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ADDENDUM TO FORMER DOG PENS TECHNICAL MEMORANDA

for the

LABORATORY FOR ENERGY-RELATED
HEALTH RESEARCH
UNIVERSITY OF CALIFORNIA AT DAVIS, CALIFORNIA

Prepared for

United States Department of Energy
Oakland Operations Office
1301 Clay Street
Oakland, California 95612-5208

Prepared by

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February 28, 2000
Rev. C

DOE Oakland Operations Contract DE-AC03-96SF20686

Weiss Associates
Environmental Science, Engineering and Management

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ACRONYMS/ABBREVIATIONS

µg/kg	micrograms per kilogram
bgs	below ground surface
bkgd.	background
CEBAM	CEBAM Analytical, Inc.
COPC	Constituent of Potential Concern
DOE	U.S. Department of Energy
fd	field duplicate
ft	feet
GEL	General Engineering Laboratories
IC	indicator constituent
IRIS	Integrated Risk Information System
K_d	soil/water partitioning coefficient
ld	lab duplicate
LEHR	Laboratory for Energy-Related Health Research
max.	maximum
MCL	maximum contaminant level
min.	minimum
no.	number
NUFT	the Non-isothermal, Unsaturated Flow and Transport model
pCi/g	picoCuries per gram

PRGs	Preliminary Remediation Goals
Quanterra	Quanterra, Inc.
RBAS	Risk-based Action Standard
RfD_0	reference dose
RPD	relative percent difference
RPM	remedial project manager
SCDM	Superfund Chemical Data Matrix
SOP	Standard Operating Procedure
US EPA	United States Environmental Protection Agency
WDP and EDP	Western and Eastern Dog Pens
WRS	Wilcoxon Rank Sum Test

SUMMARY

This report is an addendum to two previous reports (Weiss Associates, 1999a and 1999b) that compared the Western and Eastern Dog Pens (WDP and EDP) soil data with the Laboratory for Energy-related Health Research (LEHR) background soil levels, LEHR Risk-based Action Standards (RBASs), and United States Environmental Protection Agency (US EPA) Preliminary Remediation Goals (PRGs). These analyses indicate no response actions are needed to address above-background constituents in dog pens soil; however, remedial project managers (RPMs) raised two issues regarding this analysis:

1. The 3.94 mg/kg background value for mercury in shallow soil is significantly higher than is typical of surface soil in the Central Valley of California. This is of concern to the RPMs primarily because the previously-derived lowest RBAS for mercury in LEHR soil was significantly lower (0.22 mg/kg) than this background level; therefore the background level was used as the target level for cleanup.

2. Potential impact to ground water by above-background constituents in the EDP had not been specifically evaluated.

To address the mercury cleanup level, mercury speciation analyses were performed on several EDP and background soil samples. These analyses indicated that greater than 99% of the mercury is mercuric sulfide, which is nearly insoluble and much less toxic than other common forms of mercury. These more soluble and toxic forms include methyl mercury, mercuric chloride, and elemental mercury, which were either not detected or detected at very low levels (0.0017 mg/kg or less) in the LEHR soil samples. Furthermore, mercury geochemistry and site data indicate that future transformation to methyl mercury (methylation) and/or mobilization to ground water of the mercuric sulfide in shallow soil is unlikely to be significant. Based on this information and using the same methodology used to develop the previous RBASs, a new RBAS was calculated for mercuric sulfide to compare with total mercury results from the EDP and WDP soil. This new mercury RBAS is 5.75 mg/kg. The reasonable maximum exposure (RME) levels for both EDP and WDP soil are well below this new RBAS.

To address the potential ground water impact issue, the same conservative modeling approach presented in *Draft Final One-Dimensional Vadose Zone Modeling Report for the Laboratory for Energy-Related Health Research* (Weiss Associates, 1997a) was used. Ground water goals were established for all constituents identified as potentially above background in the EDP and WDP, iterative model runs were used to estimate the soil concentration that would result in a maximum ground water concentration equivalent to the goal, and this soil concentration was compared with the soil concentrations detected in the EDP and/or WDP. All maximum dog pens soil concentrations were below their respective “allowable soil concentrations”, with the exception of

those for mercuric sulfide in both the EDP and WDP. However, a reasonable maximum excess exposure concentration for mercuric sulfide was equal to or below the allowable soil concentration for both the EDP and WDP.

Therefore, comparison of soil mercury levels with the new mercuric sulfide RBAS and ground water impact modeling of all potentially above-background constituents confirm the previous conclusion that no response actions are necessary for the EDP and WDP soil.

1. INTRODUCTION

This report is an addendum to two previous reports: *Technical Memorandum: Investigation Results for the Former Eastern Dog Pens,* and *Technical Memorandum: Statistical Comparison of Western Dog Pens Soil Data with Risk-Based Target Levels* (Weiss Associates, 1999a and 1999b). These two reports compared the Western and Eastern Dog Pens (WDP and EDP) soil data with the Laboratory for Energy-Related Health Research (LEHR) background soil levels, LEHR Risk-Based Action Standards (RBASs), and United States Environmental Protection Agency (US EPA) Preliminary Remediation Goals (PRGs). The data in these reports indicated that no response actions are needed to address above-background constituents in dog pens soil. The LEHR remedial project managers (RPMs) requested further evaluation in the following areas:

1. The 3.94 mg/kg background value for mercury in shallow soil is significantly higher than typically detected in surface soil in the Central Valley of California (Wilson, 1990). This is relevant primarily because the previously-derived lowest RBAS for mercury in LEHR soil was significantly lower (0.22 mg/kg) than this background level; therefore the background level would be used as the target level for cleanup.

2. Potential impact to ground water by above-background constituents in the dog pens had not been specifically evaluated.

To address the mercury cleanup level target issue, the following activities were performed:

- Collected three EDP and three background shallow soil samples from previous sampling locations, and had them analyzed for mercury species.
- Evaluated the likelihood of future transformation of the existing mercury species to a more toxic and/or mobile form.
- Recalculated a new mercury RBAS based on the speciation results and the contaminant distribution in the dog pens.
- Collected additional soil from previous sampling locations with potentially biased-high total mercury results, and had them reanalyzed for total mercury by two other analytic labs.

These tasks are described in more detail in Section 2.

To address potential ground water impact from above-background constituents, Weiss Associates used the same conservative modeling approach used in *Draft Final One-Dimensional Vadose Zone Modeling Report for the Laboratory for Energy-Related Health Research* (Weiss Associates, 1997a). Ground water goals were established for all constituents identified as potentially

above background in the EDP and WDP, and iterative model runs were used to calculate the soil concentration that would result in a maximum ground water concentration equivalent to the goal. This soil concentration was compared with the maximum concentration detected in the EDP and/or WDP. This evaluation and its results are described in detail in Section 3.

2. MERCURY EVALUATION

2.1 Mercury Speciation Results

Six soil samples collected at and near the LEHR site were analyzed for mercury compounds or species by a lab that specializes in these analyses, CEBAM Analytical, Inc. (CEBAM), in Seattle, Washington. In October 1999, one shallow soil sample from the EDP and one from a background boring location (Figures 1 and 2) were shipped from General Engineering Laboratory (GEL), the laboratory that conducted the original total mercury analyses, to CEBAM. Although the samples were originally collected in February and March 1999, and therefore exceeded the 28-day holding time for soil mercury analyses, the speciation results were expected to be representative of the field species distribution because the samples were surface or near-surface soil that had been exposed to the atmosphere while *in situ*. To confirm that the speciation results for these two samples were indeed representative, two additional EDP and two additional background shallow soil samples (Figures 1 and 2) were collected and packaged following standard LEHR soil sampling protocol (LEHR Standard Operating Procedures [SOPs] 2.1 and 3.1, Weiss Associates, 1998a) in December 1999 and submitted to CEBAM for speciation. Sample locations were chosen based on previous total mercury analytic results to represent the range of the mercury concentrations detected in shallow soil at and near LEHR.

As shown in Table 1, the speciation results consistently found that at least 99 weight percent of the mercury in both the LEHR site and surrounding area soil is mercuric sulfide. Elemental mercury ranged from 0.005 to 0.37 weight percent, methyl mercury ranged from 0.01 to 0.1 weight percent, and mercuric chloride ranged from <0.003 to 0.03 weight percent. The results in Table 1 also show good agreement between the sum of the mercury species concentrations and the total mercury concentration for a given sample.

2.2 Mercury Methylation Evaluation

As discussed in Section 2.1, over 99% of the mercury in shallow dog pens soil is mercuric sulfide. The headwaters of Putah Creek contain the sixth largest mercury deposit in the United States. Two forms of mercuric sulfide, cinnabar and metacinnabar, are the primary ores of mercury. The shallow mercuric sulfide at LEHR is suspected to be detrial cinnabar and metacinnabar that was eroded from this mercury ore deposit and tailings piles and washed downstream before Monticello Dam was closed in 1957. These minerals have been found at concentrations of 1 to 150 mg/kg in sediments of Sulfur Creek downstream of the Sulfur Bank Mine, which is another large mercury mine located near Clear Lake.

Although mercury levels in the dog pens are generally representative of background, there appear to be a few locations with slightly elevated mercury concentrations in the EDP soil. As discussed below, mercuric sulfide is very stable and practically insoluble under most natural conditions. However, to address the possibility that mercuric sulfide originating in EDP soil might be transported to the underlying UC Davis landfill and converted to the more toxic and soluble methyl mercury, below we discuss mercury chemistry and the likelihood of mercury methylation occurring in the EDP/UC Davis Landfill #2 area.

Mercury can exist in three oxidation states: 1) Hg^0 - metallic; 2) Hg_2^{2+} - mercurous ion (monovalent mercury, mercury I); and, 3) Hg^{2+} - mercuric ion (divalent mercury, mercury II). The properties and chemical behavior of mercury are strongly dependent on the oxidation state, which in turn is influenced by changing oxidation/reduction conditions in soils (Anderson, 1979).

The majority of mercury found in water and soil is in the form of inorganic mercuric salts and organomercurics. Organomercurics are characterized by the presence of a covalent C-Hg bond. The most common mercury compounds found in the environment are the mercuric salts - $HgCl_2$, $Hg(OH)_2$ and HgS; the methyl mercury compounds - methylmercuric chloride (CH_3HgCl) and methylmercuric hydroxide (CH_3HgOH); and, in small amounts, other organomercurics (i.e., dimethylmercury and phenylmercury) (US EPA, 1997a). Mercury species in LEHR dog pens soil are discussed in Section 2.1 and shown on Table 1.

In order for methyl mercury compounds to form, the mercuric ion, Hg^{2+}, must be available along with the presence of suitable methyl donors. There are two general pathways by which the mercuric sulfide in shallow EDP soil could be converted to methyl mercury and impact ground water: 1) the mercuric sulfide is converted to methyl mercury *in situ*, dissolved and transported through the vadose zone to ground water; or 2) the mercuric sulfide is dissolved and transported into the landfill material where it is methylated and then transported to ground water.

In-situ conversion of mercuric sulfide in shallow EDP soil to methyl mercury would require chemical methylation. In aerobic conditions such as the shallow EDP, the sulfide may be oxidized to sulfate thereby making mercury available for methylation, provided a methyl source is present. However, this oxidation process is very slow and both laboratory and field experiments have shown that the release of methyl mercury from sediments is very small under aerobic conditions (Beijer and Jenelov, 1979).

For methylation to occur within the landfill, the mercuric sulfide in EDP soil would first have to be dissolved and transported down into the landfill material. Mercuric sulfide has a very low solubility in water (0.0125 mg/L, from Kirk-Othmer, 1995). The oxidized form, mercurous sulfate, has a much higher solubility (500 mg/L, from Kirk-Othmer, 1995); however, as discussed above, the oxidation process is very slow. Based on this and actual site data (see below), transport of mercury from shallow EDP soil into the landfill materials is expected to be very slow and gradual.

Any mercury that is transported into the landfill material could potentially be converted to methyl mercury through the action of sulfur-reducing bacteria. However, for this to occur the following conditions must be met: 1) low oxygen levels; 2) sufficient water; 3) sufficient bacteria,

4) sufficient nutrients to sustain the bacteria; 5) absence of strong complexing agents; and, 6) sufficiently high temperatures. There are no data available to clearly establish if these conditions are met anywhere within Landfill No. 2.

The limited transport of mercury through the vadose zone and into underlying ground water is further supported by reviewing available soil and ground water data. The soil results for boring SBL00033, located at the south end of EDP Pen K7 (Figure 1), showed 0.75 mg/kg total mercury in the surface sample, 0.98 mg/kg in the 2.5-ft-bgs sample, and less than 0.1 mg/kg in eight deeper samples collected at depths ranging from 4.7 to 25 ft bgs. The surface sample was EDP soil and the 2.5-ft-bgs sample was from the waste zone of Landfill No. 2. These results indicate no significant mercury transport from shallow to deeper sediments. In addition, quarterly ground water monitoring data over the past ten years reveal only occasional detections of mercury (0.0022 mg/L maximum), with no ground water wells or surface discharge points showing consistent mercury concentrations.

Based on this evaluation, it appears that ground water impact by methyl mercury that originated as mercuric sulfide in shallow EDP soil is unlikely to be significant, primarily because transport from the EDP soil into landfill material is very slow and gradual. The RBAS for methyl mercury is 1.9 mg/kg (see Section 2.3) and the allowable soil concentration based on potential ground water impact is 1.6 mg/kg (see Section 3.2.1). Given that the maximum mercury concentration detected in EDP soil is 8.9 mg/kg, approximately 20% of the mercuric sulfide would have to be methylated for ground water impact to be a potential concern.

2.3 Mercury RBAS Recalculation

Based on the speciation results, over 99% of the mercury in the LEHR soil is mercuric sulfide (Section 2.1). Furthermore, as described in Section 2.2, this mercuric sulfide is not likely to be converted in significant quantities to the more toxic and mobile methyl form. Because the previously calculated lowest RBAS for mercury (0.22 mg/kg) is overly conservative given the recently obtained information on mercury species and mercury distribution in the WDP soil, we recalculated the RBAS using more realistic parameters for the WDP and EDP areas.

The new mercury RBASs were calculated using the same approach used in *Draft Determination for Risk-Based Action Standards for DOE Areas* (Weiss Associates, 1997b). The calculations were performed for the non-carcinogenic effects related to mercury under Scenario 2 (i.e., Off-site East Residential Farmer), since this was the scenario producing the very low, 0.22 mg/kg RBAS (Weiss Associates, 1997b). The above-background mercury was assumed to be limited to the top 2 ft of soil, based on the investigation results for the WDP (Weiss Associates, 1999a). Chemical properties and toxicity information was obtained from the US EPA Superfund Chemical Data Matrix (SCDM, US EPA, 1996) and/or Integrated Risk Information System (IRIS). Because no US EPA-approved reference dose (RfD_0) or soil/water distribution coefficient (K_d) is available for mercuric sulfide, we used the values for mercuric chloride (Appendix A). Because mercuric sulfide is known to be less toxic and less soluble than mercuric chloride, this results in a revised RBAS for mercuric sulfide that is still very conservative. In addition to the mercuric sulfide/mercuric chloride RBAS, we also calculated a RBAS for methyl mercury.

The results of the RBAS recalculation are shown in Appendix A. The new mercuric sulfide and mercuric chloride RBAS is 5.75 mg/kg, the new methyl mercury RBAS is 1.9 mg/kg.

2.4 Eastern Dog Pens Mercury Re-analysis

As stated in Section 1, the mercury background level for shallow soil (0 to 4 ft below ground surface) was originally set at 3.94 mg/kg based on extensive background investigations in 1994 and 1998. Based on RPM input, this background level is apparently higher than typical levels for similar settings, which are usually 1 mg/kg or less. In addition, the total mercury analytic results from GEL and the QA laboratory, Quanterra, Inc. (Quanterra), suggest that some early 1999 GEL results for EDP and background samples are biased high. Because the new mercuric sulfide RBAS is higher than the 3.94 mg/kg background level, the integrity of the data used to calculate the background level is no longer a significant issue. However, in an attempt to determine if EDP and background mercury levels at LEHR are indeed elevated relative to typical background levels, or if GEL mercury results for early 1999 were biased high, we collected new shallow soil samples from previously sampled locations (Figures 1 and 2) in December 1999 and had them analyzed for total mercury by two other analytic laboratories: Quanterra and Datachem. Nine locations were sampled in the EDP and two background locations were sampled. Some of these locations and one other background location were also analyzed for total mercury by CEBAM, as part of the speciation analyses. EDP sampling locations were chosen to represent the range of mercury concentrations detected in shallow soil.

The results of the original and recent mercury analyses for these soil samples are shown on Table 2. CEBAM results are included for comparison, but are not considered quantitatively because they were not obtained with a CLP method. As shown on this table, the analytic results from Quanterra and Datachem agree quite well and in most cases are significantly lower than the GEL results. The relative percent differences (RPDs) between Quanterra and Datachem range from 0.3 to 50, while the RPDs between Quanterra/Datachem and GEL range from 36 to 171, and are mostly well over 100 (Appendix B).

Because the background mercury level is no longer the target cleanup level, and because extensive re-sampling and reanalysis would be required to develop a statistically valid revised background level, these new mercury results are used as a qualitative indicator that the background mercury level for shallow soil at and around LEHR is less than the 3.94 mg/kg value previously calculated.

For the EDP, all valid mercury results obtained using method CLP SOW ILM03.0 for a given location were averaged, and the average value is considered representative of mercury levels in soil at that location (Table 2). Because the GEL results included in these calculations appear to be biased-high, these averaged values are considered conservatively high representations of actual mercury concentrations in EDP soil.

3. POTENTIAL GROUND WATER IMPACT EVALUATION

In response to US EPA comments on *Technical Memorandum: Investigation Results for the Former Eastern Dog Pens* (Weiss Associates, 1999a), one-dimensional (1D) contaminant transport modeling was performed to assess potential ground water impacts resulting from downward migration of contaminants through unsaturated sediments beneath the EDP and WDP. A ground water goal was established for each constituent, and iterative modeling runs were conducted to determine the allowable soil concentration that would produce a peak ground water concentration equivalent to the ground water goal.

The numerical computer-code NUFT (Non-isothermal, Unsaturated Flow and Transport) (Nitao, 1998) was used to develop 1D models representing the soil profile beneath the dog pens. The modeling presented in this report uses methods and assumptions developed during previous modeling at this site, as discussed in reports on previous vadose zone modeling (Weiss Associates, 1997a, 1997b, and 1998b). A very brief discussion of model methods, assumptions and input parameters is presented in this report. Additional details can be found in Weiss Associates, 1997a, 1997b, and 1998b.

3.1 Methodology

This section presents the methodologies, assumptions, and rationale used to develop the EDP and WDP vadose zone models. The site lithology, selection of modeled constituents, and relevant input parameter values are described below.

3.1.1 Conceptual Model

LEHR site soil boring logs were used to characterize the geology and develop conceptual models for the EDP and WDP. In both areas the conceptual model is based on a conservative soil profile with regard to transport modeling. A conservative soil profile consists of sediment types that are generally more permeable with higher water retention properties, because constituents will usually travel faster through coarser sediments and reach the water table sooner.

Geologic logs for 20 borings installed in the WDP during the 1998 Characterization Investigation of the LEHR site (Weiss Associates, 1998c) were reviewed, and a composite stratigraphic column representing a conservative geology for transport modeling purposes was developed. Only one boring has been drilled in the EDP. Boring SBL00033 was drilled in 1995 and extends to a depth of 41.5 feet (Pacific Northwest Laboratory, 1995). The stratigraphy from this boring was used to create the EDP conceptual model. To be conservative, approximately 10 feet of

highly permeable gravel was used to represent the hydraulic properties of the landfill that underlies the EDP, even though the log for SBL00033 describes this interval as sandy silt containing metal, glass and wood materials (Pacific Northwest Laboratory, 1995). The stratigraphic column for each area is included in Appendix C.

Macropores caused by roots, animal burrows, desiccation cracks, landfill debris, etc., may be present in the subsurface. Although this modeling approach does not directly address the issue of macropore-influenced transport, the conservative soil profiles (i.e., maximum hydraulic conductivities and conservative soil moisture properties for each interval) should account for any macropores present. In addition, the modeling approach includes a permanent soil moisture profile with high infiltration rates. These conditions do not exist year round at the LEHR site; therefore this approach adds another level of conservatism. Furthermore, macropores are typically present close to the surface. However, trenching in other parts of the site did not reveal obvious macropores. Macropores could also be present within the landfill. However, as described above, the conservative hydraulic properties assigned to the landfill interval should account for any macropores that may be present.

3.1.1.1 Selected Constituents

The constituents of potential concern (COPCs) for the dog pens soil were reviewed, and all compounds detected above background were selected for modeling with the exceptions noted below.

Occurrence above background of inorganic constituents was determined using the Wilcoxon Rank Sum (WRS) test. Because there is some uncertainty regarding the validity of the 3.94 mg/kg mercury background level established for shallow soil at LEHR (Section 2.1), mercury species were also modeled. The following inorganic constituents were identified by the WRS test as potentially above background, but were not included: total chromium in EDP soil, total chromium in deeper (>4 ft bgs) WDP soil, iron in WDP soil, and nickel in deeper WDP soil. These metals were not included because the WRS results appear to be an artifact of sampling depth distribution and they are almost certainly representative of background levels (Weiss Associates, 1999c).

Organic COPCs that were detected in fewer than 5% of the samples and at low concentrations (less than ten times the detection limit) were not modeled. These COPCs are alpha-BHC and heptachlor epoxide in the WDP soil, and endrin and endrin ketone in the EDP.

3.1.1.2 Baseline Distribution of Constituents of Potential Concern

The lateral and vertical distribution of the COPCs in the vadose zone was evaluated by reviewing data generated during historical site investigation activities (e.g. Weiss Associates 1998c and 1999a). It was determined that all of the significant COPCs detected in the WDP were present in near-surface soil, and attenuated to non-detectable or below background levels at 2 ft bgs or shallower. In the EDP the maximum soil cover overlying the landfill is approximately 2 feet. Based on these data the conceptual model assumes that the COPCs are distributed throughout the upper 2 feet of soil in both areas.

3.1.2 Ground Water Goals

The US EPA or California maximum contaminant levels (MCLs) were used as ground water goals for those constituents for which an MCL has been established. For those without an MCL, the US EPA Preliminary Remediation Goal (PRG) for tap water was used. Because hexavalent chromium does not have an established MCL or PRG, the background concentration was used as its ground water goal.

As requested by the US EPA, the tap water PRGs for all constituents were reviewed as potential ground water goals. As shown on Table 3, the PRGs for all constituents are equal to or higher than the ground water goal used in the model. Therefore, the "Allowable soil concentrations" calculated from the model would have been as high or higher if PRGs had been used consistently as ground water goals.

In the model, the ground water goal is set for the first foot of ground water only. In addition, the one-dimensional nature of the model means that the soil concentrations assigned are assumed to be constant laterally. Because of these assumptions, the model does not account for dilution in ground water, which adds to its conservative nature.

3.1.3 Parameter Value Estimation

The primary assumptions employed during development of the LEHR site vadose zone models are discussed in detail in the Draft Final Vadose Zone Modeling for DOE Operable Units (Weiss Associates, 1997a). Assumptions that are specific to this modeling addendum and modifications to the original parameter assumptions are discussed below. Physical properties for each sediment type and associated input parameter values are presented in Appendix C.

3.1.3.1 Vadose Zone Thickness

A conservative (i.e. thinnest) vadose zone thickness was assumed for each model based on historical ground water levels. Because ground water levels can seasonally vary more than 20 ft beneath the site, contaminants in soil at the highest seasonal ground water level may impact ground water. The highest seasonal-high ground water level recorded in on-site HSU-1 is about 20 ft bgs, observed in early 1998 (Dames & Moore, 1999).

3.1.3.2 Partitioning Coefficient

The liquid/solid partitioning coefficients (K_d) used in these models are summarized in Appendix C. The K_d values are based on values presented in the Superfund Chemical Data Matrix (US EPA, 1996). The smaller the K_d, the less sorptive (more mobile) the constituent. Therefore, to be conservative, we assumed the smallest reported value of K_d for each compound.

3.1.3.3 Hydraulic Properties

Hydraulic parameter input values (e.g., porosity, hydraulic conductivity, etc.) were generally determined from on-site soil physical property data obtained during the 1996 Limited Field Investigation (Daniel B. Stephens and Associates, Inc., 1996). A detailed discussion of these properties, and the assumed values is presented in Weiss Associates, 1997a. For the EDP soil profile, the landfill was represented using a sandy gravel interval with high moisture retention properties and lower liquid/solid partitioning coefficients. This conservative approach allowed accounting for the expected heterogeneity in the landfill and essentially allowed constituents to migrate through this interval with minimal retardation and maximum mobility.

3.1.3.4 Half-Life and Decay

For radioactive COPCs appropriate half-life values were used to account for the decay. For all other inorganic and all organic COPCs, we initially assumed no decay. However, with no decay, maximum dieldrin concentrations in the EDP and maximum chlordane concentrations in the WDP exceeded the allowable soil concentration. For these two constituents, conservative half-lives were then incorporated. The half-life values used were a minimum of 50 times the highest value in *Handbook of Environmental Degradation Rates* (Howard et al., 1991).

3.1.3.5 Infiltration Rate

Transport of a contaminant in the vadose zone is directly related to the rate of rainwater infiltration. The mean annual precipitation rate in the LEHR site vicinity is about 43cm/yr. An infiltration rate of 25%, or 10.3 cm/yr was assigned to the model. Additionally, a permanent moisture content was maintained in the highly permeable landfill layer underlying the EDP.

3.1.4 Model Setup and Initialization

This transport modeling used the NUFT model, and essentially the same boundary conditions, initialization, and general assumptions used in the initial vadose zone modeling. The NUFT model, and details of the modeling initialization and process are discussed in detail in Weiss Associates, 1997a, 1997b, and 1998b.

3.2 Model Results

The results of the modeling conducted for this investigation are presented in Table 3 and discussed below. For each COPC, the maximum concentrations detected in the EDP and WDP were compared with the “allowable soil concentration” calculated with the model. The allowable soil concentration is the minimum concentration that would result in a peak ground water concentration above the water quality goal. As shown in Appendix C, the transport time for the peak concentrations ranges from 640 to 1,000,000 years, with most compounds requiring more than 1,000 years to reach peak ground water concentration.

3.2.1 Results for the Eastern Dog Pens

The only radionuclide identified as potentially above background in the EDP is strontium-90. The maximum Sr-90 activity detected in soil was 0.164 pCi/g, which is well below the calculated allowable soil concentration of 1.72×10^{15} pCi/g. Based on the model, the peak activity reaches ground water in 640 years.

Seven organic compounds were modeled: dieldrin, alpha-chlordane, gamma-chlordane, DDD, DDE, DDT and PCB-1254. All of these compounds are present in site soil at concentrations at least an order of magnitude less than the calculated allowable soil concentration. Peak concentration travel times range from 1,000 to 1,000,000 years.

Two metals, hexavalent chromium and mercury, were modeled. The maximum detected hexavalent chromium soil concentration, 0.673 mg/kg, was below the allowable soil concentration of 2.56 mg/kg, with the peak concentration arriving in 2,200 years.

Methyl mercury, elemental mercury, mercuric chloride, and mercuric sulfide are components of total mercury in dog pens soil. Based on speciation analyses (Section 2.1), methyl mercury makes up at most 0.1% of total mercury. Therefore, for the purpose of this report, the maximum methyl mercury soil concentration was assumed to be 0.1% of the 8.9 mg/kg maximum total mercury concentration (Table 3), or 0.0089 mg/kg. This maximum concentration is well below the maximum allowable soil concentration of 1.6 mg/kg. The estimated maximum elemental mercury concentration detected is 0.033 mg/kg. This maximum concentration is well below the calculated allowable soil concentration of 0.97 mg/kg.

Based on speciation analyses, mercuric sulfide generally comprises at least 99% of total mercury; therefore, for the purpose of this report, the mercuric sulfide calculations are compared to total mercury concentrations detected in soil. The calculated allowable soil concentration for mercuric sulfide is 0.94 mg/kg, which is less than the maximum detected total mercury concentration of 8.9 mg/kg.

Because the maximum mercuric sulfide concentration detected in the EDP soil exceeded the allowable soil concentration calculated from the model, another round of modeling was conducted using a more reasonable and less conservative representation of the mercuric sulfide concentration in the EDP shallow soil. This concentration is the 95% upper confidence limit (UCL) on the mean of mercuric sulfide concentrations in EDP soil, adjusted to account for background mercury levels. The background mercury levels were accounted for by subtracting out a conservatively low representation of background, defined as the average of mercury results for all pre-1999 shallow soil background samples. This “background” concentration was calculated to be 0.44 mg/kg.

Based on this approach, the 95% UCL for “added” mercury is 0.94 mg/kg, which is the same as the calculated allowable soil concentration. This result suggests mercuric sulfide may or may not be a concern in terms of ground water impact; however, the following additional factors indicate mercuric sulfide is not a concern:

1. the allowable soil concentration is based on the MCL for inorganic mercury and a generic mercury Kd, while mercuric sulfide is practically insoluble and much less toxic than other common forms of mercury;
2. the overall conservative nature of this model, as described above;
3. the mercury results for some EDP soil sample are biased high, as described in Section 2.4; and,
4. the arrival time for the peak ground water concentration is 6,420 years.

3.2.2 Results for the Western Dog Pens

Transport of four radionuclides, lead-210, strontium-90, uranium-235, and uranium-238, was modeled in the WDP. Strontium-90 and lead-210 have calculated allowable soil activities many orders of magnitude greater than the maximum detected activity. Uranium-235 and uranium-238 have calculated allowable soil activities 1 to 2 orders of magnitude greater than the maximum detected activity.

Calculated allowable soil concentrations for alpha and gamma chlordane were significantly greater than the maximum detected concentrations. The maximum alpha and gamma chlordane concentrations were 1,210 and 976 µg/kg, respectively, compared to allowable soil concentrations of 59,000 and 1.32×10^7 µg/kg, respectively, with peak times exceeding 10,000 years.

The calculated allowable soil concentrations for mercuric sulfide, methyl mercury, and elemental mercury are 0.62 mg/kg, 1.39 mg/kg, and 0.82 mg/kg, respectively. The maximum methyl mercury and elemental mercury concentrations estimated for the WDP soil based on total mercury results are several orders of magnitude lower than the allowable soil concentrations (Table 3). The maximum mercuric sulfide level detected in WDP soil is 3.7 mg/kg, above the allowable soil concentration of 0.62 mg/kg.

Because the maximum mercuric sulfide concentration detected in the WDP soil exceeded the allowable soil concentration calculated from the model, another round of modeling was conducted using a more reasonable and less conservative representation of the mercuric sulfide concentration in the WDP shallow soil. This concentration is the 95% upper confidence limit (UCL) on the mean of mercuric sulfide concentrations in WDP soil, adjusted to account for background mercury levels as described in Section 3.2.1. Based on this approach, the 95% UCL for “added” mercury is 0.56 mg/kg, which is less than the calculated allowable soil concentration 0f 0.62 mg/kg. This result suggests mercuric sulfide is not a concern in terms of ground water impact. In addition, the following factors further indicate mercuric sulfide is not a concern:

1. the allowable soil concentration is based on the MCL for inorganic mercury and a generic mercury Kd, while mercuric sulfide is practically insoluble and much less toxic than other common forms of mercury;

2. the overall conservative nature of this model, as described above; and,
3. the arrival time for the peak ground water concentration is 5,927 years.

4. CONCLUSIONS

The results of the additional work reported in this Addendum confirm that no response action is required for the EDP and WDP soil. Mercury speciation results confirm that greater than 99% of the mercury in LEHR area shallow soil is mercuric sulfide, which is nearly insoluble and much less toxic than other forms. The RBAS calculated using these speciation results indicates that mercury levels in EDP and WDP soil are not of concern to the potential receptors considered. The ground water impact evaluation also indicates that potentially above-background constituents in EDP and WDP soil will not impact underlying ground water above the ground water goals.

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TABLES

Table 1. Mercury Species in Soil (µg/kg), LEHR Site, UC Davis, California

Location	Date Analyzed	Depth (ft)	Methyl Mercury	Elemental Mercury	Mercuric Sulfide	Mercuric Chloride	Total Mercury
Background							
WA-16	10/24/99	2	0.56	0.11	2,022	<0.07	1,956
WA-8	01/03/00	0	0.32	0.09	1,090	<0.06	1,100
WA-14	01/03/00	0	0.49	1.73	460	0.12	530
Eastern Dog Pens							
M8	10/24/99	2	0.36	0.089	672	<0.07	662
M8	01/03/00	0	0.61	1.0	5,090	1.56	4,900
K3	01/03/00	2	0.16	0.69	1,540	<0.06	1,410

Notes:

See Figures 1 and 2 for soil sample locations.

Table 2. Reanalysis of Mercury in Soil (mg/kg), LEHR Site, UC Davis, California

Sample Location	Depth (ft)	Date Collected	GEL	Date Collected	Quanterra	Datachem	CEBAM	Average of CLP Analyses
Eastern Dog Pens								
M8	0	3/3/99	14.6/7(LD)	12/21/99	5	---	4.9	8.9
	2	3/3/99	4.3	12/21/99	0.34	0.481	0.66*	1.7
K3	0	3/4/99	0.51	12/21/99	0.12	0.172	---	0.27
	2	3/4/99	0.82	12/21/99	0.57		1.41	0.70
L3	0	3/3/99	1.4	12/21/99	0.47	0.278	---	0.72
	2	3/3/99	0.92	12/21/99	0.23	0.188	---	0.45
L13	0	3/4/99	3.8	12/21/99	0.45	0.434	---	1.6
	2	3/4/99	1	12/21/99	0.56	0.502	---	0.69
K18	0	3/4/99	4.6	12/21/99	0.39	0.391	---	1.8
	2	3/4/99	11/0.98 (LD)	12/21/99	0.87	0.789	---	3.2
	2	3/4/99	3.4 (FD)/2.3 (LD)	---	---	---	---	---
Background								
WA-8	0	2/11/99	1.9	12/21/99	0.48	---	1.1	1.2
WA-14	0	2/11/99	0.66	12/21/99	0.29	---	0.53	0.48
WA-16	2	2/11/99	4.9	---	---	---	1.96*	---

Notes:

LD = lab duplicate

FD = field duplicate

--- = Sample not submitted to laboratory

* = Samples collected 2/11/99 or 3/3/99, but not analyzed by CEBAM until 10/99

GEL, Quanterra and Datachem used CLP SOW ILM03.0

CEBAM used EPA Method 1631, which is an EPA Method using gold trap atomic fluorescence.

Table 3. Evaluation of Potential Ground Water Impact from Above-Background Constituents in Dog Pens Soil, LEHR Site, UC Davis, California

Constituent	No. above RL/Total Samples	Range of RL	Min. and Max. of Detections	Bkgd. [1]	Ground Water Goal[2]	Allowable Soil Concentration[3]	Max. Detection Below Allowable Soil Concentration[4]	RME Concentration[5]	RME Below Allowable Soil Concentration	Tap Water PRG[10]
EASTERN PENS										
Radionuclides		**pCi/g**	**pCi/g**	**pCi/g**	**pCi/L**	**pCi/g**				
Strontium-90	12/37	0.0145-0.0491	0.023-**0.164**	0.056	8 (MCL)	**1.72E+15**	Pass	NC	**Pass**	NE
Metals		**mg/kg**	**mg/kg**	**mg/kg**	**µg/L**	**mg/kg**				**µg/L**
Hex. Chromium	36/37	0.0347-0.0432	0.077-**0.673**	0.054	20.0 (Bkgd.[7])	**2.56**	Pass	NC	**Pass**	180
Methyl Mercury	37/37	NE	0.00009-**0.0089**[9]	NE	3.7 (PRG)	**1.6**	Pass	NC	**Pass**	3.7
Elemental Mercury	37/37	NE	0.0003-**0.033**[9]	NE	2 (MCL)	**0.97**	Pass	NC	**Pass**	NE
Mercuric Sulfide	37/37	0.029-0.38	0.09-**8.9**[9]	NE	2 (MCL)	**0.94**	Fail	0.94	**Pass**	55[11]
Pesticides		**µg/kg**	**µg/kg**	**µg/kg**	**µg/L**	**µg/kg**				**µg/L**
4,4'-DDD	7/37	3.4-3.9	0.82-**3.3** [6]	0	0.28 (PRG)	**4,900**	Pass	NC	**Pass**	0.28
4,4'-DDE	3/37	3.4-3.9	0.3-**3.6** [6]	0	0.20 (PRG)	**24,400**	Pass	NC	**Pass**	0.20
4,4'-DDT	5/37	3.4-3.9	0.48-**5.8** [6]	0	0.20 (PRG)	**9,890**	Pass	NC	**Pass**	0.20
Chlordane-alpha	12/37	1.78-3.7	0.38-**47.8** [6]	0	0.10 (MCL)	**110,000**	Pass	NC	**Pass**	0.19
Chlordane-gamma	12/37	1.7-3.7	0.4-**43.4** [6]	0	0.10 (MCL)	**2.45E+7**	Pass	NC	**Pass**	0.19
Dieldrin	13/37	3.4-18.1	0.76-**223** [6]	0	0.0042 (PRG)	**25,000**	Pass	NC	**Pass**	0.0042
PCB-1254	2/37	39.2	24.3-**54.9** [6]	0	0.50 (MCL)	**10,100**	Pass	NC	**Pass**	0.73

Table 3. Evaluation of Potential Ground Water Impact from Above-Background Constituents in Dog Pens Soil, LEHR Site, UC Davis, California (continued)

Constituent	Total No. of Samples	Range of Detections	Bkgd. [1]	Ground Water Goal[2]	Allowable Soil Concentration[3]	Max. Detection Below Allowable Soil Concentration[4]	RME Concentration[5]	RME Below Allowable Soil Concentration	Tap Water PRG[10]
WESTERN PENS									
Radionuclides		**pCi/g**	**pCi/g**	**PCi/L**	**pCi/g**				**µg/L**
Lead-210	18/199	<0.21-**4.96**	1.6	50 (MCL)	**1.12E+40**	Pass	NC	**Pass**	NE
Strontium-90	8 (<5%)/200	<0.236-**0.712**	0.056	8 (MCL)	**3.28E+18**	Pass	NC	**Pass**	NE
Uranium-235	10 (<5%)/198	<0.13-**0.317**	0.0638	2 (MCL[8])	**2.67**	Pass	NC	**Pass**	NE
Uranium-238	60/169	<0.24-**2.4**	0.565/0.645	20 (MCL)	**150**	Pass	NC	**Pass**	NE
Metals		**mg/kg**	**mg/kg**	**µg/L**	**mg/kg**				**µg/L**
Methyl Mercury	128/201	<0.00003-**0.0037**[9]	NE	3.7 (PRG)	**1.39**	Pass	NC	**Pass**	3.7
Elemental Mercury	128/201	<0.0001-**0.014**[9]	NE	2 (MCL)	**0.82**	Pass	NC	**Pass**	NE
Mercuric Sulfide	128/201	<0.03-**3.7**[9]	NE	2 (MCL)	**0.62**	Fail	0.56	**Pass**	55[11]
Pesticides		**µg/kg**	**µg/kg**	**µg/L**	**µg/kg**				
Chlordane-alpha	84/197	<1.5-**1210**	0	0.10 (MCL)	**59,000**	Pass	NC	**Pass**	0.19
Chlordane-gamma	85/197	<1.5-**976**	0	0.10 (MCL)	**1.32E+7**	Pass	NC	**Pass**	0.19

Table 3. Evaluation of Potential Ground Water Impact from Above-Background Constituents in Dog Pens Soil, LEHR Site, UC Davis, California (continued)

Notes:

[1] Site-specific background levels, as presented in Appendix C from "Sampling and Analysis Plan for Removal Actions…" (Weiss Associates, 1999b); "NA" indicates not available.

[2] "Ground Water Goal" is the lower of USEPA or California DHS maximum contaminant level (MCL) for drinking water; for those constituents without an MCL, the goal is either the USEPA Region IX Tap Water PRG or background, whichever is higher.

[3] Soil concentration that, based on NUFT vadose zone modeling, results in peak ground water concentration equal to the "Ground Water Goal," with peak times ranging from 660 years (Sr-90) to 1,000,000 years (DDE).

[4] "Pass" indicates maximum Dog Pens soil level is lower than "Allowable Soil Concentration".

[5] RME concentration is reasonable exposure concentration, defined as 95% upper confidence limit on the mean of mercury in excess of background. Background is assumed to be 0.44 mg/kg, the average concentration for shallow background samples collected before 1999.

[6] Any values below reporting limits are estimated values. (Most of the concentrations for pesticides are below reporting limits.)

[7] Hexavalent chromium background level in ground water is based on recent ground water monitoring data from well UCD1-18.

[8] U-235 "Ground Water Goal" set at 10% of uranium MCL based on approximate ratio of U-235 to U-238 in Dog Pens soil.

[9] Methyl mercury is assumed to represent 0.1% of total mercury, elemental mercury is assumed to represent 0.37% of total mercury, and mercuric sulfide is assumed to be equal to total mercury.

[10] USEPA Region IX Preliminary Remediation Goal (PRG) for Tap Water, 1999.

[11] Mercuric sulfide PRG tap water is assumed to be five times tap water PRG for mercury and compounds (i.e., mercuric chloride), based on mercuric sulfide bioavailability study (Rebus, 1990).

Additional Abbreviations:

Min. = Minimum

Max. = Maximum

NC = Not Calculated

NE = None Established

No. = Number

Bkgd. = Background

RL = Reporting Limit

FIGURES

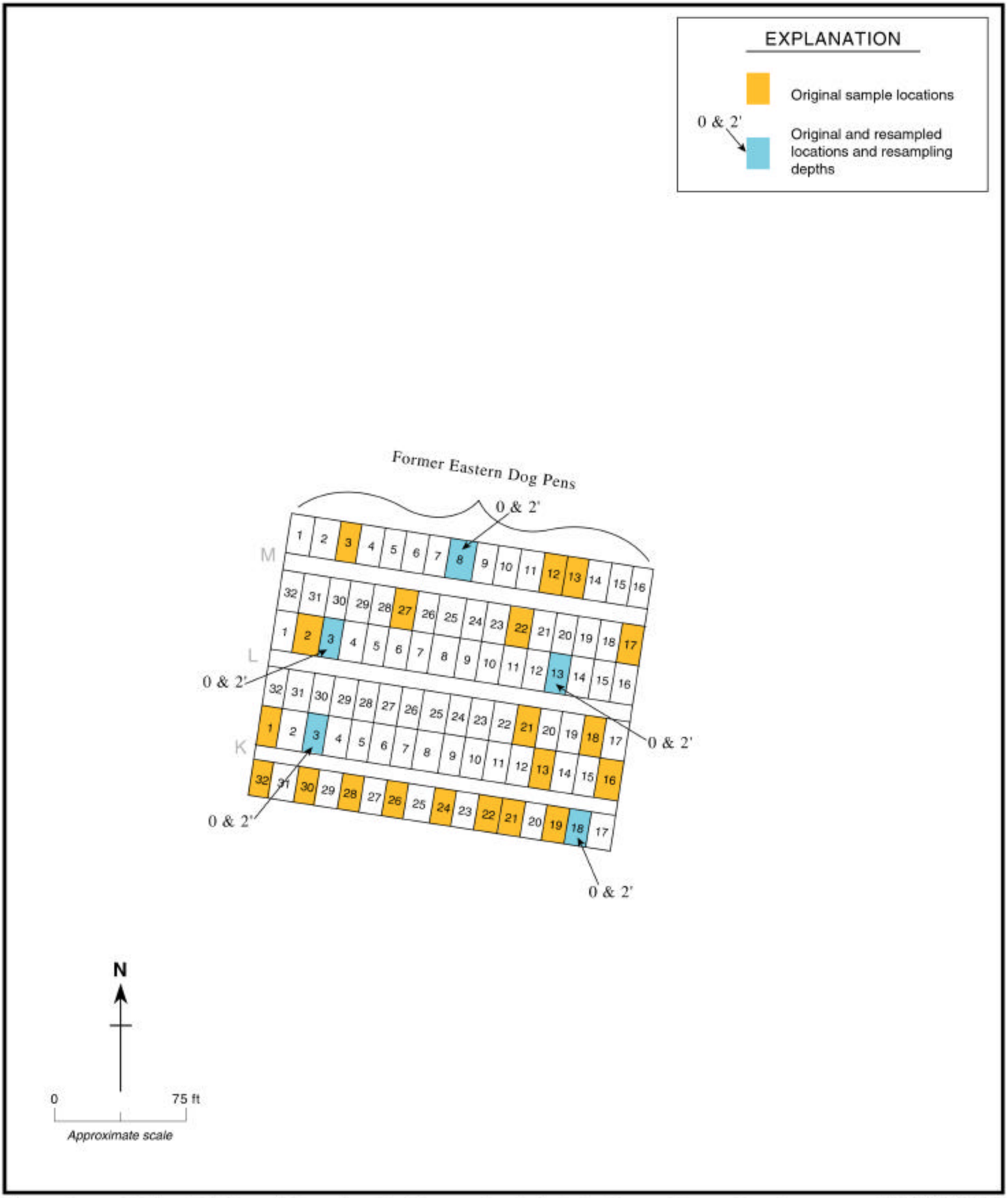

Figure 1. Shallow Soil Sample Locations for Mercury Analysis in the Former Eastern Dog Pens, LEHR Site, UC Davis, California

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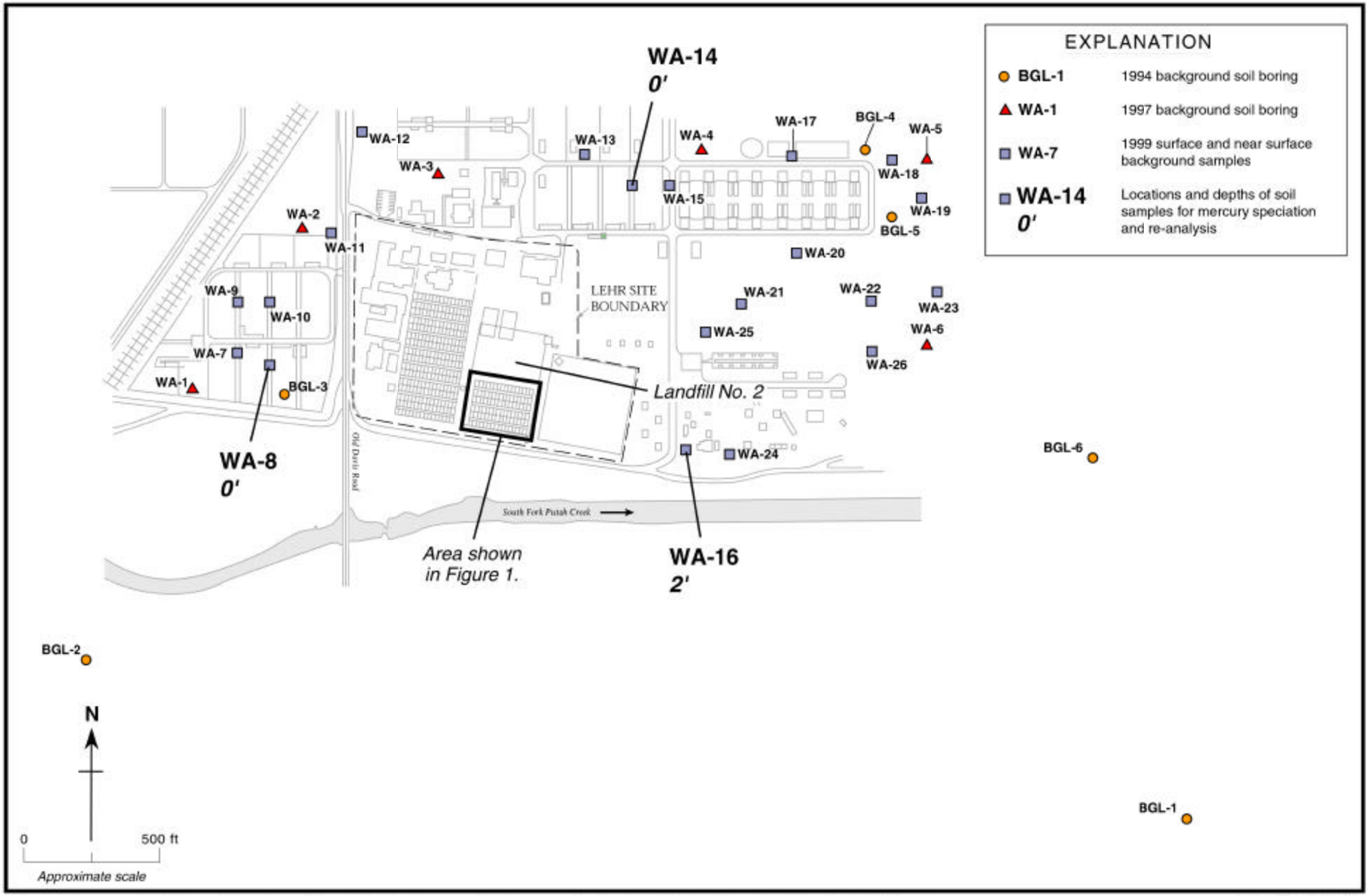

Figure 2. Soil Sampling Locations for Background MercuryAnalysis, LEHR Site, UC Davis, California

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APPENDICES

APPENDIX A

MERCURY RBAS CALCULATIONS

MERCURY RBAS CALCULATIONS

The spreadsheets on the following pages summarize the calculations performed to derive the Risk-based Action Standards (RBASs) for mercuric sulfide, mercuric chloride, and methyl mercury. For additional information on the approach used to calculate these RBASs, see *Draft Determination of Risk-Based Action Standards for U.S. Department of Energy Areas at the Laboratory for Energy-Related Health Research* (Weiss Associates, 1997b).

Appendix A. Mercury RBAS Calculations

Project: **Laboratory for Energy-Related Health Research, University of California at Davis, California**
Prepared for: U.S. Department of Energy, Oakland Operations Office, 1301 Clay Street, Oakland, CA, 95612
Prepared by: Weiss Associates, 5801 Christie Avenue, Suite 600, Emeryville, CA 94608
Account # 128-4001-110 LEHR

Task: Update to the Risk Based Action Standards (RBAS) determination for **Mercury Species** using chemical-specific values, site specific conditions, and updated site soil chemistry data.

Project Personnel:

Task Manager	Mary L. Stallard	Weiss Associates
Task Technical Performance	Zafer Demir	Weiss Associates
	Tim R. Utterback	Weiss Associates

Approach: The RBAS values for non-carcinogen chemicals at a Hazard Quotient of 1.0 are calculated using the same calculation approach used in the *Draft Determination for Risk-Based Action Standards for DOE Areas, Weiss Associates, 1997* with updates to chemical-specific parameters, site-specific conditions, and updated soil chemistry data.
Calculations will be performed for Scenario 2–East Residential Farmer.
Calculations are performed for Mercury and Compounds (i.e., mercuric chloride), Elemental Mercury, Methyl Mercury, and Mercuric Sulfide using their respective chemical properties.
Site conditions were updated for the distribution of mercury in the subsurface.
Reference doses obtained from the IRIS database for risk calculations were also updated for each chemical to ensure health conservatism.
Calculation based on a risk level of 10-6 will be conducted if the updated RBAS values based on a hazard quotient of 1.0 are higher than the previously calculated RBAS values for a risk level of 10-6.

Results:

	RfDo (mg/kg-day)	Kd (L/Kg)	RBAS (mg/kg)
$HgCl_2$	0.0003	52	5.8
CH3Hg	0.0001	52	1.9
HgS	0.0003	52	5.8
HgS (RfD_o X 5)	0.0015	52	28.7
HgS (RfD_o ORNL)	0.04	52	766.3

Note: RBAS based on RfD_o and K_d from the USEPA Superfund Chemical Data Matrix. RfD_o for both mercuric chloride and mercuric sulfide is USEPA value for "mercury and compounds." This value is based on toxicological data for $HgCl_2$ and is considered very conservative for HgS. Toxicological studies performed for Oakridge National Laboratory (ORNL) indicate HgS adsorption by GI tract is five times less than five times less than $HgCl_2$. RfD_o developed for HgS at ORNL is 133 times the HgCl2 RfD_o.

Appendix A. Mercury RBAS Calculations

Scenario #2: East Residential Farmer Scenario

Source	Transport Mechanism	Exposure Route	Pathway Complete ?	Rationale
Soil contamination	Direct contact	Dermal Exposure	no	No direct access to onsite soil assumed.
		Direct Ingestion	no	Resident assumed not to cross LEHR site boundary and ingest source soil directly.
	Migration in saturated/unsaturated zone via diffusion, advection, etc.	Ground water ingestion	yes	Ground water ingestion from residential well assumed. Receptor is downgradient of DOE OUs.
	Subsurface diffusion/volatilization	Inhalation of VOCs	no	Air monitoring at perimeter stations has not shown significant levels of volatiles. Volatiles assumed to be lost from particulates prior to off-site transport.
	Dispersion and deposition of particulates in air	Inhalation of particulates	yes	Assumed off-site transport of particulates generated on-site. Not complete for volatiles.
		Deposition with dermal exposure/Direct ingestion	yes	Assumed off-site transport of particulates followed by direct exposure. Pathway not complete for volatiles.
		Deposition with impacted food ingestion	yes	Assumed off-site transport and deposition of particulates followed by food pathway uptake. Pathway not complete for volatiles.
	Precipitation and surface water runoff	Incidental ingestion of surface water	yes	Incidental ingestion while swimming assumed possible. All pathways complete only for those contaminants present LEHR site surface soils > background, AND present in stormwater runoff from DOE OUs.
		Dermal exposure to surface water	yes	Dermal contact during swimming assumed.
		Aquatic food ingestion	yes	Residents assumed to ingest aquatic food from Putah Creek.
	Direct exposure	External radiation	yes	Assumed off-site transport of particulates containing radionuclides.

Appendix A. Mercury RBAS Calculations

Scenario 2, Summary of Forward Calculation Hazard Quotients for Chemical Non-Carcinogens assuming a soil concentration of 100 mg/kg.

Target HQ 1.00E+00

Analyte	Soil Conc. (mg/kg)	Ground Water Ingestion HQ	Swimming Ingestion HQ	Dermal Swimming HQ	Dermal Showering HQ	Soil Ingestion HQ	Dermal Soil HQ	Inhalation HQ	Fish Ingestion HQ	Plant Ingestion HQ	Meat Ingestion HQ	Milk Ingestion HQ	HQ Across Pathways
Mercury (Hg)	100	1.70E+00	4.08E-03	3.61E-04	8.32E-03	3.72E-07	1.03E-08	2.03E-07	1.57E+01	1.47E-05	1.74E-04	2.87E-06	1.740E+01

Scenario 2, Summary of Soil Action Standards and Pathway-Specific Hazard Quotients for Chemical Non-Carcinogens at a Hazard Quotient of 1.0.

Analyte	LEHR Site Action Standard mg/kg	Pathway-Specific Hazard Quotient at Action Standards											HQ Across Pathways
		Ground Water Ingestion	Swimming Ingestion	Dermal Swimming	Dermal Showering	Soil Ingestion	Dermal Soil	Inhalation	Fish Ingestion	Plant Ingestion	Meat Ingestion	Milk Ingestion	
Mercury (Hg)	5.75	9.8E-02	2.3E-04	2.1E-05	4.8E-04	2.1E-08	5.9E-10	1.2E-08	9.0E-01	8.4E-07	1.0E-05	1.6E-07	1.0

NC = Exposure pathway not complete for chemical.

Ground Water Ingestion Pathway

Scenario 2, Soil to Ground Water (Vadose Zone) On-site - On-site Ground Water to Receptor.

NUFT-SOLUTE Modeling - see Attachment F (WA, 1997).

Note on previous approach (Weiss Associates, August 1997)
Note on current approach (December, 1999)

	Ground Water/Soil Ratio (mg/L)/(mg/kg)
HgS	
Kd= 52	5.59E-05

Scenario 2, Forward HQ Calculation - Non-Carcinogens, Ground Water Concentration Conversion Factors, .

Analyte	Soil Concentration (0-15 ft bgs) (mg/kg)	Ground Water/Soil Ratio (mg/L)/(mg/kg)	Ground Water Concentration (mg/L)
Mercury (Hg)	100	5.59E-05	5.59E-03

Summary Table

Scenario 2, Forward HQ Calculation - Ingestion of chemicals in drinking water.

Chemical	CW (mg/L)	Child IR (L/d)	Adult IR (L/d)	EF (d/yr)	Child ED (yr)	Adult ED (yr)	Child BW (Kg)	Adult BW (Kg)	Child AT (days)	Adult AT (days)	I (mg/kg-day)	RfDo (mg/kg-day)	HQ (unitless)
Mercury (Hg)	5.59E-03	1.0	2	350	6	24	15	70	2190	8760	5.11E-04	0.0003	1.70E+00

CW = Chemical Concentration in Water (mg/L)
IR = Ingestion Rate (L/d)
EF = Exposure Frequency (d/yr)
ED = Exposure Duration (yr)
BW = Body Weight (Kg)
AT = Averaging Time (days)
I = Intake (mg/kg-day) = $CW \times IR_{child} \times EF \times ED_{child} / BW_{child} / AT_{child} + CW \times IR_{adult} \times EF \times ED_{adult} / BW_{adult} / AT_{adult}$
RfDo = Oral Reference Dose (mg/kg-d)
HQ = Calculated Hazard Quotient (unitless) = I / RfDo

Appendix A. Mercury RBAS Calculations

		Hg and Compunds *HgCl2 as basis*	Elemental Hg Hg	Methyl Mercury CH3Hg+	Mercuric Sulfide HgS
PARAMETER	**UNIT**				
MCL	mg/L	0.002			
Mol. Wt.	g/mole	*271.52*	200.59	216	232.68
RfDo	mg/kg-day	0.0003		0.0001	0.04
RfDi	mg/kg-day		0.000086		
Henry's Constant	atm-m3/mole	7.10E-03	7.10E-03	4.70E-07	*7.10E-03*
Kd	mL/g	24,000 - 270,000		2,700 - 31,000	
mean		58000	1000	6700	

Analyte	**Kd (ml/g)**	**Source of Data**
Mercury (Hg)	**5.20E+01**	**Superfund Chemical Data Matrix**

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Appendix A. Mercury RBAS Calculations

Surface Water Concentration Calculation
Storm Water Runoff Modeling - see Attachment E (WA, 1997).
Scenario 2, Forward HQ Calculation - Possible LEHR Impact of Non-Radionuclides to Putah Creek Surface Water

Contaminant of Concern	OU1/OU2 Surface Soil Concentration		SWL-1/SWL-2 Storm Water Concentration		Dilution Factor		Putah Creek Conc. PCU/PCD Only		Putah Creek Conc. Contributed by LEHR		Putah Creek Conc. From LEHR/ Surface Soil Conc.	
	MAX	AVERAGE	MAX	AVERAGE	MIN	AVERAGE	MAX	AVERAGE	MAX	AVERAGE	MAX	AVERAGE
	(mg/kg)	(mg/kg)	(mg/L)	(mg/L)	(-)	(-)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)/(mg/kg)	(mg/L)/(mg/kg)
Mercury	5.70E-01	3.10E-01	<2.00E-04	<2.00E-04	3.65E+01	1.37E+02	9.00E-04	5.00E-04	5.48E-06	1.46E-06	9.61E-06	4.72E-06

The following Contract Reporting Detection Limits were used because the particular analyte was not reported to have been detected in the particular set of samples:
Detection limit of 0.0002 mg/L used for Storm Water Concentration of Mercury.
Calculations:
Dilution Factor = Creek Flow/Storm Runoff Flow
Putah Creek Concentration Contributed by LEHR = Storm Water Concentration/Dilution Factor

Scenario 2, Forward Calculation of Concentration Ratio, Concentration in Putah Creek/Concentration in On-site Soil

Chemical	C_{soil} mg/kg	Csw/Csoil, on-site mg/kg(sw)]/[mg/kg(soil	Csw mg/kg
Mercury (Hg)	100	4.72E-06	4.72E-04

Swimming Ingestion/Dermal Pathways

Summary Table

Scenario 2, Forward HQ Calculation - Ingestion of Chemicals in Surface Water While Swimming.

Chemical	CW (mg/L)	CR (L/d)	EF (d/yr)	Child ED (yr)	Adult ED (yr)	Child BW (Kg)	Adult BW (Kg)	Child AT (days)	Adult AT (days)	I (mg/kg-day)	RfDo (mg/kg-day)	HQ (unitless)
Mercury (Hg)	4.72E-04	0.13	90	6	24	15	70	2190	8760	1.22547E-06	0.0003	4.08E-03

CW = Chemical Concentration in Water (mg/L)
CR = Contact Rate (L/d)
EF = Exposure Frequency (d/yr)
ED = Exposure Duration (yr)
BW = Body Weight (Kg)
AT = Averaging Time (days)
I = Intake (mg/kg-day) = CW x CR_{child} x EF x ED_{child} / BW_{child} / AT_{child} + CW x CR_{adult} x EF x ED_{adult} / BW_{adult} / AT_{adult}
RfDo = Oral Reference Dose (mg/kg-d)
HQ = Calculated Hazard Quotient (unitless) = I / RfDo

Summary Table

Scenario 2, Forward HQ Calculation - Dermal Contact With Chemicals in Surface Water While Swimming

Chemical	CW (mg/L)	SA (cm2)	PC (cm/hr)	ET (hr/d)	EF (d/yr)	Child ED (yr)	Adult ED (yr)	CF (1L/1000cm3)	Child BW (Kg)	Adult BW (Kg)	Child AT (days)	Adult AT (days)	AD (mg/kg-day)	RfDo (mg/kg-day)	HQ (unitless)
Mercury (Hg)	4.72E-04	23,000	0.001	0.5	90	6	24	0.001	15	70	2190	8760	1.08407E-07	0.0003	3.61E-04

CW = Chemical Concentration in Surface Water (mg/L)
SA = Skin Surface Area Available for Contact (cm^2)
PC = Dermal Permeability Constant (cm/hr) - chemical specific. Values from Table I-1.
ET = Exposure Time (hr/d)
EF = Exposure Frequency (d/yr)
ED = Exposure Duration (yr)
CF = Volumetric Conversion Factor for Water (1L/1000cm^3)
BW = Body Weight (Kg)
AT = Averaging Time (days)
AD = Absorbed Dose (mg/kg-day) = CW x SA x PC x ET x EF x ED_{child} x CF / BW_{child} / AT_{child} + CW x SA x PC x ET x EF x ED_{adult} x CF / BW_{adult} / AT_{adult}
RfDo = Oral Reference Dose (mg/kg-d)
HQ = Calculated Hazard Quotient (unitless) = AD / RfDo

Appendix A. Mercury RBAS Calculations

Showering - Dermal Pathway

Scenario 2, Forward HQ Calculation - Dermal Contact With Chemicals in Water While Showering.

From GW ingestion

Summary Table

Chemical	CW (mg/L)	SA (cm^2)	PC (cm/hr)	ET (hr/d)	EF (d/yr)	Child ED (yr)	Adult ED (yr)	CF ($1L/1000cm^3$)	Child BW (Kg)	Adult BW (Kg)	Child AT (days)	Adult AT (days)	AD (mg/kg-day)	RfDo (mg/kg-day)	HQ (unitless)
Mercury (Hg)	5.59E-03	23,000	0.001	0.25	350	6	24	0.001	15	70	2190	8760	2.50E-06	0.0003	8.32E-03

CW = Chemical Concentration in Water (mg/L)
SA = Skin Surface Area Available for Contact (cm^2)
PC = Dermal Permeability Constant (cm/hr) - chemical specific. Values from Table I-1.
ET = Exposure Time (hr/d)
EF = Exposure Frequency (d/yr)
ED = Exposure Duration (yr)
CF = Volumetric Conversion Factor for Water ($1L/1000cm^3$)
BW = Body Weight (Kg)
AT = Averaging Time (days)
AD = Absorbed Dose (mg/kg-day) = $CW \times SA \times PC \times ET \times EF \times ED_{child} \times CF / BW_{child} / AT_{child} + CW \times SA \times PC \times ET \times EF \times ED_{adult} \times CF / BW_{adult} / AT_{adult}$
RfDo = Oral Reference Dose (mg/kg-d)
HQ = Calculated Hazard Quotient (unitless) = AD / RfDo

Soil Pathways

Scenario 2, On-site to Off-site Soil Concentration Calculation

ISCST3 Modeling- see Attachment D (WA 1997).

Scenario 2, On-site to Off-site Soil Concentration Conversion, Forward HQ Calculation - Non Carcinogens

Analyte	On-site Soil Concentration (0-15 ft bgs) (mg/kg)	-site Soil/On-site S Concentration Rati (mg/kg)/(mg/kg)	Off-site Soil Concentration (mg/kg)
Mercury (Hg)	100	7.88E-08	7.88E-06

Summary Table

Scenario 2, Forward HQ Calculation - Ingestion of Chemicals in Soil

Chemical	CS (mg/kg)	Child IR (mg/d)	Adult IR (mg/d)	CF (10^{-6} kg/mg)	FI (unitless)	EF (d/yr)	Child ED (yr)	Adult ED (yr)	Child BW (Kg)	Adult BW (Kg)	Child AT (days)	Adult AT (days)	I (mg/kg-day)	RfDo (mg/kg-day)	HQ (unitless)
Mercury (Hg)	7.88E-06	200	100	1.00E-06	1	350	6	24	15	70	2190	8760	1.12E-10	0.0003	3.72E-07

CS = Chemical Concentration in Soil (mg/kg)
IR = Ingestion Rate (mg/d)
CF = Conversion Factor (10^{-6} kg/mg)
FI = Fraction Ingested From Contaminated Source (unitless)
EF = Exposure Frequency (d/yr)
ED = Exposure Duration (yr)
BW = Body Weight (Kg)
AT = Averaging Time (days)
I = Intake (mg/kg-day) = $CS \times IR_{child} \times CF \times FI \times EF \times ED_{child} / BW_{child} / AT_{child} + CS \times IR_{adult} \times CF \times FI \times EF \times ED_{adult} / BW_{adult} / AT_{adult}$
RfDo = Oral Reference Dose (mg/kg-d)
HQ = Calculated Hazard Quotient (unitless) = I / RfDo

Summary Table

Scenario 2, Forward HQ Calculation - Dermal Contact With Chemicals in Soil

Chemical	CS (mg/kg)	CF (10^{-6} kg/mg)	Child SA (cm^2)	Adult SA (cm^2)	AF (mg/cm^2)	ABS (unitless)	EF (d/yr)	Child ED (yr)	Adult ED (yr)	Child BW (Kg)	Adult BW (Kg)	Child AT (days)	Adult AT (days)	AD (mg/kg-day)	RfDo mg/kg-day	HQ (unitless)
Mercury (Hg)	7.88E-06	1.00E-06	2,000	5,000	0.2	0.01	350	6	24	15	70	2190	8760	3.09E-12	0.0003	1.03E-08

CS = Chemical Concentration in Soil (mg/kg)
CF = Conversion Factor (10^{-6} kg/mg)
SA = Skin Surface Area Available for Contact (cm^2)
AF = Soil to Skin Adherence Factor (mg/cm^2)
ABS = Absorption Factor (unitless)
EF = Exposure Frequency (d/yr)
ED = Exposure Duration (yr)
BW = Body Weight (Kg)
AT = Averaging Time (days)
AD = Absorbed Dose (mg/kg-day) = $CS \times CF \times SA_{child} \times AF \times ABS \times EF \times ED_{child} / BW_{child} / AT_{child} + CS \times CF \times SA_{adult} \times AF \times ABS \times EF \times ED_{adult} / BW_{adult} / AT_{adult}$
RfDo = Oral Reference Dose (mg/kg-d)
HQ = Calculated Hazard Quotient (unitless) = AD / RfDo

Appendix A. Mercury RBAS Calculations

Inhalation Pathway

Scenario 2, Indoor and Outdoor Air Calculations - see Attachment C (WA, 1997).

Scenario 2, Indoor and Outdoor Air Concentration Conversion Factor Calculations, Forward Risk Calculation.

Analyte	Fwd-Calc Soil Conc (mg/kg)	Indoor Air Conversion (mg/m^3)/(mg/kg)	Outdoor Air Conversion (mg/m^3)/(mg/kg)	Indoor Air Conc. (mg/m^3)	Outdoor Air Conc. (mg/m^3)
Non-Carcinogens					
Mercury (Hg)	100		5.80E-13	0.000E+00	5.800E-11

Scenario 2, Forward HQ Calculation -Inhalation of Airborne (Vapor Phase) Chemicals

Summary Table

Chemical	Indoor CA_i (mg/m^3)	Outdoor CA_o (mg/m^3)	Child IR (m^3/hr)	Adult IR (m^3/hr)	Indoor ET (hr/d)	Outdoor ET (hr/d)	EF (d/yr)	Child ED (yr)	Adult ED (yr)	Child BW (Kg)	Adult BW (Kg)	Child AT (days)	Adult AT (days)	Indoor I (mg/kg-day)	Outdoor I mg/kg-day	RfDi mg/kg-day	HQ (unitless)
Mercury (Hg)	0.000E+00	5.800E-11	0.416666667	0.833333333	16.08	7.92	350	6	24	15	70	2190	8760	0	1.7E-11	0.000086	2E-07

CAi = Chemical Concentration in Indoor Air (mg/m^3)
CAo = Chemical Concentration in Outdoor Air (mg/m^3)
IR = Inhalation Rate (m^3/hr)
ET = Exposure Time (hr/d)
EF = Exposure Frequency (d/yr)
ED = Exposure Duration (yr)
BW = Body Weight (Kg)
AT = Averaging Time (days)
I_{indoor} = Indoor Air Intake (mg/kg-day) = $CA_{indoor} \times IR_{child} \times ET_{indoor} \times EF \times ED_{child} / BW_{child} / AT_{child} + CA_{indoor} \times IR_{adult} \times ET_{indoor} \times EF \times ED_{adult} / BW_{adult} / AT_{adult}$
$I_{outdoor}$ = Outdoor Air Intake (mg/kg-day) = $CA_{outdoor} \times IR_{child} \times ET_{outdoor} \times EF \times ED_{child} / BW_{child} / AT_{child} + CA_{outdoor} \times IR_{adult} \times ET_{outdoor} \times EF \times ED_{adult} / BW_{adult} / AT_{adult}$
RfDo = Oral Reference Dose (mg/kg-d)
HQ = Calculated Hazard Quotient (unitless) = ($I_{indoor} + I_{outdoor}$) / RfDo

Fish Ingestion

Scenario 2. Fish Calculation - see Attachment G (WA, 1997)

Surface Water

Inorganic Chemical	Csw mg/L	Bcf L/kg	Cfish mg/kg	Csoil mg/kg	Cfish/Csoil, on-site mg/kg(fish)]/[mg/kg(soil)]
Non-Carcinogens					
Mercury (Hg)	4.7E-04	64000	3.02E+01	100	3.02E-01

Kow = Octanol/water partition coefficient.
Bcf = Bioconcentration factor for fish (L/kg)
Csw = Chemical concentration in surface water contributed by the LEHR site (mg/L)
CFish = COC concentration in fish (mg/kg).

a = Values from Fetter, 1993; Lyman et al, 1990; CalEPa, 1994; Stephens, 1996; USDOE, 1996; Weiss Associates, 1997.
b = Log(Bcf) = 0.76 Log(Kow) - 1.23, Veith et al., 1980.
c = Cfish = Csw x Bcf, CalEPA, 1993.
d = Values from Aquire database, USEPA, 1996. Chromium, barium, molybdenum, thallium and vanadium from PNNL, 1996.

Scenario 2. Forward Calculation of Concentration Ratio, Concentration in Off-site Fish Media/Concentration in On-site Soil

Organic Chemical	Csoil, on-site mg/kg	Cfish/Csoil, on-site mg/kg(fish)]/[mg/kg(soil	Cfish mg/kg
Non-Carcinogens			
Mercury (Hg)	100	3.02E-01	3.02E+01

Summary Table

Scenario 2, Forward HQ Calculation - Ingestion of Chemicals in Fish

Chemical	CF (mg/kg)	IR (kg/day)	FI (unitless)	EF (days/yr)	Child ED (yr)	Adult ED (yr)	Child BW (Kg)	Adult BW (Kg)	Child AT (days)	Adult AT (days)	I (mg/kg-day)	RfDo (mg/kg-day)	HQ (unitless)
Mercury (Hg)	3.02E+01	0.054	0.5	26	6	24	15	70	2190	8760	0.004705797	0.0003	1.57E+01

CF = Chemical Concentration in Fish (mg/kg)
IR = Ingestion Rate (kg/meal)
FI = Fraction Ingested From Contaminated Source (unitless)
EF = Exposure Frequency (meals/yr)
ED = Exposure Duration (yr)
BW = Body Weight (Kg)
AT = Averaging Time (days)
I = Intake (mg/kg-day) = $CF \times IR \times FI \times EF \times ED_{child} / BW_{child} / AT_{child} + CF \times IR \times FI \times EF \times ED_{adult} / BW_{adult} / AT_{adult}$
RfDo = Oral Reference Dose (mg/kg-d)
HQ = Calculated Hazard Quotient (unitless) = I / RfDo

Fruit and Vegetable Ingestion

Scenario 2. Vegetable and Fruit Media Calculation -see Attachment F (WA, 1997).

Appendix A. Mercury RBAS Calculations

Inorganic Chemic	Csoil mg/kg	Cap mg/m3	Css mg/Kg	Kpapt m3/Kg(fm)	Kps Kg/Kg(dm) e	biodim Kg(dm)/Kg(fm) f	Cveg mg/Kg(fm) g	Cveg/Csoil [mg/kg(fm)]/ [mg/kg(soil)]
Non-Carcinogens								
Mercury (Hg)	100	5.8E-11	0.00000788	3300	0.9	0.2	1.42E-06	1.42E-08

Kow = Octanol/Water partition coefficient.
Cap = COC concentration in particulate phase of ambient outdoor air at exposure location from chemical deposition calculation (ug/m3) or (pCi/m3).
Css = COC concentration in surface soil at exposure location from chemical deposition calculation (mg/kg) or (pCi/kg).
Kpapt = Plant-air partition coefficient for particle bound contamination (m3-air / kg-plant fresh mass).
Kps = Plant-soil partition coefficient ((mg/kg-plant fresh mass)/(mg/kg-soil)) = (kg-soil/kg-plant fresh mass).
biodim = Ratio of vegetable/fruit dry mass to fresh mass (kg-dry mass)/(kg-fresh mass).
Cveg = COC concentration in vegetable/fruit media (mg/kg-fresh mass) or (pCi/kg-fresh mass).

a = Values from Fetter, 1993; Lyman et al, 1990; CalEPA, 1994; Stephens, 1996; USDOE, 1996; Weiss Associates, 1997.
b = Value from McKone and Ryan, 1989.
c = Organic compounds: Kps (Kg/Kgfm) = 7.7 Kow-0.58 Travis and Arms, 1988.
d = Calculation for organic compounds: Cveg = Cap x Kpapt + Css x Kps. Cal EPA, 1993.
e = Values from Baes et al., 1984.
f = Value from Cal EPA, 1993.
g = Calculation for inorganic compounds and radionuclides: Cveg = Cap x Kpapt + Css x Kps x biodim. Cal EPA, 1993.

Scenario 2. Forward Calculation of Concentration Ratio - Concentration in Off-site Vegetation/Concentration in On-site Soil

Chemical	Csoil mg/kg	Cveg/Csoil mg/kg(fm)]/[mg/kg(soil]	Cveg mg/kg(fm)
Non-Carcinogens			
Mercury (Hg)	100	1.42E-08	1.42E-06

Summary Table

Scenario 2, Forward HQ Calculation - Ingestion of Chemicals in Fruits and Vegetables

Chemical	CF (mg/kg)	IR (kg/day)	FI (unitless)	EF (days/yr)	Child ED (yr)	Adult ED (yr)	Child BW (Kg)	Adult BW (Kg)	Child AT (days)	Adult AT (days)	I (mg/kg-day)	RfDo (mg/kg-day)	HQ (unitless)
Mercury (Hg)	1.42E-06	0.08	0.5	350	6	24	15	70	2190	8760	4.40E-09	0.0003	1.47E-05

CF = Chemical Concentration in Food (mg/kg)
IR = Ingestion Rate (kg/day)
FI = Fraction Ingested From Contaminated Source (unitless)
EF = Exposure Frequency (days/yr)
ED = Exposure Duration (yr)
BW = Body Weight (Kg)
AT = Averaging Time (days)
I = Intake (mg/kg-day) = CF x IR x FI x EF x ED_{child} / BW_{child} / AT_{child} + CF x IR x FI x EF x ED_{adult} / BW_{adult} / AT_{adult}
RfDo = Oral Reference Dose (mg/kg-d)
HQ = Calculated Hazard Quotient (unitless) = I / RfDo

Appendix A. Mercury RBAS Calculations

Meat Ingestion

Scenario 2. Beef Calculation - see Attachment F (WA, 1997).

Inorganic Chemical	Bt (inorganics) d/kg f	Cap mg/m3	Css mg/kg	Inhc m3/d	Kpapt m3/kg	Ivbc kg(fm)/d	Isc kg/d	Kps kg/kg[dm] g	biodim kg(dm)/kg(fm) h	Cbeef mg/kg	Csoil, on-site mg/kg	Cbeef/Csoil, on-site (mg/kg)/(mg/kg)
Non-Carcinogens												
Mercury (Hg)	0.027	5.8E-11	0.00000788	122	3300	60	0.4	0.9	0.2	2.69317E-06	100	2.69E-08

Kow = Octanol/water partition coefficient.
Bt = Biotransfer factor for beef cattle (d/kg).
Cap = COC concentration in particulate phase of ambient outdoor air at exposure location from chemical deposition calculation (ug/m3).
Css = COC concentration in surface soil at exposure location from chemical deposition calculation (mg/kg).
Inhc = Daily inhalation rate of cattle (m3/d)
Kpapt = Plant-air partition coefficient for particle-bound contamination (m3-air / kg-plant fresh mass).
Ivbc = Ingestion of pasture by beef cattle (kg-fresh mass/day).
Isc = Ingestion of soil by cattle (kg/day)
Kps = Plant-soil partition coefficient ((mg/kg-plant dry mass)/(mg/kg-soil)) = (kg-soil/kg-plant dry mass).
biodim = Ratio of vegetable/fruit dry mass to fresh mass (kg-dry mass)/(kg-fresh mass).
Cbeef = COC concentration in beef media (mg/kg)

a = Values from Fetter, 1993; Lyman et al, 1990; CalEPA, 1994; Stephens, 1996; USDOE, 1996; Weiss Associates, 1997.
b = Log(Bt) = Log(Kow) - 7.6, Travis and Arms, 1988.
c = Value from McKone and Ryan, 1989.
d = Organic compounds: Kps = 7.7 Kow-0.58 (Travis and Arms, 1988).
e = Calculation: Cbeef = Cap x (Inhc + Kpapt x Ivbc) x Bt + Css x (Isc + Kps x biodim x Ivbc) x Bt. (Cal EPA, 1993).
f = Values from Ng et al., 1982. Except arsenic, beryllium, antimony, selenium, thallium and vanadium from Baes et al., 1984.
g = Values from Baes et al., 1984.
h = Value from Cal EPA, 1993.

Scenario 2. Forward Calculation of Concentration Ratio - Concentration in Off-site Beef Media/Concentration in On-site Soil

Organic Chemical	Csoil, on-site mg/kg	Cbeef/Csoil, on-site mg/kg(beef)/[mg/kg(soil)]	Cbeef mg/kg(fm)
Non-Carcinogens			
Mercury (Hg)	100	2.69E-08	2.69E-06

Summary Table

Scenario 2, Forward HQ Calculation - Ingestion of Chemicals in Meat

Chemical	CF (mg/kg)	IR (kg/day)	FI (unitless)	EF (days/yr)	Child ED (yr)	Adult ED (yr)	Child BW (Kg)	Adult BW (Kg)	Child AT (days)	Adult AT (days)	I (mg/kg-day)	RfDo (mg/kg-day)	HQ (unitless)
Mercury (Hg)	2.69E-06	0.25	1	350	6	24	15	70	2190	8760	5.23E-08	0.0003	1.74E-04

CF = Chemical Concentration in Food (mg/kg)
IR = Ingestion Rate (kg/day)
FI = Fraction Ingested From Contaminated Source (unitless)
EF = Exposure Frequency (days/yr)
ED = Exposure Duration (yr)
BW = Body Weight (Kg)
AT = Averaging Time (days)
I = Intake (mg/kg-day) = CF x IR x FI x EF x ED_{child} / BW_{child} / AT_{child} + CF x IR x FI x EF x ED_{adult} / BW_{adult} / AT_{adult}
RfDo = Oral Reference Dose (mg/kg-d)
HQ = Calculated Hazard Quotient (unitless) = I / RfDo

Appendix A. Mercury RBAS Calculations

Scenario 2. Milk Media Calculation - see Attachment F (WA, 1997).

Inorganic Chemical	Bk d/Kg f	Cap mg/m3	Css mg/kg	Inhc m3/d	Kpapt m3/kg(fm)	Ivdc kg(fm)/d	Isc kg/d	Kps kg/kg(dm) g	biodim kg(dm)/kg(fm) h	Cmilk mg/kg i	Csoil, on-site mg/kg	Cmilk/Csoil, on-site (mg/kg)/(mg/kg)
Non-Carcinogens												
Mercury (Hg)	0.00045	5.8E-11	0.00000788	122	3300	85	0.4	0.9	0.2	6.30E-08	100	6.30E-10

Kow = Octanol/water partition coefficient.
Bk = Biotransfer factor for dairy cattle (d/kg).
Cap = COC concentration in particulate phase of ambient outdoor air at exposure location from chemical deposition calculation (ug/m3) or (pCi/m3).
Css = COC concentration in surface soil at exposure location from chemical deposition calculation (mg/kg) or (pCi/kg).
Inhc = Daily inhalation rate for cattle (m3/d)
Kpapt = Plant-air partition coefficient for particle-bound contamination (m3-air / kg-plant fresh mass).
Ivdc = Ingestion of pasture by dairy cattle (kg-fresh mass/day).
Isc = Ingestion of soil by cattle (kg/day)
Kps = Plant-soil partition coefficient ((mg/kg-plant fresh mass)/(mg/kg-soil)) = (kg-soil/kg-plant fresh mass).
biodim = Ratio of pasture dry mass to fresh mass (kg-dry mass)/(kg-fresh mass).
Cmilk = COC concentration in dairy milk media (mg/kg) or (pCi/kg).

a = Values from Fetter, 1993; Lyman et al, 1990; CalEPA, 1994; Stephens, 1996; USDOE, 1996; Weiss Associates, 1997.
b = Log(Bk) = Log(Kow) - 8.1, Travis and Arms 1988.
c = Value from McKone and Ryan 1989.
d = Organic compounds: Kps (Kg/Kgfm) = 7.7 Kow-0.58 Travis and Arms, 1988.
e = Calculation for organic compounds: Cmilk = Cap x (Inhc + Kpapt x Ivdc) x Bk + Css x (Isc + Kps x Ivdc) x Bk. Cal EPA, 1993.

f = Values from Baes et al., 1984.
g = Values from Baes et al., 1984.
h = Value from Cal EPA, 1993.
i = Calculation for inorganic compounds and radionuclides: Cmilk = Cap x (Inhc + Kpapt x Ivdc) x Bk + Css x (Isc + Kps x Ivdc x biodim) x Bk. Cal EPA 1993.

Scenario 2. Forward Calculation of Concentration Ratio -Concentration in Off-site Milk Media/Concentration in On-site Soil

Organic Chemical	Csoil mg/kg	Cmilk/Csoil, on-site (mg/kg(milk))/(mg/kg(soil))	Cmilk mg/kg
Non-Carcinogens			
Mercury (Hg)	100	6.30E-10	6.30E-08

Summary Table

Scenario 2, Forward HQ Calculation - Ingestion of Chemicals in Milk

Chemical	CF (mg/kg)	unit conv CF (mg/L)	IR (L/d)	FI (unitless)	EF (d/yr)	Child ED (yr)	Adult ED (yr)	Child BW (Kg)	Adult BW (Kg)	Child AT (days)	Adult AT (days)	I (mg/kg-day)	RfDo (mg/kg-day)	HQ (unitless)
Mercury (Hg)	6.30E-08	6.52013E-08	0.17	1	350	6	24	15	70	2190	8760	8.60419E-10	0.0003	2.87E-06

CF = Chemical Concentration in Milk (mg/kg)
unit conv for CF = CFmg/kg(milk) x 1.035 kg(milk)/L(milk) = CF mg/L
IR = Ingestion Rate (L/d)
FI = Fraction Ingested From Contaminated Source (unitless)
EF = Exposure Frequency (d/yr)
ED = Exposure Duration (yr)
BW = Body Weight (Kg)
AT = Averaging Time (days)
I = Intake (mg/kg-day) = CF x IR x FI x EF x ED_{child} / BW_{child} / AT_{child} + CF x IR x FI x EF x ED_{adult} / BW_{adult} / AT_{adult}
RfDo = Oral Reference Dose (mg/kg-d)
HQ = Calculated Hazard Quotient (unitless) = I / RfDo

End of Calculations

LEHR OU3 - One Dimensional Vadose Zone Modeling

Soil Type		GRVLFLL Gravel Fill	NSAND Sand	NCLYSLT Clayey Sandy Silt
Parameter	**Unit**			
Solid density (rs)	kg/m3	2700	2630	2570
Bulk Density (rB)	kg/m3	2100	1415	1720
Vertical Hydraulic Conductivity (Kz)	cm/sec	1.00E-02	1.27E-04	7.08E-05
	m2	1.02E-11	1.29E-13	7.22E-14
Porosity (f)	%	0.25	0.312	0.354
Residual Moisture Content (qr)	% vol	0.0275	0.0624	0.15576
Satiated Moisture Content (qs)	% vol	0.25	0.312	0.354
Van Genuchten Parameters				
n		1.9063	1.4285	1.4070
m = 1 - (1/n)		0.4754	0.3000	0.2893
a	1/cm	0.1245	0.0639	0.0211
a	1/Pa	1.270E-03	6.520E-04	2.150E-04
Residual Saturation (Sr = qr/f)	% vol	0.1100	0.2000	0.4400
Maximum Saturation (Smax = qs/f)	%vol	1.0000	1.0000	1.0000
Tortuosity Factor (ta)	%	Millington(1961)	Millington(1961)	Millington(1961)
Kd				
All mercury species	ml/g	52.0000	52.0000	52.0000
Normalized Kd(all species)	-	436.8000	235.8333	252.6554

APPENDIX B

RELATIVE PERCENT DIFFERENCE CALCULATIONS

RELATIVE PERCENT DIFFERENCE CALCULATIONS

		----------TOTAL HG RESULTS (MG/KG)----------					----------RPDS----------		
Location	Depth (ft)	GEL	GEL	GEL Average	QUAN	DATAC	QUAN/DATA	GEL/QUAN	GEL/DATA
M8	0	14.6	7.00	10.80	5			0.7341772	
	2	4.3		4.30	0.34	0.481	-0.34348356	1.7068966	1.5975737
K3	0	0.51		0.51	0.12	0.172	-0.35616438	1.2380952	0.9912023
	2	0.82		0.82	0.57			0.3597122	
L3	0	1.4		1.40	0.47	0.278	0.513368984	0.9946524	1.3373063
	2	0.92		0.92	0.23	0.188	0.200956938	1.2	1.3212996
L13	0	3.8		3.80	0.45	0.434	0.036199095	1.5764706	1.5899858
	2	1		1.00	0.56	0.502	0.109227872	0.5641026	0.6631158
K18	0	4.6		4.60	0.39	0.391	-0.00256082	1.6873747	1.6866359
	2	11	0.98	4.42	0.87	0.789	0.097649186	1.342155	1.3941256
	2	3.4	2.30						
WA-8	0	1.9		1.90	0.48			1.1932773	
WA-14	0	0.66		0.66	0.29			0.7789474	
WA-16	2	4.9		4.90					

APPENDIX C

NUFT VADOSE ZONE MODELING

NUFT VADOSE ZONE MODELING

The spreadsheets on the following pages summarize the input parameters and results of the ground water impact evaluation for above-background constituents in the Eastern Dog Pens and Western Dog Pens soil. For additional information on the modeling approach, see *Draft One-Dimensional Vadose Zone Modeling to Determine Residual Soil Concentrations Protective of Ground Water Using the Designated Level Methodology at the U.S. Department of Energy Areas at the Laboratory for Energy-Related Health Research* (Weiss Associates, 1998b).

Appendix C
Vadose Zone Modeling Results, Eastern Dog Pens
Eastern Dog Pen Lithology, 10.8 cm/yr Infiltration, 0-2ft contaminated depth interval
LEHR Site, UC Davis, California

COC	NUFT Soil Result (0-2 ft) (mg/kg) or (pCi/g)	Time to peak at Ground Water Goal level (years)	Ground Water Goal Conc (ug/L) or (pCi/L)	Goal Reference
Dieldrin(300 yr half-life)	25.0	2,879	0.0042	PRG
Chromium, Hexavalent	2.56	2,200	20.0	LEHR Background
Strontium-90	1.72E+15	640	8	MCL
alpha-Chlordane(1520 yr half life)	111	10,020	0.10	MCL
gamma-Chlordane(1520 yr half life)	24,504	15,760	0.10	MCL
alpha-Chlordane(1520 yr half life)	56	10,001	0.05	MCL
gamma-Chlordane(1520 yr half life)	12,028	14,897	0.05	MCL
alpha-Chlordane(1520 yr half life)	11	10,001	0.01	MCL
gamma-Chlordane(1520 yr half life)	2,400	16,734	0.01	MCL
DDD	4.90	250,000	0.28	PRG
DDE	24.4	1,000,000	0.20	PRG
DDT	9.89	600,000	0.20	PRG
PCB-1254	10.1	220,000	0.50	MCL
Total Chromium	12.9	2,000	50	MCL
Water	N/A	21	N/A	N/A
Methyl Mercury	1.60	6,456	3.7	PRG
Mercury Sulfide	0.94	6,420	2	MCL
Mercury, Elemental	0.97	6,400	2	MCL

Notes:

NUFT = Non-isothermal, Unsaturated Flow and Transport model
MCL = State of California Primary Maximum Contaminant Level for Ground Water
PRG = US EPA Region IX Preliminary Remediation Goal for Tap Water
N/A = not applicable

Appendix C
Vadose Zone Modeling Results, Western Dog Pens
Western Dog Pen Lithology, 10.8 cm/yr Infiltration, 0-2ft contaminated depth interval
LEHR Site, UC Davis, California

COC	NUFT Soil Result (0-2 ft) (mg/kg) or (pCi/g)	Half Life (years)	Time to peak at Ground Water Goal Level (years)	Ground Water Goal Conc. (ug/L) or (pCi/L)	Goal Reference
alpha-Chlordane	59	1520	10,008	0.10	MCL
gamma-Chlordane	13,246	1520	15,516	0.10	MCL
alpha-Chlordane	23	1520	11,351	0.05	MCL
gamma-Chlordane	4,437	1520	17,600	0.05	MCL
alpha-Chlordane	6.0	1520	10,001	0.01	MCL
gamma-Chlordane	1,086	1520	20,055	0.01	MCL
Lead-210	1.12E+40	22	979	50	MCL
U-235	2.67	7.04E+08	50,926	2.0	MCL
U-238	150	4.47E+09	51,053	20	MCL
Strontium-90	3.28E+18	29	660	8	MCL
Methyl Mercury	1.39	none	5,869	3.7	PRG
Mercury Sulfide	0.62	none	5,927	2	MCL
Mercury , Elemental	0.823	none	5,698	2	MCL

Notes:

NUFT = Non-isothermal, Unsaturated Flow and Transport model
MCL = State of California Primary Maximum Contaminant Level for Ground Water
PRG = US EPA Region IX Preliminary Remediation Goal for Tap Water

Appendix C
Representative Soil Profiles, LEHR Site, UC Davis, California

Western Dog Pens

Depth (ft)	Material (NUFT)	Soil Type
0.00	ATM	Atmosphere
0.00	ATM	
0.50	NCLYSLT	Clayey sandy silt
1.00	NCLYSLT	
1.50	NCLYSLT	
2.00	SAND	Sand
2.50	SAND	
3.00	SAND	
4.00	SAND	
5.00	SAND	
6.00	SAND	
7.00	SAND	
8.00	NCLYSLT	Clayey sandy silt
9.00	NCLYSLT	
10.00	NCLYSLT	
11.00	NCLYSLT	
12.00	NCLYSLT	
12.50	NCLYSLT	
13.00	NCLYSLT	
14.00	NCLYSLT	
15.00	NCLYSLT	
16.00	NCLYSLT	
17.00	NCLYSLT	
18.00	NCLYSLT	
19.00	NCLYSLT	
20.00	NCLYSLT	
21.00	NCLYSLT	Water table - 20 ft bgs
22.00	NCLYSLT	
23.01	NCLYSLT	
24.01	NCLYSLT	
25.01	NCLYSLT	
26.01	NCLYSLT	
27.01	NGEO6	Silty Clay

Eastern Dog Pens

Depth (ft)	Material (NUFT)	Soil Type
0.00	ATM	Atmosphere
0.00	ATM	
0.50	NCLYSLT	Clayey sandy silt
1.00	NCLYSLT	
1.50	NCLYSLT	
2.00	NCLYSLT	
2.50	GRVFLL	Gravel fill
3.00	GRVFLL	
4.00	GRVFLL	
5.00	GRVFLL	
6.00	GRVFLL	
7.00	GRVFLL	
8.00	GRVFLL	
9.00	GRVFLL	
10.00	GRVFLL	
11.00	GRVFLL	
12.00	GRVFLL	
12.50	NGEO6	Silty clay
13.00	NGEO6	
14.00	NGEO6	
15.00	NGEO6	
16.00	NGEO6	
17.00	NGEO6	
18.00	NGEO6	
19.00	NGEO6	
20.00	NGEO6	
21.00	NGEO6	Water table - 20 ft bgs
22.00	NGEO6	
23.01	NGEO6	
24.01	NGEO6	
25.01	NGEO6	
26.01	NGEO6	
27.01	NGEO6	

Appendix C
Summary of Physical and Hydraulic Properties for Representative Vadose Zone Mode Soil types at the Western and Eastern Dog Pens
LEHR Site, UC Davis, California

Chemical Specific Parameters		
COC	**Kd (ml/g)**	**Mol Wt**
Dieldrin	43	380.93
Chromium, hexavalent	19	52.00
Chromium, total	19	52.00
DDD	2000	320.00
DDE	8800	318.00
DDT	5300	354.50
alpha-Chlordane	140	409.78
gamma-Chlordane	280	409.78
PCB-1254	1700	327.00
Strontium-90	35	90.00
Lead-210	900	210.00
U-235	450	235.00
U-238	450	238.00
Methyl Mercury	52	216.00
Mercury Sulfide	52	232.68
Mercury, elemental	52	200.60
Nickel	65	58.71
Alpha-BHC	2.5	290.85
Heptachlor Epoxide	160	389.30

Formulas
Normalized Kd = rB.kd / f
Tortuosity Factor = $S^{(7/3)} . f^{(1/3)}$

Unit	**Porosity**	**Hydr. Cond. (cm/s)**	**Dry Bulk Density (g/cm3)**	**Van Genuten Parameter**	
				alpha (1/cm)	**m**
clayey sandy silt	0.35	1.00E-06	1.7	0.021	0.23
sand	0.3	1.00E-04	1.9	0.125	0.238
sandy gravel	0.29	4.70E-03	1.9	0.085	0.476
gravel fill	0.25	1.00E-02	2.1	0.125	0.238
silty clay	0.39	5.80E-08	1.7	0.024	0.145
sandy clay	0.37	6.70E-05	1.7	0.085	0.476