Appendix E-2

Technical Memorandum

(Compact Disk)

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TECHNICAL MEMORANDUM

To:	Rock Vitale, Eric Lahr – Environment Standards, Inc. Chuck Zimmerman – Brown and Caldwell, Inc.
From:	Deborah Rudnick, Les Williams
Date:	May 2, 2008
Subject:	Screening Level Values and Target Detection Limits for Chemicals in Plant and Animal Tissue for the Yerington Site
Project No.:	C294.0200.0201

INTRODUCTION

Screening level values (SLVs) for chemicals in plant and small mammal tissue were calculated to support the Yerington Site (Site) Quality Assurance Project Plan and provide a framework for establishing minimum detection limits for chemical analysis needed for these tissue types. Using literature-based toxicity reference values (TRVs) and exposure parameters for herbivorous and carnivorous wildlife, SLVs were calculated for chemical concentrations in soil and in tissues of plant food and of mammalian prey.

The following sections describe the approach used to calculate these tissue-based SLVs, including:

- Calculation of SLVs in soils
- Calculation of SLVs in plant and animal tissue based on soil SLVs
- Selection of receptors for calculation of tissue SLVs.

CALCULATION OF SLVS IN SOILS

Soil screening values are generated by solving for soil concentrations from an exposure equation that defines the hazard quotient for wildlife. The hazard quotient relates the estimated dose of a contaminant by a receptor via the incidental soil ingestion pathway to a threshold acceptable dose:

$$HQ = \frac{\left\{\left[S_j \times P_s \times AF_{sj} \times FIR\right] + \sum_i^N \left[B_{ij} \times P_i \times AF_{ij} \times FIR\right]\right\} \times AUF}{TRV_j} \qquad \text{Eq. (1)}$$

Where:

S_j	=	Threshold acceptable concentration of contaminant (j) in soil (mg/kg dry weight)
Ps	=	Soil ingestion as proportion of diet (kg sed dry weight/kg diet dry weight)
FIR	=	Food ingestion rate (kg diet dry weight/kg bw/day)
AFsj	=	Absorbed fraction of contaminant (j) from soil (s) (unitless)
Bij	=	Contaminant concentration (j) in biota type (i) (mg/kg dry weight)
Pi	=	Proportion of biota type (i) in diet (kg biota dry weight/kg diet dry weight)
AFij	=	Absorbed fraction of contaminant (j) from biota type (i) (unitless)
TRVj	=	Toxicity reference value (mg/kg bw/day)
AUF	=	Area use factor (unitless).

The following parameters are set to 1:

- HQ, so that the estimated dose is equal to the threshold acceptable dose
- AUF, receptors assumed to reside and forage exclusively within the Site
- AF_{sj}, assuming all of the contaminant is absorbed from soil
- AF_{ij}, assuming all of the contaminant is absorbed from plant or animal food
- P_i, assuming a single food type for the predator (and therefore a single value for B_{ij})

Given these assumptions, the equation reduces to:

$$TRV_j = FIR\,(S_j \times P_s + B_{ij}) \qquad \text{Eq. (2)}$$

Where the parameters are assigned using:

S_j	=	The variable that is solved for, that will yield the screening level for the concentration of contaminant in soil
P_s	=	Available from USEPA 1993 and Beyer 1994

FIR = Available in USEPA 1993 and USEPA 2005a both for individual species and allometric equations

TRV_j = No observed adverse effects level (NOAELs) based on a hierarchical selection approach.

Consistent with USEPA (1997) guidance, ecotoxicological screening values should be no-observed adverse effects levels (NOAELs) for chronic exposure to a contaminant. Consistent with recommendations from Region 9 EPA, TRVs developed for Ecological Soil Screening Levels (SSLs) (USEPA 2005a) were given first priority in calculation of SLVs for the Process Areas. Secondary sources for TRVs were San Francisco Bay Regional Toxicity Reference Values (DeVries 2007), and finally Oak Ridge National Laboratory values (Sample et al. 1996) were used if no Eco-SSL or San Francisco Bay Regional TRVs were available. NOAELs provide a threshold level at or below which no adverse effect is expected in the receptor, and were available for all three data sets. Oak Ridge National Laboratory NOAELs are based on chronic toxicity endpoints or, if only a subchronic endpoint was available, an uncertainty factor of equal to or less than 10 was applied (Sample et al. 1996).

B_{ij} is defined for bioaccumulation from soil by both plants and animals with the same linear equation, in two formats:

$$B_{ij} = a \times S_j + b \qquad \text{Eq. (3)}$$

$$\ln B_{ij} = a \times \ln(S_j) + b \qquad \text{Eq. (4)}$$

Where:

a = slope of relationship in uptake equation

b = y-intercept of relationship in uptake equation.

Solving for S_j in Equation 2 using Equation 3 yields:

$$S_j = \frac{TRV_j - FIR \times b}{FIR \times (P_s + a)} \qquad \text{Eq (5)}$$

Solving for S_j in Equation 2 using Equation 4 was conducted in two steps.

Step 1: Re-express Equation 4 as a power function to yield:

$$B_{ij} = S_j^{\,a} \times e^b \qquad \text{Eq. (6)}$$

Step 2: Substituting the Equation 6 for B_{ij} in Equation 2 yields:

$$\frac{TRV_j}{FIR} = S_j \times P_s + (S_j^{\,a} \times e^b) \qquad \text{Eq. (7)}$$

This equation can be solved iteratively for S_j using Excel's Solver utility. Because the left side of Equation 7 and the constants P_s and e^b are all known, the unknown parameter S_j can varied iteratively until the two sides of the equation are brought into equality to yield a solution for S_j.

SLVs for soil being consumed by herbivorous wildlife were calculated using soil-to-plant uptake equations (USEPA 2005b) and literature-based exposure parameters appropriate to the chosen receptor (see section below on choices of receptors for these calculations).

SLVs for soil consumed by carnivorous wildlife were calculated using literature-based wildlife exposure parameters and soil-to-small-mammal uptake equations (USEPA 2005b and Sample et al. 1998[1]).

CALCULATION OF SLVS IN PLANT AND SMALL MAMMAL TISSUES

In order to calculate SLVs for plant and small mammal tissues, the soil SLV described above was used in the following equation:

$$B_{ij} = \frac{TRV_j}{FIR} - (S_j \times P_s) \qquad \text{Eq. (8)}$$

This equation is directly derived from Equations 1 and 2, and the parameters are assigned using:

Bij	=	The variable to be solved for to calculate the screening level contaminant concentration in plant or small mammal tissue that is based on a threshold acceptable concentration of the contaminant in soil.
Sj	=	The threshold acceptable concentration of the contaminant in soil (the SLV). For calculating plant tissue SLVs, this value is the Sj for herbivorous animals, and for calculating small mammal tissue SLVs, this value is the Sj for carnivorous animals.
Ps	=	Available from USEPA (1993) and Beyer et al. (1994).
FIR	=	Available in USEPA (1993, 2005b) for individual species or determined using allometric relationships.

[1] USEPA (2005) provides soil–to-small mammal uptake equations primarily based on Sample et al. (1998). USEPA (2005) also provides a series of recommendations for which bioaccumulation models should be used on an analyte-specific basis for both general and conservative estimates. As conservative estimate guidance directed the use of upper prediction limits that cannot be calculated without site-specific data, recommendations for general estimates were used.

TRV_j = No observed adverse effects level (NOAELs) based on a hierarchical selection approach as defined above.

Tissue concentrations for forage plants and small mammal prey on a receptor-specific basis, and as the minimum of calculated values for plants and for small mammals, are presented in Table 1.

REPRESENTATIVE RECEPTORS FOR CALCULATING THRESHOLD SOIL CONCENTRATIONS

Tissue SLVs were calculated for herbivorous and carnivorous avian and mammalian receptors that may occur at the Site. The selected receptors were chosen as representative of a trophic guild of consumers that are likely to be present at the Site and that could be exposed to chemicals of interest because of their foraging behaviors (Integral and Brown and Caldwell 2007). Exposure parameters for these receptors used to develop the plant and animal tissue SLVs are presented in Table 2.

Herbivorous Receptors

The herbivore feeding guilds were selected because they are directly linked to plant uptake from soils and are linked directly to higher trophic level carnivores.

Avian Herbivorous Receptors

A potential pathway of exposure to contaminants of concern is by herbivorous birds consuming plant material and incidental ingestion of soil while foraging at the Site. Chukar (*Alectoris chukar*) is a ground-dwelling bird that has been observed on the Site and was chosen as representative of avian receptors feeding on plants.

Mammalian Herbivorous Receptors

A potential pathway of exposure to contaminants of concern is by herbivorous mammals consuming plants and incidental ingestion of soil while foraging. Meadow vole (*Microtus pennsylvanicus*) was selected as representative of mammal receptors feeding on plants. The meadow vole was selected because it is the surrogate mammalian herbivore selected by EPA for development of national ecological soil SLVs (Eco-SSLs) and because it is similar to other small herbivorous mammals that may occur at the Site.

Carnivorous Receptors

The carnivore feeding guilds were selected because they are higher trophic level carnivores directly linked to small mammal uptake from soils.

Avian Carnivorous Receptors

A potential pathway of exposure to contaminants of concern is by birds visiting the Site and consuming small mammals as well as consuming soil incidental to foraging at the Site. American kestrel (*Falco sparverius*) is used to represent avian carnivorous receptors, because it is expected that these birds would prey on small mammals at the Site.

Mammalian Carnivorous Receptors

A potential pathway of exposure to contaminants of concern is by predatory mammals consuming small mammals and incidental ingestion of soil while foraging. Kit fox (*Vulpes macrotis*) was selected as representative of mammal receptors feeding on small mammals at the Site.

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Table 1. Screening Level Values (SLVs) for Chemical Concentrations (mg/kg dw) in Plant and Animal Tissue Protective of Selected Herbivores and Carnivores.

		Forage Plant Tissue SLVs for Herbivore Consumption				Small Mammal Prey Tissue SLVs for Carnivore Predation		
Chemical Class	Chemical	Based on Mule Deer Consumption of Soil and Plants	Based on Meadow Vole Consumption of Soil and Plants	Based on Chukar Consumption of Soil and Plants	Minimum Plant Tissue SLV	Based on Kestrel Consumption of Soil and Small Mammals	Based on Kit Fox Consumption of Soil and Small Mammals	Minimum Small Mammal Tissue SLV
	PCBs (Aroclor 1254)							
Organic		10	4	1.1	1.1	0.9	6.8	0.9
Inorganic	Aluminum	8	19	1340	8.2	1046	10	10
Inorganic	Antimony	0.3	0.7	--	0.3	--	0.68	0.68
Inorganic	Arsenic	19	7	8.0	7.2	2.7	4.7	2.7
Inorganic	Barium	1305	510	168	168	104	677	104
Inorganic	Beryllium	5	11	--	5.0	--	6.6	6.6
Inorganic	Boron	220	522	352	220	275	281	275
Inorganic	Cadmium	15	7	8.2	6.8	3.5	4.7	3.5
Inorganic	Calcium	--	--	--	--	--	--	--
Inorganic	Chromium	46	17	10	10	13	35	13
Inorganic	Cobalt	57	20	7	7	48	61	48
Inorganic	Copper	38	21	14	14	15	46	15
Inorganic	Fluoride	318	760	95	95	74	408	74
Inorganic	Iron	--	--	--	--	--	--	--
Inorganic	Lead	32	16	4.7	4.7	7.5	29	7.5
Inorganic	Magnesium	--	--	--	--	--	--	--
Inorganic	Manganese	311	119	452	119	207	113	113
Inorganic	Mercury	0.8	0.3	0.48	0.30	0.37	0.51	0.37
Inorganic	Molybdenum	1.1	3	43	1.1	33	1.3	1.3
Inorganic	Nickel	23	10	15	10	18	16	16
Inorganic	Potassium	--	--	--	--	--	--	--
Inorganic	Selenium	1.4	0.5	2.6	0.54	1.7	0.91	0.91
Inorganic	Silver	70	25	3.2	3.2	1.3	15	1.3
Inorganic	Sodium	--	--	--	--	--	--	--
Inorganic	Strontium	2063	4905	--	2063	--	2641	2641
Inorganic	Thallium	13	5	--	5.3	--	9.1	9.1
Inorganic	Tungsten	--	--	--	200[a]	--	--	5.5[b]
Inorganic	Thorium	--	--	--	--	--	--	--
Inorganic	Uranium	13	30	196	13	153	16	16
Inorganic	Vanadium	23	8	0.21	0.21	0.62	25	0.62
Inorganic	Zinc	248	103	169	103	140	149	140

Notes

[a] This value represents a no-observed-adverse-effect-level (NOAEL) in plants (Strigul et al. 2005). However, it is not known whether this would be protective of herbivores that consume these plants.

[b] Inouye et al. (2006) found that a tungsten concentration of 11 mg/kg ww (ca. 55 mg/kg dw) in earthworm tissues was the lowest residue associated with decreased reproduction in earthworms. Dividing this lowest-observed-adverse-effects level (LOAEL) by 10 yields an NOAEL of 5.5 mg/kg dw for reproduction in earthworms. It is not known if this tissue concentration is representative of what might occur in a similarly exposed herbivorous mammal, nor is it known if this concentration would be protective of avian or mammalian invertivores (e.g., robin or shrew) that consume earthworms or of avian and mammalian carnivores that might consume similarly exposed herbivores.

Table 2. Exposure Values for Selected Herbivores and Carnivores.

Feeding Guild	Selected Receptor	Fraction soil in diet (Ps)[a]	Food Ingestion Rate[b] (kg dw/kg bw d)	Body Weight (kg)
Mammalian herbivore	Meadow vole	0.024 [c]	0.088	0.036 [d]
Mammalian herbivore	Mule deer	0.02 [e]	0.035 [f]	43 [g]
Mammalian carnivore	Kit fox	0.028 [h]	0.051 [i]	2.7 [j]
Avian herbivore	Chukar	0.104 [k]	0.074 [l]	0.50 [m]
Avian carnivore	Kestrel	0.057 [n]	0.099 [o]	0.103

Notes:

[a]Source, unless otherwise noted: Beyer et al. 1994.

[b]Attachment 4-1, Eco-SSL guidance (high pt est) for short-tailed shrew, long-tailed weasel, red-tailed hawk and meadow vole; for whitetail deer, kit fox, chukar, and kestrel.

[c]Soil in diet not available for shrew; meadow vole used as substitute.

[d]Myers and Krebs 1971 as cited in USEPA 1993: average wt of adult male meadow vole for study in southern Indiana.

[e]Chosen as upper bound of estimates provided for both white-tailed and mule deer.

[f]USEPA 1993, Eq 3-7: ((0.0687*bw(kg) 0.822))/bw (kg)

[g]UMMZ 2007: Lower bound of range reported for adult female mule deer.

[h]Ps for red fox; source Beyer et al. 1994 (see Footnote a).

[i]USEPA (1993) food ingestion rate (FIR) for juvenile 5-8 wk (highest reported FIR) x percent dry wt of small mammal diet (32%) to convert to dw basis

[j]Upper bound of bw provided for kit fox in red fox entry (USEPA 1993).

[k]Soil in diet not available for chukar; American woodcock used as substitute.

[l]0.0582*(BW 0.651) /bw in kg dw/kg bw d, Equation 3-3 (USEPA 1993).

[m]Average body weight of females reported in Christensen 1970.

[n]90th percentile value, Eco-SSL guidance Attachment 4-1, Table 3 (red-tailed hawk used for kestrel Ps).

[o]USEPA (1993) FIR for adult male in summer (highest reported FIR) x percent dry wt of small mammal diet (32%) to convert to dw basis.