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Preliminary Assessment of the Ecological Risks to Wide-ranging Wildlife Species on the Oak Ridge Reservation

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LOCKHEED MARTIN ENERGY SYSTEMS, INC.
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PREFACE

This report, *Preliminary Assessment of the Ecological Risks to Wide-ranging Wildlife Species on the Oak Ridge Reservation: 1996 Update,* DOE/OR/01-1407&D2, was prepared as a technical report documenting work performed under the Oak Ridge Reservation Ecological Assessment Program. This work was performed under work breakdown structure 1.4.12.2.3.4 (activity data sheet 8304, "Technical Integration"). Publication of this document meets an activity data sheet milestone of September 13, 1996. This document provides the Environmental Restoration Program with a preliminary evaluation of the ecological risks that contaminants on the Oak Ridge Reservation present to selected wide-ranging species. These results will aid in the understanding of the magnitude of ecological risks to populations at larger spatial scales and will assist in the prioritization of source operable units for investigation and remediation.

CONTENTS

FIGURES

TABLES

ACRONYMS

BEIDMS	Bechtel Environmental Information Data Management System
BCK	Bear Creek kilometer
BC	Bear Creek
BCV	Bear Creek Valley
BMAP	Biological Monitoring and Abatement Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPECs	Chemicals of Potential Ecological Concern
CR	Chestnut Ridge
DOE	U. S. Department of Energy
EFPC	East Fork Poplar Creek
EFK	East Fork kilometer
EMAP	Ecological Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
ESD	Environmental Sciences Division
ER	Environmental Restoration
EROD	ethoxyresorufin-o-deethylase
FCAP	Filled Coal Ash Pond
FFA	Federal Facilities Agreement
GIS	geographic information system
HQ	hazard quotient
MEK	Melton Branch Kilometer
MIK	Mitchell Branch Kilometer
NOAEL	no observed adverse effects level
NTK	Northwest Tributary Kilometer
LEFPC	Lower East Fork Poplar Creek
LOAEL	Lowest Observed Adverse Effects Level
OREIS	Oak Ridge Environmental Information System
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OU	operable unit
PLE	product limit estimator
RI	remedial investigation
SAIC	Science Applications International Corporation
SCF	South Campus Facility
STD	Standard Deviation
T&E	Threatened or Endangered
TWRA	Tennessee Wildlife Resources Agency
UEFPC	Upper East Fork Poplar Creek
UCL	upper confidence limit
WAG	Waste Area Grouping
WCK	White Oak Creek kilometer
WOC	White Oak Creek
WOL	White Oak Lake

ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

Historically, ecological risk assessment at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites [such as the Oak Ridge Reservation (ORR)] has focused on species that may be definitively associated with a contaminated area or source operable unit. This is necessary to identify areas where risk is sufficiently high to warrant remediation. Consequently the species that are generally considered are those with home ranges small enough such that multiple individuals or a distinct population can be expected to reside within the boundaries of the contaminated site. This approach is adequate for sites with single, discrete areas of contamination that only provide habitat for species with limited spatial (i.e., small home range) requirements. This approach is not adequate however for large sites with multiple, spatially separated contaminated areas that provide habitat for wide-ranging wildlife species. Because wide-ranging wildlife species may travel between and use multiple contaminated sites, they may be exposed to and be at risk from contaminants from multiple locations. Use (and therefore exposure and risk) of a particular contaminated site by wide-ranging species will be dependant upon the amount of suitable habitat available at that site. Therefore to adequately evaluate risks to wide-ranging species at the ORR-wide scale, the use of multiple contaminated sites must be weighted by the amount of suitable habitat on operable units (OUs). Highly contaminated OUs that provide little habitat are unlikely to be significant contributors to ORR-scale contaminant-associated risk. Conversely, moderately contaminated sites that contain considerable habitat may significantly contribute to ORR-scale contaminant-associated risk.

In spring of 1994, a series of meetings were held among the Federal Facilities Agreement parties to develop an approach and plan for assessing risks to wide-ranging species that could not be adequately addressed at the source OU level. The results of these discussions are presented in the ORR ecological risk assessment strategy document (Suter et al. 1994a). This report is based on this document and presents the preliminary assessment of ecological risks to wide-ranging species from contaminants on the ORR.

The reservation-wide ecological risk assessment is intended to serve several purposes, including identifying (1) which endpoints are significantly at risk, (2) which contaminants are responsible for this risk, and (3) which OUs significantly contribute to risk. To address these issues, this report contains the following information:

- an evaluation of the potential use of OUs by 57 endpoint species identified in Suter et al. (1994a),
- a preliminary ranking of OUs according to those that may present the greatest ecological risk,
- a preliminary assessment of risks to selected piscivorous wildlife (i.e., mink, river otter, belted kingfisher, great blue heron, osprey),
- a preliminary assessment of risks to selected vermivorous, herbivorous, and predatory wildlife (i.e., American woodcock, short-tailed shrew, white-tailed deer, wild turkey, red fox, red-tailed hawk), and
- a proposed revision schedule.

Data used in this preliminary assessment included a reservation-wide land use/land cover classification (Washington-Allen et al. 1995), reservation-wide fish bioaccumulation data from the Biological Monitoring Programs, and soil contamination data for 12 of 37 OUs. These data were derived from ORR computer databases (the Oak Ridge Environmental Information System and the Bechtel Environmental Information Data Management System).

Potential use of OUs by the endpoint species listed in Suter et al. (1994a) was estimated by comparing habitat requirements for the endpoint species (obtained from the literature) to the nine landcover types identified in Washington-Allen et al. (1995). An OU was considered to provide habitat for an endpoint species if at least one of the habitat types required by the species was present on the OU. OUs were ranked by the number of species for which they could potentially provide habitat, and endpoint species were ranked by the number of OUs on which suitable habitat was available. Conclusions of this evaluation include the following: (1) The largest OUs on the ORR generally have the most diverse habitat and consequently can support the greatest number of potential endpoint species; and (2) Species that can use urban habitats or that have broad habitat requirements have the highest potential to experience exposure as a result of the large numbers of OUs that provide suitable habitat.

Risks to piscivorous wildlife were assessed by using contaminant concentrations in fish from four watersheds on the ORR [i.e., Bear Creek, East Fork Poplar Creek, the K-25 vicinity, White Oak Creek (including White Oak Lake)]. Additional data used in this assessment included toxicity tests performed on mink and field surveys of mink, great blue heron, belted kingfisher, and osprey. Monte Carlo simulations of contaminant exposure estimates were calculated for each species by watershed. The resulting exposure distributions were then combined with literature-derived population density data for each endpoint species to estimate the number of individuals of each species likely to experience adverse effects within each watershed. These numbers were then summed for the reservation as a whole to estimate the proportion of the ORR population potentially at risk. By combining the multiple lines of evidence available to assess risks to piscivores, the following conclusions may be made:

- Mercury presents a hazard to mink in East Fork Poplar Creek and consequently to a significant portion (30%) of the ORR-wide mink population. Risks to mink from PCBs are not significant (Chap. 4).

- Evaluation of the potential risks to a future ORR-wide population of otter indicates that mercury presents a risk in all watersheds on the ORR. Because the river otter is a state threatened species, effects to any individual are significant. Therefore the weight of evidence suggests that mercury is a significant risk to individual river otter that may occupy the ORR in the future (Chap. 4)

- Comparison of exposure estimates to lowest observed adverse effects level (LOAELs) indicates a significant risk from mercury in all watersheds except White Oak Creek. This translates into a risk to 81.5% of the ORR-wide kingfisher population. The limited biomonitoring data indicate that kingfisher on the ORR (particularly in the White Oak Creek area) are accumulating mercury to potentially nephrotoxicty levels. The weight of evidence suggests mercury in all watersheds presents a significant risk to the ORR-wide belted kingfisher population. Risks from PCBs are not significant (Chap. 4).

- Although mercury in fish is estimated to represent a significant risk to great blue heron within the East Fork Poplar Creek watershed and, consequently, to an estimated 37% of the heron population on the ORR, studies on two of five colonies adjacent to the ORR (i.e., <10 km from the ORR) indicate that reproduction at these locations is not impaired. Contaminant bioaccumulation and reproductive success are unknown at the three additional colonies adjacent to the ORR. Additionally, the primary foraging locations for herons at the two studied colonies are unknown. Because herons can travel long distances in search of food (>15 km), they are likely to forage at off-site as well as on-site locations, reducing both the exposure they receive and the risk they experience. If birds from the unstudied colonies forage more extensively on the ORR, they may experience greater risk. Because of the high risk estimated for mercury exposure on the ORR, the lack of data for three of five heron colonies adjacent to the ORR, and uncertainty as to where birds from the five ORR colonies forage, a conclusion concerning whether or not great blue heron on the ORR are at risk cannot be made.

- Comparison of exposure estimates to LOAELs for osprey indicates no significant risk from mercury or PCBs in any area on the ORR that provides suitable habitat (i.e., White Oak Lake and embayment, the K-25 area). Biomonitoring data indicates that the reproductive success at osprey nests adjacent to the ORR, along Melton Hill Lake and in Poplar Creek, is greater than the average observed in the United States. The weight of evidence suggests that mercury and PCB do not present significant risks to osprey on or near the ORR.

On the ORR, although most wide-ranging wildlife species reside primarily in the uncontaminated terrestrial habitats outside of source OUs, they may also use those source OUs on which suitable habitat is present. The degree to which a source OU is used (and therefore the risk that it may present) is dependant upon the availability of suitable habitat on the OU. OUs with little or no habitat will experience little use (and will present minimal risk), whereas those with considerable habitat are likely to experience considerable use (and depending upon the degree of contamination, may present significant risks). Although *individuals* may experience adverse effects through exposures received at source OUs, the primary concern for ecological risk assessment is for effects at the population-level To evaluate effects to the ORR-wide wildlife populations, habitat suitability and population density on the ORR and within OUs must be considered. A general, six-step, habitat-based approach was developed that is applicable to all wildlife species on the ORR. The approach is outlined below:

1. Individual-based contaminant exposure estimates are generated for each OU by using the generalized exposure model outlined in Sample and Suter (1994).

2. Contaminant exposure estimates are compared to no observed adverse affects levels or LOAELs to determine the magnitude and nature of effects that may result from exposure at the OU. If the exposure estimate is greater than LOAEL, then individuals at the OU may experience adverse effects.

3. Availability and distribution of habitat on the ORR and within each OU is determined by using the ORR landcover map presented in Washington-Allen et al. (1995).

4. Habitat requirements for the endpoint species of interest are compared with the ORR habitat map to determine the area of suitable habitat on the ORR and within OUs.

5. The area of suitable habitat on the ORR and within OUs is multiplied by population density values (ORR-specific or obtained from the literature) for the selected endpoints to generate estimates of the ORR-wide population and the numbers of individuals expected to reside within each OU.

6. The number of individuals for a given endpoint species expected to be receiving exposures is greater than LOAELs for each measured contaminant is totaled. This is performed by using the OU-specific population estimate from step 5 and the results from step 2. This number is then compared with the ORR-wide population to determine the proportion of the ORR-wide population that is receiving hazardous exposures. By using the 20% criterion outlined in Suter et al. (1994a), if the proportion of the ORR-wide population receiving hazardous exposures is ≥20%, then an adverse population-level effect is assumed to be present.

Because contaminant concentrations in soil were the most readily available type of data and contaminant concentrations in plants and earthworms can be easily estimated with soil-plant or soil-worm uptake factors, vermivores and herbivores were selected as endpoint categories to demonstrate the applicability of the habitat-based approach. Conclusions of this assessment were that while there are significant risks to individuals of selected herbivore, vermivore, and predator endpoint species resident on OUs, the reservation-wide populations of these endpoints are unlikely to be significantly affected (<20% of the ORR population is affected). This conclusion must be viewed with caution, however, because data were evaluated for only 13 of 37 OUs. Inclusion of additional OUs is likely to increase the proportion of the ORR populations exposed and at risk.

Finally, this preliminary assessment of risk to wide-ranging wildlife species on the ORR is based on only a small portion of the data available for the reservation. To accurately evaluate the nature and magnitude of risks on the ORR, all available data should be incorporated and considered. It is recommended that this report be revised and updated annually until all existing data have been incorporated. Following this, revisions should be produced on a 5-year schedule to incorporate new data that become available.

1. INTRODUCTION

More than approximately 50 years of operations, storage, and disposal of wastes generated by the three facilities on the Oak Ridge Reservation (ORR) (the Oak Ridge K-25 Site, Oak Ridge National Laboratory, and the Oak Ridge Y-12 Plant) has resulted in a mosaic of uncontaminated property and lands that are contaminated to varying degrees. This contaminated property includes source areas [source operable units (OUs) that are the industrial facilities themselves and the waste disposal or waste storage areas] and the terrestrial and aquatic habitats down gradient from these source areas (integrator OUs; Fig. 1.1). Although the integrator OUs generally contain considerable habitat for biota, the source OUs provide little or no suitable habitat.

Historically, ecological risk assessment at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites has focused on species that may be definitively associated with a contaminated area or source OU. This is necessary to identify areas where risk is sufficiently high to warrant remediation. Figure 1.1 outlines a conceptual model for contaminant transfer both within and through a source OU. Endpoints considered in source OUs include plants, soil/litter invertebrates and processes, aquatic biota found in on-OU sediments and surface waters, and small herbivorous, omnivorous, and vermivorous (i.e., feeding on ground, litter, or soil invertebrates) wildlife. All of these endpoints have limited spatial distributions or home ranges such that numerous individuals or a distinct population can be expected to reside within the boundaries of the source OU. Contaminants move from the source to either surface soil, groundwater or surface water, or sediments (Fig. 1.1). Aquatic biota may be exposed to contaminants through direct contact with water and sediment; small herbivores, omnivores, and vermivores may be exposed through ingestion of contaminated surface water. Contaminants in soil may be taken up by plants and soil/litter invertebrates; consequently small herbivores, omnivores, and vermivores that feed on these food types may be exposed. These small terrestrial wildlife species may also be exposed to contaminants through incidental or purposeful ingestion of soil.

Assessment of the endpoints outlined above is adequate for source OUs and for sites with single, discrete areas of contamination that only provide habitat for species with limited spatial (i.e., small home range) requirements. It is not adequate however for large sites with multiple, spatially separated contaminated areas the ORR that provide habitat for wide-ranging wildlife species. Because wide-ranging wildlife species may travel between and use multiple contaminated sites, they may be exposed to and be at risk from contaminants from multiple locations. Use (and therefore exposure and risk) of a particular contaminated site by wide-ranging species will be dependant upon the amount of suitable habitat available at that site. Therefore to adequately evaluate risks to wide-ranging species at the reservation-wide scale, the use of multiple contaminated sites must be weighted by the amount of suitable habitat on OUs. Highly contaminated OUs that provide little habitat are unlikely to be significant contributors to ORR-scale contaminant-associated risk. Conversely, moderately contaminated sites that contain considerable habitat may significantly contribute to ORR-scale contaminant-associated risk.

In spring of 1994, a series of data quality objectives meetings were held among the Federal Facilities Agreement (FFA) parties [i.e., U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), Tennessee Department of Environment and Conservation] to develop an approach and plan for assessing risks to wide-ranging species that could not be adequately addressed

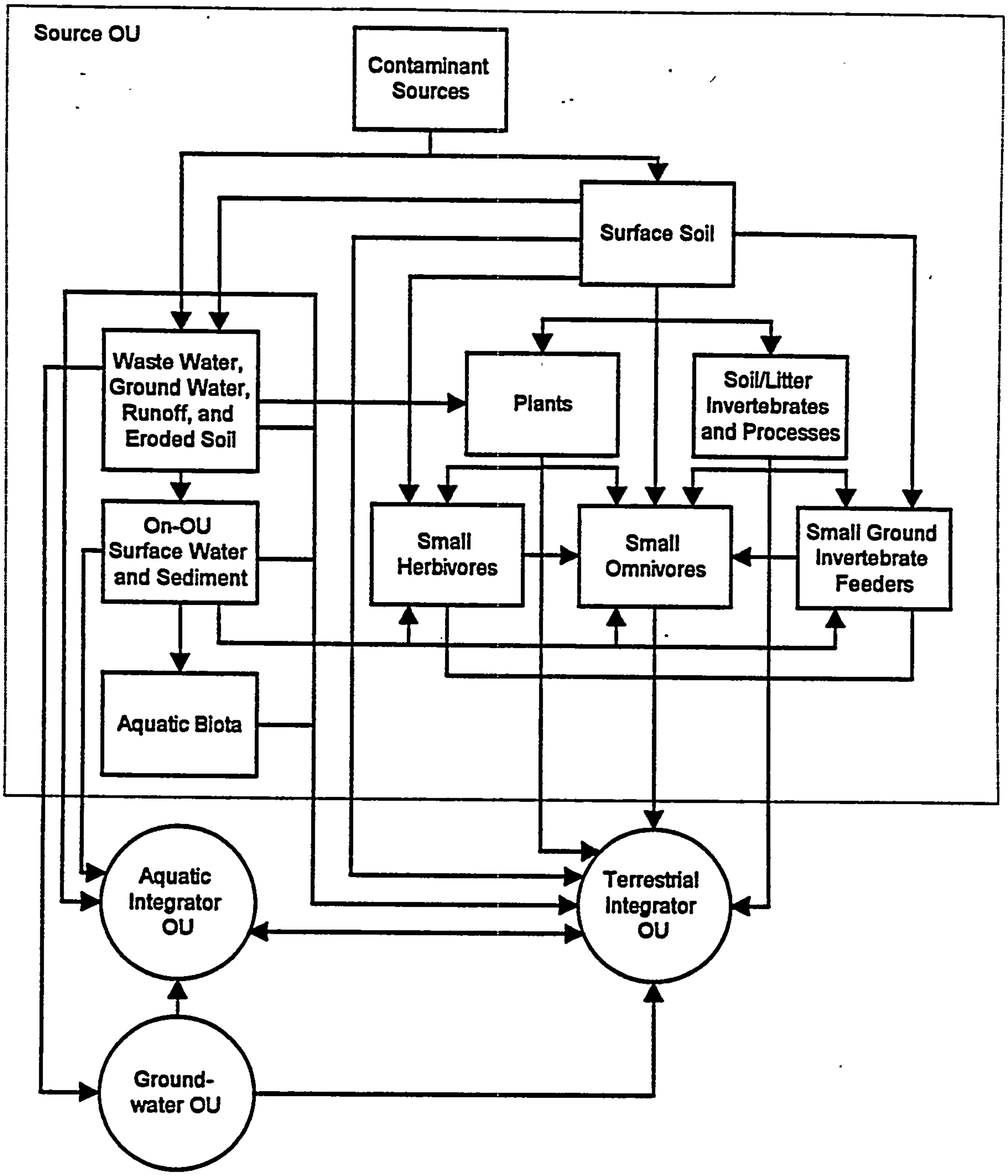

Fig. 1.1. Conceptual model of the transfer of contaminants through a source OU and into integrator OUs.

at the source OU level. The results of these discussions are presented in the ORR ecological risk assessment strategy document (Suter et al. 1994). This report is based on that document and presents the preliminary assessment of ecological risks to wide-ranging species from contaminants on the ORR.

The reservation-wide ecological risk assessment is intended to serve several purposes, including identifying (1) which endpoints are significantly at risk, (2) which contaminants are responsible for this risk, and (3) which OUs significantly contribute to risk. To address these issues, this report contains the following information:

- **An evaluation of the potential use of OUs by 57 endpoint species identified in Suter et al. (1994a)**—This is to identify endpoint species that may require additional attention in future assessments and is based on a comparison of species-specific habitat requirements and the amount of suitable habitat within OUs.

- **A preliminary ranking of OUs according to those that may present the greatest ecological risk**—This is to aid in the prioritization of OUs for potential remediation and is also based on habitat in OUs and the number of species for which this habitat is suitable.

- **A preliminary assessment of risks to piscivorous wildlife**—Because contaminants accumulate in aquatic systems, if reservation-scale risks are likely, they should be most evident among piscivores.

- **A preliminary assessment of risks to carnivorous, vermivorous, and herbivorous wildlife**—This is to demonstrate the applicability of habitat-based assessment methodology.

- **A proposed revision schedule**—Because this assessment is based on only a portion of the data available for the ORR and because remedial investigations (RIs) are currently in progress for two potential significant OUs [Waste Area Grouping (WAG) 2 and Bear Creek], periodic updates should be performed until all available data have been assembled, incorporated, and evaluated.

Detailed assessments of risk were not performed for all 57 endpoint species for which habitat availability on OUs was evaluated. Risks were evaluated only for selected piscivores, carnivores, vermivores, and herbivores. Selection of these trophic groups was determined by availability of data (i.e., fish body burdens, soil contaminant concentrations, soil-plant or soil-earthworm uptake factors). Risks to selected species from other trophic groups identified in Suter et al. (1994a) (i.e., aquatic herbivores, aquatic invertebrate feeders, flying insectivores, arboreal insectivores, large omnivores, scavengers) will be assessed in future revisions of this report.

The species for which detailed risk assessments were performed include mink, river otter, belted kingfisher, great blue heron, osprey, red fox, red-tailed hawk, wild turkey, white-tailed deer, American woodcock, and short-tailed shrew. These species were selected because they are known or expected to be sensitive to contaminants that are present on the ORR (i.e., mink, otter), are representative of groups that are likely to be highly exposed [i.e., piscivores (mink, otter, kingfisher, and heron) and vermivores (woodcock and shrew)], are threatened or endangered (T&E) species (i.e., osprey, otter) or a surrogates for related T&E species (i.e., red-tailed hawk, short-tailed shrew), or are well characterized on the ORR (site-specific data exists for mink, great blue heron, white-tailed deer, and wild turkey).

It should be emphasized that the results presented in this report are preliminary (i.e, based on only a subset of all data that exists on the ORR). The most relevant and accessible data have been selected for use at this time. As additional data are collected, made available, and incorporated, conclusions concerning the presence or magnitude of risks to wide-ranging species on the ORR may change. The quality and completeness of data used will be discussed in each chapter as it relates to the uncertainty of the risk assessment.

Assessment of ecological risks from radionuclides are not considered at this time. In human health risk assessment, the primary concern from exposure to radionuclides is increased incidence of cancer at the individual level. In ecological risk assessment, the concern is for population-level effects (except for T&E species, however). Because there is little evidence that cancer plays any significant role in wildlife populations, radionuclides were not considered at this time. Because of the importance and prevalence of radionuclide contamination on the ORR, risks associated with radionuclide exposure will be evaluated in future revisions of this report.

2. DATA

To identify data that would be useful for this project, a data search was initiated in which OU project managers were contacted and queried concerning the existence, status, nature, and availability of data concerning their OU. The search emphasized data concerning concentrations of contaminants in soil, water, sediment, and biota. The results of this survey are summarized in Appendix A. Briefly, although considerable data have been collected at OUs on the ORR, aside from data that currently reside in the Oak Ridge Environmental Information System (OREIS) or in the Bechtel Environmental Information Data Management System (BEIDMS)[1], much data were not readily available. The lack of availability was primarily a result of data being stored and maintained in multiple forms (electronic vs hard copy; various database programs, etc.). Compilation and standardization of the voluminous data for the ORR was beyond the current scope of this project. The data availability issue is currently being addressed through the Environmental Information Management Program as part of the ORR environmental restoration program.

Three general categories of data were identified, acquired, and used for this assessment. These include an reservation-wide land use/land cover classification (Washington-Allen et al. 1995), fish bioaccumulation data from the Biological Monitoring Programs, and soil contamination data derived from ORR computer databases (OREIS and BEIDMS).

The reservation-wide land use/land cover classification is presented in Washington-Allen et al. (1995). Availability and distribution of nine land use/land cover types (Table 2.1) on the ORR was determined through the use of satellite imagery and ground-truthing. These data were incorporated into a geographic information system (GIS) to produce a map of the available cover types on the ORR. OU boundaries were then overlaid on the reservation-wide cover map to produce OU-specific cover maps. Finally the area (ha) of each cover type on the ORR as a whole and within each OU was calculated.

Fish bioaccumulation data consisted of contaminant concentrations in fish and were derived from five sources. Descriptions of these data sets are presented here.

- **Name: Bear Creek OU4**
  - Spatial coverage: three locations in Bear Creek (BCK 12.4, BCK 9.4, and BCK 3.3) and one off-site location (Hinds Creek)
  - Analytes: metals and PCBs
  - Species: stone rollers
  - Principal investigator: George Southworth.

- **Name: Biological Monitoring and Abatement Program (BMAP) Bioaccumulation Task**
  - Spatial coverage: reservation-wide; 8 locations in vicinity of K-25, 2 locations in Bear Creek, 8 locations in White Oak Creek basin, and 7 locations in East Fork Poplar Creek
  - Analytes: primarily mercury and PCBs
  - Species: sunfish, largemouth bass, and carp
  - Principal investigators: George Southworth and Mark Peterson.

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[1]Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof.

Table 2.1. The land use/landcover classes used in habitat classification

Land use/landcover	Description
Urban land	Mixture of administrative buildings, laboratories, heavy commercial and industrial buildings, lawns, and clumped shade trees
Deciduous forest land	Areas of hardwood forest types
Mixed Forest Land	Areas of a mixture of hardwoods and pine trees
Evergreen forest land	Areas dominated by mature pine forest type with trees generally older than 35 years (in 1994) and having an uneven canopy
Evergreen plantation	Areas of pine trees which are row planted, are of uniform age, and are generally younger than 35 years (in 1994)
Pasture land	Fields of pasture grasses, grassland, row crops, and/or shrub land cover
Transitional areas	Secondary early successional sites, usually grassland to grassland shrub mix; generally mowed along power line corridors
Barren land	Cropped fields, plowed or bare ground areas, or areas where vegetation has been removed, such as construction sites or quarries

- **Name: Clinch River RI Program**
  Spatial coverage: Multiple locations in the Clinch and Tennessee rivers, and Poplar Creek. Data from one location in the Clinch River, near K-25, and 7 locations in Poplar Creek were used in this assessment.
  Analytes: metals, PCBs, pesticides, and other organics
  Species: sunfish, largemouth bass, catfish, carp, and shad

- **Name: K-901 Holding Pond**
  Spatial coverage: 1 location (K-901 pond)
  Analytes: metals, radionuclides, PCBs, pesticides, and other organics
  Species: shad, largemouth bass, and carp
  Principal investigator: Science Applications International Corporation

These data were combined into one large data set. While all small fish (stonerollers, shiners, and shad) were analyzed whole, all large fish (sunfish, largemouth bass, catfish, and carp) were analyzed as fillets only. Whole-body contaminant concentrations in large fish were estimated by using fillet-to-whole equations developed by Bevelheimer et al. (1996)

The last data set used in this report consists of contaminant concentrations in soil from OUs. These data were extracted from the OREIS and BEIDMS databases. The data were restricted to include only the top 2 ft of soil. This was assumed to include the soil horizons that wildlife species were most likely to be exposed to. Data were obtained for the following OUs: Bear Creek OU 2, Lower East Fork Poplar Creek, Upper East Fork Poplar Creek OU 2, WAG 1, WAG 6, South Campus Facility, K-1407, K-1414, and K-1420. In addition, soil data from risk assessments completed at four OUs (Chestnut Ridge OU 2, Bear Creek Valley OU, WAG 2, and WAG 5) were evaluated.

Again it should be noted that these data do not represent all available data. They simply represent a subset of the total that could be assembled, collated, and prepared at this time. Additional data will be acquired and incorporated in future revisions of this report.

3. EVALUATION OF POTENTIAL USE OF OPERABLE UNITS ON THE OAK RIDGE RESERVATION BY WILDLIFE

One of the primary factors determining the presence or absence of wildlife species in any area is the availability of suitable habitat. If suitable habitat is available (and the wildlife species of interest are present in the area), use of a site by wildlife is likely. Conversely, if no suitable habitat is available, use of the site is unlikely. In terms of risk to wildlife on the ORR, if an OU contains habitat for wildlife, it is likely to be used, and therefore wildlife that use the site may be exposed to contaminants and potentially be at risk. By comparing the habitat requirements of wildlife endpoints with the habitats available on OUs on the ORR, OUs that *may* present risk and endpoints that *may* be at risk can be identified.

Uncertainty associated with identifying OUs or endpoints as presenting or being at risk must be emphasized because contaminant data are not used in this evaluation; it is simply based on a co-occurrence of factors that increase the *potential* for an OU to present a risk or for an endpoint to be at risk. Although this evaluation can identify those species that are not at risk and OUs that do not present on-OU risk (if an OU contains no suitable habitat, use and exposure are unlikely, therefore risks are unlikely; it should be noted, however that OUs that do not contain any suitable habitat may act as sources of contamination to down gradient areas; therefore, although there may be no on-OU risks, they may contribute significantly to off-OU risks), without incorporating OU-specific contaminant data and estimating exposure, the actual nature and magnitude of risk at an OU cannot be determined.

Information concerning the habitat requirements for the 57 endpoint species identified in Suter et al. (1994) was obtained from the literature (Table B.1). These data were then compared to the nine landcover types identified on the ORR in Washington-Allen et al. (1995) to identify landcover types on the ORR that an endpoint is likely to use (Table B.2). Habitat requirements information for endpoint species was generally far more detailed than the landcover types identified on the ORR. Consequently some assumptions and professional judgments were applied in matching habitat requirements with available habitat types. For example, many species are listed as requiring floodplain, bottom land, or riparian forest (Table B.1). This habitat type is not specifically delineated in Washington-Allen et al. (1995). Because the dominant forest habitat types at the three OUs that are located in floodplains [WAG 2, Bear Creek, and Lower East Fork Poplar Creek (LEFPC)] are deciduous and mixed forest (Table B.3), if a species was identified as requiring floodplain forest, it was assigned to these habitats. This approach is conservative, because deciduous and mixed forests are not restricted to floodplain locations. A similar approach was used for other landcover types not specifically identified in Washington-Allen et al. (1995).

The amount of habitat (in ha) in each of the nine categories observed at each OU is summarized in Table B.3. The presence or absence of habitat for the 57 endpoint species at OUs at the K-25 Site, Oak Ridge National Laboratory (ORNL), and the Y-12 Plant are summarized in Tables B.4, B.5, and B.6, respectively. Tables B.7 and B.8 present the total number of OUs that provide habitat for each species and the total number of species with habitat on each OU, respectively. An OU was considered to have habitat for a species if any one of the landcover categories from Tables B.2 and B.3 coincided. Professional judgement was employed in determining if the habitat at an OU was suitable for an endpoint. For example, if the species required large bodies of water, and while water was present on an OU but consisted of a small stream, the habitat was considered unsuitable. Habitat was considered only on a presence/absence basis—the amount of habitat was not incorporated into the evaluation of whether or not an species would use an OU. It is recognized that this approach is overly simplistic and conservative. Use of an OU by a species will depend on the amount of habitat available (not just suitability), the connectivity of the on-OU habitat to similar habitat off the OU (isolated patches will receive less use than contiguous patches), and the amount of human activity in the vicinity (use by many species is inversely related to human activity). This evaluation was performed to determine simply if an endpoint could use an OU. A more detailed evaluation of the quality and quantity of habitat at an OU will be performed in a manner similar to that discussed in Chap. 5 as part of a future revision of this report.

As would be expected, OUs with high diversity of landcover types (i.e., many landcover types present on the OU) were determined to be able to support the greatest number of endpoint species (Table B.8). These OUs were also the largest on the ORR (Table B.3). Small OUs located within the plant sites [i.e., Upper East Fork Poplar Creel (UEFPC) OU 2 and OU 3] were estimated to support the lowest number of endpoint species. If potential on-OU risk is determined simply by the number of species that might use an OU, WAG 2, K-901, LEFPC, Bear Creek, and WAGs 4, 5, 6, and 7 present the greatest risk (Table B.8). OUs that present the least risk (based solely on number of endpoints) include K-1413, K-1004, K-1401, K-1420, UEFPC OU 2 and UEFPC OU 3.

Endpoint species estimated to be present at all 37 OUs are either habitat generalists (i.e., starlings, raccoons), tolerant of human activities (e.g., groundhog, American robins, Canada geese), or make use of structures (e.g., barn owl, Rafinesque's big-eared bat) (Table B.7). The next most common group of endpoint species (expected to be found at 31 OUs), consists of species with broad habitat preferences. These species use both forested and open (i.e., pasture and transitional) habitats. Species that require aquatic habitat (e.g., ponds, streams) are expected at 16 OUs, and only 3 OUs (K-901, K-1007, and WAG 2) are suitable for those species that need large bodies of water (bald eagle, osprey, double-crested cormorant, and gray bat) (Table B.7). Only three endpoint species are not expected to be present on any OUs on the ORR: golden eagles and cougars (the ORR as a whole probably does not provide sufficient suitable habitat for these species) and the Tennessee cave salamander (no caves are currently known to exist on any OU, therefore there is no habitat for this aquatic troglodytic salamander). The last endpoint, the green salamander, requires moist rock outcroppings. Locations and possible distributions of this habitat feature within OUs is unknown at this time.

3.1. QUALITY AND COMPLETENESS OF DATA

The completeness of data for this portion of the assessment is adequate; however, the quality of data needs improvement. Although a highly significant first step, the level of detail in the ORR landcover map is far less than what is needed to accurately estimate the actual presence of suitable habitat on each OU. Incorporation of aspect and elevation data in the ORR landcover map would be useful to differentiate dry upland sites from moist bottom lands. It would also allow floodplain habitats to be delineated. Additional, more detailed data on habitat requirements (and their relative value) for each endpoint species would also increase the precision in the habitat use predictions for each OU. By combining the relative habitat preferences for each endpoint species with the amounts of each habitat type present on each OU, a better estimate of the likelihood of use (and therefore the potential for exposure and risk) may be obtained.

4. ASSESSMENT OF RISKS TO PISCIVORES ON THE OAK RIDGE RESERVATION

Numerous, significant changes have been made throughout this section. To facilitate the flow of the document, they are summarized below but are not specifically identified in the text. The major changes in this section include the following:

- Use of BMAP bioaccumulation data only from 1994 and 1995;
- Exclusion of LEFPC RI fish data
- Inclusion of Clinch River RI fish data
- Focus on only two contaminants: mercury and PCBs. All others not considered because of a lack of ORR-wide data
- Estimated whole fish contaminant concentrations using models developed by Bevelheimer et al. (1996) instead of simple fillet–whole fish ratios.
- Use of updated benchmarks that reflect regulator comments concerning scaling factors.
- Inclusion in assessment of osprey for areas where appropriate habitats were available.
- Weighted piscivore exposures by the relative density or biomass of fish in sampling areas as per regulator comments.

4.1 PROBLEM FORMULATION

This section discusses the attributes and selection of appropriate ecological endpoints, describes the ecological setting, provides information on the sources and hazards to which organisms may be exposed, and integrates this information into a conceptual model that portrays the interaction among sources and endpoints at the sites. The information provided here sets the stage for the exposure assessment section that follows.

4.1.1 Ecological Assessment Endpoints

The hazard identification phase of an ecological risk assessment 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 that are related to effects on an assessment endpoint.

4.1.1.1 Assessment endpoints

The following assessment endpoints were selected for the assessment of risks to piscivorous wildlife: toxicity to mink (*Mustela vison*), river otter (*Lutra canadensis*), belted kingfisher (*Ceryle alcyon*), great blue heron (*Ardea herodias*), and osprey (*Pandion haliaetus*) resulting in a reduction in population abundance or production. These assessment endpoints are those that have been agreed to be appropriate for the ORR by the FFA parties (Suter et al. 1995). The criteria for selection of the entities are those recommended by EPA (1992), plus considerations of scale and practical considerations.

Both osprey and river otter are listed as a threatened species by the Tennessee Wildlife Resources Agency (TWRA). Osprey are found along the Clinch River and Poplar Creek adjacent to the ORR and use larger bodies of water on the ORR. Although otter are not known to occur on the ORR at the present time, they have been included in this assessment because the ORR contains suitable habitat, a reintroduction program is underway in East Tennessee, and they may become established on the ORR in the future. To determine if the ORR could support this threatened species, the nature and magnitude of risk that contaminants on the ORR may present to otter must be evaluated.

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. **Organism level**—In general, protection of individual organisms is appropriate only for threatened and endangered species. Two of the selected species, osprey and river otter, are T&E species; therefore, organism-level properties were used for these assessment endpoints. **Population level**—The appropriate endpoint properties for populations of endpoint species are abundance and production.

Finally, the level of effects on these properties of the endpoint entities that is considered to be potentially significant is 20% as agreed by the FFA parties (Suter et al. 1995). This level is consistent with current regulatory practice.

Assessment of piscivores is a logical first step to evaluate reservation-wide risks. Contaminants present on the ORR are known to accumulate readily in aquatic foodwebs (i.e., mercury and PCBs). Some piscivores (mink in particular) are known to be sensitive to mercury and PCBs. The diet of piscivores frequently consists exclusively of fish or other aquatic prey, therefore members of this group are likely to be highly exposed. Finally, most piscivores are highly mobile, they therefore may be exposed to contaminants from multiple locations.

The ORR was partitioned into four watersheds: Bear Creek, East Fork Poplar Creek, the K-25 area (consisting of the K-25 ponds, Mitchell Branch, and Poplar Creek and the Clinch River adjacent to the K-25 plant), and White Oak Creek (including White Oak Lake and the White Oak Lake embayment). Risks were evaluated within each watershed, and these results were used to determine risks to piscivores across the ORR as a whole.

4.1.1.2 Measurement endpoints

Three basic types of effects data are potentially available to serve as measurement endpoints: results of biological surveys, toxicity tests performed using fish from the ORR, and literature-derived toxicity test results for chemicals found on the ORR. The following are measurement endpoints for each assessment endpoint:

- **Mink**
  - Biological survey data—Limited data concerning presence/absence, movements, and bioaccumulation of contaminants are available for mink on the ORR.
  - Media toxicity data—Results of reproductive toxicity tests are available for ranch mink fed fish obtained from the Poplar Creek embayment.
  - Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in mammals with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **River otter**
  - Biological survey data—None.
  - Media toxicity data—Results of reproductive toxicity tests are available for ranch mink fed fish obtained from the Poplar Creek embayment. Because both mink and otter are mustelids,

the test endpoints for mink are assumed to correspond to the assessment endpoint (otter) after allometric scaling.
- — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in mammals with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **Belted kingfisher**
  - — Biological survey data—Limited data concerning bioaccumulation of contaminants are available for belted kingfisher on the ORR.
  - — Media toxicity data—None.
  - — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in birds with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **Great blue heron**
  - — Biological survey data—Field data concerning contaminant bioaccumulation and reproductive success were available for 4 heron rookeries near the ORR (2 rookeries <10 km and 2 rookeries >10 km from ORR; an additional 3 rookeries are located <10 km from the ORR. No data are available from these locations).
  - — Media toxicity data—None.
  - — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in birds with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **Osprey**
  - — Biological survey data—Field data concerning reproductive success was available for three osprey nests adjacent to the ORR (2 located on Melton Hill Reservoir, and one in Poplar Creek, near K-25).
  - — Media toxicity data—None.
  - — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in birds with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

4.1.2 Ecological Conceptual Model

The ecological conceptual model graphically represents the relationships between the contaminant sources and the endpoint receptors. It integrates the information in the other subsections of the hazard identification and presents them graphically. It is not intended to show all of the possible sources, routes of transport, modes of exposure, or effects. Rather, it includes the only identified CERCLA source, the receptors that are designated as assessment endpoint species or communities, and the major routes that result in exposure to contaminants from the ORR.

The conceptual model for exposure of piscivores to contaminants is presented in Fig. 4.1. Components of this model include aquatic biota (aquatic plants, invertebrates, fish, and amphibians) that reside in ponds and streams on the ORR and the piscivorous wildlife that feeds on aquatic biota. The aquatic biota are exposed to contaminants from surface water and sediments. Contaminants are bioaccumulated in lower trophic levels (i.e., plants or invertebrates) and transferred to higher trophic levels (i.e., invertebrates, fish, or amphibians). Piscivorous wildlife consume fish, amphibians, and invertebrates and are therefore exposed to accumulated contaminants (Fig. 4.1).

4.2 EXPOSURE ASSESSMENT

Piscivorous wildlife may be exposed to contaminants through ingestion of contaminated media (fish, other aquatic prey, and water) and through contaminants accumulated in the tissues of the piscivore itself. In this assessment, ingestion of food was the only pathway considered. Exposure through ingestion of water will be included in a future revision. Contaminant exposure through ingestion was estimated for mink, otter, belted kingfisher, great blue heron, and osprey. This assessment focused only on the two contaminants, mercury and PCBs, for which there is ORR-scale data. Data on mercury and PCB concentrations in fish were available from the four watersheds on the ORR. Exposure estimates were calculated for 37 locations on the ORR: 5 locations in Bear Creek, 7 locations in East Fork Poplar Creek, 17 locations in the vicinity of the K-25 Site, and 8 locations in the White Oak Creek basin. Exposure through contaminants accumulated in tissues was measured for nestling great blue herons and among adult kingfishers. Locations of sampling locations within Bear Creek, East Fork Poplar Creek, the K-25 Site, and White Oak Creek are presented in Figs. C.1 through C.4.

4.2.1 Exposure Through Oral Ingestion of Fish

For exposure estimates to be useful in the assessment of risk to wildlife, they must be expressed in terms of a body weight–normalized daily dose or milligram contaminant per kilogram body weight per day (mg/kg/d). Exposure estimates expressed in this manner may then be compared with toxicological benchmarks for wildlife, such as those derived by Sample et al. (1996a), or to doses reported in the toxicological literature. Estimation of the daily contaminant dose an individual may receive from a particular medium for a particular contaminant may be calculated by using the following equation:

$$E_j = \sum_{i=1}^{m} \left(\frac{IR_i \; x \; C_{ij}}{BW} \right) \tag{1}$$

where:

E_j = total exposure to contaminant (j) (mg/kg/d)
m = total number of ingested media (e.g., food, water, soil)
IR_i = consumption rate for medium (I) (kg/d or L/d)
C_{ij} = concentration of contaminant (j) in medium (I) (mg/kg or mg/L)
BW = body weight of endpoint species (kg).

Exposure estimates were calculated for all contaminants detected at all ORR sampling locations. Because wildlife are mobile, their exposure is best represented by the mean contaminant concentration

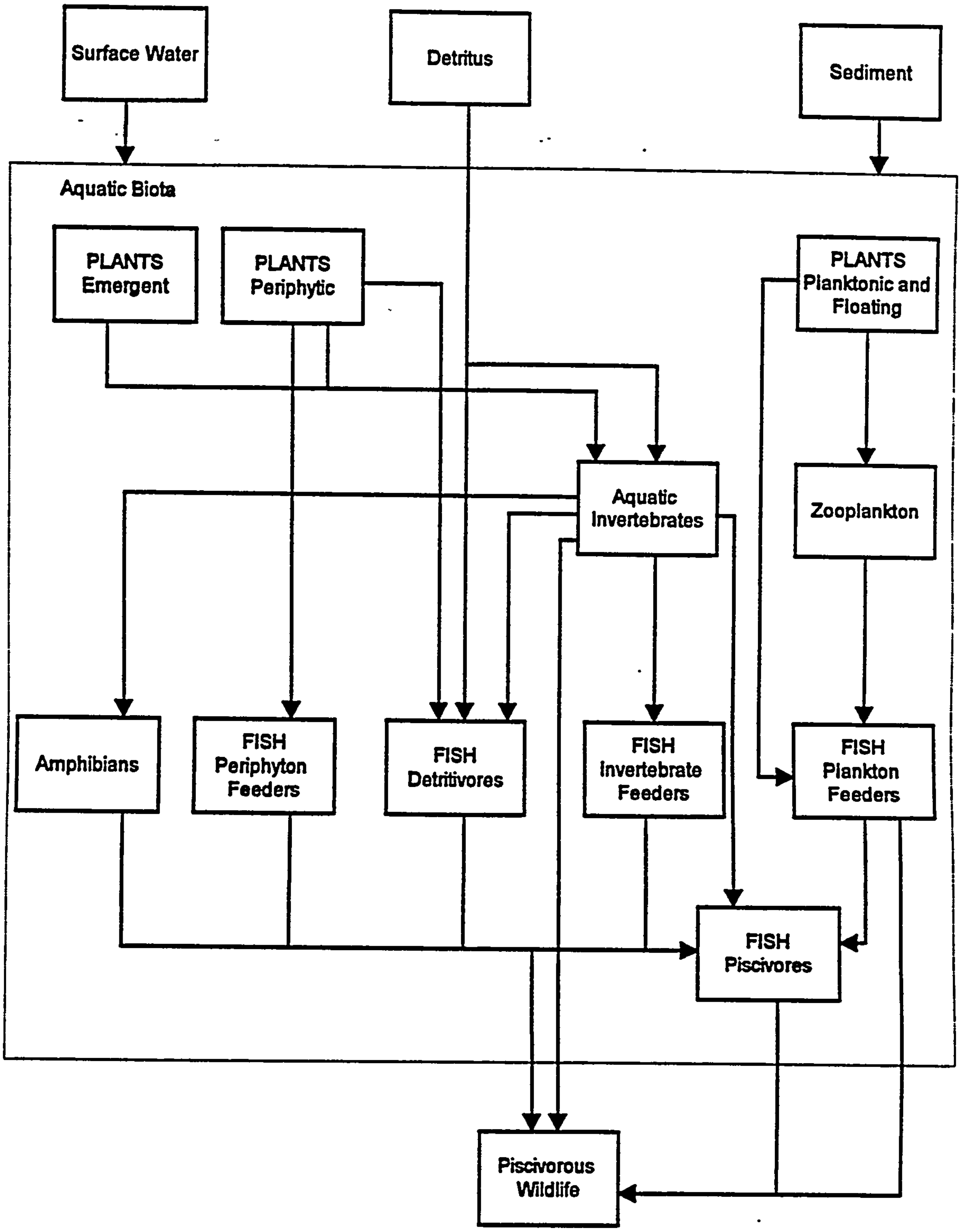

Fig. 4.1. Conceptual model for the exposure of piscivorous wildlife to contaminants.

in media. To be conservative, the 95% upper confidence limit (UCL) is used in exposure estimates. To prevent bias that may result from calculating 95% UCLs using data that contains values below the detection limit, product limit estimator (PLE) was used to calculate the 95% UCLs for contaminants observed in fish and water These data were used in the initial exposure estimates. Exposure estimates for contaminants that may potentially present a risk to piscivorous wildlife [based upon comparisons to no observed adverse effects levels (NOAELs) and LOAELs] were recalculated using Monte Carlo simulations. [**Note: Because the purpose of the initial exposure estimate is to be conservative and to identify contaminants of potential ecological concern (COPECs), the 95% UCL was used regardless of whether or not the value exceeded the maximum observed value. Overestimates of exposure that may occur at the screening level are addressed through the use of Monte Carlo simulation.**]

4.2.1.1 Estimation of whole fish contaminant concentrations from fillet data

Fish data from the ORR consisted of analyses of both whole body concentrations (generally in stonerollers, shiners, and shad) and concentrations in fillets (in sunfish, largemouth bass, and carp). Because piscivores consume whole fish (not fillets) and fillet concentrations do not accurately represent whole body concentrations, it was necessary to estimate concentrations in whole fish for those sample for which only fillet analyses were performed. Whole-fish concentrations were estimated by using the following equations:

for mercury:

$$C_{WB} = e^{[-0.8 + 0.76 * \ln(C_F)]} \tag{2}$$

for PCBs in catfish:

$$C_{WB} = e^{[0.16 + 0.54 * \ln(C_F)]} \tag{3}$$

for PCBs in bass or other fish:

$$C_{WB} = e^{[0.81 + 0.95 * \ln(C_F)]} \tag{4}$$

where:

C_{WB} = whole body contaminant concentration
C_F = fillet contaminant concentration

A detailed discussion of the development of these equations is presented in Bevelheimer et al. (1996).

4.2.1.2 Contaminant concentrations in fish

Contaminant concentrations in fish are needed to estimate exposure. The 95% UCLs (calculated by using the PLE) for contaminants detected in fish from the ORR are presented in Table C.6. Note that data were aggregated into two size classes: <30 cm and >30 cm in length. This is because piscivore species forage on different size fish and contaminant body burdens are related to size (larger, older fish generally have higher contaminant concentrations). Although mink, belted kingfisher, and great blue heron generally consume fish <30 cm in size, osprey and otter forage equally on small and large fish (see Tables C.1 to C.5). To more accurately reflect exposure, data were segregated according to size and exposure was estimated by using data from the size of fish most likely to be consumed by that endpoint species. Because it was assumed that piscivores would select fish according to size and not by species, all species were pooled within each size class.

Although data concerning fish size were included in the BMAP, Bear Creek OU4, and Clinch River RI, fish sizes were not included in the K-901 data set. On the basis of the size data in the first three data sets, all sunfish, stonerollers and shad were assumed to be <30 cm in size and largemouth bass and carp were assumed to be >30 cm for the K-901 data sets.

4.2.1.3 Exposure modeling using point-estimates

Initial estimates of exposure of piscivorous wildlife to contaminants were performed for each sampling point using point estimates of parameters in the exposure model (Equation 1). Species-specific parameters necessary to estimate exposure using Equation 1 are listed in Tables C.1–C.5.

To estimate contaminant exposure experienced by mink, the following assumptions were made:

- Body weight = 1 kg.
- Food consumption = 0.137 kg/d (fresh weight).
- Diet consists 54.6% of fish or other aquatic prey.
- Contaminant concentration in fish is representative of that in other aquatic prey.
- Fish sizes consumed = 100% <30 cm.

To estimate contaminant exposure experienced by otter, the following assumptions were made:

- Body weight = 8 kg.
- Food consumption = 0.9 kg/d (fresh weight).
- Diet consists 100% of fish or other aquatic prey.
- Contaminant concentration in fish is representative of that in other aquatic prey.
- Fish sizes consumed = 50% <30 cm and 50% >30 cm.

To estimate contaminant exposure experienced by kingfisher, the following assumptions were made:

- Body weight = 0.148 kg.
- Food consumption = 0.075 kg/d (fresh weight).
- Diet consists 100% of fish.
- Fish sizes consumed = 100% <30 cm.

To estimate contaminant exposure experienced by great blue heron, the following assumptions were made:

- Body weight = 2.39 kg.
- Food consumption = 0.42 kg/d (fresh weight).
- Diet consists 100% of fish or other aquatic prey.
- Contaminant concentration in fish is representative of that in other aquatic prey.
- Fish sizes consumed = 100% <30 cm.

To estimate contaminant exposure experienced by osprey, the following assumptions were made:

- Body weight = 1.5 kg.
- Food consumption = 0.3 kg/d (fresh weight).
- Diet consists 100% of fish or other aquatic prey.
- Contaminant concentration in fish is representative of that in other aquatic prey.
- Fish sizes consumed = 92.1% <30 cm and 7.9% >30 cm.

Using Equation 1 and the assumptions and data described above, exposure to contaminants was estimated for mink (Table C.7), otter (Table C.8), kingfisher (Table C.9), and great blue heron (Table C.10) for each location on the ORR. Because osprey use only large bodies of water, exposure estimates were generated for only for those areas where suitable habitat was availabale (the K-25 Site and White Oak Lake and embayment; Table C.11).

4.2.1.4 Exposure modeling using Monte Carlo simulations

Employing point estimates for the input parameters in the exposure model does not take into account the variation and uncertainty associated with the parameters and therefore may over or under estimate the contaminant exposure that endpoints may receive in any given reach. In addition, calculating the model using point estimates produces a point estimate of exposure. This estimate provides no information concerning the distribution of exposures or the likelihood that individuals within a watershed will actually experience potentially hazardous exposures. To incorporate the variation in exposure parameters and to provide a better estimate of the potential exposure experienced by piscivores on the ORR, the exposure model was recalculated with the Monte Carlo simulations.

Monte Carlo simulation is a resampling technique frequently used in uncertainty analysis in risk assessment (Hammonds et al. 1994). In practice, distributions are assigned to input parameters in a model, and the model is recalculated many times to produce a distribution of output parameters (e.g., estimates of contaminant exposure). Each time the model is recalculated, a value is selected from within the distribution assigned for each input parameter. As a result, a distribution of exposure estimates is produced that reflects the variability of the input parameters. To determine which input parameters most strongly influence the final exposure estimate, a sensitivity analysis is performed (Hammonds et al. 1994). Detailed discussions of sensitivity and uncertainty analysis, and the use of Monte Carlo simulations in risk assessment are provided by Hammonds et al. (1994).

Monte Carlo simulations were performed to estimate watershed-wide exposures. It was assumed that wildlife were more likely to forage in areas where food is most abundant. Density or biomass of fish at or near locations where fish bioaccumulation data were collected were assumed to represent measures of food abundance. (Biomass data were prefered but were unavailable for all watersheds. Where unavailable, density data were used.) The relative proportion that each location contributed to overall watershed density or biomass data was used to weight the contribution to the watershed-level exposure. The watershed level exposure was estimated to be weighted average of the exposure at each location sampled within the watershed. In this way, locations with high fish densities or greater fish biomass contribute more to exposure than do locations with lower density or biomass. Fish density or biomass data used to weight exposure for the Bear Creek, East Fork Poplar Creek, and White Oak Creek watersheds are presented in Tables C.12 through C.14, respectively.

No data were available with which to weight exposures in the K-25 area. Therefore watershed-level exposures for this watershed represent the average exposure at each sampled location. Each location contributes equally to the total, with no preferential weighting applied.

The percentiles of the resulting exposure distributions represent the likelihood that an individual piscivore within a watershed will experience a given exposure level. Watershed-wide simulations were performed for mercury and PCBs because these contaminants are among the most important on the ORR and data for these contaminants were available at all sampling locations.

Distributions were used for the contaminant concentrations in fish and for the proportion of fish in the diet of mink. All contaminant distributions were assumed to be lognormal. Lognormal means and standard deviations for contaminants in fish are presented in Table C.6.

The proportion of aquatic prey in the diets of otter, kingfisher, and herons were assumed to be 100%. No data suggest that nonaquatic prey constitute a significant portion of their diet (see endpoint discussion, above). In contrast, mink have a very variable diet. Aquatic prey (fish, amphibians, crayfish, etc.) may make up from 16% to 92%. Nine observations from five studies indicate the proportion of aquatic prey to be 0.546±0.21 (mean ± standard deviation; Table C.1). The proportion of aquatic prey in the diet of mink was assumed to be normally distributed.

Monte Carlo simulations were performed using the @Risk software. Samples from each distribution were selected with Latin hypercube sampling. The number of iterations, or recalculations, of each exposure simulation was determined by the convergence criteria set in the software. Under these criteria, iterations are performed until the between-iteration percent change in the percentiles, mean, and standard deviation are below 1.5% (i.e., the percentile, mean, and standard deviation for the latest iteration is <1.5% different than the those from the previous iteration). Using this convergence criteria, from 600 to 1000 model iterations were performed for each exposure estimate. Monte Carlo estimates of contaminant exposures are presented in Table C.16.

4.2.2 Internal Exposure of Great Blue Herons to Contaminants

To determine if contaminants from the ORR are being bioaccumulated by piscivorous wildlife, great blue heron eggs and chicks were collected from two colonies located within 3 km of the ORR and two colonies located >10 km from the site (Halbrook, unpubl. data; see Appendix F). Analyses were performed to determine the concentrations of arsenic, chromium, mercury, and PCBs in eggs, and feathers, liver, fat, and muscle of chicks. Elevated levels of Cr, Hg, and PCBs were observed in eggs from the ORR colonies (Tables F.2 and F.4). Mercury concentrations in feathers and liver (Table D.3, Appendix D) and PCB concentrations in fat (Table F.5), liver (Table F.6), and muscle (Table F.7) were significantly elevated in samples from the ORR as compared to data from the off-site locations. A detailed discussion of these data is presented in Appendix F.

4.3 EFFECTS ASSESSMENT FOR PISCIVOROUS WILDLIFE

4.3.1 Single Chemical Toxicity Data

Single-chemical toxicity data consist of NOAELs and LOAELs of toxicity studies reported in the literature.

In cases where an NOAEL for a specific chemical was not available, but a LOAEL had been determined experimentally or where the NOAEL was from a subchronic study, the chronic NOAEL was estimated. EPA (1993c) suggests the use of uncertainty factors of 1 to 10 for subchronic to chronic NOAEL and LOAEL to NOAEL estimation. Because no data were available to suggest the use of lower values, uncertainty factors of 10 were used in all instances in which they were required.

Smaller animals have higher metabolic rates and are usually more resistant to toxic chemicals because of more rapid rates of detoxification. In mammals, it has been shown that metabolism is best expressed in terms of body weight (bw) raised to the 3/4 power ($bw^{3/4}$) (EPA 1995). If the dose (d) itself has been calculated in terms of unit body weight (i.e., mg/kg), then the metabolic rate-based dose (D) equates to

$$D = \frac{d \ x \ bw}{bw^{3/4}} = d \ x \ bw^{1/4}. \tag{5}$$

Mineau (1996) reports that the mean allometric scaling factor for chemical toxicity to birds is 1.15 and may range as high as 1.55. Because the allometric scaling factors for the majority of the chemicals evaluated were not significantly different from 1, 1 was used as the best estimate of the allometric scaling factor for birds. If the dose (d) itself has been calculated in terms of unit body weight (i.e., mg/kg), then the dose per unit body surface area (D) equates to

$$D = \frac{d \ x \ bw}{bw^{1}} = d \ x \ bw^{0}. \tag{6}$$

The assumption is that the effective dose per body surface area for species "a" and "b" would be equivalent. Therefore, knowing the body weights of two species and the dose (d_b) producing a given effect in species "b," the dose (d_a) producing the same effect in species "a" can be determined. Using this approach, if a NOAEL was available for a mammalian test species ($NOAEL_t$), the equivalent NOAEL for a mammalian wildlife species ($NOAEL_w$) was calculated by using the adjustment factor for differences in body size:

$$NOAEL_w = NOAEL_t \left(\frac{bw_t}{bw_w} \right)^{1/4}. \tag{7}$$

For birds, if a NOAEL was available for an avian test species ($NOAEL_t$), the equivalent NOAEL for an avian wildlife species ($NOAEL_w$) would be calculated by using the adjustment factor for differences in body size:

$$NOAEL_w = NOAEL_t \left(\frac{bw_t}{bw_w} \right)^{0} = NOAEL_t \ (1) = NOAEL_t. \tag{8}$$

This methodology for toxicity extrapolation is equivalent to that EPA uses in their carcinogenicity assessments and Reportable Quantity documents for adjusting from animal data to an equivalent human dose.

NOAELs and LOAELs were derived for mink, river otter, belted kingfisher, great blue heron, and osprey. Mammalian and avian NOAELs and experimental information used to estimate wildlife NOAELs and LOAELs (e.g., test species, test endpoints, citation) are listed in Tables C.16 and C.17. Ecotoxicological profiles of the effects of mercury and PCBs to wildlife are presented in Appendix D.

4.3.2 Effects of Contaminants on the Reproductive Performance of Mink

At the Michigan State University Experimental Fur Farm, Halbrook (unpubl. data; see Appendix E) evaluated bioaccumulation of contaminants and reproductive effects in mink fed fish collected from Poplar Creek, the Clinch River (upstream of Melton Hill Dam), and the ocean. Mink were fed five diets consisting of 75% fish and 25% commercial mink diet. The diet composition and contaminant concentrations for each diet are described in the following table:

		Contaminant concentration (mg/kg)	
Diet	**Fish composition**	**Mercury**	**PCB 1260**
A	75% ocean	0.02 ± 0.00	0.169 ± 0.002
B	75% Clinch River	0.05 ± 0.00	11.44 ± 0.327
C	25% Poplar Creek 50% ocean	0.09 ± 0.00	4.69 ± 0.174
D	50% Poplar Creek 25% ocean	0.15 ± 0.01	10.41 ± 0.250
E	75% Poplar Creek	0.22 ± 0.01	20.67 ± 0.458

Twenty-three PCB congeners were also present in varying amounts. Concentrations of most congeners increased progressively from diets A through E (Table E.5).

Ten mink (eight females and two males) were fed each diet for ~7 months (3 months before breeding—6 weeks postpartum). Reproductive indices measured included number of females mated; number of females whelping; length of gestation; number of kits whelped (alive, dead); kit sex ratio; average kit body weight at birth, 3, and 6 weeks of age; and kit survival to 3 to 6 weeks of age. At 6 weeks of age, 3 kits from dietary groups A, B, C, and E were euthanized, organs (liver, spleen, and kidneys) were weighed, and tissue samples (liver, kidney, and remaining carcass) were analyzed for contaminant accumulation. (Note: kits from diet D were not sampled). At the termination of the study, all adult mink were necropsied. Organs (brain, liver, kidneys, heart, lungs, gonads, and adrenal glands) were weighed and examined for histopathologies. Adipose tissue, liver, kidney, and hair were analyzed for contaminant accumulation. Liver tissue also was analyzed for ethoxyresorufin-o-deethylase (EROD) activity.

The bioaccumulation of mercury in liver, kidney, and hair (Table E.3) and of Aroclor 1260 (and other PCB congeners) in liver and fat (Tables E.6 and E.7) substantially increased in adult female mink from groups fed diet A up to diet E. Mink offspring also bioaccumulated mercury in kidney tissue and carcasses and many other PCB congeners in the liver and carcasses (Tables E.8 and E.9), increasing progressively from mink fed diets A through E. The lowest levels were observed for mink fed diet A and increased to a maximum observed among mink fed diet E.

Significant effects were observed only among mink fed diet E; no adverse effects were observed for any other diet. Adverse effects from diet E included weight reduction in adult mink and their offspring, reduction in litter size, and increase in liver EROD activity in adult females. Weight reduction was observed at the end of the experimental period, increasing magnitude from diet groups A to E. At the end of the experiment, the mean whole body weights of female mink in diet group E were significantly less (p = 0.03) than mean weights of females in diet group A (percent reduction = 20%). Mean female relative organ weights (organ weights/body weight) were not significantly different among diet groups. At 6 weeks of age, mean whole body weights were also significantly lower (p = 0.004) in male kits from diet group E compared with those from diet group A (percent reduction = 17%). Similar trends were observed for female kits, although differences were not statistically significant. No histological lesions were attributed to any diet. Mean litter size was significantly reduced (p = 0.01) in diet group E compared with diet groups A, B, and C (percent reduction relative to diet A = 38%) but not with diet group D. Liver EROD activity was significantly increased in adult female mink from diet groups D and E compared with those from diet group A.

4.3.3 Biological Surveys

4.3.3.1 Great blue heron reproduction survey

To determine if contaminants from the ORR are adversely affecting great blue heron, Halbrook (unpubl. data; see Appendix F) monitored the reproductive success at two heron colonies located adjacent to the ORR and two colonies located >10 km from the reservation. Data were collected from each nest colony between 1992 and 1994. The mean number of eggs/nest, number of chicks/nest, egg weight, and eggshell thickness did not differ between colonies within 3 km of the ORR and those >10 km away (Table F.8). A detailed discussion of these data are presented in Appendix F.

4.3.3.2 Mink survey

Stevens (1995) investigated bioaccumulation of mercury in mink on the ORR in 1993 through 1995. The methods used in the mink survey, although indicating that mink are present on the reservation, cannot be used to estimate abundance or density on mink on the ORR. A total of 4 male mink were live-trapped over the course of 6073 trapnights (trapnight = 1 trap set for 24 h). One juvenile was captured along East Fork Poplar Creek, two adults were captured along Bear Creek, and one adult was captured along White Oak Creek. Captured mink were fitted with an intraperitoneal radio transmitter (to monitor movements and home range) and released. Before release samples of hair were collected and metals analysis were run. An additional eight roadkill mink (five male and three female) were collected from the ORR and surrounding areas of Roane and Anderson counties. One roadkill sample (a male) was collected on a bridge over Bear Creek and was assumed to be a resident of Bear Creek; all others were collected off the ORR and were used as references. The results of metals analysis are presented in the following table:

Metal concentrations in hair of mink from the ORR and from off-site reference samples
(mean ± standard deviation mg/kg dry weight)

Site	N	Hg	Se	As	Cd	Pb
East Fork Poplar Creek	1	104	0.69	not detected	not detected	0.33
Bear Creek	3	10.97 ± 3.42	1.88 ± .1.41	0.15 ± 0.09	0.04 ± .0.02	0.97 ± 1.28
White Oak Creek	1	8.8	1	not detected	not detected	0.37
Off site	7	5.15 ± 3.43	1.11 ± 0.25	0.22 ± 0.31	0.04 ± 0.02	0.7 ± 0.31

Radiotelemetry data on home ranges and movements were obtained for 3 mink—one each from the East Fork Poplar Creek, Bear Creek, and White Oak Creek watersheds. Mean (± standard deviation) home range for these three individuals was found to be 7.5 ± 3 km of stream. The entire home range of the East Fork Poplar Creek mink was in a highly urbanized area; it included all of upper East Fork inside the Y-12 Plant and all areas of East Fork upstream of the Oak Ridge Turnpike–Illinois Avenue intersection. The home range of the White Oak Creek mink included all of White Oak Creek from the headwater tributaries to the Clinch River, including ORNL. This individual was observed to use dens within ORNL and moved through the facility on several occasions.

4.3.3.3 Belted kingfisher survey

A field monitoring effort (Baron et al. 1996) was initiated in 1994 to evaluate population parameters and contaminant bioaccumulation by belted kingfisher on the ORR. Areas surveyed included White Oak Creek (WOC), White Oak Lake (WOL), White Oak Lake embayment, Melton Branch, Poplar Creek, portions of East Fork Poplar Creek (EFPC) (within Y-12 Plant to downstream of Lake Reality and approximately 1 mile east of the confluence of Poplar Creek), and portions of Bear Creek.

Methods. Nest burrows were monitored for nesting activity. If activity was observed, samples of feathers and eggshells were collected. In addition to specimens collected from the burrows, three carcasses of adult kingfisher were found on the ORR (two from East Fork Poplar Creek and one from White Oak Creek). These carcasses were necropsied; organs were extracted and analyzed for metals and radionuclides. Additional detail concerning methods are reported in Baron et al. (1996).

Results. During April–July of 1994, a total of 27 potential kingfisher burrows were identified on the ORR, 11 of which contained swallow nests. Twenty-five of these burrows were found on the Clinch River. One kingfisher burrow, containing a single unhatched kingfisher egg, was found on White Oak Creek [downstream of White Oak Creek Kilometer (WCK) 3.5].

One active burrow, containing a clutch of 6–7 eggs, was found on the Clinch River. This burrow was later abandoned with no sign of the eggs or the parents. Another burrow, containing 6 nestlings was located on the Clinch River approximately 12 miles upstream of all DOE contaminant outfalls. It was, therefore, considered uncontaminated. Three weeks following the initial observation of this burrow, three nestlings had fledged and three had died. Feathers were collected and analyzed.

Results of residue analysis for eggshells and feathers from nestlings are presented in Table C.18; results for adult carcasses are presented in Table C.19.

Nestling feathers collected from the burrow on the Clinch River, upstream of ORR outfalls (Table C.18), contained relatively low levels of metal and radioactive contaminants. Feathers from the carcasses of three fledglings accumulated similar concentrations of As, Cd, Pb, Se, and Hg. Mercury concentrations in feathers were approximately 1 mg/kg. Mercury concentrations found in fish downstream of the nesting site are approximately 0.04 ± 0.01mg/kg (Peterson et al. 1994). Thus, biomagnification is occurring in kingfishers foraging in up gradient areas of the ORR. However, these feather concentrations are much lower than those found in adult kingfishers on the ORR. Although selenium concentrations in nestling feathers appear high, they are similar to selenium levels in adult kingfishers (Table C.19) and mink and raccoons collected at reference locations (Ashwood et al. 1994). The fourth feather sample presented in Table C.18 represents a mixture of feathers retrieved from the three nestlings. This sample was analyzed to provide additional information on the variability of chemical concentrations within the feathers.

A burrow on the Clinch River contained fragments of egg shells and fish vertebrae from regurgitant. Analysis of the egg shells indicated that minimal metal contamination was present (Clinch River downstream, Table C.18). Another burrow on White Oak Creek contained an unhatched kingfisher egg (WOC, Table C.18). Metal concentrations in this egg were similar to that for the Clinch River egg, except for ^{137}Cs. The presence of this radionuclide in the egg indicates that the parent kingfisher bioaccumulated ^{137}Cs from foraging within White Oak Creek or a nearby surface impoundment (^{137}Cs is a typical contaminant of this stream and the impoundments).

Cesium-137, Cd, Pb, Se, and Hg were each detected in at least one kingfisher from the ORR (Table C.19). Arsenic was analyzed for but was not detected. Feathers of adult kingfishers contained elevated levles of mercury (Table C.19) relative to feathers from the nestlings (Table C.19). The greatest burdens of Hg, Se, Pb, and ^{137}Cs were observed in the bird from the White Oak Creek watershed (Bird 3; Table C.19). In contrast, cadmium levels were higher in the birds from East Fork Poplar Creek (Birds 1 and 2) than in the White Oak Creek bird (Table C.19).

4.3.3.4 Osprey reproduction

Although osprey monitoring studies are not performed by ORNL, an ongoing osprey reintroduction program is being conducted by TWRA in the Clinch/Tennessee River system. Osprey are currently nesting at three locations adjacent to the ORR: Gallaher and Solway bends (both located in subreach 1) and in Poplar Creek kilometer 1.6 (Fig. C.3). Mean reproductive success at these three osprey nests was 3 young/nest (B. Anderson, pers. comm). For comparison, mean reproductive success of osprey in North America ranges from 1.7 to 2.14 young/nest (EPA 1993b).

4.4 RISK CHARACTERIZATION FOR PISCIVOROUS WILDLIFE

Risk characterization integrates the results of the exposure assessment (Sect. 4.2) and effects assessment (Sect. 4.3) to estimate risks (the likelihood of effects given the exposure) based on each line of evidence and then applies a weight of evidence inference logic to determine the best estimate of risk to each assessment endpoint. In an ideal risk assessment there are three lines of evidence: literature-derived single chemical toxicity data (which indicate the toxic effects of the concentrations measured in site media), biological surveys of the affected system (these indicate the actual state of the receiving environment), and toxicity tests with ambient media (these indicate the toxic effects of the concentrations measured in site media). Although three lines of evidence are available to assess risks to piscivorous wildlife, all are not available for each endpoint or for all watersheds on the ORR. Single chemical toxicity data are available for all four endpoints within all four watersheds. Toxicity tests and a field survey/bioaccumulation study were performed for mink along Poplar Creek and in the Bear Creek, East Fork Poplar Creek, and White Oak Creek watersheds, respectively. Lastly, a field survey/bioaccumulation data were available for great blue heron and osprey along Poplar Creek and Melton Hill Lake and for kingfisher in the East Fork Poplar Creek and White Oak Creek watersheds.

Procedurally, the risk characterization is performed for each assessment endpoint by (1) screening all measured contaminants against toxicological benchmarks and background concentrations (if available), (2) estimating the effects of the contaminants retained by the screening analysis, (3) estimating the toxicity of the ambient media based on the media toxicity test results, (4) estimating the effects of exposure on the endpoint biota based on the results of the biological survey data, (5) logically integrating the lines of evidence to characterize risks to the endpoint, and (6) listing and discussing the uncertainties in the assessment. A detailed discussion of methods and the approach to risk characterization on the ORR is presented in Suter et al. (1995).

4.4.1 Single Chemical Toxicity Data

Exposure estimates generated by the exposure model (see Sect. 4.2.1.) produced by both point estimates of parameter values and Monte Carlo simulation represent exposure at the individual level. The exposure estimates using point estimates of parameter values at each individual sampling point are used to identify COPECs and locations that contribute significantly to risk. In contrast, the watershed-level exposure distributions generated by Monte Carlo simulation represent the likelihood that an individual within the area for which exposure is modeled will experience a particular exposure.

Two types of single chemical toxicity data are available with which to evaluate piscivore contaminant exposure: NOAELs and LOAELs. NOAELs are used to screen exposure estimates generated from point-estimates of exposure parameters; if the estimate is greater than the NOAEL, adverse effects are possible and additional evaluation is necessary (i.e., exposure modeling using Monte Carlo simulation). LOAELs are compared with the exposure distribution generated by the Monte Carlo simulation. If the LOAEL is lower than the 80th percentile of the exposure distribution, there is a >20% likelihood that individuals within the modeled location are experiencing contaminant exposures that are likely to produce adverse effects. By combining literature-derived population density data with the likelihood or probability of exceeding the LOAEL, population-level impacts may be estimated.

4.4.1.1 Screening point estimates of exposure

To determine if the contaminant exposures experienced by mink, river otter, belted kingfisher, great blue heron, and osprey on the ORR are potentially hazardous, the dietary contaminant exposure estimates (generated by using point estimates of parameter values; Tables C.7 through C.11) were compared with estimated NOAELs and LOAELs for these species (Tables C.16 and C.17). To quantify the magnitude of hazard, a hazard quotient (HQ) was calculated where HQ = exposure/NOAEL or LOAEL. Hazard quotients >1 indicate that individuals may be experiencing exposures that are in excess of NOAELs or LOAELs. Exceeding the NOAEL suggests that adverse effects are possible; exceeding the LOAEL suggests that adverse effects are likely. Hazard quotients for mink, river otter, belted kingfisher, and great blue heron on the ORR are presented along with the point estimates of exposure in Tables C.7 through C.11. It should be noted that because few data are available for specific PCB (Aroclor) mixtures, all PCBs were summed and the total was compared with Aroclor-1254 toxicity data.

A summary of the number of locations within each watershed where HQs>1 were observed is presented in Table C.20. NOAELs for mercury and PCBs were exceeded at at least one location for all endpoints in all watersheds. LOAELs for mercury and PCBs were exceeded at at least one location within each watershed for both otter and belted kingfisher (Table C.20). LOAELs for both contaminants were exceeded for all endpoints in East Fork Poplar Creek. LOAELs for osprey were exceeded only in the K-25 Site area.

The spatial distribution of contamination and potential risks to piscivores in Bear Creek, East Fork Poplar Creek, the K-25 Site, and White Oak Creek are illustrated in Figs. C.5, C.6, C.7, and C.8, respectively. These figures display the sum of the LOAEL-based HQs (e.g., sum of toxic units) for total PCBs and mercury. Sampling locations were arranged upstream to downstream (right to left); side tributaries or ponds are included in the order in which they enter the main stream.

In Bear Creek, no clear spatial pattern of risk is evident. Cumulative risk is greatest at Bear Creek kilometer (BCK) 4.5 and 0.6, respectively (Figs. C.5a–d). This lack of a distinct pattern is likely a result of differences in data from each location and not related to a source. Although data from BCK 12.4, 9.4, and 3.3 consisted of bodyburdens in stonerollers (a grazing species), data from BCK 4.5 and 0.6 consisted of bodyburdens in rock bass and red-breast sunfish (both invertebrate feeders). Mercury bodyburdens were substantially higher at BCK 4.5 and 0.6 (rock bass and red-breast sunfish) than at BCK 12.4, 9.4, and 3.3 (stonerollers; see Table C.6). The differences in bodyburdens are likely related to food habits of the fish and species-specific mercury uptake kinetics and not to a particular contaminant source.

In East Fork Poplar Creek, the pattern of cumulative risk is similar for all endpoint species; hazard declines with increasing distance from the Y-12 Plant (Fig. C.6a–d). As would be expected, mercury accounts for the majority of risk, with PCBs contributing 1/3 or less to the total. Risk is greatest near the Y-12 Plant East Fork kilometer (EFK) 24.5, plateaus from EFK 24.0 through EFK 6.3, with an additional decline observed at EFK 2.1 (Fig C.6)

At K-25, in Poplar Creek, mercury accounted for most risk (highest in the vicinity of the K-25 Site), and PCBs were the primary risk agent in Mitchell Branch at Mitchell Branck kilometer (MIK) 0.2 and at the K-901 and K-1007 ponds (Fig C.7). The pattern of cumulative risk was similar for mink (Fig. C.7a), kingfisher (Fig. C.7c), and herons (Fig. C.7d), with osprey (Fig. C.7e) and otter (Fig. C.7b) differing from the other three. The difference between the pattern of cumulative risk for osprey and otter and that for other piscivores can be attributed to dietary differences and variation in contaminant concentration according to fish size. Osprey and otter were assumed to consume both large (> 30 cm) and small (< 30 cm) fish; all other piscivores were assumed to consume only fish <30 cm in size. The generally greater contaminant concentrations in the larger fish acount for the inter-species differences in estimated exposures.

Similar to the K-25 Site, the pattern of cumulative risk in the White Oak Creek watershed was similar for mink (Fig. C.8a), kingfisher (Fig. C.8c), and herons (C.8d) but different for otters (C.8b). The pattern for osprey differed from all other species because only suitable habitat (large bodies of water; White Oak Lake and the embayment) were considered. In general, cumulative risk was greater in White Oak Creek than in its tributaries (the Northwest Tributary and Melton Branch). Mercury was the primary risk agent throughout the watershed, except at WCK 0.3 where PCBs dominated. A peak for risk to otters from PCBs was observed at White Oak Lake (WCK 1.5). This peak can be attributed to the presence of data for large fish (>30 cm); PCBs in large fish were 3 to 5 times higher than that in small fish (Table C.6).

4.4.1.2 Screening Monte Carlo simulation estimates of exposure

To incorporate the variation present in the parameters employed in the exposure model, Monte Carlo simulations were performed for exposure of each species to mercury and PCBs in each watershed. Simulations were performed on the average exposure within each watershed, weighted by the density or biomass of fish observed at each sampling location (see Sect. 4.2.1.4). The mean, standard deviation, and 80th percentile of the simulated exposures are presented in Table C.15. By superimposing NOAEL and LOAEL values on these distributions, the likelihood of an individual experiencing potentially hazardous exposures can be estimated and the magnitude of risk may be determined. Interpretation of the comparison of exposure distributions to NOAELs and LOAELs is described in the following table:

Comparison	Meaning	Risk-based interpretation
NOAEL>80th percentile of exposure distribution	Less than 20% of exposures are greater than NOAEL	Individual- and population-level adverse effects are highly unlikely
NOAEL<80th percentile<LOAEL	More than 20% of exposures are greater than NOAEL, but less than 20% of exposures are greater than LOAEL	Individuals experiencing exposures at the high end of the distribution may experience adverse effects, but those effects are unlikely to significantly contribute to effects on the ORR population
LOAEL<80th percentile of exposure distribution	More than 20% of exposures are greater than LOAEL	Effects on some individuals are likely and they may contribute significantly to effects on the ORR population

To evaluate the likelihood and magnitude of population-level effects on piscivores, literature-derived population density data (expressed as number of individuals/km of stream or pond shoreline) were combined with lengths of streams or pond shorelines for which risks were assessed to estimate the number of individuals of each endpoint species expected to be present in each watershed. Literature-derived population densities used for each endpoint species were mink: 0.6/km; river otter: 0.37/km; belted kingfisher: 0.4/km; and great blue heron: 2.3/km. It should be noted that density values for all endpoint species except the great blue heron represent the maximum values obtained from the literature (see Tables C.1, C.2, and C.3). The values for herons (see Table C.4) appear inflated and are not believed to accurately represent densities on the ORR. For this reason, the minimum value was used. Population estimates based on these densities are listed in the following table.

	Watershed length (km)			Estimated number of individuals by watershed			
Watershed	Stream length	Pond shoreline length	Total length	Mink	River otter	Belted kingfisher	Great blue heron
Bear Creek	12.4	0	12.4	7	5	5	29
East Fork Poplar Creek	24.8	0	24.8	15	9	10	57
K-25 Site	18.4	5.2	23.6	14	9	9	54
White Oak Creek	3.9	2.5	6.4	4	2	3	15
ORR total				40	25	27	155

Population risk estimates were not performed for osprey because as a T&E species, adverse effects to any individual are significant and because suitable density data were not available. Population risk estimates however were performed for otter, another T&E species. Although otter are not currently known to reside on the ORR, population estimates indicate the numbers that could reside on the ORR given available habitat and the risks that contaminant exposure could present.

The number of individuals within a given watershed likely to experience exposures greater than LOAELs can be estimated by using cumulative binomial probability functions (Dowdy and Wearden 1983). Binomial probability functions are estimated with the following equation:

$$b(y;n;p) = \binom{n}{y} p^{y} (1-p)^{n-y} \tag{9}$$

where:

y = the number of individuals experiencing exposures greater than LOAEL
n = total number of individuals within the watershed
p = probability of experiencing an exposure in excess of the LOAEL
b (y; n; p) = probability of y individuals out of a total of n, experiencing an exposure greater than LOAEL, given the probability of exceeding the LOAEL = p.

By solving Equation 4 for y = 0 to y = n, a cumulative binomial probability distribution may be generated that can be used to estimate the number of individuals within a watershed that are likely to experience adverse effects. Summing the number within each watershed across all watersheds and dividing by the total estimated ORR-wide population, the proportion of the total ORR population potentially at risk may be estimated.

Binomial probability distributions were generated only for contaminant-endpoint-watershed combinations where the percent of the exposure distribution exceeding the LOAEL was 20% to 80% (these values are reported in Table C.15). If the percent of the exposure distribution exceeding the LOAEL was <20%, it was assumed that no individuals within the area of interest were experiencing adverse effects. Conversely, if the percent of the exposure distribution exceeding the LOAEL was >80%, it was assumed that all individuals within the area of interest were experiencing adverse effects. Exposure estimates for 6 contaminant-endpoint-watershed combinations met the 20% to 80% exceedance criterion: mercury exposure to mink in East Fork Poplar Creek, mercury exposure to otter and kingfisher in Bear Creek, mercury exposure to otter in White Oak Creek, PCB exposure to otter in East Fork Poplar Creek and White Oak Creek. Figures C.9–C.14 graphically display the cumulative binomial probability distributions for each contaminant-endpoint-watershed combination. The total numbers of individuals for each endpoint species estimated to be experiencing adverse effects within each watershed and with the ORR as a whole are summarized in Table C.21.

On the basis of the Monte Carlo and binomial distribution analyses (Table C.21), the following conclusions may be made:

- Because >20% of the ORR mink population is estimated to be experiencing exposures greater than LOAEL, mercury presents a significant risk to mink. The ORR-scale risk is attributable solely to mercury risk in the East Fork Poplar Creek watershed.

- Because >1 individual is estimated to be experiencing exposures greater than LOAEL, mercury presents a significant risk to otter in the East Fork Poplar Creek, Bear Creek, and K-25 watersheds.

- Because >20% of the ORR kingfisher population is estimated to be experiencing exposures greater than LOAEL, mercury presents a significant risk to kingfisher. The ORR-scale risk is attributable to mercury exposure in all watersheds considered, except the White Oak Creek watershed.

- Because >20% of the ORR heron population is estimated to be experiencing exposures greater than LOAEL, mercury presents a significant risk to heron. The ORR-scale risk is attributable solely to mercury risk in the East Fork Poplar Creek watershed.

- Because <1 individual is estimated to be experiencing exposures greater than LOAEL, neither mercury nor PCBs presents a significant risk to osprey in the White Oak Creek or K-25 watersheds.

- Because <20% of the ORR populations of mink, kingfisher, or herons are estimated to be experiencing exposures greater than LOAEL, PCBs do not present a significant risk to these populations.

- Because 1 individual is estimated to be experiencing exposures greater than LOAEL, PCBs present a significant risk to otter in the East Fork Poplar Creek and White Oak Creek watersheds.

4.4.1.3 Effects of retained contaminants

Mercury. For the purposes of this assessment, it is assumed that 100% of the mercury to which wildlife are exposed consists of methyl mercury.

Both the avian NOAEL and LOAEL are based upon a study of mallard ducks fed methyl mercury for three generations (Heinz 1979). The study was considered to represent a chronic exposure, and a subchronic-chronic correction factor was not employed. The only dose level administered, 0.064 mg/kg/d, caused hens to lay fewer eggs, lay more eggs outside of the nest box, and produce fewer ducklings. This dose level was considered to be an LOAEL. Because an experimental NOAEL was not established, the NOAEL was estimated by using LOAEL-NOAEL correction factor of 0.1. On the basis of the results of Heinz (1979), kingfisher experiencing exposure greater than or equal to LOAEL are likely to display impaired reproduction.

The mink and otter NOAELs and LOAELs for mercury were derived from a study of mink fed methyl mercury for 93 d (Wobeser et al. 1976). Although consumption of 0.247 mg/kg/d methyl mercury resulted in significant mortality, weight loss, and behavioral impairment, no effects were observed at the 0.15 mg/kg/d exposure level. The 0.15 mg/kg/d exposure was considered to be an NOAEL, and the 0.247 mg/kg/d exposure was considered to be an LOAEL. Because the study was subchronic in duration (<1 year), a subchronic-chronic correction factor was applied (NOAEL = 0.015, LOAEL = 0.025). Based on the results of Wobeser et al. (1976), shrews, mice, and fox experiencing exposure greater than or equal to LOAEL are likely to display increased mortality, weight loss, and behavioral impairment.

PCBs. The otter NOAEL and LOAEL for PCBs was derived from a study of mink fed Aroclor 1254 for 4.5 months (Aulerich and Ringer 1977). Although consumption of 0.69 mg/kg/d Aroclor 1254 reduced kit survivorship, no effects were observed at the 0.14 mg/kg/d exposure level. The 0.14 mg/kg/d exposure was considered to be a chronic NOAEL; the 0.69 mg/kg/d exposure was considered to be a chronic LOAEL Based on the results of Aulerich and Ringer (1977), mink experiencing exposure greater than or equal to LOAEL are likely to display reduced kit survivorship.

4.4.2 Mink Toxicity Tests

To evaluate the nature and magnitude of toxicity of contaminants in fish from the Clinch River to mink, fish were collected from the Poplar Creek embayment, formulated into mink diets, and fed to mink. Mink were fed five different diets. Ten mink (2 males, 8 females) were fed each diet for 7 months; starting approximately 3 months before breeding, extending to 6 weeks postpartum. Bioaccumulation, growth, histopathology, and reproduction were recorded. Significant effects were observed only among mink fed diet E. These effects included statistically significant reductions in body weights of adult females and male kits and in litter size. Percent reductions were 20% and 17% for adult female and male kit weights, respectively, and 37.7% for litter size. A detailed discussion of the methods and results of the mink toxicity test is presented in Appendix E.

To evaluate how the exposures experienced by mink in the toxicity test compare with those modeled for mink on the ORR, Monte Carlo simulations of mink exposure were performed using the concentrations of mercury and PCB 1260 measured in the five diets (Tables F.1 and F.5). Parameter values in the exposure model were as follows: body weight = 0.974 ± 0.202 kg; food ingestion rate = 0.137 kg/d. Results of the exposure simulation are presented in Table C.22. Estimated exposures to mercury and PCB 1260 in diet A were below both the NOAEL and LOAEL. For diets C, D, and E, mercury exposures exceeded the NOAEL (i.e., >20% of distribution exceeded the NOAEL). Diets D and E also exceeded the LOAEL for mercury, with diet D marginally exceeding and diet E significantly exceeding the LOAEL (Table C.22). Exposures to PCB 1260 in diets B, C, D, and E were greater than both the NOAEL and LOAEL (Table C.22). These data suggest that toxicity in diet E was a result of the combined effects of PCBs and mercury and that impaired reproduction should have been evident in diets B, C, D, and E, not just diet E.

The mean mercury exposure in diet D (0.022 mg/kg/d; the highest exposure at which no adverse effects were observed) was less than the LOAEL; the mean exposure in diet E was 0.033 mg/kg/d (the lowest exposure at which adverse effects were observed). This suggests that the estimated mercury LOAEL for mink (0.025 mg/kg/d) is appropriate and representative of toxicity of mercury to mink on the ORR.

Estimating that toxicity should be observed in four diets but actually observing it only in the highest concentration suggests that the LOAEL for PCBs used in this assessment is too low and is not representative of the toxicity of the PCBs present on the ORR. ORR-specific NOAEL and LOAEL for PCBs (represented by PCB 1260) of 1.7 mg/kg/d and 3 mg/kg/d can be derived from the toxicity test exposure estimate for diets B and E (Table C.22). The ORR-specific NOAEL and LOAEL for mercury would be 0.022 mg/kg/d (diet D) and 0.033 mg/kg/d (diet E), respectively.

The mercury exposure estimate for mink in the watershed where the highest exposure estimate was obtained (East Fork Poplar Creek; mean = 0.031 ± 0.006 mg/kg/d) is approximately equivolent to that observed in diet E (Table C.22), the diet where significant reproductive effects were observed. The estimated total PCB exposure in East Fork Poplar Creek (mean = 0.17 ± 0.10 mg/kg/d) is less than that in all test diets except the control diet (diet A; Table C.22).

Several conclusions may be drawn from these toxicity test data.

- Comparisons of exposure estimates to NOAELS and LOAELs suggest that effects observed in diet E are attributable to PCBs and mercury.

- Because the estimated LOAEL used in this assessment is comparable to the exposure level that resulted in adverse effects, estimated mercury LOAEL for mink is appropriate and representative of toxicity of mercury to mink on the ORR.

- Given the difference between predicted and observed toxicity from the test diets, the PCB LOAEL used in this assessment is too low and does not reflect toxicity observed among mink exposed to Poplar Creek fish.

- Consumption of a diet consisting of 75% fish from the Poplar Creek produces reproductive impairment in mink.

- An LOAEL for mink on the ORR fish of 3 mg/kg/d can be derived. Using the ORR-specific value rather than the literature value, PCBs would not be expected to cause toxic effects on survival, growth, or reproduction of mink in any ORR watershed.

Differences between the results of the toxicity tests and modeled exposures for mink on the ORR may result for several reasons.

- Differences in fish size. Exposure estimates for mink on the ORR were based solely on contaminant concentrations in fish most likely to be consumed by mink (i.e., ≤30 cm in length). Because of the large volume of fish needed to formulate the test diets and to feed mink for 7 months, the majority of fish used in the toxicity test were large (mean = 39 cm, standard deviation = 17 cm). Because body burdens of bioaccumulative contaminants like mercury and PCBs are generally greater in older, larger individuals, concentrations in the toxicity test diets were higher than that in fish expected to be consumed by mink on the ORR.

- Differences in fish species. More than 50% of the fish used in the test diets were sucker, carp, or buffalo (Table E.1). None of these species were included in the data used to estimate mink exposure on the ORR. Because fish species accumulate contaminants differently (as seen in stonerollers and sunfish in Bear Creek), variation in species included in test diets and modeled diets may have contributed to the differences in results.

- Differences in the PCB congener composition on the ORR vs. that used in the literature toxicity test. PCBs measured in environmental samples are not Aroclors. Aroclors are specific mixtures of PCB congeners as manufactured. The environmental measurements of PCBs used in the Poplar Creek toxicity test are called PCB 1254 or PCB 1260 because they have ~54% or 60% chlorine. The congener makeup of PCB 1254 or 1260 from the Poplar Creek fish is likely to be very different from the congener makeup of Aroclor 1254 or 1260. More importantly, PCB toxicity is generally correlated with individual congeners, not with Aroclors.

4.4.3 Biological Surveys

4.4.3.1 Great blue heron reproduction study

To determine if contaminants from the ORR are adversely affecting great blue heron, bioaccumulation of contaminants and reproductive success of herons at two colonies located adjacent to the ORR and two colonies located >10 km from the site was monitored. Data were collected from each nest colony between 1992 and 1994. A detailed discussion of these data are presented in Appendix F.

Analyses indicated statistically significantly elevated levels of Cr, Hg, and PCBs in eggs (Tables F.2 and F. 4), Hg in feathers and liver of chicks (Table F.3), and PCBs in fat (Table F.5), liver (Table F.6), and muscle (Table F.7) of chicks from samples from the ORR as compared with data from the off-site locations. King et al. (1991) report that 0.5 to 1.5 mg/kg mercury concentrations in bird eggs may are associated with reproductive failure; Harris et al. (1993) report a NOAEL for hatching success of Forster's Tern eggs to be 7 mg/kg. Mean concentrations of mercury (0.17 mg/kg) and PCBs (1.68 mg/kg) in great blue heron eggs from within 3 km of the ORR are substantially below both levels, suggesting that reproductive effects from mercury or PCBs in eggs are unlikely.

Despite elevated contaminant burdens, the mean number of eggs/nest, number of chicks/nest, egg weight, and eggshell thickness did not differ between colonies within 3 km of the ORR and those >10 km away (Table F.8). In addition, the number of eggs/nest observed at the colonies within 3 km of the ORR (3.5 eggs/nest) and at the colonies >10 km away (3.2 eggs/nest) are comparable to those reported in EPA (1993b) (3.16 to 4.37 eggs/nest).

The results of the great blue heron reproduction survey indicate that herons are experiencing higher contaminant exposures at the colonies adjacent to the ORR. However, this exposure is not sufficiently high to result in adverse effects to the populations at the studied colonies. [Note:five great blue heron colonies currently exist around the margins of the ORR (R. Brewer, pers. comm.). Bioaccumulation and reproductive success have only been evaluated for two of these five colonies.]

4.4.3.2 Mink survey

Results of the mink survey (see Sect. 4.3.3) indicate that mink are present on the ORR, have large home ranges, and do not avoid the industrial facilities on the ORR. The methods employed in the study do not allow numbers or density of mink to be determined. Although mercury levels in hair of mink were statistically significantly greater on the ORR than in reference samples, no statistically significant differences were observed for As, Cd, Pb, or Se.

4.4.3.3 Kingfisher survey

Results of the kingfisher survey indicate that contaminants are being accumulated by both juveniles and adult birds. Although contaminants in eggshells and nestling feathers indicate exposure, there is insufficient information to evaluate the toxicological significance of this contamination.

The toxicological significance of the tissue concentrations in adult kingfisher was evaluated by comparison of burdens and effects levels reported in other bird species. This comparison suggests that it is unlikely that cadmium or lead in kingfisher from the ORR contribute significantly to risk. Leach et al. (1979) observed a 50% reduction in egg production among chickens consuming a diet containing 48 mg/kg cadmium. Cadmium concentrations in the livers and kidneys of these birds were 100 mg/kg and 40 mg/kg, respectively. Cadmium concentrations in healthy birds from unpolluted areas ranged from 0.1 to 32 mg/kg in liver and 0.3 to 137 mg/kg in kidney (Furness 1996). In comparison, maximum cadmium concentrations in the kidney (4.04 mg/kg) and liver (0.95 mg/kg) of kingfisher collected from the ORR watershed were significantly less than concentrations associated with reproductive impairment and at the low end of the ranges observed among healthy birds from unpolluted areas. Maximum lead concentrations in the kidney (0.42 mg/kg) and liver (0.4 mg/kg) of ORR kingfisher were approximately one order of magnitude lower than the minimal level at which overt toxicity is observed in birds (3 to 6 mg/kg; Franson 1996), suggesting that lead accumulation is unlikely to be contributing to risks to kingfishers on the ORR.

In contrast to Cd and Pb, Se and Hg burdens may present a hazard to kingfishers on the ORR. The maximum concentration of selenium observed in the liver of kingfisher from the ORR (7.5 mg/kg) is less than the 10 mg/kg toxicity threshold recommend by Heinz (1996) but greater than the 3 mg/kg reproductive impairment threshold, suggesting the potential for adverse effects on reproduction. Mercury concentrations of 49 to 125 mg/kg in kidney and 4.6 to 91 mg/kg in liver have been reported for free-living birds found dead or dying (Thompson 1996). Nephrotoxicity and kidney lesions occur in birds at mercury concentrations in kidney of 5 to 13 mg/kg (Nicholson and Osborn 1983). Although the maximum observed mercury concentrations in the kidney (26.8 mg/kg) and liver (17.6 mg/kg) of ORR kingfisher were generally lower than concentrations associated with mortality, the kidney concentration exceed nephrotoxic levels, suggesting that mercury accumulation may be causing kidney damage to kingfishers on the ORR.

4.4.3.4 Osprey survey

Mean reproductive success at the three osprey nests adjacent to the ORR was 3 young/nest (B. Anderson, pers. comm). For comparison, mean reproductive success of osprey in North America ranges from 1.7 to 2.14 young/nest (EPA 1993b). These data suggest that osprey near the ORR are not being adversely affected by contaminants.

4.4.4 Weight of Evidence

4.4.4.1 Mink

Three lines of evidence—literature toxicity data, toxicity test data, and field surveys—were available to evaluate risk to mink. Comparison of exposure estimates with LOAELs indicates a significant risk from mercury in East Fork Poplar Creek and consequently to the ORR mink population (Table C.21). PCBs are not estimated to contribute to risks to mink

Toxicity test results indicate that consumption of a diet consisting primarily of fish from the Poplar Creek embayment adversely affects mink reproduction. Mercury exposure experienced by mink at the highest dose level was comparable with that estimated for mink in East Fork Poplar Creek. This dose level was associated with impaired reproduction. PCB exposures experienced by mink on the ORR were all less than exposures experienced by mink in the toxicity test.

Limited data from field surveys indicate that although mink are present on the reservation, the health and abundance of the population is unknown (the trapping methods that were employed, although suitable for capturing animals for radiotelemetry purposes, were not adequate to estimate population abundance and density). Mink on the ORR have large home ranges, make use of the creeks within the industrial facilities, and have higher mercury concentrations in hair than do mink from off-site locations. Cadmium concentrations in hair were not different between mink on the ORR and those from off-site locations.

The weight of evidence suggests that mercury presents a hazard to mink in East Fork Poplar Creek and consequently to a significant portion (30%) of the ORR-wide mink population. Risks to mink from PCBs are not significant (Table 4.1).

4.4.4.2 River otter

Two lines of evidence—literature toxicity data and the PCB and mercury NOAEL and LOAEL derived from the Poplar Creek mink toxicity test—were available to evaluate potential risk to river otter. As a T&E species, potential adverse effects to any individual are significant. Comparison of exposure estimates with literature-derived LOAELs indicates a significant risk from mercury in Bear Creek, East Fork Poplar Creek, and the K-25 Site area and from PCBs in the East Fork Poplar Creek, and White Oak Creek watersheds.

Using Equation 3 and the ORR-specific NOAELs and LOAELs for PCBs and mercury for mink (see Sect. 4.4.2), ORR-specific values for otter were estimated to be as follows:

Analyte	Estimated NOAEL (mg/kg/d)	Estimated LOAEL (mg/kg/d)
PCBs	0.92	1.8
Mercury	0.013	0.02

Comparison of the ORR-specific PCB LOAEL to the exposure distributions presented in Table C.15 indicate that there is a <1% likelihood of individuals in any watershed experiencing PCB exposure greater than ORR-specific LOAEL. Therefore, based upon the results of the Poplar Creek mink toxicity test, PCBs are unlikely to present a significant risk to the ORR-wide otter population.

The ORR-specific mercury LOAEL is somewhat higher but still comparable to the literature-derived LOAEL (0.015 mg/kg/d; Table C.16). Therefore, the results of the Poplar Creek mink toxicity test do not significantly alter the conclusions derived from evaluation of the literature-based toxicity data.

Evaluation of the potential risks to a future ORR-wide population of otter indicates that mercury presents a risk in all watersheds on the ORR (Table C.21). Because the river otter is a state threatened species, effects to any individual is significant. Therefore the weight of evidence suggests that mercury is significant risk to individual river otter that may occupy the ORR in the future (Table 4.1).

4.4.4.3 Belted kingfisher

Two lines of evidence, literature toxicity data and biomonitoring data, were available to evaluate potential risk to belted kingfisher. Comparison of exposure estimates to LOAELs indicates a significant risk from mercury in all watersheds except White Oak Creek (Table C.15). This translates into a risk to 81.5% of the ORR-wide kingfisher population (Table C.21). The limited biomonitoring data indicate that kingfisher on the ORR (particularly in the White Oak Creek area) are accumulating mercury to potentially nephrotoxicty levels. The weight of evidence suggests mercury in all

Table 4.1. Summary of risk characterization for piscivores on the ORR

Species	Evidence	Result	Explanation
Mink	Literature toxicity data	+	Comparison of exposure estimates to LOAELs indicates a significant risk from mercury in East Fork Poplar Creek and consequently to the ORR mink population . PCBs are not estimated to contribute to risks to mink
	Biological surveys	±	Mink are present on the ORR, but abundance and density are unclear but clearly not high. While Hg in hair from mink from ORR is elevated relative to references, As, Cd, Pb, and Se are not..
	Medium toxicity tests	+	Toxicity test results indicate that consumption of a diet consisting primarily of fish from the Poplar Creek embayment adversely affects mink reproduction. Mercury exposure experienced by mink at the highest dose level was comparable to that estimated for mink in East Fork Poplar Creek. This dose level was associated with impaired reproduction. PCB exposures experienced by mink on the ORR were all less than exposures experienced by mink in the toxicity test.
	Weight of evidence	+	The weight of evidence suggests that mercury presents a hazard to mink in East Fork Poplar Creek and consequently to the ORR-wide mink population. Risks from PCBs are not significant.
River otter	Literature toxicity data	+	Comparison of exposure estimates to literature-derived LOAELs indicates that individuals may be at risk from mercury in Bear Creek, East fork Poplar Creek, and the K-25 area and from PCBs in the East Fork Poplar Creek, and White Oak Creek watersheds.
	Biological surveys	NA	
	Medium toxicity tests	+	Use of the ORR-specific PCB LOAEL generated from the mink toxicity test indicates that PCBs on the ORR are unlikely to adversely affect otter. The ORR-specific mercury LOAEL was comparable to the literature-based LOAEL. Conclusions concerning risk to otter from mercury are therefore unaffected by the results of the mink toxicity test.
	Weight of evidence	+	Because the river otter is a state threatened species, effects to any individual are significant. Consequently, mercury presents a significant risk to a individuals and potential ORR-wide otter population.
Belted kingfisher	Literature toxicity data	+	Comparison of exposure estimates to LOAELs indicates a significant risk from mercury in all watersheds except White Oak Creek. This translates into a risk to 81.5% of the ORR-wide kingfisher population
	Biological surveys	+	The limited biomonitoring data indicate that kingfisher on the ORR (particularly in the White Oak Creek area), are accumulating mercury to potentially nephrotoxicty levels.
	Medium toxicity tests	NA	
	Weight of evidence	+	The weight of evidence suggests mercury in all watersheds presents a significant risk to the ORR-wide belted kingfisher population. Risks from PCBs are not significant

Table 4.1 (continued)

Species	Evidence	Result	Explanation
Great blue heron	Literature toxicity data	+	Comparison of exposure estimates to LOAELs indicates a significant risk from mercury in East Fork Poplar Creek. This translates into a risk to 36.8% of the ORR-wide heron population.
	Biological surveys	-	Biomonitoring data at 2 of 5 colonies around the ORR indicate that while PCBs and mercury are being accumulated in heron eggs and chicks, the levels in eggs are lower than levels reported in the literature to produce adverse effects. Observations of the two of the five colonies adjacent to the ORR indicate that reproduction is not reduced relative to colonies > 10 km from the ORR.
	Medium toxicity tests	NA	
	Weight of evidence	±	Contaminant bioaccumulation and reproductive success are unknown at the three additional colonies adjacent to the ORR; the primary foraging locations for herons at the two studied colonies is unknown. Because herons can travel long distances in search of food, they are likely to forage at offsite as well as on-site locations, reducing both the exposure they receive and the risk they experience. If birds from the unstudied colonies forage more extensively on the ORR, they may experience greater risk. Due to the high risk estimated for mercury exposure on the ORR, the lack of data for three of five heron colonies adjacent to the ORR, and uncertainty as to where birds from the five ORR colonies forage, a conclusion concerning whether or not great blue heron on the ORR are at risk cannot be made
Osprey	Literature toxicity data	-	Comparison of exposure estimates to LOAELs indicates a no significant risk from mercury or PCBs in any area on the ORR that provides suitable habitat (i.e., White Oak Lake and embayment and the K-25 area)
	Biological surveys	-	Biomonitoring data indicates that the reproductive success at osprey nests adjacent to the ORR (along Melton Hill Lake and in Poplar Creek) is greater than the average observed in the U.S).
	Medium toxicity tests	NA	
	Weight of evidence	-	The weight of evidence suggests mercury and PCB do not present a significant risks to osprey on or near the ORR

+ 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.
NA indicates that the information is not available.

watersheds presents a significant risk to the ORR-wide belted kingfisher population. Risks from PCBs are not significant (Table 4.1).

4.4.4.4 Great blue heron

Two lines of evidence—literature toxicity data and biomonitoring data—were available to evaluate ecological risk to great blue heron. Comparison of exposure estimates with LOAELs indicates a significant risk from mercury in East Fork Poplar Creek (Table C.15). This translates into a risk to 36.8% of the ORR-wide heron population (Table C.21). Biomonitoring data at 2 of 5 colonies around the ORR indicate that although PCBs and mercury are being accumulated in heron eggs and chicks, the levels in eggs are lower than levels reported in the literature to produce adverse effects. Observations of the 2 of the 5 colonies adjacent to the ORR indicate that reproduction is not reduced relative to colonies >10 km from the ORR. Contaminant bioaccumulation and reproductive success are unknown at the three additional colonies adjacent to the ORR. Additionally, the primary foraging locations for herons at the two studied colonies is unknown. Because herons can travel long distances in search of food (>15 km), they are likely to forage at off-site as well as on-site locations, reducing both the exposure they receive and the risk they experience. If birds from the unstudied colonies forage more extensively on the ORR, they may experience greater risk. Because of the high risk estimated for mercury exposure on the ORR, the lack of data for three of five heron colonies adjacent to the ORR, and uncertainty as to where birds from the five ORR colonies forage, a conclusion concerning whether or not great blue heron on the ORR are at risk cannot be made (Table 4.1).

4.4.4.5 Osprey

Two lines of evidence—literature toxicity data and biomonitoring data—were available to evaluate ecological risk to osprey. As a T&E species, any adverse impact to individual osprey is significant. Comparison of exposure estimates with LOAELs indicates no significant risk from mercury or PCBs in any area on the ORR that provides suitable habitat (i.e., White Oak Lake and embayment and the K-25 Site area; Table C.15). Biomonitoring data indicates that the reproductive success at osprey nests adjacent to the ORR (along Melton Hill Lake and in Poplar Creek) is greater than the average observed in the United States. The weight of evidence suggests mercury and PCB do not present a significant risks to osprey on or near the ORR (Table 4.1).

4.4.5 Quality and Completeness of Data

The fish bioaccumulation data used in the piscivore assessment was considered to be of high quality. All data were obtained directly from the principal investigators, who collected the data. Because these persons were available to answer questions concerning interpretation of their data, few assumptions concerning sampling methods, measurements, sampling locations, and so forth were necessary.

The most severe limitation of the data used in this assessment relates to contaminants analyzed for in fish tissue. Although data for PCBs and mercury were available at all locations, data for other contaminants were not. Consequently, reservation-wide scale risks that these contaminants may present cannot be evaluated.

4.4.6 Uncertainties Concerning Risks to Piscivorous Wildlife

4.4.6.1 Bioavailability of contaminants

Bioavailability of contaminants was assumed to be comparable between fish collected from the ORR and the diets used in the literature toxicity tests. Because bioavailability may not be comparable, exposure estimates based on the contaminant concentrations in ORR fish may either under- or overestimate the actual contaminant exposure experienced.

4.4.6.2 Extrapolation from published toxicity data

Although published toxicity studies are available for mink, no published data exists for otter, kingfisher, or great blue heron. To estimate toxicity of contaminants at the site, it was necessary to extrapolate from studies performed on test species (i.e., mallard ducks, ring-necked pheasant, rats). Although it was assumed that toxicity could be estimated as a function of body size, the accuracy of the estimate is not known. For example, osprey or herons may be more or less sensitive to contaminants than ducks or pheasants as a result of factors other than metabolic rate.

Additional extrapolation uncertainty exists for those contaminants for which data consisted of only LOAELs or tests were subchronic in duration. For either case, an uncertainty factor of 10 was employed to estimate NOAELs or chronic data. The uncertainty factor of 10 may either over- or underestimate the actual LOAEL-NOAEL or subchronic-chronic relationship.

Toxicity of PCBs to piscivorous wildlife was evaluated by using toxicity data from studies on Aroclor 1254. Because toxicity of PCB congeners can vary dramatically, the applicability of data for Aroclor 1254 is unknown. Comparison of the results of the mink toxicity test results and the estimated LOAELs for mink suggests the Aroclor 1254 data do not accurately reflect (i.e., overestimate) the toxicity of the PCB mixture present in Clinch River fish.

4.4.6.3 Variable food consumption

Although food consumption by piscivorous wildlife was assumed to be similar to that reported for the same or related species in other locations, the validity of this assumption cannot be determined. Food consumption by wildlife on the ORR may be greater or less than that reported in the literature, resulting in either an increase or decrease in contaminant exposure.

4.4.6.4 Single contaminant tests vs exposure to multiple contaminants in the field

Although piscivores on the ORR are exposed to multiple contaminants concurrently, published toxicological values only consider effects experienced by exposures to single contaminants. Because some contaminants to which wildlife are exposed can interact antagonistically, single contaminant studies may overestimate their toxic potential. Similarly, for those contaminants that interact additively or synergistically, single contaminant studies may underestimate their toxic potential.

4.4.6.5 Inorganic forms or species present in the environment

Toxicity of metal species varies dramatically depending upon the valence state or form (organic or inorganic) of the metal. For example, arsenic (III) and methyl mercury are more toxic than arsenic (V) and inorganic mercury, respectively. The available data on the contaminant concentrations in media do not report which species or form of contaminant was observed. Because benchmarks used for comparison represented the more toxic species/forms of the metals (particularly for arsenic and mercury), if the less toxic species/form of the metal was actually present in fish from the Clinch River or Poplar Creek, potential toxicity at the sites may be overestimated.

4.4.6.6 Contaminant concentrations in aquatic prey

Although fish are the primary prey of piscivores, other aquatic prey are also consumed. It was assumed that the contaminant concentration in fish was representative of that in other aquatic prey. Because of the different life histories of other aquatic prey (i.e., amphibians, crayfish, benthic invertebrates), their contaminant burdens are likely to differ from that in fish. Therefore, assuming comparability to fish may either over- or underestimate exposure.

4.4.6.7 Fish size selection

Data concerning the sizes of fish consumed by piscivores were obtained from the literature. Because fish sizes consumed by piscivores on the ORR may differ from that reported in the literature, exposure may be overestimated or underestimated.

4.4.6.8 Monte Carlo simulation

To perform Monte Carlo simulations, distributions must be assigned to parameters. Because wildlife are mobile, the mean of the contaminant concentration is likely to best represent their exposure. For this report, the contaminant concentrations in fish were assumed to be normally distributed. In future revisions of this report, goodness-of-fit analyses will be performed to determine which distribution best fists the data.

The literature values used for body weights of each endpoint are nationwide values, which may overestimate or underestimate the body weight of species found at the site. Similarly the proportion of fish and aquatic prey in mink diet were derived from data from northern locations (e.g., Michigan, Canada). The applicability of these data to the percentage of fish and aquatic prey consumed by mink in Tennessee is unknown.

4.4.6.9 Estimated whole fish concentrations

Contaminant concentrations in whole fish were estimated by using contaminant-specific fillet-to-whole fish ratios. Data to generate ratios were available only for PCBs in largemouth bass and channel catfish from the Clinch River. Ratios for metals were obtained from spotted bass samples from near the Portsmouth Gaseous Diffusion Plant in Ohio. Applicability of these ratios to species other than those from which they were developed is unknown. Similarly, applicability of metal ratios from Ohio spotted bass to fish on the ORR is unknown.

5. ASSESSMENT OF RISKS TO VERMIVORES, HERBIVORES, AND PREDATORS ON THE OAK RIDGE RESERVATION

Numerous, significant changes have been made throughout this section. To facilitate the flow of the document, they are summarized below but are not specifically identified in the text. The major changes in this section include the following:

- use of ORR-specific soil-plant, soil-earthworm, and soil–small mammal uptake factors,
- inclusion in assessment of predators red fox and red-tailed hawks, and
- use of updated benchmarks that reflect regulator comments concerning scaling factors.

5.1 PROBLEM FORMULATION

On the ORR, although most wide-ranging wildlife species reside primarily in the uncontaminated terrestrial habitats outside of source OUs (the terrestrial integrator OU; Suter et al.1995), they may also use those source OUs on which suitable habitat is present. As discussed in Chap. 3, the degree to which a source OU is used (and therefore the risk that it may present) is dependant upon the availability of suitable habitat on the OU. OUs with little or no habitat will experience little use (and will present minimal risk); those with considerable habitat are likely to experience considerable use (and depending upon the degree of contamination, may present significant risks).

Although *individuals* may experience adverse effects through exposures received at source OUs, the primary concern for ecological risk assessment is for effects at the population-level (except for T&E species, for which effects to individuals are a critical concern). To evaluate effects to the reservation-wide wildlife populations, habitat suitability and population density on the ORR and within OUs must be considered. A general, six-step, habitat-based approach was developed that is applicable to all wildlife species on the ORR. The approach is outlined here.

1. Individual-based contaminant exposure estimates are generated for each OU by using the generalized exposure model outlined in Sample and Suter (1994). Data used for the exposure estimate may consist of modeled data or actual measured concentrations in food, water, or soil from the OU.

2. Contaminant exposure estimates are compared with NOAELs or LOAELs to determine the magnitude and nature of effects that may result from exposure at the OU. If the exposure estimate is greater than LOAEL, then individuals at the OU may experience adverse effects.

3. Availability and distribution of habitat on the ORR and within each OU is determined by using the ORR habitat map presented in Washington-Allen et al. (1995; see Table B.2).

4. Habitat requirements for the endpoint species of interest (from Table B.1) are compared with the ORR habitat map to determine the area of suitable habitat on the ORR and within OUs (Tables B.4, B.5, and B.6).

5. The area of suitable habitat on the ORR and within OUs is multiplied by population density values for the selected endpoints to generate estimates of the reservation-wide population and the numbers of individuals expected to reside within each OU. Population density values may be derived from the literature or may consist of site-specific data.

6. The number of individuals for a given endpoint species expected to be receiving exposures greater than LOAELs for each measured contaminant is totaled. This is performed by using the OU-specific population estimate from step 5 and the results from step 2. This number is then compared with the reservation-wide population to determine the proportion of the reservation-wide population that is receiving hazardous exposures. By using the 20% criterion outlined in Suter et al. (1995), if the proportion of the reservation-wide population receiving hazardous exposures ≥20%, then an adverse population-level effect is assumed to be present.

In this assessment, exposure estimates were calculated and risks considered for 9 OUs on the ORR: the Bear Creek OU 2, Lower and Upper East Fork Poplar Creek, 3 OUs at K-25 (K-1407, K-1420, K-1414), WAGs 1 and 6, and the South Campus Facility (SCF). In addition, results from completed risk assessments on the Bear Creek Valley OU, Chestnut Ridge OU 2, and WAGs 2 and 5 were included. Locations of these OUs on the ORR are presented in Fig. G.1 (Appendix G).

5.1.1 Ecological Assessment Endpoints

5.1.1.1 Assessment endpoints

The following assessment endpoints were selected for the assessment of risks to herbivorous, vermivorous (e.g., worm-consuming), and predatory wildlife: toxicity to white-tailed deer (*Odocoileus virginianus*) or wild turkey (*Meleagris gallopavo*) (as representative herbivores), American woodcock (*Scolopax minor*) or short-tailed shrew (*Blarina brevicauda*) (as representative vermivores), red fox (*Vulpes fulva*) or red-tailed hawk (*Buteo jamaicensis*) resulting in a reduction in population abundance or production. Deer, turkey, woodcock, red fox, and red-tailed hawk are assessment endpoints agreed to be appropriate for the ORR by the FFA parties (Suter et al. 1995). The shrew is identified as a measurement endpoint in Suter et al. (1995). It is selected here as a surrogate for the several T&E shrew species listed in Suter et al. (1995). The criteria for selection of the entities are those recommended by the EPA (Risk Assessment Forum 1992), plus considerations of scale and practical considerations.

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. Although the primary concern for wildlife is effects at the population level, due to limited population sizes, effects to individuals are critical for T&E species. Because none of the selected endpoint species is a T&E species, the appropriate endpoint properties for populations of endpoint species are abundance and production.

Finally, the level of effects on these properties of the endpoint entities that is considered to be potentially significant is 20% as agreed by the FFA parties (Suter et al. 1995). This level is consistent with current regulatory practice.

5.1.1.2 Measurement endpoints

Three basic types of effects data are potentially available to serve as measurement endpoints: results of biological surveys, toxicity tests performed with fish from the ORR, and literature-derived toxicity test results for chemicals found on the ORR. Measurement endpoints for each assessment endpoint are presented here.

- **White-tailed deer**
  - Biological Survey Data—None.
  - Media Toxicity Data—None.

— Single Chemical Toxicity Data—These data consist of chronic toxicity thresholds for contaminants of concern in mammals with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **Wild turkey**
  — Biological survey data—None.
  — Media toxicity data—None.
  — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in birds with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **American woodcock**
  — Biological survey data—None.
  — Media toxicity data—None.
  — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in birds with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **Short-tailed shrew**
  — Biological survey data—None.
  — Media toxicity data—None.
  — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in mammals with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **Red fox**
  — Biological survey data—None.
  — Media toxicity data—None.
  — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in mammals with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **Red-tailed hawk**
  — Biological survey data—None.
  — Media toxicity data—None.
  — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in mammals with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

5.1.2. Ecological Conceptual Model

The ecological conceptual model graphically represents the relationships between the contaminant sources and the endpoint receptors. It integrates the information in the other subsections of the hazard identification and presents them graphically. It is not intended to show all of the possible sources, routes of transport, modes of exposure, or effects. Rather, it includes the only identified CERCLA source, the receptors that are designated as assessment endpoint species or communities, and the major routes that result in exposure to contaminants from the ORR.

The conceptual model for exposure of herbivores, vermivores, and predators to contaminants is presented in Fig. 5.1. Components of this model include plants and soil/litter invertebrates that reside on OUs on the ORR, the herbivorous and vermivorous wildlife that feed on them, and the predators that feed on the herbivores and vermivores. Plants and soil/litter invertebrates are exposed to contaminants from surface soil. Contaminants are bioaccumulated in lower trophic levels (i.e., plants or invertebrates) and transferred to higher trophic levels (i.e., herbivores, vermivores, predators). Herbivorous and vermivorous wildlife are exposed to contaminants through consumption of plants and soil/litter invertebrates, respectively. Predators are exposed to contaminants through consumption of herbivores and vermivores. All three wildlife endpoint groups are also exposed to contaminants through incidental ingestion of contaminated soil.

5.2 EXPOSURE ASSESSMENT FOR HERBIVOROUS, VERMIVOROUS, AND PREDATORY WILDLIFE

Potential routes of exposure for wildlife inhabiting the ORR include ingestion of food (either plant or animal) and surface water. In addition, some species may ingest soil incidentally while foraging or purposefully to meet nutrient needs. The total exposure experienced by terrestrial wildlife is represented by the sum of the exposure from each individual source (e.g., vegetation, earthworms, small mammals, soil, water).

The primary pathway of contaminant exposure is through oral ingestion of food and soil. Consumption of surface water, in most cases, contributes minimal contaminant exposure. Exposure from ingestion of surface water within the OU will not be included in the total exposure estimation. The surface water contaminant concentrations available in the ORR database will be compared with the water consumption benchmarks for each endpoint in the future revision of this document. Contaminant exposures were estimated for white-tailed deer, wild turkey, short-tailed shrew, American woodcock, red fox, and red-tailed hawk.

5.2.1 Exposure Through Oral Ingestion of Food and Soil

Exposure estimates were calculated for all contaminants detected at all ORR sampling locations within an OU by using Equation 1 from Sect. 4.2.1. The 95% UCL is used in exposure estimates.

5.2.1.1 Life history parameters for endpoint species

Species-specific parameters for herbivorous and vermivorous endpoints necessary to estimate exposure through the use of the above equation are listed in Tables G.1 to G.6. Habitat requirements and densities for each endpoint will be used to determine the percentage of the population which is experiencing unacceptable levels of contaminant exposure.

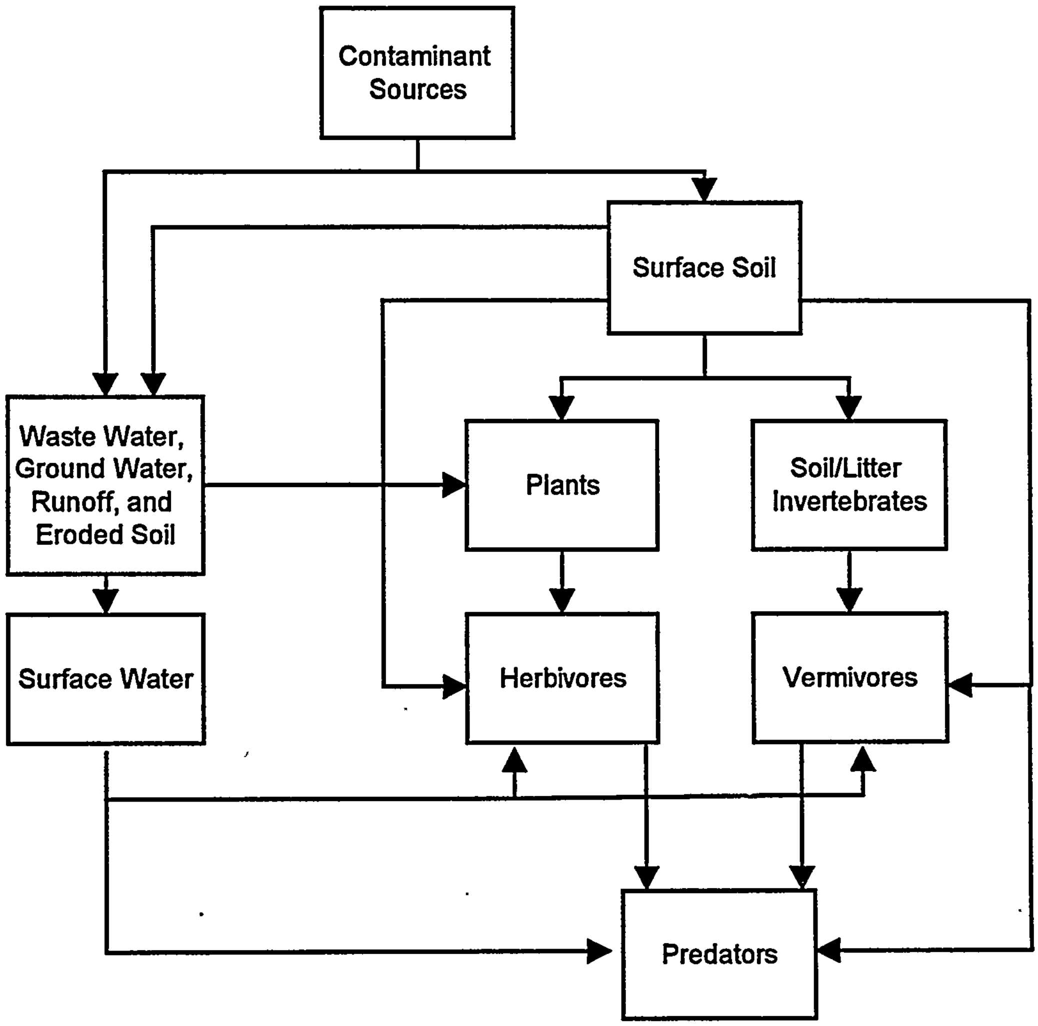

Fig. 5.1. Conceptual model for the exposure of vermivorous, herbivorous, and predatory wildlife to contaminants.

5.2.1.2 Contaminant concentrations in biotic and abiotic media

Contaminant concentrations in soil, vegetation, soil invertebrates, and small mammals are needed to estimate exposure. The surface soil 95% UCL (Table G.7) was used to calculate incidental ingestion of soil for each endpoint species. However, if the contaminant was only detected in a single sample, the single concentration was used to calculate exposure. The surface soil samples used in the calculations were collected at a depth ranging from 0 to 2 ft. Contaminants that were not detected or do not have an associated wildlife ecotoxicological benchmark were not evaluated. The 95% UCL soil concentrations were compared with background concentrations identified from the ORR Background Soils Characterization Project (Environmental Sciences Divison 1993; Table G.8). Concentrations of inorganic contaminants in vegetation were estimated by using the 90th percentile of the ORR-specific soil-plant uptake factors presented in Efroymson et al. (1996). Soil-plant uptake factors for organic contaminants were derived from the log octanol-water partition coefficient (log K_{ow}) by using the following equation (Travis and Arms 1988; Table G.9):

$$\text{Log soil-plant uptake factor} = 1.588 - 0.578 (\log K_{ow})$$

Concentrations of inorganic contaminants and PCBs in earthworms and small mammals were estimated using the 90th percentile of the ORR-specific soil-earthworm and soil-small mammal uptake factors presented in Sample et al. (1996b).

5.2.1.3 Exposure modeling using point-estimates

To estimate contaminant exposure experienced by white-tailed deer feeding within each OU, the following assumptions were made:

- Body weight = 56.5 kg.
- Food consumption = 1.74 kg/d.
- Soil consumption = 0.0348 kg/d.
- Diet consists 100% of vegetation.

To estimate contaminant exposure experienced by wild turkey feeding within each OU, the following assumptions were made:

- Body weight = 5.8 kg.
- Food consumption = 0.174 kg/d.
- Soil consumption = 0.0162 kg/d.
- Diet consists 100% of vegetation, seeds, and fruits.
- Contaminant concentrations in seeds and fruits are similar to vegetation.

To estimate contaminant exposure experienced by short-tailed shrew feeding within each OU, the following assumptions were made:

- Body weight = 0.015 kg.
- Food consumption = 0.009 kg/d.
- Soil consumption = 0.00117 kg/d.
- Diet consists 100% of earthworms.

To estimate contaminant exposure experienced by American woodcock feeding within each OU, the following assumptions were made:

- Body weight = 0.198 kg.
- Food consumption = 0.15 kg/d.
- Soil consumption = 0.0156 kg/d.
- Diet consists 100% of earthworms.

To estimate contaminant exposure experienced by red fox feeding within each OU, the following assumptions were made:

- Body weight = 4.5 kg.
- Food consumption = 0.45 kg/d.
- Soil consumption = 0.0126 kg/d.
- Diet consists 80.8% of small mammals, 10.4% plants, and 8.8% of earthworms..

To estimate contaminant exposure experienced by red-tailed hawk feeding within each OU, the following assumptions were made:

- Body weight = 1.126 kg.
- Food consumption = 0.109 kg/d.
- Soil consumption = 0 kg/d.
- Diet consists 100% of small mammals

By using the Equation 1 from Sect. 4.2.1 and the assumptions and data described above, the total exposure to contaminants was estimated for the white-tailed deer (Table G.10) wild turkey (Table G.11), short-tailed shrew (Table G12), American woodcock (Table G.13), red fox (Table G.14), and red-tailed hawk (Table G.15) foraging within each OU.

5.3 EFFECTS ASSESSMENT FOR HERBIVOROUS, VERMIVOROUS, AND PREDATORY WILDLIFE

5.3.1 Toxicological Benchmarks

To determine if the contaminant exposures experienced by terrestrial wildlife foraging on individual OUs could produce adverse effects, exposure estimates are compared with NOAELs and LOAELs derived according to the methods outlined by Sample et al. (1996). NOAELs represent the highest exposure at which no adverse effects were observed among the animals tested. LOAELs represent the lowest exposure at which significant adverse effects are observed.

Toxicological studies of the effects of contaminants observed in the soil were obtained from the open literature. Only studies of long-term, chronic oral exposures were used to estimate the NOAEL or LOAEL. To make the NOAELs and LOAELs relevant to possible population effects, preference was given to studies that evaluated effects on reproductive parameters. In the absence of a reproduction endpoint, studies that considered effects on growth, survival, and longevity were used. Experimental data used for the development of NOAELs and LOAELs for mammalian endpoints are presented in Table G.16; estimated NOAELs and LOAELs for mammalian endpoints are listed in Table G. 17. Experimental data used for the development of NOAELs and LOAELs for avian endpoints and estimated wildlife NOAELs and LOAELs are presented in Table G.18. Specific details on development of the NOAELs and LOAELs for all wildlife endpoints are discussed in Sect. 4.3.1.

5.3.2 Ecotoxicological Profiles for Herbivorous and Vermivorous Wildlife

The ecotoxicological profiles for COPECs for herbivorous and vermivorous wildlife on the ORR may be found in Appendix D.

5.4 RISK CHARACTERIZATION FOR HERBIVOROUS, VERMIVOROUS, AND PREDATORY WILDLIFE

Risk characterization integrates the results of the exposure assessment (Sect. 5.2) and effects assessment (Sect. 5.3) to estimate risks (the likelihood of effects given the exposure) based on each line of evidence. A weight of evidence approach, as outlined in Suter et al. (1995), is applied to determine the best estimate of risk to each assessment endpoint. This risk assessment is based on only one line of evidence: literature-derived single chemical toxicity data that indicates the toxic effects of media concentrations measured within each OU.

Procedurally, the risk characterization in this assessment is performed for each assessment endpoint by

- screening all measured contaminants within each OU against background soil levels and toxicological benchmarks;
- estimating the effects of the contaminants retained by the screening analysis for individuals of each endpoint species;
- estimating the number of individuals within the ORR population;
- estimating the number of individuals within an OU that are potentially exposed based on habitat availability and population density;
- calculating the total number of individuals on the ORR that may be at risk (addition of number of animals exposed within all OUs for which data exist);
- calculating the percentage of the ORR population that may experience adverse effects from contaminant exposure;
- using the 20% exposure criteria outlined in Suter et al. (1995), determine if reservation-wide endpoint populations are significantly at risk from contaminants present within OUs for which data is available;
- prioritizing the OUs based on the contribution of risk to the entire ORR population; and
- discussing the uncertainties in the assessment.

Data for this assessment was limited to single chemical toxicity data and habitat availability for herbivores, vermivores, and predators inhabiting the ORR.

5.4.1 Contaminant Screening of Soil to Background Levels

The initial screening for COPECs in soil begins with a comparison of the 95% UCL or single detected concentration found in surface soil in each OU with appropriate ORR background soils identified in the ORR Background Soils Characterization Project (Environmental Sciences Division 1993). Table G.8 identifies the background levels (95% UCL) found for each formation indicative of each OU. In some cases, an OU may be located on multiple formations. Therefore, a range of the minimum and maximum 95% UCL background values for multiple formations were used for comparison. Data were not available for certain formations indicative of an OU; thus, the range of 95% UCLs of all formations was used.

Chemicals were rejected from further consideration if the 95% UCL concentrations in OU soil were <95% UCL background concentration for the specific formation. Aluminum was eliminated from the analysis for WAG 1 and WAG 6. Arsenic was eliminated from K-1420 OU, LEFPC, and UEFPC OU 2. Chromium, mercury, and zinc were eliminated from WAG 6. Vanadium was eliminated from K-1407, the South Campus Facility, and UEFPC OU.

5.4.2 Single Chemical Toxicity Data for Herbivorous, Vermivorous, and Predatory Wildlife (Individuals)

Exposure of endpoint species to chemicals found in concentrations greater than background was calculated. The total contaminant exposure estimates for herbivores, vermivores, and predators foraging on vegetation, earthworms, and/or small mammals within an OU were compared with estimated LOAELs. If the LOAEL was lower than the exposure, portions of the endpoint population may experience contaminant exposures that are likely to produce adverse effects. Consequently, the *individuals* living within the OU are at risk because of hazardous exposures.

5.4.2.1 Screening point estimates of exposure

To determine if the contaminant exposures experienced by herbivores, vermivores, and predators feeding on each OU are potentially hazardous, the total exposure estimates were compared with estimated LOAELs. HQs were calculated to quantify the magnitude of the hazard where

NOAEL HQ = estimated contaminant exposure (mg/kg/d)/NOAEL

LOAEL HQ = estimated contaminant exposure (mg/kg/d)/LOAEL.

HQs>1 indicate that individuals may be experiencing exposures that are in excess of LOAELs and suggest that adverse effects may be occurring. HQs for all endpoints are presented along with exposure estimates in Tables G.10 to G.15. Contaminants that may most likely adversely impact the individual endpoints foraging within OUs are discussed below. The location (operable unit) of COPECs for each endpoint species are further detailed in Table 5.1. This discussion is limited to those contaminants for which the 95% UCL was greater than background concentrations and for which the LOAEL HQ was >1.

Exposure of herbivores, vermivores, and predators to aluminum exceeded both NOAELs and LOAELs at many locations, including the background. However, it is highly unlikely that the aluminum exposures estimated within the OUs are toxic and present a hazard to wildlife. This is for several reasons. Aluminum is a common and abundant structural element in soil whose most common

Table 5.1. Location (operable units[a]) of contaminants of potential concern for each endpoint species

Contaminant	White-tailed deer	Wild Turkey	Short-tailed shrew	American Woodcock	Red Fox	Red-tailed Hawk
Acetone	SCF		SCF		SCF	
Antimony			BC OU 1 BCV OU			
Arsenic	FCAP		BC OU 2 FCAP K-1407 OU SCF WAG 1	BC OU 2 K-1407 OU SCF	BC OU 2 FCAP	
Barium	FCAP		FCAP UEFPC OU 2 WAG 5	UEFPC OU 2		
Boron				WAG 1		
Cadmium			SCF WAG 2	LEFPC SCF		
Chromium			BC OU 2 K-1407 OU K-1420 OU LEFPC SCF UEFPC OU 2 WAG 1	BC OU 2 K-1407 OU K-1420 OU UEFPC OU 2 WAG 1 WAG 5	UEFPC OU 2 FCAP	
Copper			BCV OU LEFPC	LEFPC		
DDT and metabolites		LEFPC	LEFPC	LEFPC		
Lead				BC OU 2 K-1420 OU LEFPC UEFPC OU 2		
Lithium			K-1420 OU			

Table 5.1 (continued)

Contaminant	White-tailed deer	Wild Turkey	Short-tailed shrew	American Woodcock	Red Fox	Red-tailed Hawk
Mercury	BC OU 2 LEFPC	BC OU 2 K-1407 OU LEFPC WAG 2	BC OU 1 BC OU 2 BCV OU K-1407 OU K-1420 OU LEFPC SCF WAG 1 WAG 2 WAG 5	BC OU 2 K-1407 OU K-1420 OU LEFPC SCF WAG 1 WAG 5	BC OU 2 FCAP K-1407 OU K-1420 OU LEFPC SCF WAG 1 WAG 2	BC OU 2 FCAP K-1407 OU LEFPC WAG 1
Methylene chloride	SCF					
Nickel			K-1407 OU UEFPC OU 2	BC OU 2 K-1407 OU K-1420 OU LEFPC UEFPC OU 2 WAG 6		
Selenium	FCAP		BC OU 2 FCAP K-1407 OU LEFPC SCF WAG 1 WAG 2	BC OU 2 K-1407 OU LEFPC SCF WAG 1	FCAP K-1407 OU LEFPC WAG 1	FCAP
Thallium	FCAP		FCAP WAG 1		FCAP WAG 1	

Table 5.1 (continued)

Contaminant	White-tailed deer	Wild Turkey	Short-tailed shrew	American Woodcock	Red Fox	Red-tailed Hawk
Total PCBs	BC OU 2 K-1420 OU LEFPC WAG 1		BC OU 1 BC OU 2 BCV OU K-1420 OU LEFPC SCF WAG 1 WAG 2	BC OU 2 K-1420 OU LEFPC WAG 1	K-1420 OU LEFPC	
Uranium			K-1407 OU K-1420 OU			
Vanadium	FCAP		BC OU 1 BC OU 2 FCAP SCF			
Zinc			UEFPC OU 2	BC OU 2 K-1407 OU K-1420 OU LEFPC SCF UEFPC OU 2 WAG 1 WAG 5		

[a] Data from Bear Creek (BC) OU 1, Bear Creek Valley (BCV) OU, Filled Coal Ash Pond (FCAP), WAG 2, and WAG 5 were taken from the following sources:

Environmental Sciences Division. 1996. Report on the Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee. Volume 6. Appendix G—Baseline Ecological Risk Assessment Report. DOE/OR/01-1455/V6&D0. Oak Ridge National Laboratory. Oak Ridge, TN.

CDM Federal. 1995. Remedial Investigation Report on Chestnut Ridge Operable Unit 2 (Filled Coal Ash Pond/Upper McCoy Branch) at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee. Volume 1. Main Text. DOE/OR/01-1268/V1&D2. Y/ER-172/V1&D2. Oak Ridge, TN.

Efroymson, R. A., B. L. Jackson, D. S. Jones, B. E. Sample, G. W. Suter II, and C. J. E. Welsh. 1996. Waste Area Grouping 2 Phase I Task Data Report: Ecological Risk Assessment and White Oak Creek Watershed Screening Ecological Risk Assessment. ORNL/ER-366. Oak Ridge National Laboratory, Oak Ridge, TN.

Bechtel National, Inc./ CH2M Hill/ Ogden/PEER. 1995. Remedial Investigation Report on Waste Area Grouping 5 at Oak Ridge National Laboratory, Oak Ridge, Tennessee. Volume 4. Appendix C: Risk Assessment. DOE/OR/01-1326&D2/V4. ORNL/ER-284&D2/V4. ORNL/ER/Sub/87-99053/76/V4. Oak Ridge, TN.

forms are unlikely to be bioavailable and therefore toxic; toxicity data for aluminum are derived from soluble salts (e.g., $AlCl_3$) that do not accurately reflect the toxicity of the forms generally found in soil (e.g., oxides). Therefore, aluminum was eliminated as a COPEC from all subsequent analyses.

White-tailed deer. Deer foraging on the Filled Coal Ash Pond (FCAP) are potentially at greatest risk with five COPECs (Table 5.1). Deer foraging on SCF, Bear Creek (BC) OU 2, and LEFPC are also at risk; each OU had three COPECs with HQs>1. K-1420 OU, K-1407 OU, UEFPC OU 2, and WAG 1 had two, one, one, and one COPECs with HQs>1, respectively. COPECs for deer were PCBs (five locations), mercury (two locations), acetone (one location), and methylene chloride (one location).

Wild turkey. Mercury is the only major contaminant that poses a risk to wild turkey on BC OU 2, K-1407 OU, and LEFPC. DDT (and metabolites) is 24 times the benchmark for turkey on LEFPC. No other COPECs were identified for wild turkey on any of the other OUs.

Short-tailed shrews. Short-tailed shrews may be at significant risk foraging at all OUs except WAG 6 (Table 5.1). Each OU had from two to eight COPECs. Mercury, Cr, Se, total PCBs, and As contributed to the majority of the risk. Mercury at BC OU 2 and LEFPC were 560 and 306 times the benchmark, respectively.

American woodcock. American woodcock may be at significant risk foraging at most OUs except for BC OU 1, Bear Creek Valley (BCV) OU, FCAP, WAG 2, and WAG 6 (Table 5.1). Risk is primarily due to exposure to mercury, DDT and metabolites, and chromium. Foraging at LEFPC poses the most significant risk, with possible exposure to 10 COPECs. The remaining OUs with HQs>1 had from three to eight COPECs except for WAG 6, which had only one COPEC, nickel, at only 1.73 times the benchmark. Zinc was identified as a COPEC at eight locations. Other significant COPECs for woodcock were Hg at seven locations, Ni and Cr at six locations, Se (five), Pb and total PCBs (four), and As (three). Barium, B, Cu, DDT, and metabolites were above benchmark values at one location, and Cd was found at two locations.

Red fox. Mercury poses the most significant risk to red fox foraging on 8 of the 13 OUs. Mercury concentrations at BC OU 2 and LEFPC are 462 and 253 times the benchmark, respectively. With the exception of WAG 6, each of the OUs has between two to four COPECs found at concentrations large enough to exceed benchmark values. Other COPECs for red fox were Se (4 locations), total PCBs (2), and As, Cr, and Tl (2).

Red-tailed hawk. Mercury and selenium were the only contaminants that pose a risk to red-tailed hawks on the ORR. Mercury was identified as a COPEC at five locations. BC OU 2 and LEFPC were the primary contributors to risk from mercury, with levels that exceeded benchmarks by 86 and 47 times, respectively. Selenium was identified as a COPEC at FCAP.

5.4.3 Effects of Retained Contaminants for Herbivorous, Vermivorous, and Predatory Wildlife

5.4.3.1 Acetone

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which liver and kidney damage was observed in rats fed acetone for 90 days (EPA 1986). Three dose levels were administered (100, 500, and 2500 mg/kg/d). Significant tubular degeneration of the kidneys and increases in kidney weights were observed at the 500 mg/kg/d dose level. No adverse effects were observed at the 100 mg/kg/d level. These doses are considered subchronic values and therefore were multiplied by the subchronic-chronic uncertainty factor of 0.1. On the basis of the results of EPA (1986), white-tailed deer foraging at SCF experiencing exposure greater than or equal to LOAEL may display tubular degeneration of the kidneys.

Although acetone is highly volatile, the exposure experienced by white-tailed deer is 24.98 times the LOAEL, and the exposure to short-tailed shrews is 3.5 times the LOAEL at SCF. The presence of acetone may be a concern if it is a continuous source.

5.4.3.2 Antimony

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which lifespan and longevity was observed in mice fed antimony potassium tartrate for the lifetime of the organism (Schroeder et al. 1968b). One dose level was administered. Because median lifespan was reduced among female mice exposed to the 5 ppm dose level and because the study considered exposure throughout the entire lifespan, this dose was considered to be a chronic LOAEL. A chronic NOAEL was estimated by multiplying the chronic LOAEL by a LOAEL-NOAEL uncertainty factor of 0.1. On the basis of the results of Schroeder et al. (1968b), short-tailed shrews foraging on BCV OU and BC OU 1 may have reduced lifespans.

5.4.3.3 Arsenic

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which reproductive success and offspring survival was observed among mice fed arsenite for three generations (Schroeder and Mitchener 1971). One dose level administered (1.261 mg/kg/d), designated as the chronic LOAEL, resulted in declining litter size with each successive generation. A chronic NOAEL was estimated by multiplying the chronic LOAEL by a LOAEL-NOAEL correction factor of 0.1. Based on the results of Schroeder and Mitchener (1971), short-tailed shrews foraging within most of the OUs and red fox foraging on BC OU 2 experiencing exposures greater than or equal to LOAEL are likely to display a decline in litter size.

The NOAEL and LOAEL for American woodcock are based upon a study in which mortality was observed in mallard ducks fed sodium arsenite for 128 days (U.S. Fish and Wildlife Service 1964). Four dose levels were administered. Mallards in the 1000, 500, and 250 ppm groups experienced 92%, 60%, and 12% mortality, respectively. Because those in the 100 ppm group experienced 0% mortality, and the study considered exposure over 128 days, the 100 ppm Sodium Arsenite (51.35 mg/kg As^{+3}) dose was considered to be a chronic NOAEL. The 250 ppm Sodium Arsenite (128.375 mg/kg As^{+3}) dose was considered to be a chronic LOAEL. On the basis of the results of the U.S. Fish and Wildlife Service (1964), American woodcock foraging on BC OU 2, K-1407 OU, and SCF experiencing exposures greater than or equal to LOAEL may display increased mortality.

5.4.3.4 Barium

The NOAELs for mammals are based on a study in which growth, food and water consumption, and hypertension was observed among rats fed barium chloride for 16 months (Perry et al. 1983). Three dose levels were administered. The maximum dose (5.1 mg/kg/d) did not affect growth or food or water consumption and was therefore considered to be a chronic NOAEL. The LOAEL was based on a study which observed mortality in rats fed barium for 10 days (Borzelleca et al. 1988). Four doses were administered and exposure of rats to the highest dose (300 mg/kg/d) resulted in 30% mortality to female rats. The 300 mg/kg/d dose is considered to be a subchronic LOAEL; therefore a chronic LOAEL was estimated by multiplying the subchronic LOAEL by a subchronic to chronic uncertainty factor of 0.1. On the basis of the results of Borzelleca et al. (1988), short-tailed shrews foraging on UEFPC OU 2 and WAG 5 experiencing exposures greater than or equal to LOAEL may display increased mortality.

Both the NOAELs and LOAELs for woodcock are based on a study that observed mortality to 1-day-old chicks fed 8 doses of barium hydroxide for 4 weeks (Johnson et al. 1960). The NOAEL dosage (208.3 mg/kg/d) produced no mortality; the LOAEL dosage (416.5 mg/kg) and highest dosage (40.3 mg/kg/d) resulted in 5% to 100% mortality. The NOAEL and LOAEL were considered subchronic and was multiplied by the subchronic to chronic uncertainty factor of 0.1. On the basis of the results of Johnson et al. (1960), American woodcock foraging at UEFPC OU 2 experiencing exposures greater than or equal to LOAEL may display increased mortality.

5.4.3.5 Boron

Both the NOAELs and LOAELs for mammals are based on a study in which reproductive success was observed among rats fed boric acid for three generations (Weir and Fisher 1972). Three does levels were administered. Although consumption of 1170 ppm boron as either boric acid or borax resulted in sterility, no adverse reproductive effects were observed among rats consuming 117 or 350 ppm boron. Because the study considered exposure throughout 3 generations including critical lifestages (reproduction), the 350 ppm dose was considered to be a chronic NOAEL and the 1170 ppm dose was considered a chronic LOAEL. There are no mammalian species at risk from boron at any of the OUs.

Both NOAEL and LOAEL for avian endpoints are based on a study in which reproductive success and mortality was monitored for mallard ducks fed boric acid 3 weeks before, during, and 3 weeks after reproduction (Smith and Anders 1989). Four dose levels were administered. Although consumption of 1000 ppm boron resulted in reduced egg fertility and duckling growth and increased embryo and duckling mortality, no adverse reproductive effects were observed among the other dose levels. Because the study considered exposure throughout reproduction, the 288 ppm dose was considered to be a chronic NOAEL and the 1000 ppm dose was considered a chronic LOAEL. On the basis of the results of Smith and Anders (1989), American woodcock foraging on WAG 1 experiencing exposures greater than or equal to LOAEL may display decreased reproduction.

5.4.3.6 Cadmium

Both the NOAEL and LOAEL for mammalian endpoints are based upon a study in which reproductive success was observed among rats fed cadmium chloride for 6 weeks through mating and gestation (Sutou et al. 1980). Four dose levels were administered. Although no adverse effects were observed at the 1 mg/kg/d dose level, fetal implantations were reduced by 28%, fetal survivorship was reduced by 50%, and fetal resorptions increased by 400% among the 10 mg/kg/d group. Because the study considered oral exposure during reproduction, the 1 and 10 mg/kg/d doses were considered to be chronic NOAELs and LOAELs, respectively. On the basis of the results of Sutou et al. (1980b), short-tailed shrews foraging on SCF experiencing exposures greater than or equal to LOAEL may display decreased reproduction.

Both the NOAEL and LOAEL for avian endpoints are based on a study in which reproductive success was observed among mallard ducks fed cadmium chloride for 90 days (White and Finley 1978). Three dose levels were administered. The highest dosage (20.03 mg/kg/d), designated as the chronic LOAEL, produced significantly fewer eggs. A dosage of 1.45 mg/kg/d produced no adverse effects and was designated as the chronic NOAEL. On the basis of the results of White and Finley

(1978), American woodcock experiencing exposures greater than or equal to LOAEL at BC OU 1 may display impaired reproduction. Also on the basis of the results of White and Finely (1978), American woodcock foraging on LEFPC and SCF experiencing exposures greater than or equal to LOAEL may display decreased reproductive success.

5.4.3.7 Chromium

The LOAEL for mammalian endpoints is based upon a study in which mortality was observed in rats fed chromium (Cr^{+6}) for three months [Steven et al. 1976 (cited in Eisler 1986a)]. Two doses were administered. Because the 1000 ppm dose was identified as the toxicity threshold, this dose was considered to be a subchronic LOAEL. A chronic LOAEL was estimated by multiplying the subchronic LOAEL by a subchronic-chronic uncertainty factor of 0.1. On the basis of the studies of Steven et al. (1976), short-tailed shrews foraging on most OUs and red fox foraging on UEFPC OU 2 experiencing exposures greater than or equal to LOAEL may display increased mortality.

Both the NOAEL and LOAEL for avian endpoints are based upon a study in which reproduction in black ducks was observed fed chromium [Cr^{+3} as $CrK(SO_4)_2$] for ten months (Haseltine et al., unpubl. data). Two doses were administered. Although duckling survival was reduced at the 50 ppm dose level, no significant differences were observed at the 10 ppm Cr^{+3} dose level. Because the study considered exposure throughout a critical lifestage (reproduction), the dose 50 ppm dose was considered to be a chronic LOAEL and the dose 10 ppm dose was considered to be a chronic NOAEL. On the basis of the results of Haseltine et al., American woodcock foraging on most OUs experiencing exposures greater than or equal to LOAEL may display decreased reproductive success.

5.4.3.8 Copper

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which mink were fed copper sulfate for 357 days (including a critical life stage) (Aulerich et al. 1982). Although consumption of 15.14 mg/kg/d copper increased the percentage of mortality in mink kits, no adverse effects were observed at a 11.71 mg/kg/d exposure level. On the basis of the results of Aulerich et al. (1982), short-tailed shrews experiencing exposures greater than or equal to LOAEL within LEFPC display a reduction in offspring survival.

Both the NOAEL and LOAEL for avian endpoints are based on a study in which 1-day-old chicks were fed copper oxide for 10 weeks (Mehring et al. 1960). Eleven dose levels were administered in the study. No adverse effects were observed on the growth of chicks up to dose levels of 47 mg/kg/d. Consumption of 61.7 mg/kg/d copper in the diet, designated as the LOAEL, resulted in reduced growth by over 30% and produced 15 % mortality. On the basis of the results of Mehring et al. (1960), American woodcock experiencing exposures greater than or equal to LOAEL at LEFPC may display a reduction in growth and survivorship.

5.4.3.9 DDT and metabolites

Both the NOAEL and LOAEL for mammalian endpoints are based upon a study in which reproduction was observed in rats fed DDT for 2 years (Fitzhugh 1948). Four dose levels were administered. Although consumption of 50 ppm or more DDT in the diet reduced the number of young produced, no adverse effects were observed at the 10 ppm DDT dose level. Because the study considered exposure throughout 2 years and reproduction, the 10 and 50 ppm DDT doses were considered to be chronic NOAELs and LOAELs, respectively. On the basis of the results of Fitzhugh

(1948), short-tailed shrews experiencing exposures greater than or equal to LOAEL may display decreased reproductive success.

Both the NOAEL and LOAEL for avian endpoints are based on a study in which reproduction was observed in brown pelican for 5 years (Anderson et al. 1975). One dose level was administered. Anderson et al. (1975) studied the reproductive success of pelicans from 1969 through 1974. During this time, DDT residues in anchovies, their primary food, declined from 4.27 ppm (wet weight) to 0.15 ppm (wet weight). Although reproductive success improved from 1969 to 1974, in 1974 the fledgling rate was still 30% below that needed to maintain a stable population. Because this study was long-term and considered reproductive effects in a wildlife species, EPA (1993) judged this study to be the most appropriate to evaluate DDT effects to avian wildlife. Therefore the 0.15 ppm DDT value was considered to be a chronic LOAEL. To estimate the chronic NOAEL, the chronic NOAEL was multiplied by a LOAEL-NOAEL uncertainty factor of 0.1. On the basis of the results of Anderson et al. (1975), wild turkey and American woodcock experiencing exposures greater than or equal to LOAEL may experience long-term reproductive effects.

5.4.3.10 Lead

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which reproduction was observed in rats fed lead (lead acetate) for three generations (Azar et al. 1973). Five dose levels were administered. Although none of the lead exposure levels studied affected the number of pregnancies, the number of live births, or other reproductive indices, lead exposure of 1000 and 2000 ppm resulted in reduced offspring weights and produced kidney damage in the young. Therefore the 100 ppm lead dose was considered to be a chronic NOAEL and the 1000 ppm lead dose was considered to be a chronic LOAEL.

The NOAEL and LOAEL for avian species are based on a study in which the reproductive success of Japanese quail fed lead (acetate) was observed for 12 weeks (Edens et al. 1976). Four dose levels were administered. Although egg hatching success was reduced among birds consuming the 100 ppm lead dose, reproduction was not impaired by the 10 ppm lead dose. Because the study considered exposure over 12 weeks and throughout a critical lifestage (reproduction), these values were considered to be chronic LOAELs and NOAELs. Final NOAEL: 1.13 mg/kg/d; final LOAEL: 11.3 mg/kg/d. On the basis of the results of Edens et al. (1976), American woodcock foraging on BC OU 2, K-1420 OU, LEFPC, and UEFPC OU 2 experiencing exposures greater than or equal to LOAEL may display decreased reproductive success.

5.4.3.11 Mercury

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which reproductive success and offspring survival was observed among rats fed methyl mercury for three generations (Verschuuren et al. 1976c). The highest dose administered (0.16 mg/kg/d), designated as the LOAEL, resulted in reduction in offspring viability. This exposure also resulted in reduction in growth, increased kidney weight, and altered kidney histochemistry (Verschuuren et al. 1976b). No effects were observed at a dose of 0.032 mg/kg/d. The study was considered to represent chronic exposure; therefore, a subchronic-chronic correction factor was not employed. On the basis of the results of Verschuuren et al. (1976a–c), white-tailed deer, short-tailed shrews, and red fox experiencing exposure greater than or equal to LOAELs are likely to display impaired reproduction.

Both the wild turkey and American woodcock NOAELs and LOAELs are based on a study in which reproductive success was observed among mallard ducks that were fed methyl mercury for three generations (Heinz 1979). The study was considered to represent a chronic exposure. The only dose level administered, 0.064 mg/kg/d, caused hens to lay fewer eggs, lay more eggs outside the nest box, and produce fewer ducklings. This dose level was considered the chronic LOAEL. Because an experimental NOAEL was not established, the chronic NOAEL was estimated by multiplying the chronic LOAEL by a LOAEL-NOAEL uncertainty factor of 0.1. On the basis of the results of Heinz (1979), wild turkeys, American woodcock, and red-tailed hawk experiencing exposures greater than or equal to LOAELs may display impaired reproduction.

5.4.3.12 Methylene chloride

The NOAEL and LOAEL for the mammalian endpoints was based on a study in which rats were fed methylene chloride for 2 years (National Coffee Association 1982). Rats fed a 5.85 mg/kg/d dose level did not experience adverse effects and is considered the chronic NOAEL. Rats consuming 50 mg/kg/d or greater produced histological changes in the liver. This dose level was designated as the chronic LOAEL. On the basis of the results of the National Coffee Association (1982), white-tailed deer experiencing exposures greater than or equal to LOAELs at SCF may display changes in liver histology.

5.4.3.13 Nickel

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which reproduction was observed in rats fed nickel (nickel sulfate hexahydrate) for three generations (Ambrose et al. 1976). Three dose levels were administered. Although 1000 ppm Ni in the diet reduced offspring body weights, no adverse effects were observed in the other dose levels. Because this study considers exposures over multiple generations, the 500 ppm dose was considered to be a chronic NOAEL and the 1000 ppm dose was considered to be a chronic LOAEL. On the basis of the results of Ambrose et al. (1976), short-tailed shrew foraging on K-1407 OU and UEFPC OU 2 experiencing exposures greater than or equal to LOAEL may display reduced offspring body weight.

Both the NOAEL and LOAEL for avian species are based on a study in which mortality, growth, and behavior were observed in mallard ducklings fed nickel (nickel sulfate) for 90 days (Cain and Pafford 1981). Three doses were administered. Although consumption of up to 774 ppm nickel in diet did not increase mortality or reduce growth, the 1069 ppm nickel diet reduced growth and resulted in 70% mortality. Because the study considered exposure over 90 days, the 774 ppm dose was considered to be a chronic NOAEL and the 1069 ppm dose was considered to be a chronic LOAEL. To estimate daily nickel intake throughout the 90-day study period, food consumption of 45-day-old ducklings was calculated. Although this value will over- and underestimate food consumption by younger and older ducklings, it was assumed to approximate food consumption throughout the entire 90-day study. On the basis of the results of Cain and Pafford (1981), American woodcock foraging on most OUs experiencing exposures greater than or equal to LOAEL may have impaired growth.

5.4.3.14 PCBs

The mammalian endpoint NOAEL and LOAEL are based on a study in which old field mice were fed Aroclor 1254 for 12 months (McCoy et al. 1995). A dose level of 0.68 mg/kg/d, designated as the chronic LOAEL, caused a reduction in the number of litters, offspring weights, and offspring survival. Because an experimental NOAEL was not established, the chronic NOAEL was estimated by multiplying the chronic LOAEL by a LOAEL-NOAEL uncertainty factor of 0.1.On the basis of the results of McCoy et al. (1995), short-tailed shrews and wild turkeys at most OUs, as well as red fox at K-1420 OU and LEFPC, experiencing exposures greater than or equal to the LOAEL may display impaired reproduction and offspring viability.

The American woodcock NOAEL and LOAEL are based on a study in which ring-necked pheasants were fed Aroclor 1254 for 17 weeks (Dahlgren et al. 1972). A dose level of 1.8 mg/kg/d, designated as the chronic LOAEL, caused a significant reduction in egg hatchability. Because an experimental NOAEL was not established, the chronic NOAEL was estimated by multiplying the chronic LOAEL by a LOAEL-NOAEL uncertainty factor of 0.1. On the basis of the results of Dahlgren et al. (1972), American woodcock experiencing exposures greater than or equal to the LOAEL may display a reduction in egg hatchability.

5.4.3.15 Selenium

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which reproduction was observed in rats fed selenium (SeO_4) for 1 year (Rosenfeld and Beath 1954). Three dose levels were administered. Although no adverse effects on reproduction were observed among rats exposed to 1.5 mg Se /L in drinking water, the number of second-generation young was reduced by 50% among females in the 2.5 mg/L group. In the 7.5 mg/L group, fertility, juvenile growth and survival were all reduced. Because study considered exposure over multiple generations, the 1.5 and 2.5 mg/L doses were considered to be chronic NOAEL and LOAEL, respectively. On the basis of the results of Rosenfield and Beath (1954), short-tailed shrews at most OUs, and red fox at K-1407 OU, LEFPC, and WAG 1 experiencing exposures greater than or equal to LOAEL may display long-term reductions in reproductive viability.

The NOAEL and LOAEL for avian endpoints are based on a study in which reproductive success was observed in mallard ducks fed selenium (sodium selenite) for 78 days (Heinz et al. 1987). Five dose levels were administered. Although consumption of 1, 5, or 10 ppm selenium on the diet as Sodium Selenite had no effect on weight or survival of adults, 100 ppm selenium reduced adult survival and 25 ppm selenium reduced duckling survival. Consumption of 10 or 25 ppm selenium in the diet resulted in a significantly larger frequency of lethally deformed embryos as compared with the 1 or 5 ppm selenium exposures. Because 5 ppm selenium in the diet was the highest dose level that produced no adverse effects and the study considered exposure through reproduction, this dose was considered to be a chronic NOAEL. The lowest dose at which adverse effects were observed, 10 ppm, was considered to be a chronic LOAEL. On the basis of the results of Heinz et al. (1987), American woodcock foraging at most OUs experiencing exposures greater than or equal to LOAEL may display an increased frequency of deformed embryos.

5.4.3.16 Thallium

The mammalian endpoint NOAEL and LOAEL are based on a study in which rats were fed thallium sulfate for 60 days (Formigli et al. 1986). This study represents subchronic exposures because the duration of the study did not include a critical life stage. Rats exposed to a single dose, 0.074 mg/kg/d, displayed reduced sperm motility. Because this is a subchronic exposure, a subchronic-chronic uncertainty factor of 0.1 was applied to obtain a chronic LOAEL. To estimate the chronic NOAEL, the chronic LOAEL was multiplied by a LOAEL-NOAEL uncertainty factor of 0.1. On the basis of the results of Formigli et al. (1986), short-tailed shrews and red fox foraging on WAG 1 experiencing exposures greater than or equal to the LOAEL may display impaired reproduction from a reduction of sperm motility.

5.4.3.17 Uranium

The short-tailed shrew NOAEL and LOAEL are based on a study in which mice were fed uranyl acetate for 60 days prior to gestation, through gestation, delivery, and lactation (Paternain et al. 1989). This study represents chronic exposures because it took place during the critical life stage of the mouse. Significant effects on reproduction including increased number dead young/litter and reduction in size and weight of offspring were observed at 6.13 mg/kg/d. The lowest dose administered, 3.07 mg/kg/d, resulted in no significant differences in measured reproductive parameters. Therefore, these doses were considered the chronic LOAEL and NOAEL, respectively. On the basis of the results of Paternain et al. (1989), short-tailed shrews foraging on K-1407 or K-1420 OUs experiencing exposures greater than or equal to the LOAEL may display a reduction in reproductive success.

5.4.3.18 Vanadium

The short-tailed shrew NOAEL and LOAEL are based on a study in which rats were fed sodium metavanadate for 60 days prior to gestation, through gestation, delivery, and lactation (Domingo et al. 1986). This study represents chronic exposures because it took place during the rat's critical life stage. Significant effects on reproduction including increased number dead young/litter and reduction in size and weight of offspring were observed at the lowest dose administered, 5 mg/kg/d. Therefore, this dose was considered the chronic LOAEL. To estimate the chronic NOAEL, the chronic LOAEL was multiplied by a LOAEL-NOAEL uncertainty factor of 0.1. On the basis of the results of Domingo et al. (1986), short-tailed shrews foraging at BC OU 2 or SCF experiencing exposures greaterm than or equal to the LOAEL may display a reduction in reproductive success.

5.4.3.19 Zinc

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which reproductive success was observed in rats fed zinc oxide for days 1–16 of gestation (Schlicker and Cox 1968). Two dose levels were administered. Rats exposed to 4000 ppm zinc in the diet displayed increased rates of fetal resorption and reduced fetal growth rates. Because no effects were observed at the 2000 ppm zinc dose rate and because the exposure occurred during gestation (a critical lifestage), this dose was considered a chronic NOAEL. The 4000 ppm zinc dose was considered to be a chronic LOAEL. On the basis of the results of Schlicker and Cox (1968), short-tailed shrews foraging on UEFPC OU 2 experiencing exposures greater than or equal to LOAEL may display increased rates of fetal resorption and reduced fetal growth rates.

Both the NOAEL and LOAEL for avian endpoints are based upon a study in which reproductive success was observed for white leghorn hens fed zinc sulfate for 44 weeks (Stahl et al. 1990). Three dose levels were administered. Although no adverse effects were observed among hens consuming 48 and 228 ppm zinc, egg hatchability was <20% of controls among hens consuming 2028 ppm zinc. Because the study was greater than 10 weeks in duration and considered exposure during reproduction, the 228 ppm dose was considered a chronic NOAEL, and the 2028 ppm dose was considered a chronic LOAEL. On the basis of the studies of Stahl et al. (1990), American woodcock foraging at most OUs experiencing exposures greater than or equal to the LOAEL may display reduced egg hatchability.

5.4.4 Population Level Risks on the Oak Ridge Reservation

The COPECs within each OU, as designated by the screening process (Sect. 5.4.1), may cause adverse effects (Sect. 5.4.2) to *individuals* foraging within each OU. To consider adverse effects on the reservation-wide *population*, steps 3 through 6 within the problem formulation (Sect. 5.1) must be completed. By comparing an endpoint species habitat requirements (Table B.1), the amount of suitable habitat within each OU (Table B.3), and population densities for each endpoint (see following), the number of individuals exposed on an OU can be estimated. The densities used for each endpoint species are presented in the following table.

	White-tailed deer	Wild turkey	Short-tailed shrew	American woodcock	Red fox	Red-tailed hawk
Density	0.1704[a]	0.0426[a]	23/ha (median of 2.5 to 45/ha range)	.28/ha (based on 5.6 males /100 ha; assuming 1:1 sex ratio)	0.77/ha	0.03 pairs/ha
No. on the ORR (if known)	2000	>500				
Source	Personal communication, Jim Evans	Personal communication, Jim Evans	Getz 1989	Stewart and Robbins 1958	EPA 1993b	EPA 1993b

[a]Density calculated based on total deer and turkey habitat on ORR (11,734.8 ha) and total number of deer and turkey estimated on ORR (2000 deer and 500 turkey).

Because contaminants found on all OUs, except for K-1414, present a risk to all assessment endpoints, the number of animals present in the OU is equivalent to the number of individuals exposed at unacceptable levels. The estimated number of individuals of endpoint species exposed within each OU and the proportion of the reservation-wide population that are at risk are summarized in Tables 5.2 through 5.7.

Although specific OUs pose unacceptable risks to the individuals, the total number of exposed individuals within the entire ORR population is minimal. Approximately 8.77% and 8.8.1% of the reservation-wide populations of turkey and deer are at risk. Only 8.6% and 8.95% of short-tailed shrews and woodcock on the ORR are at risk. Approximately 8.82% of the red-tailed hawk and 8.71% of the red fox are at risk on the ORR. Therefore, using the 20% criterion outlined by Suter et al. (1995), the occurrence of population-level effects on the reservation are highly unlikely. However, because the short-tailed shrew is a measurement endpoint for four species of T&E shrews, 8.6% of the impacted population may represent a significant risk to T&E shrews on the ORR.

BCV OU and LEFPC OU contributed, by far, the highest number of deer, shrews, foxes, woodcock, and turkeys at risk on the ORR (Tables 5.2–5.7). The population of short-tailed shrews in Bear Creek Valley is estimated to be experiencing exposures greater than LOAEL from Sb, Cu, Hg, PCBs, and V; foxes are at risk from Cu and Hg (Table 5.1). Contaminants contributing to the majority of the risk at LEFPC include Hg, total PCBs, DDT and metabolites, Se, and Al. Other contaminants of concern include Cd, Cr, Cu, Ni, and Zn. WAG 2 is the third highest contributor to risk on the ORR. The short-tailed shrew population in WAG 2 is estimated to be experiencing exposures greater

Table 5.2. The number of potentially exposed white-tailed deer within each OU and the entire reservation

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[ab]	% of the ORR population exposed[c]
BCV OU	Evergreen plantation(20.94) Evergreen forest (37.37) Deciduous forest (192.81) Mixed forest (140.56) Pasture (14.62) Transitional (246.06)	652.36	111	5.55
LEFPC	Evergreen plantation (2.62) Evergreen forest (7.37) Deciduous forest (41.06) Mixed forest (50.87) Pasture (8.5) Transitional (133.87)	244.29	42	2.1
WAG 2	Evergreen forest (1) Deciduous forest (15.75) Mixed forest (29) Pasture (0.06) Transitional (14.81)	60.62	10	0.5
WAG 5	Deciduous forest (3.56) Mixed forest (6.44) Pasture (7.69) Transitional (9.06)	26.75	5	0.25
South Campus Facility	Pasture (13.25) Transitional (4.5)	17.75	3	0.15
WAG 6	Deciduous forest (5.06) Mixed forest (2.06) Pasture (0.5) Transitional (2.94)	10.56	2	0.10
Chestnut Ridge OU2	Deciduous forest (3.81) Mixed forest (0.38) Transitional (2.62)	6.81	1	0.05
WAG 1	Evergreen forest (0.81) Deciduous forest (1.25) Mixed forest (0.81) Pasture (0.94)	3.81	0.7	0.04
K-1407 OU	Transitional (4.19)	4.19	0.7	0.04
BC OU2	Transitional (0.62)	0.62	0.1	0.005
UEFPC OU2	0	0	0	0.00
K-1420 OU	0	0	0	0.00
K-1414 Ou[d]				

Table 5.2 (continued)

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[a,b]	% of the ORR population exposed
Total no. exposed within 13 OUs			62[b]	
Total reservation	Evergreen plantations (323.5) Evergreen forest (704.87) Deciduous forest (4,028.62) Mixed forest (3,469) Pasture (312.44) Transitional (2,896.19)	11,734.8	2000[e]	
Percentage of the ORR population at risk				**8.8%**

[a]The number of animals present within OU was calculated by multiplying the total area of suitable habitat (ha) by 0.1704 deer/ha (calculated from 2,000 deer on reservation).

[b]All white-tailed deer present on OUs are exposed at contaminant levels >LOAELs, with the exception of animals at WAG 5 and K-1414.

[c]The percentage of the ORR population exposed = (estimated no. of animals present on the OU/the total no. of animals on the reservation) x 100.

[d]Habitat maps are not available for the K-1414 OU.

[e]The approximately 2,000 deer present on the ORR were estimated from deer hunts (personal communication, Jim Evans 1995).

Table 5.3. The number of potentially exposed wild turkey within each OU and the entire reservation

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[ab]	% of ORR population exposed[c]
BCV OU	Evergreen plantation (20.9) Evergreen forest (37.37) Deciduous forest (192.81) Mixed forest (140.56) Pasture (14.62) Transitional (246.06)	652.32	28	5.6
LEFPC	Evergreen plantation (2.62) Evergreen forest (7.37) Deciduous forest (41.06) Mixed forest (50.87) Pasture (8.5) Transitional (133.87)	244.29	10	2.0
WAG 2	Evergreen forest (1) Deciduous forest (15.75) Mixed forest (29) Pasture (0.06) Transitional (14.81)	60.62	3	0.6
WAG 5	Deciduous forest (3.56) Mixed forest (6.44) Pasture (7.69) Transitional (9.06)	26.75	1	0.2
South Campus Facility	Pasture (13.25) Transitional (4.5)	17.75	0.8	0.16
WAG 6	Deciduous forest (5.06) Mixed forest (2.06) Pasture (0.5) Transitional (2.94)	10.56	0.5	0.10
Chestnut Ridge OU2	Deciduous forest (3.81) Mixed forest (0.38) Transitional (2.62)	6.81	0.3	0.06
K-1407 OU	Transitional (4.19)	4.19	0.2	0.04
BC OU2	Transitional (0.62)	0.62	0.03	0.006
WAG 1	Evergreen forest (0.81) Deciduous forest (1.25) Mixed forest (0.81) Pasture (0.94)	3.81	0.2	0.00
UEFPC OU2	0	0	0	0.00
K-1420 OU	0	0	0	0.00
K-1414 OU[d]				

Table 5.3 (continued)

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[a,b]	% of ORR population exposed[c]
Total no. exposed within 13 OUs			15[b]	
Total reservation	Evergreen plantations (323.5) Evergreen forest (704.87) Deciduous forest (4,028.62) Mixed forest (3,469) Pasture (312.44) Transitional (2,896.19)	11,734.8	500[e]	
Percentage of ORR population at risk				**8.77%**

[a]The number of animals present within the OU was calculated by multiplying the total area of suitable habitat (ha) by 0.0426 wild turkey/ha (calculated from 500 turkey observed on the reservation).

[b]All wild turkey present on OUs are exposed at contaminant levels >LOAELs, with the exception of animals at WAG 1, WAG 5, and K-1414.

[c]The percentage of the ORR population exposed = (estimated no. of animals present on the OU/total no. of animals on the reservation) x 100.

[d]Habitat maps are not available for the K-1414 OU.

[e]Approximately 500 wild turkey are present on the ORR (personal communication, Jim Evans 1995).

Table 5.4. The number of potentially exposed short-tailed shrews within each OU and the entire reservation

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present [a,b]	% of the ORR population exposed[c]
BCV OU	Evergreen plantation (20.9) Evergreen forest (37.37) Deciduous forest (192.81) Mixed forest (140.56) Transitional (246.06)	637.7	14,667	5.58
LEFPC	Evergreen plantation (2.62) Evergreen forest (7.37) Deciduous forest (41.06) Mixed forest (50.87) Transitional (133.87)	235.79	5,423	2.06
WAG 2	Evergreen forest (1) Deciduous forest (15.75) Mixed forest (29) Transitional (14.81)	59.85	1377	0.52
WAG 5	Deciduous forest (3.56) Mixed forest (6.44) Transitional (9.06)	19.06	438	0.17
WAG 6	Deciduous forest (5.06) Mixed forest (2.06) Transitional (2.94)	10.06	231	0.09
Chestnut Ridge OU2	Deciduous forest (3.81) Mixed forest (0.38) Transitional (2.62)	6.81	157	0.06
K-1407 OU	Transitional (4.19)	4.19	96	0.04
South Campus Facility	Transitional (4.5)	4.5	104	0.04
WAG 1	Evergreen forest (0.81) Deciduous forest (1.25) Mixed forest (0.81)	2.87	66	0.03
BC OU2	Transitional (0.62)	0.62	14	0.005
UEFPC OU2	0	0	0	0.00
K-1420 OU	0	0	0	0.00
K-1414 OU[d]				

Table 5.4 (continued)

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present [a,b]	% of the ORR population exposed[c]
Total no. exposed within 13 OUs			7,274[b]	
Total reservation	Evergreen plantations (323.5) Evergreen forest (704.87) Deciduous forest (4,028.62) Mixed forest (3,469) Transitional (2,896.19)	11,422.36	262,714	
Percentage of ORR population at Risk				**8.6%**

[a]The number of animals present within the OU was calculated by multiplying the total area of suitable habitat (ha) by 23 short-tailed shrews/ha (Getz 1989, as cited in EPA 1987).

[b]All animals present within OUs are exposed at levels exceeding LOAELs, with the exception of animals at K-1414.

[c]The percentage of the ORR population exposed = (estimated no. of animals present on the OU/total no. of animals on the reservation) x 100.

[d]Habitat maps are not available for the K-1414 OU.

Table 5.5. The number of potentially exposed American woodcock within each OU and the entire reservation

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[a,b]	% of the ORR population exposed[c]
BCV OU	Deciduous forest (192.81) Mixed forest (140.56) Pasture (14.62) Transitional (246.06)	594.05	166	5.5
LEFPC	Deciduous forest (41.06) Mixed forest (50.87) Pasture (8.5) Transitional (133.87)	234.3	66	2.2
WAG 2	Deciduous forest (15.75) Mixed forest (29) Pasture (0.06) Transitional (14.81)	59.62	17	0.57
WAG 5	Deciduous forest (3.56) Mixed forest (6.44) Pasture (7.69) Transitional (9.06)	26.75	8	0.27
South Campus Facility	Pasture (13.25) Transitional (4.5)	17.75	5	0.17
WAG 6	Deciduous forest (5.06) Mixed forest (2.06) Pasture (0.5) Transitional (2.94)	10.56	3	0.10
Chestnut Ridge OU2	Deciduous forest (3.81) Mixed forest (0.38) Transitional (2.62)	6.81	2	0.07
WAG 1	Deciduous forest (1.25) Mixed forest (0.81) Pasture (0.94)	3	0.8	0.03
K-1407 OU	Transitional (4.19)	4.19	1	0.03
BC OU2	Transitional (0.62)	0.62	0.2	0.007
UEFPC OU2	0	0	0	0.00
K-1420 OU	0	0	0	0.00
K-1414 OU[d]				

Table 5.5 (continued)

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[a,b]	% of the ORR population exposed[c]
Total no. exposed within 13 OUs			98	
Total reservation	Deciduous Forest (4,028.62) Mixed Forest (3,469) Pasture (312.44) Transitional (2,896.19)	10,706.25	2,998	
Percentage of the ORR population at risk				8.95%

[a]The number of animals present within the OU was calculated by multiplying the total area of suitable habitat (ha) by 0.28 American woodcock/ha (derived from Stewart and Robbins 1958).

[b]All woodcock present within OUs are exposed at levels exceeding the LOAEL, with the exception of animals at K-1414.

[c]The percentage of the ORR population exposed = (estimated no. of animals present on the OU/total no. of animals on the reservation) x 100.

[d]Habitat maps are not available for the K-1414 OU.

Table 5.6 The number of potentially exposed red-tailed hawk within each OU and the entire reservation

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[a]	% of the ORR population exposed[b]
BCV OU	Evergreen plantation (20.9) Evergreen forest (37.37) Deciduous forest (192.81) Mixed forest (140.56) Pasture (14.62) Transitional (246.06)	652.32	39	5.5
LEFPC	Evergreen plantation (2.62) Evergreen forest (7.37) Deciduous forest (41.06) Mixed forest (50.87) Pasture (8.5) Transitional (133.87)	244.29	15	2.1
WAG 2	Evergreen forest (1) Deciduous forest (15.75) Mixed forest (29) Pasture (0.06) Transitional (14.81)	606.2	4	0.57
WAG 5	Deciduous forest (3.56) Mixed forest (6.44) Pasture (7.69) Transitional (9.06)	26.75	2	0.28
South Campus Facility	Pasture (13.25) Transitional (4.5)	17.75	1	0.14
WAG 6	Deciduous forest (5.06) Mixed forest (2.06) Pasture (0.5) Transitional (2.94)	10.56	0.63	0.09
Chestnut Ridge OU2	Deciduous forest (3.81) Mixed forest (0.38) Transitional (2.62)	6.81	0.41	0.06
K-1407 OU	Transitional (4.19)	4.19	0.25	0.04
WAG 1	Evergreen forest (0.81) Deciduous forest (1.25) Mixed forest (0.81) Pasture (0.94)	3.81	0.23	0.03
BC OU2	Transitional (0.62)	0.62	0.04	0.006
UEFPC OU2	0	0	0	0.00
K-1420 OU	0	0	0	0.00

Table 5.6 (continued)

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[a]	% of the ORR population exposed
K-1414 OU[c]				
Total no. exposed within 13 OUs			8	
Total reservation	Evergreen plantations (323.5) Evergreen forest (704.87) Deciduous forest (4,028.62) Mixed forest (3,469) Pasture (312.44) Transitional (2,896.19)	11,734.8	704	
Percentage of the ORR population at risk				**8.82%**

[a]The number of animals present within OU was calculated by multiplying the total area of suitable habitat (ha) by 0.06 red tailed hawks/ha (calculated from 0.03 pairs/ha, EPA 1993).

[b]The percentage of the ORR population exposed = (estimated no. of animals present on the OU/the total no. of animals on the reservation) x 100.

[c]Habitat maps are not available for the K-1414 OU.

Table 5.7. The number of potentially exposed red fox within each OU and the entire reservation

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[ab]	% of the ORR population exposed[c]
BCV OU	Evergreen plantation (20.9) Evergreen forest (37.37) Deciduous forest (192.81) Mixed forest (140.56) Pasture (14.62) Transitional (246.06)	652.32	50	5.5
LEFPC	Evergreen plantation (2.62) Evergreen forest (7.37) Deciduous forest (41.06) Mixed forest (50.87) Pasture (8.5) Transitional (133.87)	244.29	19	2.1
WAG 2	Evergreen forest (1) Deciduous forest (15.75) Mixed forest (29) Pasture (0.06) Transitional (14.81)	60.62	5	0.55
WAG 5	Deciduous forest (3.56) Mixed forest (6.44) Pasture (7.69) Transitional (9.06)	26.75	2	0.22
South Campus Facility	Pasture (13.25) Transitional (4.5)	17.75	1	0.11
WAG 6	Deciduous forest (5.06) Mixed forest (2.06) Pasture (0.5) Transitional (2.94)	10.56	0.81	0.09
Chestnut Ridge OU2	Deciduous forest (3.81) Mixed forest (0.38) Transitional (2.62)	6.81	0.52	0.05
K-1407 OU	Transitional (4.19)	4.19	0.32	0.04
WAG 1	Evergreen forest (0.81) Deciduous forest (1.25) Mixed forest (0.81) Pasture (0.94)	3.81	0.29	0.03
BC OU2	Transitional (0.62)	0.62	0.05	0.006
UEFPC OU2	0	0	0	0.00
K-1420 OU	0	0	0	0.00

Table 5.7 (continued)

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[a,b]	% of the ORR population exposed
K-1414 OU[d]				
Total no. exposed within 13 OUs			79[b]	
Total reservation	Evergreen plantations (323.5) Evergreen forest (704.87) Deciduous forest (4,028.62) Mixed forest (3,469) Pasture (312.44) Transitional (2,896.19)	11,734.8	904	
Percentage of the ORR population at risk				**8.71%**

[a]The number of animals present within OU was calculated by multiplying the total area of suitable habitat (ha) by 0.077 foxes/ha (EPA 1993).

[b]All red fox present on OUs are exposed at contaminant levels >LOAELs, with the exception of animals at WAG 5 and K-1414.

[c]The percentage of theORR population exposed = (estimated no. of animals present on the OU/the total no. of animals on the reservation) x 100.

[d]Habitat maps are not available for the K-1414 OU.

than LOAEL from Aroclor 1260, Cd, Cr, Hg, and Se (Efroymson et al. 1996). WAG 5, the fourth ranked contributor, only poses a risk to the short-tailed shrew and woodcock populations from Cr, Hg, and Zn exposure.

5.4.5 Quality and Completeness of Data

Although the data used in this portion of the assessment were generally considered to be of high quality, spatial coverage of the ORR was incomplete. Soil data were available for only 12 of 37 OUs on the ORR. Consequently, the magnitude of risk to reservation-wide populations is underestimated. The actual magnitude cannot be determined without incorporating data from additional OUs.

Another limitation, discussed in Chap. 4, concerns the level of detail in the ORR habitat map. There is a need for the habitat maps to identify specific characteristics of the habitat categories. For example, identification of floodplain forests, dense forests, etc. is necessary to better determine suitable habitat for many endpoint species. Furthermore, a better estimate of the number of individuals of each endpoint species within each OU may be predicted.

Additionally, the lack of site specific vegetation and earthworm concentrations on many OUs result in the use of average calculated soil-plant or soil-earthworm uptake factors. The uptake factors have a high degree of uncertainty associated with them and may over or underestimate the risk to herbivorous or vermivorous wildlife.

5.4.6 Uncertainties Concerning Risks to Herbivorous, Vermivorous, and Predatory Wildlife

5.4.6.1 Limitations of habitat maps

The level of precision differs between the habitat maps and the habitat requirements data. For example, habitat type such as open forest, dense forest, or floodplain forest cannot be identified. More detailed information is necessary because the actual habitat that is used may be only portions of the habitat categories (e.g., woodcock prefer moist floodplain soils in forested areas). This may overestimate or underestimate the number of individuals present within an OU.

5.4.6.2 Soil to vegetation and earthworm uptake factors

There is a large degree of uncertainty when using soil to vegetation and earthworm uptake factors to model contaminant concentrations found in vegetation and earthworms. Uptake factors of inorganics will vary by soil condition (e.g., pH, water availability, organic matter content, texture, aeration, elemental concentrations) and plant/earthworm conditions (species and age) (Sommers et al. 1987; Chaney et al. 1984). The use of plant uptake factors assumes that all species and all soil conditions will result in the same uptake rate. Also, the use of uptake factors assumes that the uptake rate is best estimated by taking the average of all observed values. These site specific factors within the OUs are not taken into consideration for the uptake factors that were used. Therefore, the predicted contaminant concentrations in vegetation and earthworms may be overestimated or underestimated; thus overestimating or underestimating contaminant exposure for each endpoint species.

5.4.6.3 Relative quality of habitats

It was assumed that the quality of habitat found within each land cover type was equivalent. Although specific landcover types were designated as providing suitable habitat, the usability of the areas will vary and certain habitat types may be used preferentially. This will either overestimate or underestimate the number of animals found within each OU based on the lower or higher quality of certain habitat types.

5.4.6.4 Distribution of contamination within habitats on operable units

It was assumed that contamination was equally distributed throughout the OU. Therefore, all available habitat that is used by the specific endpoint was assumed to be equally contaminated throughout the entire OU. Because most contamination is likely to be in less suitable habitats (urban areas, lawns, etc.), on-OU contaminant exposure is likely to be overestimated.

5.4.6.5 Literature density values

The use of literature density values of endpoint species, with the exception of deer and turkey, obtained from other areas of the United States, are considered representative of the ORR. This may overestimate or underestimate the number of exposed individuals.

5.4.6.6 Bioavailability of contaminants

It was assumed that 100% of the contaminant concentrations reported in soil and modeled vegetation and earthworms were bioavailable. The double acid extraction method used to determine soil concentrations reflect the total potential pool of contaminants. The future bioavailability of these contaminants, which is dependent upon the chemical (e.g., pH, organic carbon) and physical (e.g., clay, moisture content) nature of the soil, cannot be addressed for this assessment. Therefore, exposure estimates based on the contaminant concentrations in media are highly conservative and are likely to overestimate the actual contaminant exposure experienced.

5.4.6.7 Extrapolation from published toxicity data

To estimate toxicity of contaminants at the site, it was necessary to extrapolate from NOAELs observed for test species (i.e., rats, mice). Although it was assumed that toxicity could be estimated as a function of body size, the accuracy of the estimate is not known. For example, white-tailed deer may be more or less sensitive than rats or mice.

Additional extrapolation uncertainty exists for those contaminants for which data consisted of either LOAELs or was subchronic in duration. For either case, an uncertainty factor of 10 was employed to estimate NOAELs or chronic data. The uncertainty factor of 10 may either over- or underestimate the actual LOAEL-NOAEL or subchronic-chronic relationship.

5.4.6.8 Variable food and water consumption

Although food consumption by wildlife was assumed to be similar to that reported for the same species in other locations, the validity of this assumption cannot be determined. Food consumption at the Clinch River and Poplar Creek may be greater or less than that reported in the literature, resulting in either an increase or decrease in contaminant exposure. Similarly, water consumption was estimated according to the allometric equations of Calder and Braun (1983). The accuracy with which the estimated water consumption represents actual water consumption is unknown.

5.4.6.9 Single contaminant tests vs exposure to multiple contaminants in the field

Although plants and mammals are exposed to multiple contaminants concurrently, published toxicological values only consider effects experienced by exposures to single contaminants. Because some contaminants can interact antagonistically, single contaminant studies may overestimate their toxic potential. Similarly, for those contaminants that interact additively or synergistically, single contaminant studies may underestimate their toxic potential.

5.4.6.10 Inorganic constituents or species present in the environment

Toxicity of metal species varies dramatically depending upon the valence state or form (organic or inorganic) of the metal. For example, arsenic (III) and methyl mercury are more toxic than arsenic (V) and inorganic mercury, respectively. The available data on the contaminant concentrations in media do not report which species or form of contaminant was observed. Because benchmarks used for comparison represented the more toxic species/forms of the metals (particularly for arsenic and mercury), if the less toxic species/form of the metal was actually present in modeled vegetation or sediment from the Clinch River or Poplar Creek, potential toxicity at the sites may be overestimated.

6. CONCLUSIONS

Based upon a preliminary evaluation of the currently available data, the following conclusions may be made concerning risks to selected wide-ranging wildlife species on the ORR:

- The largest OUs on the ORR generally have the most diverse habitat and consequently can support the greatest number of potential endpoint species (Chap. 3).

- Species that can use urban habitats or that have broad habitat requirements have the highest potential to experience exposure because of the large numbers of OUs that provide suitable habitat (Chap. 3).

- Mercury presents a hazard to mink in East Fork Poplar Creek and consequently to a significant portion (30%) of the ORR-wide mink population. Risks to mink from PCBs are not significant (Chap. 4).

- Evaluation of the potential risks to a future ORR-wide population of otter indicates that mercury presents a risk in all watersheds on the ORR. Because the river otter is a state threatened species, effects to any individual is significant. Therefore, the weight of evidence suggests that mercury is significant risk to individual river otter that may occupy the ORR in the future (Chap. 4)

- Comparison of exposure estimates to LOAELs indicates a significant risk from mercury in all watersheds except White Oak Creek. This translates into a risk to 81.5% of the ORR-wide kingfisher population. The limited biomonitoring data indicate that kingfisher on the ORR (particularly in the White Oak Creek area) are accumulating mercury to potentially nephrotoxicty levels. The weight of evidence suggests mercury in all watersheds presents a significant risk to the ORR-wide belted kingfisher population. Risks from PCBs are not significant (Chap. 4).

- Although mercury in fish is estimated to represent a significant risk to great blue heron within the EFPC watershed and, consequently, to an estimated 37% of the heron population on the ORR, studies on two of five colonies adjacent to the ORR indicate that reproduction at these locations is not impaired. Contaminant bioaccumulation and reproductive success are unknown at the three additional colonies adjacent to the ORR. Additionally, the primary foraging locations for herons at the two studied colonies is unknown. Because herons can travel long distances in search of food (>15 km), they are likely to forage at off-site as well as on-site locations, reducing both the exposure they receive and the risk they experience. If birds from the unstudied colonies forage more extensively on the ORR, they may experience greater risk. Because of the high risk estimated for mercury exposure on the ORR, the lack of data for three of five heron colonies adjacent to the ORR, and uncertainty as to where birds from the five ORR colonies forage, a conclusion concerning whether or not great blue heron on the ORR are at risk cannot be made (Chap. 4).

- Comparison of exposure estimates to LOAELs for osprey indicates no significant risk from mercury or PCBs in any area on the ORR that provides suitable habitat (i.e., White Oak Lake and embayment and the K-25 Site area). Biomonitoring data indicates that the reproductive success at osprey nests adjacent to the ORR, along Melton Hill Lake and in Poplar Creek, is greater than the average observed in the United States. The weight of evidence suggests mercury and PCB do not present significant risks to osprey on or near the ORR (Chap. 4).

- On the basis of a habitat-based evaluation of risk, although significant risks exist to individuals of selected herbivore, vermivore, and predator endpoint species resident on OUs, the reservation-wide populations of these endpoints are unlikely to be significantly affected (<20% of the ORR population is affected). This conclusion must be viewed with caution, however, because data were evaluated for only 13 of 37 OUs. Inclusion of additional OUs is likely to increase the proportion of the ORR populations exposed and at risk. (Chap. 5).

7. RECOMMENDED REVISION SCHEDULE

This assessment is based on only a small portion of the data available on the ORR. To accurately evaluate the nature and magnitude of risks on the ORR, all available data should be incorporated and considered. This report should be revised and updated annually until all existing data have been incorporated. Following this, revisions should be produced on a 5-year schedule to incorporate new data that become available.

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