sampling sites (●) in relation to various waste disposal areas. The sampling sites range from BCK 12.36 to BCK 9.40 (unlabeled site just southeast of burial grounds is BCK 10.32).

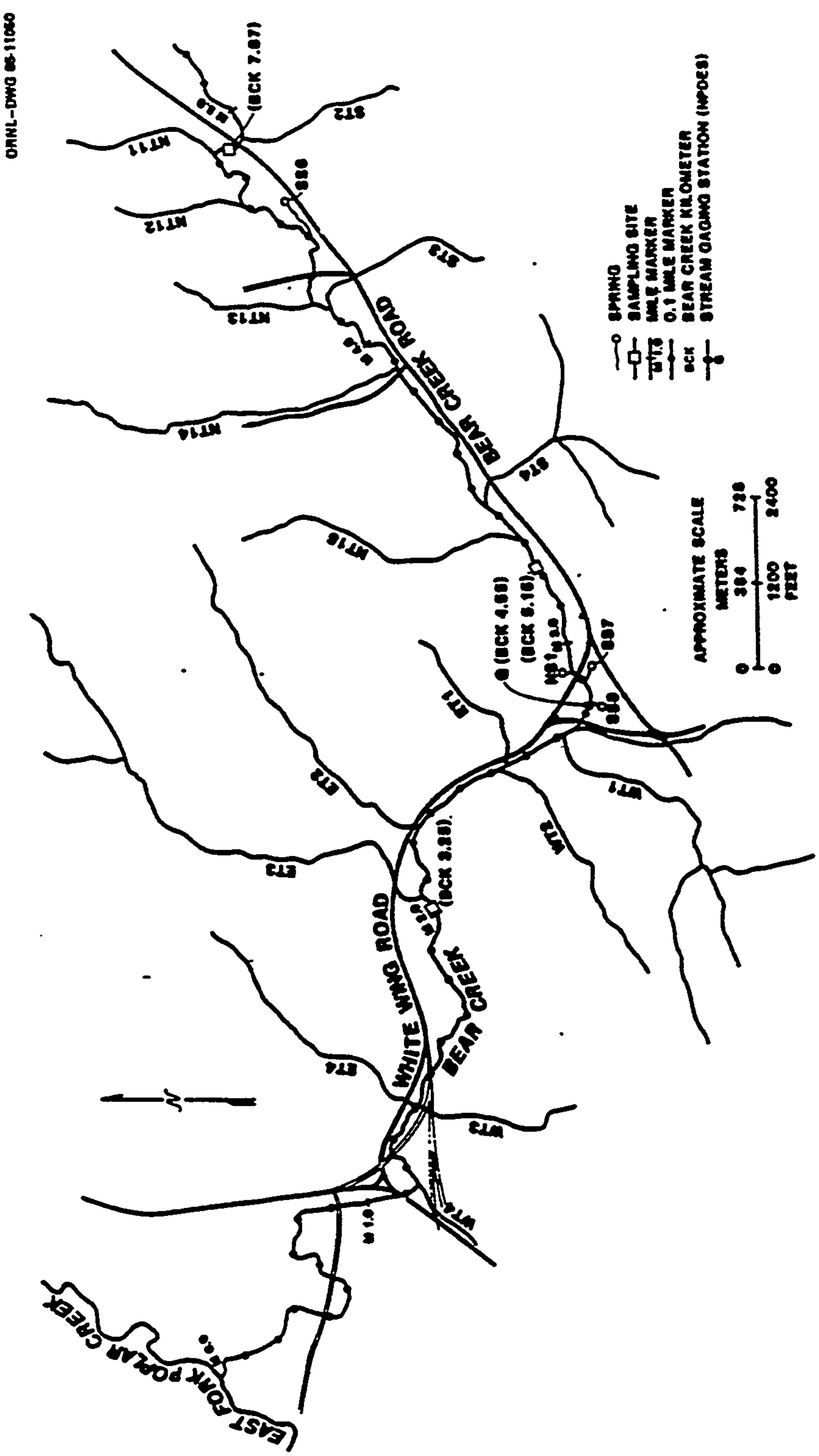

Fig. C.9. Map of lower Bear Creek showing the location of biological sampling sites BCK 7.87 to BCK 3.25.

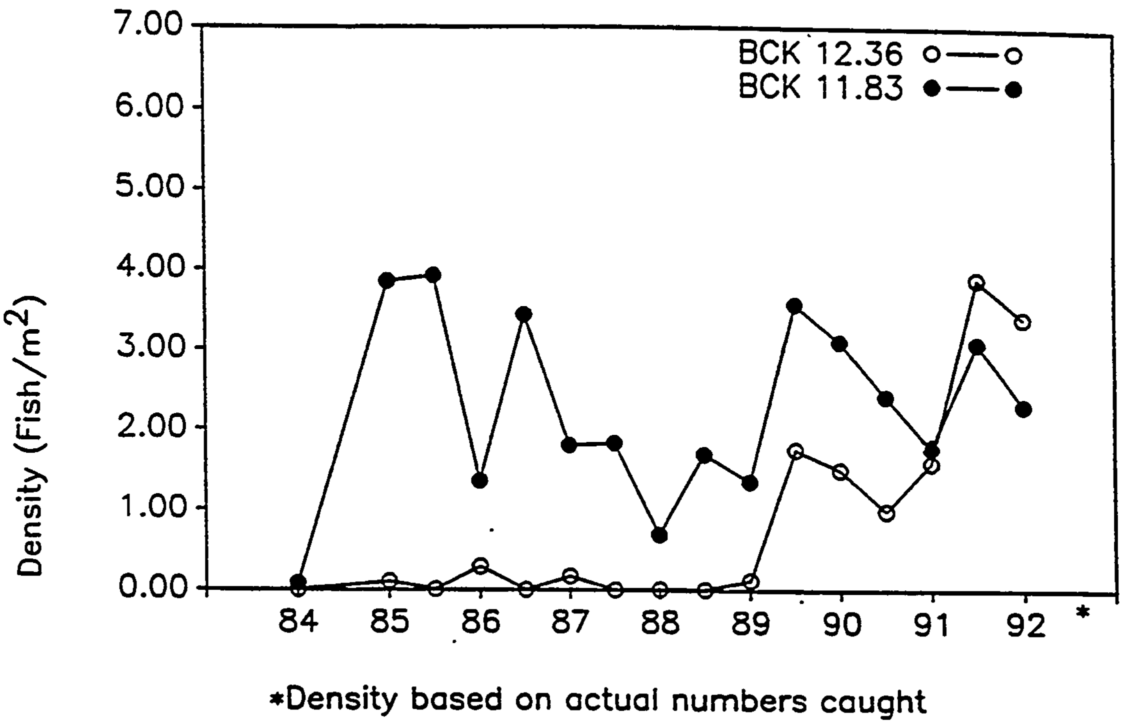

Fig. C.10. Total fish densities at two monitoring sites in the headwaters of Bear Creek, May 1984–April 1992.

ORNL-DWG 94M-1106

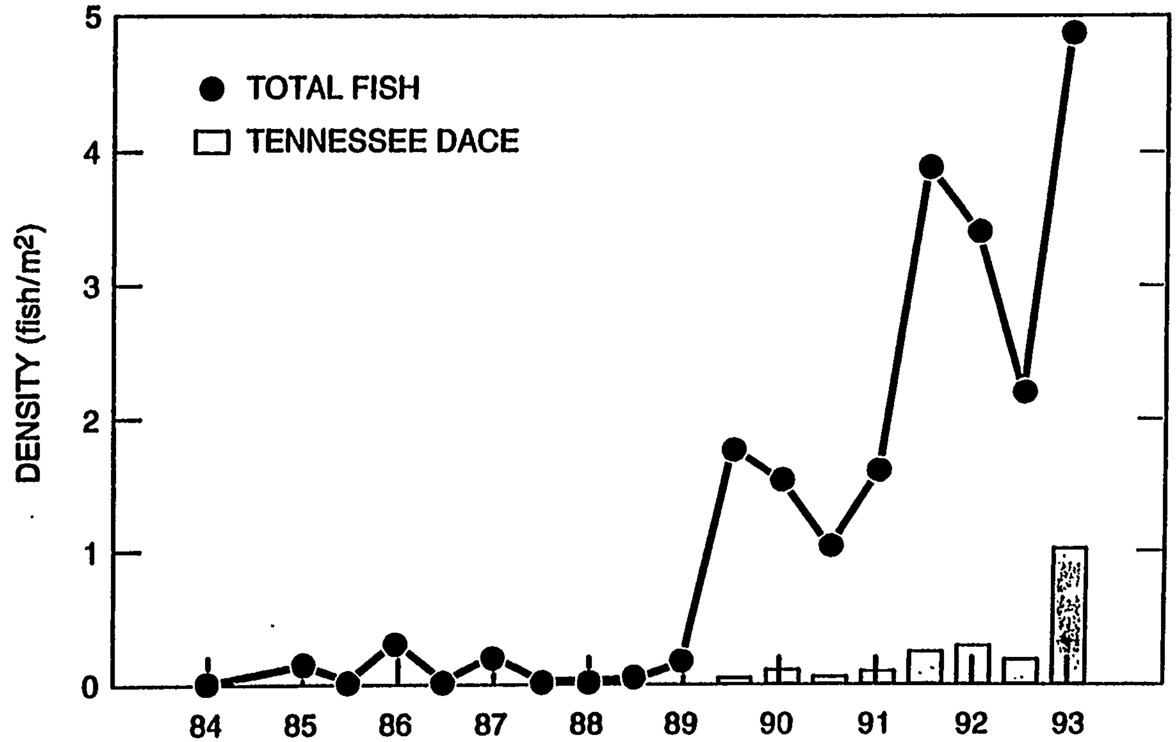

Fig. C.11. Total fish and Tennessee dace densities in upper Bear Creek at BCK 12.36, May 1984–April 1993.

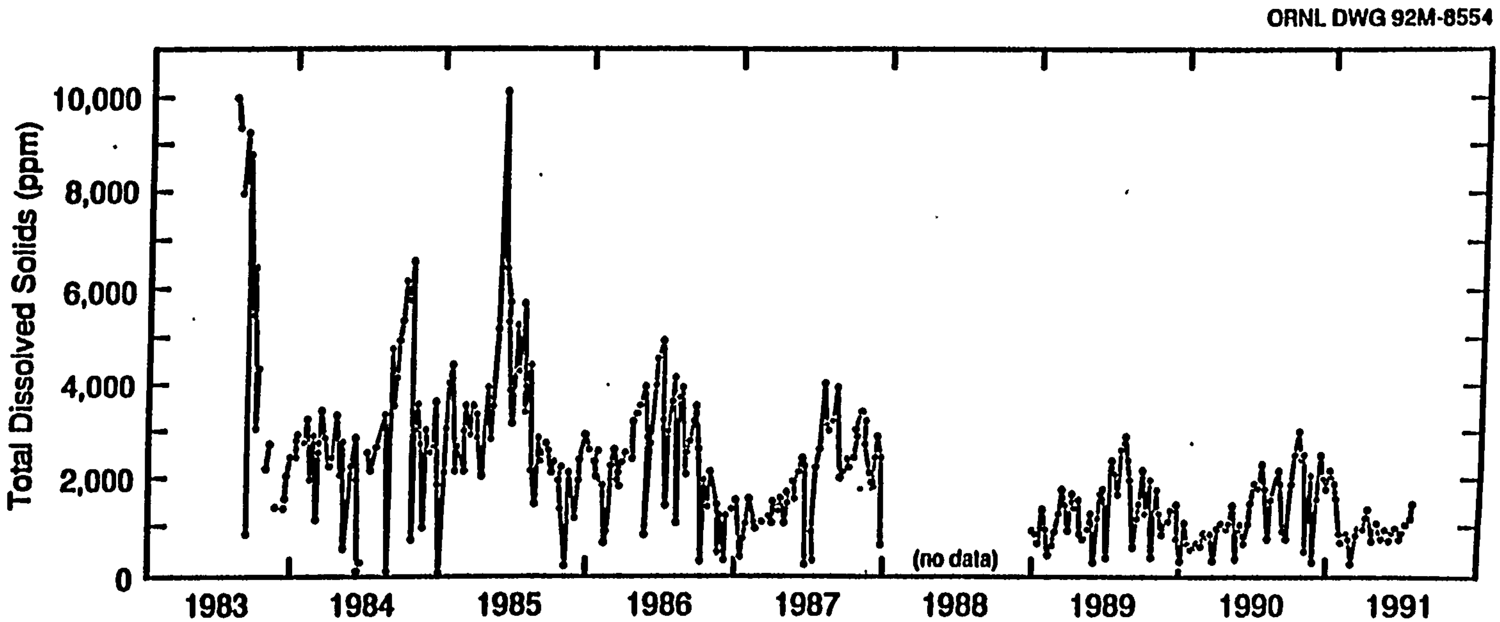

Fig. C.12. Change in total dissolved solids in headwaters of Bear Creek just below S-3 ponds.

ORNL-DWG 93M-9067

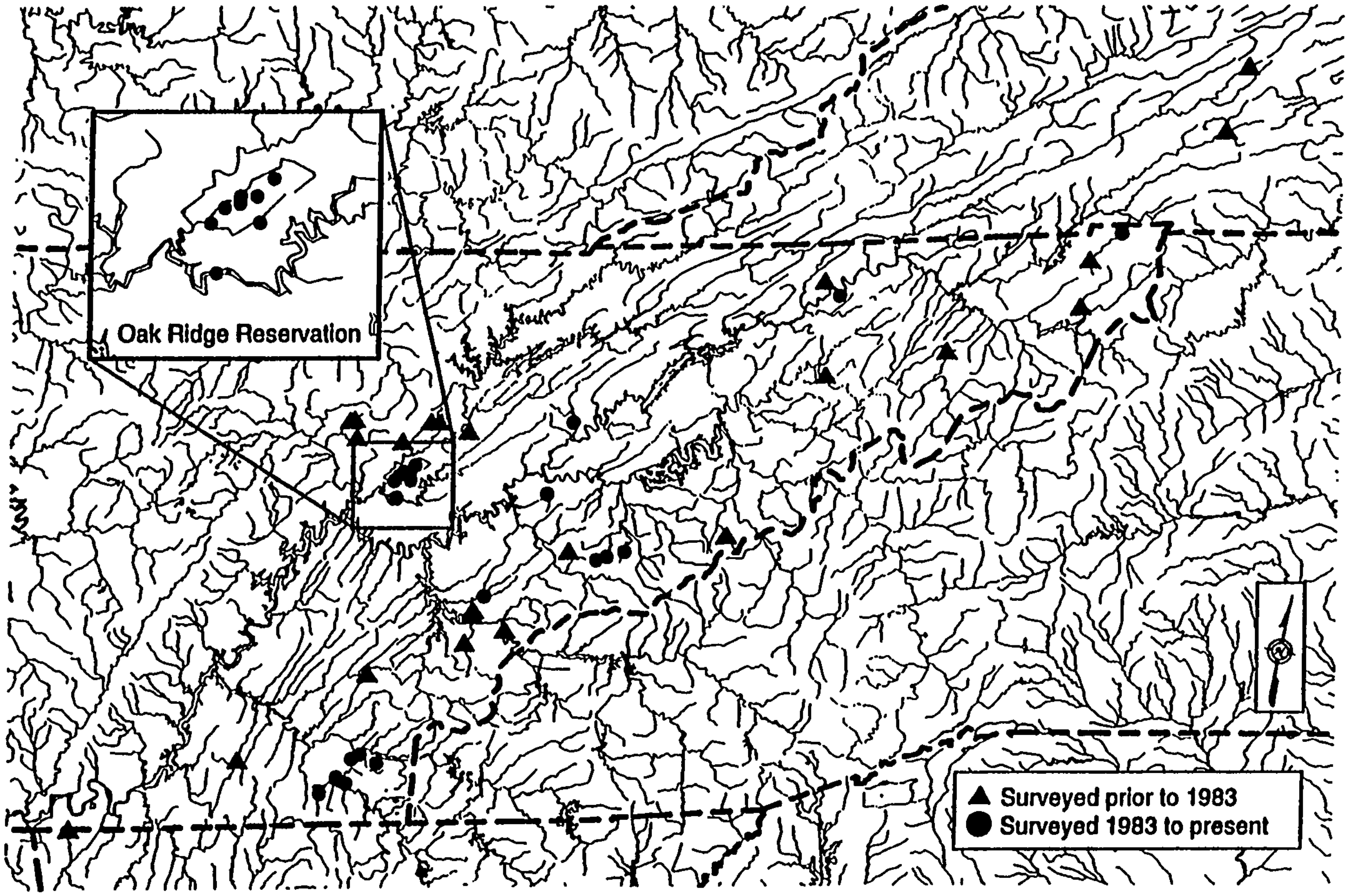

Fig. C.13. Distribution of the Tennessee dace (*Phoxinus tennesseensis*).

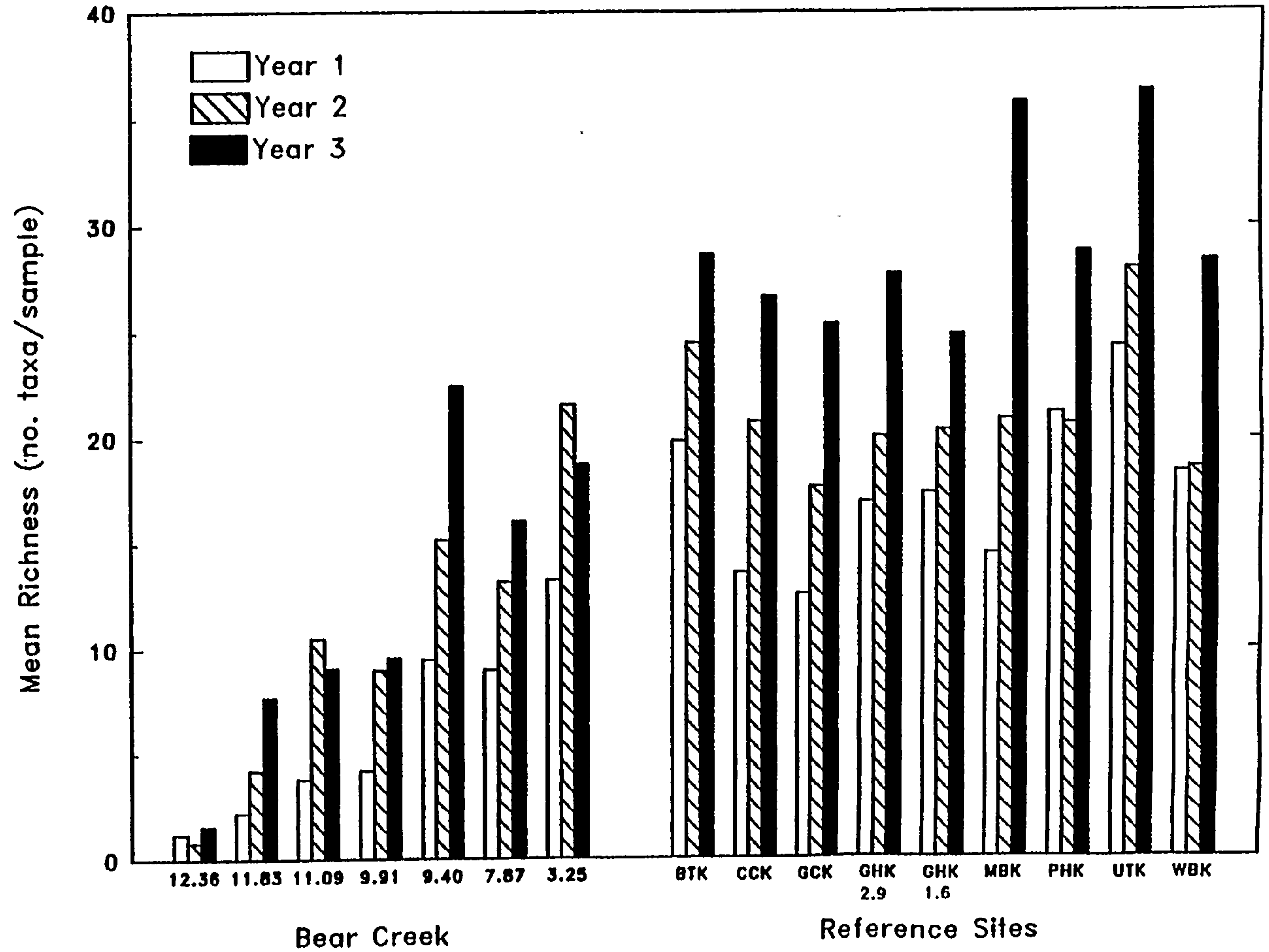

Fig. C.14. Taxonomic richness of benthic macroinvertebrates in Bear Creek. Mean values were calculated for each of three years between May 1984 and April 1987.

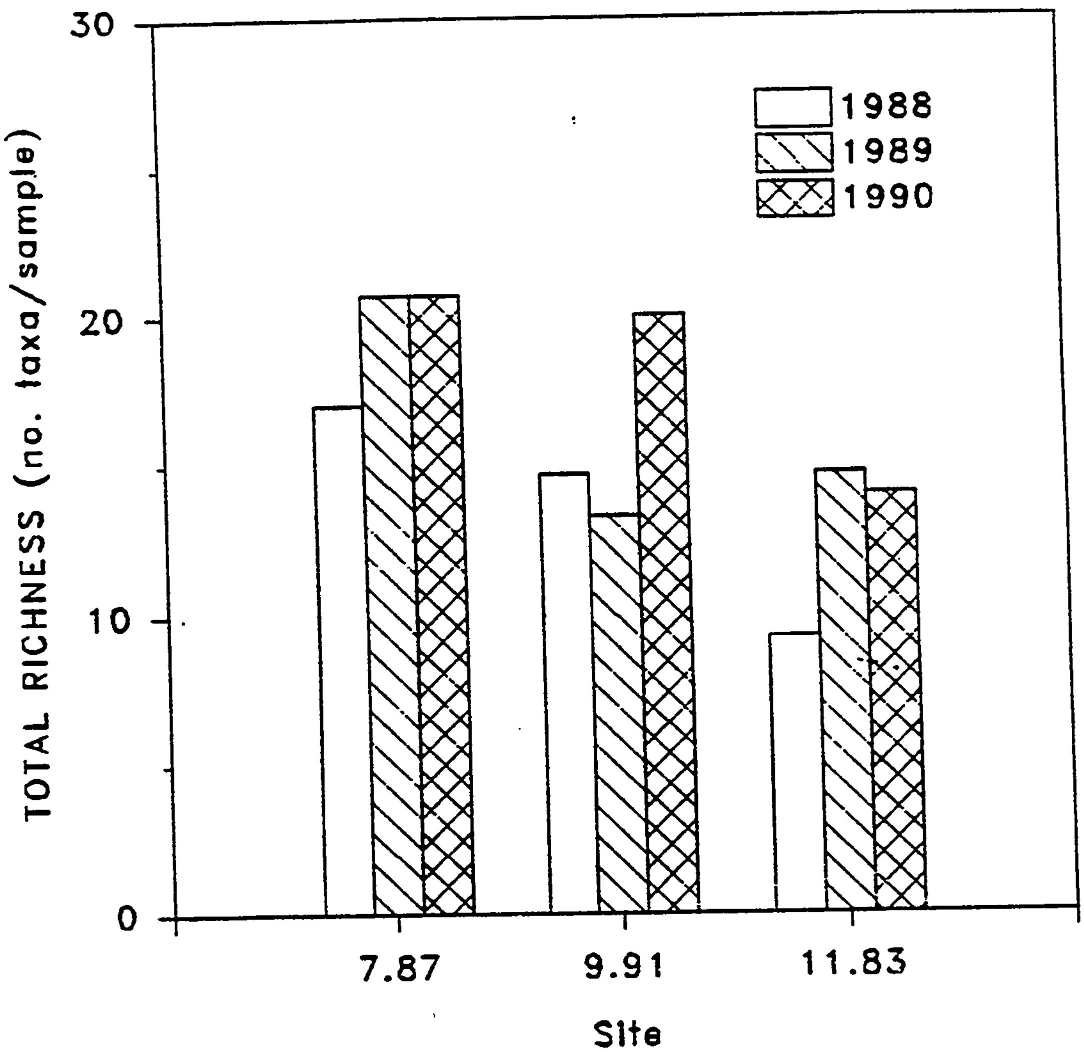

Fig. C.15. Mean total richness of benthic macroinvertebrates at three sites in the middle to upper reaches of Bear Creek.

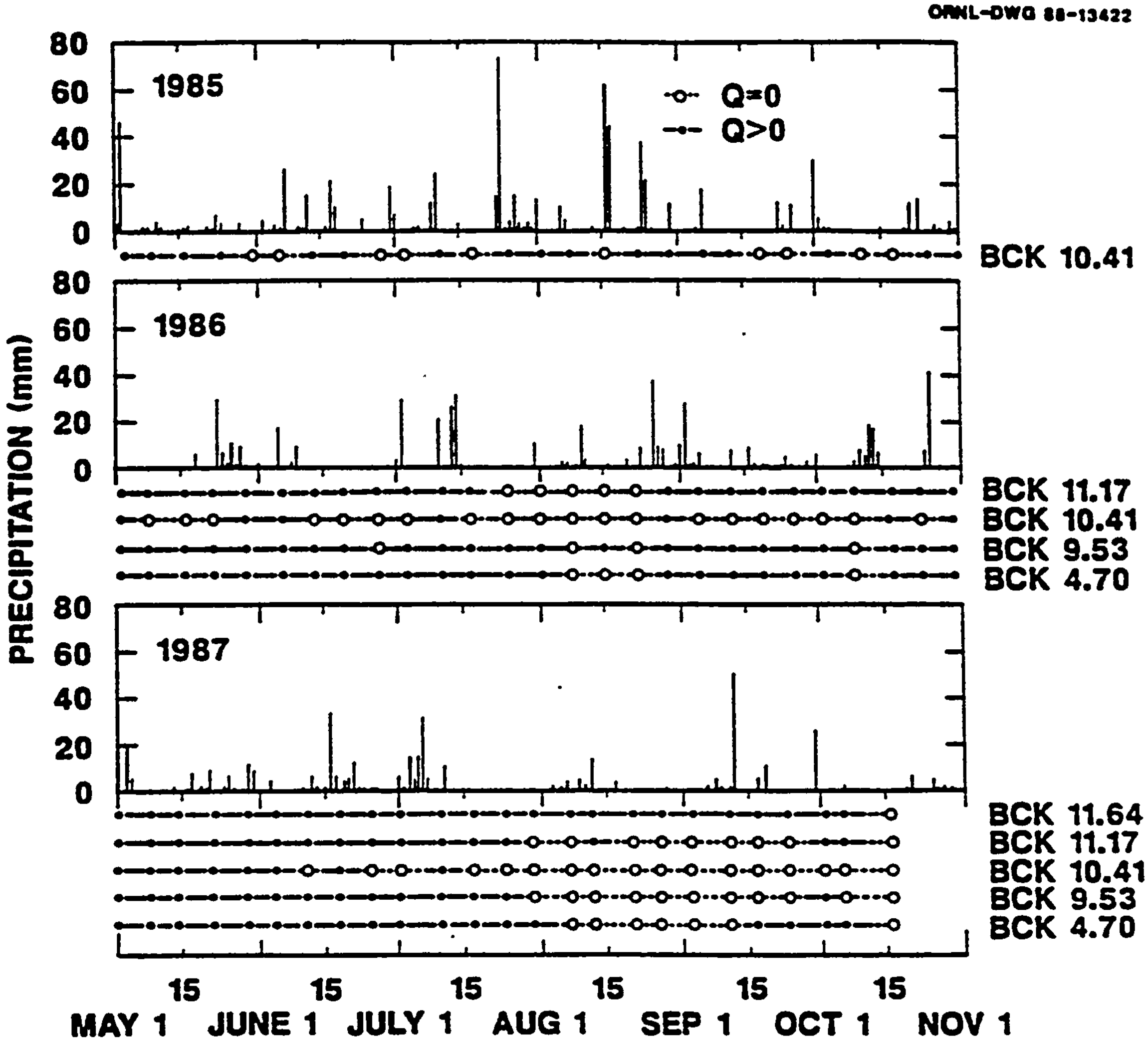

Fig. C.16. Comparison of total daily precipitation and the frequency of occurrence of zero flow in Bear Creek, 1985–1987. Sampling dates are indicated by open circles (zero flow) and closed circles (flow > 0.02 L/s). Precipitation was measured at a rain gage located near BCK 10.6 in the Bear Creek Burial Grounds.

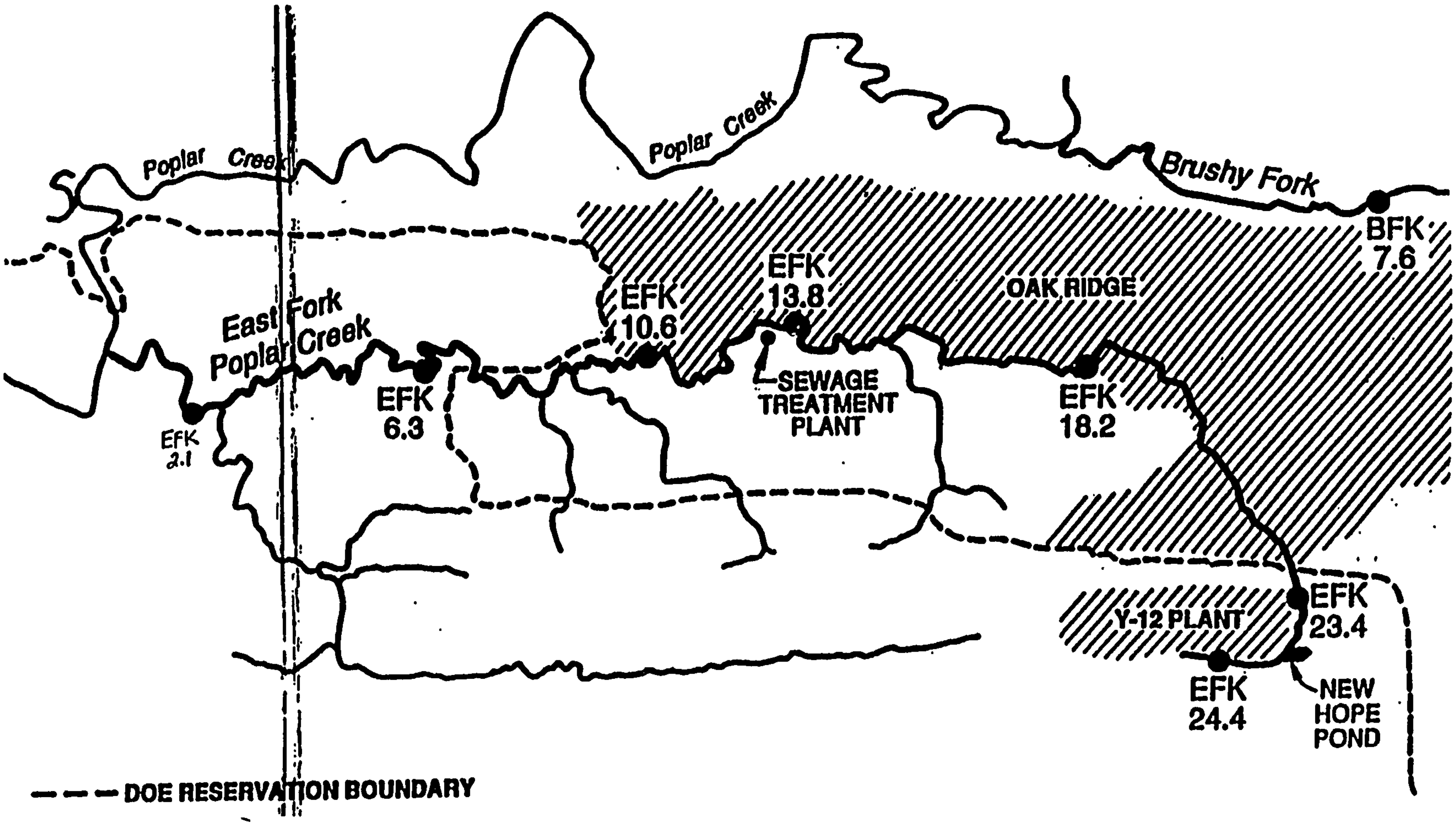

Fig. C.17. Map of East Fork Poplar Creek showing the location of the seven biological monitoring sites and the reference site on Brushy Fork (BFK) north of Oak Ridge.

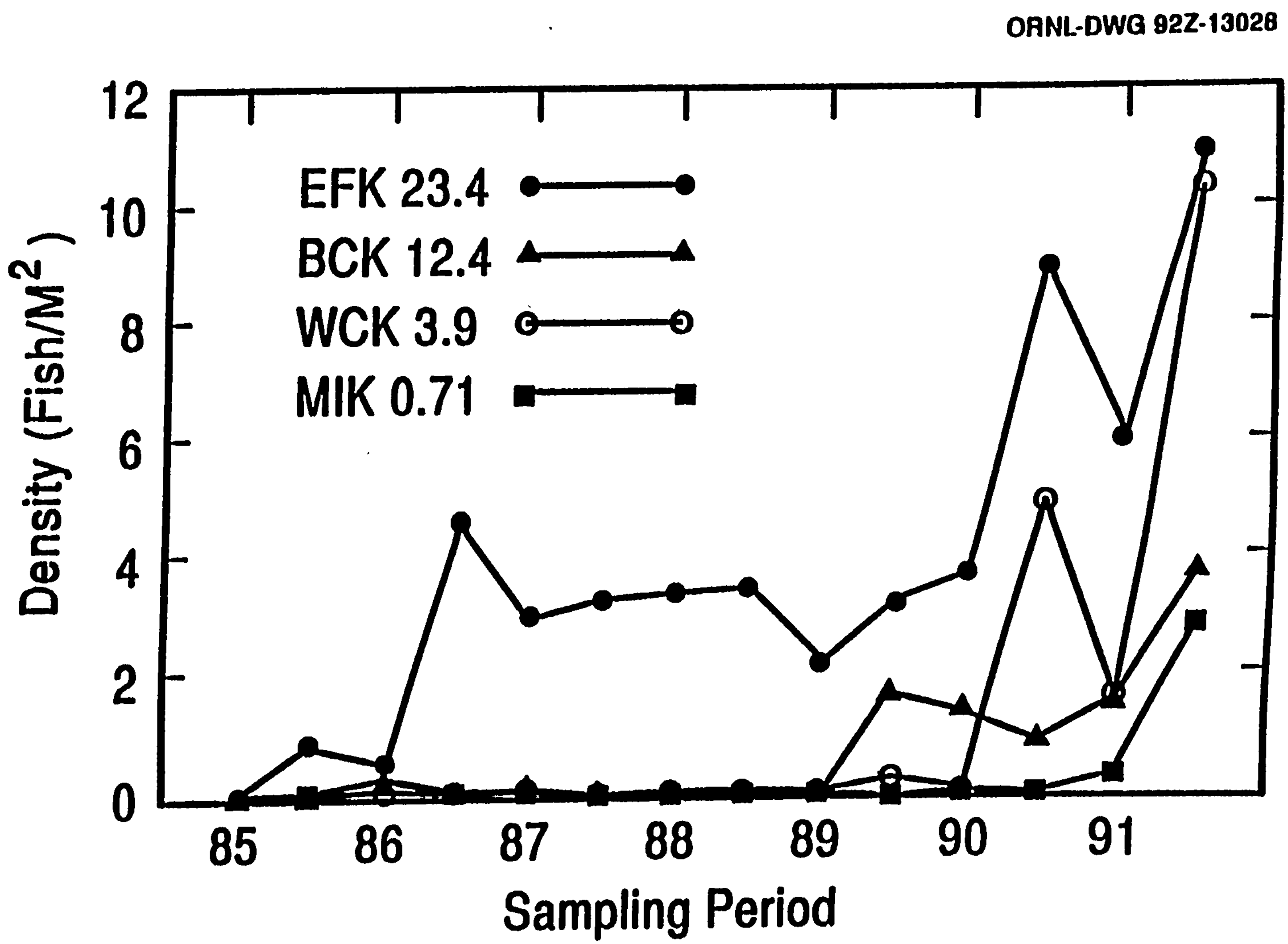

Fig. C.18. Changes in fish population abundance in four streams on the Oak Ridge Reservation. EFK = East Fork Poplar Creek; BFK = Bear Creek; WCK = White Oak Creek; MIK = Mitchell Branch.

ORNL-DWG 92Z-13029

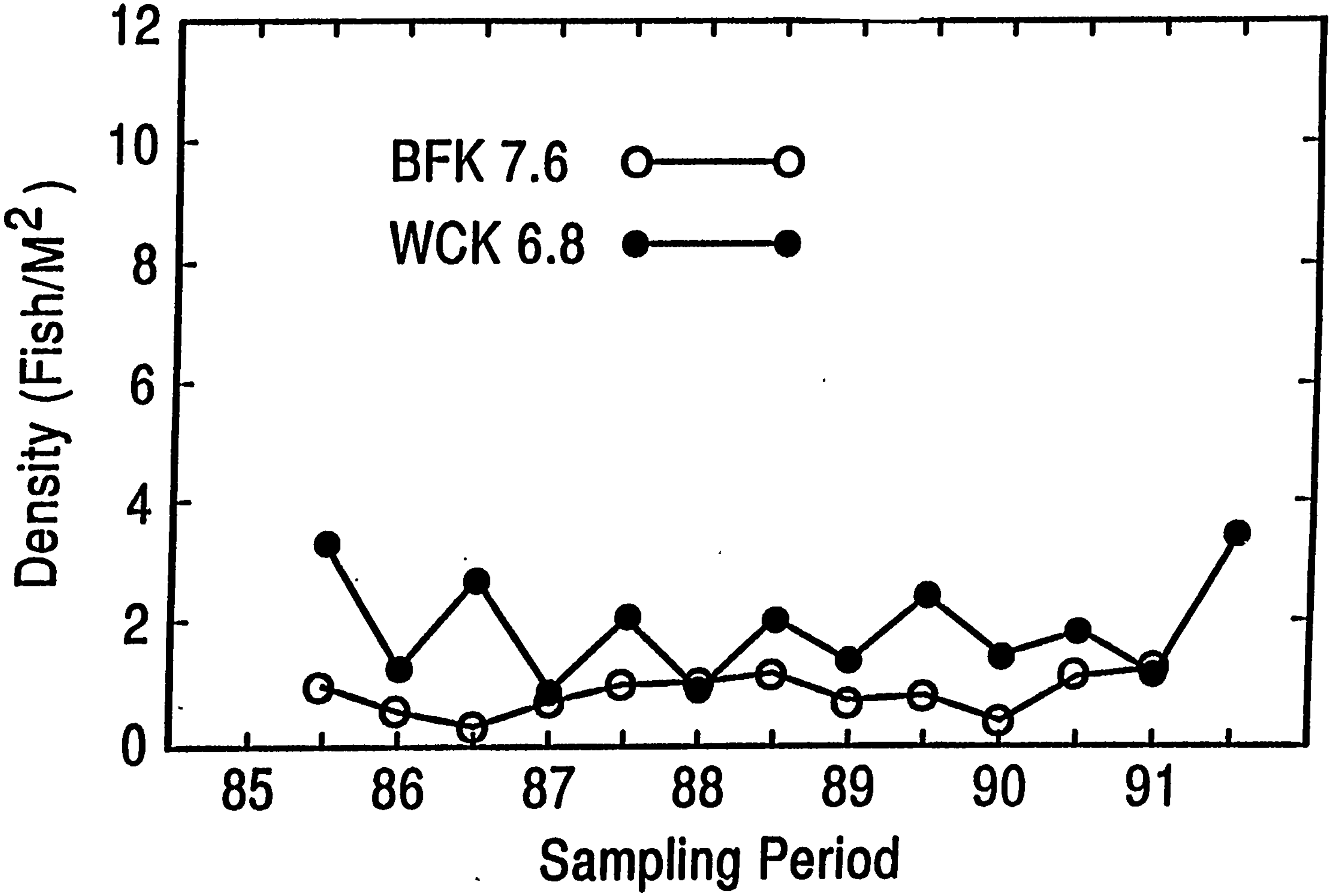

Fig. C.19. Changes in fish population abundance in two reference streams, the headwaters of White Oak Creek (WCK) above ORNL and Brushy Fork (BFK) north of Oak Ridge.

ORNL-DWG 93M-1143

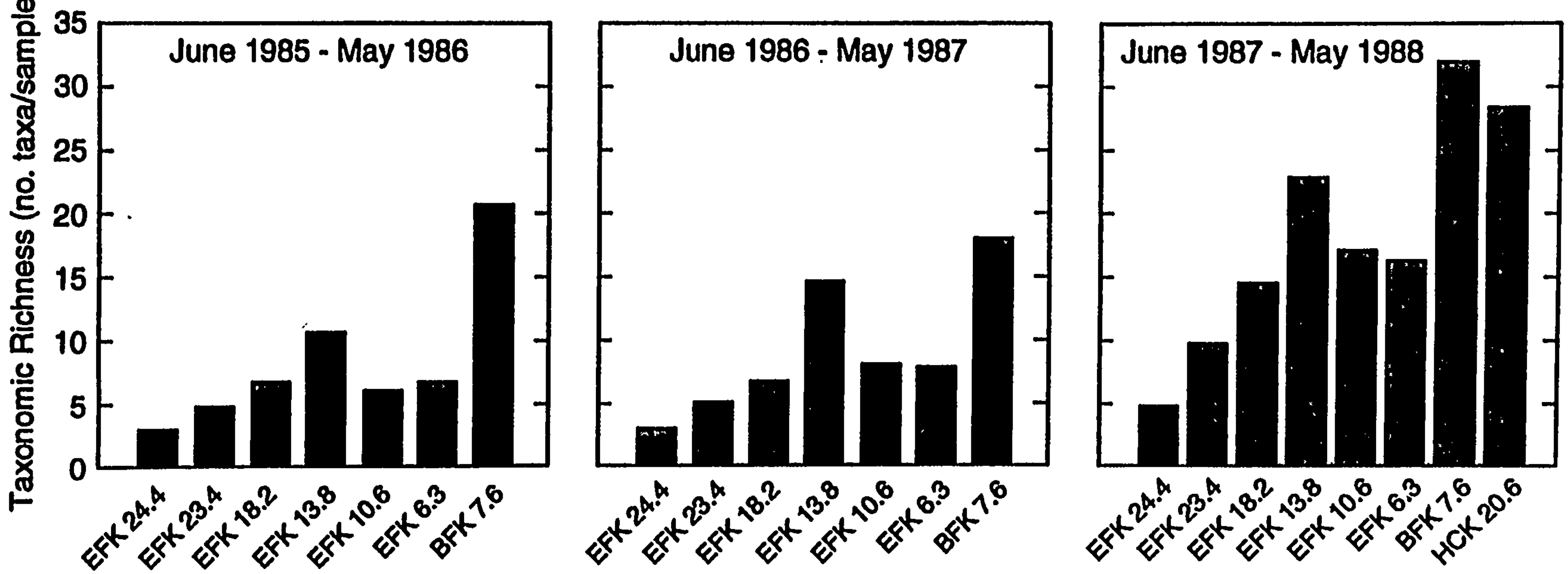

Fig. C.20. Mean annual taxonomic richness of benthic macroinvertebrates in East Fork Poplar Creek and two reference streams, Brushy Fork (BFK) and Hinds Creek (HCK).

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

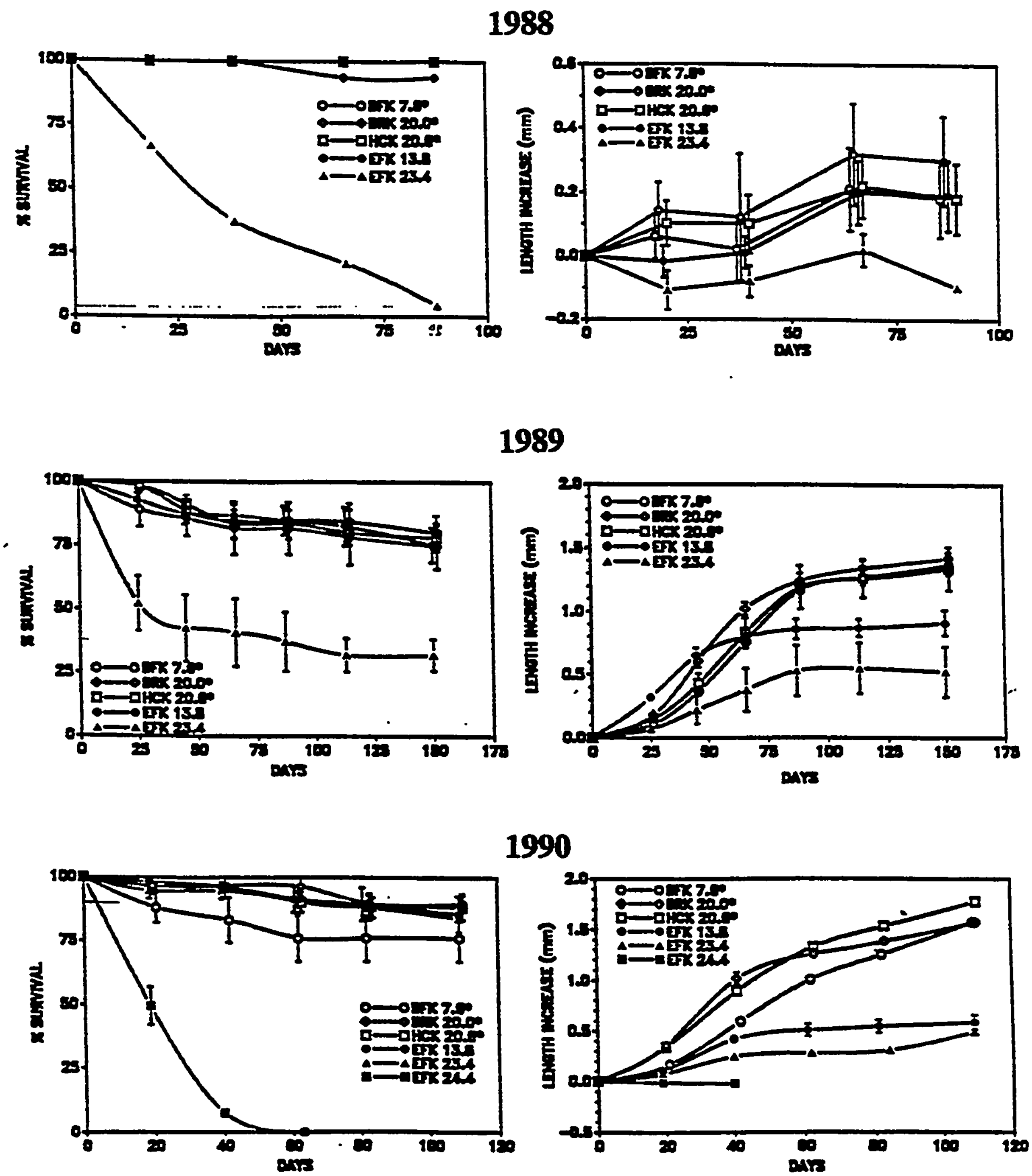

Fig. C.21. Survival and growth of fingernail clams in screened, plexiglass containers placed in East Fork Poplar Creek (EFK) and several reference streams, including Brushy Fork (BFK), Hinds Creek (HCK), and Bull Run (BRK).

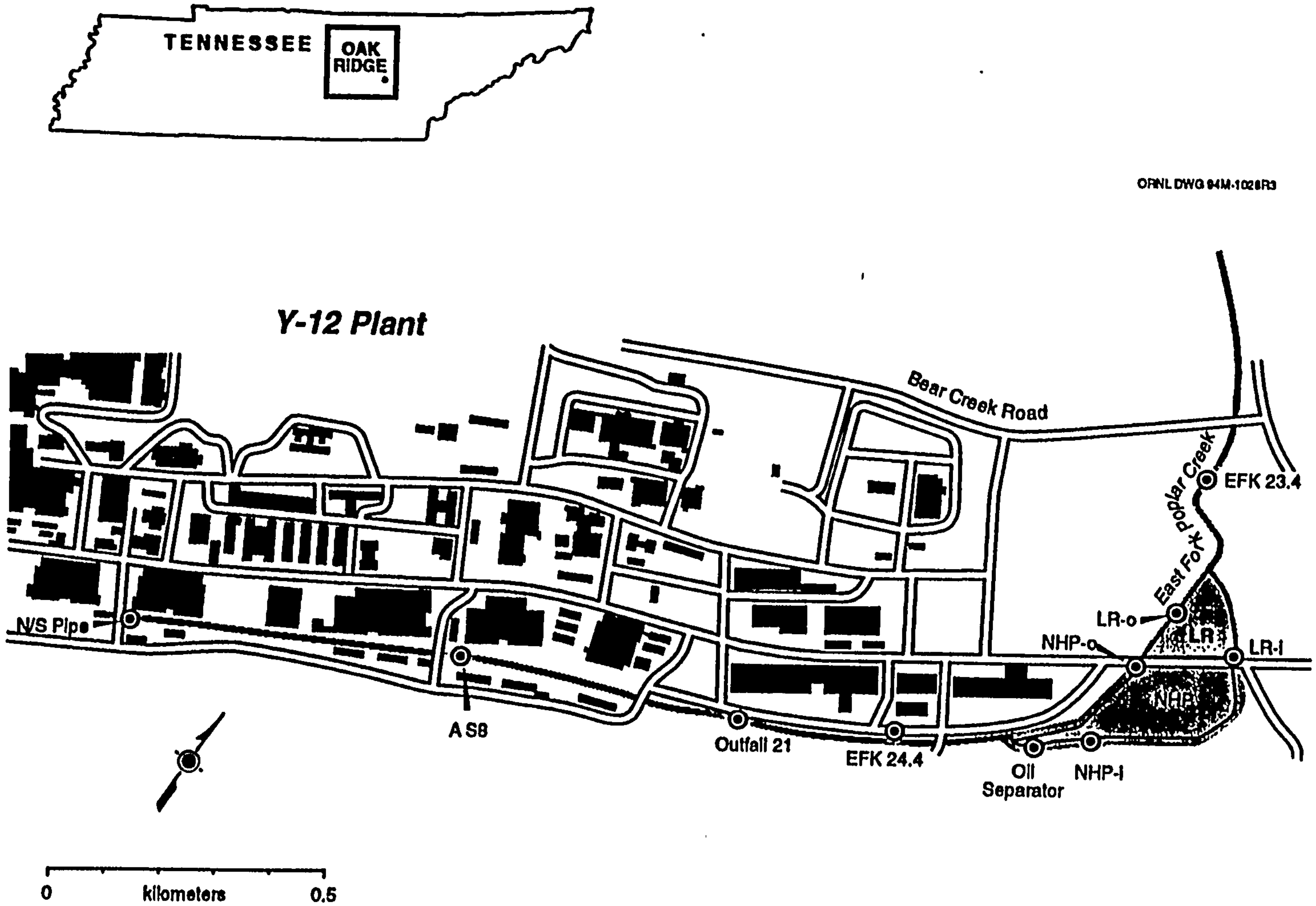

Fig. C.22. Map of upper East Fork Poplar Creek at the Y-12 Plant. N/S = North-South pipes; AS8 = Area Source Study Site 8; NHP-i/NHP-o = New Hope Pond inlet/outlet; LR = Lake Reality. NHP was drained in November 1988 and capped in 1989.

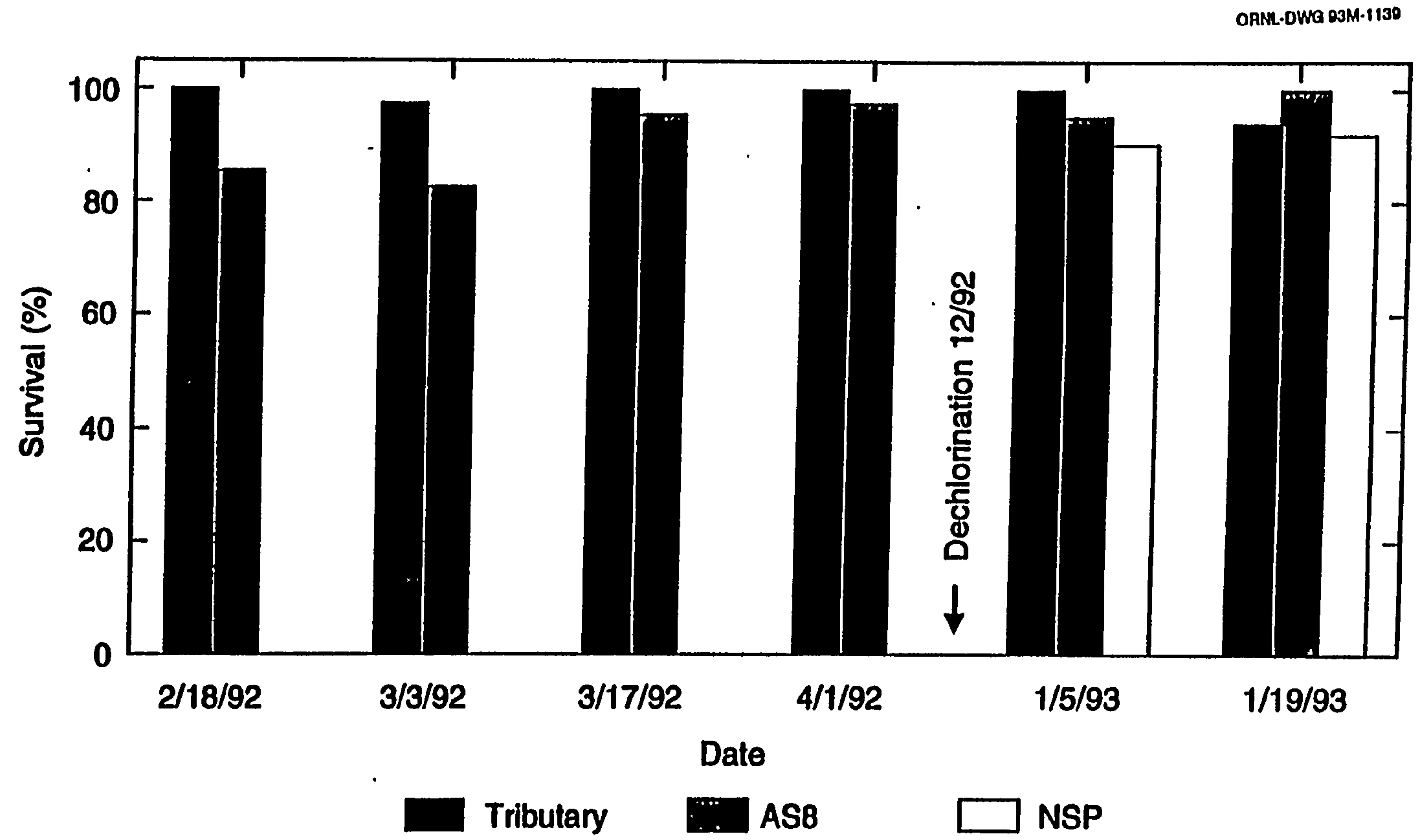

Fig. C.23. Snail survival in East Fork Poplar Creek (EFPC) before and after dechlorination. Survival was zero at the North-South pipes (NSP) before dechlorination and ≥90% after dechlorination. An uncontaminated tributary of EFPC was used as the reference site.

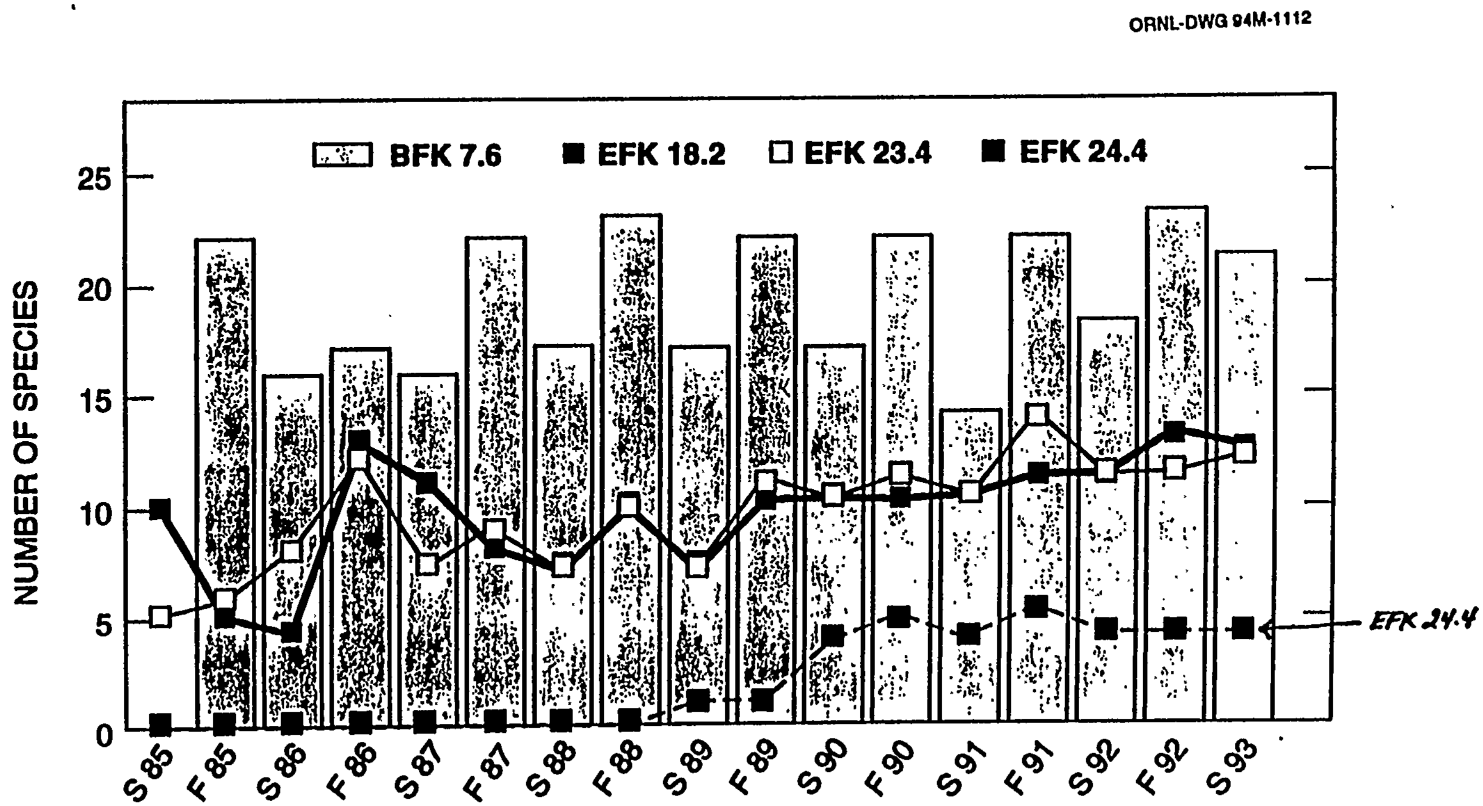

Fig. C.24. Fish species richness in upper East Fork Poplar Creek (EFK) and a reference stream (BFK), May 1985–March 1993.

ORNL-DWG 94M-1111

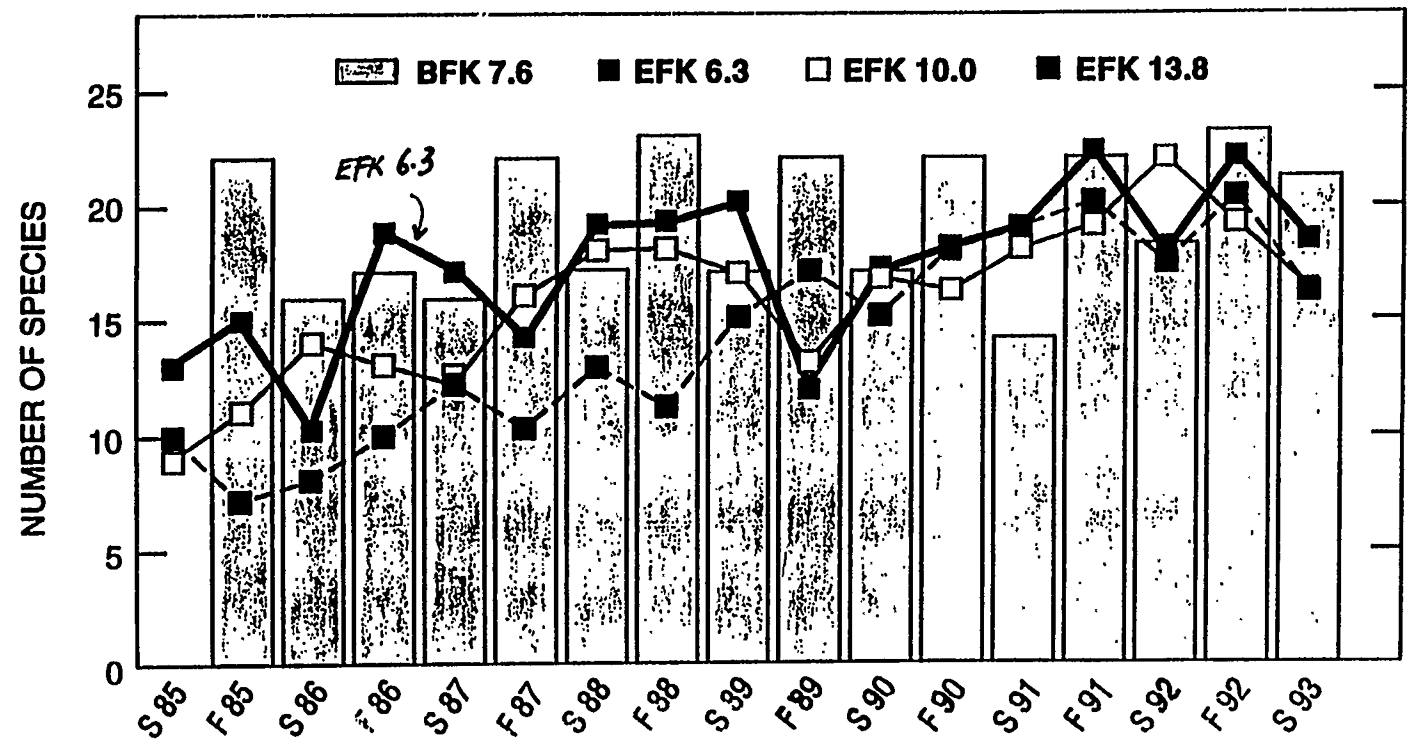

Fig. C.25. Fish species richness in lower East Fork Poplar Creek (EFK) and a reference stream (BFK), May 1985–March 1993.

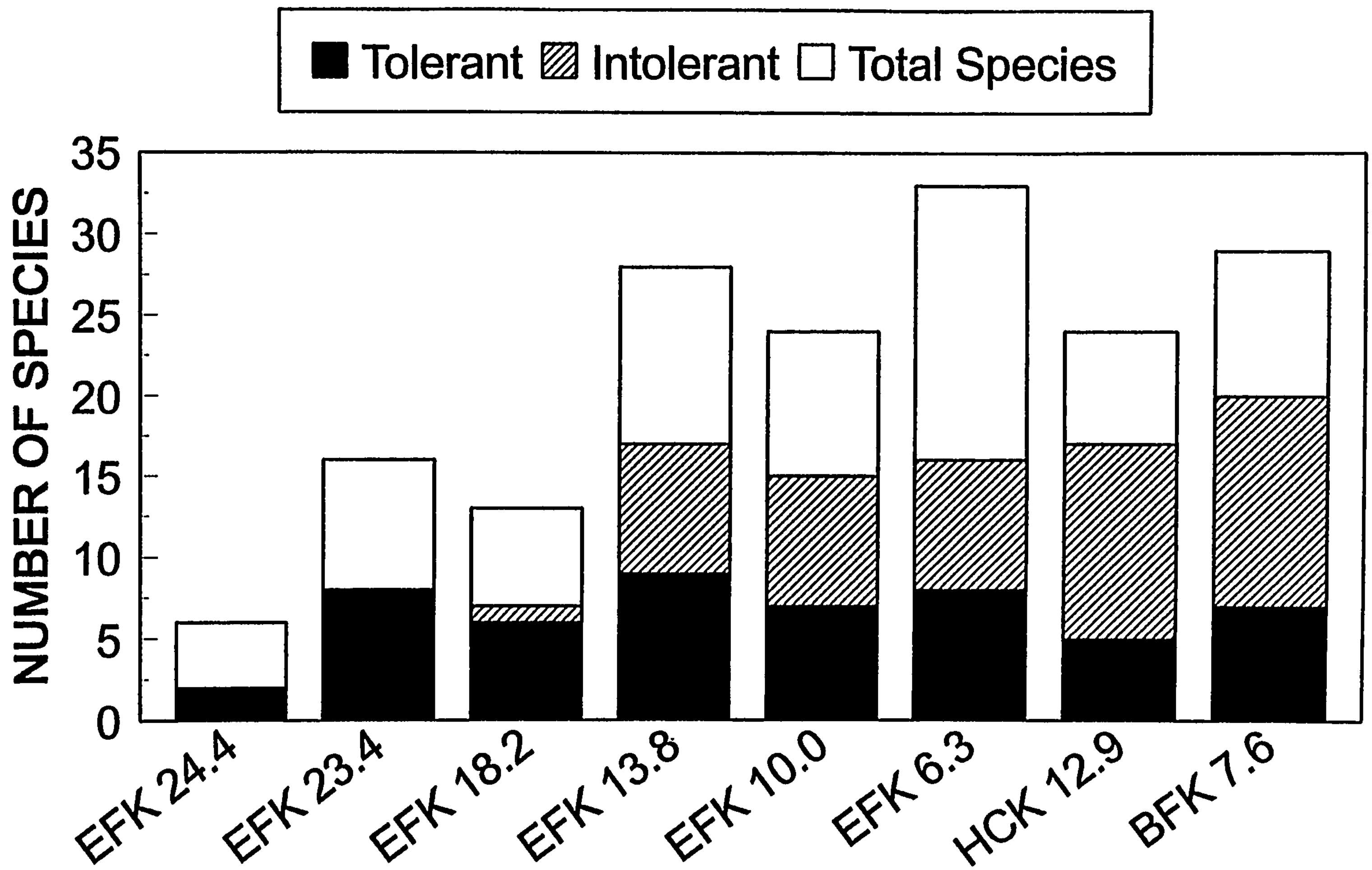

Fig. C. 26. Number of pollutant-tolerant and pollutant-intolerant fishes in East Fork Poplar Creek (EFK) and two reference streams, Hinds Creek (HCK) and Brushy Fork (BFK). Data are based on sampling conducted from May 1985 through October 1993.

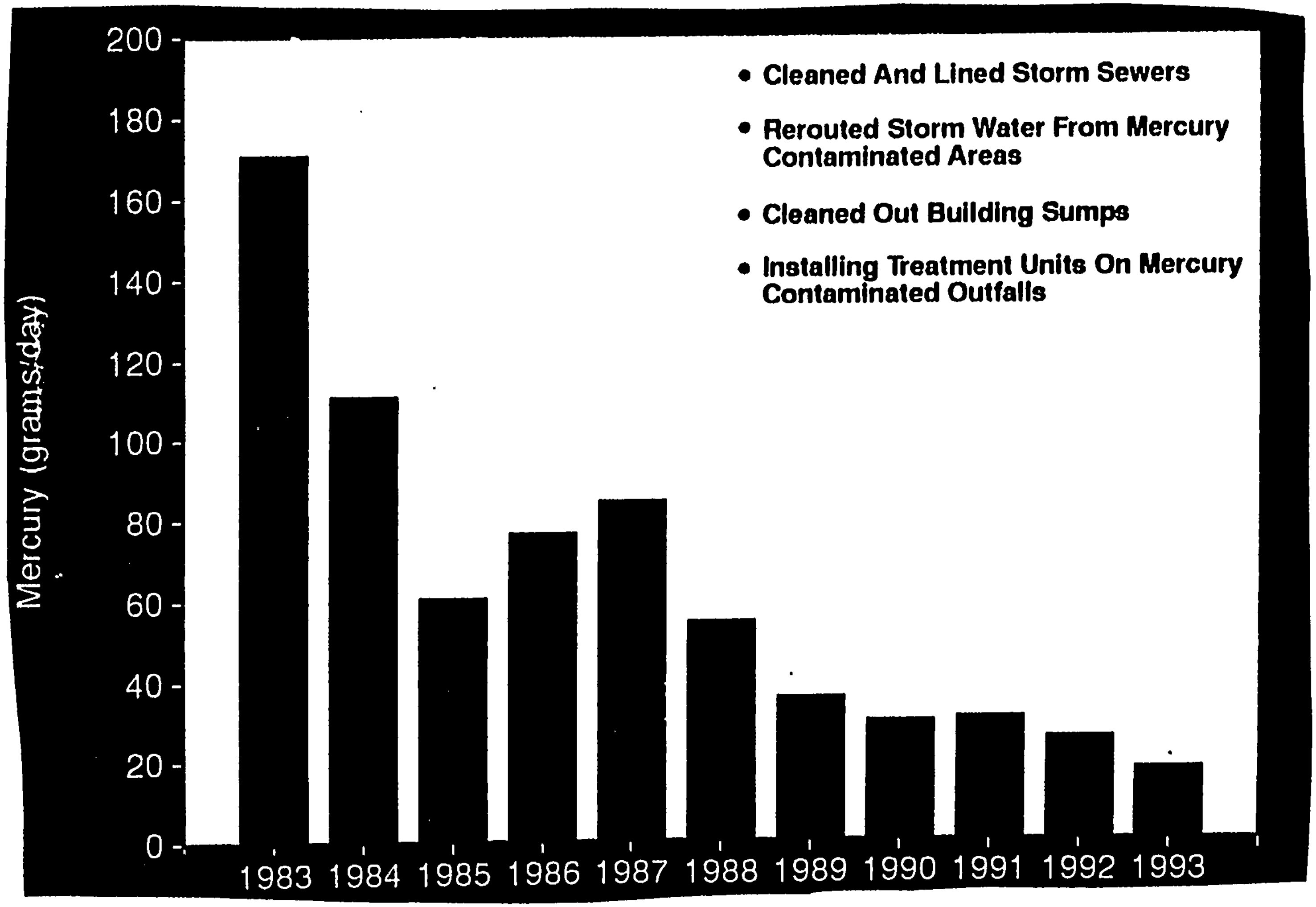

Fig. C.27. Mercury loading to East Fork Poplar Creek at the Y-12 Plant boundary.

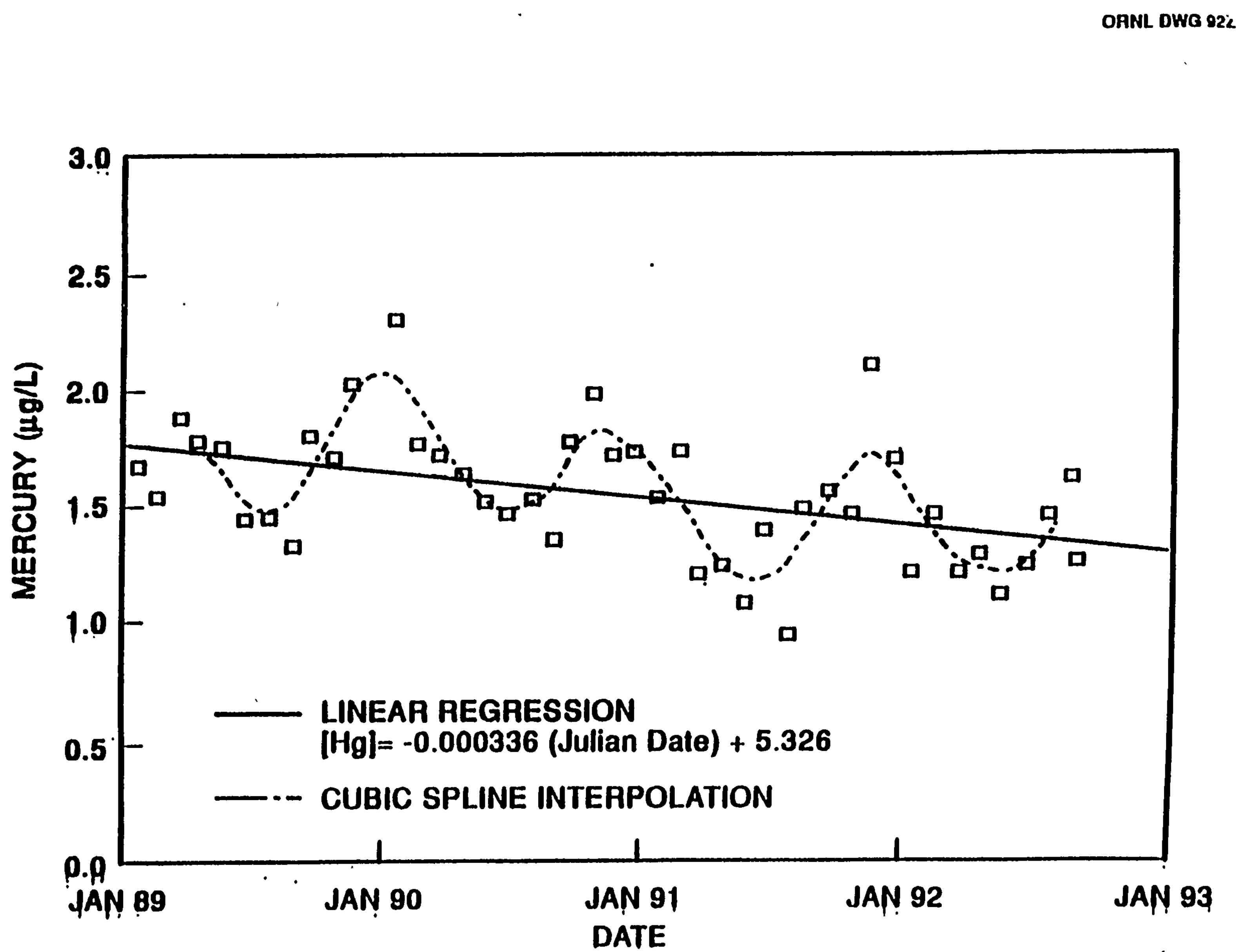

Fig. C.28. Decrease in total mercury concentration in East Fork Poplar Creek just below Lake Reality, 1989–1992.

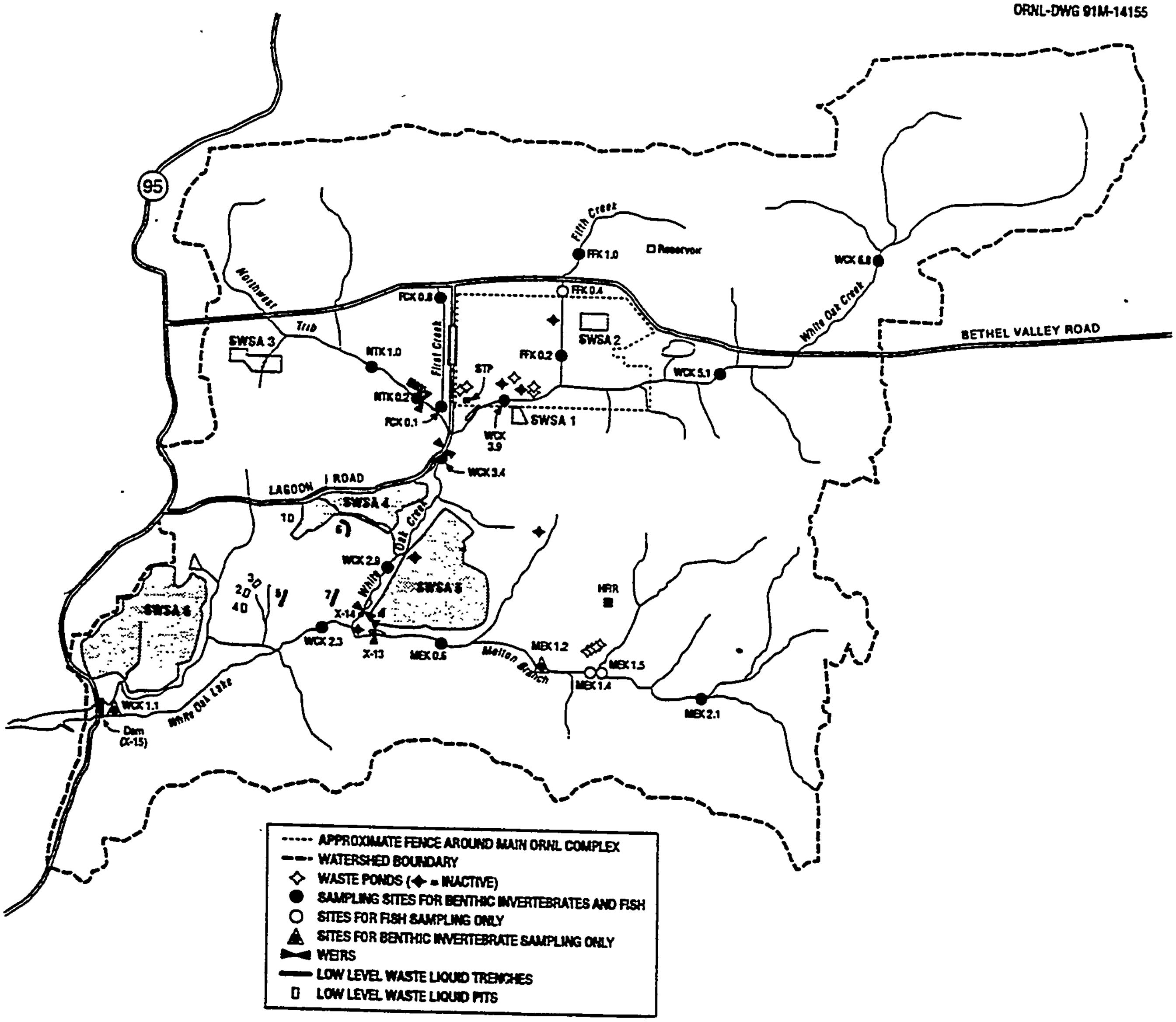

Fig. C.29. Location of biological monitoring sites and liquid and solid radioactive waste disposal areas in White Oak Creek watershed.

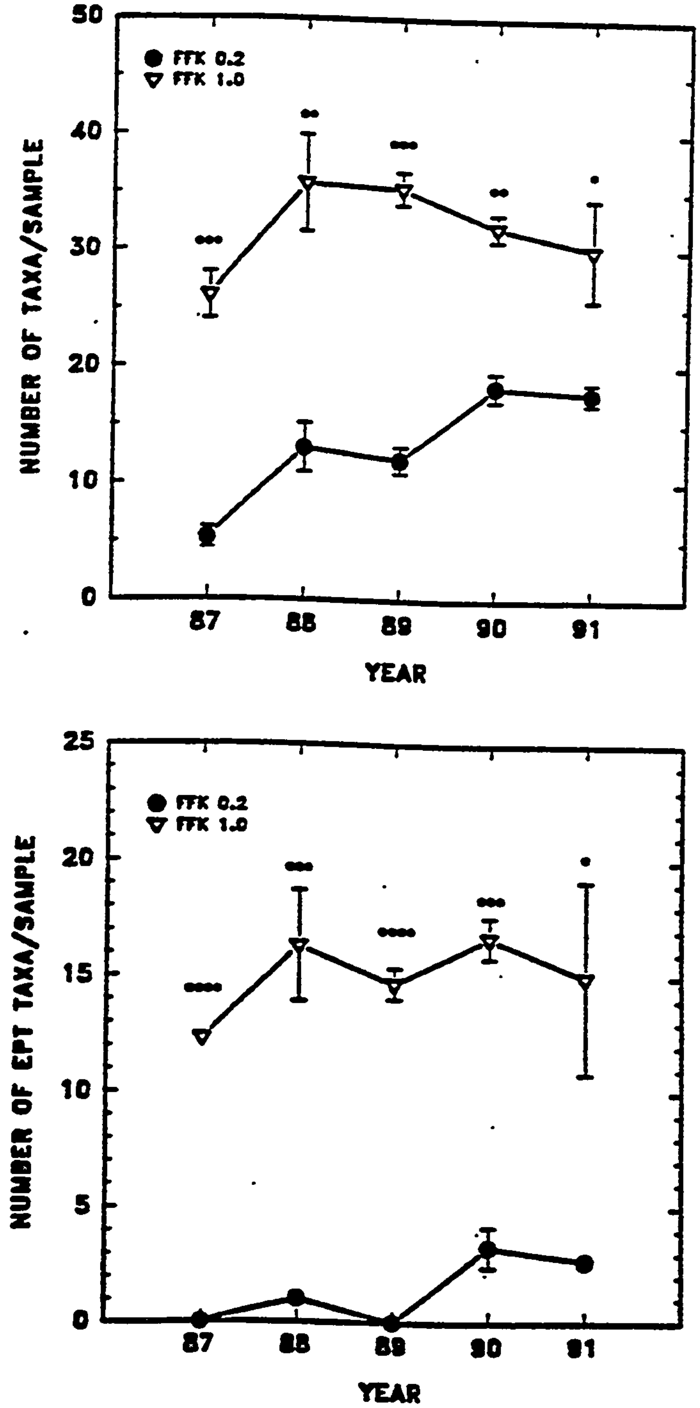

Fig. C.30. Mean total richness (number of taxa/sample) and mean EPT (Ephemeroptera, Plecoptera, and Trichoptera) richness (number of EPT taxa/sample) of the benthic macroinvertebrate community in Fifth Creek during the April sampling periods of 1987–1991. Standard error (±1 SE) of the mean for each parameter 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.

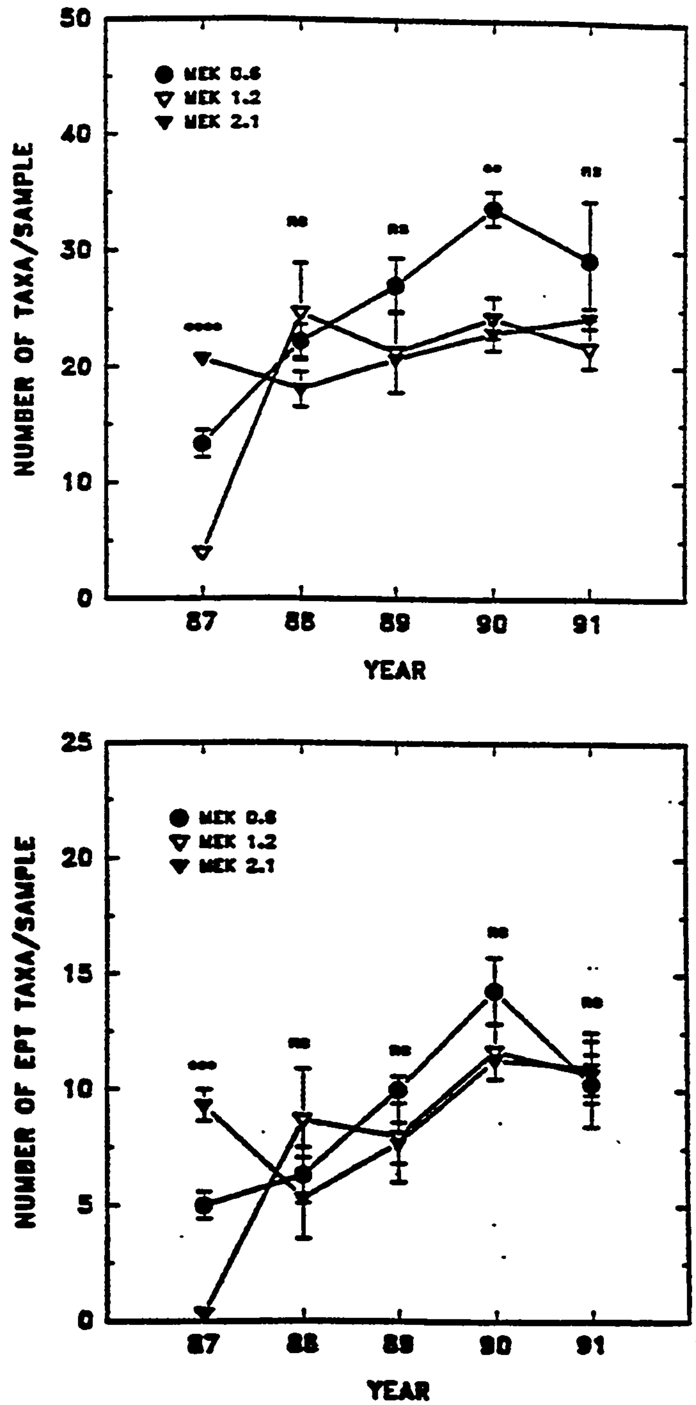

Fig. C.31. Mean total richness (number of taxa/sample) and mean EPT (Ephemeroptera, Plecoptera, and Trichoptera) richness (number of EPT taxa/sample) of the benthic macroinvertebrate community in Melton Branch during the April sampling periods of 1987–1991. Standard error (±1 SE) of the mean for each 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.

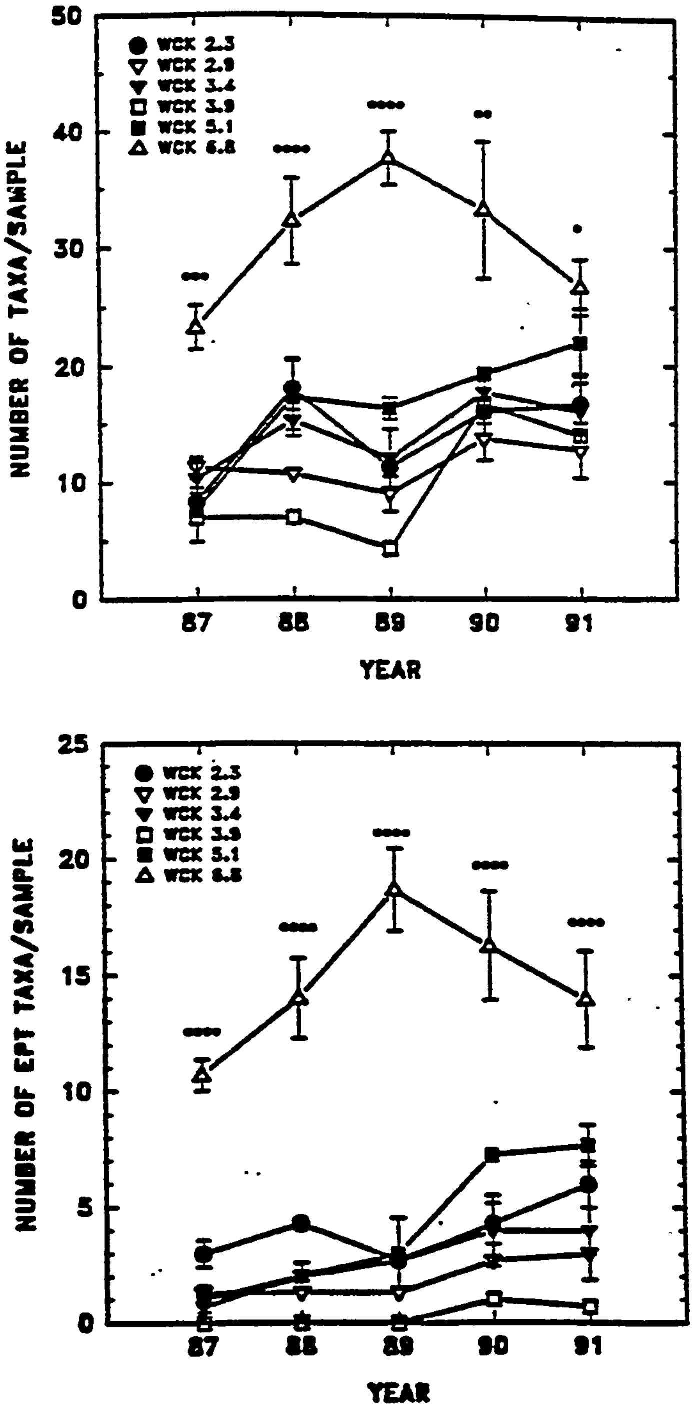

Fig. C.32. Mean total richness (number of taxa/sample) and mean EPT (Ephemeroptera, Plecoptera, and Trichoptera) richness (number of EPT taxa/sample) of the benthic macroinvertebrate community in White Oak Creek during the April sampling periods of 1987–1991. Standard error (± 1 SE) of the mean for each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

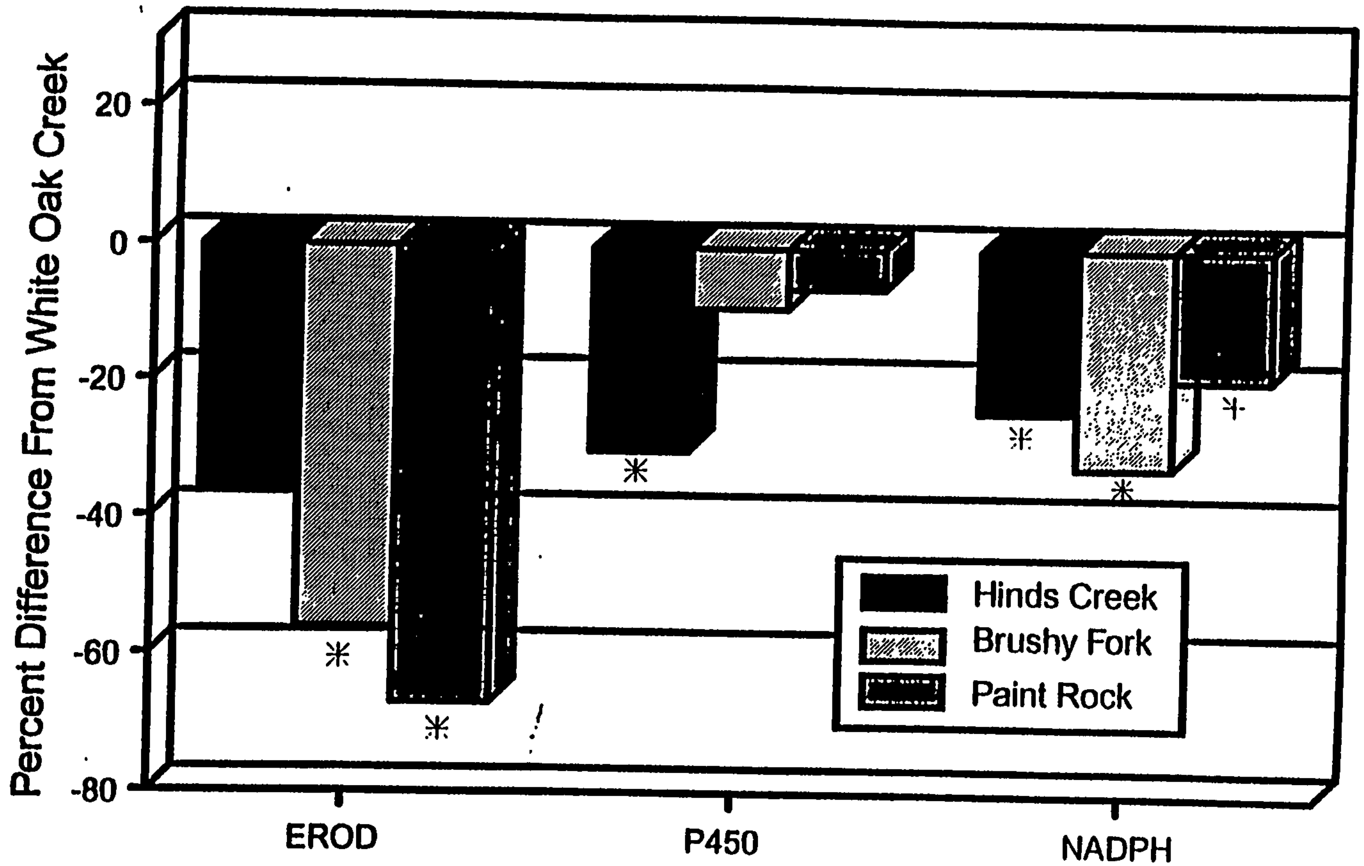

Fig. C.33. Relative differences in the mean response of three detoxification enzymes for male redbreast sunfish from each of three reference streams compared to White Oak Creek (WOC), summer 1991. Values above (or below) the zero line indicate that the response for fish from each of the reference streams 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.

ORNL-DWG-92M-14717

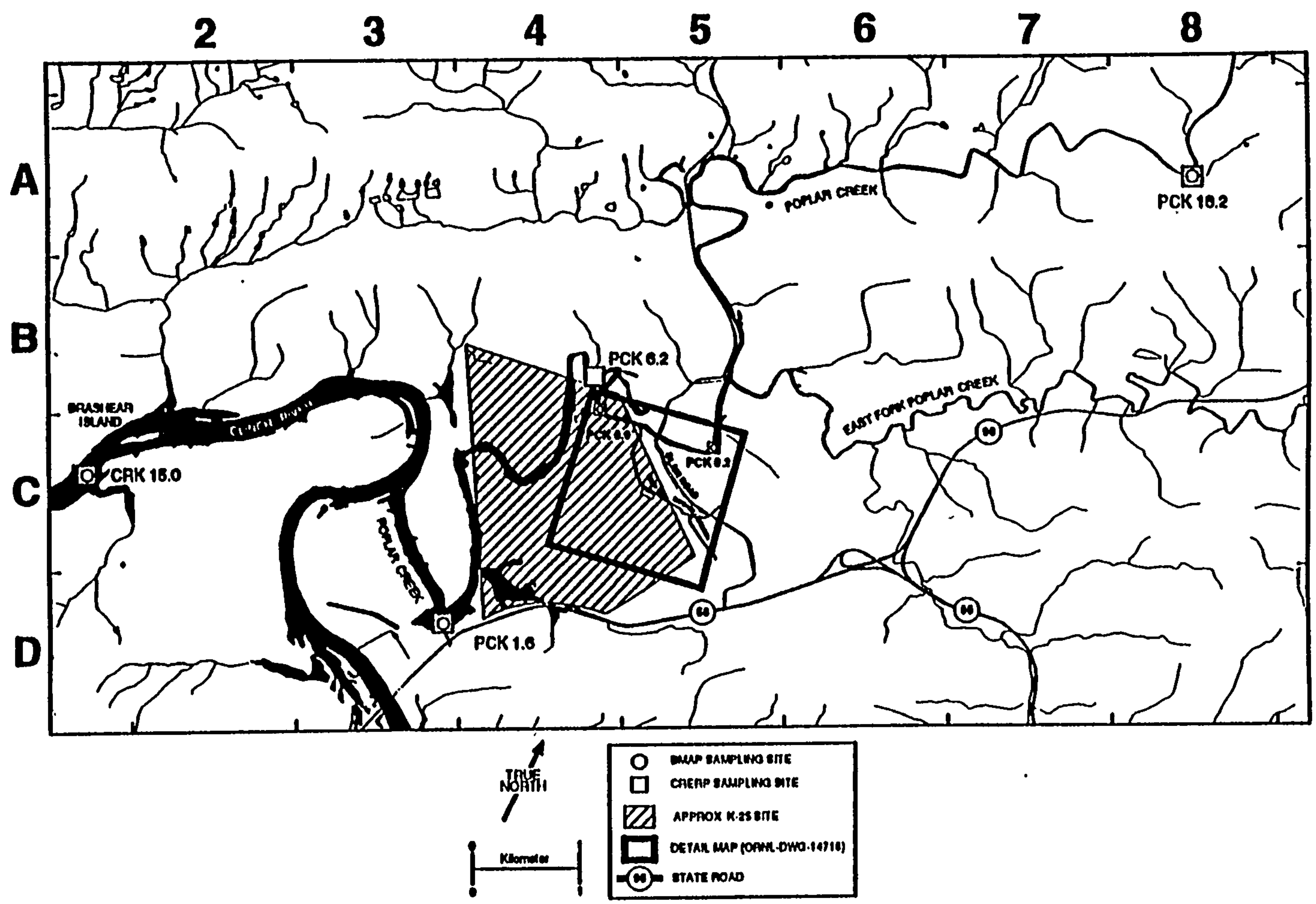

Fig. C.34. Drawing of the Oak Ridge K-25 Site area showing the location of sampling sites on Poplar Creek. The drawing of the area delineated as "detail map" is Fig. 35.

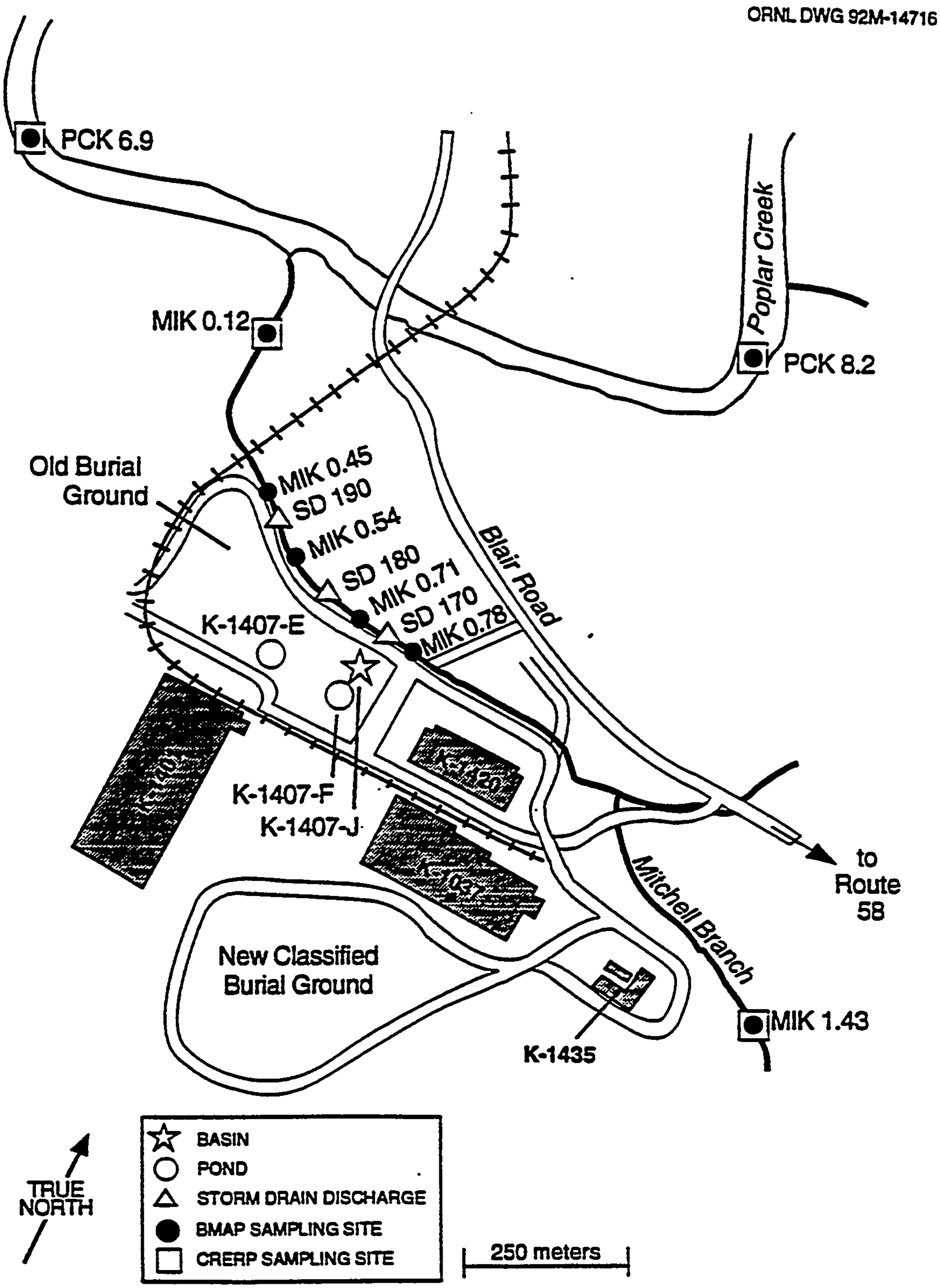

Fig. C.35. Detail drawing of the biological sampling locations on Mitchell Branch. CRERP = Clinch River Environmental Restoration Program; MIK = Mitchell Branch kilometer; = PCK = Poplar Creek kilometer.

ORNL-DWG 94M-1107

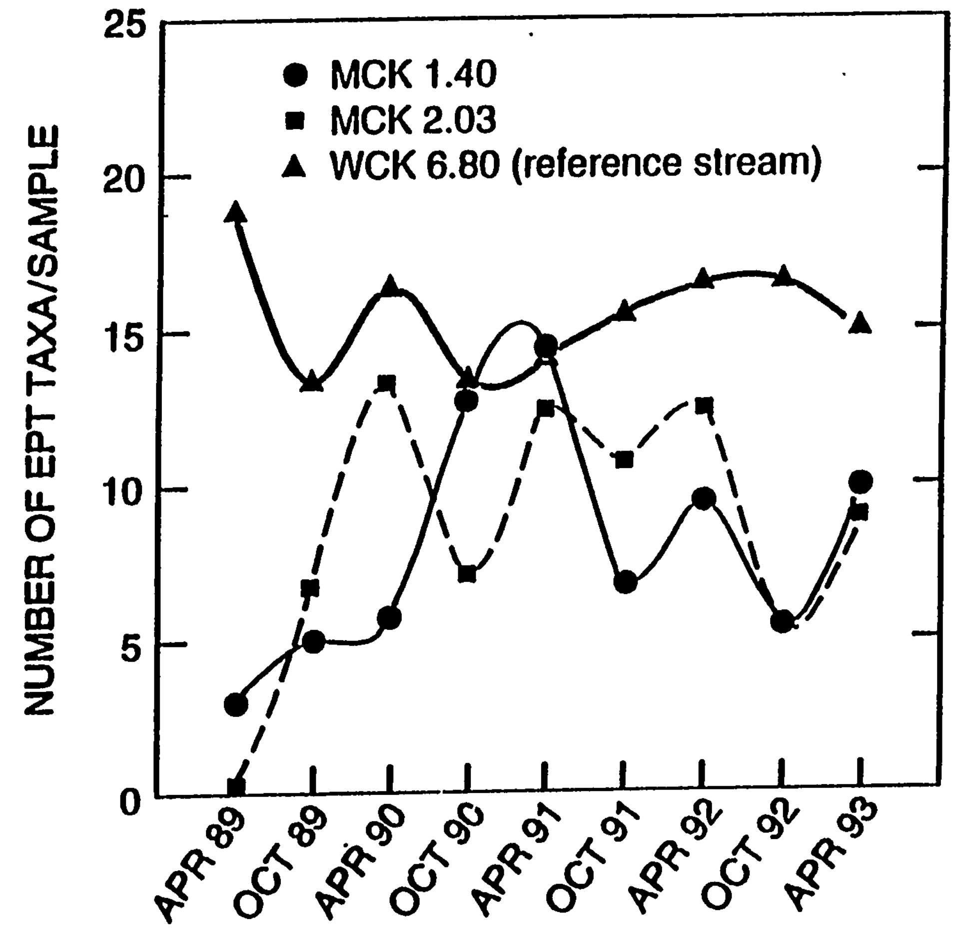

Fig. C.36. Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa in upper McCoy Branch above and below Rogers Quarry, 1989–1993. MCK = McCoy Branch kilometer, which indicates the distance above the confluence with the Clinch River (MCK 2.03 and MCK 1.40 are located above and below Rogers Quarry, respectively).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

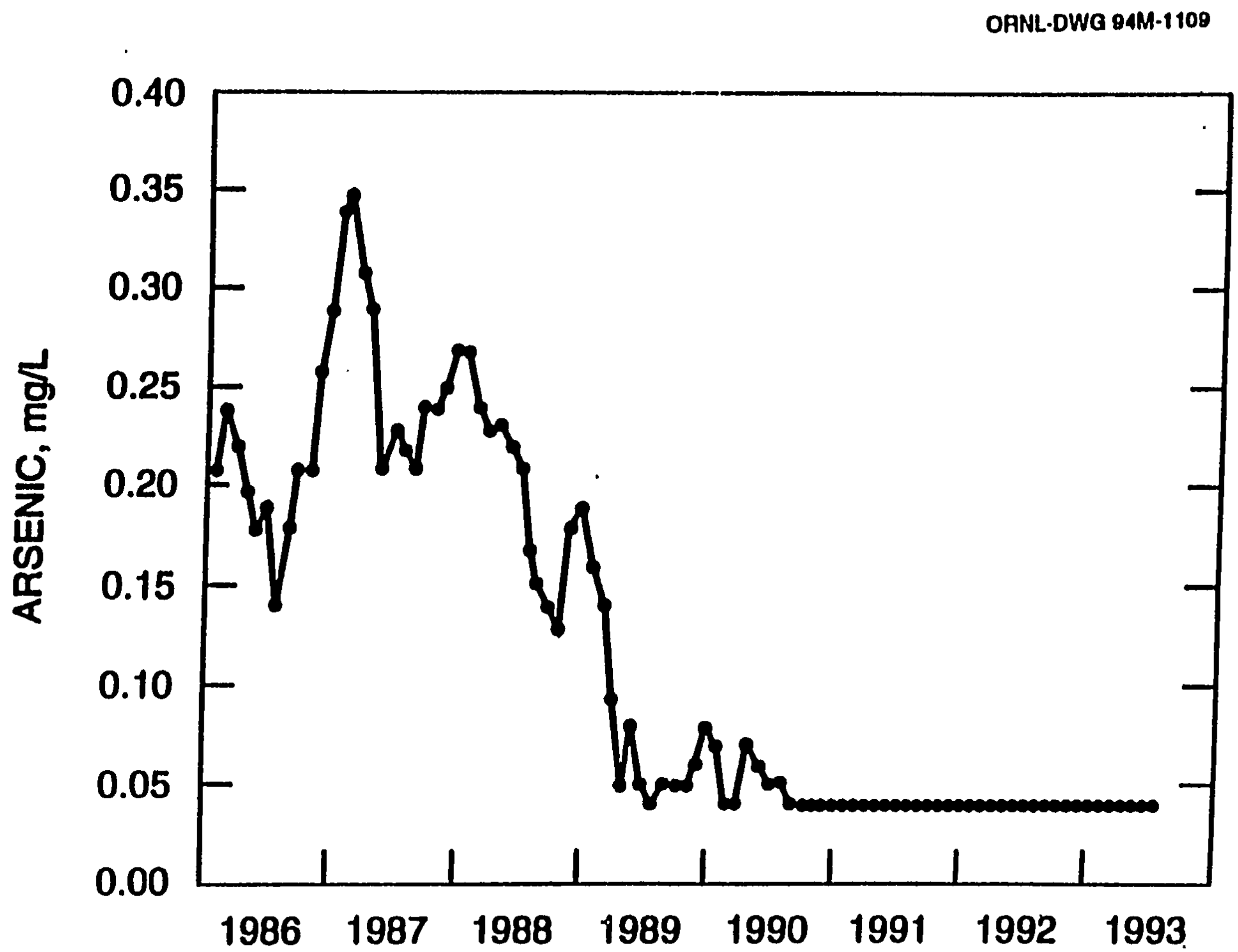

Fig. C.37. Average monthly arsenic concentrations in the outfall of Rogers Quarry, January 1986–July 1993. The EPA national ambient water quality criterion for protection of freshwater aquatic life to chronic exposure of arsenic is 0.19 mg/L.

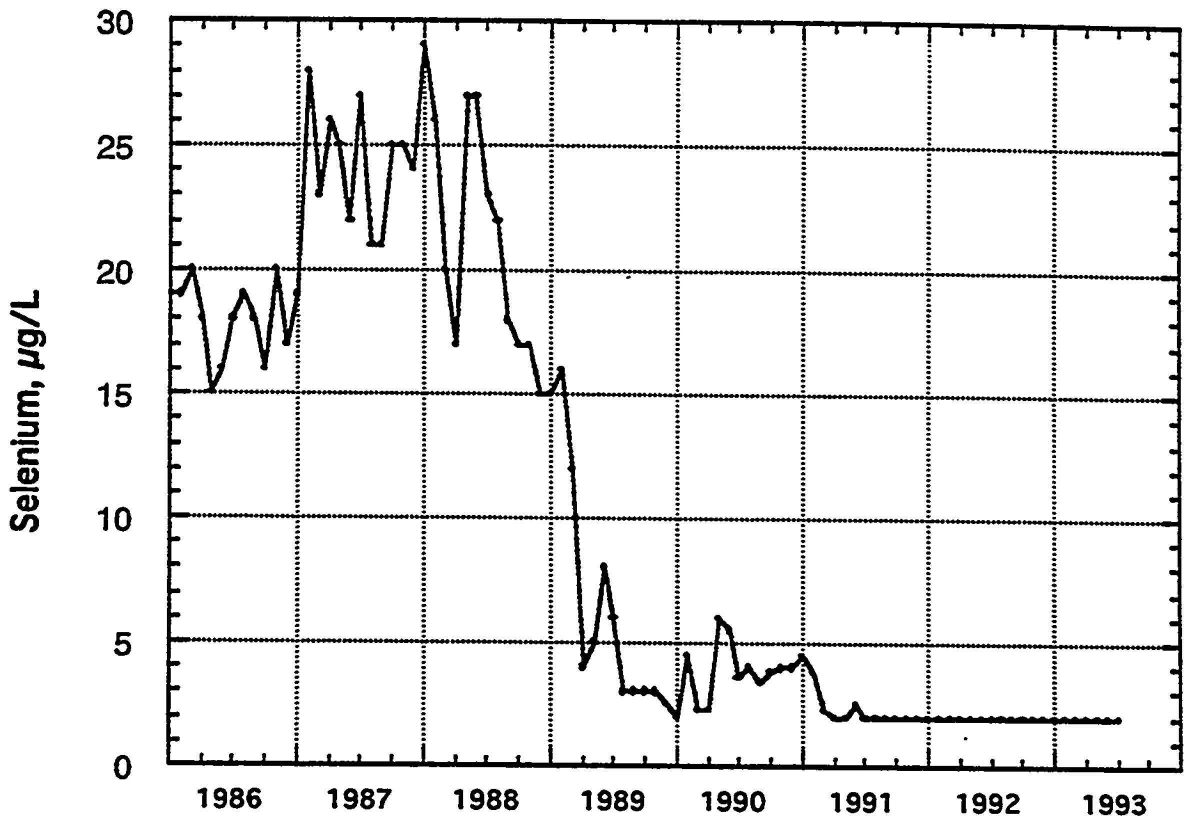

Fig. C.38. Average monthly selenium concentrations in the outfall of Rogers Quarry, January 1986–July 1993.

ORNL-DWG 92M-1762R2

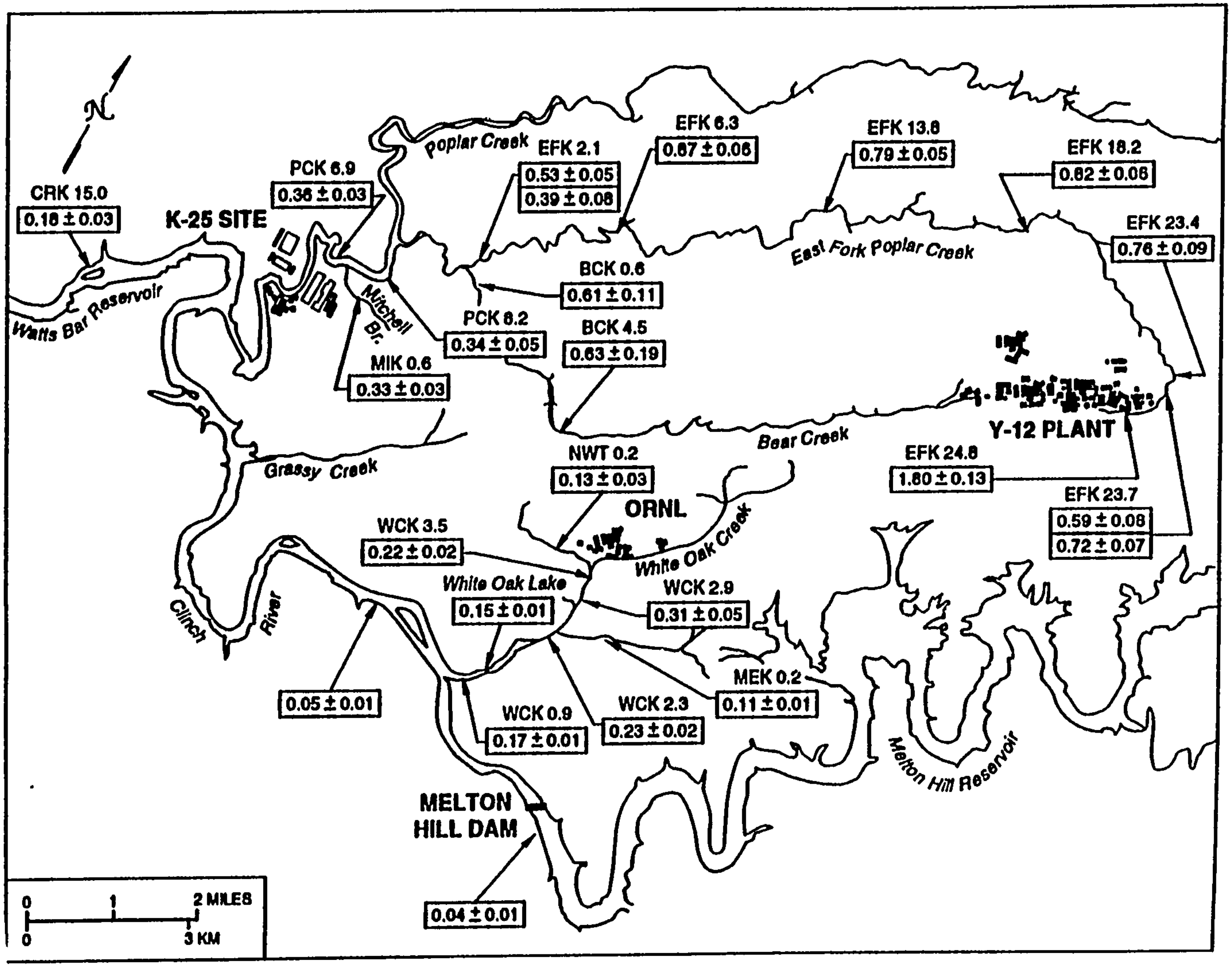

Fig. C.39. Average concentrations (± SE) of mercury (μg/g, wet weight) in sunfish collected from November 1992 through March 1993 at sites on the ORR. Fish are redbreast sunfish (*Lepomis auritus*) at MIK 0.6, EFK sites (bottom values where two appear) and WCK 2.9; rock bass (*Ambloplites rupestris*)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

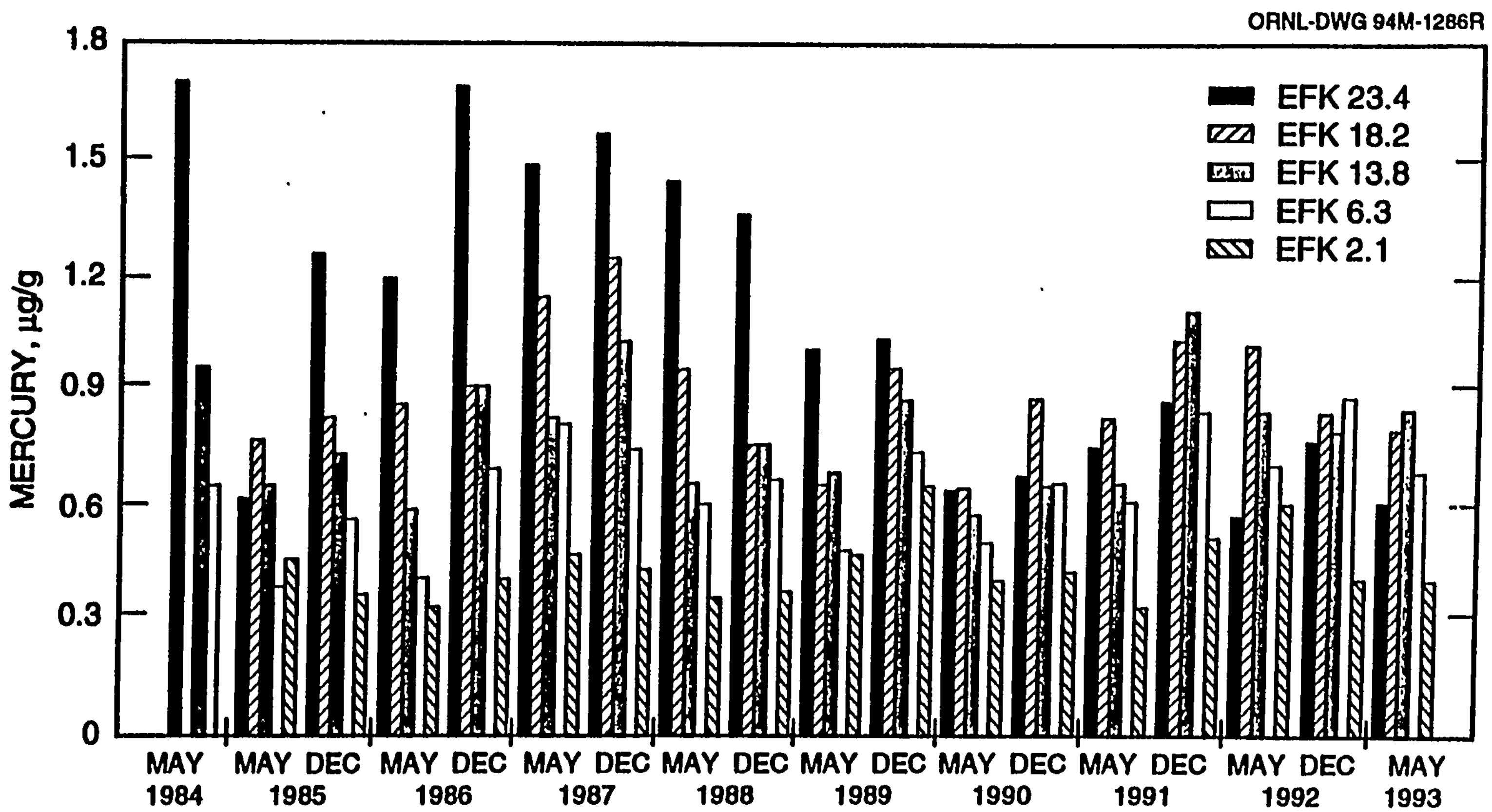

Fig. C.40. Average concentrations of mercury in redbreast sunfish (n=8) collected at sites in East Fork Poplar Creek, 1984–1993. The 1984 data are from the Oak Ridge Task Force study (TVA 1985).

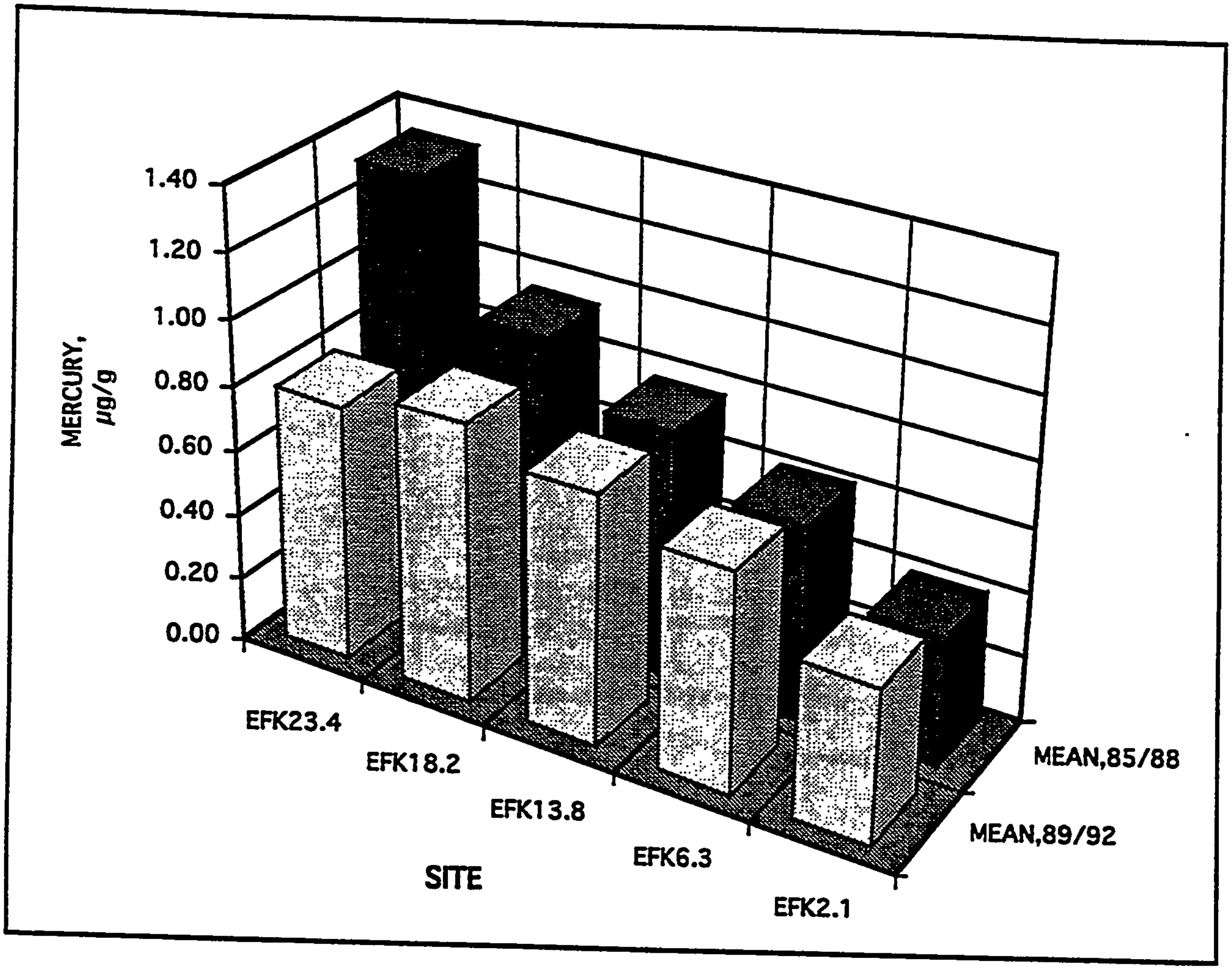

Fig. C.41. Mercury in redbreast sunfish from East Fork Poplar Creek, before and after New Hope Pond closure (November 1988).

ORNL-DWG 94M-1173

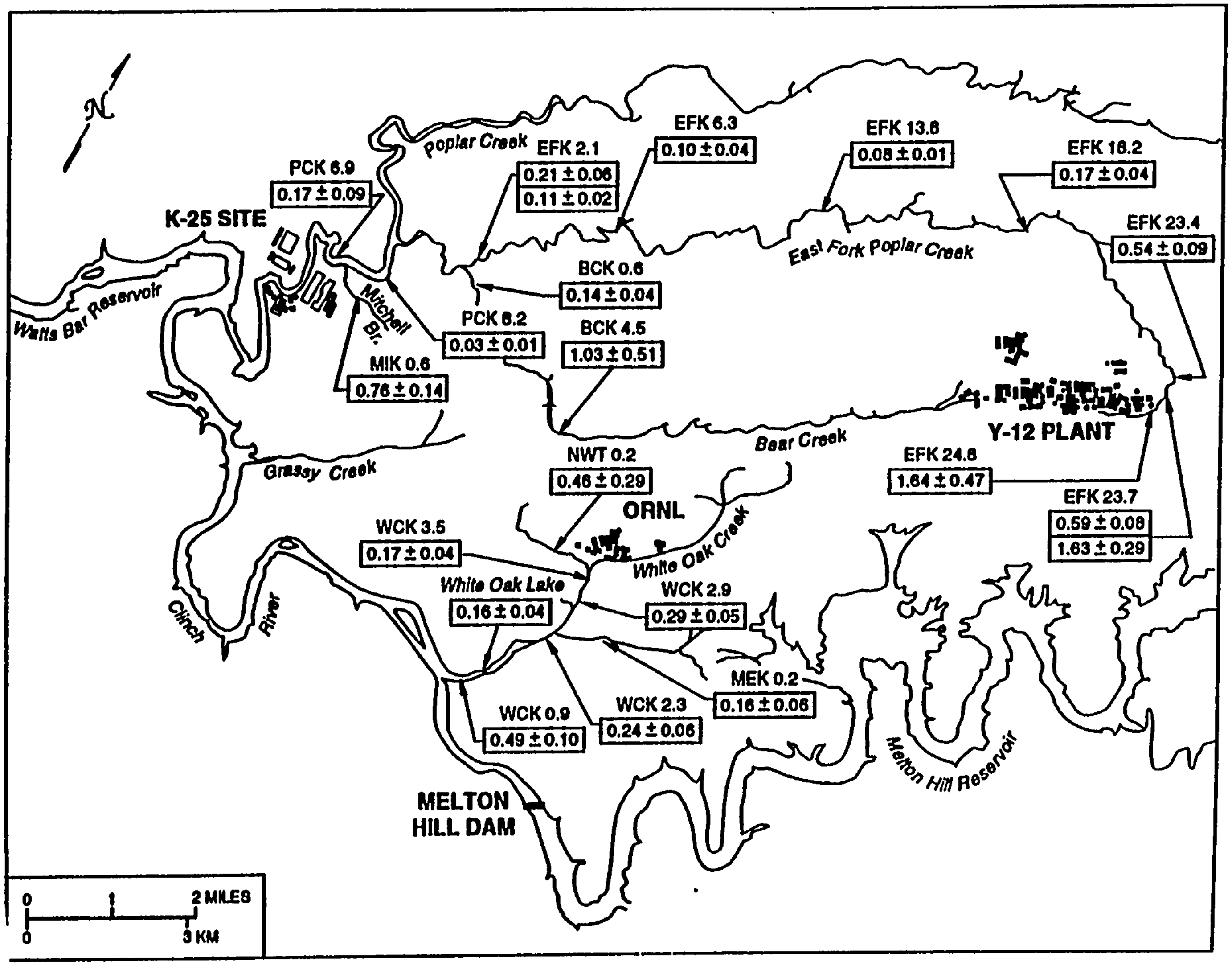

Fig. C.42. **Average concentrations (± SE) of PCBs (μg/g, wet weight) in sunfish collected from November 1992 through March 1993 at sites on the ORR.** Fish are redbreast sunfish (*Lepomis auritus*) at MIK 0.6, EFK sites (bottom values where two appear) and WCK 2.9; rock bass (*Ambloplites rupestris*)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

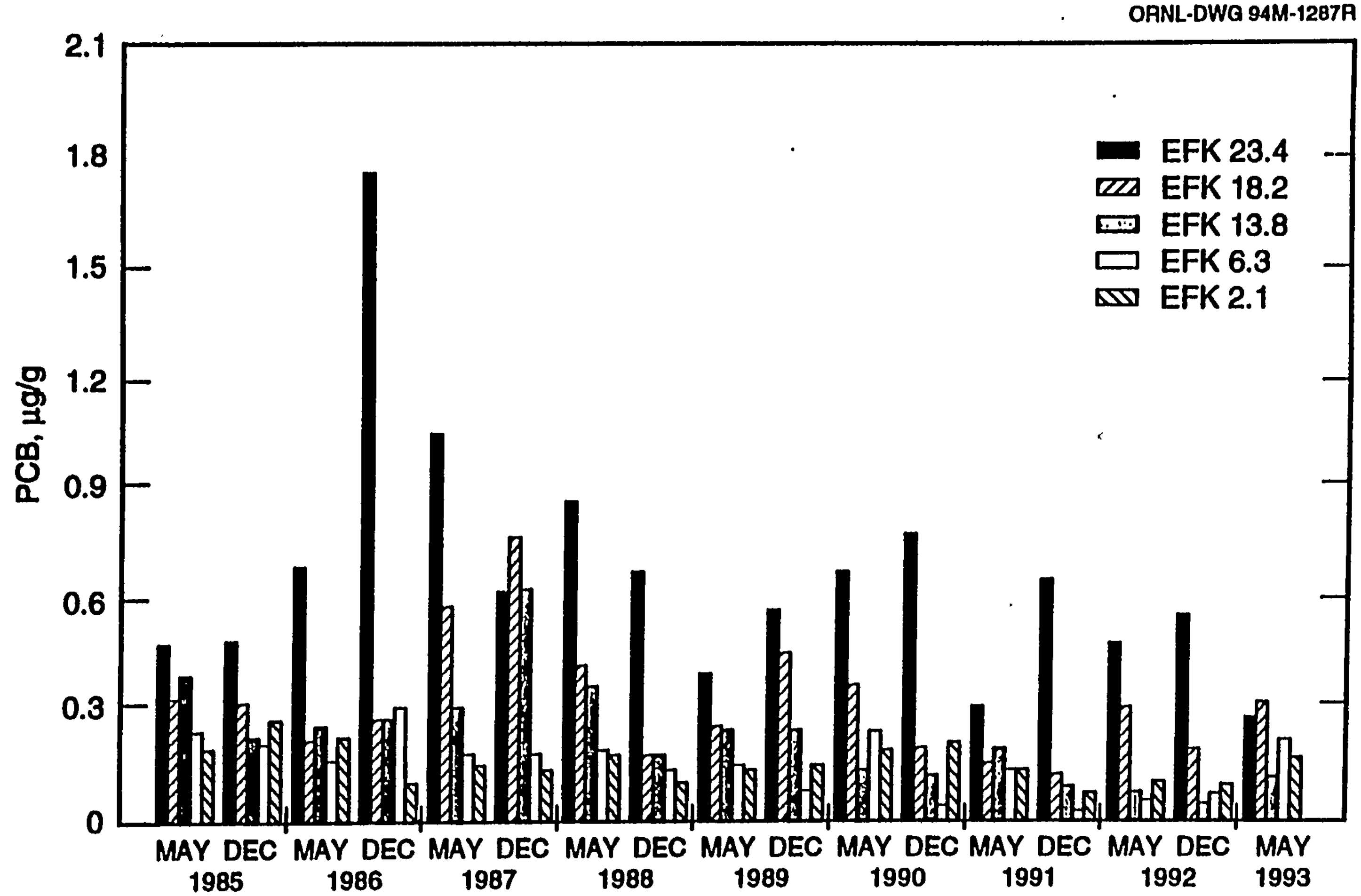

Fig. C.43. Average concentrations of PCBs in redbreast sunfish (n=8) collected at sites in East Fork Poplar Creek, 1985–1993.

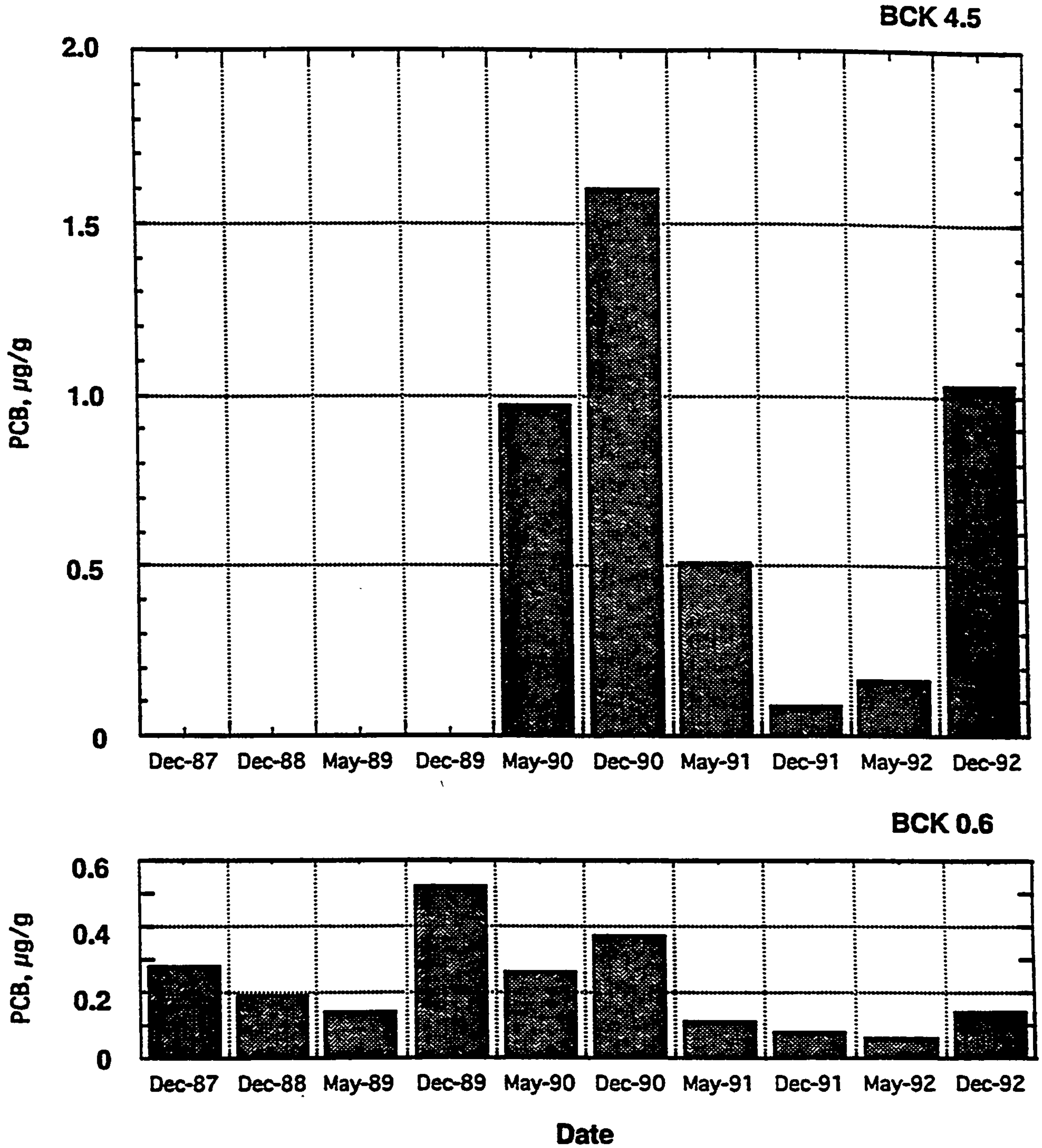

Fig. C.44. Mean PCB concentrations in rockbass from Bear Creek near the old NPDES weir (BCK 4.5) and near EFPC (BCK 0.6). Closure of oil retention ponds on NT6 and NT7 was completed in April 1990.

ORNL-DWG 94M-1156

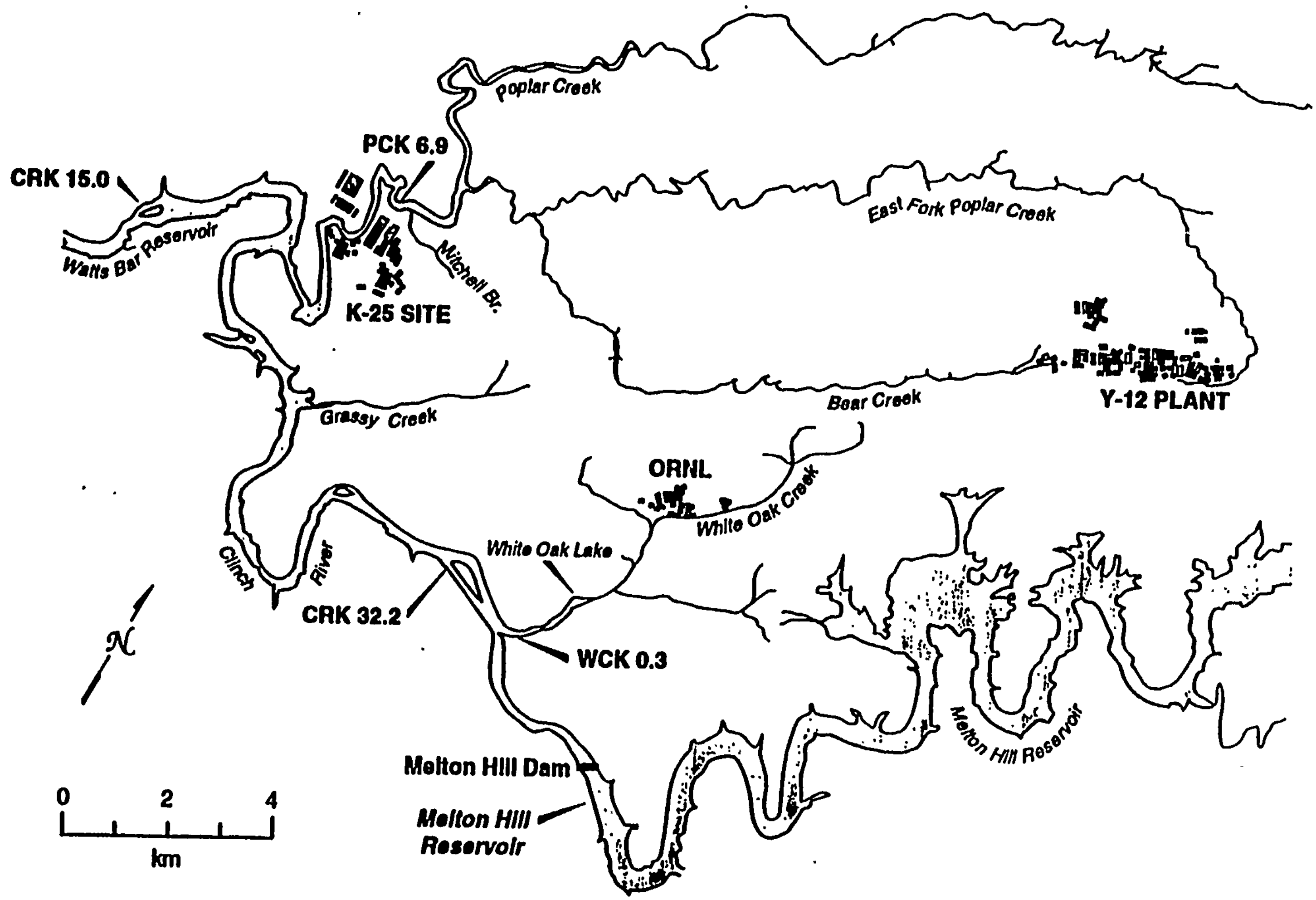

Fig. C.45. Location of sites on the ORR where channel catfish were collected for PCB analysis in August/November 1993.

Appendix D

SUMMARY OF EXISTING INFORMATION ON TERRESTRIAL ECOSYSTEMS OF THE OAK RIDGE RESERVATION

D. SUMMARY OF EXISTING INFORMATION ON TERRESTRIAL ECOSYSTEMS OF THE OAK RIDGE RESERVATION

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 tulipfera*), 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).

ORR-Wide Chemicals 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.

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 in accordance with Operating Instruction I-5 of Appendix I in the Federal Facilities Agreement. 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.

Using the methodology described above, a total of 134 contaminants were identified (Table D.1). 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 D.1)], 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.

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 will analyses for specific bioaccumulative radionuclides listed in Table D.1 be performed.

Contaminants in Terrestrial Biota

Beginning in 1960 several ecological researchers have measured contaminants in biota on the ORR. Table D.2 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 D.2 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 D.1. Evaluation of Contaminants Observed at the Oak Ridge Reservation for Determination of Reservation-wide COPECs

Contaminant	Priority[1]	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References
Inorganics (includes organic and inorganic forms)				
Aluminum	2	a ubiquitous element; While soluble Al may be toxic, toxicity of insoluble Al is low[a]. Most Al in environment is in relatively insoluble forms[b] and biologically unavailable; may become available under conditions of low pH (<4.5)[c].	NO	[a] Adriano 1986 [b] Lindsay 1979 [c] 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 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; released at Y-12	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 1992c
Copper	2	essential element; low potential for bioaccumulation	NO	ATSDR 1990b

Table D.1. (continued)

Contaminant	Priority[1]	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References
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
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 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 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

Table D.1. (continued)

Contaminant	Priority[1]	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References
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
Vanadium	1	while V consumed by animals is rapidly excreted, some plant 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
Radionuclides				
Americium (Am-241)		taken up by both plants and animals	YES	Garton 1981
Cesium (Cs-137)		Cs-173 accumulates in biota and may be transferred up food chains	YES	Straney et al. 1975 Kalas et al. 1994
Curium (Cm-244)		taken up by both plants and animals	YES	Garton 1981

Table D.1. (continued)

Contaminant	Priority[1]	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References
Cobalt (Co-60)	3	may be mobile in soils; may bioaccumulate	YES	ATSDR 1992e
Plutonium (Pu-239)		taken up by both plants and animals	YES	Garton 1981
Strontium (Sr-90, Sr-91)	3	Sr (including radiostrontium) is taken up by plants and accumulates in bones	YES	NAS 1980
Technetium (Tc-99)		taken up by plants	YES	Garton et al. 1986
Uranium (U-233, U-234, U-238)	2	bioaccumulation low due to low assimilation efficiency, released by all facilities on reservation	YES	ATSDR 1990j
Volatile Organics				
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			
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	Verschueren 1983

Table D.1. (continued)

Contaminant	Priority[1]	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References
Dichlorodifluoromethane	2	highly volatile; low toxicity	NO	Verschueren 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	Verschueren 1983
Ethyl benzene	3	highly volatile; low potential for bioaccumulation	NO	ATSDR 1990f
Ethyl dimethyl benzene	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 Tanner 1989
Methyl propenyl benzene	4			
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 PAH's, may bioaccumulate and are addressed separately	NO	ATSDR 1993j
Hexane	4	highly volatile; rapid photo-degradation	NO	Verschueren 1983

Table D.1. (continued)

Contaminant	Priority[1]	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References
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
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
Semi-volatile Organics				

Table D.1. (continued)

Contaminant	Priority[1]	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References
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, may bioaccumulate	YES	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	4	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
Ethylene glycol		does not bioaccumulate; rapidly biodegraded	NO	ATSDR 1993k

Table D.1. (continued)

Contaminant	Priority[1]	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References
Freon-113	4	highly volatile; low toxicity	NO	Sax and Lewis 1987
Freon-123	4	highly volatile	NO	HSDB 1994c
2,5-Hexanedione	3			
1-Methylpentyl Hydroperoxide	4			
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
Polycyclic Aromatic Hydrocarbons		Associated with coal, asphalt, heavy oils, etc.		

Table D.1. (continued)

Contaminant	Priority[1]	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References
Acenaphelene	4	both lipophilic and persistent	YES	Eisler 1987b
Anthracene	2	both lipophilic and persistent	YES	Eisler 1987b
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
Dimethyl naphthalene	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	highly volatile; bioaccumulates but is rapidly metabolized and excreted; rapidly degraded in both soil and water	NO	ATSDR 1990g
Phenanthrene	2	both lipophilic and persistent	YES	Eisler 1987b
Pyrene	2	both lipophilic and persistent	YES	Eisler 1987b

Table D.1. (continued)

Contaminant	Priority[1]	Factors Considered in Evaluation (Presence, Volatility, Persistence, Lipophilicity, Bioaccumulation, etc.)	Retained	References
PCB's, Pesticides (and metabolites), and Related Compounds				
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	
Dioxins, Chlorinated Dibenzofurans		persistent, and bioaccumulate	YES[2]	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

[1] 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;

Table D.1. (continued)

[2] 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.

[a] Boldface type indicates contaminants selected for further evaluation as contaminants of potential ecological concern (COPECs).

Table D.2. Contaminants in terrestrial biota on the Oak Ridge Reservation

Common Name	Trophic Position[a]	Sample Location[b]	Date(s)	Analyte	Tissue	Value[c]	Units	Reference
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)
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 µ	g/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)

Table D.2. (continued)

Common Name	Trophic Position[a]	Sample Location[b]	Date(s)	Analyte	Tissue	Value[c]	Units	Reference
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)
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)

Table D.2. (continued)

Common Name	Trophic Position[a]	Sample Location[b]	Date(s)	Analyte	Tissue	Value[c]	Units	Reference
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)

Table D.2. (continued)

Common Name	Trophic Position[a]	Sample Location[b]	Date(s)	Analyte	Tissue	Value[c]	Units	Reference
Raccoon	LO3	EFPC	1991-93	^{137}Cs	Hair	0.3	pCi/g	Ashwood et al. (1993)
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)

Table D.2. (continued)

Common Name	Trophic Position[a]	Sample Location[b]	Date(s)	Analyte	Tissue	Value[c]	Units	Reference
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)
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)

Table D.2. (continued)

Common Name	Trophic Position[a]	Sample Location[b]	Date(s)	Analyte	Tissue	Value[c]	Units	Reference
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)
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)

Table D.2. (continued)

Common Name	Trophic Position[a]	Sample Location[b]	Date(s)	Analyte	Tissue	Value[c]	Units	Reference
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-SchöneandWalton(1994b,c)
Pond Slider	AqH3	Bearden Cr.	1988	^{60}Co	Muscle	<0.1	pCi/g	Meyers-SchöneandWalton(1994b,c)
Pond Slider	AqH3	WOL	1988	^{137}Cs	Muscle	13,554.	pCi/g	Meyers-SchöneandWalton(1994b,c)
Pond Slider	AqH3	Bearden Cr.	1988	^{137}Cs	Muscle	0.4	pCi/g	Meyers-SchöneandWalton(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-SchöneandWalton(1994b,c)
Pond Slider	AqH3	Bearden Cr.	1988	^{90}Sr	Shell	31.9	pCi/g	Meyers-SchöneandWalton(1994b,c)
Snapping Turtle	LC1	WOL	1988	^{60}Co	Muscle	<0.1	pCi/g	Meyers-SchöneandWalton(1994b,c)
Snapping Turtle	LC1	Bearden Cr.	1988	^{60}Co	Muscle	<0.1	pCi/g	Meyers-SchöneandWalton(1994b,c)
Snapping Turtle	LC1	WOL	1988	^{137}Cs	Muscle	37.0	pCi/g	Meyers-SchöneandWalton(1994b,c)
Snapping Turtle	LC1	Bearden Cr.	1988	^{137}Cs	Muscle	<0.1	pCi/g	Meyers-SchöneandWalton(1994b,c)
Snapping Turtle	LC1	WOL	1988	Hg	Kidney	1.1	µg/g	Meyers-Schöne and Walton (1994b,c)
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	18,532*	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)

Table D.2. (continued)

Common Name	Trophic Position[a]	Sample Location[b]	Date(s)	Analyte	Tissue	Value[c]	Units	Reference
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)
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)

Table D.2. (continued)

NOTES

[a] 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.

[b] 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.

c 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.

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