Appendix K2

Development of Preliminary Remediation Goal for Lead Using a Monte Carlo Approach

CONTENTS

TABLES

Appendix K2

Development of Ecological Preliminary Remediation Goal for Lead using Monte Carlo Analysis

K2-1. INTRODUCTION

Monte Carlo simulation is a statistical technique by which a quantity is calculated repeatedly, using randomly selected "what-if" scenarios for each calculation. Recent EPA guidance on probabilistic risk assessment (EPA 1999) discusses the problem of single-point estimates in depth and recommend the use of multiple risk descriptors (e.g., exposure parameters) in appropriate cases. Single point estimates of exposure parameters or toxicity values fail to address the wide range of environmental variability that occurs, and when each parameter is the most conservative, the final risk estimate propagates this conservatism in a multiplicative manner.

A Monte Carlo approach to developing preliminary remediation goals (PRGs) for OU 10-04 ecological receptors (Eco-PRGs) at the INEEL, addresses much of the uncertainty inherent in the ecological risk assessment input parameters and the variability representing the true heterogeneity or diversity inherent in a well-characterized population. The calculation of an Eco-PRG is similar to the derivation of INEEL-specific ecologically based screening level (EBSL) which were presented in the Guidance Manual (Van Horn et al., 1995) and developed for functional groups. In fact, the equations are the same; however, the toxicity reference values (TRVs) for lead were varied, as were exposure parameters (e.g., body weight, dietary ingestion rate, and uptake factors), and the Eco-PRGs were developed for species-specific mammalian and avian receptors (e.g., coyote, loggerhead shrike) rather than for functional groups. In addition, an Eco-PRG was developed for plants in direct contact with lead in soil.

K2-1.1 Mammalian and Avian Species

Using the endpoint assessment species selected in the OU 10-04 site-wide Ecological Risk Assessment (ERA), a Monte Carlo quantitative uncertainty analysis was performed to obtain an Eco-PRG for lead for the ecological receptors at the STF-01 (an OU 10-04 site containing lead). The following equation, which implies a hazard quotient (HQ) of 1 in the numerator, was used to develop soil Eco-PRGs for mammalian and avian species:

$$Eco-PRG_{soil} = \frac{TRV * BW}{[(PP * BAF) + (PV * PUF) + PS] * IR * ED * AUF}$$

where:

Eco-PRG = Ecologically-based soil remediation level for non-radiological contaminants in soil (mg/kg soil)

TRV = Toxicity reference value (mg/kg-day)

PP = Percentage of diet represented by prey ingested (unitless)

PV = Percentage of diet represented by vegetation ingested (unitless)

PS = Percentage of diet represented by soil ingested (unitless)

IR = Ingestion rate (kg/day)

ED = Exposure duration (fraction of year spent in the assessment area, unitless; set = 1)

BW = Receptor-specific body weight (kg)

PUF = Contaminant-specific plant uptake factor (unitless)

BAF = Contaminant-specific prey bioaccumulation factor (unitless)

AUF = Area use factor (site area/home range)(unitless)

Uncertainty in each of the parameters in the equation was addressed by assigning a distribution to each parameter. The triangular distribution requires only a minimum and maximum value, which sets the upper and lower bounds of the distribution. The center of the distribution is defined by the most likely value to occur. Details on the distributions assigned to each parameter are provided in Appendix K2 Attachment K2-1.

Body weights tend to be normally distributed. When a mean and standard deviation were available for body weights, they were assigned a normal distribution. When a mean but no standard deviation was reported in the literature, a triangular distribution was assigned with the range (minimum and maximum) used to set the upper and lower bounds of the distribution. The mean was then used to estimate the most likely value. When only a range was available for body weight, a triangular distribution was assigned, and the most likely value was conservatively assumed to be the lower end of the range. For example, a normal distribution was assumed to evaluate uncertainty in body weight for the mourning dove (see Attachment K2-1, Table K2-1-1).

The percent of each item in the diet was determined by review of the literature for dietary habits and for soil ingestion. The following formula was used to obtain the percent of each item in the diet:

Maximum % diet =100% - minimum % soil

Minimum % diet =100% - maximum % soil

Herbivorous birds (e.g., mourning dove) eat approximately 100% vegetation. Thus, factoring out the percent soil (estimated range of 3.3 to 10.4%) results in an estimated percent diet of 89.6 to 96.7 %. This same approach was used to estimate the percent diet for carnivores or insectivores. To estimate diet for omnivores, the total minimum and maximum diet remaining after factoring out soil ingestion was divided, and half allotted to ingestion of vegetation and half to ingestion of prey. The percent of soil and each dietary item used in the Eco-PRG equation for each receptor is presented in Attachment K2-1, Tables K2-1-1 through K2-1-11.

Dietary ingestion rates (IRs) were estimated by allometric equations for each receptor. The allometric equation was substituted into the Eco-PRG equation in lieu of IR, and allowed to vary with body weight in each trial of the simulation. Thus, each time the value for body weight changed in the simulation, the respective IR would also change. The allometric equations used for each receptor are presented in Attachment K2-1, Tables K2-1-1 through K2-1-11.

The information used to develop the TRVs is provided as Attachment K2-2. The Eco-PRG was based on a TRV that incorporated adjustment factors to account for taxonomic differences between the TRV test species and the OU 10-04 species of concern. These adjustment factors artificially reduce the

Eco-PRG in order to provide additional conservatism to the Eco-PRG estimate. The TRV for each receptor was assigned a triangular distribution. Examination of the lead toxicity data for birds indicates that most of the Quantified Critical Endpoints (QCEs) vary between 14.5 and 50 mg/kg-d (Attachment K2-2). After applying an uncertainty factor for taxonomic variability (i.e., an R factor), the avian TRVs were predicted to range from 4.8 to 14.5 mg/kg bw-day (Attachment K2-2). These values were used to set the range for the triangular distribution for body weight, while the most likely value was set to the taxon-specific TRV, either 4.8, 7.2, or 14.5 mg/kg bw-d (Attachment K2-2).

The data for lead toxicity in mammals is more extensive than that for birds. Therefore, the study, which used the mammalian species most closely related to the receptor of concern, was used in the Monte Carlo assessment. This reduces the overall uncertainty in the estimate. As for birds, a taxonomic uncertainty factor up to a value of 3 was applied, but the most likely value was set to the TRV corresponding to the most closely related species (Attachments K2-1 and K2-2). The TRV used for each receptor is described in more detail below.

Previous sensitivity studies have shown that the plant uptake factors (PUFs), bioaccumulation factors for invertebrates or prey (BAFs), and TRVs have the greatest impact on the analysis. No adjustment was made for seasonal migration or hibernation in order to be protective of receptors that reside in the area year round. The exposure duration is thus set to 1. However, an AUF was applied to represent the receptor's movement within its home range. This is consistent with current EPA guidance (EPA 2000).

Home range information was obtained by review of the literature. Data for Idaho were preferred, but other data were used if data for Idaho were lacking. The home range information is presented in Tables K2-1-1 through K2-1-11, and Table K2-1-14. The home range information was used to estimate an area use factor (AUF) for each receptor. The AUF is calculated with the following equation:

AUF = site area/home range

Receptors with small home ranges have a potentially higher rate of exposure since they may not move outside of the exposure area as often. Conversely, receptors with larger home ranges may contact the exposure area, but it is estimated to be on an infrequent basis relative to the size of the home range. The STF-01 area is only 1.31 ha, which is smaller than the home range of most of the receptors. Only one receptor had a home range smaller than the site area; this was the deer mouse. Thus, since the AUF would be greater than 1, the AUF was set to 1 for this receptor.

The Monte Carlo method selects a value from a defined distribution for each parameter in the Eco-PRG equation. An Eco- PRG value is then calculated. This is called a "trial". Each simulation was allowed to run for 5,000 iterations. There are thus 5,000 different PRG values calculated during each simulation. Each simulation is different because each of the underlying parameters can be different for each of the iterations. A mean and other summary statistics for the distribution of each of the Eco-PRGs is provided as Attachment K2-3. The Monte Carlo analysis was performed with Crystal Ball™, Version 4.0c.

After performing the quantitative uncertainty analysis, the Eco-PRG for each receptor is expressed as a range of soil concentrations. Given the variability inherent in each of the parameters, the "true" Eco-PRG falls within this range. Conservative exposure parameters were used in the Eco-PRG equation, which thus tends to overestimate exposure. The uncertainty in each of these parameters was defined with their minimum and maximum values. Soil lead concentrations as high as the maximum represent the upper bound of an Eco-PRG soil concentration that could be attained with the exposure parameters and their known or suspected variability used in the Eco-PRG equation.

Values above the high end of the range exceed the Eco-PRG. The Eco-PRG range represents a range of soil lead concentrations unlikely to adversely affect receptor populations at the INEEL. The minimum represents the 0^{th} percentile, i.e., all Eco-PRGs values fall above the minimum. The maximum represents the 100^{th} percentile, in that all Eco-PRG values will fall below this value, and above the 100^{th} percentile, adverse effects can be reasonably expected. The 100^{th} percentile PRG is attained when all of the exposure parameters are minimal, whereas the 0^{th} percentile is attained when all exposure parameters are maximized. The mean value was selected as the value most representative of the Eco-PRG for lead.

The amount of variation in the TRVs and in the exposure parameters is the driving force behind the ultimate range of the Eco-PRG. If the amount of variation is very wide, the range in the Eco-PRG will also be wide. If there is little variation in each of the parameters, the Eco-PRG will also vary little. For example, the Eco-PRG range for the mourning dove is wider than that for the sage sparrow. The PUF for vegetation varies by about 5 orders of magnitude, whereas the invertebrate BAF varies by less than 2. This obviously impacts the range in the expected dietary intake, which is then reflected in the Eco-PRG.

K2-2. RESULTS FOR MAMMALS AND BIRDS

The results of the Monte Carlo analyses for birds and mammals are summarized in Table K2-1, below. Tables K2-1-1 through K2-1-11 in Attachment K2-1 provide the detailed information used in the Monte Carlo simulation for each species. Tables K2-1-12 through K2-1-13 provide the raw data used to derive BAFs and parameter ranges for the simulations. Table K2-1-14 presents the raw data used to develop the home range estimates. Supporting documentation for the TRVs is found in Attachment K2-2. The results of the simulation are presented as Attachment K2-3, and show the shape of the distributions for each of the exposure parameters, as well as statistics for the Eco-PRGs for each receptor. The simulation mean is presented for each OU 10-04 receptor.

K2-2.1 Mourning Dove

The Eco-PRG for the mourning dove was estimated with the parameters summarized in Attachment K2-1, Table K2-1-1. A TRV of 4.8 mg/kg-d was used for the mourning dove based on a no observed adverse effect level (NOAEL) in kestrels of 14.5 mg/kg bw-d (Attachment B) divided by a taxonomic adjustment factor (R) of 3.

The Eco-PRG ranges from a low of 5,226 mg/kg to a high of 2,946,779 mg/kg. Much of this uncertainty is due to the large range in the PUF values for plants (Table K2-1-1). The recommended value for the Eco-PRG is the mean. The mean Eco-PRG for the mourning dove is 442,624 mg/kg.

K2-2.2 Sage Sparrow

The Eco-PRG for the sage sparrow was estimated with the parameters summarized in Attachment K2-1, Table K2-1-2. The Breeding Bird Survey results indicate that the INEEL does not constitute a significant portion of the sage sparrow range; however, this receptor could represent other primarily insectivorous passerine birds. A TRV of 4.8 mg/kg-d was used for the sage sparrow based a NOAEL in kestrels (Attachment K2-2) of 14.5 mg/kg bw-d divided by an R value of 3.

The Eco-PRG ranges from a low of 105 mg/kg to a high of 763 mg/kg. The mean is the recommended value for the Eco-PRG. The mean Eco-PRG for the sage sparrow is 263 mg/kg, but soil concentrations as high as 763 mg/kg are within the range of the Eco-PRG, when all exposure parameters are minimized.

K2-2.3 Ferruginous Hawk

The Eco-PRG for the ferruginous hawk was estimted with the parameters summarized in Attachment K2-1, Table K2-1-3. A TRV of 14.5 mg/kg-d was used for the hawk based on a NOAEL in kestrels (Attachment B). The TRV range for birds is 4.8 to 14.5 mg/kg bw-d, and because the hawk is within the same order and trophic level as the kestrel (i.e., Falconiformes), the most likely value is 14.5 mg/kg bw-d (Table K2-1-3).

The Eco-PRG ranges from a low of 97,062 mg/kg to a high of 2,389,995 mg/kg (Table K2-1-3). Much of this large range of uncertainty is due to the small mammal BAF range, which spans about four orders of magnitude. The high values of the Eco-PRG reflect the large AUF for hawks, which are expected to contact the exposure area infrequently during their movements within their home range. The body weight and intake rate estimates for the hawk also each vary by a factor of 2. The mean Eco-PRG is the recommended value, and is 378,451 mg/kg.

K2-2.4 Loggerhead Shrike

The Eco-PRG for the loggerhead shrike was estimated with the parameters summarized in Attachment K2-1, Table K2-1-4. A TRV of 7.2 mg/kg-d was used for the shrike based on a NOAEL in kestrels (Attachment B). The TRV was selected because the shrike has similar feeding habits to those of kestrels, but it is in a different order. The TRV range for the simulation was 4.8 to 14.5 (Table K2-1-4).

The Eco-PRG ranges from a low of 400 mg/kg to a high of 12,721 mg/kg. The mean Eco-PRG for the loggerhead shrike is 1,386 mg/kg.

K2-2.5 Burrowing Owl

The Eco-PRG for the burrowing owl was estimated with the parameters summarized in Attachment K2-1, Table K2-1-5. A TRV of 7.2 mg/kg-d was used for the owl based on a NOAEL in kestrels (Attachment B). The TRV was selected because the owl has similar feeding habits to those of kestrels, but it is in a different order. The TRV range for the simulation was 4.8 to 14.5 (Table K2-1-4).

The Eco-PRG ranges from a low of 1,899 mg/kg to a high of 59,283 mg/kg. The mean Eco-PRG for the burrowing owl is 6,921 mg/kg.

K2-2.6 Black-billed Magpie

The Eco-PRG for the black-billed magpie was estimated with the parameters summarized in Attachment K2-1, Table K2-1-6. A TRV of 4.8 mg/kg-d was used for the magpie that was based on a NOAEL in kestrels (Attachment B) divided by an adjustment factor of 3. To make the PRG estimates adequately conservative for passerine birds, an additional adjustment factor of 3 was incorporated into the TRV, thus setting the range for passerine birds from 1.6 to 4.8 (Table K2-1-2). This encompasses a predicted QCE of 2.8 for starlings (Attachment B).

The Eco-PRG ranges from a low of 168 mg/kg to a high of 24,308 mg/kg. The mean Eco-PRG for the black-billed magpie is 3,591mg/kg.

K2-2.7 Mule Deer

The Eco-PRG for the mule deer was estimated with the parameters summarized in Attachment K2-1, Table K2-1-7. The TRV used for the mule deer was based on a study with cattle (Attachment B), which are ruminants as are the deer.

The Eco-PRG ranges from a low of 144 mg/kg to a high of 167,197 mg/kg. The wide range of uncertainty is due predominantly to the wide range for the PUF for the vegetation. The large AUF for the mule deer increases the Eco-PRG accordingly, since the area of the site is such a small component of the deer's' home range. The mean Eco-PRG for the mule deer is 23,881mg/kg.

K2-2.8 Pygmy rabbit

The Eco-PRG for the pygmy rabbit was estimated with the parameters summarized in Attachment K2-1, Table K2-1-8. The TRV is based on a chronic study with dogs and rats. The Azar et al. (1973) study selected as the most scientifically justified TRV was reviewed. This study examined the chronic toxicity of lead acetate to dogs (0, 10, 50, 100, and 500 ppm) and rats (0, 10, 50, 100, 500, 1,000, and 2,000 ppm). The endpoints evaluated included blood chemistry, reproduction, mortality, behavior, and histopathology.

Male rats appeared more sensitive to lead than females and apparently exhibited mortality at a lower dose. There were no statistics performed by the authors on the mortality data for rats. A chi-square test run on the data indicated that mortality between the controls and treatment levels was not significantly different below a dietary level of 2,000 ppm. This statistical analysis resulted in a NOAEL of 1,000 ppm diet and a Lowest Observed Adverse Effect Level (LOAEL) of 2,000 ppm diet for mortality.

Male rats exhibited kidney tumors at 500, 1,000, and 2,000 ppm lead acetate in diet, whereas female rats did not exhibit pathology below 2,000 ppm lead acetate in diet. Kidney tumors are not an ecologically relevant endpoint, particularly since in this study there is no direct link between population effects or reproductive effects. If tumors are lethal during the normal lifespan of the animal, and the tumor rates high enough, the endpoint will be exhibited as significantly decreased survival. Significantly decreased survival was not observed below a dietary concentration of 2,000 ppm.

There were no effects on reproductive indices including number of pregnancies, number of pups born alive, fertility index, gestation index, viability index, or lactation index throughout the chronic multigenerational study. However, offspring exposed to 1,000 ppm lead exhibited decreased body weight. This is an ecologically relevant endpoint since decreased body weight or growth could preclude survival in the wild. Based on this discussion, it was determined that for the rat, the NOAEL for growth of offspring is 500 ppm, and the LOAEL is 1,000 ppm. Insufficient data were provided by the author to test this endpoint significantly, but it provides the same NOAEL as measured for dogs, and thus appears to be a technically justified number.

The TRV for rabbit, bat, and deer mouse in the Monte Carlo analysis was thus set at 500 ppm (40 mg/kg-d) divided by the R value for taxonomic relatedness and trophic level. This TRV is based on an endpoint of body weight of offspring. Considering that these data are based on consumption of lead acetate, which has a higher bioavailability and toxicity than inorganic lead, this TRV should be adequately conservative to represent mammalian exposure to inorganic or organic lead compounds at the INEEL. A lower bound to the TRV was set by dividing the most likely TRV value (40 mg/kg-d) by 3 (Table K2-1-8).

The Eco-PRG ranges from a low of 21 mg/kg to a high of 34,573 mg/kg. The uncertainty in this estimate is largely due to the large PUF, which spans about 5 orders of magnitude. The mean Eco-PRG for the pygmy rabbit is 3,626 mg/kg.

K2-2.9 Townsend's Big-Eared Bat

The Eco-PRG for the bat was estimated with the parameters summarized in Attachment K2-1, Table K2-1-9. Since bats roost in caves, mines, and buildings (Fitzgerald at al, 1994), they have minimal contact with soil. Their prey includes flying insects and they skim water to drink. As such, soil ingestion represents an insignificant exposure pathway. Including this pathway overestimates potential risk to bats, and it was therefore removed from the Eco-PRG calculation. The TRV of 40 mg/kg-d was used to represent toxicity to the bat. The most likely value for the TRV was 20 mg/kg-d based on taxonomic and trophic level relationships between the bat and the study animal (the rat), with the low end of the range set by dividing the TRV of 40 mg/kg-d by 3. The bat and the rat, although in a different order, fill a similar trophic level.

The Eco-PRG ranges from a low of 23,924 mg/kg to a high of 208,582 mg/kg. The mean Eco-PRG for the bat is 66,790 mg/kg. The uncertainty in this estimate is due largely to the BAF for invertebrates, as well as the species-specific exposure parameters for the bat. The Eco-PRG is high since there is no direct soil ingestion exposure.

K2-2.10 Coyote

The Eco-PRG for the coyote was estimated with the parameters summarized in Attachment K2-1, Table K2-1-10. The TRV for the coyote was based on a NOAEL for dogs (Azar et al., 1973), which are taxonomically related to the coyote and in a similar trophic level (Attachment B). The most likely TRV is that derived from the study (3.3 mg/kg-d) with an R factor for taxonomic or trophic level uncertainty of 1, while the lower bound was set by dividing the most likely TRV by a factor of 3. The TRV range was thus 0.81 to 3.3 mg/kg-d.

The Eco-PRG ranges from a low of 151,814 mg/kg to a high of 8,321,196 mg/kg. The mean Eco-PRG for the coyote is 903,791 mg/kg. The uncertainty is due largely to uncertainty in the small mammal prey BAF, which spans four orders of magnitude.

K2-2.11 Deer Mouse

The Eco-PRG for the deer mouse was estimated with the parameters summarized in Attachment K2-1, Table K2-1-11. The TRV for the deer mouse was based the study with rats (Azar et al., 1973) described above for the pygmy rabbit. This study produced a TRV of 40 mg/kg-d. Based on the taxonomic similarity between rats and deer mice (both are in the Order Rodentia), and the fact both are omnivorous, an R factor of 1 was applied to select the most likely value. The lower bound was set by dividing the TRV by 3 as shown in Table K2-1-11.

The Eco-PRG ranges from a low of 23 mg/kg to a high of 3,562 mg/kg. The mean Eco-PRG for the deer mouse is 1,140 mg/kg.

Table K2-1. Summary of Monte Carlo Lead in Soil Eco-PRG Results for Mammals and Birds

Receptor	$Eco\text{-}PRG_{0\%}$ (mg/kg)	$Eco\text{-}PRG_{50\%}$ (mg/kg)	$Eco\text{-}PRG_{80\%}$ (mg/kg)	$Eco\text{-}PRG_{100\%}$ (mg/kg)	Mean Eco-PRG (mg/kg)
Mourning dove	5,226	379,217	692,877	2,946,779	442,624
Sage sparrow	105	247	332	763	263
Ferruginous hawk	97,062	325,272	479,417	2,389,995	378,451
Loggerhead shrike	400	1,155	1,756	12,721	1,386
Burrowing owl	1,899	5,839	8,796	59,283	6,921
Black-billed magpie	168	3,172	4,858	24,308	3,591
Mule deer	144	14,601	40,527	167,197	23,881
Pygmy rabbit	21	2,134	5,927	34,573	3,626
Townsend's big-eared bat	23,924	62,415	83,627	208,582	66,790
Coyote	151,814	769,549	1,161,931	8,321,196	903,791
Deer mouse	23	1,102	1,650	3,562	1,140

K2-3. PLANTS

Plants are continuously exposed to contaminants in soils. Physical conditions in the soil such as pH or cation exchange capacity (CEC) can affect the toxicity of metals to plants. Different plant species are more tolerant of metal exposure than others. Table K2-2 presents the Eco-PRGs for plants.

A literature review was conducted to obtain a wide range of toxicity reference values (TRVs) for plants of different species and for different soil types. TRVs were obtained from ORNL (1997), EPA (1992), and Geballe et al. (1990). Only studies where toxicity was studied by exposing plants in soil were used. Studies that indicated soil pH levels were below 4 were not used in the estimation of a PRG since metal bioavailability increases with increasing acidity, and soils at the INEEL are not expected to be highly acidic.

Table K2-2. Plant Lead Soil Eco-PRGs based on NOEC and EC_{25} Values

NOEC (mg/kg)	$Eco\text{-}PRG_{NOEC}$ (mg/kg)	PRG_{25} (mg/kg)	$Eco\text{-}PRG_{25}$ (mg/kg)	EC_{25} (mg/kg)
334	334** 353*	453	453** 469*	561

* Monte Carlo simulation range maximum
** Monte Carlo simulation range mean
NOEC—no observed effects concentration
mg/kg—milligram per kilogram

Table K2-3 presents the information for lead toxicity in plants. Studies that indicated a no observed effect concentration (NOEC) were averaged to obtain a mean of 334 mg lead/kg soil. Studies that had some effects up to a 25% reduction in a measured parameter such as biomass, growth, leaf area, or root length were averaged to obtain a value termed the EC_{25}. This value is expected to produce nonlethal effects in up to 25% of the exposed population. The NOEC was 334 mg/kg, and the EC_{25} was 561 mg/kg.

The values used in the EC_{25} were also averaged with the NOEC values to obtain a soil concentration that would be unlikely to significantly affect plants in the field. This average was labeled the PRG_{25}. The PRG_{25} is an average of the NOEC and EC_{25} values that were reported to produce a 25% change relative to the controls in some type of effect (i.e., reduction in root or shoot length or biomass). Thus, the PRG_{25} is a soil concentration below which nonlethal effects are expected in less than 25% of the population.

A toxicity value associated with a decrease in survival was not considered an appropriate endpoint for development of the PRG_{25} or the EC_{25}. The mean of the NOEC values and the values associated with a 25% or less reduction in the measured endpoint was 453 mg lead/kg soil.

Each of the TRVs selected for inclusion into the NOEC or the PRG_{25} was assigned a triangular distribution with a minimum and maximum of 10% of the reported value. In a triangular distribution, most of the TRV distribution falls near the reported TRV value. Assigning a distribution for each TRV value adjusts for the inherent variation in soil concentrations and analytical variability likely to occur in plant toxicity tests. However, actual uncertainty in each study could be higher or lower. Using a value of 10% around the reported TRV allows incorporation of uncertainty into the Eco-PRG estimate, which makes the estimate more realistic.

A Monte Carlo uncertainty analysis was performed with Crystal Ball® on the NOEC and the PRG_{25} estimates. This analysis repeatedly selects a value from within the assumed distribution of each of the TRV values, and recalculates the mean NOEC or PRG_{25} with each set of TRV estimates. This process was repeated for 2,000 iterations. The result of the simulation is shown in Table K2-2 as the Eco-PRG_{NOEC} and the Eco-PRG_{25}. The mean Eco-PRG is nearly identical to the value obtained without Monte Carlo analysis; this is because the distributions for each parameter were equal. The maximum Eco-PRG represents the highest Eco-PRG that can be expected given the minimal uncertainty incorporated into the analysis.

The Eco-PRG_{NOEC} soil concentrations from the Monte Carlo simulation, incorporating uncertainty in the underlying data, range from 315 mg/kg to 353 mg/kg. This means that soil concentrations as high as 353 mg lead/kg soil are within an expected NOEC soil concentration and are not expected to produce phytotoxicity. The Eco-PRG_{25} soil concentrations from the Monte Carlo simulation, incorporating uncertainty in the underlying data, range from 431 mg/kg to 470 mg/kg. This means that soil concentrations as high as 470 mg lead/kg soil are below an expected EC_{25} soil concentration and are not expected to produce phytotoxicity.

Generally, a change of at least 20% or more must be observed to be statistically different and detectable under field conditions (Efroymson et al., 1997). The EC_{25} includes only values at which effects were observed in up to 25% of the population. Therefore, the EC_{25} represents a soil concentration above which adverse effects might begin to be observed in the field. Furthermore, the endpoints cited in the studies do not necessarily indicate a loss of ecosystem function in that a reduction in root or shoot weight may be no more damaging to the habitat than the impacts of intermittent, mild grazing.

Given the wide number of plant species evaluated, use of a value as high as 353 mg/kg would be adequately protective of plant communities at the INEEL. Thus, 353 mg/kg is the lead Eco-PRG_{NOEC} for plants. However, management decisions should also consider the EC_{25} as a potential and reasonable cleanup goal, since no loss of ecosystem structure or function is expected based on the studies reviewed and used to develop this value. The EC_{25} would be acceptable in disturbed or industrialized areas, around buildings.

The data used to develop the Monte Carlo uncertainty analysis for lead toxicity for plants were obtained from the following sources:

- EPA, 1992. Ecological Effects of Soil Lead Contamination. Toxics Integration Branch, Office of Emergency and Remedial Response. September 9, 1992.
- Efroymson et al., 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. November 1997. ES/ER/TM-85/R3.
- Geballe et al., 1990

These three sources offer a compilation and review of other work, and together provide a presumably complete summary of the toxicity of lead to plants for the period leading up to 1997. Thus, these represent fairly current data. Many studies were reviewed by both reports; the extent of overlap between the two reports suggests that the summary is comprehensive up to 1997. The wide range of species, soil types, and lead compounds for which data are reported increase confidence in the resulting Eco-PRG for plants.

The species for which data were available include common agricultural crops (i.e., lettuce, radish, and corn), as well as agricultural crops that have wild relatives on the INEEL such as wheat, rye, fescue, or oat. The soil conditions and the lead speciation and their effect on bioavailability are likely to affect the toxicity of lead to plants as much as species-specific variables such as root uptake rate. For example, a study by John and van Laerhoven (1972) reported a difference of 10% leaf reduction (a factor of 1.4) within the same species for two chemical formulations of lead under identical soil conditions. A factor of 2 variation was observed in the LOEC for radish for exposure to two lead formulations under similar test conditions (Khan & Frankland 1983). Varying the soil pH from 4.8 to 7.8, while increasing both cation exchange capacity (CEC) and organic matter increased reduction in root weight from 25 to 52% (a factor of 2.1) for exposure of bluestem to $PbCl_2$ (Miles and Parker, 1979b).

A similar range of variability in response to lead is observed for between species comparisons. Under similar test conditions, the NOEC for a reduction in root weight ranging between 24 and 37% for PbCl2 varied by a factor of 5 between three species, but the LOEC varied by only a factor of 2 (Khan & Frankland, 1984). Thus, it appears that the uncertainty in the lead PRG ranges between only a factor of 1.4 to 5 given the existing data.

The PRG_{25} Monte Carlo results range from between 431 to 470 mg lead/kg soil after incorporating the uncertainty in the data. The low end of this range (i.e., 431 mg/kg) is recommended as the plant lead Eco-PRG_{25}. Thus, minimal effects on plants are not expected to occur below soil concentrations of 431 mg/kg. This indicates that there is a margin of safety between the recommended NOEC-based Eco-PRG of 353 mg/kg, and a PRG at which some minimal effects on vegetation might be observed. Attachment K2-4 presents the results of the Monte Carlo analysis, including percentiles and statistics, for the NOEC and PRG_{25} Eco-PRGs for all plant species.

In response to EPA concerns regarding the appropriateness of the plants used to determine the literature TRVs, an additional simulation using the EC_{25} values was run. For this simulation, only little bluestem was included in the simulation. There were no NOEC values in this limited dataset, and only EC_{25} values from the literature studies were included. The mean Eco-PRG_{25} calculated for this simulation was 401 mg/kg, with a range of 354 to 426 mg/kg. Since this value is similar to the recommended Eco-PRG_{25} of 431 mg/kg, the original simulation results with all species were retained for final evaluation. Attachment K2-4 presents the results of the Monte Carlo analysis, including percentiles and statistics, for the PRG_{25} Eco-PRG for little bluestem only.

The studies upon which the Eco-PRG_{25} is based are shown in Table K2-3. They represent a wide range of soil and test conditions and plant species, which increases the likelihood that they will be adequately representative of the wide range of field conditions at the INEEL. Table K2-3 lists the effects observed at each soil lead concentration for various plant species. This soil lead concentration corresponds to the TRV listed. Some decrease in survival in black-eyed susan, the most sensitive plant species of those listed, occurred at 450 mg/kg, and high mortality for this species was associated with 900 mg/kg. Thus, the Eco-PRG_{25} (431 mg/kg) appears to be adequately protective of most plant species, and would cause only minimal effects to the most sensitive of species. The NOEC-based Eco-PRG (353 mg/kg) would be completely protective of even the most sensitive plant species listed.

Table K2-3. Summary of Effects of Lead in Soil on Plants

Taxa	TRV (mg/kg)	Effect	Reference
Red oak	20	Soil NOEC	Dixon, 1988a[1]
Red Oak	26	29% decrease in leaf area; soil was sandy loam @ pH 6, 16 weeks	Dixon 1988b[2]
Red oak	50	Reduced biomass by 26%. Same study as EPA but using nominal soil concentrations	Dixon, 1988a[1]
Sycamore	50	30% reduction in leaf weight	Carlson and Bazzaz, 1977 [1]
Autumn olive	80	Soil NOEC	Rolfe and Bazzaz, 1975 [1]
Mixed Species	95	Decreased root growth	Majdi and Persson, 1989 [2]
Oat	100	NOEC	Khan and Frankland 1984 [1]
Radish	100	Soil NOEC	Khan and Frankland 1983 [1]
Corn	125	Decreased biomass; pH 6, 17 and 24 days	Miller et al. 1977a [2]
Corn	125	Soil NOEC	Miller et al. 1977b [1]
Autumn olive	160	25% reduction in transpiration	Rolfe and Bazzaz 1975 [1]
Red Spruce	200	NOEC: No effect on vigor, height, diameter, or live bud content	Geballe et al. 1990
Corn	250	Decreased root growth	Miller et al. 1977a [2]
Corn	250	42 % reduction in plant weight	Miller et al. 1977b [1]
Corn	250	Soil NOEC	Hassett et al. 1976 [1]
Little Bluestem	295.47	25% decreased root biomass	Miles and Parker 1979a [2]
Wheat	300	Soil NOEC	Muramoto et al. 1990 [1]
Little Bluestem	340.81	25% decreased biomass; @ pH 4.8	Miles and Parker 1979a [2]
Black-eyed Susan	450	Decreased survival in acid soil	Miles and Parker 1979a [2]
Little Bluestem	450	52 % reduction in root & shoot weights	Miles and Parker 1979b [1]
Little Bluestem	450	25% reduction in root weight	Miles and Parker 1979b [1]
Corn	500	48% reduction in root length	Hassett et al. 1976 [1]

Taxa	TRV (mg/kg)	Effect	Reference
Oat	500	37 % reduction in root weight	Khan and Frankland 1984 [1]
Radish	500	24% reduction in root weight	Khan and Frankland 1983 [1]
Wheat	500	NOEC	Khan and Frankland 1984 [1]
Little Bluestem	516.69	25% decrease in shoot weight	Miles and Parker 1979a [2]
Black-eyed Susan	900	100% mortality in mortality	Miles and Parker 1979a [2]
Little Bluestem	900	Decreased survival @ pH of 7.82	Miles and Parker 1979a [2]
Fescue	1000	Soil NOEC	Carlson and Rolfe 1979 [1]
Lettuce	1000	35 % reduction in leaf weight	John and van Laerhoven 1972 [1]
Lettuce	1000	25 % reduction in leaf weight	John and van Laerhoven 1972 [1]
Radish	1000	27 % reduction in root weight	Khan and Frankland 1983 [1]
Rye	1000	Soil NOEC	Carlson and Rolfe 1979 [1]
Wheat	1000	34 % reduction in root weight	Khan and Frankland 1984 [1]
Wheat	1000	22% reduction in root & shoot weights	Muramoto et al. 1990 [1]
Red Spruce	2000	Reduced vigor and diameter	Geballe et al. 1990 [3]
Fescue	5000	31% reduction in shoot weight	Carlson and Rolfe 1979 [1]
Rye	5000	46 % reduction in shoot weight	Carlson and Rolfe 1979 [1]

[1] Efroymson, R. A. , M. E. Will, G. W. Suter II, A. C. Wooten. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Contract No. DE-AC05-84OR21400. ES/ER/TM-85/R3

[2] EPA. 1992. Ecological Effects of Soil Lead Contamination. Toxics Integration Branch. Office of Emergency and Remedial Response. September 1992.

[3] Geballe, G.T., W.H. Smith, and P.M. Waroo. 1990. Red Spruce Seedling Health: an assessment of acid fog deposition and heavy metal soil contaminationas interactive stress factors. Canadian Journal of Forest Research 20:1680-1683.

K2-4. CONCLUSIONS

The mean wildlife Eco-PRGs for lead range from 263 mg/kg for the sage sparrow to 903,791 mg/kg for the coyote. These estimates are conservative since they incorporate conservative exposure assumptions, such as emphasizing the lower range of body weight in the triangular distributions, and do not include factors for seasonal migration. Since many of the OU 10-04 receptors are migratory or hibernate, this enhances conservatism for many receptors.

The PRG estimates use the most scientifically justified TRV. The TRV was determined by review of the literature and selection of the TRV from the most appropriate study given the taxonomic similarity to the receptor species, with the overall best design, and the lowest magnitude of uncertainty factors. The most likely TRV then was adjusted to be more conservative by incorporating an adjustment factor of 3 for taxonomic variability. The mourning dove had the widest range of uncertainty of all of the receptors evaluated due the wide range of variability in the PUF, which spans six orders of magnitude. Since the mourning dove was modeled as being completely herbivorous, the PUF had a larger impact on the uncertainty estimates than it would for a species modeled as omnivorous.

The NOEC-based Eco-PRG for plants (353 mg/kg) would be adequately protective of even the most sensitive plant species listed in Table K2-3. Therefore, the plant Eco-PRG of 353 mg/kg is recommended for vegetation in direct exposure to lead in soils.

K2-4.1 Recommendations:

Use of a single soil lead Eco-PRG of 263 mg/kg for the sage sparrow would be protective of all plant and wildlife ecological receptors evaluated at the STF-01. Note that the Eco-PRG was based on a HQ of 1. The STF-01 site is only 1.31 ha. In small areas such as this, entire populations of even small animals are not expected to occur, and any effects would be at an individual level. Thus, a higher HQ could be tolerated without the risk of adverse population effects.

The NOAEL-based TRVs contain an uncertainty factor of 3. Removing this uncertainty factor would increase the TRV for the sage sparrow to 14.5, which since the equation is linear is equivalent to using an HQ of 3 or multiplying the Eco-PRG by 3. This would suggest that soil lead concentrations as high as 789 mg/kg would not affect the sage sparrow, particularly if the lead contamination was highly localized, and in only a few areas. This is supported by the fact that the maximum Eco-PRG for the sage sparrow, obtained when all exposure parameters are minimized, was 763 mg/kg. However, these concentrations exceed the EC_{25} value for plants.

Thus, it is recommended that the Eco-PRG for the sage sparrow be used to screen the data for lead exceedances. However, an upper bound on lead levels should be considered based on the lowest percentile for the plant $Eco\text{-}PRG_{25}$, which is 431 mg/kg. Lead concentrations below this value would protect plant communities, as well as wildlife populations.

Therefore for consistency in remediation goals, 400 mg/kg is recommended as the ECO-PRG. This is the same as is recommended for human receptors.

K2-5. REFERENCES

Azar, A., H.J. Trochimowicz, M.E. Maxfield, 1973. Review of lead studies in animals carried out at Haskell Laboratory: Two-year feeding study and response to hemorrhage study. In: *Environmental Health Aspects of Lead: Proceedings, International Symposium,* D. Barth et al., (ed.), Commission of European Communities, pp. 199-210.

Bechard, M.J., K.D. Hague-Bechard, and D.H. Porter. 1986. Historical and current distributions of Swainson's and Ferruginous Hawks in southern Idaho. Dept. Biol., Boise St. Univ., Boise. 58pp. http://imnh.isu.edu/digitalatlas/splash_navigate/pcmain.htm

Beyer, W.N., E.E. Conner, and S. Gerould. 1994. Estimates of Soil Ingestion by Wildlife. Journal of Wildlife Management 58:375-382.

California Department of Fish and Game. 2001. Website. http://www.dfg.ca.gov/whdab/M037.html.

Carlson, R. W. and F. A. Bazzaz. 1977. Growth reduction in American Sycamore (*Plantanus occidentalis* L.) caused by Pb-Cd interaction. *Environ. Pollut.* 12:243-53. In: Efroymson, R. A., M. E. Will, G. W. Suter II, A. C. Wooten. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Contract No. DE-AC05-84OR21400. ES/ER/TM-85/R3.

Carlson, R.W. and G.L. Rolfe. 1979. Growth of Rye Grass and Fescue as Affected by Lead-Cadmium-Fertilizer Interaction. Journal of Environmental Quality 8:349-353. In: Efroymson, R. A., M. E. Will, G. W. Suter II, A. C. Wooten. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Contract No. DE-AC05-84OR21400. ES/ER/TM-85/R3.

Donker, M.H., H.E. van Capelleveen, and N.M. van Straalen. 1993. Metal Contamination Affects Size-Structure and Life-History Dynamics in Isopod Field Populations. Chapter 19. Ecotoxicology of Metals in Invertebrates. Lewis Publishers. pp. 384-399.

Dixon, R.K. 1988a. Response of Ectomycorrhizal *Quercus rubra* to Soil Cadmium, Nickel, and Lead. Soil Biology and Biochemistry 20:555-559. In: U.S. Environmental Protection Agency (EPA). 1992. Ecological Effects of Soil Lead Contamination. Toxics Integration Branch, Office of Emergency and Remedial Response. September 9, 1992.

Dixon, R.K. 1988b. Response of Ectomycorrhizal *Quercus rubra* to Soil Cadmium, Nickel, and Lead. Soil Biology and Biochemistry 20:555-559. In: Efroymson, R. A., M. E. Will, G. W. Suter II, A. C. Wooten. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Contract No. DE-AC05-84OR21400. ES/ER/TM-85/R3.

Dunning, J.B. Jr. 1993. CRC Handbook of Avian Body Masses. CRC Press, Boca Raton, FL, 371 pp.

Efroymson, R. A., M. E. Will, G. W. Suter II, A. C. Wooten. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Contract No. DE-AC05-84OR21400, ES/ER/TM-85/R3.

Fisher, J.W., T. A. Whittaker, D.H. Taylor, H.J. Clewell III, and M.E. Anderson. 1989. Physiologically Based Pharmacokinetic Modeling of the Pregnant Rat: A Multiroute Exposure Model for Trichloroethylene and its Metabolite, Trichloroacetic Acid, Toxicology and Applied Pharmacology 99:395-414.

Fitzgerald, J.P., C. A. Meaney, and D. M. Armstrong. 1994. Mammals of Colorado. Denver Museum of Natural History and University Press of Colorado. 467 pp.

Franson et al., 1983. Effects of Chronic Dietary Lead in American Kestrels (*Falco sparverius*). Journal of Wildlife Diseases 19:110-113.

Geballe, G.T., W.H. Smith, and P.M. Waroo. 1990. Red Spruce Seedling Health: an assessment of acid fog deposition and heavy metal soil contamination as interactive stress factors. Canadian Journal of Forest Research 20:1680-1683.

Hassett, J.J., J.E. Miller, and D.E. Koeppe. 1976. Interaction of Lead and Cadmium on Maize Root Growth and Uptake of Lead and Cadmium by Roots. Environmental Pollution 11:297-303. In: Efroymson, R. A., M. E. Will, G. W. Suter II, A. C. Wooten. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Contract No. DE-AC05-84OR21400. ES/ER/TM-85/R3.

Hoffman et al., 1985. Survival, Growth, and Accumulation of Ingested Lead in Nestling American Kestrels (*Falco sparverius*). Archives Environmental Contamination and Toxicology 14:89-94.

John, M. K. and C. Van Laerhoven. 1972. Lead uptake by lettuce and oats as affected by lime, nitrogen, and sources of lead. *J. Environ. Qual.* 1(2):169-171. In: Efroymson et al., 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. November 1997. ES/ER/TM-85/R3

Johnsgard, P.A. 1990. Hawks, Eagles, and Falcons of North America. Biology and Natural History. Smithsonian Institution Press, Washington, D.C. pg. 248.

Khan, D. H. and B. Frankland. 1983. Effects of cadmium and lead on radish plants with particular reference to movement of metals through soil profile and plant. *Plant Soil.* 70:335-345.In: Efroymson et al., 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. November 1997. ES/ER/TM-85/R3

Khan, D.H. and B. Frankland. 1984. Cellulolytic Activity and Root Biomass Production in Some Metal Contaminated Soils. Environmental Pollution Series A 33:63-74. In: Efroymson et al., 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. November 1997. ES/ER/TM-85/R3

Madji, H. and H. Persson. 1989. Effects of Road-Traffic Pollutants (Lead and Cadmium) on Tree Fine-Roots Along a Motor Road. Plant and Soil 119:1-5. In: U.S. Environmental Protection Agency (EPA). 1992. Ecological Effects of Soil Lead Contamination. Toxics Integration Branch, Office of Emergency and Remedial Response. September 9, 1992.

Miles, L.J. and G.R. Parker. 1979a. Heavy Metal Interactions for *Andropogon scoparius* and *Rudbeckia hirta* Grown on Soil from Urban and Rural Sites with Heavy Metals Additions. Journal of Environmental Quality 8:443-450. In: U.S. Environmental Protection Agency

(EPA). 1992. Ecological Effects of Soil Lead Contamination. Toxics Integration Branch, Office of Emergency and Remedial Response. September 9, 1992.

Miles, L.J. and G.R. Parker. 1979b. Heavy Metal Interactions for *Andropogon scoparius* and *Rudbeckia hirta* Grown on Soil from Urban and Rural Sites with Heavy Metals Addtions. Journal of Environmental Quality 8:443-450. In: Efroymson et al., 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. November 1997. ES/ER/TM-85/R3

Miller, J.E., J.J. Hassett, and D.E. Koeppe. 1977a. Interactions of Lead and Cadmium on Metal Uptake and Growth of Corn Plants. Journal of Environmental Quality 6:18-21. In: U.S. Environmental Protection Agency (EPA). 1992. Ecological Effects of Soil Lead Contamination. Toxics Integration Branch, Office of Emergency and Remedial Response. September 9, 1992.

Miller, J.E., J.J. Hassett, and D.E. Koeppe. 1977b. Interactions of Lead and Cadmium on Metal Uptake and Growth of Corn Plants. Journal of Environmental Quality 6:18-21. In: Efroymson, R. A., M. E. Will, G. W. Suter II, A. C. Wooten. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Contract No. DE-AC05-84OR21400. ES/ER/TM-85/R3.

Muramoto, S., H. Nishizaki, and I. Aoyama. 1990. The critical levels and the maximum metal uptake for wheat and rice plants when applying metal oxides to soil. *J. Environ. Sci. Health, Part B* 25(2):273-80. In: Efroymson, R. A., M. E. Will, G. W. Suter II, A. C. Wooten. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Contract No. DE-AC05-84OR21400. ES/ER/TM-85/R3.

ORNL. 1998. Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants. Prepared by Bechtel Jacobs Company LLC, Oak Ridge National Laboratory, Contract No. DE-AC05-98OR22700. BJC/OR-133. September 1998.

Palmer, E.L. and H.S. Fowler, 1975. Fieldbook of Natural History. 2nd. Ed. McGraw-Hill Book Company, New York. 779 pp.

Peterson, 1982. RVH

Peterson, K.L. and L.B. Best. 1985. Nest-site selection by Sage Sparrows. Condor 87:217-221. http://imnh.isu.edu/digitalatlas/splash_navigate/pcmain.htm

Reeves, H.M., R.E. Tomlinson, and J.C. Bartonek. 1993. Population characteristics and trends in the western management unit. Pp. 341-376 in T.S. Basket et al., eds. Ecology and management of the mourning dove. Stackpole Books, Harrisburg, PA. http://imnh.isu.edu/digitalatlas/splash navigate /pcmain.htm

Rich, T. 1986. Habitat and nest-site selection by burrowing owls in the sagebrush steppe of Idaho. Journal of Wildlife Management 50:548-555. http://imnh.isu.edu/digitalatlas/splash_navigate /pcmain.htm.

Rolfe, G. L. and F. A. Bazzaz. 1975. Effect of lead contamination on transpiration and photosynthesis of loblolly pine and autumn olive. *Forest Sci.* 21(1):33-35. In: Efroymson, R. A., M. E. Will, G. W. Suter II, A. C. Wooten. 1997. Toxicological Benchmarks for

Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Contract No. DE-AC05-84OR21400. ES/ER/TM-85/R3.

Shore, R.F. 1995. Predicting Cadmium, Lead, and Fluoride Levels in Small Mammals from Soil Residues and by Species-Species Extrapolation. Environmental Pollution 88:333-340.

U.S. Environmental Protection Agency (EPA). 1992. Ecological Effects of Soil Lead Contamination. Toxics Integration Branch, Office of Emergency and Remedial Response. September 9, 1992.

______. 1993. Wildlife Exposure Factors Handbook. EPA/600/R-93/187b. December 1993.

______. 1999. Risk Assessment Guidance for Superfund: Volume 3 (Part A – Process for Conducting Probabilistic Risk Assessment) Draft, Revision 5. Office of Solid Waste and Emergency Response. EPA 000-0-99-000, December 1999.

______. 2000. Ecological Soil Screening Level Guidance. Draft. Office of Emergency and Remedial Response. Washington, D.C. July 10, 2000.

Van Horn, R.H., N.L. Hampton, and R.C. Morris. 1995. Guidance Manual for Conducting Screening Level Ecological Risk Assessments at the INEL. INEL-95/0190, Rev. 1, June 1995.

Woods, C.P. and T.J. Cade. 1996. Nesting habits of the loggerhead shrike in sagebrush. Condor 98:75-81. http://imnh.isu.edu/digitalatlas/splash_navigate/pcmain.htm.

Zmudski, J., et al., 1983, "Lead poisoning in cattle: Reassessment of the minimum toxic oral dose," *Bulletin of Environmental Contamination*, 30:435-441.

Attachment 1

Summary of Input Parameters and Data Used for the Wildlife Monte Carlo Simulation

Table A1-1. Summary of Parameters Used to Derive the PRG for the Mourning Dove.

Mourning Dove	PRG (mg/kg)	TRV (mg/kg-d)	BW (kg)	PP	BAF	PV	PUF	PS	AUF
	1.04E+05	4.80	0.115	0.000	0.000	0.932	0.343	0.069	0.00096

Parameter	Abbreviation	Minimum	Maximum	Notes:
Toxicity Reference Value (mg/kg-d)	TRV	4.8	14.5	TRV is from kestrel studies (Franson et al., 1983 and Hoffman et al., 1985). Range (QCE/R) is from 4.8 to 14.5 mg/kg-d. Used triangular distribution with 4.8 mg/kg-d as most likely based on taxonomic/trophic level relationship to kestrels (R=3).
Body Weight (g)	BW	NA	NA	Males: mean 123 g, standard deviation 1.85 g. Females mean 115 g, standard deviation (SD) 1.76 g from Dunning 1993. Assumed normal distribution; used lowest mean body weights to be conservative (i.e., female mean weight and SD with mean as most likely value). Range not provided.
Percent Prey	PP	0	0	NA - dove is herbivorous
Prey Bioaccumulation Factor	BAF	0	0	NA - dove is herbivorous
Percent Vegetation	PV	89.6	96.7	Difference between 100% and percent lost to soil ingestion; triangular distribution with midpoint of range (93.2%) set as the most likely value.
Plant Uptake Factor	PUF	0.000113	10.601	ORNL 1998 evaluation of lead uptake identified mean and SD as well as that data fit lognormal distribution. Used lognormal distribution with mean of 0.343 and SD of 1.078. Minimum and maximum values also provided by ORNL (1988).
Percent Soil	PS	3.3	10.4	Mallard (3.3%), woodcock (10.4%) values from Beyer et al., 1994 used as most closely related in feeding guild and behavior. Triangular distribution with likeliest value is the midpoint of the range.
Home Range	HR	1232	1505.9	Assume 10% variation around HR of 1369 ha (Reeves et al., 1993).
Area Use Factor	AUF	0.00087	0.00106	Based on site area of 1.31 ha for the Bermed Area. AUF is site area divided by most likely HR (1.31/1369= 0.00096) for a triangular distribution with most likely value of 0.00096, minimum and maximum AUFs are defined by site area divided by minimum and maximum HR.
Dietary Ingestion Rate (g dm/d)	IR	Varies	Varies	IR (g dm/d)= 0.0582*(BW^0.651); BW in kg; IR in g dry matter (dm) per day; Nagy equation for avian dietary intake (EPA, 1993). PRG equation incorporates allometric equation and varies around body weight.

Table A1-2. Summary of Parameters Used to Derive the PRG for the Sage Sparrow.

	PRG (mg/kg)	TRV (mg/kg-d)	BW (kg)	PP	BAF	PV	PUF	PS	AUF
Sage Sparrow	155	4.80	0.0193	0.931	0.175	0.000	0.000	0.0685	0.580

Parameter	Abbreviation	Minimum	Maximum	Notes:
Toxicity Reference Value (mg/kg-d)	TRV	4.8	14.5	TRV is from kestrel studies (Franson et al., 1983 and Hoffman et al., 1985). Range (QCE/R) is from 4.8 to 14.5 mg/kg-d. Used triangular distribution with 4.8 mg/kg-d as most likely based on taxonomic/trophic level relationship to kestrels (R=3).
Body Weight (g)	BW	NA	NA	Both sexes combined, mean weight 19.3 g. with standard deviation of 1.20 from Peterson 1982. Assumed a normal distribution with mean as most likely value. Range not available from information provided in Peterson (1982).
Percent Prey	PP	89.6	96.7	Difference between 100% and percent lost to soil ingestion. Used triangular distribution with 93.1% (midpoint of range) as likeliest.
Invertebrate Bioaccumulation Factor	BAF_i	0.08	0.27	BAF for invertebrates: Donker et al., 1993. Triangular distribution with most likely value (0.175) mid-point of range.
Percent Vegetation	PV	0	0	NA-Insectivore
Plant Uptake Factor	PUF	0	0	NA-Insectivore
Percent Soil	PS	3.3	10.4	Mallard, woodcock values from Beyer et al., 1994 used as most closely related in feeding guild and behavior. Assume triangular distribution with likeliest value the midpoint of range (6.85% or 0.0685).
Home Range	HR	2.025	2.475	Assume 10% variation around HR of 2.25 ha (Peterson and Best, 1985).
Area Use Factor	AUF	0.529	0.647	Based on site area of 1.31 ha for the Bermed Area. AUF is site area divided by most likely HR (1.31/2.25= 0.58) for a triangular distribution with most likely value of 0.58, minimum and maximum AUFs are defined by site area divided by minimum and maximum HR.
Dietary Ingestion Rate (g dm/d)	IR	Varies	Varies	IR (g dm/d) =0.0582*BW^0.651; BW in kg; IR in g dry matter (dm) per day; Nagy equation for avian dietary intake (EPA, 1993). PRG equation incorporates allometric equation and varies around body weight.

NA - Not available

Table A1-3. Summary of Parameters Used to Derive the PRG for the Ferruginous Hawk.

Ferruginous Hawk	PRG (mg/kg)	TRV (mg/kg-d)	BW (kg)	PP	BAF	PV	PUF	PS	AUF
	3.84E+05	14.5	1.059	0.934	0.33400	0.000	0.000	0.066	0.00175

Parameter	Abbreviation	Minimum	Maximum	Notes:
Toxicity Reference Value (mg/kg-d)	TRV	4.8	14.5	TRV is from kestrel studies (Franson et al., 1983 and Hoffman et al., 1985). Range (QCE/R) is from 4.8 to 14.5 mg/kg-d. Used triangular distribution with 14.5 mg/kg-d as most likely based on taxonomic/trophic level relationship to kestrels (R=1).
Body Weight (g)	BW	980	2030	Range from 980 to 2030 g from Johnsgard, 1990. Mean for males (1059 g) and females (1231 g) from Dunning 1993. Assumed triangular distribution with range defined by minimum and maximum, and most likely value conservatively set to the lowest mean value of 1059 g.
Percent Prey	PP	89.6	97.2	Difference between 100% and percent lost to soil ingestion. Used triangular distribution with midpoint of range (93.4%) as most likely value.
Prey Bioaccumulation Factor	BAF_c	0.00004	0.667	Estimated small mammal whole body BAF from data from Shore (1995) using conversion factor from Fisher et al. (1989) (Table K2-1-12). Set as triangular distribution with a most likely value of midpoint of range.
Percent Vegetation	PV	0	0	NA
Plant Uptake Factor	PUF	0	0	NA
Percent Soil	PS	2.8	10.4	Red fox, woodcock values from Beyer et al., 1994 used as most closely related in feeding guild and behavior. Triangular distribution with 6.6% most likely value.
Home Range	HR	675	825	Assume 10% variation around HR of 750 ha (Bechard et al., 1986).
Area Use Factor	AUF	0.0016	0.0019	Based on site area of 1.31 ha for the Bermed Area. AUF is site area divided by most likely HR (1.31/750= 0.00175) for a triangular distribution with most likely value of 0.00175. Minimum and maximum AUFs are defined by site area divided by minimum and maximum HR.
Dietary Ingestion Rate (g dm/d)	IR	Varies	Varies	IR (g dm/d)= 0.0582*(BW^0.651); BW in kg; IR in g dry matter (dm) per day; Nagy equation for avian dietary intake (EPA, 1993). PRG equation incorporates allometric equation and varies around body weight.

Table A1-4. Summary of Parameters Used to Derive the PRG for the Loggerhead Shrike.

Loggerhead Shrike	PRG (mg/kg)	TRV (mg/kg-d)	BW (kg)	PP	BAF	PV	PUF	PS	AUF
	550	7.2	0.0474	0.934	0.60000	0.000	0.000	0.066	0.124

Parameter	Abbreviation	Minimum	Maximum	Notes:
Toxicity Reference Value (mg/kg-d)	TRV	4.8	14.5	TRV is from kestrel studies (Franson et al., 1983 and Hoffman et al., 1985). Range (QCE/R) is from 4.8 to 14.5 mg/kg-d. Used triangular distribution with 7.2 mg/kg-d as most likely based on taxonomic/trophic level relationship to kestrels (R=2).
Body Weight (g)	BW	40.5	54.1	No sex identified in study, mean weight 47.4 g. with standard deviation of 3.26, and range 40.5 to 54.1 g from Dunning 1993. Assume normal distribution.
Percent Prey	PP	89.6	97.2	Difference between 100% and percent lost to soil ingestion; Used triangular distribution with 93.4% (0.934) as most likely value.
Prey Bioaccumulation Factor	BAF_c	0.00004	0.67	Estimated small mammal whole body BAF from data from Shore (1995) using conversion factor from Fisher et al. (1989) (Table K2-1-12). Set as triangular distribution with a most likely value of midpoint of range.
Percent Vegetation	PV	0	0	Not applicable
Plant Uptake Factor	PUF	0	0	Not applicable.
Percent Soil	PS	2.8	10.4	Red fox, woodcock values from Beyer et al., 1994 used as most closely related in feeding guild and behavior. Triangular distribution with 6.6% most likely value.
Home Range	HR	9.603	11.737	Assume 10% variation around HR of 10.67 ha (Woods and Cade, 1996).
Area Use Factor	AUF	0.112	0.136	Based on site area of 1.31 ha for the Bermed Area. AUF is site area divided by most likely HR (1.31/10.67= 0.124) for a triangular distribution with most likely value of 0.124. Minimum and maximum AUFs are defined by site area divided by minimum and maximum HR.
Dietary Ingestion Rate (g dm/d)	IR	Varies	Varies	IR (g dm/d)= 0.0582*(BW^0.651); BW in kg; IR in g dry matter (dm) per day; Nagy equation for avian dietary intake (EPA, 1993). PRG equation incorporates allometric equation and varies around body weight.

Table A1-5. Summary of Parameters Used to Derive the PRG for the Burrowing Owl.

Burrowing Owl	PRG (mg/kg)	TRV (mg/kg-d)	BW (kg)	PP	BAF	PV	PUF	PS	AUF
	4662	7.2	0.151	0.934	0.33400	0.000	0.000	0.066	0.036

Parameter	Abbreviation	Minimum	Maximum	Notes:
Toxicity Reference Value (mg/kg-d)	TRV	4.8	14.5	TRV is from kestrel studies (Franson et al., 1983 and Hoffman et al., 1985). Range (QCE/R) is from 4.8 to 14.5 mg/kg-d. Used triangular distribution with 7.2 mg/kg-d as most likely value based on taxonomic/trophic level relationship to kestrels (R=2).
Body Weight (g)	BW	120	228	Mean for males, 151 g, with range 129 g -185 g; mean for females is 159 g with range of 120 g - 228 g (Dunning 1993). Use mean for males since this is lower (more conservative) and range for females since this is wider and encompasses both sexes, and assume a triangular distribution.
Percent Prey	PP	89.6	97.2	Difference between 100% and percent lost to soil ingestion; used triangular distribution with 93.4% as most likely value.
Prey Bioaccumulation Factor	BAF_{ci}	0.00004	0.67	Estimated small mammal whole body BAF from data from Shore (1995) using liver/whole body conversion factor from Fisher et al. (1989) (Table K2-1-12). Set as triangular distribution with a most likely value of midpoint of range. Will encompass the invertebrate BAF range since invertebrates an important component of this owl's diet.
Percent Vegetation	PV	0	0	Not applicable- receptor is an insectivore/carnivore
Plant Uptake Factor	PUF	0	0	Not applicable.
Percent Soil	PS	2.8	10.4	Red fox, woodcock values from Beyer et al., 1994 used as most closely related in feeding guild and behavior. Triangular distribution with midpoint (6.6%) the most likely value.
Home Range	HR	32.4	39.6	Assume 10% variation around HR of 36 ha (Rich, 1986).
Area Use Factor	AUF	0.033	0.040	Based on site area of 1.31 ha for the Bermed Area. AUF is 1.31/36=0.036. Triangular distribution with 0.036 most likely value. Minimum and maximum AUFs are defined by site area divided by minimum and maximum HR.
Dietary Ingestion Rate (g dm/d)	IR	Varies	Varies	IR (g dm/d)= 0.0582*(BW^0.651); BW in kg; IR in g dry matter (dm) per day; Nagy equation for avian dietary intake (EPA, 1993). PRG equation incorporates allometric equation and varies around body weight.

Table A1-6. Summary of Parameters Used to Derive the PRG for the Black-Billed Magpie.

Black-billed Magpie	PRG (mg/kg)	TRV (mg/kg-d)	BW (kg)	PP	BAF	PV	PUF	PS	AUF
	1558	4.8	0.166	0.467	0.33400	0.467	0.343	0.066	0.074

Parameter	Abbreviation	Minimum	Maximum	Notes:
Toxicity Reference Value (mg/kg-d)	TRV	4.8	14.5	TRV is from kestrel studies (Franson et al., 1983 and Hoffman et al., 1985). Range (QCE/R) is from 4.8 to 14.5 mg/kg-d. Used triangular distribution with 4.8 mg/kg-d as most likely based on taxonomic/trophic level relationship to kestrels (R=3).
Body Weight (g)	BW	135	197	Males mean weight 189 g, standard deviation (SD) 10.30 g, range 159-209 g. Females mean 166 g, SD of 14.30 g, range 135-197 g (Dunning 1993). Assume normal distribution. Conservatively used mean and SD values for females since lower.
Percent Prey	PP	44.8	48.6	Minimum PP and PV when PS is maximal. Maximum PP and PV when PS is minimal. Triangular distribution with midpoint of range as the likeliest value.
Prey Bioaccumulation Factor	BAFci	0.00004	0.667	Estimated small mammal whole body BAF from data from Shore (1995) using liver/whole body conversion factor from Fisher et al. (1989) (Table K2-1-12). Set as triangular distribution with a most likely value of midpoint of range. Will encompass the invertebrate BAF range since invertebrates an important component of this bird's diet.
Percent Vegetation	PV	44.8	48.6	Minimum PP and PV when PS is maximal. Maximum PP and PV when PS is minimal. Triangular distribution with midpoint of range as the likeliest value.
Plant Uptake Factor	PUF	0.000113	10.601	ORNL 1998 evaluation of lead uptake identified mean and SD as well as that data fit lognormal distribution. Used lognormal distribution with mean of 0.343 and SD of 1.078. Minimum and maximum values also provided by ORNL (1988).
Percent Soil	PS	2.8	10.4	Red fox, woodcock values from Beyer et al., 1994 used as most closely related in feeding guild and behavior. Most likely is midpoint of range due to omnivorous behavior.
Home Range	HR	16.02	19.60	Assume 10% variation around HR of 17.8 ha (Mean of robin, woodcock values; EPA, 1993).
Area Use Factor	AUF	0.067	0.082	Based on site area of 1.31 ha for the Bermed Area. AUF is site area divided by most likely HR (1.31 ha/17.8 ha 0.074). Assume a triangular distribution with most likely value of 0.074. Minimum and maximum AUFs are defined by site area divided by minimum and maximum HR.
Dietary Ingestion Rate (g dm/d)	IR	Varies	Varies	IR (g dm/d)= 0.0582*(BW^0.651); BW in kg; IR in g dry matter (dm) per day; Nagy equation for avian dietary intake (EPA, 1993). PRG equation incorporates allometric equation and varies around body weight.

Table A1-7. Summary of Parameters Used to Derive the PRG for the Mule Deer.

Mule Deer	PRG (mg/kg)	TRV (mg/kg-d)	BW (kg)	PP	BAF	PV	PUF	PS	AUF
	6362	0.075	70.0	0.000	0.000	0.99985	0.343	0.015	0.0012

Parameter	Abbreviation	Minimum	Maximum	Notes:
Toxicity Reference Value (mg/kg-d)	TRV	0.025	0.075	TRV is 0.075 based on toxicity study with cattle (Zmudski et al., 1983). Range (QCE/R) is from 0.025 to 0.075 mg/kg-d. Used triangular distribution with 0.075 mg/kg-d as most likely based on taxonomic/trophic level relationship between study test species and receptor (R=1).
Body Weight (g)	BW	70000	200000	Fitzgerald et al., 1994. Use low end of range as most likely to be conservative since data limited and mean not available.
Percent Prey	PP	0	0	NA - herbivore
Prey Bioaccumulation Factor	BAF_c	0	0	NA - herbivore
Percent Vegetation	PV	99.98	99.99	Difference between 100% and percent lost to soil ingestion
Plant Uptake Factor	PUF	0.000113	10.601	ORNL 1998 evaluation of lead uptake identified mean and SD as well as that data fit lognormal distribution. Used lognormal distribution with mean of 0.343 and SD of 1.078. Minimum and maximum values also provided by ORNL (1988).
Percent Soil	PS	0.01	0.02	Mule deer, white-tailed deer values from Beyer et al., 1994 were <0.02. Assume 0.01 as low end of range.
Home Range	HR	1010.00	1235.00	Assume 10% variation around HR of 1123 ha.
Area Use Factor	AUF	0.0011	0.0013	Based on site area of 1.31 ha for the Bermed Area. AUF is site area divided by most likely HR (1.31 ha/1123 ha = 0.00117). Assume a triangular distribution with most likely value of 0.0012. Minimum and maximum AUFs are defined by site area divided by minimum and maximum HR.
Dietary Ingestion Rate (g dm/d)	IR	Varies	Varies	IR (g dm/d)=0.577*BW^0.727; BW in g; IR in g dry matter (dm) per day; Nagy equation for mammalian herbivore dietary intake (EPA, 1993). PRG equation incorporates allometric equation and varies around body weight.

Table A1-8. Summary of Parameters Used to Derive the PRG for the Pygmy Rabbit.

Pygmy Rabbit	PRG (mg/kg)	TRV (mg/kg-d)	BW (kg)	PP	BAF	PV	PUF	PS	AUF
	413	13.3	0.20	0	0	0.99985	0.343	0.015	0.662

Parameter	Abbreviation	Minimum	Maximum	Notes:
Toxicity Reference Value (mg/kg-d)	TRV	13.33	40	TRV is from rat studies (Azar et al., 1973). Range (QCE/R) is from 13.3 to 40 mg/kg-d. Used triangular distribution with 13.3 mg/kg-d as most likely based on taxonomic/trophic level relationship to rats (R=3).
Body Weight (g)	BW	200	500	Assume triangular distribution from data in EPA, 1993. Use lower bound of range as most likely value since data limited and there is no mean available by which to establish a most likely value.
Percent Prey	PP	0	0	NA – Herbivore
Prey Bioaccumulation Factor	BAF_c	0	0	NA – Herbivore
Percent Vegetation	PV	99.98	99.99	Difference between 100% and percent lost to soil ingestion
Plant Uptake Factor	PUF	0.000113	10.601	ORNL 1998 evaluation of lead uptake identified mean and SD as well as that data fit lognormal distribution. Used lognormal distribution with mean of 0.343 and SD of 1.078. Minimum and maximum values also provided by ORNL (1988).
Percent Soil	PS	0.01	0.02	Mule deer, white-tailed deer values from Beyer et al., 1994 were <0.02. Assume 0.01 as low end of range.
Home Range	HR	1.8	2.2	Assume 10% variation around HR of 2 ha (Eastern cottontail; Fitzgerald et al., 1994).
Area Use Factor	AUF	0.728	0.595	Based on site area of 1.31 ha for the Bermed Area. AUF is site area divided by most likely HR (1.31/2= 0.662) assuming a triangular distribution with most likely value of 0.662. Minimum and maximum AUFs are defined by site area divided by minimum and maximum HR.
Dietary Ingestion Rate (g dm/d)	IR	Varies	Varies	IR (g dm/d)=0.577*BW^0.727; BW in g; IR in g dry matter (dm) per day; Nagy equation for mammalian herbivore dietary intake (EPA, 1993). PRG equation incorporates allometric equation and varies around body weight.

Table A1-9. Summary of Parameters Used to Derive the PRG for the Townsend's Big Eared Bat.

Townsend's Big-Eared Bat	PRG (mg/kg)	TRV (mg/kg-d)	BW (kg)	PP	BAF	PV	PUF	PS	AUF
	5.02E+04	20.00	0.009	1.000	0.175	0.000	0.000	0.000	0.010

Parameter	Abbreviation	Minimum	Maximum	Notes:
Toxicity Reference Value (mg/kg-d)	TRV	13.33	40	TRV is from rat studies (Azar et al., 1973). Range (QCE/R) is from 13.3 to 40 mg/kg-d. Used triangular distribution with 20 mg/kg-d as most likely based on taxonomic/trophic level relationship to rats (R=2).
Body Weight (g)	BW	9	14	Data from Fitzgerald et al., 1994. Use lower bound of range as most likely value since data limited and there is no mean available by which to establish a most likely value. Assume triangular distribution.
Percent Prey	PP	100	100	Difference between 100% and percent lost to soil ingestion
Invertebrate Bioaccumulation Factor	BAFi	0.08	0.27	BAF for invertebrates: Donker et al., 1993. Triangular distribution with most likely value as mid-point of range.
Percent Vegetation	PV	0	0	NA - Insectivore
Plant Uptake Factor	PUF	0	0	NA - Insectivore
Percent Soil	PS	0	0	Flying/gleaning feeders not expected to contact soils.
Home Range	HR	113.4	138.6	Assume 10% variation around HR of 126 ha (CaDFG, 2001).
Area Use Factor	AUF	0.009	0.012	Based on site area of 1.31 ha for the Bermed Area. AUF is site area divided by most likely HR (1.31/126= 0.01) for a triangular distribution with most likely value of 0.01. Minimum and maximum AUFs are defined by site area divided by minimum and maximum HR.
Dietary Ingestion Rate (g dm/d)	IR	Varies	Varies	IR (g dm/d) =0.621*(C8^0.564); BW in g; IR in g dry matter (dm) per day; Nagy equation for rodent dietary intake (EPA, 1993). PRG equation incorporates allometric equation and varies around body weight.

Table A1-10. Summary of Parameters Used to Derive the PRG for the Coyote.

Coyote	PRG (mg/kg)	TRV (mg/kg-d)	BW (kg)	PP	BAF	PV	PUF	PS	AUF
	9.94E+05	3.30	7.00	0.939	0.33400	0.000	0.000	0.028	0.00020

Parameter	Abbreviation	Minimum	Maximum	Notes:
Toxicity Reference Value (mg/kg-d)	TRV	0.81	3.3	TRV is from dog study (Azar et al., 1973). Range (QCE/R) is from 0.81 to 3.3 mg/kg-d. Used triangular distribution with 3.3 mg/kg-d as most likely based on taxonomic/trophic level relationship to dogs (R=1).
Body Weight (g)	BW	7000	20000	Fitzgerald et al., 1994. Use low end of range as most likely to be conservative since data limited and mean not available.
Percent Prey	PP	90.6	97.2	Difference between 100% and percent lost to soil ingestion. Assume triangular distribution with midpoint of range as most likely value (0.939).
Prey Bioaccumulation Factor	BAF_c	0.00004	0.667	Estimated small mammal whole body BAF from data from Shore (1995) using liver/whole body conversion factor from Fisher et al. (1989) (Table K2-1-12). Set as triangular distribution with a most likely value of midpoint of range. Will encompass the invertebrate BAF range since invertebrates an important component of this animal's diet.
Percent Vegetation	PV	0	0	NA
Plant Uptake Factor	PUF	0	0	NA
Percent Soil	PS	2.8	9.4	Red fox, raccoon values from Beyer et al., 1994 used as closest feeding guild surrogates. Fox more closely related so use 2.8% (0.028) as most likely value.
Home Range	HR	5,969	7,295	Assume 10% variation around HR of 6,632 ha (Fitzgerald et al., 1994).
Area Use Factor	AUF	0.00018	0.00022	Based on site area of 1.31 ha for the Bermed Area. AUF is site area divided by most likely HR (1.31/6632= 0.0002) for a triangular distribution with most likely value of 0.0002. Minimum and maximum AUFs are defined by site area divided by minimum and maximum HR.
Dietary Ingestion Rate (g dm/d)	IR	Varies	Varies	IR (g dm/d) =0.235*(C8^0.822); BW in g; IR in g dry matter (dm) per day; Nagy equation for mammalian dietary intake (EPA, 1993). Most likely is midpoint of range.

Table A1-11. Summary of Parameters Used to Derive the PRG for the Deer Mouse.

Deer Mouse	PRG (mg/kg)	TRV (mg/kg-d)	BW (kg)	PP	BAF	PV	PUF	PS	AUF
	767.85	40.00	0.0148	0.4915	0.175	0.4915	0.343	0.017	1.000

Parameter	Abbreviation	Minimum	Maximum	Notes:
Toxicity Reference Value (mg/kg-d)	TRV	13.33	40	TRV is from rat studies (Azar et al., 1973). Range (QCE/R) is from 13.3 to 40 mg/kg-d. Used triangular distribution with 40 mg/kg-d as most likely based on taxonomic/trophic level relationship to rats (R=1).
Body Weight (g)	BW	14.8	31.5	Assume triangular distribution from data from EPA, 1993. Values for adults; use low end of range as most likely value to be conservative.
Percent Prey	PP	48.8	49.5	Minimum PP and PV when PS is maximal. Maximum PP and PV when PS is minimal. Triangular distribution with midpoint of range (49.15%) the likeliest value.
Invertebrate Bioaccumulation Factor	BAFi	0.08	0.27	BAF for invertebrates: Donker et al., 1993. Triangular distribution with most likely value as mid-point of range.
Percent Vegetation	PV	48.8	49.5	Minimum PP and PV when PS is maximal. Maximum PP and PV when PS is minimal. Triangular distribution with midpoint of range as the likeliest value.
Plant Uptake Factor	PUF	0.000113	10.601	ORNL 1998 evaluation of lead uptake identified mean and SD as well as that data fit lognormal distribution. Used lognormal distribution with mean of 0.343 and SD of 1.078. Minimum and maximum values also provided by ORNL (1988).
Percent Soil	PS	1	2.4	Mouse, vole values from Beyer et al., 1994 were <2% (<0.02). Assume 1% (0.01) as low end of range since value reported as <2% (<0.02); midpoint of range (1.7% or 0.017) most likely.
Home Range	HR	0.0940	0.1280	Values for an Idaho desert reported in EPA (1993); use average of 0.111 ha as the most likely value.
Area Use Factor	AUF	10.23	13.94	Based on site area of 1.31 ha for the Bermed Area. Since AUF>1, use 1. There is no input into simulation for this receptor.
Dietary Ingestion Rate (g dm/d)	IR	Varies	Varies	IR (g dm/d) =0.621*(C8^0.564); BW in g; IR in g dry matter (dm) per day; Nagy equation for rodent dietary intake (EPA, 1993). PRG equation incorporates allometric equation and varies around body weight.

Table A1-12. Raw Data Used to Derive Mammalian BAF Ranges

Prey BAF	Liver	Diet or Soil	Liver Bioaccumulation factor (BAF) (dry weight basis, dwb)	Whole Body BAF (dwb)	Source	Notes
wood mouse, liver	11.7	8430	0.0014	0.0001	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)
wood mouse, liver	7.85	96.3	0.0815	0.0033	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)
wood mouse, liver	13	14010	0.0009	0.0000	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)
wood mouse, liver	5.37	78	0.0688	0.0028	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)
wood mouse, liver	12.1	4030	0.0030	0.0001	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)
wood mouse, liver	6.63	76.1	0.0871	0.0035	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)
wood mouse, liver	0.5	0.03	16.6667	0.6667	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)
wood mouse, liver	9	90	0.1000	0.0040	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)
field vole, liver	12.8	4234	0.0030	0.0001	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)
field vole, liver	6.1	113	0.0540	0.0022	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)
field vole, liver	1.2	130	0.0092	0.0004	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)
field vole, liver	1.1	177	0.0062	0.0002	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)
field vole, liver	13.7	14010	0.0010	0.0000	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)
field vole, liver	4.67	78	0.0599	0.0024	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)
field vole, liver	5	90	0.0556	0.0022	Shore, 1995	DWB, Table 2 of Shore, 1995; divide by CF of 25 for whole body (Fisher et al., 1989)

Notes:

Liver BAF is the concentration in liver divided by the concentration in exposure media

Whole body BAF is the liver BAF divided by a conversion factor (CF) of 25 since the liver is only a small component (1/25) of the total body mass for rodents

Table A1-13. Raw Data Used to Derive Ranges for Invertebrate and Plant Bioaccumulation Factors (BAFs)

Invertebrate BAFs (dry weight basis)	Minimum	Maximum	Source
Isopod	0.08	0.27	Donker et al., 1993

BAF for Plants	BAF	Source
Plants	10.601	ORNL, 1998
Plants	0.000113	ORNL, 1998

Table A1-14. Raw Data Used to Establish Home Range.

Species	Home Range (ha)	Avg (ha)	Reference
Mourning dove	May fly long distances in search of water; Idaho study found doves in desert moved an average of 3.7 km from feeding and loafing sites to watering sites.	1369	Reeves, H.M., R.E. Tomlinson, and J.C. Bartonek. 1993. Population characteristics and trends in the western management unit. Pp. 341-376 in T.S. Basket et al., eds. Ecology and management of the mourning dove. Stackpole Books, Harrisburg, PA. http://imnh.isu.edu/digitalatlas/splash_navigate/pcmain.htm
Blue-winged teal	468 111 540 620	435	NA-Use HR for mallard duck from EPA, 1993
Sage sparrow	Breeding territory size usually averages about 1.5-3 ha.	2	Peterson, K.L. and L.B. Best. 1985. Nest-site selection by Sage Sparrows. Condor 87:217-221. http://imnh.isu.edu/digitalatlas/splash_navigate/pcmain.htm
Ferruginous hawk	Idaho study estimated average home range of males to be 7-8 km2;	750	Bechard, M.J., K.D. Hague-Bechard, and D.H. Porter. 1986. Historical and current distributions of Swainson's and Ferruginous Hawks in southern Idaho. Dept. Biol., Boise St. Univ., Boise. 58pp. http://imnh.isu.edu/digitalatlas/splash_navigate/pcmain.htm
Loggerhead shrike	Size of territory may be about 6 ha in grassy hills; 10-16 ha in semi-desert	11	Woods, C.P. and T.J. Cade. 1996. Nesting habits of the loggerhead shrike in sagebrush. Condor 98:75-81. http://imnh.isu.edu/digitalatlas/splash_navigate/pcmain.htm
Burrowing Owl	Home range in Saskatchewan reported at 0.14-4.81 km2; 95% of all movements were within 600 m of nest burrow.	36	Rich, T. 1986. Habitat and nest-site selection by burrowing owls in the sagebrush steppe of Idaho. J. Wildl. Manage. 50:548-555. http://imnh.isu.edu/digitalatlas/splash_navigate/pcmain.htm

Species	Home Range (ha)	Avg (ha)	Reference
Black-billed magpie	0.12-0.84 0.11-0.21 3.1 73.6 4.5 32.4 10.5	17.8	NA-Use HR for American robin and American woodcock from EPA (1993) as most closely related species for which data available. Note all values for eastern U.S. so HR likely smaller than at INEEL. Use midpoint of each range if given to get the mean.
Mule deer	40 – 900 700.01 2200.03	1123	Fitzgerald et al., 1994. Use midpoint of range, other values to estimate mean.
Pygmy rabbit		2	NA - use HR for eastern cottontail
Townsend's western big-eared bat	126	126	http://www.dfg.ca.gov/whdab/M037.html
Coyote	500.01 14300.20 1130.02 10600.15	6633	Fitzgerald et al., 1994
Deer mouse	0.015-0.026 .02-.05	0.03	Fitzgerald et al., 1994 EPA 1993
Sagebrush lizard	.04-.1	NA	http://www.fw.vt.edu/fishex/nmex_main/species/030085.htm
Conversion factors Used for Home Range			
247.1	ac/km2		
0.4047	ha/ac		