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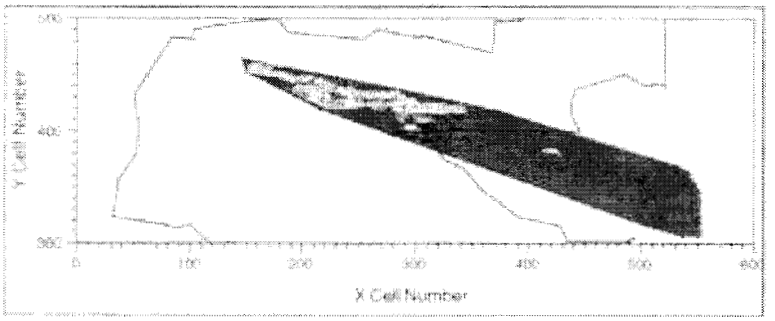
The Application of ECORSK.9 to the Mexican Spotted Owl, Western Bluebird, Deer Mouse, and Southwestern Willow Flycatcher in Mortandad Canyon at the Los Alamos National Laboratory



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Edited by Hector Hinojosa, Group IRM-CAS

About the cover: Male western bluebird at Los Alamos National Laboratory (photo taken by David Keller of Ecology and Air Quality Group) and hazard index contour plot for the bluebird from which spatially explicit population-level effects from contaminants are estimated for Mortandad Canyon. Contour plots are generated using ECORSK.9 output data.

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LA-14305
Issued: September 2006

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The Application of ECORSK.9 to the Mexican Spotted Owl, Western Bluebird, Deer Mouse, and Southwestern Willow Flycatcher in Mortandad Canyon at the Los Alamos National Laboratory

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ABSTRACT

ECORSK.9, a FORTRAN95 model used as one line of evidence for assessing risk to animals from chemicals of potential ecological concern (COPECs), was applied at the Los Alamos National Laboratory to four receptors—the Mexican spotted owl (*Strix occidentalis lucida*), western bluebird (*Sialia mexicana bairdi*), deer mouse (*Peromyscus maniculatus*), and southwestern willow flycatcher (*Empidonax traillii extimus*)—in a study area including Mortandad Canyon and several tributaries, collectively comprising the Mortandad Canyon watershed. Application of the model was in support of a Mortandad Canyon biota investigation and baseline ecological risk assessment. The results of the model application enhanced the spatial and temporal coverage of risk screening and empirical studies that were conducted concurrently. Specifically, we compiled contaminant data from canyons and non-canyons sources so that an understanding of the potential for adverse effects across the Mortandad Canyon watershed could be evaluated. ECORSK.9 assesses potential effects to terrestrial animals over large spatial areas on the basis of the U.S. Environmental Protection Agency Quotient Method. Estimates of animal exposure over a gridded area are compared with assumed health effects levels to generate hazard quotients (HQs) and hazard indices (HIs). Mean total HIs, HI distributions, COPEC-specific HQs, and contour maps are presented for assessing potential adverse effect to individuals or populations of animals in the Mortandad Canyon watershed. The mean total HI is a general indicator of potential adverse effect and is most useful in identifying issues needing further study. Adjusted mean total HIs for the four receptors were as follows: Mexican spotted owl—1.6 (n = 999); western bluebird—1.2 (n = 997); deer mouse—0.19 (n = 997); and southwestern willow flycatcher—6.2 (n = 57). On average there is a small potential that Mexican spotted owls, western bluebirds, and southwestern willow flycatchers will experience adverse effects from exposure to COPECs in the Mortandad Canyon watershed. Threatened and endangered species warrant protection of each individual in the population and, although there were a few HIs in the range of 10–100 for both the owl and flycatcher and a few HIs in excess of 100 for the owl, many factors that result in biasing HIs and HQs upwards may have resulted in significant overestimates. The treatment of non-detect sample values for the canyons data was one of these factors; however, this factor mostly affected the geographical distribution of HIs and HQs and had little effect on maximum HIs and HQs. The primary source for the elevated HIs may have been non-canyons. In general, the western part of the watershed in the vicinity of Technical Area 35 had the highest concentrations of COPECs and, therefore, poses the greatest potential for ecological risks to the modeled receptors. There were HIs >1 in some parts of the watershed that indicate the potential for adverse effects on individual owls and flycatchers; however, the adjusted HI for the grid cell in Mortandad Canyon in which a pair of nesting owls actually exists was only 0.2. The percentages of western bluebird and deer mouse populations that could experience adverse effects from the COPECs studied are probably too low to have an effect on their population viability.

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INTRODUCTION

Mortandad Canyon and its tributaries (Effluent, Pratt, and Ten Site canyons and an unnamed tributary) comprise a watershed area that is collectively called "Mortandad Canyon" at the Los Alamos National Laboratory (LANL). Mortandad Canyon has been the subject of a biota investigation as required by the Mortandad Canyon Work Plan, hereafter referred to as "the work plan." ECORSK.9 is a model written in FORTRAN95 computer code that has been applied for the biota investigation as one of many lines of evidence for evaluating potential adverse ecological effects from chemicals of potential ecological concern (COPECs) in soil. ECORSK.9 assesses potential effects in general to terrestrial animals over large spatial areas on the basis of the U.S. Environmental Protection Agency (EPA) Quotient Method (EPAQM). Estimates of animal exposure over a gridded area are compared with assumed health effects levels to generate hazard quotients (HQs) and hazard indices (HIs). ECORSK.9 integrates biological, ecological, and toxicological information using geographic information system (GIS) interfaces so that all model input and output are spatially explicit.

BACKGROUND

Ecological risk screenings and other risk-related information have indicated the need to perform aggregate studies of a more robust nature in Mortandad Canyon (LANL 2005a). The assessments of ecological effects from legacy COPEC releases at LANL were undertaken to assist in making remediation decisions and to develop plans for future environmental monitoring. Shown in Figure 1, in addition to Mortandad Canyon, the area considered in this assessment includes the smaller, subsidiary canyons of Effluent, Mortandad, Pratt, and Ten Site and an unnamed tributary. Diverse terrestrial and aquatic biological communities in these canyons are potentially exposed to contaminated soil, sediment, surface water, and shallow alluvial groundwater.

In the years 1996–1999, the potential impact of chemical and radiological COPECs on threatened and endangered species in the environment surrounding LANL was appraised using ECORSK.5. Performed as required for the Record of Decision for the construction of the Dual-Axis Radiographic Hydrodynamic Test (DARHT) Facility at LANL as part of the DARHT Environmental Impact Statement, these assessments also became the ecological risk assessments of record for the *Site-Wide Environmental Impact Statement (SWEIS) for Continued Operation of the Los Alamos National Laboratory* (USDOE 1999). ECORSK modeling has also been conducted for a SWEIS update in 2005, various site-wide biological assessments, and, more recently, biota investigations and baseline ecological risk assessments. Much has changed in COPEC data sets and other parameters over time.

Shortly after issuance of the SWEIS, LANL began formal planning on comprehensive biological resources management to provide policy, guide biological resources surveillance and monitoring, and ensure regulatory compliance. The development of a biological resources management plan (BRMP) was identified as necessary for the Laboratory to have continued success in the dual objectives of operating a nuclear industry in harmony with a sustained surrounding environment. This plan included the need to avoid the hindrance of the land management objectives of adjacent Native American pueblos and federal land management agencies.

With trace levels of chemical (inorganic and organic) and radioactive contamination in the LANL-related environment, understanding potential risk to wildlife that is presented by these

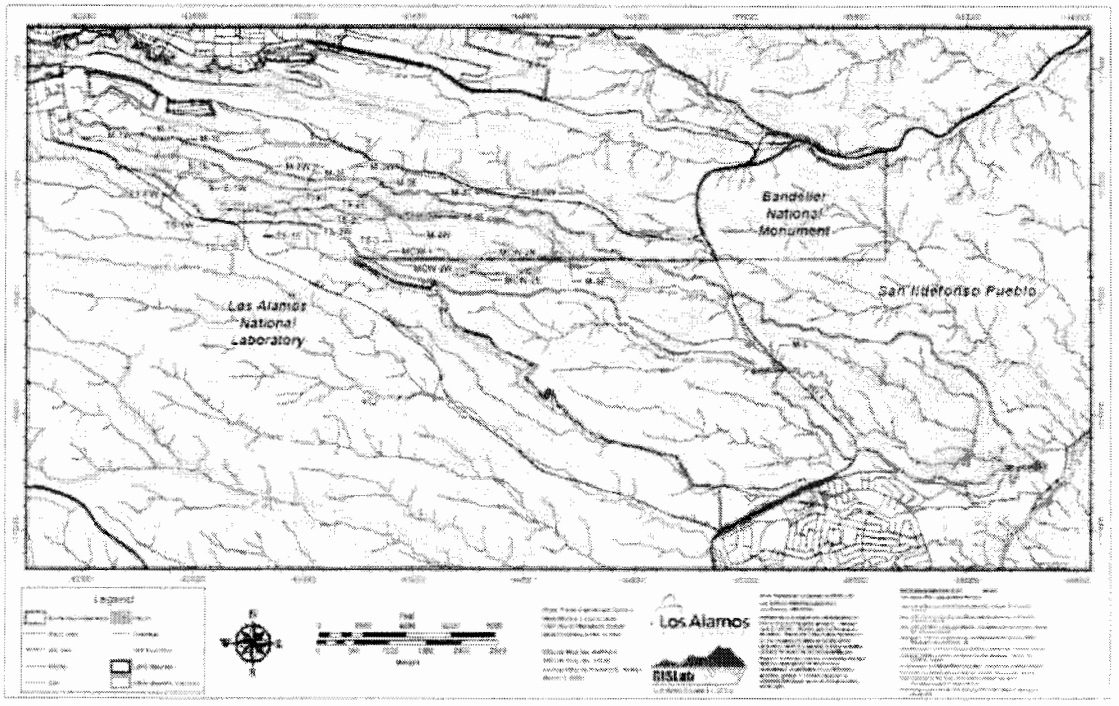


Figure 1. Study area—Mortandad Canyon watershed (LANL 2005a).

COPECs is an important biological quality issue emphasized by many stakeholders. With a region-wide spatial scope identified by the BRMP, planners identified ECORSK as a tool that could satisfy the needs of the BRMP planning and implementation process because ECORSK has its strength in assessing large areas of land, thus having the same broad spatial extent as the regional context of the BRMP. And, ECORSK allows the use of animal distribution data to determine the spatial dynamics for estimating exposure. ECORSK.6 was applied to the Rocky Mountain elk (*Cervus elaphus*), the American robin (*Turdus migratorius*), and the deer mouse (*Peromyscus maniculatus*) (Gonzales et al. 2002). The spatial extent covered by ECORSK was also envisioned to help satisfy the "broad ecosystem-level component" requirement of the Natural Resource Damages Assessments (43 CFR 11). Similar to the application of ECORSK.9 to Mortandad Canyon, in 2002 and 2003 ECORSK.7 was applied to the Los Alamos and Pueblo canyons watershed concerning the deer mouse, Mexican spotted owl, and western bluebird (Gonzales et al. 2004).

While ECORSK.7 simulated receptor nest distribution by computationally adjusting the output data (HIs and HQs), ECORSK.9 associates nest x,y and row,column values according to predetermined weighted distributions that are associated with real receptor habitat preference data. This method of weighting the physical distribution of nest sites (or focal points) comprises the difference between ECORSK.7 and ECORSK.9.

This current application of the ECORSK model helps to integrate the previous screening level assessments performed in Mortandad Canyon into a broader spatial context. Previous screening level assessments have been documented in the work plan, which evaluated affected media—soil, sediments, and water—in canyon bottoms. Other screening assessments have been performed on source areas of contamination known as "solid waste management units" (SWMUs) in relation to the Resource Conservation and Recovery Act. The application of ECORSK.9 to Mortandad Canyon, used collectively with field studies, helps to test model assumptions; and model results enhance spatial and temporal coverage of field measures. The operations strategy, documentation of code, mathematical models used, and previous applications of ECORSK have been documented in numerous reports (Gallegos et al. 1997a; Gonzales et al. 1998a, b; Gonzales et al. 2002; Gonzales et al. 2004).

METHODS

Receptors

The representative receptors evaluated using ECORSK.9 were the Mexican spotted owl (*Strix occidentalis lucida*), western bluebird (*Sialia mexicana bairdi*), deer mouse (*Peromyscus maniculatus*), and southwestern willow flycatcher (*Empidonax traillii extimus*) (LANL 2005a). These species collectively represent a variety of receptors with regard to attributes related to social/cultural and ecological factors and model strength factors.

The Mexican spotted owl, a federally protected species on the Nation's list of threatened and endangered species, nests in a portion of Mortandad Canyon. It is a top carnivore, and since ECORSK.9 includes soil-to-receptor and food-chain transfers of COPECs, modeling of the owl addresses the issue of potential biomagnifications. As a federally protected species, it has very high social importance. The Mexican spotted owl's diet and habitat are well known and these are key attributes of risk assessments. The owl was a subject of assessment with ECORSK.5 in 1997 (Gallegos et al. 1997a) and it has been the subject of numerous studies at LANL. All of these

factors make the Mexican spotted owl a key indicator species chosen for the application of ECORSK.9.

The western bluebird is a ground-foraging insectivore; with some individuals residing at LANL year-round the bluebird has been the subject of field studies at LANL since 1997 (Fair and Colestock 2003; Fair and Sommer 2003), therefore, habitat use and other population ecological information specific to LANL has been measured. There are nest box monitoring stations located in Mortandad Canyon and study results from the nest box network are being used as a line of evidence in the Mortandad Canyon biota investigation. Attributes of these receptors as entities for measuring potential adverse effects as well as their value as indicator species for different land management agencies are discussed in a previous report (Gonzales et al. 2002).

Deer mice are omnivores with a tendency for relatively high exposure to COPECs resulting from consumption of invertebrates as a food source—and they have a relatively high food intake rate (considering body weight). Their distribution and density are known such that this information can be used in ECORSK.9 in a manner that affects COPEC exposure calculations; they have a wide distribution, which is conducive to the ability of ECORSK.9 to simulate large spatial areas; they are within an animal taxonomic group for which toxicological information exists, i.e., mammals; and their importance as an indicator species has been expressed by external stakeholders (Gonzales et al. 2002). The deer mouse is also often the receptor on which risk screens are based (USDOE 2000; LANL 2004).

The southwestern willow flycatcher, another federally protected species, has a small amount of suitable habitat in Mortandad Canyon (Keller 2004). In addition to its protected status, the flycatcher is a good indicator species because it feeds primarily on insects that are associated with aquatic communities, therefore it can be used to represent potential COPEC pathways originating in wetlands and riparian areas that exist in Mortandad Canyon and its tributaries.

ECORSK.9 Organization and Operations

A summary of the general organization of ECORSK.9 in relation to GIS information and input and output files is shown in Figure 2. ECORSK.9 integrates several different kinds of GIS information; COPEC data; and animal biological, ecological, and toxicological information.

The basic spatial unit used by ECORSK.9 is a 100- × 100-ft grid that is assigned a unique grid cell identification (ID) value, which corresponds to a unique New Mexico State Plane Coordinate System 'x' and 'y' value. All environmental information, such as COPEC concentrations, are cataloged by location (grid cell ID) using this spatial system. The spatial extent of Mortandad Canyon watershed was established in the work plan and we overlaid a grid with the 30- × 30-m units on the watershed. Some receptors, such as the owl, have nesting habitats that are discrete from the surrounding foraging areas (or home ranges [HRs]), which together comprise ecological exposure units (EEUs) as defined in the ECORSK model.

Nest Site/Focal Point Designation. During ECORSK operation, the model assigns nest sites (or focal points) within a nesting habitat based on user inputs (random or as specified) and differentiates the spatial components by the grid cell ID. Random nest site selection is based on Monte Carlo methods, or alternatively, nests can be specifically assigned to particular grid cells such as a grid cell occupied by a known contaminated area (SWMU or area of concern [AOC])

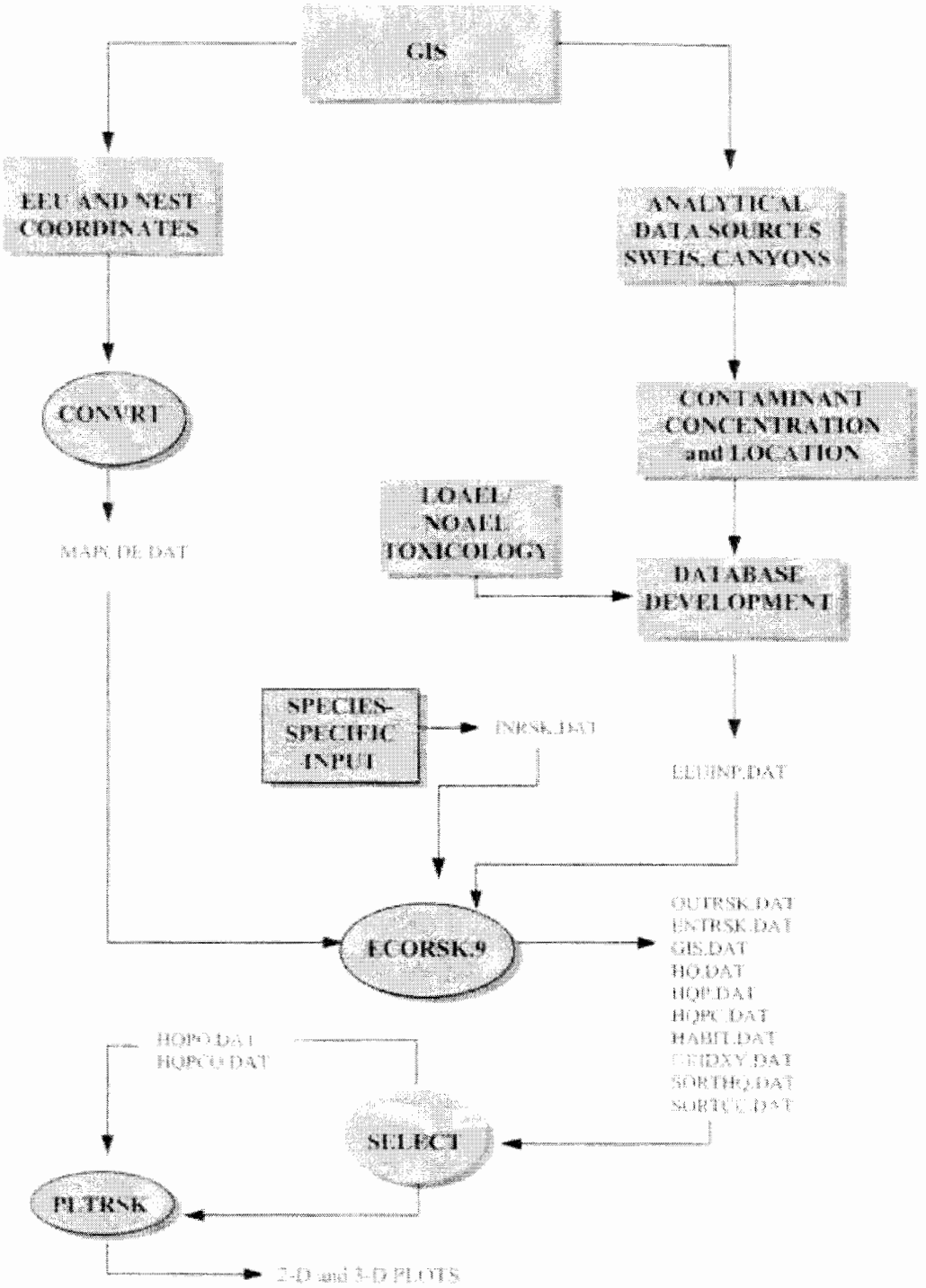


Figure 2. Schematic of strategy for integrating FORTRAN95 code with analytical data. (Note: LOAEL is "lowest observed adverse effects level;" NOAEL is "no observed adverse effects level").

and/or a grid cell known to contain an actual nest or other niche of an animal. The distribution of nest/focal point locations can be unweighted throughout the EEU whereby each grid cell within a nesting habitat or EEU receives equal consideration, or distribution can be weighted on the basis of the natural distribution tendencies of the animal that are determined by habitat. At LANL, land cover types, including classes of animal habitat, have been determined from ground-verified aerial data.

Weighted Distribution of Nests or Focal Points

Given a specified total number of nest sites or focal points for each execution of ECORSK.9 (ECORSK.9 can manage up to 5,000), the number of nest sites/focal points for each habitat type can be weighted on the basis of the product of habitat suitability intersected with the proportion of the total EEU made up by a given habitat type. For example, if the abundance of the western bluebird on piñon (*Pinus edulis*)-juniper (*Juniperus monosperma*) woodlands is three times the abundance on grasslands, three times more nest sites would be assigned to the piñon-juniper habitat as to the grasslands habitat if there were equal relative amounts (area) of piñon-juniper and grassland habitats in the area being assessed (EEU). In reality, for most species there are unequal amounts of area in the various habitat types, therefore the habitat weighting is interacted against the relative proportion of total area made up by each of the habitat types (piñon-juniper, grasslands, etc.). Using the Mexican spotted owl, a more realistic example would be as follows:

If we specified 1,000 nest sites to be distributed by the model on a weighted basis,
and the total area being assessed was 206,354 grids,
and the habitat weighting, number of grids, and proportion of three habitat types was

habitat value (weighting) = 1 = 145,084 grids (70.3% of total area)
habitat value (weighting) = 10 = 30,842 grids (14.95%)
habitat value (weighting) = 100 = 30,428 grids (14.75%)

then

map coded value 1 areas = 70.3% × 1% (relative weighting) = 4.59% of nests
map coded value 10 areas = 14.95% × 9% (relative weighting) = 8.78% of nests
map coded value 100 areas = 14.75% × 90% (relative weighting) = 86.63% of nests

and ECORSK.9 would distribute the nests as follows:
~46 nests to map coded value 1 areas
~88 nests to map coded value 10 areas and
~866 nests to map coded value 100 areas.

This method of weighting the physical distribution of nest sites (or focal points) comprises the difference between ECORSK.7 and ECORSK.9. While ECORSK.7 accomplished this by computationally adjusting the output data (HIs and HQs), ECORSK.9 associates nest x,y and row,column values according to the predetermined weighted distributions. The weightings also affect simulated foraging (or occupancy) as discussed later. Habitat suitability distributions for the four receptors are presented in the next subsection. In actuality, nests were not placed in map coded value 1 habitat for the owl and flycatcher; i.e., no nests were placed outside habitat

designated as buffer in the LANL Habitat Management Plan for the owl nor outside the wetland for the flycatcher.

Simulated Foraging Process

Beginning at any given nest site (grid cell), if the HR of an animal is larger than one grid cell, ECORSK begins the selection of grid cells in a concentric fashion around the nest site and continues until the HR of an animal is reached. If the model cannot complete its development of the HR in any direction because it encounters a pre-defined boundary (i.e., Mortandad Canyon watershed boundary), it adds to the HR in other directions until the HR is complete. Foraging outside the pre-defined EEU does not occur. The model iterates this process for the specified number of nest sites/focal points for a receptor, e.g., approximately 1,000 for the owl, bluebird, and deer mouse; 57 for the flycatcher. For each nest site, ECORSK.9 calculates HIs and HQs as discussed below.

Distance-Weighted Foraging. Only the Mexican spotted owl had a HR sufficiently large to apply an exponential function that is based on the central place foraging theory. The assumption can be made that the relative probability of foraging is inversely related to the radial distance from the animal's nest site, roosting area, or other focal point and mathematically this can be expressed through the use of an exponential function:

$$O_i = A_i/\sum A_i \, ENH_i \; Exp\,(-R_i/R_c)\,,$$

where

O_i = occupancy factor for any grid cell (i) of an EEU,
A_i = surface area, km^2, of the ith grid within the HR of a given animal,
ENH_i = enhancement factor,
R_i = radial distance, m, of the ith grid from the grid center containing the nest site, and
R_c = a scaling constant, m, for a given species.

A scaling constant of 350 m was estimated from Johnson (1993) for the Mexican spotted owl. Application of this function results in almost 75% of the foraging within 1 km of a nest site. Distance-weighted foraging was used only for the owl. Scaling constants for non-avian species with large HRs can be obtained in a similar manner.

Habitat-Weighted Foraging. The relative density or abundance data mentioned previously in discussion of nest site selection also can affect the foraging process during calculation of HQs and HIs if this option is selected. From field data collected at LANL, absolute measures of density or abundance were converted to the relative values shown in Table 1 (A, B, C, D). ARC/INFO was used to integrate land cover and topography with species distribution data across the study area. Relative values are associated with the integer values that are used as map codes by ECORSK.9 to give every grid cell an identifier that is associated with a particular weighting (relative value) when the model is executed. HI/HQ output data are populated using the density/abundance data such that, for example, in essence 12.35 deer mice will forage in grid cells occupied by ponderosa pine (*Pinus ponderosa*) mesas for every one deer mouse that forages in grid cells with wetlands/riparian habitat. With a spatial distribution of HIs, HI contours can then be applied to address population risk by geographical area.

Density for deer mouse was calculated by land cover and topography (mesa top or canyon bottom). To develop the deer mouse EEU spatial layer, we first intersected (using ARC/INFO INTERSECT command) the land cover layer with the canyon/mesa top layer to produce a composite layer with land cover attributes and canyon and mesa top attributes. We coded this new layer with the relative importance values derived from the average density information. These values are listed in Table 1A.

Distribution of the Mexican spotted owl was based on the suitability of three generalized habitats (Table 1B) to be consistent with methods used for protecting the owl as described in the Habitat Management Plan (LANL 1998). Habitats are designated as core area, buffer area, or extraneous and the relative difference in weighting is 100, 10, and 1, respectively. The relative differences in habitat suitability were determined using a topographic model that was modified to include other factors (such as land cover type) that influence habitat suitability. Potential nesting/roosting zones were based on work performed by Johnson (1993) in which he developed a topographic model to rate the physical potential of habitat for breeding spotted owls. Topographic data of the U.S. Geological Survey provided the input for modeling the potential habitat. Historical owl locations were extracted from a New Mexico Department of Game and Fish database prepared by the New Mexico Natural Heritage Program. The model was developed by examination of topographic characteristics of owl locations and random locations to find a scalar function of topography that quantitatively separated inhabited areas from random locations. The database included 1,383 records of historical reports and U.S. Forest Service inventory and monitoring daytime follow-up field work through 1991. See Johnson (1993) for more detail on the methodology for identifying potential owl nesting habitat. Areas of the watershed outside of core and buffer habitat were excluded from nest site selection.

Relative abundance of bluebirds by land cover type was estimated (Table 1C) from 2002 field data on presence and absence, which was collected from a total of 561 boxes placed throughout LANL (Fair and Sommer 2003). Abundance was estimated on the basis of proportion of total presence-count made up by presence-count in each land cover type. Bluebirds typically invade burned areas in response to increases in invertebrate populations, so a higher abundance in areas burned by the Cerro Grande Fire might have been expected. However, competition by other bird species may have slowed the re-establishment of bluebirds in the burned areas. Also, years of drought on the Pajarito Plateau may have compounded the effect of the fire such that recovery of the burned ecosystems may be retarded.

Habitat for the southwestern willow flycatcher in Mortandad Canyon was arbitrarily graded on a relative basis into suitability categories like those of the Mexican spotted owl. The flycatcher is found in riparian areas in association with willows (*Salix* spp.), arrowweed (*Pluchea* spp.), buttonbush (*Cephalanthus* spp.), tamarisk (*Tamarix* spp.), Russian olive (*Elaeagnus angustifolia* L.), cattails (*Typha* spp.), and some other riparian vegetation, often with a scattered overstory of cottonwood (*Populus* spp.; NMDGF 2006). The flycatcher breeds in riparian habitats—along rivers, streams, and wetlands. Although occurring widely in New Mexico during migration, willow flycatchers are confined to riparian woodlands in the breeding season (NMDGF 2005). There is a small wetland/riparian area in the upper portion of Mortandad Canyon that is capable of supporting flycatcher nests and foraging needs (Keller 2004). The wetland is small and the riparian habitat is of moderate quality. Its total area occupies only 57 grid cells. Habitat in the watershed was assigned either a 1 or 10 to represent relative suitability

of occurrence. This means that the likelihood that the wetland habitat in Mortandad Canyon could support flycatchers is 10 times greater than that of the remainder of the watershed.

Table 1A. Relative Importance Values and Weighting of Land Cover Types for the Deer Mouse in the Mortandad Canyon Watershed

Land Type	Average Density (No./ha)	Relative Density (Weight)	Assigned Map Code Integer/ Grid Values	No. Grid Cells in Study Area	No. Grid Cells With Sample Value Data
Wetlands/Riparian/Water	3.4	1.0	100	0	0
Piñon-Juniper-Mesas	4.0	1.17	120	2,463*	27*
Piñon-Juniper-Canyon	6.0	1.76	180	6,990**	705**
Bare Ground Areas	4.0	2.64	120	2,463*	27*
Deciduous/Aspen (*Populus* spp.)/Oak (*Quercus* spp.)	6.0	1.76	180	6,990**	705**
Ponderosa Pine Canyons	6.0	1.76	180	6,990**	705**
Ponderosa Pine Mesa	42.0	12.35	1240	966	65
Grasslands	9.0	2.64	260	2,020***	110***
Juniper Woodlands	9.0	2.64	260	2,020***	110***
Mixed Conifer	11.0	3.26	320	231	69
Disturbed Areas	16.0	4.7	470	856	123

*Split among the two land cover types with this grid value.
**Distributed among the three land cover types with this grid value.
***Split among the two land cover types with this grid value.

Table 1B. Relative Importance Values and Weighting of Land Cover Types for the Mexican Spotted Owl in the Mortandad Canyon Watershed

Land Type	Absolute Preference	Relative Preference (Weighting)	Assigned Map Code Integer Values	No. Grid Cells in Study Area	No. Grid Cells With Sample Value Data
Outside Core and Buffer, Within Study Area	1.0	1.0	1	10,230	513
Buffer Zone	10.0	10.0	10	1,415	249
Core Area	100.0	100.0	100	1,881	337
Outside Watershed	0.0	0.0	0	0	0

Table 1C. Relative Importance Values and Weighting of Land Cover Types for the Western Bluebird in the Mortandad Canyon Watershed

Land Type	Absolute Abundance	Relative Abundance (Weighting)	Assigned Map Code Integer Values	No. Grid Cells in Study Area	No. Grid Cells With Sample Value Data
Burned	0.03	1.0	3	32*	0
Open Water	0.00	0.0	0	0	0
Urban-Sparse-Bare Rock	0.09	3.0	9	790	189
Grass Species	0.06	2.0	6	306	6
Shrub Species	0.18	6.0	18	433	48
Piñon-Juniper	0.33	11.0	33	10,950	760
Mixed Conifer/Spruce (*Picea* spp.)-Fir (*Abies* spp.)	0.00	0.0	0	1	1
Aspen/Riparian/Wetland	0.03	1.0	3	32*	0

*Split among the two land cover types with this grid value.

Table 1D. Relative Importance Values and Weighting of Land Cover Types for the Southwestern Willow Flycatcher in the Mortandad Canyon Watershed

Land Type	Absolute Preference	Relative Preference (Weighting)	Assigned Map Code Integer Values	No. Grid Cells in Study Area	No. Grid Cells With Sample Value Data
Mortandad Watershed Outside Wetlands	1.0	1.0	1	13,469	1082
Wetlands	10.0	10.0	10	57	17
Outside Watershed	0.0	0.0	0	0	0

THE EPAQM

The EPAQM, or some variation of it, has been frequently applied in the past decade in screening level and more sophisticated ecological risk assessments. The HQ is a ratio between exposure and an effect level (as represented by a toxicity reference value [TRV]), which can be used as a potential indicator of effects. The HI is defined as the sum of HQ values for all COPECs. If the HQ or HI is greater than 1.0, then this is an indication of the potential for adverse ecological effects.

The following equations are simplified versions of how the HQ and HI are calculated, and are discussed in the Ecological Risk Assessment Guidance for Superfund (USEPA 1997):

$$HQ_{ij} = \frac{exposure\ level}{effect\ level\ (or TRV)} \quad \text{and} \quad HI_i = \sum_{j=1}^{n} HQ_{ij} \ ,$$

where

HQ_{ij} = hazard quotient for receptor i to COPEC j (unitless),

exposure level = exposure dose received by the animal receptor (units are mg of COPEC per kg body weight of the exposed animal per day or mg/kg/day),

effect level = effect level (represented by TRV) for exposure to COPEC j for receptor i (mg/kg/day),
and HI_i = hazard index for receptor i for n (all) COPECs (unitless).

The mean total HI is the arithmetic average of HIs for a specified total number of nest sites for a receptor—totaled across all COPECs. When the HQ for all COPECs is summed, the assumption is that they elicit similar effects. Although this also assumes that there are no synergistic effects, the summation of HQs likely errs to the side of overestimating effects. The more detailed calculation of HIs is discussed below.

Although HQs for all classes of COPECs (radionuclides, nonradionuclide metals, and organic chemicals) are summed into one HI, we discuss their derivation separately.

For nonradionuclides,

$$HI = Food \times (Soilf + BCF) / Bodwt \times \sum_{j=1}^{ncs} Occup_j \sum_{l=1}^{ncoc} Dc_{j,l} / TRV_l \ ,$$

where

HI = hazard index (cumulative HQ for all COPECs),
Food = amount of food consumed by a given animal, kg/day,
Soilf = fraction of diet comprised of soil,
BCF = bioconcentration factor (transfer factors from Ecorisk Database R2.2, LANL 2005b), where the BCF is used in a manner that soil-to-receptor and food chain transfer of COPECs are included in the HI calculation;
$Occup_j$ = occupancy factor on the jth contamination site,
$Dc_{j,l}$ = concentration of COPEC in soil (mg COPEC/kg soil) for the jth contamination site (exposure dose) of the lth COPEC,
TRV_l = consumed dose above which observable adverse effects may occur, mg-COPEC/kg-body weight-day of the lth COPEC,
ncs = number of contaminated sites, and
ncoc = number of COPECs in the jth contamination site.

For radionuclides, effects levels (TRVs) have been back-calculated to concentrations in soil (ecological screening levels [ESLs], defined below) so the derivation of HIs for radionuclides is simplified as

$$HI = \sum_{j=1}^{ncs} Occup_j \sum_{l=1}^{ncoc} SC_{j,l} / (ESL_l \times ESL_{a_l}) \ ,$$

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 lth COPEC,
ESL_l = ecological screening level, pCi COPEC/kg soil of the lth COPEC,
$ESLa_l$ = adjustment factor for ESL_l above for the lth COPEC,
$Occup_j$ = occupancy factor on the jth contamination site,
ncs = number of contamination sites, and
ncoc = number of COPECs in the jth contamination site.

The derivation of ESLs is described in a LANL report titled Screening Level Ecological Risk Assessment (SLERA) Methods (LANL 2004), and ESLs were taken from LANL's Ecorisk Database 2.2 (LANL 2005b).

A cumulative HQ across all COPECs, or HI, assumes that sublethal doses of various COPECs are additive in their effect, rather than synergistic, antagonistic, or independent. Although HQs for all classes of COPECs (radionuclides, nonradionuclide metals, and organic chemicals) are summed into an HI, the output files are such that HQs can be easily separated on any basis, such as radionuclides from nonradionuclides, and then summed into HIs by class of COPEC.

Approach

The ECORSK model was designed to contribute to or comprise a Tier 2 level of assessment, which generally is more realistic than screening assessments. For example, arithmetic mean COPEC sample values and background concentrations were used rather than maximum values or upper tolerance limits. When available, geometric mean (GMM) values were used rather than minimum TRVs. Actual animal distribution data were used and their natural HR tendencies were simulated, at least within the confines of the watershed study area or EEU, rather than assuming that their distribution is restricted to a contaminated area such as a SWMU or AOC.

Risk Sources

ECORSK.9 computes HIs and HQs for potential effects associated with three source types: unadjusted, background, and adjusted.

Unadjusted. This source type is a quantified total HI/HQ associated with anthropogenic and background levels of COPECs. Mathematically, unadjusted HIs are the sum of the contribution from "background" and "Lab-added" sources. Sample values are read into the model through the major input file *eeuinp.dat*. In un-sampled grid cells in canyon bottoms, concentrations were interpolated (predicted) from the nearest measured values; elsewhere, mean background concentrations were entered. When a sample value is less than the mean background concentration, the sample value is entered. The source of background concentrations was a report by Ryti et al. (1998). Background data exist for most inorganic chemicals and radionuclides, but not for organic chemicals. The unadjusted mean total HI is the arithmetic average of HIs for a specified total number of nest sites or focal points established by the model operator for each receptor. As mentioned previously, the HI for a given nest site is the sum of HQs for all COPECs within the HR of an animal.

Background. This source type is a quantified HI associated with "natural" (nonradionuclides) and "regional" (radionuclides) non-Laboratory sources of COPECs. The mean natural or regional background soil or sediment concentration is entered into the HQ formula. Natural is distinguished from regional because radionuclide background values exist from sources other than LANL (e.g., atmospheric fallout).

Adjusted. This source type is a quantified HI/HQ for potential effects associated with "Lab-added" concentrations of COPECs. Although regional sampling has shown that there are measurable concentrations of organic COPECs upslope and upwind of LANL, on a practical level we did not use a background value for organic COPECs, therefore, while all of the modeled

effects associated with organics is ascribed to LANL sources, in reality some of it is from non-LANL sources.

Thus, mathematically,

Unadjusted HIs/HQs = Lab-added + background contributions,

and

Adjusted HIs/HQs ("Lab-added") = total – background contributions.

Detailed Model Output. Several different output files are generated by ECORSK, varying in the degree of summarization or breakout that is represented by a value. The mean total HI, a single value representing the mean of HIs for all nests or focal points and summed for all COPECs, is the most summarized value and is generated for each execution of ECORSK. For example, if 1,000 nest sites were selected for a given model execution (or run), then a single value, the grand mean total HI (in *outrsk.dat*), would be the mean of 1,000 HIs. Mean HIs can be used as a general indication of potential population-level effects for species not threatened or endangered and can indicate the level of effort that might be required to investigate area-specific and other more specific potential effects. The model also provides HI and HQ data on specific nest sites or focal points, useful for evaluating potential effects to individual threatened or endangered species that occupy specific nest sites or focal points. The distribution of HIs is outputted in *hq.dat* and in sorted order in *sorthq.dat*.

HIs assume that all classes of COPECs—organic, metal, and radiological—have common toxicological effects; however, detailed model breakouts by COPEC enable the user to sum HIs and HQs by any particular grouping of COPEC. The HI for one nest site (in a total of, say, 1,000) would result from the sum of the HQs for each COPEC for each grid cell in the HR. The 1,000 sets of HQs (summed within a HR) by COPEC are output in *hqp.dat*. Thus far we have discussed "sink" values that are derived from break-out or "source" values. The ECORSK output in its rawest (most broken down) form consists of "source" values—values that contribute toward the "roll-up" values; i.e., source values consist of an HQ for each COPEC of each grid cell within an HR that was summed to result in an *hqp.dat* value; e.g., if a HR consisted of 3,500 grid cells for a given species and all 3,500 cells had a sample value for, say Aroclor-1254, and 1,000 nest sites were specified and every grid cell surrounding every nest site had a sample value for Aroclor-1254, then ECORSK would output into *HQPC.DAT* 1,000 sets of 3,500 partial HQs for Aroclor-1254 alone, or 3,500,000 total source HQs for each execution of ECORSK. Thus, the raw output can get quite lengthy. The mathematical representations of these outputs have been documented in detail in a report by Gallegos and Gonzales (1999).

Contaminant Data

The Mortandad Canyon work plan summarizes contaminant source and transport information for Mortandad Canyon, the extent of contamination that was known to the time of work plan development, and soil/sediment sampling that was planned for 2005. Soil COPEC data sources for the application of ECORSK.9 to Mortandad Canyon included measured soil concentrations and interpolated soil concentrations. Sources of measured data included (1) LANL canyons data and (2) the RACER (Risk Analysis, Communication, Evaluation, and Reduction) database (RAC 2005). We note that we used the RACER database "as is" for the purposes of this report because it was not feasible to carefully track the pedigree and accuracy of the sample results in this database (it contains millions of records). Interpolated data, described

below, consisted of estimated COPEC concentrations for channel and floodplain areas in canyon bottoms that have not been sampled but include areas of fluvial sediment deposits between sampled investigation reaches (e.g., Reneau et al. 2003). So, there were three data sources, or "sets," that served as input to ECORSK.9—(1) the canyons measured data set, (2) canyons interpolated data, and (3) a RACER data set. If, for a given grid cell, there existed multiple data sources, then a value was selected from the data sources in the order that they are presented above for evaluation in the ECORSK.9 model runs.

Non-Detect Replacement Values. Replacement of non-detects (NDs) with the detection limit or some proportion of the detection limit is a commonly used technique and whether or not this method is practiced and the value used should depend on the particular objectives of an assessment (Gilbert 1987). Use of one-half the detection limit (½DL) value is less conservative than using the detection limit and more conservative than using "0". Some measure of effect of using replacement values should be evaluated when interpreting results of an assessment. Many of the sample results in both the canyons database and the RACER data set were qualified as "not detected." A ND can be interpreted as a sample result for which the true COPEC concentration is somewhere between zero and the detection limit. In both cases, radionuclide sample results were not censored and negative values were accepted, thus the measured canyons COPEC data included all reported radionuclide results.

As a simple sensitivity analysis, two scenarios were developed and executed in ECORSK.9 to assess the impact on model results of how ND results were treated:

- Scenario A: ND results for non-radiological COPECs were assigned ½DL, which is somewhat of a conventional practice for environmental data analysis; and
- Scenario B (canyons and interpolated data only): For the three avian receptors, only inorganic non-radiological chemical NDs were replaced with the ½DL; organic chemical NDs were replaced with a zero ('0'). Replacement of NDs occurred before calculating cell or reach average concentrations. Data types and sources of data are described below.

Measured Canyons Contaminant Data. The canyons COPEC database was obtained from the Environmental Restoration Database (ERDB). Some of these data are reported in the work plan for Mortandad Canyon biota investigation (LANL 2005a) and other documents (e.g., Reneau et al. 2003). These data will also be reported in the Mortandad Canyon Investigation Report. COPECs identified in the work plan and that have a TRV for the receptor are evaluated using ECORSK.9. There are 35 COPECs for the three avian receptors and 46 COPECs for the deer mouse. A list of the COPECs can be found in the work plan.

Interpolation of Measured Contaminant Data. Based on our understanding of COPEC dispersion during floods, we interpolated COPEC concentrations in canyon inter-reaches at grid cell locations that are usually down-slope from a measured concentration. Interpolated values were derived from all measured concentration data (both detected and ND). The interpolations were based on reach averages of measured canyons sediment samples and trends were evaluated with distance along the watershed measured to the Rio Grande. Prior reports, especially the Los Alamos and Pueblo Canyons Investigation Report (LANL 2004), show that there are general spatial trends in the sediment data. For a single source and downgradient attenuation of a marker substance in canyon sediments, one useful interpolation model is $\log(concentration) = \alpha + \beta \cdot x$, where x is distance from the source and α and β are estimated from the measured data. We also

evaluated a simple linear regression of concentration versus distance. The model with the larger coefficient of determination (r^2) was selected to interpolate the inter-reach concentrations. If there were no significant concentrations trends then the average concentration in the watershed was used as the estimate of the analyte concentration in non-measured canyon-bottom grid cells. For Mortandad Canyon we substituted distance (kilometers) from the Rio Grande measured along the active channel. One factor affecting analyte concentrations is the input of sediments from an adjacent subwatershed, such as when Effluent and Ten Site canyons empty into Mortandad Canyon. If the tributary canyon has low concentrations of the analyte, then concentrations can sharply decrease at the confluence. Concentrations can also sharply increase if higher concentrations exist in the tributary compared to the main canyon drainage. The trend plots were inspected for such discontinuities, and information on nature and sources of contamination from the prior reports were also instructive in establishing interpolation models with a sound basis.

Sediment texture is another factor affecting concentrations of analytes. However, for these interpolations, variations in concentration based on texture were not evaluated. Instead it was assumed that texture does not vary sufficiently across the watershed for texture to make a significant difference in the exposure concentrations for wildlife receptors or wildlife populations. We evaluated reach averages for spatial trends as reaches represent the most ecologically relevant spatial scale for wildlife receptors and populations.

Summary of COPEC Data

This section describes the model input data used for model executions.

EEUINP.DAT Summary Data. Tables 2A (birds) and 2B (deer mouse) contain the summary statistics for the environmental data along with the TRVs and bioconcentration factors (BCFs) used to create the major input file (*eeuinp.dat*) to ECORSK.9. Tables 2A-1 and 2A-2 differentiate Scenarios A and B, respectively. The COPEC sample value summary statistics (average, maximum, minimum) as well as a corresponding background value are listed for each analyte. The table also contains the TRV and weighted BCFs associated with a particular COPEC for each of the four screening receptors (birds—western bluebird, Mexican spotted owl, and southwestern willow flycatcher; mammals—deer mouse). The term TRV is used generically and can refer to a level of a COPEC in food such as a NOAEL (in units of mg/kg/d) or a level in soil such as an ESL (in units of pCi/g). TRVs were adopted from LANL's Ecorisk Database Release 2.2 (LANL 2005b) and the tiered TRV development process is discussed in LANL's SLERA Methods document for the Environmental Restoration Project (LANL 2004).

Nonradionuclide TRVs. All the nonradionuclide TRVs are from the LANL Ecorisk Database Release 2.2 (LANL 2005b) and were developed using a tiered TRV development process implemented in 2003. Descriptions of TRV selection criteria can be found in the SLERA Methods document (LANL 2004). Full documentation of the derivation of each TRV can be found in the Ecorisk Database (LANL 2005b).

Radionuclide TRVs. The TRVs for radionuclides are ESLs. ESLs for the deer mouse are taken directly from the Ecorisk Database Release 2.2 (LANL 2005b). ESLs for the bluebird, owl, and flycatcher were calculated using ESL models for their feeding guilds that are available in the Ecorisk Database. The ESL for the bluebird is based on the American robin (omnivore) model, the ESL for the owl is based on the American kestrel (*Falco peregrinus*) model (carnivore/

Table 2A-1. Summary of Data Input to ECORSK.9 for the Three Avian Receptors, Scenario A

						Western Bluebird			Mexican Spotted Owl			Southwestern Willow Fylcatcher		
Analyte Group	Analyte Name	Average Sample Value[a]	Maximum Sample Value[a]	Minimum Sample Value[a]	Background Sediment Mean[a]	TRV[b]		BCF[c]	TRV[b]		BCF[c]	TRV[b]		BCF[c]
INORG	Arsenic	2.28E+00	1.75E+02	1.75E-01	1.84E+00	2.24E+00	h	2.17E-01	2.24E+00	h	2.17E-01	2.24E+00	h	2.17E-01
INORG	Barium	9.34E+01	9.97E+03	4.95E+00	6.04E+01	7.35E+01	d	9.69E-02	7.35E+01	d	9.69E-02	7.35E+01	d	9.69E-02
INORG	Beryllium	9.13E-01	1.47E+02	2.00E-02	5.90E-01		n	4.15E-02		n	4.15E-02		n	4.15E-02
INORG	Boron	1.57E+01	2.53E+01	6.00E-01	0.00E+00	2.92E+00	d	1.30E+00	2.92E+00	d	1.30E+00	2.92E+00	d	1.30E+00
INORG	Cadmium	5.42E-01	1.45E+02	5.00E-03	9.30E-02	1.47E+00	i	1.29E+01	1.47E+00	i	1.29E+01	1.47E+00	i	1.29E+01
INORG	Chromium (total)	1.29E+01	1.22E+03	8.50E-02	5.62E+00	7.70E+01	e	1.45E-01	7.70E+01	e	1.45E-01	7.70E+01	e	1.45E-01
INORG	Cobalt	2.43E+00	2.32E+01	2.00E-01	2.35E+00	7.61E+00	i	1.12E-01	7.61E+00	i	1.12E-01	7.61E+00	i	1.12E-01
INORG	Copper	1.03E+02	4.28E+04	2.10E-01	4.57E+00	2.98E+00	d	5.93E-01	2.98E+00	d	5.93E-01	2.98E+00	d	5.93E-01
INORG	Cyanide (total)	4.71E-01	6.63E+01	4.20E-02	2.95E-01	4.00E-02	g	1.00E+00	4.00E-02	g	1.00E+00	4.00E-02	g	1.00E+00
INORG	Fluoride	2.65E+00	7.06E+01	1.26E-02	0.00E+00	1.22E+01	e	9.06E-01	1.22E+01	e	9.06E-01	1.22E+01	e	9.06E-01
INORG	Lead	1.12E+02	4.42E+04	2.00E+00	9.25E+00	1.63E+00	h	2.14E-01	1.63E+00	h	2.14E-01	1.63E+00	h	2.14E-01
INORG	Manganese	2.72E+02	3.75E+03	3.49E+01	2.90E+02	5.81E+02	e	7.95E-02	5.81E+02	e	7.95E-02	5.81E+02	e	7.95E-02
INORG	Mercury (inorganic)	6.29E-01	5.39E+01	9.33E-04	1.20E-02	1.90E-02	e	3.61E+00	1.90E-02	e	3.61E+00	1.90E-02	e	3.61E+00
INORG	Nickel	6.59E+00	4.36E+02	5.93E-01	4.98E+00	2.19E+01	d	7.01E-01	2.19E+01	d	7.01E-01	2.19E+01	d	7.01E-01
INORG	Perchlorate Ion	9.78E-02	9.59E-01	1.00E-03	0.00E+00		n	n		n	n		n	n
INORG	Selenium	5.55E-01	3.05E+01	3.59E-02	1.00E-01	4.40E-01	f	9.61E-01	4.40E-01	f	9.61E-01	4.40E-01	f	9.61E-01
INORG	Silver	2.52E+00	3.84E+02	1.47E-02	6.60E-02	5.44E+00	e	1.88E+00	5.44E+00	e	1.88E+00	5.44E+00	e	1.88E+00
INORG	Thallium	4.57E-01	3.05E+01	2.00E-06	7.30E-01	3.50E-01	j	9.00E-01	3.50E-01	j	9.00E-01	3.50E-01	j	9.00E-01
INORG	Vnadium	1.07E+01	5.48E+01	8.90E-01	1.04E+01	3.44E-01	h	3.84E-02	3.44E-01	h	3.84E-02	3.44E-01	h	3.84E-02
INORG	Zinc	6.05E+01	8.04E+03	6.85E+00	3.39E+01	3.77E+01	d	3.45E+00	3.77E+01	d	3.45E+00	3.77E+01	d	3.45E+00
ORG	Acenaphthene	4.45E-01	1.43E+01	9.00E-05	0.00E+00		n	2.51E+00		n	2.51E+00		n	2.51E+00
ORG	Aroclor-1254	1.01E-01	1.16E+01	1.00E-03	0.00E+00	1.00E-01	e	6.13E+00	1.00E-01	e	6.13E+00	1.00E-01	e	6.13E+00
ORG	Aroclor-1260	5.57E-01	2.07E+01	1.00E-03	0.00E+00	2.15E+00	d	6.12E+00	2.15E+00	d	6.12E+00	2.15E+00	d	6.12E+00
ORG	Benzo(a)anthracene	8.34E-01	7.28E+01	9.00E-05	0.00E+00		n	1.90E-01		n	1.90E-01		n	1.90E-01
ORG	Benzo(a)pyrene	8.12E-01	7.58E+01	9.00E-05	0.00E+00		n	3.98E-01		n	3.98E-01		n	3.98E-01
ORG	Benzo(b)fluoranthene	9.41E-01	8.71E+01	9.00E-05	0.00E+00		n	4.09E-01		n	4.09E-01		n	4.09E-01
ORG	Benzo(g,h,i)perylene	6.27E-01	3.91E+01	9.00E-05	0.00E+00		n	1.25E+00		n	1.25E+00		n	1.25E+00
ORG	BHC[gamma-]	1.26E-01	8.70E+00	3.35E-04	0.00E+00	5.60E-01	f	6.75E+00	5.60E-01	f	6.75E+00	5.60E-01	f	6.75E+00
ORG	Bis(2-ethylhexyl) phthalate	8.08E-01	1.60E+02	9.00E-05	0.00E+00	1.10E+00	f	1.39E+02	1.10E+00	f	1.39E+02	1.10E+00	f	1.39E+02
ORG	Chrysene	8.96E-01	7.93E+01	9.00E-05	0.00E+00		n	2.43E-01		n	2.43E-01		n	2.43E-01
ORG	DDT[4,4'-]	1.29E-01	8.70E+00	6.50E-04	0.00E+00	1.68E+00	d	1.40E+01	1.68E+00	d	1.40E+01	1.68E+00	d	1.40E+01

Table 2A-1. (cont.)

						Western Bluebird			Mexican Spotted Owl			Southwestern Willow Fylcatcher		
Analyte Group	Analyte Name	Average Sample Value[a]	Maximum Sample Value[a]	Minimum Sample Value[a]	Background Sediment Mean[a]	TRV[b]		BCF[c]	TRV[b]		BCF[c]	TRV[b]		BCF[c]
ORG	Di-n-Butyl Phthalate	5.55E-01	1.65E+01	9.00E-05	0.00E+00	1.40E-01	e	3.21E+01	1.40E-01	e	3.21E+01	1.40E-01	e	3.21E+01
ORG	Endrin	1.43E-01	1.65E+01	1.65E-04	0.00E+00	1.00E-02	f, o	1.76E+01	1.00E-02	f, o	1.76E+01	1.00E-02	fo	1.76E+01
ORG	Fluoranthene	1.59E+00	1.57E+02	9.00E-05	0.00E+00		n	2.50E+00		n	2.50E+00		n	2.50E+00
ORG	Fluorene	4.69E-01	1.65E+01	9.00E-05	0.00E+00		n	2.29E+00		n	2.29E+00		n	2.29E+00
ORG	Naphthalene	4.56E-01	1.65E+01	9.00E-05	0.00E+00	1.60E+02	d	3.49E+00	1.60E+02	n	3.49E+00	1.60E+02	d	3.49E+00
ORG	Phenanthrene	1.29E+00	9.27E+01	9.00E-05	0.00E+00		n	2.15E+00		n	2.15E+00		n	2.15E+00
ORG	Pyrene	1.47E+00	1.34E+02	9.00E-05	0.00E+00		n	1.51E+00		n	1.51E+00		n	1.51E+00
RAD	Americium-241	3.32E+00	1.42E+02	-7.10E-01	2.60E-02	2.50E+04	k	p	2.50E+04	l	p	2.50E+04	m	p
RAD	Cesium-137 + Barium-137	1.07E+01	3.94E+02	-9.00E-02	2.11E-01	4.70E+03	k	p	4.70E+03	l	p	4.70E+03	m	p
RAD	Plutonium-238	1.58E+00	8.56E+01	-1.70E-01	1.90E-03	1.90E+04	k	p	1.90E+04	l	p	1.90E+04	m	p
RAD	Plutonium-239, 240	3.17E+00	1.33E+02	-2.45E-01	2.50E-02	2.00E+04	k	p	2.00E+04	l	p	2.00E+04	m	p
RAD	Strontium-90 + Yittrium-90	4.82E+00	4.41E+02	-5.19E+00	2.29E-01	3.00E+03	k	p	3.00E+03	l	p	3.00E+03	m	p
RAD	Thorium-228	9.88E-01	4.51E+00	-1.00E-02	1.44E+00	1.60E+03	k	p	1.60E+03	l	p	1.60E+03	m	p
RAD	Thorium-230	8.50E-01	7.68E+00	9.20E-03	1.37E+00	2.10E+04	k	p	2.10E+04	l	p	2.10E+04	m	p
RAD	Thorium-232	1.21E+00	3.65E+00	4.70E-03	1.43E+00	2.70E+03	k	p	2.70E+03	l	p	2.70E+03	m	p
RAD	Uranium-234	7.23E+00	1.65E+03	0.00E+00	1.40E+00	8.40E+04	k	p	8.40E+04	l	p	8.40E+04	m	p

INORG = inorganic chemical; ORG = organic chemical; RAD = radionuclide

[a]Units for INORG and ORG values are mg/kg soil while units for RAD values are pCi/g soil

[b]Units for INORG and ORG TRVs are mg COPEC/kg body wt of receptor/day; i.e., "mg/kg/d." Units for RAD TRVs are pCi/g soil

[c]Units for INORG and ORG BCFs are mg analyte/kg dry food per mg analyte/kg dry soil. Units for RAD BCFs are pCi analyte/g fresh food per pCi analyte/g dry soil

[d]LANL-derived GMM TRV

[e]LANL-derived critical study (CS) TRV

[f]Oak Ridge National Laboratory TRV

[g]LANL threatened and endangered species TRV

[h]EPA EcoSSL CS TRV

[i]EPA EcoSSL GMM TRV

[j]EPA Region VI screening value TRV

[k]LANL ESL model for diet of soil invertebrates

[l]LANL ESL model for diet of flesh and soil invertebrates

[m]LANL ESL model for diet of sediment invertebrates

[n]Not available

[o]Toxicity data for endrin aldehyde is used as surrogate toxicty data for endrin

[p]Not applicable

Table 2A-2. Summary of Data Input to ECORSK.9 for the Avian Receptors, Scenario B*

Analyte Group	ANALYTE	Avg of Sample Value	Max of Sample Value	Min of Sample Value	Background Sediment Mean	Count of Sample Value
INORG	Arsenic	2.36E+00	1.75E+02	1.75E-01	1.84E+00	1,259
INORG	Barium	9.88E+01	9.97E+03	4.95E+00	6.04E+01	1,383
INORG	Beryllium	8.22E-01	1.47E+02	2.00E-02	5.90E-01	1,288
INORG	Boron	1.64E+01	2.53E+01	6.00E-01	0.00E+00	425
INORG	Cadmium	4.91E-01	1.45E+02	5.00E-03	9.30E-02	1,272
INORG	Chromium (total)	1.44E+01	1.22E+03	8.50E-02	5.62E+00	1,268
INORG	Cobalt	2.49E+00	2.32E+01	2.00E-01	2.35E+00	1,177
INORG	Copper	8.46E+01	4.28E+04	2.10E-01	4.57E+00	1,178
INORG	Cyanide (total)	3.81E-01	6.63E+01	4.20E-02	2.95E-01	559
INORG	Fluoride	2.67E+00	7.06E+01	1.26E-02	0.00E+00	398
INORG	Lead	7.49E+01	4.42E+04	2.00E+00	9.25E+00	1,281
INORG	Manganese	2.87E+02	3.75E+03	3.49E+01	2.90E+02	1,175
INORG	Mercury (inorganic)	2.14E-01	5.39E+01	9.33E-04	1.20E-02	1,209
INORG	Nickel	5.89E+00	4.36E+02	5.93E-01	4.98E+00	1,269
INORG	Perchlorate Ion	7.32E-02	9.59E-01	1.00E-03	0.00E+00	335
INORG	Selenium	5.18E-01	3.05E+01	3.59E-02	1.00E-01	1,269
INORG	Silver	1.58E+00	3.84E+02	1.47E-02	6.60E-02	1,278
INORG	Thallium	3.78E-01	3.05E+01	2.00E-06	7.30E-01	1,267
INORG	Vanadium	1.09E+01	5.48E+01	8.90E-01	1.04E+01	1,176
INORG	Zinc	5.58E+01	8.04E+03	6.85E+00	3.39E+01	1,301
ORG	Acenaphthene	1.56E-01	1.42E+01	0.00E+00	0.00E+00	1,147
ORG	Aroclor-1254	3.99E-02	1.16E+01	0.00E+00	0.00E+00	747
ORG	Aroclor-1260	7.91E-02	2.07E+01	0.00E+00	0.00E+00	748
ORG	Benzo(a)anthracene	3.76E-01	7.28E+01	0.00E+00	0.00E+00	964
ORG	Benzo(a)pyrene	3.69E-01	7.58E+01	0.00E+00	0.00E+00	964
ORG	Benzo(b)fluoranthene	4.56E-01	8.70E+01	0.00E+00	0.00E+00	964
ORG	Benzo(g,h,i)perylene	2.56E-01	3.91E+01	0.00E+00	0.00E+00	964
ORG	BHC[gamma-]	6.89E-02	8.54E+00	0.00E+00	0.00E+00	771
ORG	Bis(2-ethylhexyl) phthalate	2.45E-01	1.60E+02	0.00E+00	0.00E+00	1,297
ORG	Chrysene	4.37E-01	7.93E+01	0.00E+00	0.00E+00	964
ORG	DDT[4,4'-]	8.21E-02	8.54E+00	0.00E+00	0.00E+00	658
ORG	Di-n-Butyl Phthalate	1.37E-01	1.65E+01	0.00E+00	0.00E+00	955
ORG	Endrin	9.36E-02	1.65E+01	0.00E+00	0.00E+00	655
ORG	Fluoranthene	8.04E-01	1.57E+02	0.00E+00	0.00E+00	964
ORG	Fluorene	1.60E-01	1.65E+01	0.00E+00	0.00E+00	964
ORG	Naphthalene	1.27E-01	1.65E+01	0.00E+00	0.00E+00	971
ORG	Phenanthrene	5.91E-01	9.27E+01	0.00E+00	0.00E+00	964
ORG	Pyrene	7.39E-01	1.34E+02	0.00E+00	0.00E+00	964
RAD	Americium-241	2.56E+00	1.42E+02	-8.25E+00	2.60E-02	1,295
RAD	Cesium-137 + Barium-137	7.51E+00	3.94E+02	-8.12E+01	2.11E-01	1,309
RAD	Plutonium-238	1.05E+00	8.56E+01	-1.70E-01	1.90E-03	1,303
RAD	Plutonium-239, 240	2.40E+00	1.33E+02	-1.11E+01	2.50E-02	1,302
RAD	Strontium-90+Yittrium-90	1.72E+00	4.41E+02	-5.19E+00	2.29E-01	1,080
RAD	Thorium-228	9.57E-01	4.51E+00	-1.00E-02	1.44E+00	956
RAD	Thorium-230	8.21E-01	7.68E+00	9.20E-03	1.37E+00	956
RAD	Thorium-232	1.10E+00	3.65E+00	4.70E-03	1.43E+00	956
RAD	Uranium-234	3.83E+00	1.65E+03	0.00E+00	1.40E+00	1,314

*Values of organics changed from those listed in Table 2A-1 because of the new treatment of NDs. Values of inorganics decreased slightly because of a minor correction in study area boundary that reduced the count slightly. TRVs and BCFs are the same as in Table 2A-1.

Table 2B. Summary of Data Input to ECORSK.9 for the Mammal (Deer Mouse) Receptor

						Deer Mouse		
Analyte Group	Analyte Name	Average Sample Value[a]	Maximum Sample Value[a]	Minimum Sample Value[a]	Background Sediment Mean[a]	TRV[b]		BCF[c]
INORG	Arsenic	2.28E+00	1.75E+02	1.75E-01	1.84E+00	1.04E+00	h	1.42E-01
INORG	Barium	9.34E+01	9.97E+03	4.95E+00	6.04E+01	5.18E+01	i	1.21E-01
INORG	Beryllium	9.13E-01	1.47E+02	2.00E-02	5.90E-01	5.32E-01	h	2.75E-02
INORG	Boron	1.57E+01	2.53E+01	6.00E-01	0.00E+00	2.80E+01	e	2.50E+00
INORG	Cadmium	5.42E-01	1.45E+02	5.00E-03	9.30E-02	7.70E-01	h	7.55E+00
INORG	Chromium (total)	1.29E+01	1.22E+03	8.50E-02	5.62E+00	3.96E+01	k	8.41E-02
INORG	Cobalt	2.43E+00	2.32E+01	2.00E-01	2.35E+00	7.33E+00	i	7.10E-02
INORG	Copper	1.03E+02	4.28E+04	2.10E-01	4.57E+00	5.13E+00	e	4.18E-01
INORG	Cyanide (total)	4.71E-01	6.63E+01	4.20E-02	2.95E-01	6.87E+01	f	1.00E+00
INORG	Fluoride	2.65E+00	7.06E+01	1.26E-02	0.00E+00	2.66E+01	e	5.30E-01
INORG	Lead	1.12E+02	4.42E+04	2.00E+00	9.25E+00	4.70E+00	h	1.71E-01
INORG	Manganese	2.72E+02	3.75E+03	3.49E+01	2.90E+02	4.40E+01	e	1.55E-01
INORG	Mercury (inorganic)	6.29E-01	5.39E+01	9.33E-04	1.20E-02	1.41E+00	e	2.30E+00
INORG	Nickel	6.59E+00	4.36E+02	5.93E-01	4.98E+00	4.39E+01	d	3.96E-01
INORG	Perchlorate Ion	9.78E-02	9.59E-01	1.00E-03	0.00E+00		m	o
INORG	Selenium	5.55E-01	3.05E+01	3.59E-02	1.00E-01	2.00E-01	f	8.45E-01
INORG	Silver	2.52E+00	3.84E+02	1.47E-02	6.60E-02	1.90E+01	e	1.22E+00
INORG	Thallium	4.57E-01	3.05E+01	2.00E-06	7.30E-01	7.10E-03	e	5.02E-01
INORG	Vanadium	1.07E+01	5.48E+01	8.90E-01	1.04E+01	4.16E+00	h	2.38E-02
INORG	Zinc	6.05E+01	8.04E+03	6.85E+00	3.39E+01	1.26E+02	e	2.11E+00
ORG	Acenaphthene	4.45E-01	1.43E+01	9.00E-05	0.00E+00	7.00E+01	g	2.09E+00
ORG	Aroclor-1254	1.01E-01	1.16E+01	1.00E-03	0.00E+00	6.11E-01	d	3.45E+00
ORG	Aroclor-1260	5.57E-01	2.07E+01	1.00E-03	0.00E+00	1.38E+01	d	3.41E+00
ORG	Benzo(a)anthracene	8.34E-01	7.28E+01	9.00E-05	0.00E+00	1.70E-01	g	2.29E-01
ORG	Benzo(a)pyrene	8.12E-01	7.58E+01	9.00E-05	0.00E+00	1.00E+00	f	3.09E-01
ORG	Benzo(b)fluoranthene	9.41E-01	8.71E+01	9.00E-05	0.00E+00	4.00E+00	g	3.65E-01
ORG	Benzo(g,h,i)perylene	6.27E-01	3.91E+01	9.00E-05	0.00E+00	7.20E+00	g	7.47E-01
ORG	BHC[gamma-]	1.26E-01	8.70E+00	3.35E-04	0.00E+00	1.40E-02	f	4.31E+00
ORG	BEHP	8.08E-01	1.60E+02	9.00E-05	0.00E+00	1.83E+01	f	7.70E+01
ORG	Chrysene	8.96E-01	7.93E+01	9.00E-05	0.00E+00	1.70E-01	g	2.53E-01
ORG	DDT[4,4'-]	1.29E-01	8.70E+00	6.50E-04	0.00E+00	1.07E+00	d	7.85E+00
ORG	Di-n-Butyl Phthalate	5.55E-01	1.65E+01	9.00E-05	0.00E+00	1.34E+03	d	1.83E+01
ORG	Endrin	1.43E-01	1.65E+01	1.65E-04	0.00E+00	9.20E-02	f,o	9.98E+00
ORG	Fluoranthene	1.59E+00	1.57E+02	9.00E-05	0.00E+00	1.25E+01	k	1.61E+00
ORG	Fluorene	4.69E-01	1.65E+01	9.00E-05	0.00E+00	1.25E+02	g	1.82E+00
ORG	Naphthalene	4.56E-01	1.65E+01	9.00E-05	0.00E+00	5.00E-01	g	7.36E+00
ORG	Phenanthrene	1.29E+00	9.27E+01	9.00E-05	0.00E+00	5.14E+00	g	1.61E+00
ORG	Pyrene	1.47E+00	1.34E+02	9.00E-05	0.00E+00	7.50E+00	j	1.16E+00
RAD	Americium-241	3.32E+00	1.42E+02	-7.10E-01	2.60E-02	3.20E+04	l	n
RAD	Cesium-137 + Barium-137	1.07E+01	3.94E+02	-9.00E-02	2.11E-01	2.40E+03	l	n
RAD	Plutonium-238	1.58E+00	8.56E+01	-1.70E-01	1.90E-03	1.10E+05	l	n
RAD	Plutonium-239, 240	3.17E+00	1.33E+02	-2.45E-01	2.50E-02	1.50E+05	l	n
RAD	Strontium-90 + Yittrium-90	4.82E+00	4.41E+02	-5.19E+00	2.29E-01	1.70E+03	l	n

Table 2B. (cont.)

						Deer Mouse		
Analyte Group	Analyte Name	Average Sample Value[a]	Maximum Sample Value[a]	Minimum Sample Value[a]	Background Sediment Mean[a]	TRV[b]		BCF[c]
RAD	Thorium-228	9.88E-01	4.51E+00	-1.00E-02	1.44E+00	8.30E+02	l	n
RAD	Thorium-230	8.50E-01	7.68E+00	9.20E-03	1.37E+00	9.30E+04	l	n
RAD	Thorium-232	1.21E+00	3.65E+00	4.70E-03	1.43E+00	2.90E+04	l	n
RAD	Uranium-234	7.23E+00	1.65E+03	0.00E+00	1.40E+00	9.10E+04	l	n

INORG = inorganic chemical; ORG = organic chemical; RAD = radionuclide
[a]Units for INORG and ORG values are mg/kg soil while units for RAD values are pCi/g soil.
[b]Units for INORG and ORG TRVs are mg/kg/d. Units for RAD TRVs are pCi/g soil.
[c]Units for INORG and ORG BCFs are mg analyte/ kg dry food per mg analyte/ kg dry soil. Units for RAD BCFs are pCi analyte/ g fresh food per pCi analyte/ g dry soil.
[d]LANL-derived GMM TRV
[e]LANL-derived CS TRV
[f]Oak Ridge National Laboratory TRV
[g]LANL threatened and endangered species TRV
[h]EPA EcoSSL CS TRV
[i]EPA EcoSSL GMM TRV
[j]Sandia National Laboratories TRV
[k]LANL TRV based on EPA EcoSSL value
[l]LANL ESL model for diet of soil invertebrates and plants
[m]Not available
[n]Not applicable
[o]Toxicity data for endrin aldehyde is used as surrogate toxicty data for endrin.

insectivore), and the ESL for the flycatcher is based on the violet-green swallow (*Tachycineta thalassina*) model (insectivore). Further information on these models can be found in the SLERA Methods document (LANL 2004). Receptor-specific information such as life span, body weight, food intake, and dietary component fractions and associated BCFs were used to calculate bluebird, owl, and flycatcher radionuclide ESLs. See Table 3 for the parameters used. Parameters are also shown for the deer mouse since some of the listed parameters were also used by ECORSK.9 in the exposure calculation. Some site-specific data were also derived and used. As the default, ECORSK.9 can calculate many of the parameters from various allometric equations when site-specific data are not available.

Table 3. Parameters Used in Radionuclide ESL Models

	Receptor			
Parameter	Mouse	Bluebird	Owl	Fylcatcher
Life span (d)	365	2555	7300	1460
Body weight (kg)	0.02	0.025	0.6	0.012
Food intake (kg dwt/d)	0.004	0.006	0.019	0.003
Fraction plant diet	0.5	0.1	0	0
Fraction invertebrate diet	0.5	0.9	0.12	1
Fraction of flesh in diet	0	0	0.88	0
Fraction of soil in diet	0.02	0.05	0.05	0.05
Home Range (km^2)	6.40E-04	4.30E-03	4.1	3.8E-03–1.4*
Exponential foraging function	N/A	N/A	$e^{-r/350}$	N/A

*Source: Cardinal (2005). HR was varied for model executions—3.8E-03 and 6.5E-01 km^2. Only HIs using 3.8E-03 km^2 are reported in table format in the results section.

List of COPECs Without TRVs. Sensitivity analyses performed in the 1990s using ECORSK.4 (Gallegos et al. 1997a) showed that of the many parameters used by the model, variation of the TRV and BCF parameters can have a substantial effect on HIs and HQs. While uncertainty exists in the state of the art of toxic effects of COPECs on nonhuman biota, LANL's method of TRV derivation has resulted in fewer COPECs without TRVs. Table 4 lists the COPECs without TRVs for the birds. These COPECs were not included in the ECORSK.9 input files (eeuinp.dat) for the bird receptors. There were no COPECs without TRVs for the mammal receptor, so all COPECs were included in the *eeuinp.dat* file for the mammal receptor.

Table 4. COPECs Without TRVs for the Bird Receptors

Analyte Group	Analyte	Analyte Group	Analyte
INORG	Beryllium	ORG	Chrysene
ORG	Acenaphthene	ORG	Fluoranthene
ORG	Benzo(a)anthracene	ORG	Fluorene
ORG	Benzo(a)pyrene	ORG	Phenanthrene
ORG	Benzo(b)fluoranthene	ORG	Pyrene
ORG	Benzo(g,h,i)perylene		

RESULTS AND DISCUSSION

Mean Total HI

Table 5 has mean total HIs and dominant COPECs for the four receptors. Results for Scenarios A and B are separated. Mean HIs for the threatened and endangered species are only included for comparison purposes, but individuals of threatened and endangered species, not populations and therefore not summary statistics, are the more appropriate focus. The mean total HI is the arithmetic average of the total number of HIs whereby each HI represents a nest site or focal point and its corresponding HR over which the animal theoretically fed. It is a general indicator of potential adverse effect to a population of animals in Mortandad Canyon watershed, but more importantly it establishes the extent to which more detailed results might need to be investigated.

Scenario A. Scenario A adjusted mean total HIs for the four receptors were as follows: Mexican spotted owl—1.8 (n = 999); western bluebird—4.8 (n = 997); deer mouse—0.19 (n = 997); and southwestern willow flycatcher—26.8 (n = 57). These values generally indicate that there is a small potential for impacts, with the exception of the HI for the deer mouse, which indicates that no appreciable impact is expected.

Scenario B. Scenario B adjusted mean total HIs for the four receptors were as follows: Mexican spotted owl—1.6 (n = 999); western bluebird—1.2 (n = 997); and southwestern willow flycatcher—6.2 (n = 57). The effect on mean total HIs of replacing organic chemical NDs with zeros ranged from an 11% reduction to a 77% reduction. The adjusted HI for the grid cell in Mortandad Canyon in which a pair of nesting owls exists was 0.2.

Dominant COPECs

Scenario A. In Scenario A the dominant COPECs generally were BEHP, DNBP, Pb, and Hg. BEHP, DNBP, and, to a lesser extent, Hg had the majority of their sample values (concentrations in soil) supplied as replacement values (i.e., ½DLs) (Table 6). [Note: Table 6

Table 5. Mean Total HIs and Dominant COPECs for Four Receptors Using ECORSK.9

Scenario A. Organic and Inorganic Chemical Non-Detects = ½DL		
Risk Source	**Mean Total HI***	**Dominant (≥0.3) COPEC Mean HQs**
Mexican spotted owl		
Unadjusted	1.9	BEHP (1.2), Pb (0.57)
Background	0.1	
Adjusted	1.8	BEHP (1.2), Pb (0.57)
Western bluebird		
Unadjusted	9.2	DNBP (2.3), cyanide (1.6), BEHP (1.1), Hg (1.0), Zn (0.68), V (0.55), Pb (0.45), Tl (0.35)
Background	4.4	Cyanide (0.3)
Adjusted	4.8	DNBP (2.3), BEHP (1.1), Hg (0.53)
Deer mouse		
Unadjusted	11.1	Tl (10.0)
Background	10.9	
Adjusted	0.19	None ≥0.3 on average
Southwestern willow flycatcher		
Unadjusted	33.8	DNBP (14), BEHP (6.4),Cyanide (2.6), Hg (2.5), Zn (1.4), B (1.4), Endrin (1.3), V (1.0), Pb (0.6), Cu (0.6), Cd (0.58), Tl (0.38), Se (0.36)
Background	7.0	Cyanide (2.6), Zn (1.1), V (0.9), Hg (0.8), Tl (0.7), Pb (0.5), Cu (0.35), (Cd (0.3)
Adjusted	26.8	DNBP (14), BEHP (6.4), Cyanide (2.6), Hg (1.7), B (1.4), Endrin (1.3)

Scenario B. Organic Chemical Non-Detects = 0		
Risk Source	**Mean Total HI***	**Dominant (≥0.3) COPEC Mean HQs**
Mexican spotted owl		
Unadjusted	1.7	BEHP (1.0), Pb (0.57)
Background	0.1	None≥0.3
Adjusted	1.6	BEHP (1.0), Pb (0.57)
Western bluebird		
Unadjusted	5.6	Cyanide (1.6), Hg (0.86), Zn (0.67), V (0.54), Pb (0.44), Tl (0.37)
Background	4.4	Cyanide (1.6), Zn (0.64), V (0.54)
Adjusted	1.2	Hg (0.38)
Southwestern willow flycatcher		
Unadjusted	13.9	Cyanide (2.6), Hg (2.5), DNBP (1.5), B (1.4), Zn (1.4), V (1.0), Pb (0.63), Cu (0.60), Cd (0.58), BEHP (0.48), Tl (0.38), Se (0.36)
Background	7.7	Cyanide (2.6), Zn (1.1), V (0.9), Hg (0.8), Tl (0.38), Pb (0.52), Cu (0.35), Cd (0.3)
Adjusted	6.2	Hg (1.7), DNBP (1.5), B (1.4), BEHP (0.48)

* Value is an arithmetic mean of total observations/nest site HIs (n = 999 for owl; n = 997 for bluebird; n = 57 for flycatcher).

Table 6. Proportion of Sample Results Detected and Non-detected

Analyte	No. (Count) Detected	No. (Count) Non-Detected	Total	Percent of Total Non-Detected
Americium-241	1,342	760	2,102	36.16
Aroclor-1254	172	1,377	1,549	88.90
Aroclor-1260	454	957	1,411	67.82
Arsenic	3,416	598	4,014	14.90
Barium	3,896	155	4,051	3.83
BHC[gamma-]	21	1105	1,126	98.13
BEHP	806	2,442	3,248	75.18
Boron	45	155	200	77.50
Cadmium	1,779	2,889	4,668	61.89
Cesium-137 + Barium-137	1,632	414	2,046	20.23
Chromium (total)	3,845	64	3,909	1.64
Cobalt	2,786	947	3,733	25.37
Copper	3,473	207	3,680	5.63
Cyanide (total)	190	1,118	1,308	85.47
DDT[4,4'-]	134	961	1,095	87.76
Di-n-Butyl Phthalate	256	2,601	2,857	91.04
Endrin	16	887	903	98.23
Fluoride	78	41	119	34.45
Lead	4,113	15	4,128	0.36
Manganese	3,976	2	3,978	0.05
Mercury (inorganic)	1,718	2,092	3,810	54.91
Naphthalene	227	3,247	3,474	93.47
Nickel	3,349	812	4,161	19.51
Plutonium-238	1,658	533	2,191	24.33
Plutonium-239, 240	1,833	227	2,060	11.02
Selenium	1,303	3,300	4,603	71.69
Silver	1,496	3,137	4,633	67.71
Strontium-90 + Yittrium-90	1,371	155	1,526	10.16
Thallium	1,250	3,290	4,540	72.47
Thorium-228	599	34	633	5.37
Thorium-230	603	23	626	3.67
Thorium-232	600	66	666	9.91
Uranium-234	1,934	39	1,973	1.98
Vnadium	3,348	308	3,656	8.42
Zinc	3,898	2	3,900	0.05

presents important data as the proportion of sample results detected and ND is often cited in this report.] While a high percentage of the sample values for DNBP and BEHP were replacement values, they were also detected in water and were retained as sediment and soil COPECs (LANL 2005b). In general, the highest concentrations of these COPECs in soil that triggered the model's output of some high HIs were from the RACER data set. These high values probably reflect

mesa-top SWMUs. We reviewed the sample values (concentrations in soil) of the COPECs that dominated the contribution to the highest HIs for apparent quality issues. This review is discussed on page 33 at the end of this section. We found no information that would lead us to question the accuracy of the data.

The metals that contributed mean adjusted (Lab-added) HQs≥0.3 for the flycatcher were cyanide, Hg, and B. Metals generally also had the largest HQs in the screen that was conducted on various receptors and reported in the work plan (LANL 2005a). Many metals had unadjusted (background + Lab-added) HQs≥0.3; however, much of the contribution was from background. For example, all of the unadjusted HQ for cyanide was contributed by background.

The deer mouse had no mean COPEC adjusted HQs≥0.3. Only Tl had an unadjusted mean HQ≥0.3. There are a few documented LANL sources of Tl and only a few detections of Tl occurred in the risk screening study as reported in the work plan (LANL 2005a). Background contributions of Tl HQs were low. Tl does have a relatively low TRV and a high percentage of sample values for Tl were replacement values (i.e., ½DLs), so our concern is low for Tl HQs as representing Laboratory contaminant sources.

By and large, the mean COPEC-specific HQs (means across all nest sites/focal points) were representative of many nest sites. For example, of the 999 nest sites for the owl the one with the highest HI was x,y 267,420. BEHP contributed 99% of the HI and Pb contributed 0.5%. Reviews of similar data for the other receptors resulted in the same observations.

Scenario B. Mean total HQs for the organics BEHP and DNBP decreased for the owl compared with Scenario A, disappeared as dominant COPECs for the bluebird, and decreased significantly for the flycatcher when NDs were replaced by zeros. Since these two organics were also detected in water and were retained as sediment and soil COPECs (LANL 2005b), the Scenario B values might represent more realistic risk albeit small. The HQs generated for endrin aldehyde in Scenario A were apparently all the result of ND replacements.

The COPECs that do appear to present some real risk to one or more of the receptors are BEHP, DNBP, Pb, Hg, and B. For the flycatcher several metals had adjusted mean HQs between 0.1 and 0.3 (not shown in Table 5), which are below the level of concern (≥0.3). Some of those (i.e., Se, Cd, and cyanide) had a large percentage of their sample values comprised of replacements values (i.e., ½DLs) and others (i.e., Cu, V, Zn) have a very low percentage of their sample values comprised of replacement values, therefore are more realistic.

HI Distributions

Scenario A. Table 7 shows HI frequency distributions for the four receptors. Forty-nine percent of the Mexican spotted owl HIs were ≥1.0 and 81% of the southwestern willow flycatcher HIs were ≥1.0. For the bluebird and deer mouse, relatively low percentages of the HIs were ≥1.0—24% for the bluebird and 8% for the deer mouse. For the owl, a few high HIs (≥100), probably associated with SWMUs, skewed the mean total HI upwards.

Scenario B. Treating organic NDs as zeros had the greatest effect on bluebird and flycatcher HI frequency distributions. For the bluebird, HIs that had occurred between 10 and 100 largely shifted to the 1–10 range (Table 7). For the flycatcher, roughly half of the HIs that had fallen between 10 and 100 shifted to the 1–10 range. The alternate treatment of organic chemical NDs (i.e., ND = 0) reduced the percentage of owl HIs≥1 from 49% to 36%. Given that several metals had high percentages of their sample values comprised of ½DL replacement

values, replacing metals NDs with zero could be expected to have similar effects on model output.

Table 7. HI Frequency Distributions for Scenarios A and B. Values are number of nest sites/focal points with a mean total HI in the noted HI ranges.

Scenario A. Organic and Inorganic Chemical Non-Detects = ½DL

HI Range	Mexican Spotted Owl	Bluebird	Deer Mouse	Flycatcher
≥100	7	4	0	0
10–100	4	191	2	46
1–10	481	46	73	0
<1	507	756	922	11
Total	999	997	997	57

Scenario B. Organic Chemical Non-Detects = 0

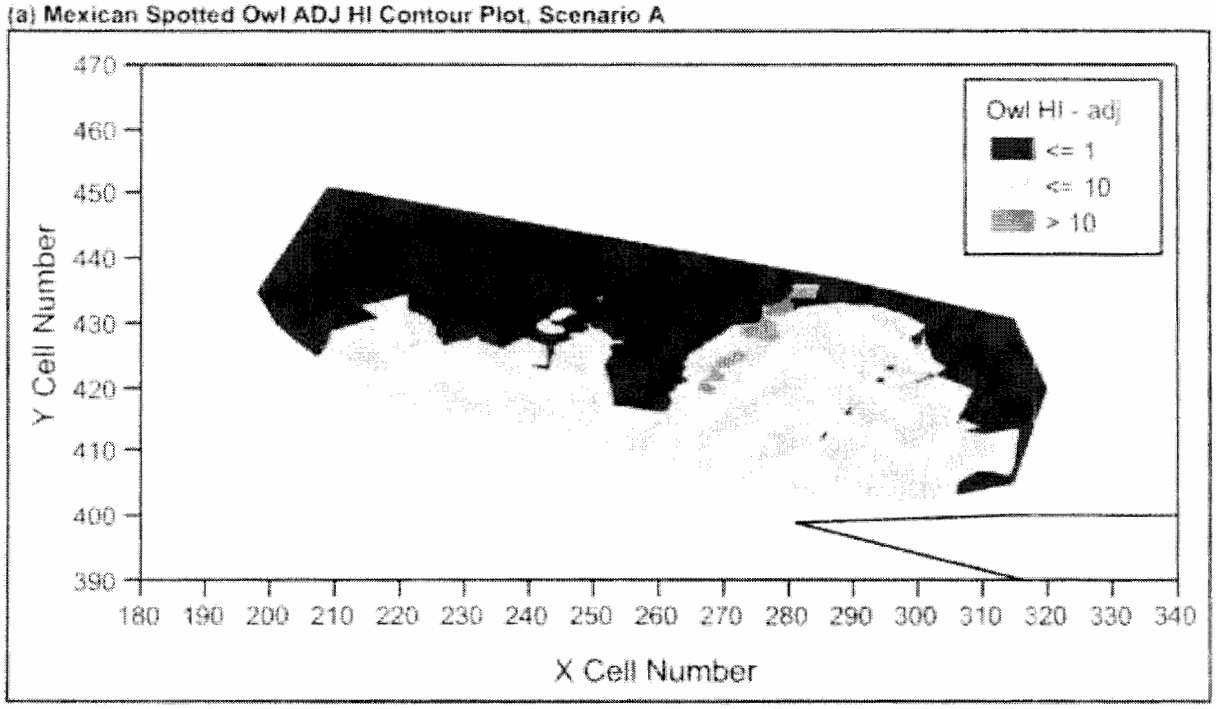
HI Range	Mexican Spotted Owl	Bluebird	Flycatcher
≥100	7	2	0
10–100	4	7	21
1–10	353	117	24
<1	635	871	12
Total	999	997	57

Risk by Geographic Area: HI Contours and Posting Plots

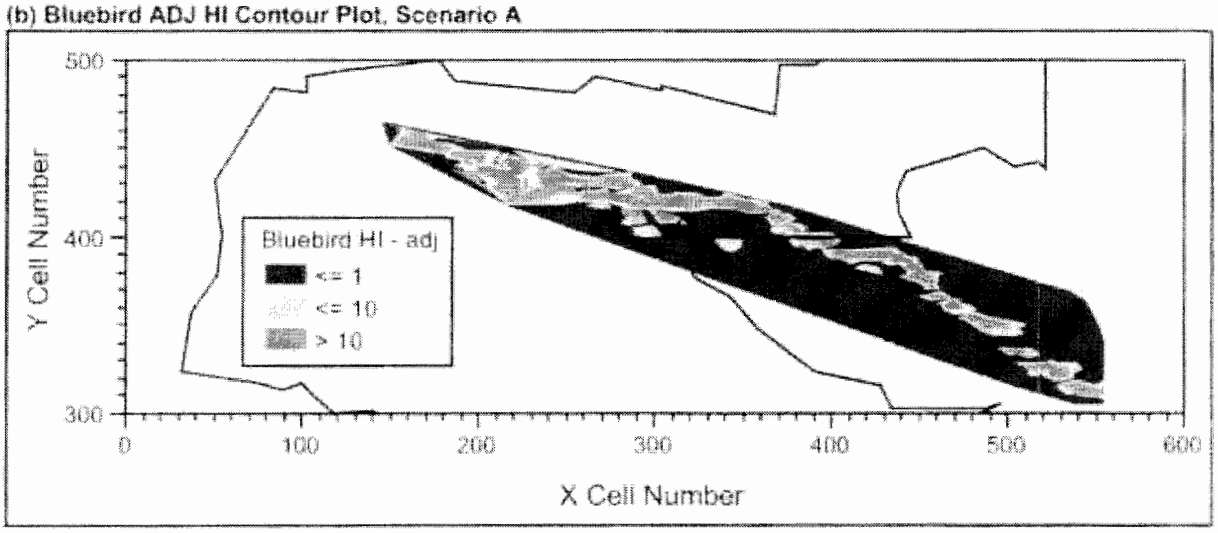
Contours of HIs are useful for demarcating general areas of risk.

Scenario A. Figures 3a–c show the physical distribution of adjusted HIs in the study area for the owl, bluebird, and deer mouse. The limited number of nest sites and, thus, HIs for the flycatcher were not conducive to contour plotting so Figure 4 is a posting plot (the HI values are posted as text next to the cell markers) of the 57 HIs for the flycatcher. The entire flycatcher habitat is in or adjacent to reach E-1W. The shape of the owl contour plot is somewhat different than for the other three receptors because areas of the watershed outside of habitat that is considered to be of marginal quality ("buffer habitat") for owls were excluded from nest site selection; i.e., areas coded with a "1" were excluded. The owl contours were also affected by limiting the spatial contaminant data to Mortandad Canyon. This created the open contour of HI = 10 at the southern part of the modeled area (Figure 3a). The owls located near the boundary of the watershed are also restricted in their foraging area and the model extends their foraging range in other directions to provide sufficient habitat area. It is also worth noting the owl HR of 4.1 km^2 is approximately equal to the suitable nesting habitat in the Mortandad Canyon watershed boundary. Being that the modeled animal exposures are a result of a number of interactions, including weighted animal distributions, spatial distributions of COPECs, toxicological and biological functions, distance-based exponential foraging (in the case of the owl), and other factors, HIs and HI contours are complex and not necessarily directly proportionate with underlying COPEC concentration distributions.

(a) Mexican Spotted Owl ADJ HI Contour Plot, Scenario A



(b) Bluebird ADJ HI Contour Plot, Scenario A



(c) Deer Mouse ADJ HI Contour Plot, Scenario A

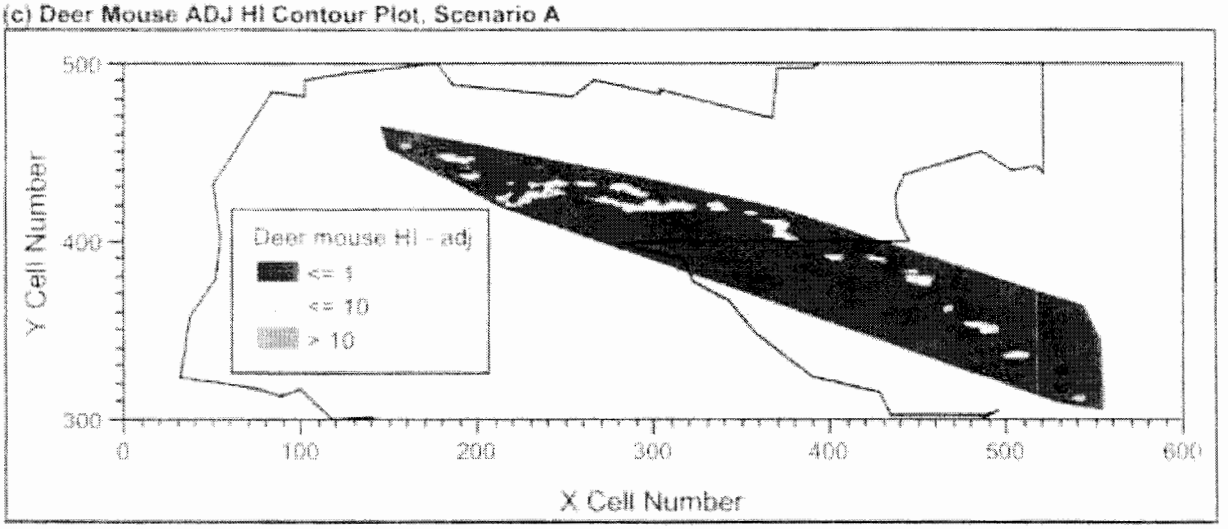


Figure 3. Contour plots of adjusted (ADJ) HIs (Scenario A) for (a) the Mexican spotted owl, (b) western bluebird, and (c) deer mouse. [Note: The border line shown is the LANL boundary.]

Southwestern Willow Flycatcher ADJ HI Data Posting Plot, Scenario A

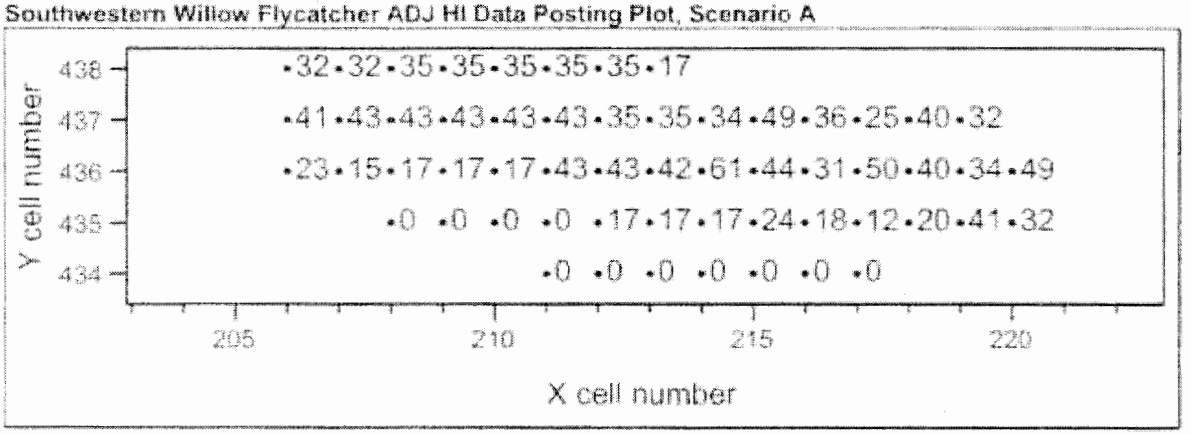


Figure 4. Data posting plot showing HIs by grid cell location for the southwestern willow flycatcher, Scenario A.

The concentration of highest adjusted HIs for the owl is in the general area of east Ten Site Canyon including Technical Area 35 and reaches M-2E, TS-2E, and TS-2C. Given the owl HR of 4.1 km^2, it is difficult to ascribe a canyons from non-canyons contribution without running the ECORSK.9 model on each data set separately. The contours for the bluebird and deer mouse can be reviewed to associate the areas of elevated HIs with either canyons or non-canyons data sources. Although the bluebird HIs are much more elevated than the deer mouse HIs, the patterns of elevated HIs are similar following the contour of the canyon bottom. The similarity is probably an artifact of how NDs were treated, and elevated HIs ($\geq$1) in the roughly eastern one-third of the watershed are probably also an artifact of the ND replacement values. The small area of flycatcher habitat limits the area of elevated HIs to the Effluent Canyon area.

Scenario B. Figures 5a, b and 6 show the physical distribution of adjusted HIs for Scenario B. The area of elevated HIs for the owl decreased only slightly. This may be because owl habitat is closer to the operational area in Mortandad Canyon where there was less canyons or canyons-interpolated data. This also makes sense from the standpoint of the contribution of the organics to the owl HIs. That is, one organic—BEHP— dominated contribution to owl HIs, but the Scenario B adjustments most affected areas that had no measured values. The mean total BEHP HQ for the owl only decreased by 0.2, and this translated to little change in the owl HI contour. So the owl HI contour was likely dominated by non-canyons COPEC sample values and not so much by ND replacement values, therefore Scenario B adjustments didn't affect owl HIs much. It's worth noting again that the owls located near the boundary of the watershed are restricted in their foraging area and the model extends their foraging range in other directions to provide sufficient habitat area. Restricting foraging area in this manner can result in the HIs and HI contours not necessarily being directly proportionate with underlying COPEC concentration distributions.

For the bluebird, most of the elevated adjusted HIs in the eastern half of the watershed were eliminated by treating organic chemical NDs in the canyons data set differently. The remaining elevated HIs ($\geq$1) generally follow the contour of the canyons and were largely driven by canyons data.

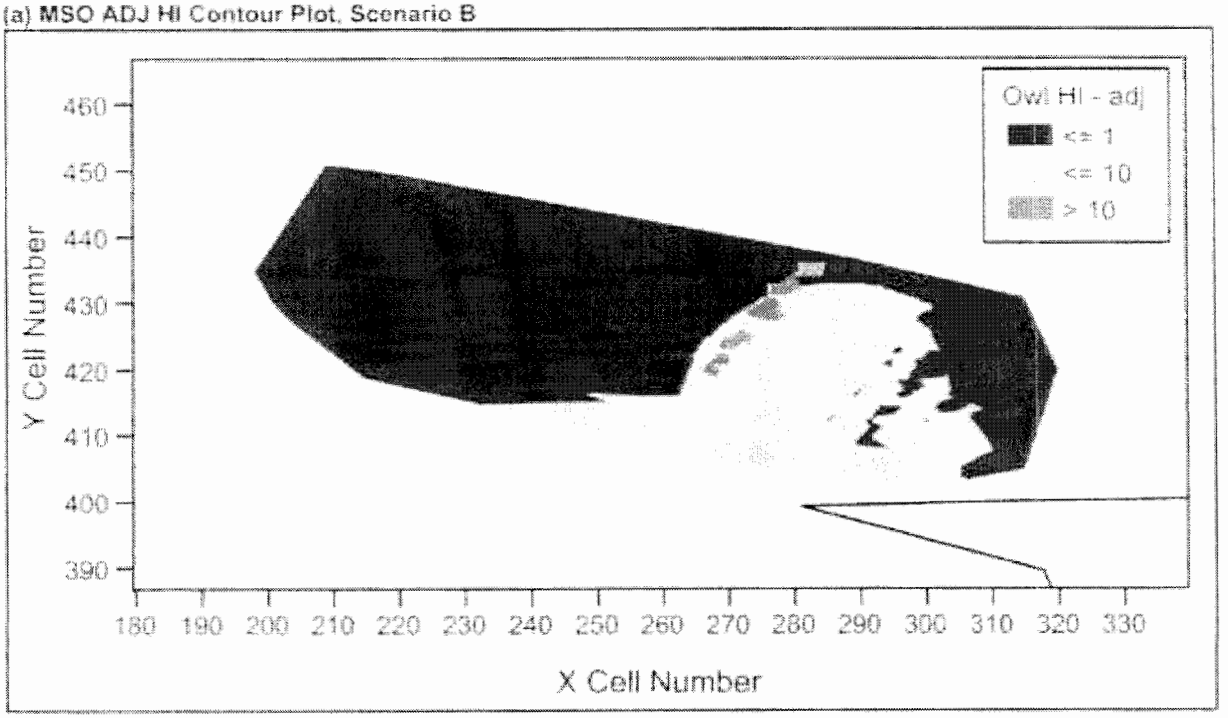
The physical distribution and pattern of flycatcher unadjusted HIs in Scenario B (Figure 6) remained the same as for Scenario A, consisting of markedly lower HIs in Scenario B, reflecting the impact that organics NDs were having in Scenario A.

COPEC-Specific HQ Distributions

Contour or posting plots of HQ distributions were developed for COPECs with mean total HQs$\geq$0.3. Scenario B plots are not necessarily repetitions of Scenario A plots.

Scenario A. Figures 7a and b are adjusted HQ contour plots of Pb for the owl and DNBP for the bluebird under Scenario A. The Pb HQ contour for the owl is very similar to the HI contour plot indicating that the Pb distribution was responsible for much of the HI distribution. Given the "bullseye" of the Pb HQ contours is at the southern boundary of the contour plot, it seems likely that non-canyons data are the key contributors to the pattern. If canyons data were most important, then the visual effect would be elevated Pb HQ values along the stream channel, which runs generally west to east.

(a) MSO ADJ HI Contour Plot, Scenario B



(b) Bluebird ADJ HI Contour Plot, Scenario B

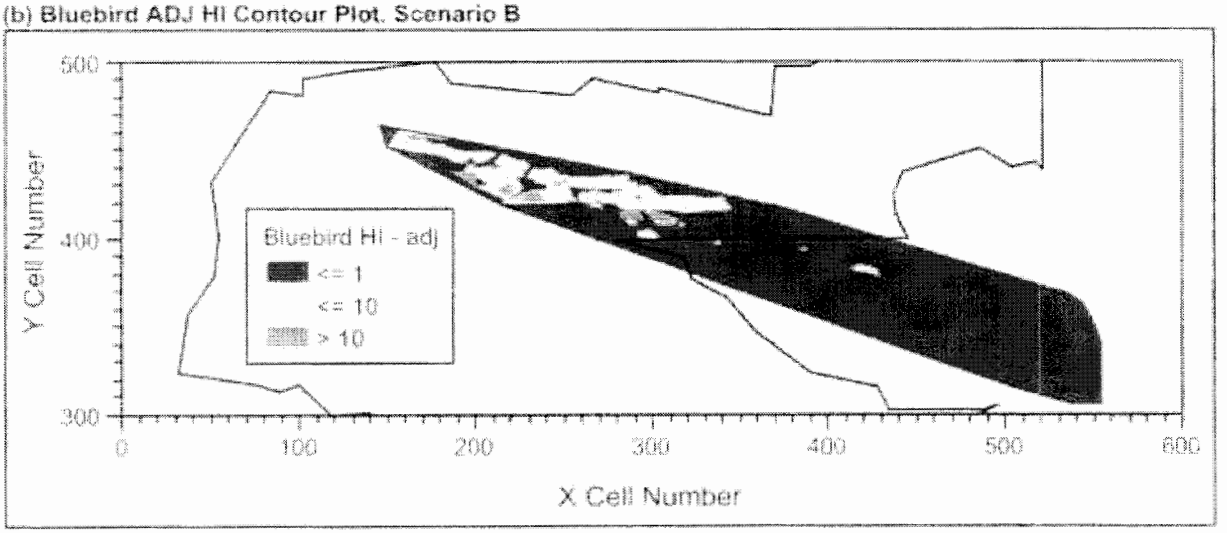


Figure 5. Contour plots of adjusted HIs (Scenario B) for (a) the Mexican spotted owl and (b) western bluebird. [Note: The border line shown is the LANL boundary.]

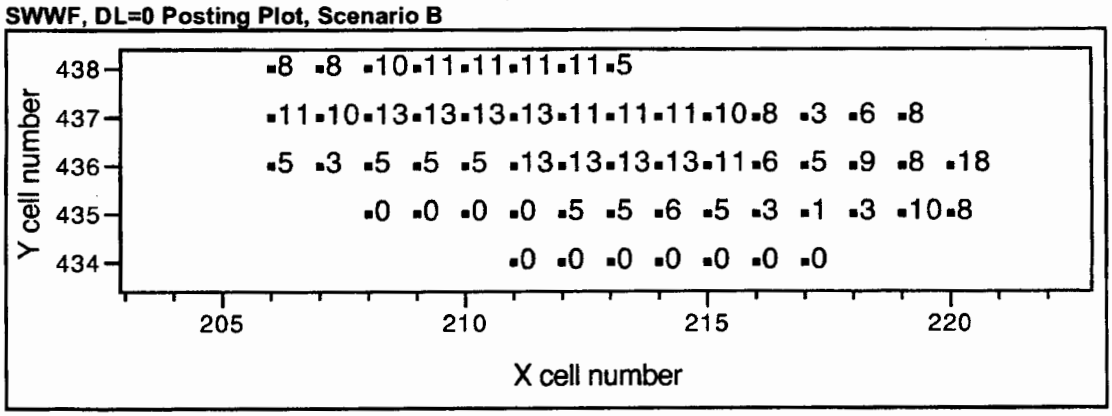


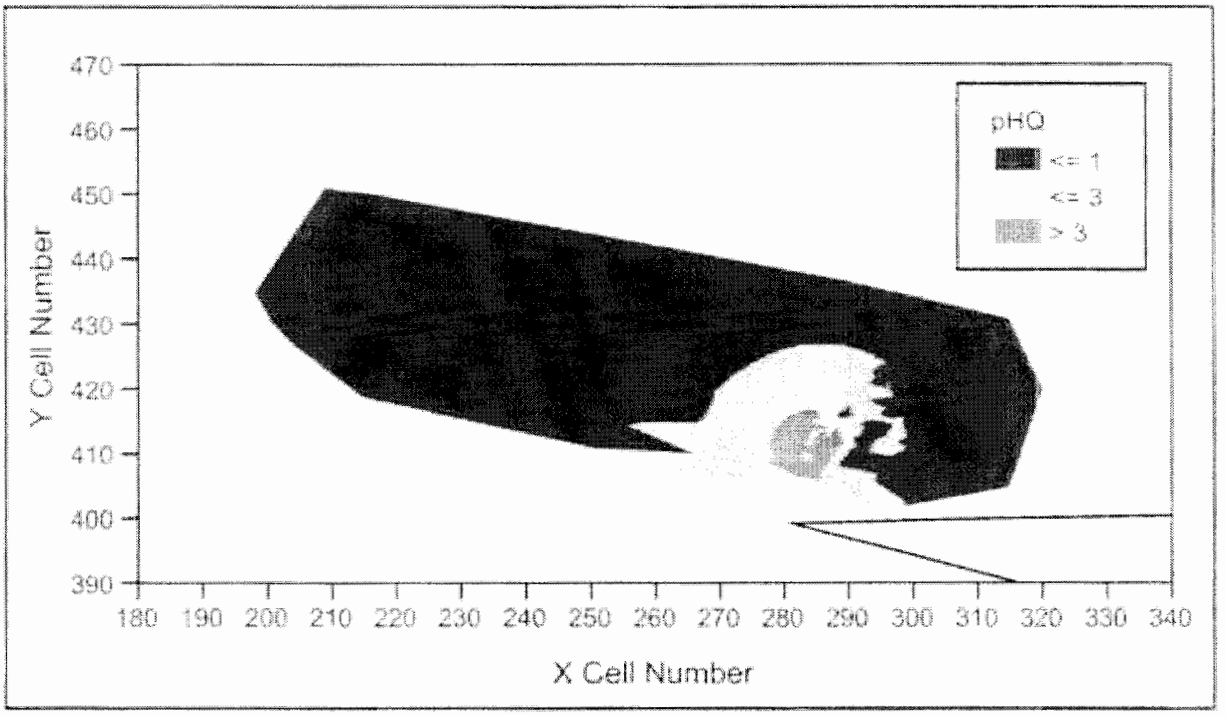
Figure 6. Data posting plot showing HIs by grid cell location for the southwestern willow flycatcher, Scenario B.

Figure 7b shows the distribution of DNBP HQs for the bluebird. In general, considering the three avian receptors, DNBP and BEHP dominated contributions to the HIs, but the spatial patterns were different, with the bluebird and flycatcher grouped into one pattern and the owl into another. The DNPB and HI contours for the bluebird are quite similar. The elevated HQs for DNBP in the roughly eastern one-third of the watershed were likely an artifact of Scenario A treatment of organic chemicals NDs. The phthalates were detected in water and retained as soil COPECs in the risk screen (LANL 2005b), however DNBP was detected in only four of 24 reaches. The HQ patterns for these organics appear to follow the contour of canyon bottoms/channel sediment. Bis(2-ethylhexyl) phthalate was detected in 13 reaches, but there was no clear pattern in its distribution that points to sources (LANL 2005a). There is an area of elevated HQs for DNBP around Reach TS-1E (Fig. 7b), and there were some detections of this organic in Ten Site Canyon sediment and soil (LANL 2005a); however, the levels for canyon bottom sediment reported in the work plan are too low to cause the HQs≥10.0 generated by ECORSK.9, therefore non-canyons data is playing a role in the higher HQs.

Scenario B. Figures 8a and b are adjusted HQ contour plots of DNBP for the owl and Hg for the bluebird under Scenario B. Two pockets of elevated DNBP adjusted HQs for the owl are present—a larger pocket of the highest HQs in the area of east Ten Site Canyon and reaches M-2E, TS-2E, and TS-2C and to the south and east of that a pocket of lower-elevated HQs (Figure 8a). Figure 8b shows elevated Hg for the bluebird in the western one-third to one-half of the watershed, generally following canyons sediment. The highest Hg HQ appears to be in the area of Reach E1-FW.

Data posting plots for B, DNBP, and Hg for the flycatcher are shown in Figures 9a–c. The limited area of flycatcher nesting habitat in Reach E-1W restricted elevated HQs to this area. Elevated HQs of 3 and 4 appear for Hg and DNBP, whereas elevated HQs for B only reach 2 (3 in one instance); however, in Scenario B 77% and 55% of the sample values for B and Hg, respectively, still consist of ½DLs as they did in Scenario A, whereas DNBP NDs were replaced with zero in Scenario B. On this basis, DNBP HQs may be more realistic; however, as mentioned earlier, the higher HIs and HQs were caused by measured non-canyons data while the treatment of NDs affected primarily the geographical distribution of low to moderated HIs and HQs.

(a) MSO Lead ADJ HQ Contour Plot, Scenario A



(b) Bluebird DNBP ADJ HQ Contour Plot, Scenario A

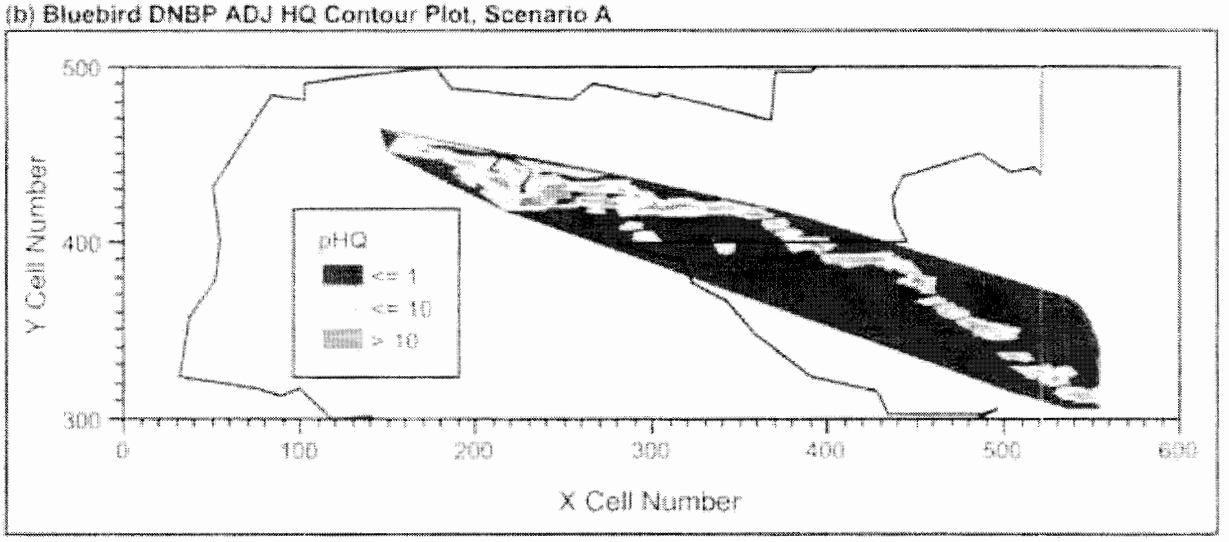


Figure 7. Contour plots of pHQs (Scenario A) for (a) Pb, Mexican spotted owl, and (b) DNBP, western bluebird. [Note: The border line shown is the LANL boundary.]

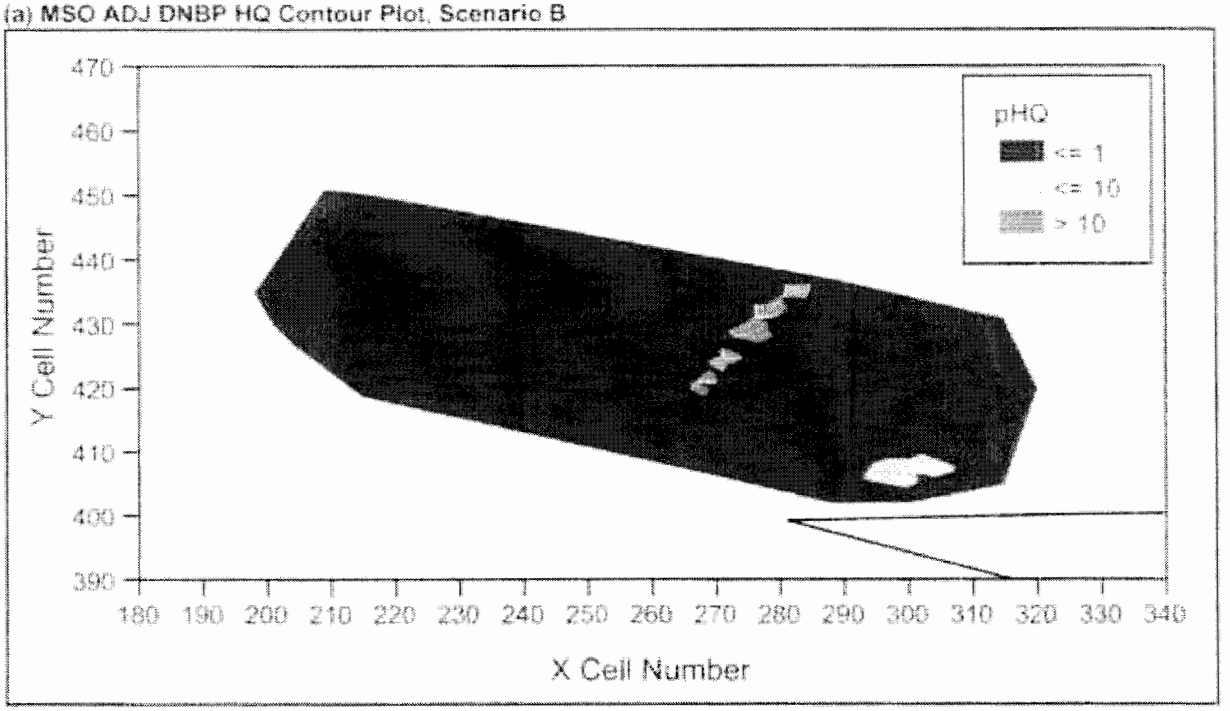
Table 8 identifies decisions that were made regarding the selection of parameters and how they might have impacted the results. A sensitivity analysis of the effect of parameter variation on ECORSK results conducted on the American peregrine falcon (*Falco peregrinus*) in 1997 established that the TRV and BCF selection were quite important to effects on HI and HQ results (Gallegos et al. 1997b). Since the time of assessments on threatened and endangered species in the late 1990s, LANL has developed a rigorous process (discussed in Methods) for the selection of TRVs and BCFs. The TRV database currently is reflective of the large majority of available primary and secondary literature on animal toxicological data; however, TRVs are often still conservative as the result of selection criteria and how uncertainties, such as LOAEL to NOAEL extrapolation, are dealt with. BCFs have increased for some COPECs. For example, the BCF for BEHP for the avian receptors for this assessment on Mortandad Canyon was a factor of about 100 times higher than the one used in the Los Alamos/Pueblo Canyon model application (Gonzales et al. 2004).

For some areas modeled, the replacement of NDs with ½DL values may have dominated contribution to HIs and HQs. Under Scenario A, where organic and non-radionuclide inorganic chemical NDs were replaced with ½DL values, replacement values are thought to have dominated contribution to HQs and HIs in areas where little or no measured values existed. For geographical areas where relatively high HIs resulted, treatment of NDs likely had little effect. Because organic chemicals dominated the contribution to mean total HIs and HQs after the first round of model executions (Scenario A), we traced back from the highest HIs and HQs to the origin of the high HIs and HQ—the raw sample values, prior to averaging. We investigated the Mexican spotted owl input; however, the large set of sample values and averages are the same across all receptors. All of the relatively high sample values were from the Risk Assessment Corporation's RACER Concentration Tables Database and were associated with records pulled from LANL ERDB. This is logical because the RACER database includes data from SWMUs. Below is a summary of our quality review of the data that led to the relatively high model results (HIs and HQs) under Scenario A.

Quality Review of Data Leading to Relatively High Model Results (HIs and HQs) for the Mexican Spotted Owl, Scenario A. The results that produced the five highest COPEC HQs for the owl averaged over 1,000 nest sites included bis(2-ethylhexyl)phthalate, Pb, di-n-butyl phthalate, Hg (inorganic), and Cu. Only a select group of the results associated with these COPEC HQs were reviewed, generally the top three or four values. Three records were reviewed for bis(2-ethylhexyl)phthalate, Pb, and Cu. Four records were reviewed for di-n-butyl phthalate and Hg (inorganic). All the results considered originated in the Risk Assessment Corporation's RACER Concentration Tables Database, and were associated with records pulled from the LANL ERDB.

Location Characteristics. According to the location data fields, the data were loaded into the RACER Database on November 28, 2000, and modified on August 20, 2002. The types of modifications made to the records are unknown. One result for bis(2-ethylhexyl)phthalate and two results for di-n-butly phthalate are in the same location while the rest of the 14 results are at various locations and show no pattern of results being associated with any particular location as determined by comparing map coordinate systems (ULI and UTM) x,y coordinates. The elevation of the locations ranged from 6,998 to 7,576 feet. The locations were all coded as GENERIC location type, and the coordinate method code is S and the coordinate unit of measure is FT.

(a) MSO ADJ DNBP HQ Contour Plot, Scenario B



(b) Bluebird Hg ADJ HQ Contour Plot, Scenario B

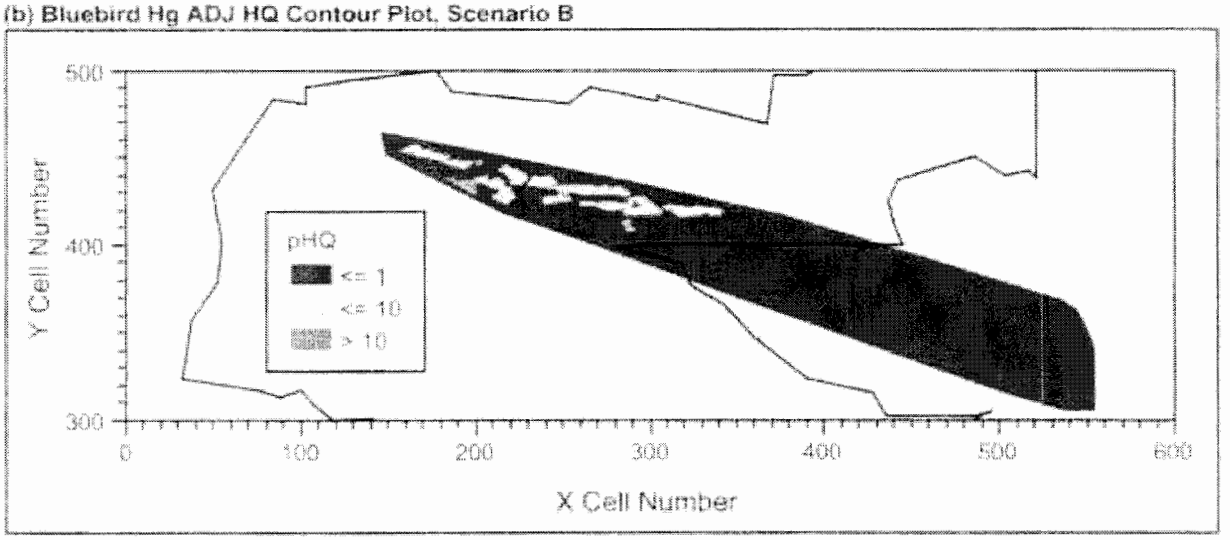
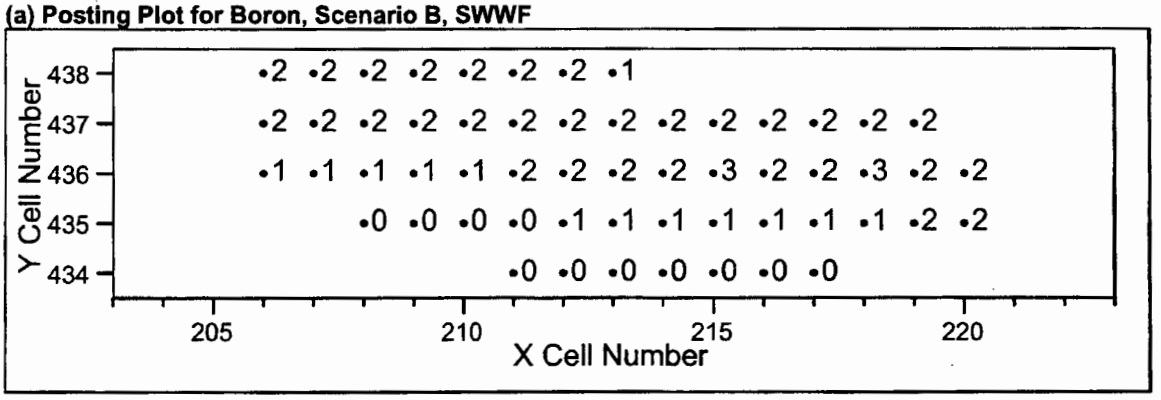
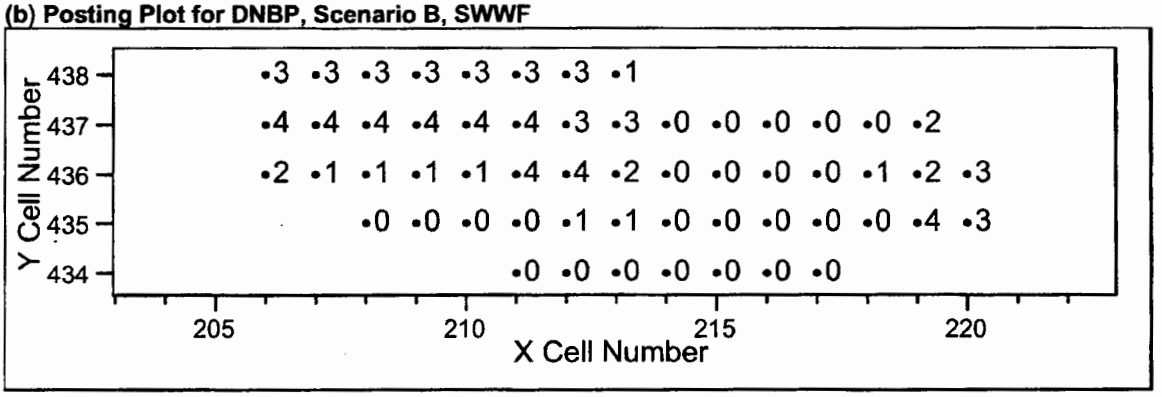


Figure 8. Contour plots of pHQs (Scenario B) for (a) DNBP, Mexican spotted owl, and (b) Hg, western bluebird. [Note: The border line shown is the LANL boundary.]

(a) Posting Plot for Boron, Scenario B, SWWF



(b) Posting Plot for DNBP, Scenario B, SWWF



(c) Posting Plot for Hg, Scenario B, SWWF

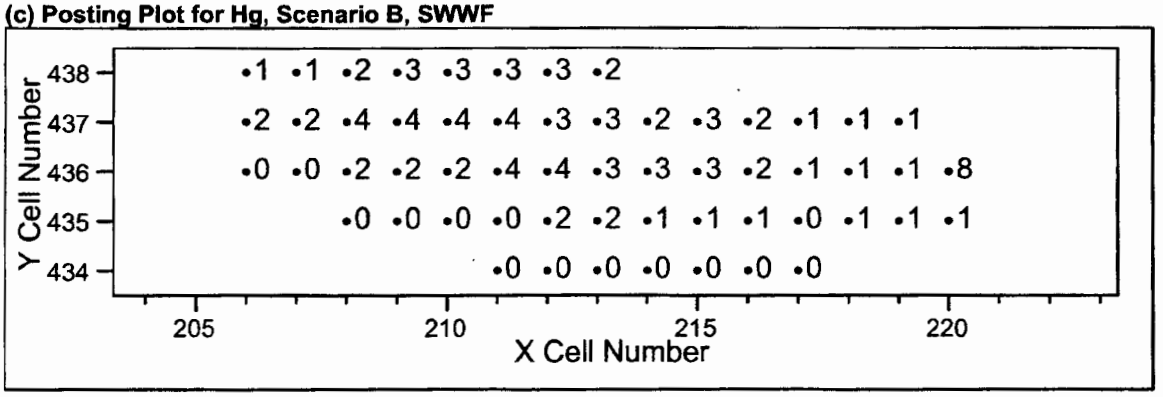


Figure 9. Data posting plots showing HQs by grid cell location for (a) B, (b) DNBP, and (c) Hg in the southwestern willow flycatcher, Scenario B.

Table 8. Parameter and Assumption Selections for ECORSK Modeling and Subjective Binning of Effects of Parameters on Model Results

Conservative (overestimate potential for adverse effects)	Realistic	Nonconservative (underestimate potential for adverse effects)
In some reaches (~western one-third of watershed), sampling on which HIs and HQs are based is biased to areas known or suspected of having elevated concentrations.		
Nondetects replaced with the ½DL, which is an overestimate if the detection limits for some samples and analytes are artificially elevated.		
	Grid cells where no soil sampling occurred are populated with inter-polated data, as appropriate	
Contamination level measured at sampling points assumed for entire 100- by 100-ft area of a grid cell, when in fact, sometimes, the contaminated area is less than the 10,000 ft^2 grid cell.		
HIs assume all COPECs have same biological effect, therefore treated as additive.		
CS TRVs	GMM TRVs	HQs not calculated for COPECs for which TRVs not available.
Assumed bioavailability of COPECs = 100%.		
	Average, not maximum, COPEC concentrations in soil and sediment used.	
Percent of dietary food intake as soil = 5 for owl, bluebird, and flycatcher.		
BCFs increased by a factor of 10 for each major uncertainty in TRVs or ESLs; e.g., LOAEL to NOAEL extrapolation.		
Used BCFs developed for the ESLs; these are intended to be upper bounds of contaminant uptake.		
Owl foraging area for nest sites near the perimeter of the watershed must grow in other directions to satisfy the HR area requirement—this can lead to unrealistically high exposure for owls with nest site locations near a boundary.		

Sample Characterisitcs. According to the sample data fields the samples were taken from similar depths ranging from a top depth of 0 to 1 foot and a bottom depth of 0.5 to 2 feet. The samples were primarily soil samples. One bis(2-ethylhexyl)phthalate and one di-n-butly phthalate sample were coded as fill. Copper did have two sediment samples and Hg (inorganic) had one sediment sample. There did not appear to be any data flags to suggest the data were not of good quality. The samples were loaded into the RACER Database on November 28, 2000, and modified between the years of 2003 and 2004. The modifications made are unknown. The samples were taken between the years of 1994 and 1995. All but one of the samples was an INV sample. The other sample was a QC sample. There did not appear to be any pattern associating these samples with a particular sample ID.

Result Characteristics. Lead was analyzed by two different methods. The analysis method did not vary for the other COPECs, except by COPEC. A Pb sample and a Cu sample had a qualifier reason of V. Di-n-butyl phthalate had a qualifier reason of O. The others did not have a qualifier reason. The dilution factors varied within a COPEC data set or were not reported. The labs varied. Bis(2-ethylhexyl)phthalate has records with J and JB lab qualifiers. Di-n-butyl phthalate had records with U and UJ lab qualifiers and Hg (inorganic) had a J lab-qualified record. Records were loaded into the RACER database between December 2000 and January 2001 and modified in August 2005. The modifications made are unknown. The percent moisture was recorded for some results, but not all.

In summary, the parameters that caused high HIs and HQs could have included (1) high percentages of sample values comprised of replacement values (i.e., ½DLs), (2) more sensitive TRVs/ESLs and BCFs, (3) high, potentially real, sample values in the RACER data set, and (4) interpolated values.

CONCLUSIONS

On average there is a small potential that Mexican spotted owls, western bluebirds, and southwestern willow flycatchers will experience adverse effects from exposure to COPECs in Mortandad Canyon. Threatened and endangered species warrant protection of each individual in the population and, although there were a few HIs in the range of 10–100 for both the owl and flycatcher and a few HIs in excess of 100 for the owl, many factors that result in biasing HIs and HQs upwards may have resulted in significant overestimates of potential adverse effects. This is largely a function of modeling risk over large areas and restricting the simulated foraging area can also play a role. When data mining by the ECORSK modeling process involves large areas of land and a vigorous method of populating grid cells with data through the interpolations method is used, quotients and indices of potential adverse effect are significantly biased upwards. The treatment of ND sample values was another factor that biased HIs and HQs, however this factor mostly affected the geographical distribution of HIs and HQs and had little effect on the highest HIs and HQs. Some areas in Mortandad Canyon have been identified that should be considered for additional study because of potential effects to individual owls and flycatchers; however, considering the potential effects on HIs and HQs of several variables collectively, we anticipate no appreciable adverse effects to these animals from the COPECs studied. Also, the adjusted HI for the grid cell in Mortandad Canyon in which a pair of nesting owls actually exists indicates little to no threat of potential adverse effects from Lab-related contaminants. Lastly, the percentages of western bluebird and deer mouse populations that could

experience adverse effects from the COPECs studied are probably too low to have an effect on their population viability.

ACKNOWLEDGMENTS

The modeling task, one component of the Mortandad Canyon biota investigation, was supported by the Canyons Investigation Team of LANL's Environment & Remediation Support Services (ERSS) Division. Steven Reneau of ERSS did an extensive peer review of the report. Kathryn Bennett of ERSS developed GIS map code and animal distribution data. David Keller of the Ecology and Air Quality Group provided habitat information on the southwestern willow flycatcher and Mexican spotted owl.

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