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A Spatially-Dynamic Preliminary Risk Assessment of the Bald Eagle at the Los Alamos National Laboratory

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List of Acronyms

BAF	bioaccumulation factor
BMF	biomagnification factor
BODWT	body weight
COPEC	contaminant of potential ecological concern
DARHT	Dual Axis Radiographic Hydrodynamic Test (Facility)
DDD	dichlorodiphenyldichlor
DDE	dichlorodiphenylethelyne
DDT	dichlorodiphenyltrichloroethane
DOE	Department of Energy
EEU	ecological exposure unit
EIS	Environmental Impact Statement
EPA	US Environmental Protection Agency
ER	Environmental Restoration
FIMAD	Facility for Information Management, Analysis, and Display
F_s	fraction of food intake as soil
GIS	geographic information system
HI	hazard index
HMP	Habitat Management Plan
HQ	hazard quotient
HR	home range
LANL	Los Alamos National Laboratory
NOAEL	no observed adverse effects level
PCBs	polychlorinated biphenyls
RfD	reference dose
SAL	screening action level (soil)
TES	threatened and endangered species
TRV	toxicity reference value (e.g., NOAEL)
UF	uncertainty factor
UTL	upper tolerance level (e.g., 95^{th} percentile)

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Abstract

The Endangered Species Act of 1973 and the Record of Decision on the Dual Axis Radiographic Hydrodynamic Test Facility at the Los Alamos National Laboratory (LANL) require that the Department of Energy protect the bald eagle (*Haliaeetus leucocephalus*), a state and federally listed species, from stressors such as contaminants. A preliminary risk assessment of the bald eagle was performed using a custom FORTRAN code, ECORSK5, and the geographical information system. Estimated exposure doses to the eagle for radionuclide, inorganic metal, and organic contaminants were derived for varying ratios of aquatic vs. terrestrial simulated diet and compared against toxicity reference values to generate hazard indices (HIs). HI results indicate that no appreciable impact to the bald eagle is expected from contaminants at LANL from soil ingestion and food consumption pathways. This includes a measure of cumulative effects from multiple contaminants that assumes linear additive toxicity. Improving model realism by weighting simulated eagle foraging based on distance from potential roost sites increased the HI by 76%, but still to inconsequential levels. Information on risk by specific geographical location was generated, which can be used to manage contaminated areas, eagle habitat, facility siting, and/or facility operations in order to maintain risk from contaminants at low levels.

1.0 Introduction

The Endangered Species Act of 1973 (16 USC 1531 et seq.) mandates protection, conservation, and perpetuation of biological species. Consequently, the Record of Decision on the Dual Axis Radiographic Hydrodynamic Test Facility (DARHT) Environmental Impact Statement (EIS) requires that the US Department of Energy (DOE) take special precautions to protect threatened and endangered species (TES) including the bald eagle (*Haliaeetus leucocephalus*) at the Los Alamos National Laboratory (LANL) from stressors including contaminants (EPA 1995, DOE 1996, DOE 1995). In order to do so, risks to the bald eagle presented by radiological and nonradiological contaminants must be estimated and reported as part of a TES Habitat Management Plan (HMP). This report presents the results of a preliminary risk assessment on the bald eagle as a component of the HMP. Previous assessments have been conducted on the Mexican spotted owl (*Strix occidentalis*) and the American peregrine falcon (*Falco peregrinus anatum*) with the results summarized in Gonzales et al. (1997). The assessments are regulated by the US Fish and Wildlife Service as the statutory authority of the Endangered Species Act of 1973.

The general approach for performing the assessment was to make a quantitative appraisal of the potential effects that soil contaminants might have on the bald eagle when introduced through soil ingestion and food consumption pathways using a modified Quotient Method described by the US Environmental Protection Agency (EPA) (EPA 1996, EPA 1992). The method generally involved comparing calculated doses to the bald eagle against toxicity reference values (TRVs) either provided in or estimated from the scientific literature. An "ecological exposure unit (EEU)," consisting of a predetermined potential roosting habitat and a calculated foraging area or home range (HR), was evaluated. Collectively the roosting habitat and the HR comprised a bald eagle EEU (Figure 1).

2.0 Background

2.0.1 The Bald Eagle and Contaminants

The bald eagle inhabits the North American continent from the Gulf of Mexico to the Arctic (USFWS 1982). In the early 1900s, human interest in the bald eagle may have begun a slow but gradual decline in eagle populations as bird watchers collected eggs and bird specimens with little regard for preservation of the species (Colborn 1991). Many states and provinces paid bounties on bald eagles because they were considered to be nuisances that preyed on livestock and ate too many salmon. The lack of forestry management led to habitat destruction and loss of adequate roosting sites (Colborn 1991). Since eagles stay close to the waterways that they rely on, people recreating on and around water near eagle habitat drove them away.

Even with these early pressures on eagle populations, the bald eagle is a robust bird that has managed to survive for over a million years including periods of widely varying environmental conditions (Colborn 1991). The bald eagle is a top predator that has an efficient energy-conversion system and the versatility to survive climate and food base changes (Colborn 1991). This adaptability led to the conclusion that, with much more rapid declines that began in the 1940s, something entirely new had to be introduced into the eagle's environment to suddenly reduce it's reproductive fitness after a million years (Colborn 1991). The bald eagle's proven hardiness suggested that the more recent rapid decline was probably not the result of natural stresses, but more likely from anthropogenic sources. Three probable causes were identified that most likely contributed to the rapid decline: poaching by humans, the release of dichlorodiphenyltrichloroethane (DDT) and other organochlorine insecticides into the environment, and inadvertent but detrimental human interaction with the bald eagle.

Chemical pesticides and chlorinated hydrocarbons were once used indiscriminately in the United States to control insects and are still used lavishly in some parts of the world. The rapid and severe decline in the bald eagle population, which began in the 1940s, was specifically associated with the potential effects of the pesticide DDT (USFWS 1982). In the United States, heaviest use of DDT began in the 1950s, and an estimated one million metric tons of DDT had been released globally by 1969 (Colborn 1991). Synthetic organic chemicals such as DDT are particularly harmful to the bald eagle

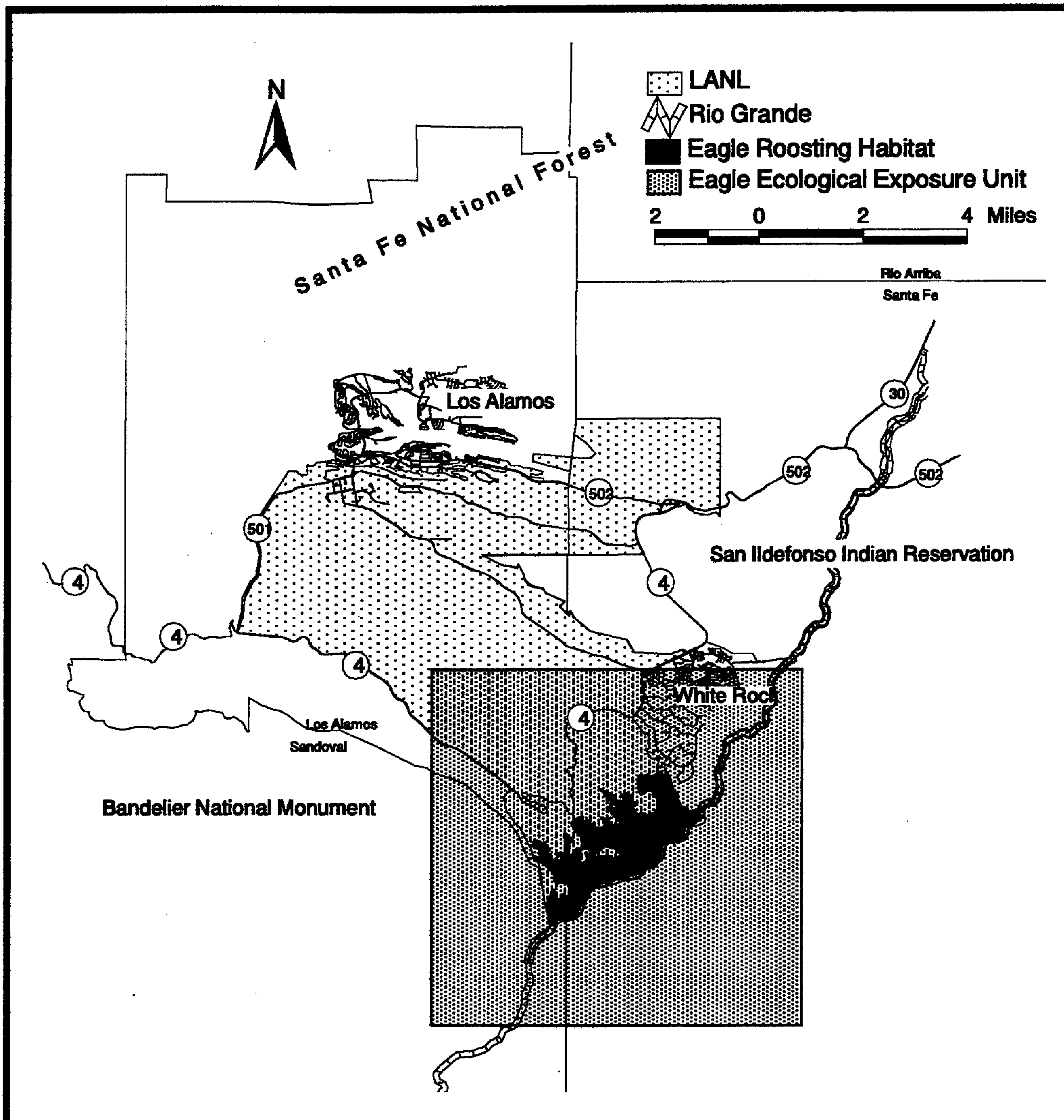

Figure 1. Location of EEUs for risk assessment of the bald eagle at the Los Alamos National Laboratory.

because their predation from the top of their food web led to the accumulation of chemicals in their tissue through the process known as biomagnification. DDT, its metabolites, and other organochlorine pesticide residues build up in the bird's body tissue as a result of the dangerous concentrations within their prey (Burnett et al. 1989). The concentrations typically found in bald eagles were not lethal to the adults, but dichlorodiphenylethelyne (DDE), a break-down product of DDT, resulted in eggshell thinning and breaking, leading to reduced roosting success (Burnett et al. 1989). DDT also limits bald eagle reproduction by increasing embryo mortality (Koeman et al. 1972). By the mid 1960s, the decline in breeding bald eagles exceeded 50 percent in some areas and approached 100 percent in extreme cases (Nebraska Wildlife 1997). In addition, roosting failures of 55 percent to 96 percent were found for the remaining roosting pairs.

Human perspectives about eagles have shifted from indifference and ignorance to a great regard, and led to extensive action to protect the bald eagle. Major eagle breeding areas have been designated and protected. The Bald Eagle Act was passed in 1940 making it illegal to sell, transport, export, or import any live or dead bald eagle, its parts, roosts, or eggs. In 1966, the US Department of Interior closed eagle roosting sites on most public lands during the roosting season. In 1972, the use of poisons on public lands was banned by Presidential Executive Order. Then in 1978, the bald eagle was classified as endangered in 43 states and threatened in another five states (USFWS 1982). All of these efforts have elevated the bald eagle from virtual extinction to threatened status. Population increases have been recorded throughout much of the bald eagle range. As a result, in 1995, the status of the bald eagle was changed from endangered to threatened for all of the lower 48 states.

Since the 1972 ban of DDT, levels of DDT, DDE and dichlorodiphenyldichlor (DDD) in bald eagles have decreased significantly (WWF 1990). In a study at Padre Island, Texas, between 1978 and 1994 the geometric mean of DDE residues dropped from 1.43 to 0.41 µg/g wet wt (Henny et al. 1996). DDT and DDD levels dropped to nondetectable levels in 1994 compared to 0.44 and 0.28 µg/g, respectively in 1984. It is important to note, however, that neither pesticide contamination nor population decline for any species in North America have been uniform (USFWS 1982).

Locally, the bald eagle is a migrant and winter resident along the Rio Grande and on lands adjacent to LANL. Winter roosting counts of bald eagles in the Cochiti Lake area have generally increased from 1979 to 1996 (Johnson 1993). As the Cochiti Lake delta continues to expand, the number of wintering eagles on DOE land in White Rock Canyon should increase (Johnson 1993).

2.0.2 Risk Assessment at Los Alamos National Laboratory

The development of methods for estimating the effects of toxic substances on animal and plant populations at LANL, with particular interest in ecosystem dynamics, is an ongoing program at this Laboratory. Recent efforts to standardize the estimation methods for LANL have been published and were used as a guide for this study (Ferenbaugh et al. 1997). The method employs a tiered approach whereby conservative risk screening is conducted first, and then successive stages of progressively more complex risk assessments are performed in subsequent "tiers." The HMP risk component for a TES does not include an initial screening of contaminated sites. Since it is required that TES are given a greater level of protection than other populations, a result of "no further action" obtained using a screening method would likely not be accepted by regulators (Ferenbaugh 1997). Also, risk determination for protected species requires a greater level of accuracy than can sometimes be attained using simple screening methods. This study is considered a "Tier 2" risk assessment, and the level of detail and complexity of risk parameters are commensurate with the tiered approach.

2.1 Methods

2.1.1 Development of Ecological Exposure Units

An EEU, for purposes of this study, is a unit defined by the biology of a species or group, within which an ecological risk assessment is conducted. The EEU for the bald eagle consisted of a predetermined suitable roosting habitat and an estimated HR that is based on body weight, both as described below.

2.1.2 Nesting Habitat

The preferred roosting habitat of the bald eagle is waterfront or shoreline with large perch trees that offer an unobstructed view of foraging areas (Garrett et al. 1993). Visibility and proximity to food and water are critical in roosting habitat (Stalmaster 1976, Swensen et al. 1986).

Locally, habitat identification has been based on analysis of foraging and roosting topography and cliff characteristics associated with bald eagle breeding areas (Johnson 1996a, 1992). Roosting suitability is based on factors of cliff or tree size, structure, position, proximity to aquatic habitat, and temperature (Johnson 1991). Suitable roosting habitats are monitored for occupancy and roosting activity (Johnson 1996a, 1983). Suitability of breeding territories is indexed to factors of elevation, slope, prey abundance, diversity, and vulnerability. Roosting is restricted to the lower portions of LANL near the Rio Grande, which includes all or sections of the lower portions of Potrillo Canyon, Water Canyon, Ancho Canyon, and Chaquehui Canyon (Johnson 1996a). Bald eagles have been sighted flying in upper Los Alamos Canyon, however, they are not known to roost in the upper portions of LANL (Johnson 1996a).

2.1.3 Home Range

The bald eagle will travel approximately 2.6 km in radius from their roost to forage (Garrett et al. 1993). The HR, or foraging area, around any specific roosting site was estimated according to Peters' (1993) equation for carnivorous birds as

$$HR = 8.3 \bullet BODWT^{1.37}, \qquad (1)$$

where

HR = animal home range, km^2, and
BODWT = animal body weight, kilograms fresh weight (kgfwt).

The heavier body weight of the two genders, 3.1 kgfwt, was assumed for both male and female bald eagle (WWFC 1996), although some variation occurs between and within sexes.

2.1.4 Ecological Exposure Units and Home Range Mapping

The extreme boundaries of the bald eagle EEU were established by mapping an area that was 3.1 km from the extreme most north, south, west, and east boundary of the roosting habitat. The resultant EEU, measuring 125 km^2, is shown in Figure 1. EEU-70 encompasses all or portions of LANL Technical Areas 33, 36, 39, 49, 54, 68, 70, and 71. EEU-70 was mapped by using a geographic information system (GIS) and the GIS software ARC/INFO (ESRI 1996a) as previously described (Gallegos et al. 1997a).

The GIS was used to create spatial data sets, combine information from different spatial data sets, generate a spatial grid, and produce maps. The spatial extent of the roosting bald eagle habitat was digitized into ARC/INFO to create a coverage (theme, or layer). This habitat was assigned an attribute coverage factor (map code value). The modeling also required additional coverages, a grid set, and a forage habitat coverage to be developed.

2.2 Data Compilation

2.2.1 Data Source and Compilation Procedure

Data used for this risk assessment were collected for environmental surveillance and restoration activities at LANL by sampling and analyzing fish in the Rio Grande (Fresquez et al. 1994) for radionuclides and inorganic metals; sediment in the Rio Grande for organics, radionuclides, and inorganic metals; and terrestrial soils for inorganic, organic, and radioactive contaminants form 1992 – 1996 (e.g., LANL 1997). Analytical results from this sampling are maintained in an Oracle database (Oracle 1994a) by Facility for Information Management, Analysis, and Display (FIMAD). FIMAD data can be accessed through the command line Structured Query Language (Oracle 1994b) or through the graphical interface Databrowser (Oracle 1994c). The data for the risk assessment component of the TES project were accessed primarily with the latter. Data were compiled from the FIMAD database and organized by grid cell following procedures previously described (Gallegos et al. 1997a). A summary of the data compilation and management process is as follows:

- As part of the query language, analytical results were screened to contain only samples with a beginning depth equal to zero. Although higher quantities of contaminants have been found at intermediate soil depths than at shallow depths elsewhere at LANL (Gonzales and Newell 1996), their availability to aboveground biota is unlikely. The data was then exported to a personal computer and modified further using Microsoft Access® software.
- For the organics and inorganics, measured soil concentrations reported as below the detection limits of the instrumentation used in the analysis were assigned one-half the detection limit per Gilbert (1987).
- Where more than one sampling point existed within a 100- × 100-ft grid cell, arithmetic means were calculated and used as representative of the grid cell. Considerations on assigning contaminant concentrations to unsampled points and on spatial weighting techniques were previously discussed (Gallegos et al. 1997). Sophisticated estimation techniques were not employed for this level ("Tier 2") of risk assessment. Assuming that an entire 100- × 100-ft area contained an analyte concentration that was measured in as few as one sample is a conservative assumption in cases in which contamination is actually confined to an area less than 10,000 ft^2.
- Sources of mean "natural" (inorganics) or "regional" (radionuclides) soil background concentration values were Fresquez et al. (1996) and Longmire et al. (1996).
- The final data contained the fields: grid cell identification, analyte name, analyte code, analyte average (by grid cell), TRVs, TRV adjustment factor,

occupancy factor, background value, number of analytes per cell, x-coordinate, y-coordinate, and bioaccumulation factor (BAF) and/or biomagnification factor (BMF). Finally, the fields were formatted as a database ("eeuinp.dat") for input to the model "ECORSK5."

2.2.2 Data Quality Assurance

2.2.2.1 Facility for Information Management, Analysis, and Display Data

The electronic data that were available for the ecological risk database were the anyl_master table maintained by FIMAD. The basic assumption in this study was that FIMAD data were sufficiently current and sufficiently accurate such that any deviation in accuracy and currency that was not factored in would not impact the conclusion on risk. There is some evidence supporting this assumption.

The Environmental Restoration (ER) Office has committed resources to quality assurance/quality control issues to ensure that the electronic data are reliable. This process generally includes a comparison between hard copy results received from the laboratories and the electronic version of the data. Estimates are that anyl_master table data are accurate, i.e., generally between 95% and 98% (Manzel 1997). At the time that the data were downloaded, approximately 75% of the data in the stage_tables had been edited and the data that were yet to be edited were considered only 50% accurate. Based on the source distribution of the data used in this study (99% analytical_info tables and 1% staging tables) and the estimated accuracies, <1% (1% × 0.75 × 0.5) of the stage table data and 2 to 5% of the analytical info table data were potentially inaccurate.

Although the accuracy estimates are subjective, the amount of uncertainty in FIMAD data would have little impact on risk values and no impact on risk conclusions primarily because the number of grid cells sampled for each execution of ECORSK5 for the bald eagle was so large – approximately 41,964 per HR – that any single contaminant value or small set of values that were erroneous would impact the entire data population by negligible amounts.

Of greater significance is (1) the currency of data and (2) the spatial completeness of sampling in an EEU as related to the status of ER's RFI Work Plans. The first addresses the time lag between the date of sampling and the date when the analytical results are available in FIMAD. The process of compiling data for ecorisk databases is inextricably linked to availability of spatial data for analytical samples. Only those samples that have coordinates stored electronically in FIMAD have been included in the analysis, and FIMAD updates its libraries weekly. However, if samples were taken and analytical results were uploaded to FIMAD, but location information was not, the sample was not included in the ecorisk database. Coordinates for nearly 75% of the sample results stored in an95_output had not been submitted to FIMAD, consequently they were not included in the analysis. The latter issue – completeness, or totality, of sampling – addresses the underestimate of risk associated with the presence of potentially contaminated areas that are yet to be sampled. As currently planned, both of these sources of uncertainty could be addressed by periodically repeating the data download, compilation, and risk assessment process as currently planned. This will take advantage of any increases in database accuracy.

2.2.2.2 Data Retrieval

The process of downloading analytical results from FIMAD, identifying sampling locations using ArcView, compiling them into a location table, and performing queries has been detailed in a prior report (Gallegos et al. 1997a). As a final check on currentness, a database originally compiled in August 1996 for a previous study (Gallegos et al. 1997b) was updated in January 1997 to include any new data that may have been uploaded since the original compilation. Most grid cell averages remained unchanged, indicating that inconsequential amounts of new or changed data were downloaded in that five-month period.

One final issue relates to the kinds of sample values used to compile the ecorisk database. Specifically, the FIMAD database did not identify whether a given sample was collected as part of the initial investigation of a site with sample values that should be replaced by confirmation sample values after a site was cleaned. This error would create bias for grid cells that contain remediated sites, leading to a conservative or overestimate of risk. If this became important because an unacceptable level of risk was estimated, efforts would be made to identify and eliminate precleanup values that are no longer valid.

Another source of conservatism is the collection of samples from locations that are suspected of having the highest contaminant levels.

2.2.2.3 Conclusion on Data Quality Assurance

The majority of the relevant available data used for this preliminary ecological risk assessment provide an adequately conservative representation of soil contamination within the EEU. Improvements in future studies will be the inclusion of data from the an95_output table, which has higher accuracy. As the EEUs considered in this study contain grid cells that were also components of previous studies (Gallegos et al. 1997a and 1997b) and are likely to be components of future studies, review of data quality is a continuous, sometimes repetitive, process that will provide added assurance that the data are reliable and accurate.

2.3 Preliminary List of Contaminants of Potential Ecological Concern

Contaminants of potential ecological concern (COPECs) are those

- known to have been used or to be present in the EEU,
- to which receptors within the EEU are known to be sensitive,
- identified as of concern during any human health risk assessment conducted in the same area, and
- that warrant concern because of their toxicity, persistence, exposure potential, or food chain transfer (Ferenbaugh et al. 1997).

Querying LANL's FIMAD database for surface layer soil analytical results generated a preliminary list of COPECs for each EEU. Any analyte listed in the FIMAD database for which no analytical detections were made in the entire EEU was not included in the list.

Contribution to risk by any given COPEC could be calculated, as discussed later, only if a TRV was available for that COPEC. The preliminary COPEC list for the bald eagle should ultimately be revised on the basis of the eagle's sensitivity, and whether complete pathways exist from contaminant sources to the bald eagle (Ferenbaugh et al. 1997).

2.4 Eagle Diet

Adjacent to LANL, bald eagles forage along the Rio Grande and Cochiti Lake, and their wintering includes the area within LANL boundaries. While they forage most often in the vicinity of Cochiti Lake, they use all of White Rock Canyon regularly, and the entire Pajarito Plateau occasionally (Johnson 1996a). The bald eagle's use of White Rock Canyon within the LANL boundary is expected to increase as the Cochiti Lake delta expands upstream and as numbers of wintering bald eagles increase (Johnson 1996a).

Bald eagles are second-order carnivores. They are predators and opportunistic scavengers. In 14 breeding areas of Arizona, the average composition of bald eagle diet was 76% fish, 18% mammal, 4% bird, and 2% reptile/amphibian (Grubb 1995). Fish consumption comprised 76% of the eagle's diet on average and ranged from 49% to 94%. Locally, the bald eagle consumes primarily fish, and also eats waterfowl, small mammals, especially rabbits, and carrion at about the same ratio of aquatic to terrestrial foraging as documented in the Arizona study (Johnson 1996b), although, they can consume significant amounts of carrion, especially deer and elk.

2.5 Pathways of Exposure

Based on a general conceptual model of pathways of contaminant exposure at LANL (Ferenbaugh et al. 1997), pathways for the bald eagle are generally established as

- Primary Source of Contamination: Burial and outfalls;
- Primary Release Mechanisms: Erosion, runoff, direct contact of soil, rodent burrowing, outfall release, plant uptake, volatilization, and soil particle suspension;
- Primary Direct Exposure Pathways: Ingestion of contaminated soil and sediment that is on or in prey species and food consumption.

2.6 Risk Calculation

Defined simplistically, ecological risk assessment is the appraisal of actual or potential effects of contaminants on flora and fauna. The measure used in this study to quantitatively appraise risk from contaminants to the bald eagle is a modified Quotient Method (EPA 1996, 1992) whereby the Hazard Quotient (HQ) serves as the measure of potential risk. Modification of the method primarily entailed the inclusion of "noncontaminated" areas (grid cells) in the simulated foraging process.

Section 2.4 established the range in fish consumption by the bald eagle as 49% to 94%. On this basis, the proportion of fish assumed in the diet of the eagle for this study ranged from 50% to 90%. Specifically, three different dietary ratios of aquatic (fish) to terrestrial foraging were considered—90:10, 75:25, and 50:50.

2.6.1 Nonradionuclide Contaminants

The general form of the HQ used for the inorganic metal and organic contaminants is defined as

$$HQ = Dc/TRV, \tag{2}$$

where

HQ = Hazard Quotient,

Dc = estimated chronically consumed dose, mg COPEC/kg body weight per day, and

TRV = consumed dose, mg COPEC/kg body weight per day, below which adverse effects are not expected to occur.

When HQs for all contaminants are summed, it becomes a cumulative HQ and is termed Hazard Index (HI). The risk evaluation criteria used for interpreting HI results are shown in Table 1. With a threshold evaluative criteria of 1.0, HIs or HQs >1.0 are considered indicative of potential for impact and, more conclusively, indicate the need to further assess risk to the species by (a) examining the conservative assumptions and model input parameters for excessive conservatism, and/or (b) conducting a more complex ("Tier 3") risk assessment. A more detailed version of the formula above for computing the HI from multiple contaminants and multiple contaminated areas is

Nonradionuclides:

$$HI = Food \times Fs/Bodwt \times \sum_{j=1}^{ncs} Occup_j \sum_{l=1}^{ncoc} BMF_l \, Dc_{j,l}/(Dr_l \times Dar_l), \quad (3)$$

where,

HI = Hazard Index (cumulative HQ for all COPECs),

Food = amount of food consumed by a given animal, kg/day,

Fs = fraction of food ingestion consumed as soil,

BMF = biomagnification factor (for 15 COPECs),

$Occup_j$ = occupancy factor on the jth contamination site,

$Dc_{j,l}$ = concentration of COPEC in soil (mg COPEC/kg soil) for the jth contamination site of the lth COPEC,

Dr_l = consumed dose above which observable adverse effects may occur, mg-COPEC/kg-body weight-day of the lth COPEC, and

Dar_l = adjustment factor for Dr_l above for the lth COPEC,

Bodwt = body weight, kgfwt, of the receptor species,

ncs = # contaminated sites, and

ncoc = # contaminants.

Table 1. Risk evaluation criteria used to interpret results of applying the EPA Hazard Quotient method (Menzie et al. 1993; EPA 1986).

Hazard Index Range	Conclusion
<1.0	No appreciable impact
1.0 – 10.0	Small potential for impacts
10 – 100	Substantial potential for impacts
>100	Ecological impacts very probable

2.6.2 Food Intake (Food)

Daily food consumption of a given animal is estimated in ECORSK5 using the following relationships (EPA 1993a):

$$Food = 0.0687 \times BODWT^{0.886} \text{ mammals,} \quad (4a)$$

$$Food = 582 \times BODWT^{0.651} \text{ birds,} \quad (4b)$$

$$Food = 0.0135 \times (BODWT \cdot 1000)^{0.773} \text{ reptiles and amphibians,} \quad (4c)$$

where

Food = food consumption rate, kg/day, of dry matter, and

BODWT = body weight of animal, kgfwt.

The heavier body weight of the two genders, 3.1 kgfwt, was assumed for both male and female bald eagle (WWFC 1996). The equations above represent relationships that can be applied to the general types of animals specified above, however, more specific relationships for special subtypes are also available if greater accuracy is required.

2.6.3 Occupancy Factor (Occup)

Occupancy factors are defined in this study as the fraction of the time in a given day that an animal spends feeding in a given area. Occupancy is assumed to be time averaged over a long period to obtain a probabilistic relationship. This factor can be determined on an a real basis if it is assumed that any given area within an animal's habitat is equally likely to serve as a feeding location for a given animal over the long term. However, many factors could restrict or enhance a given area to support feeding activities depending on the distribution of food in the EEU, the relative accessibility of feeding areas, and feeding patterns/habits of the predator.

$$Occup_j = \frac{A_j}{\sum_{j=1}^{ng} A_j Ef_j} \qquad (5)$$

,

where

$Occup_j$ = occupancy factor of the j^{th} grid,

A_j = area, km^2, of the j^{th} grid within the HR of a given animal,

Ef_j = enhancement factor of the j^{th} grid within the HR of a given animal, and

ng = number of grid cell sites within the HR of a given animal.

Two cases of $Occup_j$ were considered for the terrestrial portion of the simulated diet:

1. Unweighted foraging: the bald eagle feeds within its calculated HR with no regard to distance of any feeding area (grid cell) from a potential roost site, and
2. Weighted foraging: $Occup_j = e^{-r/2000}$ (Johnson 1996b), which estimates the relative probability of foraging as a function of radial distance in meters from the roost. This results in approximately 50% of the foraging within two km of the roost site for the terrestrial portion of the diet (Johnson 1996b).

Since the occupancy factor is part of the ECORSK5 input, the user is able to modify this relationship to reflect increased or decreased feeding in a specific grid area. The location of the potential roosting site within an EEU determines which contaminated and noncontaminated grid cells are included in the summation portion of Eq. 5. The selection process is discussed in the following subsection.

2.6.4 Radionuclides

Animal toxicity data such as "no observed adverse effects levels" (NOAELs) for radionuclides are largely unavailable, therefore an alternative method was employed. Levels of radionuclides in soil called screening action levels (SALs) have been estimated for use as standards protective of humans. The SALs for radionuclides are estimated using the RESRAD code for radionuclide exposure to humans from elements of the food chain and non-food chain deposition processes (LANL 1993). The application of human standards to animals is conservative. This has been quantified and previously discussed in a report on the American peregrine falcon (Gallegos et al. 1997a).

The HQ method applying human SALs to animals is similar to the HQ method involving ingested doses:

Radionuclides:

$$HI = \sum_{j=1}^{ncs} Occup_j \sum_{l=1}^{ncoc} SC_{j,l} / (SAL_l \times SALa_l), \quad (6)$$

where,

HI = Hazard Index (cumulative HQ for all COPECs),

$SC_{j,l}$ = soil concentration of COPEC, pCi-COPEC/kg-soil for the jth contamination site of the 1th COPEC,

SAL_l = screening action level, pCi COPEC/kg soil of the lth COPEC,

$SALa_l$ = adjustment factor for SAL_l above for the 1th COPEC,

$Occup_j$ = occupancy factor on the jth contamination site,

ncs = number of contamination sites, and

ncoc = number of contaminants in the jth contamination site.

This study used the above relationship for estimating radionuclide HQs. They were then added to HQs for nonradionuclides, but can be easily separated from nonradionuclides and presented in that format. As with the nonradionuclides, two cases of hypothetical foraging were considered for the radionuclides – unweighted foraging and weighted foraging.

2.6.5 Fraction of Food Intake as Soil, F_s

The fraction of food intake as soil, F_s, is currently an issue under consideration at LANL and has been previously discussed by Gallegos et al. (1997a). Studies on cattle, sheep, and swine have shown that soil was the main source of exposure to environmental contaminants that included lead, polychlorinated biphenyls (PCBs), polybrominated biphenyls, hexachlorobenzene, and DDT (Fries 1982, Russel et al. 1985, Fries and Jacobs 1986, Fries and Marrow 1982, Fries et al. 1982). Because soil ingestion rates of some wildlife species are estimated to be at least as great as those for domestic species, soil ingestion is an important route of exposure to environmental contaminants for wildlife (Beyer et al. 1994). Wildlife may ingest amounts of soil while feeding that are substantial enough to constitute the main source of exposure to environmental contaminants.

The F_s used for the bald eagle in this study was conservatively estimated from real data on concentrations of radionuclides in fish and sediment as

$$F_s = \frac{I_{sed}}{C_{food}}, \quad (7)$$

where

F_s = fraction of diet comprised of soil,

I_{sed} = sediment ingestion rate ($g_{dry}\ d^{-1}$), and

C_{food}= food consumption rate ($g_{dry}\ d^{-1}$) based on gut content;

$$I_{sed} = \frac{S_{rad}}{SC_{rad}}, \quad (8)$$

where

S_{rad} = radionuclide sediment intake rate (pCi d^{-1}) and

SC_{rad} = concentration of radionuclide in sediment (pCi g^{-1});

and

$$S_{rad} = C_{food} \times T_{rad} \quad (9)$$

where

T_{rad} = radionuclide concentration in fish viscera, muscle, and associated skeleton (pCi·$g_{(dry)}^{-1}$).

Data on radionuclide concentration in fish were taken from Fresquez et al. (1994) and data on radionuclide concentrations in sediment were taken from LANL annual environmental surveillance reports for the years 1992 – 1996 (e.g., LANL 1997). The estimated F_s was 1.16%. A conservative F_s of 2.0% was used. A previous study (Gallegos et al. 1997b) estimated 2.8–3.0% as an accurate F_s value for a species (Mexican spotted owl) that consumes predominantly rodents (including pelts) that have direct contact with soil on a daily basis. Bald eagle prey does not have as much direct contact of soil as that of Mexican spotted owl prey. Bald eagles consume primarily fish, waterfowl, small mammals, and carrion (Johnson 1991). Since they don't consume pelts or feathers like the owl, the F_s for the eagle would be smaller for the terrestrial component of their diet. Thus, an F_s of 2.0% for the bald eagle is adequately conservative.

2.6.6 Bioaccumulation and Biomagnification

Several historical cases have implied that the higher the trophic level of an organism on a food chain, the greater its susceptibility to biomagnification (Leidy 1980). In this scenario, carnivores such as the bald eagle could be more subject to biomagnification than herbivores. However, biomagnification is more apparent in aquatic systems than terrestrial, and recent studies question the validity of biomagnification in terrestrial systems (Laskowski 1991). While biomagnification of the chlorinated hydrocarbons (organochlorines) is fairly well proven (Walker 1990), the concentration of heavy metals in animals is not necessarily a property of food chains (Laskowski 1991). Heavy metal biomagnification has been implicated mostly in mammals (Shore and Douben 1994, Hegstrom and West 1989, Ma 1987). Conclusions to the contrary are that

- heavy metal biomagnification is not a rule in terrestrial food chains (Laskowski 1991, Beyer et al. 1985, Grodzinska et al. 1987, Willamo and Nuorteva 1987, Nuorteva 1988),
- "biomagnification alone cannot lead to very high concentrations of most heavy metals in top carnivores" (Laskowski 1991), and
- "biomagnification cannot be responsible for toxic effects of heavy metals in terrestrial carnivores" (Laskowski 1991).

Nevertheless,

- biomagnification of heavy metals to toxic levels can occur from relatively low concentrations in soil (Ma 1987);
- even if a chemical or its metabolites have high NOAELs in long-term ecotoxicity or toxicity tests, incomplete metabolic elimination of contaminants, also known as bound residues, can result in potential risk from bioaccumulation or biomagnification (Franke et al. 1994).

Therefore, scenarios including bioaccumulation and biomagnification phenomena were assessed.

2.6.6.1 Aquatic BAFs/BMFs

BAFs and BMFs for the aquatic (fish) portion of the foraging scheme were inherently included in the calculation of F_s. As previously mentioned, contaminant data in fish was available only for radionuclides and metals. Since sampling results have consistently shown no detection of organics in sediment (LANL 1996) and organics in fish have not been analyzed for organics, bioaccumulation and biomagnification of organic COPECs was included in the estimates of risk for the terrestrial diet component only.

2.6.6.2 Terrestrial BAFs/BMFs

BAFs for aldrin, dieldrin, endrin, DDT, and DDE were 5.35, 5.35, 7.9, 2.62, and 2.62, respectively, taken from Calabrese and Baldwin (1993) for the bald eagle in a terrestrial food web. For the same respective COPECs in a terrestrial food web, BMFs were 9.42, 9.52, 2.04, 89.2, and 28.2, respectively. On average, these terrestrial-based BMFs were 0.111% of the BMFs for aquatic systems published as human health value criteria under the Clean Water Act (EPA 1993b), and the terrestrial-based BAFs listed above were 31.35% of aquatic-based BAFs. These fractions were used to adjust mean aquatic BMFs and BAFs for 10 additional COPECs for use on terrestrial systems in this study. The source of the aquatic BMFs for the 10 additional COPECs was Smith et al. (1988). The terrestrial-adjusted BMFs by COPEC, used in this study were anthracene, 1.02; all aroclors, 34.63; benzo(a)pyrene, 1.68; chlordane, 15.65; 1,4-dichlorobenzene, 0.06; lindane, 0.30; mercury, 6.11; phenanthrene, 13.39; pyrene, 21.64; and thallium, 0.13. BMFs for radioactive isotopes of Am, Cs, Pu, and Sr, were 4.47, 3.55, 2.23 and 0.44, respectively. BAFs and BMFs for additional COPECs will continue to be incorporated into the risk estimate as they are identified.

2.6.7 Nest Site Selection and Simulated Bald Eagle Foraging

Details of this process have been previously described (Gallegos et al. 1997a). Upon randomly selecting a potential roost site within the defined roosting habitat of the 125-km^2 EEU, ECORSK5 (described later in this report) develops an HR of approximately 39 km^2 for the bald eagle and calculates an HQ for each COPEC within each 100- × 100-ft grid cell of the foraging area. The model repeats this process the number of times specified, which in this case was a total of 100 simulations. Three cases of the ratio of simulated foraging on aquatic prey (fish) vs. terrestrial organisms (carrion) were modeled - 50:50, 75:25, and 90:10. Contaminated grid cells "selected" during one simulation are "replaced" for possible selection during a subsequent simulation, therefore the soil contaminant population is not independent from one simulation to another.

By assuming that the bald eagle forages in noncontaminated as well as contaminated grid cells, our risk estimate lessens a source of error that Tiebout and Brugger (1995) conclude leads to overestimation of risk; i.e., the error associated with the implicit assumption normally made in the Quotient Method that birds remain in a contaminated zone. This assumption also satisfies EPA guidance that "for many terrestrial animals, adjustments of exposure estimates may be needed to account for the possibility that all food obtained by a given animal may not be from the affected area" (EPA 1989). This is especially true for wide ranging animals such as the bald eagle.

2.6.8 Toxicity Reference Values

2.6.8.1 Nonradionuclides

The TRVs chosen to use in quantifying risk from organic and metal COPECs were the chronic NOAELs in units of mg COPEC per kg body wt of the bald eagle per day. A previous report (Gallegos et al. 1997a) can be consulted for information on (1) the NOAELs used in this assessment, (2) references from which the NOAELs were taken or derived, (3) test species on which they are based, (4) the chemical form on which the NOAEL is based, (5) the toxicological test endpoint in the laboratory studies in which the NOAELs were determined, and (6) comparison of alternative NOAELs or TRVs which could have been used. The NOAELs for the metal COPECs are based on avian test species. Lacking avian-based NOAELs, the NOAELs for the organic COPECs are based on laboratory rats. NOAELs can have a substantial impact on risk estimates, therefore it is important to use NOAELs that are based on toxicity testing of species that are as close phylogenetically to the assessed species as possible. EPA databases largely contain NOAELs that are based on testing laboratory rats. Examples of the influence that NOAELs can have on risk estimates, or model sensitivity, have been previously reported (Gallegos et al. 1997a). The replacement of rat-based NOAELs with NOAELs based on birds is a continuous process in this study, and this report will be updated periodically as substantially different NOAELs and other information become available.

In human risk assessments, reference doses (RfDs) are typically adjusted (lowered) by a factor of 10 to account for the uncertainty of extrapolating RfDs within and between species. Because of a broader range of uncertainty in ecological risk, an uncertainty factor (UF) of 10 may be inadequate in ecological risk assessment (Calabrese and Baldwin 1993). Attempts to calculate extrapolations of TRVs have been made by some researchers, however, the bases vary from one researcher to another. For example, Sample et al. (1995) assumed that "smaller animals have higher metabolic rates and are usually more resistant to toxic chemicals because of more rapid rates of metabolic elimination and metabolism is proportional to body weight." Conversely, in a study of risk to vertebrates from pesticides, Tiebout and Brugger (1995) predicted that small-bodied insectivores faced the highest risk.

Other possible sources of uncertainty that are not necessarily exclusive of each other include

- extrapolation of acute dose-derived NOAELs to chronic responses,
- lowest observed adverse effect level to NOAEL conversions,
- extrapolation of sensitive-test-species data to nonsensitive or "normal" life stages,
- extrapolation of less-than-life-span toxicological data to life span,
- time to achievement of contaminant steady-state in laboratory tests on which NOAELs are based, and
- laboratory to field extrapolation (Calabrese and Baldwin 1993).

Some of the above-listed factors have the potential to increase or decrease (under or overestimate) toxicological values. Also, several instances of interdependence of UFs exist, therefore, the assumption that these factors are independent in their application as UFs would likely lead to overconservatism (Calabrese and Baldwin 1993). For these reasons and others previously explained (Gallegos et al. 1997a), UFs were not applied in this study.

2.6.8.2 Radionuclides

Because TRVs for radionuclides in avian species were unavailable, human risk SALs, in mg of radionuclide per kg of soil were used in place of TRVs. As reported previously (Gallegos et al. 1997a and 1997b), the application of values for protecting humans to non-human biota may lead to an overestimate of risk by a factor between 185 and 3,650 when compared to the standard of 0.1 rad/day recommended by the International Atomic Energy Agency (IAEA 1992).

2.7 Risk Sources and Hazard Value Types

The option exists in ECORSK5 to generate indices for three "Hazard Value Types" and three "Risk Sources" as follows:

Hazard Value Type

- HI (Hazard Index) - A sum of the HQs for all COPECs and all grid cells in a foraging area (or HR) averaged across the number of "simulations."
- Mean Partial HQ × Location (Grid Cell) - A sum of the HQs for all COPECs separated by location.
- Mean Partial HQ × Location (Grid Cell) × COPEC - A sum of the HQs separated by location (grid cell) and COPEC.

Risk Sources

- Unadjusted Risk - Quantified impact associated with sampling within LANL boundaries. Sources of HQ values include (i) HQs associated with sampled grid cells, making no adjustment for background soil concentrations; and (ii) for grid cells where sampled COPEC soil concentrations are less than background values, then the soil background value is entered for the calculation of HQs.
- Background Risk - Quantified impact associated with "natural" (nonradionuclides) and "regional" (radionuclides) mean concentrations of COPECs. The mean natural or regional background soil concentration is entered into the HQ formula for grid cells within a HR for which COPECs existed in the Unadjusted Risk data set. Since for Unadjusted Risk, soil background values may be included only for grid cells that were sampled, the same practice for determining Background Risk makes it comparable to Unadjusted Risk. Clifford et al. (1995) have shown that assignment of background levels in Quotient Method risk estimation can be inconsequential in terms of final results.
- Contaminated Nest Site - Represents the unadjusted risk resulting from "situating" potential roost sites on contaminated grid cells within the "roosting" zone. Although this was intended to be a worst case of sorts, but not the absolute worst case, a previous study on the Mexican spotted owl (Gallegos et al. 1997b) showed no appreciable difference between Unadjusted Risk and Contaminated Nest Site risk.

The most useful Hazard Value Type for conveying total risk is the HI. For each of 100 randomly selected potential roost sites of the bald eagle and, thus, 100 simulations, an HQ was calculated for a 39.1-km^2 HR, or foraging area, for each COPEC at each grid cell. The HI (or Mean Total HQ) sums the HQs for all COPECs and all grid cells in a HR and is an average of the 100 sets of data (simulations). Because the HI is the sum of the HQs for all COPECs, it serves as an index of cumulative effects from multiple contaminants and is the most conservative (bias, if any, toward overestimation of risk) of the three Hazard Value Types. Since the 100 simulations may have some contaminant data in common, the distribution of HIs for the 100 roost sites cannot be considered independent.

2.8 Model

The process by which ECORSK5 develops the basic building blocks of the risk assessment has been previously reported (Gallegos et al. 1997a). Some of the features of ECORSK5 are summarized below.

2.8.1 Computer Code Software Development for Ecorisk Determination

A set of computer codes with graphics capabilities, written in FORTRAN 77 (Salford Software Limited 1994), was developed specifically to perform risk assessments of federal and state protected TES for the HMP. The executable code, ECORSK5, integrates spatial data (EEU, roosting habitat, HR, grid cell location, contaminant data) with basic toxicological information and physiological data to estimate risk to a specific animal. Figure 2 illustrates how the codes that accomplish these functions integrate.

The ECORSK5 code estimates partial and total HQs and HIs, respectively, from GIS-located contaminants. Potential roosting sites are also located by GIS mapping, and it is from these focal points that HQs and HIs are estimated using the files shown in Figure 2. These files have been previously defined (Gallegos et al. 1997a).

Code operation follows an ordered procedure that has been summarized previously (Gallegos et al. 1997a). ECORSK5 has the option of selecting potential roost sites within the roosting habitat on the basis of:

- randomness,
- automated placement on "contaminated" grid cells (that are within the roosting habitat),
- user-specified locations, or
- any combination of the above three.

The executable versions of the codes are MS-DOS PC versions, which are transportable to other PCs (for PC users without Salford/Interacter software) by appropriate Run DBOS software that is provided by Salford for this purpose. Satisfactory transport and use of these codes have been demonstrated at LANL's Ecology Group.

2.8.2 HR Dimension Scaling and Slope

To account for variation in the shape of a bald eagle HR that may result from hunting pattern influencing factors such as prey location, an option was programmed into ECORSK5 that enables the user to select a square HR or a rectangular HR with a specified width to height (X/Y) ratio. For example, the ratio of width to height of the estimated roosting habitat for the eagle was 2.6:1. With the input of an X/Y ratio of 2.6, ECORSK5 would scale the HR dimensions so that its width was 2.6 times greater than high. The user also has the option of sloping the HR.

2.9 Hypothesis Testing

In comparison to issues regarding model sensitivity, statistical analyses of differences in risk source (background vs. LANL-related) is relatively unimportant. Contaminants can exert their effect on a threshold basis even in small amounts, regardless of source. For these reasons, testing hypotheses of risk source parameter or distribution differences is not presented. This does not dispel the following

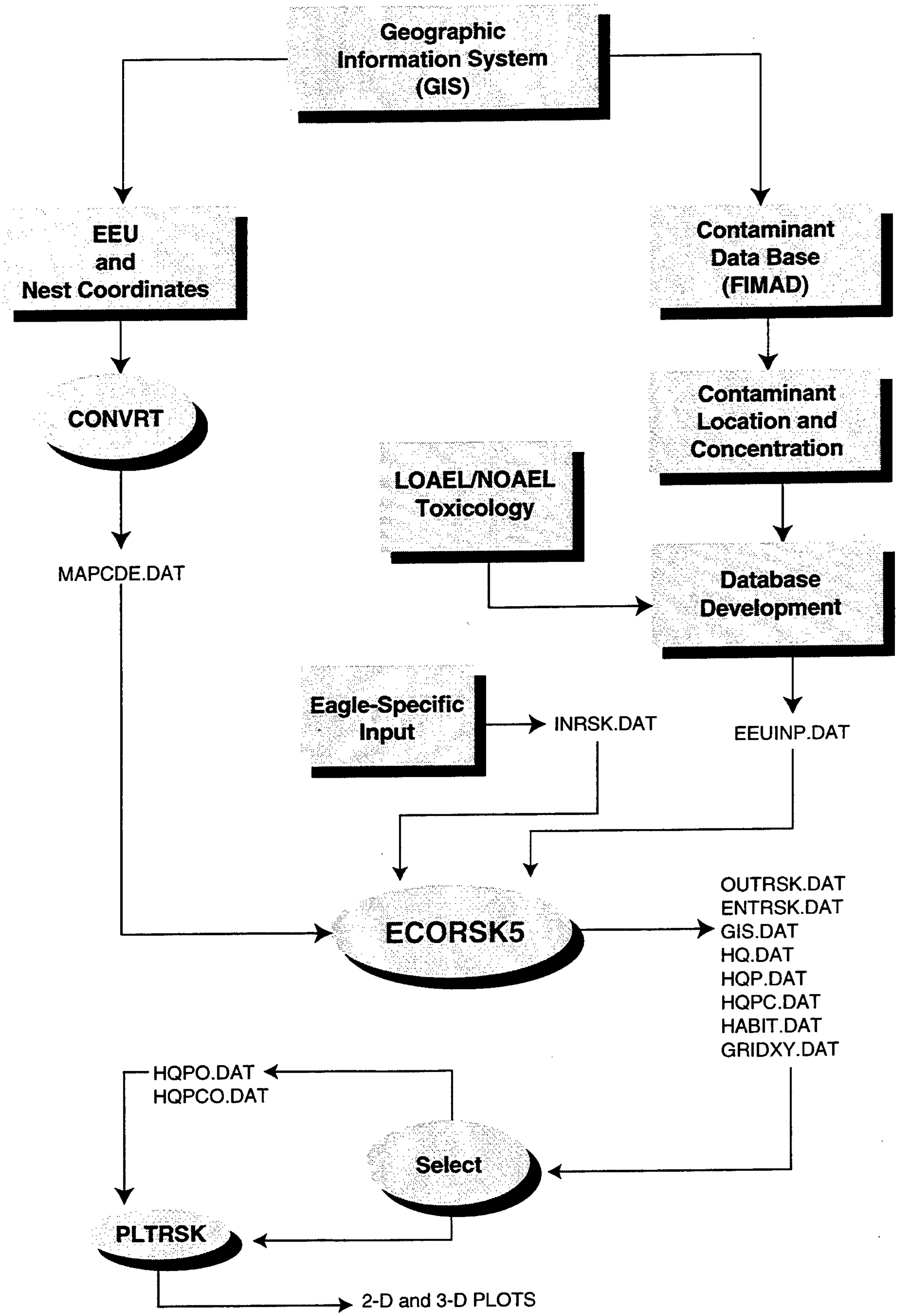

Figure 2. Schematic of strategy for integrating FORTRAN code with GIS and FIMAD data.

possibility – if total (unadjusted) risk is estimated to be relatively high to a species that is present or prevalent in the area assessed, and background risk dominates the total risk, the risk model may be overly conservative.

For those interested in separating risk associated with different sources, statistical analyses could be performed. The key question in doing so would be whether to apply *parametric* or *nonparametric* statistics. Assumptions of independence and randomness have been made in studies similar to this one (Clifford et al. 1995).

3.0 Results

The results of this study are also summarized in Gonzales et al. (1997).

3.1 Unadjusted Mean Hazard Index

Table 2 reports the mean HI for 100 potential roost sites for scenarios including (1) unscaled HR (2) scaled HR; and (a) unweighted and (b) weighted foraging. The highest HI mean was 0.015 (±5.0E-03) (for the scaled, weighted, 50% fish scenario) with a maximum of 2.33E-02. These values represent relative risk from radionuclides, inorganic metals, and organics combined, which implies the same assessment endpoints for all three contaminant types. This is a conservative assumption that can be eliminated by separating HIs by contaminant type or by assessment endpoint.

As stated previously, the weighted foraging scenario is most realistic. The unweighted occupancy case is presented for comparison purposes in order to gain an understanding of how risk distributions and their variance are affected by improvements in model realism.

The HI is a sum of the HQs for all COPECs, thus serving as an index of cumulative effects from multiple contaminants and multiple sites. HIs less than 1.0 indicate that, under the assumptions and conditions applied, it is expected that no appreciable impact to the bald eagle is anticipated. The HI measures additive or linear effects, making no measure of synergistic nor amelioristic effects of multiple COPECs. Mean HIs for the bald eagle were well below 1.0 for all diet scenarios.

As the proportion of diet made up by terrestrial foraging increased, the mean HI increased (Table 2).

Table A-1 in the appendix lists the HIs for each of the 100 randomly selected roost sites for each of six combinations of diet and foraging scenario. Nest sites can be considered "risk sinks" for purposes of considering risk at different roost sites across a relatively large roosting habitat. Table A-2 is an example of "risk sources" generated as an output file by ECORSK5. The example is for Roost Site Number One for the scenario of weighted foraging in an unscaled, or square, HR and a hypothetical diet of 50% fish, 50% terrestrial prey. The entire output has similar data for all 100 roosting sites. Note that the sum of the HQs in Table A-2 is the value shown for Roost Site Number One, under column F in Table A-1. Each execution of ECORSK5 typically would contain 100 times the amount of raw data in Table A-2, plus HI distributions such as one of the columns in Table A-1, and HQs by COPEC such as shown in Table A-3.

Table A-3 is a list of HQs × COPEC for the scenario of 50:50 fish: terrestrial consumption and weighted foraging in a square HR for the terrestrial component. Note that the sum of the HQs is the same value as in Table 1 for this scenario. Aluminum, pentachlorophenol, and ^{137}Cs consistently dominated the risk contribution for all scenarios albeit that total risk is very small. These contaminants differ from those dominating the risk for the peregrine falcon,

Table 2. Mean hazard indices (HI) for various combinations of forage weighting, home range shape, and ratio of aquatic (fish) to terrestrial food in diet. Mean HI values are followed by the mean standard error. All values include bioaccumulation for the soil ingestion pathway and biomagnification for the food consumption pathway.

Ecological Exposure Unit 70			
Scenario	**Mean Hazard Index (Cumulative Hazard Quotient)**		
	Diet*		
	90% fish	**75% fish**	**50% fish**
1. Home Range Unscaled**			
a. Foraging Unweighted***			
Unadjusted Risk†	3.2E-03 (±3.4E-4)	5.8E-03 (±7.5E-4)	1.2E-2 (±1.9E-03)
Background Risk‡	2.5 E-03 (±3.0E-4)		
b. Foraging Weighted****			
Unadjusted Risk	3.7E-3 (±6.5E-04)	6.9E-3 (±1.8E-03)	1.5E-2 (±4.4E-03)
2. Home Range Scaled*****2.6:1**			
a. Foraging Unweighted			
Unadjusted Risk	3.2E-03 (±3.2E-04)	5.9E-3 (±7.6E-04)	1.3E-02 (±1.9E-03)
b. Foraging Weighted			
Unadjusted Risk	3.6E-03 (±8.2E-04)	6.9E-03 (±2.2E-03)	1.5E-02 (±5.0E-03)

*Includes a biomagnification component.

**Unscaled – Refers to a home range with equal border dimensions, i.e., a circle or square.

***Unweighted – Refers to a foraging scheme in which foraging occurs equally throughout a HR.

****Weighted – Refers to a foraging scheme in which foraging is proportional to distance from a nest site; i.e., foraging decreases with distance from the nest site.

*****Scaled – Refers to rectangular shaped home range (HR) with a width to height ratio of 2.6:1.

†Unadjusted Risk – Quantified impact associated with sampling within LANL boundaries.

‡ Background Risk – Quantified risk associated with "natural (nonradionuclides) and "regional" (radionuclides) mean concentrations of COPECs exterior to LANL.

where Aroclor-1254, DDT, and DDE dominated the risk contribution.

Analyses of organic contaminants in sediment of the Rio Grande have consistently resulted in no detection above the limit of quantitation (LANL 1996). This is reflected in the aquatic portion of the eagle diet and is one reason for the low HIs.

4.0 Discussion

4.1 Management Use of Results

The spatial representation of risk results can be used to identify the particular source locations of contamination, which if managed, would most effectively maintain the risk to the bald eagle from contamination at low levels. The geographical distribution of risk by roost location, such as shown in Figure 3, can be used to identify how to maintain risk to the eagle at acceptably low levels; this could include the management of bald eagle habitat, contaminant sources, facility operations, and/or siting of new facilities.

4.2 Foraging Strategy and Scaling the HR Dimension

In the unweighted case, occupancy and foraging on grid cells is equal throughout the HRs regardless of distance from potential roost sites. Improving model realism by weighting simulated foraging such that

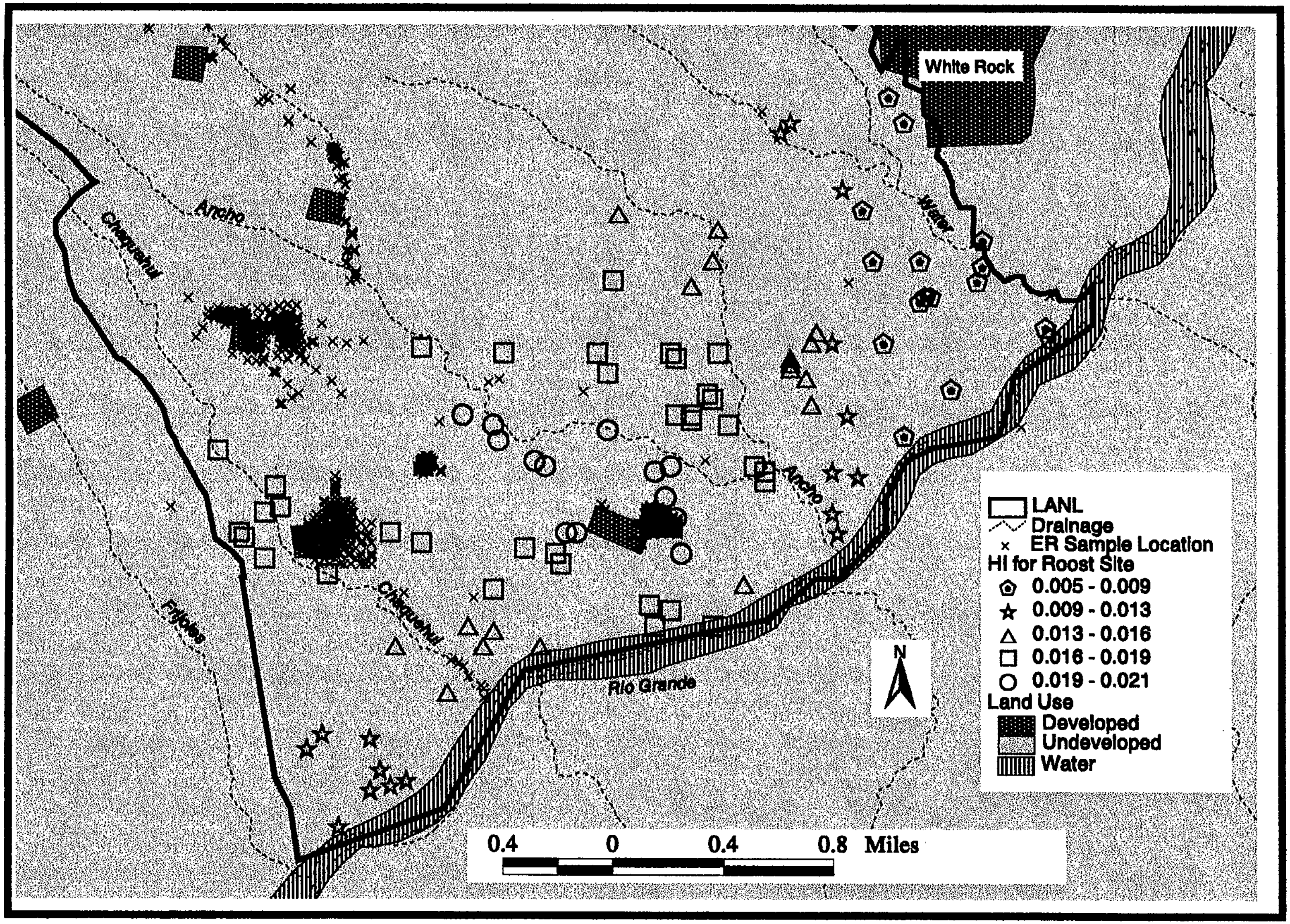

Figure 3. Spatial distribution of unadjusted HIs for each of 100 random potential roost sites of the bald eagle for the simulated scenario of unweighted foraging in a square home range and a diet of 50% fish, 50% terrestrial food.

foraging is greater close to roost sites increased risk in all cases (Table 2). Altering the shape of HRs had no appreciable effect on HIs.

4.3 Limitations and Uncertainty

The particular TRVs (NOAELs) utilized for estimating risk using the Quotient Method can have a substantial impact on risk estimates (Gallegos et al. 1997a). Of the approximately 90 NOAELs for the nonradiological metals and organics found in EPA databases and other literature and used in this study, approximately 41 were based on the toxicological testing of species within the same taxonomical class (*Aves*) as the eagle, but none of the TRVs are based on testing of species that are within the same taxonomical order, family, or genus as the bald eagle. Most of the additional 49 NOAELs were based on toxicological testing of the laboratory rat or various species of mice. The replacement of NOAELs that are based on rats with NOAELs that are based on the toxicological testing of birds is a continual process in this study.

The terrestrial pathway included BMFs for 15 COPECs, and BMFs for all COPECs were inherent in the data used for the aquatic pathway to the trophic level of fish. The addition of BMFs for the terrestrial pathway increased the mean HI by 76%, but the relative risk index (HI) prior to factoring in BMFs was so low that the risk conclusion remained the same. The use of BMFs in studies on other species (Gallegos et al. 1997a and 1997b) have had more impact on the risk conclusion than was the case for the bald eagle.

Many of the uncertainties associated with this type of assessment have been discussed in previous documents (Gallegos et al. 1997a) and previous sections of this document. Concerning the potential for impact to the eagle from radionuclides, since risk indices were so low and we have estimated that risk from radionuclides has been overestimated in this study by a factor ranging between 185 and 3,650, no further study of the bald eagle is planned at this time.

Table 3 summarizes the assumptions made in this study, categorized according to whether we consider them "conservative," "realistic," or "nonconservative." The proper interpretation of any risk assessment requires perspective that includes acknowledgement of assumptions used in performing the assessment. As previously stated, an adjustment of TRVs using uncertainty factors was not made. This decision was based on two factors: (1) some of the assumptions made could cause an overestimate of risk and others could cause an underestimate; to use UFs that effectively eliminate only those assumptions with the potential to cause an underestimate of risk, thus artificially raising the HI, would result in a model that is overly conservative, producing results that may be unusable; (2) the collective amount of uncertainty originating from different sources is great enough and/or variable enough so that application of UFs would make the results less usable because of large total margins of introduced error.

5.0 Conclusions

The integration of the custom FORTRAN computer code ECORSK5 with the GIS and a contaminant database was successfully demonstrated for estimating risk to the bald eagle from contaminants. Considering soil ingestion and food consumption contaminant pathways that included a biomagnification component, estimated risk to the bald eagle was well below levels of concern. The assumptions in Table 3 were made in calculating risk from

Table 3. The assumptions, conditions, and factors used in calculating risk from contaminants.

Conservative (overestimate risk)	Realistic	Nonconservative (underestimate risk)
all COPECs assumed to have same biological effect	FIMAD database is current and accurate	risk not estimated for contaminants for which TRVs not available
radioactive decay of radionuclides not calculated	TRVs/NOAELs for metals based on avian test species and are chronic	environmental restoration (clean-up) not factored
antagonism (ameliorism) not assessed		quotient method not probabilistic
FIMAD database is current and accurate	mean natural background COPEC values, not UTLs, used for inorganics	FIMAD database is current and accurate
	average, not maximum, COPEC soil concentrations used	synergism not assessed
TRVs (SALs) for radionuclides based on humans, which are between 185 and 3650 times more protective of animals than IAEA standard for protection of animals	uncertainty factor not applied to across-animal-class NOAELs	
contamination level measured at sampling points assumed for 100 by 100 ft area		
assumed bioavailability of COPECs for which bioaccumulation and biomagnification not factored = 100%		
% of dietary food intake as soil = 3		

contaminants to the bald eagle. An assumption of importance is that the use of human-based TRVs for radionuclides most likely leads to an overestimate of risk to the bald eagle.

Additional assessment, related to assessment of TES as a whole, is needed in the areas of

- sensitivity and uncertainty analyses of ECORSK5,
- the continued establishment of NOAELs for the organic and radionuclide COPECs that are more directly applicable to avian species,
- grouping of COPECs by biological effect types, including the consideration of synergism and/or ameliorism,
- validation of ECORSK5, and
- potential impact to TES from hypothetical accidental contaminant releases identified in the DARHT EIS.

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Literature Cited

Beyer WN, Conner EE, Gerould S (1994) Estimates of Soil Ingestion by Wildlife. J Wildlife Manage 58(2): 375–382.

Beyer WN, Pattee OH, Sileo L, Hoffman DJ, Mulherin BM (1985) Metal Contamination in Wildlife Living Near Smelters. Environ. Pollut A 38:63–86. In Laskowski R (1991) Are the Top Carnivores Endangered by Heavy Metal Biomagnification? Oikos 60:387–390.

Burnett JA, Dauphine Jr CT, McCrindle SH, Mosquin T (1989) On the Brink, Endangered Species in Canada. Western Producer Prairie Books, Saskatoon, Saskatchewan.

Calabrese EJ, Baldwin LA (1993) Performing Ecological Risk Assessments. Lewis Publishers, Chelsea, Michigan.

Clifford PA, Barchers DE, Ludwig DF, Sielken RL, Klingensmith JS, Grahm RV, Marcy IB (1995) An Approach to Quantifying Spatial Components of Exposure for Ecological Risk Assessment. Environ Toxicol Chem 14(5):895–906.

Colborn T (1991) Epidemiology of Great Lakes Bald Eagles. Journal of Toxicology and Environmental Health 33:395–453.

DOE (US Department of Energy) (1995) Dual Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement. US DOE report DOE/EIS-0228.

DOE (US Department of Energy) (1996) Dual Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement: Mitigation Action Plan. Department of Energy, Albuquerque Operations Office, Los Alamos Area Office, Albuquerque, New Mexico, DOE/EIS-0228.

EPA (US Environmental Protection Agency) (1989) Risk Assessment Guidance for Superfund, Vol. 2, Environmental Evaluation Manual. EPA/540/1-89/001, Office of Emergency and Remedial Response, Washington, DC.

EPA (US Environmental Protection Agency) (1992). Framework for Ecological Risk Assessment. EPA report EPA/630/R-92/001, Risk Assessment Forum, Washington, DC.

EPA (US Environmental Protection Agency) (1993a) Wildlife Exposure Factors Handbook, Vol. I and II. EPA report EPA/600/R-93/187 a & b.

EPA (US Environmental Protection Agency) (1993b) EPA Region VIII Clean Water Act §304(a) Updated Human Health Value Criteria, 126 Priority Toxic Pollutants.

EPA (US Environmental Protection Agency) (1995) Federal Register, Notice of Availability, Dual Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement. 60FR46833. Washington, DC.

EPA (US Environmental Protection Agency) (1996) Proposed Guidelines for Ecological Risk Assessment. EPA/630/R-95/002B, Risk Assessment Forum, Washington, DC.

ESRI (Environmental Systems Research Institute, Inc.) (1996) ARC/INFO Version 7.0.4. Redlands, CA.

Ferenbaugh R (1997) Ecorisk Coordination. Personal communication, Roger Ferenbaugh (LANL/EES-15) to Robert Vocke (LANL/EM), Electronic mail message, Mon., 28 Apr 1997 19:38:02 – 0600.

Ferenbaugh RW, Ebinger MH, Hansen WR (1997) Preliminary Ecological Risk Assessment Methodology for Los Alamos National Laboratory. Los Alamos National Laboratory draft report (November 12, 1997).

Franke C, Studinger G, Berger G, Bohling S, Bruckmann U, Cohors-Fresenborg D, Johncke U

(1994) The Assessment of Bioaccumulation. Chemosphere 29(7):1501–1514.

Fresquez PA, Mullen MA, Ferenbaugh JK, Perona RA (1996) Radionuclides and Radioactivity in Soils Within and Around Los Alamos National Laboratory, 1974 through 1994: Concentrations, Trends, and Dose Comparisons. Los Alamos National Laboratory report LA-13149-MS.

Fresquez PA, Armstrong DR, Salazar JG (1994) Radionuclide Concentrations in Game and Nongame Fish Upstream and Downstream of Los Alamos National Laboratory: 1981 to 1993. Los Alamos National Laboratory report LA-12818-MS.

Fries GF (1982) Potential Polychlorinated Biphenyl Residues in Animal Products from Application of Contaminated Sewage Sludge to Land. J Environ Qual 11:14–20.

Fries GF, Jacobs LW (1986) Evaluation of Residual Polybrominated Biphenyl Contamination Present on Michigan Farms in 1978. Mich. State Univ. Agric. Exp. Stn. res. rep. 477, Ann Arbor. 15pp.

Fries GF, Marrow GS (1982) Residues in the Fat of Ewes Grazing on Soil Contaminated with Halogenated Hydrocarbons. J Anim Sci 55:1118–1124.

Fries GF, Marrow GS, Snow PA (1982) Soil Ingestion by Swine as a Route of Contaminant Exposure. Environ Chem 1:201–204.

Gallegos AF (1996) Documentation and Utilization of the Ecological Transport Model (BIOTRAN.2) Part 1 of 2, Los Alamos National Laboratory report (Draft).

Gallegos AF, Gonzales GJ, Bennett KD, Pratt LE, Cram DS (1997a) A Spatially-Dynamic Preliminary Risk Assessment of the American Peregrine Falcon at the Los Alamos National Laboratory. Los Alamos National Laboratory report LA-13321-MS.

Gallegos AF, Gonzales GJ, Bennett KD, Pratt LE (1997b) Preliminary Risk Assessment of the Mexican Spotted Owl under a Spatially-Weighted Foraging Regime at the Los Alamos National Laboratory. Los Alamos National Laboratory report LA-13259-MS.

Garrett MG, Watson JW, Anthony RG (1993) Bald Eagle Home Range and Habitat Use in the Columbia River Estuary. J. Wildl. Manage. 57(1):19-27.

Gilbert RO (1987) Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold, New York.

Gonzales GJ, Gallegos AF, Foxx, TE (1997). Second Annual Review Update: Preliminary Risk Assessment of Federally Listed Species at the Los Alamos National Laboratory. Los Alamos National Laboratory report LA-UR-97-4732.

Gonzales GJ, Newell PG (1996) Ecotoxicological Screen of Potential Release Site 50-006(d) of Operable Unit 1147 of Mortandad Canyon and Relationship to the Radioactive Liquid Waste Treatment Facilities Project. Los Alamos National Laboratory report LA-13148-MS.

Grodzinska K, Godzik B, Darowska E, Pawlowska B (1987) Concentration of Heavy Metals in Trophic Chains of Niepolomice Forest, S. Poland. Ekol. Pol. 35:327–344. In Laskowski R (1991) Are the Top Carnivores Endangered by Heavy Metal Biomagnification? Oikos 60:387–390.

Grubb, TG (1995) Food Habits of Bald Eagles Breeding in the Arizona Desert. Wilson Bull 107(2):258–274.

Hegstrom LJ, West SD (1989) Heavy Metal Accumulation in Small Mammals Following Sewage Sludge Application to Forests. J Environ Qual 18:345–349.

Henny CJ, Seegar WS, Maechtle TL (1996) DDE Decreases in Plasma of Spring Migrant

Peregrine Falcons, 1978–1994. J Wildl Manage 60(2)342–349.

IAEA (International Atomic Energy Agency) (1992) Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Standards. Technical Report Series No. 332 Vienna, Austria.

Johnson TH (1983) Identification of Essential Peregrine Breeding Habitat. US Forest Service report, unpublished.

Johnson TH (1986) Biological Assessment of the Effects of the Proposed Ojo Line Extension on the Peregrine Falcon. US Forest Service report, unpublished.

Johnson (1991) White Rock Canyon Eagle Habitat Management. Memorandum TH Johnson (consultant) to T.E. Foxx (LANL), December 6, 1991.

Johnson TH (1992) Topographic Model of Potential Peregrine Falcon Breeding Habitat. US Forest Service report 43-83D5-1-0217, 43-83A7-1-0105, 43-8379-1-0296.

Johnson, TH (1993) Bald eagles wintering near Cochiti Reservoir, 1979–1993. US Forest Service, US Army Corps of Engineers and US Bureau of Reclamation, unpublished report.

Johnson TH (1996a) Bald Eagle Habitat Management in the Los Alamos National Environmental Research Park. Threatened and Endangered Species, Habitat Management Plan, Annual Review. LA-UR-96-3444.

Johnson TH (1996b) Personal communication (e-mail) from T. Johnson (consultant) to G. Gonzales (LANL/ESH-20), "Bald eagle foraging," (Nov. 25, 1996).

Koeman J, Hadderingh R, and Bijleveld M (1972) Persistent pollutants in the White-Tailed Eagle (*Haliaeetus albicilla*) in the Federal Republic of Germany. Biol. Conserv. 4(5):373-377.

LANL (Los Alamos National Laboratory) (1993) Installation Work Plan for Environmental Restoration. Revision 3, Los Alamos National Laboratory report LA-UR-93-3987.

LANL (1997) Environmental Surveillance and Compliance at Los Alamos during 1996. Los Alamos National Laboratory report LA-13343-ENV.

Laskowski R (1991) Are the Top Carnivores Endangered by Heavy Metal Biomagnification? Oikos 60:387–390.

Leidy RB (1980) Aquatic Organisms, pages 120–134 in Introduction to Environmental Toxicology, Guthrie EF, Perry JJ (Eds), Elsevier North Holland, Inc.

Longmire PA, Reneau SL, Watt PM, McFadden LD, Gardner JN, Duffy CJ, Ryti RT (1996) Natural Background Geochemistry, Geomorphology, and Pedogenesis of Selected Soil Profiles and Bandelier Tuff at Los Alamos, New Mexico. Los Alamos National Laboratory report LA-12913-MS.

Ma WC (1987) Heavy Metal Accumulation in the Mole, *Talpa europea*, and Earthworms as an Indicator of Metal Bioavailability in Terrestrial Environments. Bull Environ Contam Toxicol 30:424–427.

Manzel M (1997) Personal Communication: "FIMAD", M. Manzel (LANL/FIMAD/Environmental Restoration Tabular Data Manager) to L. Pratt (LANL/ESH-20), Jan 1997.

Menzie CJ, Cura J, Freshman J, Svirsky S (1993) Evaluating Ecological Risks and Developing Remedial Objectives at Forested Wetland Systems in New England, Workshop on Ecological Risk Assessment to Hazardous Waste Site Remediation. Water Environ Federation.

Nebraska Wildlife (1997). http://ngpc.state.ne.us/wildlife/eagles.html#description. (April 8, 1997).

Nuorteva P (1988) Tutkimuksia Metallien Osuudesta Metsia Tuhoavassa Monistressisairaudessa. (Finnish) (The Role of Metals in the Multistress Disease Killing Forests in Europe.) Lounais-Hameen Luonto 75:62–76. in Laskowski R (1991) Are the Top Carnivores Endangered by Heavy Metal Biomagnification? Oikos 60:387–390.

Oracle (1994a) Oracle Corporation, Redwood Shores, CA.

Oracle (1994b) SQL *Plus, Release 3.2.2.0.0 Oracle Corporation, Redwood Shores, CA.

Oracle (1994c) Databrowser, Release 2.0.7.4.2. Oracle Corporation, Redwood Shores, CA.

Peters RH (1993) The Ecological Implications of Body Size. Cambridge University Press, New York.

Russel K, Brebner J, Thornton I, Suttle NF (1985) The Influence of Soil Ingestion on the Intake of Potentially Toxic Metals and Absorption of Essential Trace Elements by Grazing Livestock, pages 847–849 in CF Mills, I. Bremner, JK Chesters, (eds). Proc. 5th International Symposium on Trace Elements in Man and Animals. Grampian, Aberdeen, U.K.

Salford Software Limited (1994) FTN77/x86™ Reference Manual. Vol. 1 and 2 University of Salford, Salford, England.

Sample BE, Baron LA, Jackson BL (1995) Preliminary Assessment of the Ecological Risks to Wide-ranging Wildlife Species on the Oak Ridge Reservation. Oak Ridge National Laboratory report DOE/OR/01-1407&D1.

Shore RF, Douben PE (1994) The Ecotoxicological Significance of Cadmium Intake and Residues in Terrestrial Small Mammals. Ecotox and Environ Safety 29:101–112.

Smith JA, Witkowski PJ, Fusillo TV (1988) Man-made Organic Compounds in the Surface Waters of the United States—A Review of Current Understanding. United States Geological Survey circular 1007.

Stalmaster MV (1976) Winter Ecology and Effects of Human Activity on Bald Eagles in the Nooksack River Valley, Washington. M. S. Thesis. Western Washington State Coll., Bellingham. 100pp.

Swenson JE, Alt KL, and Eng RL (1986) Ecology of Bald Eagle in the Greater Yellowstone Ecosystem. Wildl Monogr 95, 46pp.

Tiebout HM, Brugger KE (1995) Ecological Risk Assessment of Pesticides for Terrestrial Vertebrates: Evaluation and Application of the US Environmental Protection Agency's Quotient Model. Conserv Biol 9(6)1605–1618.

USFWS (United States Fish and Wildlife Service) (1982) Southwestern Bald Eagle Recovery Plan. Bald Eagle Recovery Team, United States Department of Interior Fish and Wildlife Service report no. 02-8280714 (September 8, 1982).

Walker CH (1990) Kinetic Model to Predict Bioaccumulation of Pollutants. Funct Ecol 4:295–301. In: Laskowski R 1991 Are the Top Carnivores Endangered by Heavy Metal Biomagnification? Oikos 60:387–390.

Willamo R, Nuorteva P (1987) The Role of Heavy Metals in Forest Die-Off. In: Anttila P, Kauppi P (eds) Symp Finnish Res Proj Acidification (HAPRO) Ministry of the Environment, Ministry of Agriculture and Forestry, pp 64–67 in Laskowski R (1991) Are the Top Carnivores Endangered by Heavy Metal Biomagnification? Oikos 60:387–390.

WWF (World Wildlife Fund) (1990) Bald eagle, *Haliaeetus leucocephalus.* The Official World Wildlife Fund Guide to Endangered Species of North America, Vol. I, pp. 624 – 627, Mathews JR (Originating Ed), Beacham Publishing, Inc., Washington, D.C.

WWFC (World Wildlife Federation Canada) (1996) Bald eagle, factsheets. "Http://www.wwfcanada.org/facts/bldeagle.html"

APPENDIX A

Table A-1. Hazard indices (cumulative HQ) for each of 100 randomly selected potential roosting sites of the bald eagle in EEU-70. Data is for an unscaled, square home range. The distributions are for (A) unweighted foraging with a 90% aquatic diet, (B) weighted foraging with a 90% aquatic diet, (C) unweighted foraging with a 75% aquatic diet, (D) weighted foraging with a 75% aquatic diet, (E) unweighted foraging with a 50% aquatic diet, (F) wieghted foraging with a 50% aquatic diet.

Roosting Site No.	Column	Row	A	B	C	D	E	F
1	220	207	3.72E-03	4.36E-03	6.47E-03	8.29E-03	1.38E-02	1.85E-02
2	161	222	2.87E-03	4.16E-03	5.78E-03	9.06E-03	1.28E-02	1.92E-02
3	183	200	3.21E-03	4.26E-03	6.02E-03	8.86E-03	1.33E-02	1.97E-02
4	197	217	3.20E-03	4.02E-03	6.02E-03	8.26E-03	1.33E-02	1.85E-02
5	151	136	3.20E-03	2.87E-03	6.02E-03	5.07E-03	1.33E-02	1.09E-02
6	257	231	2.88E-03	2.83E-03	4.31E-03	4.19E-03	8.42E-03	8.08E-03
7	166	155	3.23E-03	3.31E-03	6.05E-03	6.25E-03	1.33E-02	1.37E-02
8	263	214	2.76E-03	2.67E-03	4.19E-03	3.93E-03	8.30E-03	7.57E-03
9	133	195	2.87E-03	4.09E-03	5.78E-03	8.80E-03	1.28E-02	1.84E-02
10	236	211	3.74E-03	3.91E-03	6.44E-03	6.94E-03	1.37E-02	1.51E-02
11	205	172	3.66E-03	4.31E-03	6.42E-03	8.25E-03	1.38E-02	1.84E-02
12	155	186	3.08E-03	4.20E-03	5.92E-03	8.84E-03	1.31E-02	1.91E-02
13	250	223	2.96E-03	2.99E-03	4.54E-03	4.65E-03	9.04E-03	9.37E-03
14	245	197	3.14E-03	3.10E-03	5.37E-03	5.26E-03	1.14E-02	1.12E-02
15	236	223	3.65E-03	3.72E-03	6.36E-03	6.56E-03	1.36E-02	1.42E-02
16	206	198	3.57E-03	4.59E-03	6.34E-03	9.20E-03	1.37E-02	2.07E-02
17	259	232	2.87E-03	2.79E-03	4.30E-03	4.09E-03	8.41E-03	7.83E-03
18	142	147	3.07E-03	2.90E-03	5.92E-03	5.44E-03	1.31E-02	1.19E-02
19	198	235	3.01E-03	3.58E-03	5.87E-03	7.42E-03	1.30E-02	1.66E-02
20	268	235	2.70E-03	2.60E-03	3.88E-03	3.56E-03	7.29E-03	6.37E-03
21	248	239	2.89E-03	2.80E-03	4.63E-03	4.39E-03	9.52E-03	8.89E-03
22	217	168	3.69E-03	4.06E-03	6.44E-03	7.52E-03	1.38E-02	1.66E-02
23	187	182	3.37E-03	4.19E-03	6.16E-03	8.43E-03	1.34E-02	1.89E-02
24	153	140	3.20E-03	2.95E-03	6.02E-03	5.30E-03	1.33E-02	1.14E-02
25	139	185	2.95E-03	4.07E-03	5.83E-03	8.65E-03	1.29E-02	1.83E-02
26	241	186	3.33E-03	3.30E-03	5.84E-03	5.78E-03	1.25E-02	1.25E-02
27	175	207	3.11E-03	4.27E-03	5.94E-03	9.04E-03	1.31E-02	1.98E-02
28	237	225	3.63E-03	3.66E-03	6.33E-03	6.43E-03	1.36E-02	1.39E-02
29	258	232	2.87E-03	2.81E-03	4.30E-03	4.13E-03	8.41E-03	7.92E-03
30	127	185	2.88E-03	3.77E-03	5.79E-03	8.02E-03	1.29E-02	1.70E-02
31	254	205	2.65E-03	2.65E-03	4.08E-03	4.11E-03	8.18E-03	8.25E-03
32	216	213	3.62E-03	4.28E-03	6.38E-03	8.24E-03	1.37E-02	1.84E-02
33	269	238	2.71E-03	2.58E-03	3.89E-03	3.51E-03	7.30E-03	6.23E-03
34	218	221	3.57E-03	4.07E-03	6.33E-03	7.75E-03	1.37E-02	1.73E-02
35	269	243	2.70E-03	2.56E-03	3.88E-03	3.46E-03	7.29E-03	6.10E-03
36	209	171	3.70E-03	4.30E-03	6.46E-03	8.13E-03	1.38E-02	1.81E-02
37	170	168	3.23E-03	3.66E-03	6.05E-03	7.21E-03	1.33E-02	1.60E-02
38	225	199	3.72E-03	4.23E-03	6.47E-03	7.93E-03	1.38E-02	1.76E-02
39	189	186	3.38E-03	4.30E-03	6.17E-03	8.71E-03	1.35E-02	1.95E-02
40	240	223	3.56E-03	3.58E-03	6.07E-03	6.14E-03	1.28E-02	1.31E-02
41	155	137	3.22E-03	2.91E-03	6.04E-03	5.17E-03	1.33E-02	1.11E-02
42	122	202	2.78E-03	3.91E-03	5.73E-03	8.48E-03	1.27E-02	1.75E-02
43	173	164	3.29E-03	3.62E-03	6.09E-03	6.99E-03	1.34E-02	1.55E-02
44	176	204	3.14E-03	4.29E-03	5.97E-03	9.03E-03	1.32E-02	1.99E-02
45	213	209	3.61E-03	4.38E-03	6.37E-03	8.54E-03	1.37E-02	1.92E-02
46	175	167	3.30E-03	3.70E-03	6.10E-03	7.22E-03	1.34E-02	1.60E-02
47	213	208	3.62E-03	4.41E-03	6.38E-03	8.60E-03	1.37E-02	1.93E-02
48	232	220	3.64E-03	3.82E-03	6.35E-03	6.88E-03	1.36E-02	1.51E-02

Table A-1. (Cont.)

Roosting Site No.	Column	Row	A	B	C	D	E	F
49	139	144	3.05E-03	2.80E-03	5.91E-03	5.20E-03	1.31E-02	1.13E-02
50	175	175	3.28E-03	3.91E-03	6.08E-03	7.82E-03	1.33E-02	1.74E-02
51	213	234	3.32E-03	3.71E-03	6.12E-03	7.21E-03	1.34E-02	1.61E-02
52	232	218	3.65E-03	3.85E-03	6.36E-03	6.94E-03	1.36E-02	1.52E-02
53	281	226	2.45E-03	2.23E-03	3.64E-03	2.99E-03	7.04E-03	5.19E-03
54	232	219	3.65E-03	3.84E-03	6.35E-03	6.91E-03	1.36E-02	1.51E-02
55	156	164	3.15E-03	3.51E-03	5.98E-03	6.93E-03	1.32E-02	1.53E-02
56	240	198	3.43E-03	3.47E-03	5.96E-03	6.08E-03	1.27E-02	1.31E-02
57	246	249	3.03E-03	2.82E-03	5.12E-03	4.53E-03	1.08E-02	9.30E-03
58	158	138	3.23E-03	2.95E-03	6.05E-03	5.25E-03	1.33E-02	1.13E-02
59	210	189	3.70E-03	4.77E-03	6.45E-03	9.46E-03	1.38E-02	2.14E-02
60	209	199	3.63E-03	4.62E-03	6.39E-03	9.15E-03	1.37E-02	2.06E-02
61	211	182	3.74E-03	4.65E-03	6.49E-03	9.06E-03	1.39E-02	2.04E-02
62	161	184	3.12E-03	4.10E-03	5.96E-03	8.54E-03	1.32E-02	1.86E-02
63	131	181	2.92E-03	3.77E-03	5.81E-03	7.96E-03	1.29E-02	1.70E-02
64	232	266	3.27E-03	2.92E-03	6.22E-03	5.24E-03	1.38E-02	1.15E-02
65	199	248	2.95E-03	3.39E-03	5.83E-03	7.04E-03	1.29E-02	1.57E-02
66	195	221	3.16E-03	3.98E-03	5.99E-03	8.22E-03	1.32E-02	1.84E-02
67	282	224	2.43E-03	2.21E-03	3.62E-03	2.96E-03	7.02E-03	5.14E-03
68	126	186	2.87E-03	3.77E-03	5.78E-03	8.02E-03	1.28E-02	1.70E-02
69	151	146	3.18E-03	3.05E-03	6.00E-03	5.63E-03	1.32E-02	1.23E-02
70	227	198	3.69E-03	4.12E-03	6.44E-03	7.66E-03	1.38E-02	1.70E-02
71	184	164	3.36E-03	3.68E-03	6.15E-03	7.04E-03	1.34E-02	1.56E-02
72	191	186	3.40E-03	4.32E-03	6.19E-03	8.74E-03	1.35E-02	1.96E-02
73	169	209	3.01E-03	4.23E-03	5.87E-03	9.05E-03	1.30E-02	1.96E-02
74	257	239	2.83E-03	2.75E-03	4.26E-03	4.03E-03	8.37E-03	7.71E-03
75	131	190	2.89E-03	3.98E-03	5.79E-03	8.51E-03	1.29E-02	1.79E-02
76	177	221	3.00E-03	4.08E-03	5.86E-03	8.71E-03	1.30E-02	1.90E-02
77	209	221	3.44E-03	4.10E-03	6.22E-03	8.07E-03	1.35E-02	1.81E-02
78	206	168	3.67E-03	4.20E-03	6.43E-03	7.92E-03	1.38E-02	1.76E-02
79	251	271	2.51E-03	2.18E-03	4.29E-03	3.33E-03	9.20E-03	6.60E-03
80	218	245	3.32E-03	3.50E-03	6.12E-03	6.63E-03	1.34E-02	1.47E-02
81	188	180	3.40E-03	4.19E-03	6.19E-03	8.36E-03	1.35E-02	1.87E-02
82	243	209	3.51E-03	3.57E-03	5.87E-03	6.06E-03	1.23E-02	1.29E-02
83	227	196	3.68E-03	4.10E-03	6.43E-03	7.63E-03	1.38E-02	1.69E-02
84	134	191	2.90E-03	4.06E-03	5.79E-03	8.71E-03	1.29E-02	1.83E-02
85	254	266	2.61E-03	2.33E-03	4.25E-03	3.45E-03	8.87E-03	6.66E-03
86	217	212	3.64E-03	4.29E-03	6.40E-03	8.22E-03	1.37E-02	1.84E-02
87	185	199	3.23E-03	4.26E-03	6.04E-03	8.84E-03	1.33E-02	1.97E-02
88	217	239	3.35E-03	3.61E-03	6.14E-03	6.88E-03	1.34E-02	1.53E-02
89	242	253	3.20E-03	2.93E-03	5.61E-03	4.86E-03	1.21E-02	1.02E-02
90	235	216	3.70E-03	3.85E-03	6.40E-03	6.85E-03	1.37E-02	1.49E-02
91	208	193	3.65E-03	4.72E-03	6.40E-03	9.42E-03	1.38E-02	2.12E-02
92	210	220	3.45E-03	4.11E-03	6.23E-03	8.06E-03	1.35E-02	1.81E-02
93	210	209	3.56E-03	4.37E-03	6.32E-03	8.61E-03	1.37E-02	1.93E-02
94	240	190	3.39E-03	3.40E-03	5.92E-03	5.97E-03	1.27E-02	1.29E-02
95	143	178	3.00E-03	3.89E-03	5.87E-03	8.16E-03	1.30E-02	1.76E-02
96	223	176	3.62E-03	3.96E-03	6.38E-03	7.36E-03	1.37E-02	1.63E-02
97	230	264	3.27E-03	2.99E-03	6.16E-03	5.39E-03	1.36E-02	1.18E-02
98	197	206	3.31E-03	4.26E-03	6.11E-03	8.72E-03	1.34E-02	1.96E-02
99	145	129	3.15E-03	2.64E-03	5.97E-03	4.55E-03	1.32E-02	9.66E-03
100	181	183	3.29E-03	4.12E-03	6.09E-03	8.35E-03	1.34E-02	1.86E-02

Table A-1. (Cont.)

Roosting Site No.	Column	Row	A	B	C	D	E	F
		TOTAL	3.24E-03	3.66E-03	5.80E-03	6.92E-03	1.25E-02	1.50E-02

Table A-2. Example of "risk sources." Hazard quotient values are for grid cells within the home range of roosting site number one and represent the values contributing to the hazard index for roosting site No. 1. Note that sum of the HQ column is the same as the value in column F of Table A-1 for roosting site No. 1.

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
139	184	1.27E-04	1	220	207
135	228	1.48E-04	1	220	207
136	228	2.08E-04	1	220	207
207	188	1.06E-03	1	220	207
207	189	3.47E-04	1	220	207
207	187	3.33E-04	1	220	207
208	188	1.98E-04	1	220	207
209	188	2.51E-04	1	220	207
205	188	3.30E-04	1	220	207
208	189	3.31E-04	1	220	207
205	189	2.69E-04	1	220	207
210	188	2.59E-04	1	220	207
210	187	3.65E-04	1	220	207
206	189	3.34E-04	1	220	207
204	186	1.50E-03	1	220	207
206	186	3.56E-04	1	220	207
207	186	3.44E-04	1	220	207
208	186	3.41E-04	1	220	207
209	186	3.87E-04	1	220	207
210	186	3.59E-04	1	220	207
205	187	3.31E-04	1	220	207
208	187	3.31E-04	1	220	207
145	190	7.35E-05	1	220	207
209	187	3.34E-04	1	220	207
209	189	3.84E-04	1	220	207
143	190	7.01E-05	1	220	207
144	190	1.20E-04	1	220	207
146	190	7.18E-05	1	220	207
143	191	7.79E-05	1	220	207
146	191	7.31E-05	1	220	207
165	198	4.42E-04	1	220	207
139	183	8.37E-05	1	220	207
204	188	7.71E-05	1	220	207
206	188	7.47E-05	1	220	207
204	189	4.32E-04	1	220	207
210	189	1.58E-04	1	220	207
136	224	1.20E-04	1	220	207
136	223	1.05E-04	1	220	207
128	219	6.73E-05	1	220	207
134	224	2.82E-05	1	220	207
144	183	2.60E-04	1	220	207
141	186	4.95E-05	1	220	207
140	184	4.80E-05	1	220	207
146	184	1.06E-04	1	220	207
149	185	6.33E-05	1	220	207
147	186	5.93E-05	1	220	207
139	188	5.57E-05	1	220	207
146	192	5.92E-05	1	220	207
144	182	5.28E-05	1	220	207
144	184	5.02E-05	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
145	184	7.11E-05	1	220	207
146	180	9.25E-05	1	220	207
150	180	6.93E-05	1	220	207
141	181	7.32E-05	1	220	207
143	181	5.49E-05	1	220	207
149	181	5.39E-05	1	220	207
151	181	5.53E-05	1	220	207
141	182	6.26E-05	1	220	207
143	182	4.97E-05	1	220	207
147	182	5.80E-05	1	220	207
141	184	5.28E-05	1	220	207
143	184	5.34E-05	1	220	207
150	184	7.28E-05	1	220	207
139	185	4.93E-05	1	220	207
140	185	4.93E-05	1	220	207
143	185	5.07E-05	1	220	207
144	185	5.31E-05	1	220	207
145	185	8.36E-05	1	220	207
151	185	7.21E-05	1	220	207
142	186	5.02E-05	1	220	207
143	186	5.20E-05	1	220	207
144	186	5.07E-05	1	220	207
145	186	7.26E-05	1	220	207
146	186	6.33E-05	1	220	207
148	186	9.94E-05	1	220	207
141	188	5.05E-05	1	220	207
143	188	5.10E-05	1	220	207
145	188	5.25E-05	1	220	207
148	188	5.49E-05	1	220	207
144	189	4.98E-05	1	220	207
141	190	4.98E-05	1	220	207
148	190	6.55E-05	1	220	207
205	190	1.22E-04	1	220	207
206	190	1.53E-04	1	220	207
144	191	5.28E-05	1	220	207
204	191	1.26E-04	1	220	207
206	191	3.45E-04	1	220	207
142	192	1.15E-04	1	220	207
144	192	5.26E-05	1	220	207
144	194	6.10E-05	1	220	207
145	196	7.07E-05	1	220	207
138	185	3.83E-05	1	220	207
138	186	3.94E-05	1	220	207
161	199	9.49E-05	1	220	207
32	370	0.00E+01	1	220	207
143	183	2.11E-05	1	220	207
203	184	2.76E-04	1	220	207
125	228	5.94E-05	1	220	207
161	198	9.92E-05	1	220	207
162	198	6.95E-05	1	220	207
162	199	7.21E-05	1	220	207
163	199	1.28E-04	1	220	207
161	200	1.34E-04	1	220	207
162	200	8.75E-05	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
163	200	8.30E-05	1	220	207
162	201	1.20E-04	1	220	207
31	369	0.00E+01	1	220	207
208	190	4.75E-05	1	220	207
209	191	5.56E-05	1	220	207
135	224	2.44E-08	1	220	207
124	104	8.65E-07	1	220	207
125	104	8.74E-07	1	220	207
126	104	8.83E-07	1	220	207
127	104	8.92E-07	1	220	207
128	104	9.01E-07	1	220	207
126	105	8.93E-07	1	220	207
127	105	9.02E-07	1	220	207
128	105	9.11E-07	1	220	207
129	105	9.21E-07	1	220	207
130	105	9.30E-07	1	220	207
127	106	9.12E-07	1	220	207
128	106	9.22E-07	1	220	207
130	106	9.41E-07	1	220	207
131	106	9.50E-07	1	220	207
128	107	9.32E-07	1	220	207
129	107	9.42E-07	1	220	207
131	107	9.61E-07	1	220	207
132	107	9.71E-07	1	220	207
129	108	9.53E-07	1	220	207
130	108	9.62E-07	1	220	207
131	108	9.72E-07	1	220	207
132	108	9.82E-07	1	220	207
133	108	9.92E-07	1	220	207
134	108	1.00E-06	1	220	207
131	109	9.83E-07	1	220	207
132	109	9.93E-07	1	220	207
134	109	1.01E-06	1	220	207
135	109	1.02E-06	1	220	207
132	110	1.00E-06	1	220	207
133	110	1.02E-06	1	220	207
134	110	1.03E-06	1	220	207
135	110	1.04E-06	1	220	207
136	110	1.05E-06	1	220	207
134	111	1.04E-06	1	220	207
135	111	1.05E-06	1	220	207
136	111	1.06E-06	1	220	207
137	111	1.07E-06	1	220	207
138	111	1.08E-06	1	220	207
136	112	1.07E-06	1	220	207
137	112	1.08E-06	1	220	207
138	112	1.09E-06	1	220	207
139	112	1.10E-06	1	220	207
137	113	1.09E-06	1	220	207
138	113	1.10E-06	1	220	207
139	113	1.12E-06	1	220	207
140	113	1.13E-06	1	220	207
138	114	1.12E-06	1	220	207
139	114	1.13E-06	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
140	114	1.14E-06	1	220	207
141	114	1.15E-06	1	220	207
139	115	1.14E-06	1	220	207
140	115	1.15E-06	1	220	207
141	115	1.17E-06	1	220	207
140	116	1.17E-06	1	220	207
141	116	1.18E-06	1	220	207
140	117	1.18E-06	1	220	207
141	117	1.19E-06	1	220	207
142	117	1.20E-06	1	220	207
140	118	1.19E-06	1	220	207
141	118	1.21E-06	1	220	207
142	118	1.22E-06	1	220	207
140	119	1.21E-06	1	220	207
141	119	1.22E-06	1	220	207
142	119	1.23E-06	1	220	207
140	120	1.22E-06	1	220	207
141	120	1.23E-06	1	220	207
142	120	1.25E-06	1	220	207
143	120	1.26E-06	1	220	207
141	121	1.25E-06	1	220	207
143	121	1.27E-06	1	220	207
141	122	1.26E-06	1	220	207
143	122	1.29E-06	1	220	207
144	122	1.30E-06	1	220	207
141	123	1.28E-06	1	220	207
142	123	1.29E-06	1	220	207
144	123	1.32E-06	1	220	207
145	123	1.33E-06	1	220	207
142	124	1.30E-06	1	220	207
145	124	1.34E-06	1	220	207
146	124	1.36E-06	1	220	207
147	124	1.37E-06	1	220	207
142	125	1.32E-06	1	220	207
143	125	1.33E-06	1	220	207
144	125	1.35E-06	1	220	207
147	125	1.39E-06	1	220	207
148	125	1.40E-06	1	220	207
149	125	1.42E-06	1	220	207
150	125	1.43E-06	1	220	207
151	125	1.44E-06	1	220	207
152	125	1.46E-06	1	220	207
153	125	1.47E-06	1	220	207
154	125	1.49E-06	1	220	207
155	125	1.50E-06	1	220	207
156	125	1.52E-06	1	220	207
157	125	1.53E-06	1	220	207
144	126	1.36E-06	1	220	207
145	126	1.38E-06	1	220	207
146	126	1.39E-06	1	220	207
157	126	1.55E-06	1	220	207
158	126	1.56E-06	1	220	207
159	126	1.58E-06	1	220	207
160	126	1.59E-06	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
161	126	1.61E-06	1	220	207
146	127	1.41E-06	1	220	207
147	127	1.42E-06	1	220	207
148	127	1.43E-06	1	220	207
153	127	1.51E-06	1	220	207
154	127	1.52E-06	1	220	207
155	127	1.54E-06	1	220	207
156	127	1.55E-06	1	220	207
157	127	1.57E-06	1	220	207
158	127	1.58E-06	1	220	207
161	127	1.63E-06	1	220	207
162	127	1.64E-06	1	220	207
148	128	1.45E-06	1	220	207
149	128	1.47E-06	1	220	207
150	128	1.48E-06	1	220	207
151	128	1.50E-06	1	220	207
152	128	1.51E-06	1	220	207
153	128	1.53E-06	1	220	207
158	128	1.60E-06	1	220	207
159	128	1.62E-06	1	220	207
160	128	1.63E-06	1	220	207
161	128	1.65E-06	1	220	207
162	128	1.66E-06	1	220	207
163	128	1.68E-06	1	220	207
164	128	1.69E-06	1	220	207
161	129	1.67E-06	1	220	207
162	129	1.68E-06	1	220	207
163	129	1.70E-06	1	220	207
164	129	1.71E-06	1	220	207
165	129	1.73E-06	1	220	207
163	130	1.72E-06	1	220	207
164	130	1.73E-06	1	220	207
165	130	1.75E-06	1	220	207
166	130	1.76E-06	1	220	207
164	131	1.75E-06	1	220	207
165	131	1.77E-06	1	220	207
166	131	1.79E-06	1	220	207
167	131	1.80E-06	1	220	207
165	132	1.79E-06	1	220	207
166	132	1.81E-06	1	220	207
167	132	1.82E-06	1	220	207
166	133	1.83E-06	1	220	207
167	133	1.85E-06	1	220	207
168	133	1.86E-06	1	220	207
167	134	1.87E-06	1	220	207
168	134	1.89E-06	1	220	207
167	135	1.89E-06	1	220	207
168	135	1.91E-06	1	220	207
169	135	1.93E-06	1	220	207
168	136	1.93E-06	1	220	207
169	136	1.95E-06	1	220	207
168	137	1.96E-06	1	220	207
169	137	1.98E-06	1	220	207
170	137	1.99E-06	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
168	138	1.98E-06	1	220	207
169	138	2.00E-06	1	220	207
170	138	2.02E-06	1	220	207
169	139	2.03E-06	1	220	207
170	139	2.04E-06	1	220	207
169	140	2.05E-06	1	220	207
170	140	2.07E-06	1	220	207
171	140	2.09E-06	1	220	207
170	141	2.09E-06	1	220	207
171	141	2.11E-06	1	220	207
170	142	2.12E-06	1	220	207
171	142	2.14E-06	1	220	207
170	143	2.15E-06	1	220	207
171	143	2.17E-06	1	220	207
172	143	2.19E-06	1	220	207
170	144	2.17E-06	1	220	207
172	144	2.21E-06	1	220	207
170	145	2.20E-06	1	220	207
171	145	2.22E-06	1	220	207
172	145	2.24E-06	1	220	207
173	145	2.26E-06	1	220	207
171	146	2.25E-06	1	220	207
173	146	2.29E-06	1	220	207
171	147	2.27E-06	1	220	207
172	147	2.29E-06	1	220	207
173	147	2.32E-06	1	220	207
174	147	2.34E-06	1	220	207
172	148	2.32E-06	1	220	207
173	148	2.34E-06	1	220	207
174	148	2.37E-06	1	220	207
173	149	2.37E-06	1	220	207
174	149	2.39E-06	1	220	207
175	149	2.42E-06	1	220	207
173	150	2.40E-06	1	220	207
174	150	2.42E-06	1	220	207
175	150	2.45E-06	1	220	207
174	151	2.45E-06	1	220	207
175	151	2.48E-06	1	220	207
176	151	2.50E-06	1	220	207
175	152	2.51E-06	1	220	207
176	152	2.53E-06	1	220	207
175	153	2.53E-06	1	220	207
176	153	2.56E-06	1	220	207
177	153	2.58E-06	1	220	207
176	154	2.59E-06	1	220	207
177	154	2.61E-06	1	220	207
178	154	2.64E-06	1	220	207
176	155	2.62E-06	1	220	207
177	155	2.65E-06	1	220	207
178	155	2.67E-06	1	220	207
177	156	2.68E-06	1	220	207
178	156	2.70E-06	1	220	207
179	156	2.73E-06	1	220	207
177	157	2.71E-06	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
178	157	2.74E-06	1	220	207
179	157	2.76E-06	1	220	207
180	157	2.79E-06	1	220	207
178	158	2.77E-06	1	220	207
179	158	2.79E-06	1	220	207
180	158	2.82E-06	1	220	207
181	158	2.85E-06	1	220	207
182	158	2.88E-06	1	220	207
183	158	2.90E-06	1	220	207
184	158	2.93E-06	1	220	207
185	158	2.96E-06	1	220	207
186	158	2.98E-06	1	220	207
187	158	3.01E-06	1	220	207
179	159	2.83E-06	1	220	207
180	159	2.86E-06	1	220	207
181	159	2.88E-06	1	220	207
182	159	2.91E-06	1	220	207
183	159	2.94E-06	1	220	207
184	159	2.97E-06	1	220	207
185	159	2.99E-06	1	220	207
186	159	3.02E-06	1	220	207
187	159	3.05E-06	1	220	207
188	159	3.07E-06	1	220	207
189	159	3.10E-06	1	220	207
190	159	3.12E-06	1	220	207
191	159	3.15E-06	1	220	207
192	159	3.17E-06	1	220	207
186	160	3.06E-06	1	220	207
187	160	3.08E-06	1	220	207
188	160	3.11E-06	1	220	207
189	160	3.14E-06	1	220	207
190	160	3.16E-06	1	220	207
191	160	3.19E-06	1	220	207
192	160	3.21E-06	1	220	207
193	160	3.24E-06	1	220	207
194	160	3.26E-06	1	220	207
191	161	3.23E-06	1	220	207
192	161	3.26E-06	1	220	207
193	161	3.28E-06	1	220	207
194	161	3.31E-06	1	220	207
195	161	3.33E-06	1	220	207
196	161	3.36E-06	1	220	207
197	161	3.38E-06	1	220	207
198	161	3.40E-06	1	220	207
199	161	3.42E-06	1	220	207
195	162	3.38E-06	1	220	207
196	162	3.40E-06	1	220	207
197	162	3.43E-06	1	220	207
198	162	3.45E-06	1	220	207
199	162	3.47E-06	1	220	207
200	162	3.49E-06	1	220	207
201	162	3.52E-06	1	220	207
202	162	3.54E-06	1	220	207
203	162	3.56E-06	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
200	163	3.54E-06	1	220	207
201	163	3.56E-06	1	220	207
202	163	3.59E-06	1	220	207
203	163	3.61E-06	1	220	207
204	163	3.63E-06	1	220	207
205	163	3.64E-06	1	220	207
206	163	3.66E-06	1	220	207
204	164	3.68E-06	1	220	207
205	164	3.70E-06	1	220	207
206	164	3.72E-06	1	220	207
207	164	3.73E-06	1	220	207
208	164	3.75E-06	1	220	207
209	164	3.76E-06	1	220	207
207	165	3.79E-06	1	220	207
208	165	3.80E-06	1	220	207
209	165	3.82E-06	1	220	207
210	165	3.83E-06	1	220	207
211	165	3.85E-06	1	220	207
212	165	3.86E-06	1	220	207
213	165	3.87E-06	1	220	207
210	166	3.89E-06	1	220	207
211	166	3.90E-06	1	220	207
212	166	3.92E-06	1	220	207
213	166	3.93E-06	1	220	207
214	166	3.94E-06	1	220	207
215	166	3.94E-06	1	220	207
216	166	3.95E-06	1	220	207
217	166	3.96E-06	1	220	207
218	166	3.96E-06	1	220	207
219	166	3.96E-06	1	220	207
220	166	3.96E-06	1	220	207
213	167	3.99E-06	1	220	207
214	167	4.00E-06	1	220	207
215	167	4.00E-06	1	220	207
216	167	4.01E-06	1	220	207
217	167	4.02E-06	1	220	207
218	167	4.02E-06	1	220	207
220	167	4.02E-06	1	220	207
221	167	4.02E-06	1	220	207
222	167	4.02E-06	1	220	207
223	167	4.02E-06	1	220	207
224	167	4.01E-06	1	220	207
225	167	4.00E-06	1	220	207
218	168	4.08E-06	1	220	207
219	168	4.08E-06	1	220	207
220	168	4.08E-06	1	220	207
221	168	4.08E-06	1	220	207
222	168	4.08E-06	1	220	207
223	168	4.08E-06	1	220	207
225	168	4.07E-06	1	220	207
226	168	4.06E-06	1	220	207
227	168	4.05E-06	1	220	207
228	168	4.03E-06	1	220	207
223	169	4.14E-06	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
224	169	4.13E-06	1	220	207
225	169	4.13E-06	1	220	207
226	169	4.12E-06	1	220	207
227	169	4.11E-06	1	220	207
228	169	4.10E-06	1	220	207
229	169	4.08E-06	1	220	207
227	170	4.17E-06	1	220	207
228	170	4.16E-06	1	220	207
229	170	4.14E-06	1	220	207
230	170	4.13E-06	1	220	207
228	171	4.22E-06	1	220	207
229	171	4.20E-06	1	220	207
230	171	4.19E-06	1	220	207
229	172	4.27E-06	1	220	207
230	172	4.25E-06	1	220	207
231	172	4.23E-06	1	220	207
230	173	4.31E-06	1	220	207
231	173	4.29E-06	1	220	207
232	173	4.27E-06	1	220	207
231	174	4.36E-06	1	220	207
232	174	4.33E-06	1	220	207
231	175	4.42E-06	1	220	207
232	175	4.40E-06	1	220	207
233	175	4.37E-06	1	220	207
232	176	4.46E-06	1	220	207
233	176	4.43E-06	1	220	207
234	176	4.41E-06	1	220	207
233	177	4.50E-06	1	220	207
234	177	4.47E-06	1	220	207
235	177	4.44E-06	1	220	207
236	177	4.41E-06	1	220	207
237	177	4.38E-06	1	220	207
238	177	4.34E-06	1	220	207
239	177	4.31E-06	1	220	207
240	177	4.27E-06	1	220	207
234	178	4.53E-06	1	220	207
235	178	4.50E-06	1	220	207
236	178	4.47E-06	1	220	207
237	178	4.43E-06	1	220	207
238	178	4.40E-06	1	220	207
239	178	4.36E-06	1	220	207
240	178	4.33E-06	1	220	207
241	178	4.29E-06	1	220	207
242	178	4.25E-06	1	220	207
235	179	4.56E-06	1	220	207
236	179	4.53E-06	1	220	207
240	179	4.38E-06	1	220	207
241	179	4.34E-06	1	220	207
242	179	4.30E-06	1	220	207
243	179	4.26E-06	1	220	207
242	180	4.35E-06	1	220	207
243	180	4.31E-06	1	220	207
244	180	4.27E-06	1	220	207
245	180	4.22E-06	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
243	181	4.36E-06	1	220	207
244	181	4.32E-06	1	220	207
245	181	4.27E-06	1	220	207
244	182	4.36E-06	1	220	207
245	182	4.32E-06	1	220	207
246	182	4.27E-06	1	220	207
245	183	4.36E-06	1	220	207
246	183	4.32E-06	1	220	207
247	183	4.27E-06	1	220	207
245	184	4.41E-06	1	220	207
246	184	4.36E-06	1	220	207
247	184	4.31E-06	1	220	207
246	185	4.40E-06	1	220	207
247	185	4.35E-06	1	220	207
248	185	4.30E-06	1	220	207
249	185	4.25E-06	1	220	207
247	186	4.39E-06	1	220	207
248	186	4.34E-06	1	220	207
249	186	4.29E-06	1	220	207
250	186	4.24E-06	1	220	207
248	187	4.38E-06	1	220	207
249	187	4.33E-06	1	220	207
250	187	4.27E-06	1	220	207
251	187	4.22E-06	1	220	207
249	188	4.36E-06	1	220	207
250	188	4.31E-06	1	220	207
251	188	4.25E-06	1	220	207
252	188	4.20E-06	1	220	207
251	189	4.29E-06	1	220	207
252	189	4.23E-06	1	220	207
251	190	4.32E-06	1	220	207
252	190	4.26E-06	1	220	207
251	191	4.35E-06	1	220	207
252	191	4.29E-06	1	220	207
251	192	4.38E-06	1	220	207
252	192	4.32E-06	1	220	207
251	193	4.41E-06	1	220	207
252	193	4.35E-06	1	220	207
251	194	4.43E-06	1	220	207
252	194	4.37E-06	1	220	207
251	195	4.46E-06	1	220	207
252	195	4.40E-06	1	220	207
251	196	4.48E-06	1	220	207
252	196	4.42E-06	1	220	207
253	196	4.36E-06	1	220	207
252	197	4.44E-06	1	220	207
253	197	4.38E-06	1	220	207
252	198	4.46E-06	1	220	207
253	198	4.39E-06	1	220	207
254	198	4.33E-06	1	220	207
253	199	4.41E-06	1	220	207
254	199	4.35E-06	1	220	207
253	200	4.43E-06	1	220	207
254	200	4.36E-06	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
254	201	4.37E-06	1	220	207
255	201	4.31E-06	1	220	207
254	202	4.38E-06	1	220	207
255	202	4.32E-06	1	220	207
256	202	4.25E-06	1	220	207
257	202	4.19E-06	1	220	207
255	203	4.33E-06	1	220	207
256	203	4.26E-06	1	220	207
257	203	4.20E-06	1	220	207
258	203	4.13E-06	1	220	207
259	203	4.07E-06	1	220	207
260	203	4.01E-06	1	220	207
261	203	3.95E-06	1	220	207
262	203	3.89E-06	1	220	207
263	203	3.83E-06	1	220	207
257	204	4.20E-06	1	220	207
258	204	4.14E-06	1	220	207
259	204	4.08E-06	1	220	207
260	204	4.02E-06	1	220	207
261	204	3.96E-06	1	220	207
263	204	3.84E-06	1	220	207
264	204	3.78E-06	1	220	207
265	204	3.72E-06	1	220	207
266	204	3.67E-06	1	220	207
267	204	3.61E-06	1	220	207
268	204	3.56E-06	1	220	207
261	205	3.96E-06	1	220	207
262	205	3.90E-06	1	220	207
263	205	3.84E-06	1	220	207
264	205	3.78E-06	1	220	207
265	205	3.73E-06	1	220	207
266	205	3.67E-06	1	220	207
267	205	3.61E-06	1	220	207
268	205	3.56E-06	1	220	207
269	205	3.50E-06	1	220	207
270	205	3.45E-06	1	220	207
271	205	3.40E-06	1	220	207
267	206	3.62E-06	1	220	207
268	206	3.56E-06	1	220	207
269	206	3.51E-06	1	220	207
270	206	3.45E-06	1	220	207
271	206	3.40E-06	1	220	207
272	206	3.35E-06	1	220	207
273	206	3.30E-06	1	220	207
270	207	3.45E-06	1	220	207
271	207	3.40E-06	1	220	207
272	207	3.35E-06	1	220	207
273	207	3.30E-06	1	220	207
274	207	3.25E-06	1	220	207
272	208	3.35E-06	1	220	207
273	208	3.30E-06	1	220	207
274	208	3.25E-06	1	220	207
275	208	3.20E-06	1	220	207
273	209	3.30E-06	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
274	209	3.25E-06	1	220	207
275	209	3.20E-06	1	220	207
274	210	3.25E-06	1	220	207
275	210	3.20E-06	1	220	207
274	211	3.24E-06	1	220	207
275	211	3.19E-06	1	220	207
276	211	3.15E-06	1	220	207
274	212	3.24E-06	1	220	207
276	212	3.14E-06	1	220	207
274	213	3.23E-06	1	220	207
275	213	3.18E-06	1	220	207
276	213	3.14E-06	1	220	207
275	214	3.18E-06	1	220	207
276	214	3.13E-06	1	220	207
275	215	3.17E-06	1	220	207
276	215	3.12E-06	1	220	207
275	216	3.16E-06	1	220	207
276	216	3.12E-06	1	220	207
277	216	3.07E-06	1	220	207
275	217	3.16E-06	1	220	207
277	217	3.06E-06	1	220	207
275	218	3.15E-06	1	220	207
276	218	3.10E-06	1	220	207
277	218	3.05E-06	1	220	207
278	218	3.01E-06	1	220	207
279	218	2.96E-06	1	220	207
276	219	3.09E-06	1	220	207
277	219	3.05E-06	1	220	207
278	219	3.00E-06	1	220	207
279	219	2.96E-06	1	220	207
280	219	2.91E-06	1	220	207
278	220	2.99E-06	1	220	207
279	220	2.95E-06	1	220	207
280	220	2.90E-06	1	220	207
281	220	2.86E-06	1	220	207
282	220	2.82E-06	1	220	207
283	220	2.78E-06	1	220	207
284	220	2.73E-06	1	220	207
280	221	2.89E-06	1	220	207
281	221	2.85E-06	1	220	207
282	221	2.81E-06	1	220	207
284	221	2.73E-06	1	220	207
285	221	2.69E-06	1	220	207
286	221	2.65E-06	1	220	207
287	221	2.61E-06	1	220	207
288	221	2.57E-06	1	220	207
289	221	2.53E-06	1	220	207
282	222	2.80E-06	1	220	207
283	222	2.76E-06	1	220	207
289	222	2.52E-06	1	220	207
290	222	2.49E-06	1	220	207
291	222	2.45E-06	1	220	207
283	223	2.75E-06	1	220	207
284	223	2.71E-06	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
291	223	2.44E-06	1	220	207
292	223	2.40E-06	1	220	207
284	224	2.70E-06	1	220	207
285	224	2.66E-06	1	220	207
286	224	2.62E-06	1	220	207
292	224	2.40E-06	1	220	207
286	225	2.61E-06	1	220	207
287	225	2.57E-06	1	220	207
292	225	2.39E-06	1	220	207
287	226	2.56E-06	1	220	207
288	226	2.52E-06	1	220	207
292	226	2.38E-06	1	220	207
288	227	2.51E-06	1	220	207
289	227	2.48E-06	1	220	207
292	227	2.37E-06	1	220	207
289	228	2.46E-06	1	220	207
290	228	2.43E-06	1	220	207
291	228	2.39E-06	1	220	207
292	228	2.36E-06	1	220	207
290	229	2.42E-06	1	220	207
291	229	2.38E-06	1	220	207
290	230	2.41E-06	1	220	207
291	230	2.37E-06	1	220	207
290	231	2.40E-06	1	220	207
291	231	2.36E-06	1	220	207
290	232	2.38E-06	1	220	207
291	232	2.35E-06	1	220	207
290	233	2.37E-06	1	220	207
291	233	2.34E-06	1	220	207
290	234	2.36E-06	1	220	207
291	234	2.32E-06	1	220	207
291	235	2.31E-06	1	220	207
292	235	2.28E-06	1	220	207
291	236	2.30E-06	1	220	207
292	236	2.27E-06	1	220	207
291	237	2.29E-06	1	220	207
292	237	2.25E-06	1	220	207
293	237	2.22E-06	1	220	207
291	238	2.27E-06	1	220	207
292	238	2.24E-06	1	220	207
293	238	2.21E-06	1	220	207
294	238	2.18E-06	1	220	207
292	239	2.23E-06	1	220	207
293	239	2.20E-06	1	220	207
294	239	2.17E-06	1	220	207
295	239	2.14E-06	1	220	207
293	240	2.18E-06	1	220	207
294	240	2.15E-06	1	220	207
295	240	2.12E-06	1	220	207
296	240	2.09E-06	1	220	207
297	240	2.06E-06	1	220	207
294	241	2.14E-06	1	220	207
295	241	2.11E-06	1	220	207
296	241	2.08E-06	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
297	241	2.05E-06	1	220	207
298	241	2.02E-06	1	220	207
299	241	1.99E-06	1	220	207
300	241	1.97E-06	1	220	207
301	241	1.94E-06	1	220	207
302	241	1.91E-06	1	220	207
303	241	1.89E-06	1	220	207
304	241	1.86E-06	1	220	207
296	242	2.07E-06	1	220	207
297	242	2.04E-06	1	220	207
298	242	2.01E-06	1	220	207
301	242	1.93E-06	1	220	207
302	242	1.90E-06	1	220	207
303	242	1.87E-06	1	220	207
304	242	1.85E-06	1	220	207
305	242	1.82E-06	1	220	207
298	243	2.00E-06	1	220	207
299	243	1.97E-06	1	220	207
300	243	1.94E-06	1	220	207
301	243	1.92E-06	1	220	207
303	243	1.86E-06	1	220	207
304	243	1.84E-06	1	220	207
305	243	1.81E-06	1	220	207
306	243	1.79E-06	1	220	207
307	243	1.76E-06	1	220	207
304	244	1.83E-06	1	220	207
305	244	1.80E-06	1	220	207
307	244	1.75E-06	1	220	207
305	245	1.79E-06	1	220	207
307	245	1.74E-06	1	220	207
308	245	1.72E-06	1	220	207
305	246	1.78E-06	1	220	207
306	246	1.75E-06	1	220	207
308	246	1.71E-06	1	220	207
306	247	1.74E-06	1	220	207
308	247	1.70E-06	1	220	207
306	248	1.73E-06	1	220	207
308	248	1.68E-06	1	220	207
306	249	1.72E-06	1	220	207
307	249	1.70E-06	1	220	207
308	249	1.67E-06	1	220	207
309	249	1.65E-06	1	220	207
307	250	1.69E-06	1	220	207
309	250	1.64E-06	1	220	207
310	250	1.62E-06	1	220	207
307	251	1.67E-06	1	220	207
310	251	1.61E-06	1	220	207
307	252	1.66E-06	1	220	207
308	252	1.64E-06	1	220	207
310	252	1.60E-06	1	220	207
308	253	1.63E-06	1	220	207
310	253	1.59E-06	1	220	207
311	253	1.56E-06	1	220	207
308	254	1.62E-06	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
309	254	1.60E-06	1	220	207
311	254	1.55E-06	1	220	207
309	255	1.58E-06	1	220	207
311	255	1.54E-06	1	220	207
309	256	1.57E-06	1	220	207
311	256	1.53E-06	1	220	207
309	257	1.56E-06	1	220	207
311	257	1.52E-06	1	220	207
309	258	1.55E-06	1	220	207
311	258	1.51E-06	1	220	207
309	259	1.54E-06	1	220	207
311	259	1.50E-06	1	220	207
309	260	1.53E-06	1	220	207
310	260	1.51E-06	1	220	207
311	260	1.49E-06	1	220	207
309	261	1.51E-06	1	220	207
310	261	1.49E-06	1	220	207
309	262	1.50E-06	1	220	207
310	262	1.48E-06	1	220	207
309	263	1.49E-06	1	220	207
310	263	1.47E-06	1	220	207
309	264	1.48E-06	1	220	207
310	264	1.46E-06	1	220	207
308	265	1.48E-06	1	220	207
309	265	1.47E-06	1	220	207
308	266	1.47E-06	1	220	207
309	266	1.45E-06	1	220	207
308	267	1.46E-06	1	220	207
309	267	1.44E-06	1	220	207
308	268	1.45E-06	1	220	207
309	268	1.43E-06	1	220	207
307	269	1.45E-06	1	220	207
308	269	1.43E-06	1	220	207
309	269	1.42E-06	1	220	207
307	270	1.44E-06	1	220	207
308	270	1.42E-06	1	220	207
306	271	1.44E-06	1	220	207
307	271	1.43E-06	1	220	207
308	271	1.41E-06	1	220	207
306	272	1.43E-06	1	220	207
307	272	1.41E-06	1	220	207
308	272	1.40E-06	1	220	207
307	273	1.40E-06	1	220	207
308	273	1.38E-06	1	220	207
309	273	1.37E-06	1	220	207
307	274	1.39E-06	1	220	207
308	274	1.37E-06	1	220	207
309	274	1.35E-06	1	220	207
310	274	1.34E-06	1	220	207
308	275	1.36E-06	1	220	207
310	275	1.33E-06	1	220	207
308	276	1.35E-06	1	220	207
309	276	1.33E-06	1	220	207
310	276	1.31E-06	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
311	276	1.30E-06	1	220	207
309	277	1.32E-06	1	220	207
310	277	1.30E-06	1	220	207
311	277	1.29E-06	1	220	207
312	277	1.27E-06	1	220	207
311	278	1.27E-06	1	220	207
313	278	1.24E-06	1	220	207
311	279	1.26E-06	1	220	207
312	279	1.25E-06	1	220	207
313	279	1.23E-06	1	220	207
312	280	1.23E-06	1	220	207
313	280	1.22E-06	1	220	207
312	281	1.22E-06	1	220	207
313	281	1.21E-06	1	220	207
312	282	1.21E-06	1	220	207
313	282	1.20E-06	1	220	207
312	283	1.20E-06	1	220	207
313	283	1.19E-06	1	220	207
312	284	1.19E-06	1	220	207
313	284	1.17E-06	1	220	207
314	284	1.16E-06	1	220	207
313	285	1.16E-06	1	220	207
314	285	1.15E-06	1	220	207
315	285	1.14E-06	1	220	207
313	286	1.15E-06	1	220	207
315	286	1.13E-06	1	220	207
316	286	1.11E-06	1	220	207
313	287	1.14E-06	1	220	207
314	287	1.13E-06	1	220	207
316	287	1.10E-06	1	220	207
314	288	1.12E-06	1	220	207
315	288	1.10E-06	1	220	207
316	288	1.09E-06	1	220	207
317	288	1.08E-06	1	220	207
315	289	1.09E-06	1	220	207
316	289	1.08E-06	1	220	207
317	289	1.07E-06	1	220	207
316	290	1.07E-06	1	220	207
317	290	1.06E-06	1	220	207
316	291	1.06E-06	1	220	207
317	291	1.05E-06	1	220	207
318	291	1.03E-06	1	220	207
317	292	1.04E-06	1	220	207
318	292	1.02E-06	1	220	207
317	293	1.03E-06	1	220	207
318	293	1.01E-06	1	220	207
317	294	1.02E-06	1	220	207
318	294	1.00E-06	1	220	207
318	295	9.93E-07	1	220	207
317	296	9.94E-07	1	220	207
318	296	9.83E-07	1	220	207
317	297	9.84E-07	1	220	207
318	297	9.73E-07	1	220	207
317	298	9.74E-07	1	220	207

Table A-2. (Cont.)

Source Column	Location Row	HQ	Roost No.	Roosting Column	Location Row
318	298	9.63E-07	1	220	207
319	298	9.53E-07	1	220	207
318	299	9.53E-07	1	220	207
319	299	9.43E-07	1	220	207
317	300	9.54E-07	1	220	207
318	300	9.43E-07	1	220	207
319	300	9.33E-07	1	220	207
317	301	9.44E-07	1	220	207
318	301	9.33E-07	1	220	207
317	302	9.34E-07	1	220	207
318	302	9.24E-07	1	220	207
319	302	9.14E-07	1	220	207
317	303	9.24E-07	1	220	207
318	303	9.14E-07	1	220	207
319	303	9.04E-07	1	220	207
318	304	9.04E-07	1	220	207
319	304	8.94E-07	1	220	207
320	304	8.85E-07	1	220	207
321	304	8.75E-07	1	220	207
319	305	8.85E-07	1	220	207
320	305	8.75E-07	1	220	207
321	305	8.66E-07	1	220	207
322	305	8.56E-07	1	220	207
323	305	8.47E-07	1	220	207
321	306	8.57E-07	1	220	207
322	306	8.47E-07	1	220	207
323	306	8.38E-07	1	220	207
324	306	8.29E-07	1	220	207
325	306	0.00E+01	1	220	207
322	307	8.38E-07	1	220	207
323	307	8.29E-07	1	220	207
324	307	8.20E-07	1	220	207
324	308	8.12E-07	1	220	207
	Total	1.85E-02			

Table A-3. Ranked mean partial HQ by contaminant for EEU-70 for the bald eagle. The scenario included a foraging occupancy ratio of 0.50:0.50 for aquatic: terrestrial, and terrestrial foraging was weighted in a square home range.

Note: COPECs with HQ = 0 lacked parameter input values such as a TRV

Rank	COPEC	HQ	Std Err	No. Obs.	HQ % of Total
1	Pentachlorophenol	3.66E-03	1.19E-03	100	24.38%
2	Cesium-137	2.23E-03	8.49E-04	100	14.83%
3	Aluminum	1.83E-03	3.74E-04	100	12.16%
4	Calcium	1.39E-03	4.87E-04	100	9.25%
5	Mercury	1.08E-03	4.57E-04	100	7.17%
6	Vanadium	6.62E-04	2.49E-04	100	4.41%
7	Cobalt-60	5.39E-04	1.88E-04	100	3.59%
8	Magnesium	5.15E-04	2.05E-04	100	3.42%
9	Aroclor 1248	3.76E-04	1.30E-04	100	2.50%
10	Antimony	3.55E-04	1.43E-04	100	2.36%
11	DDT [p,p	3.38E-04	1.06E-04	100	2.25%
12	Nickel	3.25E-04	7.66E-05	100	2.17%
13	Manganese	2.80E-04	6.28E-05	100	1.87%
14	Lead	2.29E-04	5.50E-05	100	1.52%
15	Aroclor 1254	2.17E-04	7.50E-05	100	1.44%
16	Zinc	2.10E-04	3.02E-05	100	1.40%
17	Barium	2.04E-04	2.51E-05	100	1.36%
18	Potassium-40	7.44E-05	2.64E-05	100	0.50%
19	DDE [p,p	7.40E-05	2.55E-05	100	0.49%
20	Chromium	5.35E-05	8.43E-06	100	0.36%
21	Arsenic	5.16E-05	1.05E-05	100	0.34%
22	Copper	4.72E-05	2.67E-05	100	0.31%
23	Radium-226	4.70E-05	1.66E-05	100	0.31%
24	Silver	4.32E-05	5.25E-06	100	0.29%
25	Molybdenum	4.04E-05	9.41E-06	100	0.27%
26	Cadmium	2.60E-05	6.71E-06	100	0.17%
27	Beryllium	2.57E-05	4.20E-06	100	0.17%
28	Sodium	2.31E-05	9.19E-06	100	0.15%
29	Selenium	2.20E-05	5.51E-06	100	0.15%
30	Pyrene	1.47E-05	8.10E-06	100	0.10%
31	Thallium	7.92E-06	2.63E-06	100	0.05%
32	Hexachlorobenzene	5.42E-06	1.74E-06	100	0.04%
33	Mecoprop(MCPP)	4.54E-06	1.50E-06	100	0.03%
34	Di-n-butyl phthalate	4.32E-06	1.48E-06	100	0.03%
35	RDX	3.56E-06	1.39E-06	100	0.02%
36	Uranium	3.21E-06	1.65E-06	100	0.02%
37	Dieldrin	2.81E-06	9.69E-07	100	0.02%
38	Aroclor 1260	2.45E-06	8.48E-07	100	0.02%
39	Dinitrotoluene [2,4-	2.24E-06	8.16E-07	100	0.01%
40	Uranium-238	1.78E-06	6.20E-07	100	0.01%
41	Aldrin	1.42E-06	4.86E-07	100	0.01%
42	Dichlorophenol [2,4-	1.27E-06	4.06E-07	100	0.01%
43	Uranium-234	1.04E-06	3.76E-07	100	0.01%
44	Boron	8.10E-07	1.89E-07	100	0.01%
45	Dinitrophenol [2,4-]	6.96E-07	2.26E-07	100	0.005%
46	Dinitrobenzene [1,3-	6.32E-07	2.45E-07	100	0.004%
47	Trinitrotoluene [2,4	5.24E-07	2.06E-07	100	0.003%
48	Trinitrobenzene [1,3	5.08E-07	1.97E-07	100	0.003%
49	Bis(2-ethylhexyl)pht	4.81E-07	1.63E-07	100	0.003%
50	Benzoic Acid	4.78E-07	1.55E-07	100	0.003%

Table A-3. (Cont.)

Rank	COPEC	HQ	Std Err	No. Obs.	HQ % of Total
51	Hexachloroethane	3.80E-07	1.22E-07	100	0.003%
52	Plutonium-239	3.45E-07	2.62E-07	100	0.002%
53	Naphthalene	2.89E-07	9.29E-08	100	0.002%
54	Uranium-235	2.73E-07	9.40E-08	100	0.002%
55	Tritium	1.95E-07	1.29E-07	100	0.001%
56	Plutonium-238	1.13E-07	7.72E-08	100	0.001%
57	D [2,4-]	1.04E-07	3.43E-08	100	0.001%
58	Nitrobenzene	9.93E-08	3.67E-08	100	0.001%
59	DB [2,4-]	7.79E-08	2.59E-08	100	0.001%
60	Chlorophenol [o-]	7.59E-08	2.44E-08	100	0.001%
61	Methylphenol [4-]	7.59E-08	2.44E-08	100	0.001%
62	Cyanide	6.42E-08	2.16E-08	100	0.0004%
63	(2,4-Dichlorophenoxy	5.66E-08	1.86E-08	100	0.0004%
64	Hexachlorocyclopenta	5.42E-08	1.74E-08	100	0.0004%
65	Dalapon	4.85E-08	1.60E-08	100	0.0003%
66	HMX	4.64E-08	1.79E-08	100	0.0003%
67	Endrin aldehyde	4.09E-08	1.41E-08	100	0.0003%
68	Endrin ketone	4.09E-08	1.41E-08	100	0.0003%
69	Endrin	4.09E-08	1.41E-08	100	0.0003%
70	Americium-241	2.80E-08	1.41E-07	100	0.0002%
71	Fluoranthene	2.35E-08	1.32E-08	100	0.0002%
72	Chlordane [alpha-]	2.20E-08	7.53E-09	100	0.0001%
73	Chlordane [gamma-]	2.20E-08	7.53E-09	100	0.0001%
74	Heptachlor epoxide	1.50E-08	5.13E-09	100	0.0001%
75	Anthracene	1.48E-08	6.22E-09	100	0.0001%
76	Azobenzene	1.45E-08	4.65E-09	100	0.0001%
77	Trichlorophenol [2,4	1.37E-08	4.44E-09	100	0.0001%
78	Dichlorobenzene (1,2	9.49E-09	3.04E-09	100	0.0001%
79	Sodium-22	8.49E-09	4.22E-08	100	0.0001%
80	Phenol	7.86E-09	2.52E-09	100	0.0001%
81	Dimethylphenol [2,4-	7.59E-09	2.44E-09	100	0.0001%
82	Methylphenol [2-]	7.59E-09	2.44E-09	100	0.0001%
83	Ruthenium-106	5.91E-09	3.00E-08	100	0.00004%
84	Dinoseb	5.07E-09	1.68E-09	100	0.00003%
85	Dicamba	4.90E-09	1.64E-09	100	0.00003%
86	Lindane	4.37E-09	1.50E-09	100	0.00003%
87	Trichlorobenzene [1,	3.80E-09	1.22E-09	100	0.00003%
88	Vinyl Chloride	3.63E-09	2.32E-09	100	0.00002%
89	Fluorene	3.50E-09	1.16E-09	100	0.00002%
90	Isophorone	2.53E-09	8.13E-10	100	0.00002%
91	Butyl benzyl phthala	2.39E-09	7.67E-10	100	0.00002%
92	Acenaphthene	2.31E-09	7.45E-10	100	0.00002%
93	Di-n-octyl phthalate	2.17E-09	6.97E-10	100	0.00001%
94	Endosulfan II	1.96E-09	6.75E-10	100	0.00001%
95	Heptachlor	1.87E-09	6.41E-10	100	0.00001%
96	Cerium-144	1.82E-09	9.07E-09	100	0.00001%
97	Toxaphene	1.77E-09	6.06E-10	100	0.00001%
98	DDD [p,p	1.28E-09	4.40E-10	100	0.00001%
99	Endosulfan I	9.99E-10	3.42E-10	100	0.00001%
100	Methoxychlor	4.74E-10	1.62E-10	100	0.000003%
101	Bromomethane	4.41E-10	2.82E-10	100	0.000003%
102	Dimethyl phthalate	3.80E-10	1.22E-10	100	0.000003%
103	Methylene Chloride	2.49E-10	1.66E-10	100	0.000002%

Table A-3. (Cont.)

Rank	COPEC	HQ	Std Err	No. Obs.	HQ % of Total
104	Diethyl phthalate	8.28E-11	2.66E-11	100	0.000001%
105	Trichloroethane [1,1	8.25E-11	5.29E-11	100	0.000001%
106	Dichlorodifluorometh	4.11E-11	2.63E-11	100	0.0000003%
107	Xylenes (o + m + p)	3.98E-11	2.55E-11	100	0.0000003%
108	Trichloropropane [1,	3.86E-11	2.47E-11	100	0.0000003%
109	Dichloroethane [1,1-	3.43E-11	2.20E-11	100	0.0000002%
110	Endosulfan sulfate	2.93E-11	1.01E-11	100	0.0000002%
111	Carbon disulfide	2.80E-11	1.80E-11	100	0.0000002%
112	Tetrachloroethylene	2.20E-11	1.41E-11	100	0.0000001%
113	Chloroform	2.06E-11	1.32E-11	100	0.0000001%
114	Carbon tetrachloride	1.93E-11	1.23E-11	100	0.0000001%
115	Dichloroethane [1,2-	1.79E-11	1.15E-11	100	0.0000001%
116	Bromodichloromethane	1.72E-11	1.10E-11	100	0.0000001%
117	Bromoform	1.72E-11	1.10E-11	100	0.0000001%
118	Chlorobenzene	1.62E-11	1.04E-11	100	0.0000001%
119	Toluene	1.19E-11	7.61E-12	100	0.0000001%
120	Benzene	1.17E-11	7.49E-12	100	0.0000001%
121	Dichloroethene [tran	6.65E-12	4.46E-12	100	0.00000004%
122	Acetone	4.18E-12	2.69E-12	100	0.00000003%
123	Ethylbenzene	3.18E-12	2.03E-12	100	0.00000002%
124	Styrene	1.54E-12	9.88E-13	100	0.00000001%
125	Trichlorofluorometha	3.09E-13	1.98E-13	100	0.000000002%
126	Acenaphthylene	0	0	100	
127	Aniline	0	0	100	
128	Benzo[a]anthracene	0	0	100	
129	Benzo[a]pyrene	0	0	100	
130	Benzo[b]fluoranthene	0	0	100	
131	Benzo[g,h,i]perylene	0	0	100	
132	Benzo[k]fluoranthene	0	0	100	
133	Benzyl alcohol	0	0	100	
134	Bis(2-chloroethoxy)m	0	0	100	
135	Bis(2-chloroethyl)et	0	0	100	
136	Bis(2-chloroisopropy	0	0	100	
137	Bromobenzene	0	0	100	
138	Bromochloromethane	0	0	100	
139	Bromophenylphenyl et	0	0	100	
140	Butanone [2-]	0	0	100	
141	Butylbenzene [n-]	0	0	100	
142	Butylbenzene [sec-]	0	0	100	
143	Butylbenzene [tert-]	0	0	100	
144	Chloro-3-methylpheno	0	0	100	
145	Chloroaniline [4-]	0	0	100	
146	Chlorodibromomethane	0	0	100	
147	Chloroethane	0	0	100	
148	Chloromethane	0	0	100	
149	Chloronaphthalene [2	0	0	100	
150	Chlorophenylphenyl e	0	0	100	
151	Chlorotoluene [o-]	0	0	100	
152	Chlorotoluene [p-]	0	0	100	
153	Chrysene	0	0	100	
154	Cobalt	0	0	100	
155	Dibenzo[a,h]anthrace	0	0	100	
156	Dibenzofuran	0	0	100	

Table A-3. (Cont.)

Rank	COPEC	HQ	Std Err	No. Obs.	HQ % of Total
157	Dibromo-3-chloroprop	0	0	100	
158	Dibromoethane [1,2-]	0	0	100	
159	Dibromomethane	0	0	100	
160	Dichlorobenzene (1,3	0	0	100	
161	Dichlorobenzene (1,4	0	0	100	
162	Dichlorobenzidine [3	0	0	100	
163	Dichloroethene [1,1-	0	0	100	
164	Dichloroethylene [ci	0	0	100	
165	Dichloropropane [1,2	0	0	100	
166	Dichloropropane [1,3	0	0	100	
167	Dichloropropane [2,2	0	0	100	
168	Dichloropropene [1,1	0	0	100	
169	Dichloropropene [cis	0	0	100	
170	Dichloropropene [tra	0	0	100	
171	Dinitrotoluene [2,6-	0	0	100	
172	Hexachlorobutadiene	0	0	100	
173	Hexanone [2-]	0	0	100	
174	Indeno[1,2,3-cd]pyre	0	0	100	
175	Iron	0	0	100	
176	Isopropylbenzene	0	0	100	
177	Isopropyltoluene [4-	0	0	100	
178	Methyl Iodide	0	0	100	
179	Methyl-2-pentanone [	0	0	100	
180	Methyl-4,6-dinitroph	0	0	100	
181	Methylnaphthalene [2	0	0	100	
182	Nitroaniline [2-]	0	0	100	
183	Nitroaniline [3-]	0	0	100	
184	Nitroaniline [4-]	0	0	100	
185	Nitrophenol [2-]	0	0	100	
186	Nitrophenol [4-]	0	0	100	
187	Nitrosodi-n-propylam	0	0	100	
188	Nitrosodimethylamine	0	0	100	
189	Nitrosodiphenylamine	0	0	100	
190	Nonacosane	0	0	100	
191	Phenanthrene	0	0	100	
192	Potassium	0	0	100	
193	Propylbenzene	0	0	100	
194	Radvan Gross Alpha S	0	0	100	
195	Radvan Gross Beta Sc	0	0	100	
196	Radvan Gross Gamma S	0	0	100	
197	Saturated Hydrocarbo	0	0	100	
198	Terpene Hydrocarbons	0	0	100	
199	Tetrachloroethane [1	0	0	100	
200	Trichloro-1,2,2-trif	0	0	100	
201	Trichloroethene	0	0	100	
202	Trimethylbenzene [1,	0	0	100	
203	Unknown organic comp	0	0	100	
204	Unknown Polynuclear	0	0	100	
205	Dichloroethene [1,2-	0	0	100	
206	Aroclor 1016	0	0	100	
207	Aroclor 1221	0	0	100	
208	Aroclor 1232	0	0	100	
209	Aroclor 1242	0	0	100	

Table A-3. (Cont.)

Rank	COPEC	HQ	Std Err	No. Obs.	HQ % of Total
210	BHC [alpha-]	0	0	100	
211	BHC [beta-]	0	0	100	
212	BHC [delta-]	0	0	100	
213	Chloro-o-tolyloxyace	0	0	100	
214	T [2,4,5-]	0	0	100	
215	TP [2,4,5-]	0	0	100	
216	Amino-2,6-dinitrotol	0	0	100	
217	Amino-4,6-dinitrotol	0	0	100	
218	Nitrotoluene [m-]	0	0	100	
219	Nitrotoluene [o-]	0	0	100	
220	Nitrotoluene [p-]	0	0	100	
221	Octadecanoic acid	0	0	100	
222	Tetryl(methyl-2,4,6-	0	0	100	
223	Carbazole	0	0	100	
224	Benzidine [m-]	0	0	100	
225	Totarol or isomer	0	0	100	
226	Unknown alkanes	0	0	100	
227	Oxygenated Hydrocarb	0	0	100	
228	Actinium-228	0	0	100	
229	Bismuth-211	0	0	100	
230	Bismuth-212	0	0	100	
231	Bismuth-214	0	0	100	
232	Lead-212	0	0	100	
233	Lead-214	0	0	100	
234	Radium-224	0	0	100	
235	Thallium-208	0	0	100	
236	Radvan Tritium Scree	0	0	100	
237	Unknown organic acid	0	0	100	
238	Hexadecanoic acid	0	0	100	
239	Strontium-90	0	0	100	
240	Gross Apha	0	0	100	
241	Gross Beta	0	0	100	
242	Gross Gamma	0	0	100	
243	Tin	0	0	100	
244	Strontium	0	0	100	
245	Barium-140	0	0	100	
246	Europium-152	0	0	100	
247	Neptunium-237	0	0	100	
	Total	1.50E-02			

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