Child Lead Risk Assessment
Reading, Pennsylvania

Prepared for
Exide Technologies
3000 Montrose St.
Reading, PA 19605

Prepared by
Gradient Corporation
238 Main Street
Cambridge, MA 02142

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1 Introduction

1.1 Site Description and History

Exide operates a secondary lead smelter and battery manufacturing/distribution facility (Facility) in Berks County, Pennsylvania. Since 1991, several studies have been performed on soil, sediment and groundwater in areas adjacent to and in the vicinity of the Facility to investigate the occurrence of lead that may be attributable to past Facility operations. The areas included as part of the investigations are herein referred to as the "Study Area." The Study Area covers approximately a one-square mile area centered around the Facility (see Plates 1A and 1B). The Study Area includes portions of Laureldale Borough and Muhlenburg Township, Berks County, Pennsylvania, and is situated less than one mile north of the City of Reading.

Several investigations conducted to date indicate that historic Facility air emissions, prior to the promulgation of standards under the Federal Clean Air Act and installation of air emission control devices, may be responsible, in part, for elevated levels of lead in soil in portions of the Study Area.

1.2 Background

Exide Technologies (Exide) has entered into an Administrative Order on Consent (Order) (USEPA Docket No. RCRA-III-3-2000-002TH) with the United States Environmental Protection Agency (USEPA) concerning areas in the vicinity of its facility in Muhlenberg Township and Laureldale Borough, Berks County, Pennsylvania. The work to be performed under the Order includes refinement of the Study Area, investigation and assessment using exposure models, and remediation, as necessary. A Step 2 Work Plan was prepared in July, 2002, by Advanced Geoservices Corp. (AGC). The tasks to be performed under Step 2 include:

- Blood Lead Study;
- Risk Assessment Sampling (*i.e.*, dust and tap water sampling and paint screening); and
- Site-Specific Risk Assessment.

The blood lead study and risk assessment sampling were conducted in August and September, 2002. This work was performed under a work plan approved by EPA. The results of the blood lead study and sampling were presented in the "Blood Lead Study and Environmental Sampling Report" dated January 8, 2003 (Gradient Corporation, 2003). This report presents the results of the site-specific risk assessment conducted using the results of the blood lead study and environmental sampling.

2 Adverse Effects of Lead Exposure

Excess exposure to lead can result in adverse effects in humans. Chronic low-level exposure (as is of potential concern at this site) is usually of greater concern for young children than older children or adults. There are several reasons for this focus on young children, including: 1) young children typically have higher exposures to lead-contaminated media per unit body weight than adults, 2) young children typically have higher lead absorption rates than adults, and 3) young children are more susceptible to effects of lead than are adults. The following sections summarize the most characteristic and significant adverse effects of lead on children, and current guidelines for classifying exposures as acceptable or unacceptable.

2.1 Neurological Effects

The effect of lead that is usually considered to be of greatest concern in children is impairment of the nervous system. Many studies have shown that animals and humans are most sensitive to the effects of lead during the time of nervous system development, and because of this, the fetus, infants and young children (0-7 years of age) are particularly vulnerable. The effects of chronic low-level exposure on the nervous system are subtle, and normally cannot be detected in individuals, but only in studies of groups of children. Common measurement endpoints include various types of tests of intelligence, attention span, hand-eye coordination, *etc.* Most studies observe effects in such tests at blood lead levels of 20-30 μg/dL. Some report effects at levels as low as 10 μg/dL and even lower. However, difficulties in methodology (*e.g.*, adequate control for other factors (such as maternal and paternal IQ) that affect the child's IQ) lead to significant uncertainty in this conclusion.

2.2 Effects on Pregnancy and Fetal Development

Studies in animals reveal that high blood lead levels during pregnancy can cause fetotoxic and teratogenic effects. Some epidemiologic studies in humans have detected an association between elevated blood lead levels and endpoints such as decreased fetal size or weight, shortened gestation period, decreased birth weight, congenital abnormalities, spontaneous abortion and stillbirth (USEPA, 1986; ATSDR, 1999). However, these effects are not detected consistently in different studies, and some researchers have detected no significant association between blood lead levels and signs of fetotoxicity. While some studies provide suggestive evidence that blood lead levels in the range of 10-15 μg/dL may cause small increases in the risk of undesirable prenatal as well as postnatal effects, the evidence is not definitive. Moreover, effects may be reversible in the presence of reduced post-natal blood lead levels (Gardella, 2001).

2.3 Effects on Heme Synthesis

A characteristic effect of chronic high lead exposure is anemia stemming from lead-induced inhibition of heme synthesis and a decrease in red blood cell life span. ACGIH (1995) concluded that decreases in ALA-D activity (a key early enzyme involved in heme synthesis) can be detected at blood lead levels below 10 µg/dL. It should be noted, however, that clinically significant effects due to impaired heme synthesis (*i.e.,* anemia) occur at significantly higher levels (ATSDR, 1999). Heme synthesis is inhibited not only in red blood cells but in other tissues. Several key enzymes that contain heme, including those needed to form vitamin D, also show decreased activity following lead exposure (USEPA, 1986). The CDC (1991) reviewed studies on the synthesis of an active metabolite of vitamin D and found that impairment was detectable at blood lead levels of 10-15 µg/dL.

2.4 Cancer Effects

Studies in animals indicate that chronic oral exposure to very high doses of lead salts may cause an increased frequency of tumors of the kidney (ACGIH, 1995). However, there is only limited evidence suggesting that lead may be carcinogenic in humans, and the noncarcinogenic effects on the nervous system are usually considered to be the most important and sensitive endpoints of lead toxicity (USEPA, 1988). ACGIH (1995) states that there is insufficient evidence to classify lead as a human carcinogen.

2.5 Current Guidelines for Protecting Children from Lead

It is currently difficult to identify what degree of lead exposure, if any, can be considered safe for infants and children. As discussed above, some studies report subtle signs of lead-induced effects in children beginning at around 10 µg/dL or even lower, with population effects becoming clearer and more definite in the range of 30-40 µg/dL. It should be noted that there is still uncertainty regarding the nature and magnitude of neurobehavioral impairment in children with blood lead levels in the 10-20 µg/dL range (see for example Kaufman, 2001). Nonetheless, some researchers have concluded that effects of lead on neurobehavioral performance, heme synthesis, and fetal development may not have a threshold value, and that the effects are long-lasting (USEPA, 1986; ATSDR, 1999). On the other hand, some researchers and clinicians believe the effects that occur in children at low blood lead levels are either so minor or based on inconclusive evidence that they need not be cause for concern (ATSDR, 1999).

After a thorough review of all the data, the USEPA identified 10 μg/dL as the concentration level at which effects begin to occur that warrant avoidance, and has set as a goal that there should be no more than a 5% probability that a child will have a blood lead value above 10 μg/dL (USEPA, 1990). Likewise, the Centers for Disease Control (CDC) has established a guideline of 10 μg/dL in preschool children that is believed to prevent or minimize lead-associated cognitive deficits (CDC, 1991). It should be emphasized that in no case does 10 μg/dL represent a blood lead level at which medical intervention or abatement is considered. For example, CDC recommends more frequent blood lead screening for children with blood lead levels between 10 and 14 μg/dL, rather than any intervention activity (CDC, 1991).

3 Blood Lead Study

3.1 Blood Lead Study Objectives

The Step 2 blood lead study was performed to evaluate children's lead exposure within the Study Area, and to determine current risks to children from ongoing exposures to lead. If a child has chronic exposure to sources of lead, blood lead measurements provide a useful indication of lead exposure over the preceding months.

The blood lead study involved obtaining blood lead measurements from children in the community, and the risk assessment sampling (*i.e.*, the environmental sampling) involved collecting dust and residential tap water samples and screening for lead in paint. Residential soil samples were collected during previous investigations (Step 1); therefore, the Step 2 environmental sampling did not include residential soil sampling. The objectives of the Step 2 study were as follows:

- Determine whether children living in the Muhlenberg Township and Laureldale Borough, Pennsylvania area currently exhibit elevated blood lead levels (> 10 µg/dL).
- Identify and quantify sources of lead in residential environments where young children are present, with emphasis on those where the children have blood lead levels greater than 10 µg/dL.
- Estimate the relative direct and indirect impact of each source on blood lead levels.
- Use the blood lead and environmental lead data obtained during the study to aid in developing site-specific inputs to the IEUBK model, following EPA guidance documents.

3.2 Study Overview

A voluntary blood lead sampling program was conducted to collect blood lead samples from children between 6 and 84 months of age who either resided in, or frequently visited, the Study Area. A key objective of the blood lead sampling program was to obtain a high participation rate from the resident children. The first step involved contacting all residences within the Study Area to determine whether any children in the age range 6 to 84 months reside there, and then recruiting those children to participate in the blood lead sampling program. Financial incentives (a U.S. Savings Bond) were offered to encourage participation in both the demographic survey and the blood lead sampling program.

The blood lead study also included environmental sampling to collect dust and residential tap water samples and screen for lead in paint from residences within the Study Area. Residential soil samples were collected during previous investigations; therefore, the blood lead study did not include residential soil sampling.

An exposure survey and an environmental survey were conducted for participants in the blood lead study. The exposure survey covered the following general topics:

- Time of residence at current address.
- Time spent indoors, outdoors, at day care centers, or secondary residences.
- Time spent at community playgrounds.
- Frequency of childhood habits such as mouthing behavior and pica.
- The type of playing surface at the residence, *i.e.*, presence of grass, dirt, swing set, sandbox, or driveway.

Exposure surveys were completed for all children ages 6-84 months who had their blood lead tested.

The environmental survey covered the following general topics:

- Parental occupation and education.
- Lead-related hobbies or occupations.
- The presence of smokers or pets in the house.
- Recent major renovation at current or prior address (if during last twelve months).
- Awareness of home in the Study Area.

An environmental survey was completed for all houses where environmental sampling was conducted.

3.3 Environmental Sampling

Environmental sampling was conducted as part of the Blood Lead Study. Properties identified during the residential census as being within the Study Area and occupied by children under the age of 84 months, or pregnant or nursing women, were the subject of the environmental sampling activities intended to aid in developing site-specific input parameters for the IEUBK model. Samples of household interior surface dust were collected during the Blood Lead Study. Residential soil samples were collected during the Step 1 characterization soil sampling, which was intended to identify the average soil lead concentration on each property (or exposure area) within the Study Area.

The interior housedust sampling is described in the blood lead study report (Gradient Corporation, 2003). One composite dust sample was collected from each residence to assess children's exposure to lead in interior dust. The interior housedust sample was composited by collecting from a minimum of four floor regions within a house. The areas sampled were selected to represent areas frequented by children, for example: directly inside of the main entry to the residence, the most frequently occupied room (usually living room), the kitchen near the main sink, and the child's bedroom.

3.4 Study Results

The methodology and results of the blood lead study were presented in the "Blood Lead Study and Environmental Sampling Report" dated January 8, 2003 (Gradient Corporation, 2003). A total of 48 children in the age range 6 to 84 months participated in the blood lead study; 36 were residents and 12 were visitors. Blood lead results for each participant are presented in Appendix A. Blood lead summary statistics are presented in Table 1 for children ages 6 to 84 months. For visitor children, the time estimated by parents that the child visited a house within the Study Area ranged from 15 to 75 percent of their time. No field duplicates or split samples were included in the summary statistics. One child in the 6-84 month age group had a blood lead level above 10 µg/dL; he was a two year old visitor to the Study Area with a blood lead level of 14 µg/dL. At the time of the blood lead study, this child had lived in the surrounding community and visited the study area for 18 months, and had a history of elevated blood lead levels that pre-dated his visits to the study area.

Table 1
Blood Lead Summary Statistics (µg/dL)
Ages 6-84 months

Type	N	Min	Max	Mean	GM	GSD
Resident	36	0.5	7	2.8	2.4	1.7
Visitor	12	0.75	14	4.0	3.1	2.1
Total	48					

The results of the blood lead study indicated that child blood lead levels in the Study Area surrounding the Exide facility are generally not elevated and do not present a community-wide problem. The study found that child blood lead levels in this community were not well correlated with environmental lead levels, including dust and soil concentrations, and interior paint lead readings.

4 IEUBK Model Analysis with Default Inputs

4.1 IEUBK Model Inputs

Children's blood lead levels are assessed using the Integrated Exposure and Uptake Biokinetic (IEUBK) Model (USEPA, 1994). The IEUBK Model is a computer-based deterministic simulation that estimates the blood lead concentration in children resulting from their exposure to lead in soil, dust, drinking water, diet, and air. Specifically, the model estimates the intake and uptake of lead into the body and then uses biokinetic modeling to predict blood lead levels. Because of variations in behavior and physiology among individual children, different children will have different PbBs, even if they are exposed to the same environment. The IEUBK Model addresses this by treating its central estimate of blood lead concentration (averaged over childhood from age 0 to 7 yrs) as a geometric mean (GM) of a lognormal distribution among similarly exposed children. A default GSD of 1.6 is used to calculate the proportion of children in the variable population with blood lead levels falling above 10 μg/dL.

The IEUBK model was run in batch mode, using the batch input file shown in Appendix B. The batch file provides child-specific inputs for age, soil concentration, dust concentration, and observed PbB. The batch data consisted of 40 children who reside in or visit the Study Area, who are between the ages of 6 and 84 months, and for whom there are blood lead, soil lead, and dust lead data. (Eight of the 48 children lived in or visited homes which did not have interior dust data). Other than the child-specific inputs, the input values used in the IEUBK model were the default values recommended by USEPA. We also used USEPA's recently updated (2003) default values for dietary lead intake in the IEUBK model – these are based on data from the U.S. Food and Drug Administration (FDA) total diet study. The IEUBK default inputs are presented in Table 2. Drinking water concentrations were specific to each house, and were available for 23 children. For children in houses that did not have drinking water data, we used a value of 1 μg/L, which was the median concentration for all of the drinking water data.

Table 2
IEUBK Model Default Input Parameters

Medium	Parameter	Age (years)						
		0-1	**1-2**	**2-3**	**3-4**	**4-5**	**5-6**	**6-7**
Air	Concentration ($\mu g/m^3$)	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Breathing Rate (m^3/hr)	2	3	5	5	5	7	7
	Time outside (hr/day)	1	2	3	4	4	4	4
	C_{in}/C_{out}	0.30	0.30	0.30	0.30	0.30	0.30	0.30
	Lung Absorption Fraction	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Diet	Daily intake (µg/day)	3.16	2.60	2.87	2.74	2.61	2.74	2.99
	Absorption Fraction	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Drinking Water	Ingestion Rate (L/day)	0.20	0.50	0.52	0.53	0.55	0.58	0.59
	Absorption Fraction	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Soil/Dust	Total daily intake (mg/day)	85	135	135	135	100	90	85
	Fraction soil	0.45	0.45	0.45	0.45	0.45	0.45	0.45
	Absorption Fraction	0.30	0.30	0.30	0.30	0.30	0.30	0.30
	Soil/dust transfer coefficient	0.70	0.70	0.70	0.70	0.70	0.70	0.70
All	GSD	1.6	1.6	1.6	1.6	1.6	1.6	1.6

4.2 Comparison of Predicted to Observed PbB

Based on the input parameters described above, the IEUBK model was used to calculate the expected PbB for each child between 6 and 84 months of age whose PbB was measured during the blood lead study and for whom all environmental inputs were available. The output from the batch run consists of a predicted PbB for each child in the dataset. Table 3 presents summary statistics for the observed and predicted PbBs, for residents, visitors, and residents and visitors combined. For the predicted blood lead levels, the mean probability of having a PbB greater than USEPA's target level of 10 µg/dL was calculated using the default GSD of 1.6. The mean probability of exceeding a PbB of 10 µg/dL is what the model predicts would be the percent of the population with blood leads above 10 µg/dL, given these environmental exposures. Each person has an individual probability of exceeding a PbB of 10 µg/dL, and the mean probability is the average of all the individual probabilities. The predicted mean probability of exceeding a blood lead level of 10 µg/dL can be compared to the observed percent of children in the community with blood leads greater than 10 µg/dL.

Table 3
Summary of IEUBK Predictions Using Model Defaults[1]

	Residents		Visitors		Combined	
	Observed	**Predicted**	**Observed**	**Predicted**	**Observed**	**Predicted**
	PbB (µg/dL)	**PbB (µg/dL)**	**PbB (µg/dL)**	**PbB (µg/dL)**	**PbB (µg/dL)**	**PbB (µg/dL)**
N	31	31	9	9	40	40
Mean	2.7	7.7	2.5	12.7	2.7	8.8
GM	2.3	6.9	2.3	11.1	2.3	7.7
Min	0.5	2.1	0.8	3.0	0.5	2.1
Max	7.0	17.0	4.0	23.8	7	23.8
Percent PbB >10µg/dL	0%	29%	0%	60%	0%	36%

The model-predicted PbBs are higher on average than the observed PbBs, for all three groups. For residents and visitors combined, the GM of all the predicted PbBs is 7.7 µg/dL, *vs.* a GM of 2.3 µg/dL for observed PbBs. In addition, the mean probability of exceeding a PbB of 10 µg/dL is 36% for the predicted PbBs *vs.* 0% for the observed PbBs.[2] Since the GM of the observed PbB is the same for residents and visitors (2.3 µg/dL), and the GM of the predicted PbB is higher than observed for both residents and visitors, these two groups were combined for all subsequent analyses.

For the maximum model-predicted PbB of 23.8 µg/dL, the model predicts that the child has a 96.7% probability of having a PbB greater than 10 µg/dL; however, the observed PbB at this residence is 4 µg/dL for a 6-year old child. One reason for the elevated predicted PbB is that the dust lead concentration at this house is 8100 mg/kg, which is the maximum observed dust lead concentration. However, the child does not have an elevated PbB even in the presence of elevated dust lead levels. Therefore, it is likely that the child's exposure to dust is low, possibly due to low dust lead loading, frequent hand-washing, limited playtime contact with dust, or low dust lead bioavailability.

Exceedance probability distributions for the observed and predicted PbBs are presented in Figure 1. The exceedance probability distribution shows the percentage of the observed or predicted blood

[1] Table 3 presents the observed and predicted blood lead levels for the 40 children included in the IEUBK modeling, whereas Table 1 presents blood lead data for all the children who participated in the blood lead study. Eight children were excluded from the IEUBK modeling due to the fact that not all of the environmental inputs were available.
[2] The child with the elevated blood lead level was not included in this analysis because dust data were not collected at the residence he visited.

lead distribution that exceeds the PbB shown on the x-axis (see USEPA Lead Guidance Manual, p. 3-9). The exceedance probabilities were calculated using the model default GSD of 1.6. For the predicted blood lead values, the probability of exceeding a given PbB (y-axis of Figure 1) was determined as the *average* probability of exceeding that PbB for each predicted value in the data set. For example, the probability that an individual predicted value exceeds 10 μg/dL was determined from the following equation:

$$\textit{Probability of } PbB_{predicted} > 10\ \mu g/dL = 1 - F(z)$$

$$z = \left[\frac{\ln 10 - \ln \text{PbB}_{\text{predicted}}}{\ln \text{GSD}}\right]$$

where:

GSD	=	1.6
F(z)	=	function that gives the area under the standard normal cumulative distribution between -∞ and *z*.

As shown in Figure 1, there is weak agreement between the observed and model-predicted exceedance probability distributions, and the model exceedance probability is greater than that for the observed PbB for each point along the curve. In addition, the model-predicted PbB exceeds the observed PbB for 37 of the 40 data points. For this community, the model combined with its default input parameters overestimates the impact of soil, and especially dust, on blood lead.

4.3 Soil Action Level Using Model Defaults

4.3.1 Screening Level

The USEPA has established a screening level for lead in soil of 400 ppm (USEPA, 1994b). As discussed by USEPA, this screening level is not intended to be a default cleanup goal or action level, but rather specifies the concentration in soil where it is safe to conclude that risks from lead are below a level of concern without any site-specific investigation or analysis. If the mean soil lead is above 400 ppm, then site-specific investigations should be used to determine what soil lead level is appropriate to protect the health of children.

4.3.2 Basis of Soil Action Level

This section calculates a soil action level that is appropriate for protecting children in the Target Area from excess risk from lead in residential soils. The approach used is consistent with USEPA guidance on calculation of Preliminary Remediation Goals (USEPA, 1991). The soil action level applies to the average concentration over the exposure area (front and back yards), rather than to individual samples.

USEPA recommends that there should be no more than a 5% likelihood that a young child should have a PbB value greater than 10 µg/dL (USEPA, 1990). Thus, the health criterion selected for use in this evaluation is that there should be no more than a 5% chance that a child's PbB will be above 10 µg/dL. This is equivalent to specifying that the 95th percentile of the child PbB distribution does not exceed 10 µg/dL:

$$PbB_{95} \leq 10\ \mu g/dL$$

Using a 95th percentile PbB of 10 µg/dL, the target GM is calculated from:

$$GM_{target} = \frac{10\,\mu g/dL}{GSD^{1.645}}$$

The target GM PbB for a child is 4.6 µg/dL using the model default GSD of 1.6.

4.3.3 Calculated Soil Action Level

Using the target GM of 4.6 µg/dL, the IEUBK model was run in the "Find Blood Pb Concentration" mode, to calculate a soil action level for children ages 0 to 84 months. The Reading median drinking water concentration of 1 µg/L was used in the model. The calculated soil action level using the model default inputs is 420 mg/kg.

5 Uncertainty in Lead Risks

This section discusses uncertainties in predicted blood lead levels and associated lead risk. One source of uncertainty in the IEUBK model is due to uncertainty in the true level of lead exposure that humans receive from soil and other environmental sources. This in turn is due to uncertainty in environmental concentrations and human intake parameters. Another uncertainty is the blood lead level which results from any specified level of lead exposure ("model uncertainty"). Model uncertainty arises from uncertainty in pharmacokinetic parameters, and also from the fact that the biological processes being modeled (absorption, distribution, clearance from all of the different body compartments) are very complex, thus the mathematical representation of these processes is likely to be an oversimplification.

IEUBK model predictions that are based solely on default input values may be highly uncertain, because it is not possible to evaluate how closely the default values describe the actual community under consideration. This section evaluates uncertainty associated with model predictions by running the model with alternate or site-specific inputs, and comparing the model predictions to the observed PbB from the community. Site-specific inputs help to reduce uncertainty because they are derived from actual data from the community being modeled.

As noted in Section 4, the model used with default values for the input parameters overpredicts PbBs for this community. Model overpredictions may be related to overestimates in the values used for certain input parameters. Sections 5.1 and 5.2 discuss uncertainties associated with two of the model input parameters: soil ingestion rate and GSD. The soil ingestion rate is used in calculating predicted PbB and site-specific action levels. The GSD is used in calculating exceedance probabilities and site-specific action levels. These sections also provide plausible alternative values for these parameters, based on recent literature or site-specific data. Section 5.3 presents the results of the IEUBK modeling conducted using the alternative input values developed in Section 5.1 and 5.2. Section 5.4 presents the soil lead action levels calculated using the alternate model input values developed in Sections 5.1 and 5.2. Section 5.5 discusses other sources of uncertainty associated with the lead risks calculated using the IEUBK model.

5.1 Soil Ingestion Rate

USEPA's Technical Review Workgroup (TRW) recommends the use of the model default values for soil ingestion rate to support lead risk assessment analyses performed with the IEUBK model. (This section uses the term "soil ingestion rate" to refer to the combined intake of both soil and dust. Similarly, literature describing soil ingestion rate studies represent combined soil and dust intake rates. To date, no studies have been designed to assess either soil or dust ingestion rates independently.) However, USEPA recognizes that the default values do not account for differences associated with variables that may affect ingestion rates at different sites, such as ground cover and climate (USEPA, 1999).

The contribution of the soil ingestion rate to blood lead levels is specified in the IEUBK Model by a set of age-dependent soil ingestion rates. Table 4 shows the current default values in the Model, the range of intakes that the default values are based on, alternative soil ingestion rates used in two USEPA risk assessments (Butte, MT and Palmerton, PA), and values based on papers by Stanek and Calabrese for Amherst, MA (Stanek and Calabrese, 1995a) and Anaconda, MT (Stanek and Calabrese, 2000). These values are discussed in more detail below.

Table 4
Summary of Soil Ingestion Rates for Children (g/day)

Age	IEUBK Default[a]	Range of Intakes[a]	Butte, MT	Palmerton, PA	Amherst[b] (Stanek and Calabrese, 1995a)	Anaconda[b] (Stanek and Calabrese, 2000)
6-11 months	0.085	0 - 0.085	0.043	0.053	0.028	0.011
1-2 years	0.135	0.080 - 0.135	0.108	0.084	0.045	0.017
2-3 years	0.135	0.080 - 0.135	0.108	0.084	0.045	0.017
3-4 years	0.135	0.080 - 0.135	0.108	0.084	0.045	0.017
4-5 years	0.100	0.070 - 0.100	0.085	0.062	0.033	0.013
5-6 years	0.090	0.060 - 0.090	0.075	0.056	0.030	0.011
6-7 years	0.085	0.055 - 0.085	0.070	0.053	0.028	0.011

Notes:
a. Source: Table 2-7 of USEPA (1994, p. 2-40)
b. Stanek and Calabrese measured soil ingestion rates for children ages 1-4 years. Values for other age groups are estimated here by Gradient based on the age-dependency of soil ingestion rates in the IEUBK defaults.

5.1.1 Basis for IEUBK Default and Alternative Values

IEUBK Default

USEPA developed the default soil and dust ingestion rates based on results from two mass balance studies: Calabrese et al. (1989) studied 64 children between the ages of 1 and 4 years from Massachusetts; Davis et al. (1990) studied 104 children between the ages of 2 and 7 years from the State of Washington. Mass balance studies estimate soil ingestion by comparing the concentration of various tracer metals in soil and dust to the quantity of these tracers recovered from feces. By measuring the quantity of such tracers recovered from feces and then subtracting the amount of tracer that can be attributed to the ingestion of alternative materials, investigators can estimate the amount of soil and dust a child must have ingested. USEPA cited, but did not use, data from three other mass balance studies (Binder et al., 1986, Clausing et al., 1987, and Van Wijnen et al., 1990) because these other studies did not adequately quantify the tracer intake from sources other than soil and dust, most notably diet. USEPA (1994) states that (p. 2-39):

> *Two of the studies, Davis et al. (1990) and Calabrese et al. (1989), measured the dietary (including medication) intake of the trace elements and subtracted this quantity in estimating soil ingestion. These studies therefore provide the most complete quantification of ingestion.*

The results from these two studies, as reported by USEPA (1994, Table 2-6), appear in Table 5.

Table 5
Daily Intake of Soil and Dust Estimated From Elemental Abundances[a]

		Soil/Dust Intake, mg/day		
Study	**Element**	**Median**	**Mean**	**Maximum**
Davis *et al.* (1990)	Al	25	39	904
	Si	59	82	535
	Ti	81	246	6,182
Calabrese *et al.* (1989)	Al	30	154	4,929
	Ti	30	170	3,597
	Y	11	65	5,269
	Zr	11	23	838

Notes:
a. Source: Table 2-6 of USEPA (1994, p. 2-39)

The IEUBK Model's design and development is based on the assumption that input parameter values in general (and the soil and dust ingestion rate value in particular) are central estimates – not high end estimates[3]. USEPA's guidance for the IEUBK Model recommends use of a central soil ingestion rate estimate, stating: "[t]he values recommended for use in this model (85 to 135 mg/d) represent a more central value within the range of values seen in different studies" (USEPA, 1994, p. 2-40). In the case of soil ingestion, USEPA recommends use of the arithmetic mean value, stating that (p. 2-40),

[3] Note that this methodology is distinct from that used in typical reasonable maximum exposure cancer and noncancer risk assessments where exposure parameters are generally a combination of average and upper-bound estimates. The Exposure Factors Handbook (EFH) suggests than 100 mg/day is a reasonable estimate of an average ingestion rate for young children (USEPA, 1997). This value is consistent with the current IEUBK default values. The EFH also suggests 400 mg/day as an upper percentile soil ingestion rate for some children. However, it would not be appropriate to use such an upper bound estimate in the IEUBK model because the GSD parameter provides the adjustment from average to upper bound.

The reader should also note that there are statistical problems in interpreting an observed median value from these studies. For example, in a population of children who all ingested very small amounts of soil on most days but occasionally ingested larger quantities, the median from a short term measurement study will be below the average daily quantity ingested by any of the children. The mean value is not subject to this bias, and therefore is judged to be a more meaningful measure of ingestion.

Based on the data reported by Calabrese *et al.* (1989) and Davis *et al.* (1990), USEPA derived a range of intakes and recommended that the upper ends of the ranges be used as the default values in the model (Table 4). The default values recommended for use in the model (85 to 135 mg/day) are considered by USEPA to be representative of average daily intake rates (USEPA, 1999).

Butte, MT Risk Assessment

In the risk assessment for the Butte, Montana NPL site, USEPA used the central tendency (midpoint of the range for each age group) of the Office of Air Quality Planning and Standards (OAQPS) age-adjusted ingestion rates, which range from 0.043 to 0.108 g/day (USEPA, 1993; p.3).

Palmerton, PA Risk Assessment

In the risk assessment for Palmerton, Pennsylvania, USEPA adjusted the default soil ingestion rates, based on the Binder *et al.* (1986) soil ingestion study, and the range of possible soil/dust ingestion rates for young children (USEPA, 1989; cited in USEPA, 1998; page 3-26). The Palmerton risk assessment describes that in this adjustment, the model's default soil/dust ingestion rate of 100 mg/day[4] was reduced to the geometric mean soil ingestion rate (84 mg/day) from the Binder *et al.* (1986) study, and the ingestion rates for other age groups were adjusted by the same ratio. The resulting ingestion rates range from 53 to 84 mg/day.

[4] It is possible that the value given here of 100 mg/day represents a typographical error in the Palmerton risk assessment, and that this value should have been 135 mg/day.

5.1.2 Values from Recent Literature

Stanek and Calabrese (1995a)

Since the publication of the USEPA's IEUBK Model guidance manual in 1994, Stanek and Calabrese (1995a) have published a re-analysis of the data USEPA relied on to develop the Agency's original guidance – i.e., the Calabrese et al. (1989) data (for 1-4 year olds) and the Davis et al. (1990) data. The revised analysis involves the calculation of an average soil ingestion rate for each child over the time period of the study. These average soil ingestion rates for each child then form a distribution of soil ingestion rates, which is approximately lognormal. Stanek and Calabrese report soil ingestion rates at percentiles of this distribution, e.g., for the 50th percentile child (50% of children have an average soil ingestion rate below this value) and the 95th percentile child (95% of children have an average soil ingestion rate below this value). We discuss average soil ingestion rates for both the 50th and 95th percentile child below, although data for the 50th percentile child is most relevant for the IEUBK model with its need for an estimate for the median child.

The revised analysis by Stanek and Calabrese shows that the average soil ingestion rate for the 50th percentile child was 33 mg/day for the Amherst population, 44 mg/day for the population in the Davis et al. study, and 37 mg/day for the combined populations of the two studies. Average soil ingestion rates for the 95th percentile child were 154, 246, and 217 mg/day for the Amherst, Davis et al., and combined populations, respectively. The revised analysis suggests that average soil ingestion rates for 50th percentile children are significantly lower than the Agency's assumed average ingestion rate of 135 mg/day for this age range.

The methodology used in these reanalyses was introduced by Stanek and Calabrese, and is referred to as the "Best Tracer Method," or "BTM." The BTM restricts attention to measurements based on the four best tracers for each child, where a tracer's quality is ranked according to the ratio of total tracer in feces to total tracer in food (high ratios are best). The rationale for this ranking scheme is that measurement of tracer quantities in food is a source of so-called "framing error," which reflects the tendency to incorrectly match fecal tracer measurements with the temporally corresponding food tracer measurement. Tracers that are least present in food (i.e., tracers with <u>high</u> total tracer to food tracer quantity ratios) have the lowest potential for these errors, hence minimizing the influence of framing errors on the estimate of soil ingestion. The <u>median</u> of the four best tracers (calculated as the average of the results inferred using the second and third tracers ranked by estimated soil ingestion rate) is selected because individual tracers are sometimes subject to "source attribution error." This type of error occurs when a tracer is unknowingly ingested via some medium other than food or soil (e.g., inadvertent ingestion of the tracer in toothpaste). Since source attribution errors tend to affect individual tracers, taking the median of several "good" tracers decreases the probability of this type of error. Stanek and Calabrese (1995a) note (pp. 149, 152) that

> *This study presents an improved methodology for estimating soil ingestion from multiple tracer mass-balance studies. The methodology is designed to overcome concerns with currently published soil ingestion estimates from mass-balance studies that provide tracer-specific soil ingestion estimates (Calabrese et al., 1989, 1990; Davis et al., 1990). Such tracer specific results have lead to extraordinarily large inter-tracer variability in soil ingestion estimates, and considerable confusion over which tracers provide the most reliable estimates...*
>
> *The BTM is able to overcome the above limitations based on a methodology that recognizes the occurrence and magnitude of transit time error, and incorporates such information into a precision recovery estimate at the level of the individual subject for each specific tracer.*

Stanek and Calabrese (1995a, p. 152) also note that their reanalysis of the Davis *et al.* data may be positively biased. Because that study used only 3 tracers, results calculated using all three had to be used to implement the BTM methodology. Stanek and Calabrese suspect that source attribution error associated with one of these tracers (Ti) inflated the estimated 95th percentile soil and dust ingestion rate. This inflation would also positively bias an estimate of the arithmetic mean. Therefore, the Stanek and Calabrese (1995a) reanalysis of the Calabrese *et al.* (1989) data may yield a better estimate of soil ingestion rates for children aged 1 to 4 years.

Stanek and Calabrese (1995a) describe the subjects in the Calabrese *et al.* (1989) study as aged 1 to 4 years. In order to propose age-adjusted soil ingestion rates for use in the IEUBK Model we assume that soil and dust ingestion rates during childhood peak at 45 mg/day, and that this peak is applicable to ages 1 - <2, 2 - <3, and 3 - <4. We further assume that the relative magnitude of the soil and dust ingestion rates at other ages is the same as that implied by the values adopted by USEPA in its IEUBK guidance manual (USEPA, 1994, Table 2-7). Gradient's soil ingestion rate estimates for all age groups, based on the Stanek and Calabrese 1-4 year olds, are shown in the column labeled "Amherst" in Table 4.

Stanek and Calabrese (1995b)

Stanek and Calabrese (1995b) performed an additional reanalysis of the 1989 Amherst data set where they estimate daily soil ingestion in children. Here they report average soil ingestion rates for the 50^{th} percentile child of 45 mg/day, and for the 95^{th} percentile child of 208 mg/day, very similar to, but slightly different from the 1995a analysis.

This paper represented a first attempt by Stanek and Calabrese to extrapolate the results of their seven-day studies to longer time periods. They present a methodology that they later refine significantly in Stanek and Calabrese (2000).

Stanek and Calabrese (2000)

A more recent study by Stanek and Calabrese (2000) provides daily soil ingestion estimates for 64 children, ages 1 to 4 years, residing at a Superfund site in Anaconda, Montana. Stanek and Calabrese derived a seven-day average soil ingestion rate for the 50^{th} percentile child of 17 mg/day. (The comparable value based on the 1989 Amherst population was 45 mg/day.) The seven-day average soil ingestion rate for the 95^{th} percentile child was 141 mg/day (compared to 208 mg/day for the Amherst population.)

Stanek and Calabrese (2000) also estimate average soil ingestion rates over longer time periods, based on the seven-day study period. They estimate that the 95^{th} percentile child will have a 365 day average soil ingestion rate of 106 mg/day for the Anaconda population and 124 mg/day for the Amherst population. These estimates are based on an analysis of uncertainty in the daily soil ingestion estimates, using standard statistical techniques. The estimates do not include an adjustment for seasonal effects (*e.g.*, amount of frozen ground or snow cover in winter). Although children continue to be exposed to indoor dust even when the ground is frozen in winter, their overall winter exposure to soil and dust is expected to average less than in summer. Stanek and Calabrese note the appropriate use of these estimates in risk assessment (page 633):

> *Estimates of the distribution of longer term average soil ingestion are expected to be narrower, with 95^{th}-percentile estimates being as much as 25% lower than those given in Table II. Such average exposure maybe most appropriate when considering the impact of chronic (i.e., 1-year) exposure to lead-contaminated soil on blood-lead levels.*

Stanek and Calabrese do not present comparable long term averages for the 50th percentile child.

5.1.3 Recommended Alternative Soil Ingestion Rates

Clearly, there are large differences between the IEUBK default soil ingestion rates, the soil ingestion rates used in various USEPA risk assessments, and the more recent values proposed by the Stanek and Calabrese papers. One possible reason for these differences is confusion over the correct measure of soil ingestion to use in the IEUBK model. USEPA's 1994 Guidance Manual is clear that an average, or central estimate, of soil ingestion should be used (page 2-40). Stanek and Calabrese (2000) further clarify that this should be a long-term average where chronic risk is being assessed. However, every child's average soil ingestion rate is different. Stanek and Calabrese, in their various publications, have presented values including the 50th percentile (or median) child's average, the 95th percentile child's average, the average estimate of the populations' averages (*i.e.*, sum each child's average rate and take the average of that, does not correspond to any particular percentile of the distribution of children), and many more. It is not clear in the 1994 Guidance Manual which measure of ingestion the defaults represent, although we believe it is the average of the averages. This would explain some (but not all) of the difference between the default values and those given in Table 4 here based on the Stanek and Calabrese studies.

We recommend that the alternative soil ingestion rates used in the IEUBK Model should correspond to average soil ingestion rates for the 50th percentile child. The reason for this is that the IEUBK Model estimates a geometric mean blood lead (this is the same as the blood lead for the 50th percentile child for a lognormal distribution) and then uses the geometric standard deviation to estimate a 95th (or other) percentile PbB based on the geometric mean blood lead. This risk assessment construct requires inputs that correspond to geometric means, including an average soil ingestion rate for the geometric mean child.

There are additional major differences in soil ingestion rate estimates for the Amherst and Anaconda populations, whereas the population studied by Davis *et al.* appears to be similar to the Amherst population. It is unknown whether the differences in soil ingestion rates between the Amherst and Anaconda populations represent differences in climate, soil-to-dust transfer, knowledge among the Anaconda population that they are living on a Superfund site, or the "improved study design" (Stanek and

Calabrese, 2000, page 634) of the Anaconda study. Both population differences and study analysis differences may play a role.

In summary, reanalysis of the original studies that supported the IEUBK default soil ingestion values suggests that average soil ingestion rates are lower than the model defaults. The Palmerton and Butte risk assessments used soil ingestion rates that are 38% and 20% lower, respectively, than the model defaults in order to better approximate exposure in those communities. Estimates of average soil ingestion rates for the 50th percentile child by Stanek and Calabrese are also lower than the model defaults, and vary considerably between the Amherst and Anaconda populations. Note that even the long-term average estimates for the 95th percentile child are lower than the model default values (106 mg/day for Anaconda or 124 mg/day for Amherst *vs.* 135 mg/day default). This suggests that the model default values may be too high.

Actual soil and dust ingestion rates probably fall somewhere within the ranges given by the values in Table 4. The soil ingestion rates from both the Palmerton and Amherst studies are used in Section 5.3 to examine uncertainty in blood lead predictions resulting from uncertainty in soil ingestion rates.

5.2 Geometric Standard Deviation (GSD)

As part of this evaluation, we developed an estimate of the site-specific individual geometric standard deviation (GSD) for child blood lead levels in the community surrounding the Exide site in Reading, PA. The IEUBK model uses a GSD to describe the lognormal distribution of PbB values attributable to variation in individual biological and behavioral parameters, independent of environmental concentration factors. It is generally accepted that children of a given age, with similar soil and dust exposures, will have, theoretically, a range of PbB levels that can be described by a lognormal distribution. In groups of children of the same age who are exposed to similar concentrations of lead in soil and dust, the observed variability is characterized by the individual GSD. Children in a community can be grouped by their exposure to similar soil and dust lead levels, and an estimate of the individual GSD can be calculated for each group. The median of the individual GSDs is considered representative for use in modeling the entire population of interest (Life Systems, 1995). EPA uses a GSD default value of 1.6 in the IEUBK model in the absence of a site-specific number.[5]

[5] For the purpose of this report, we have not requested or evaluated the data from which the default GSD of 1.6 was generated.

EPA developed site-specific GSD values for the Sandy, UT; Bingham Creek, UT; and Palmerton, PA sites. The table below shows the default GSD value used in the Model, together with site-specific values used by EPA at other sites. The GSD value estimated, following EPA's methodology, for the Exide Reading site is 1.34.

Site	Site-specific Individual GSD
IEUBK Model Default	1.6
Sandy, UT	1.4
Kennecott/Bingham Creek	
Community	1.56
High Exposure group	1.43
.Palmerton, PA	1.46
Exide Reading, PA	1.34

5.2.1 Data Used in this Evaluation

The soil, indoor dust, and blood lead data used in developing the site-specific GSD are described in Sections 3.2 and 3.3 of this report.

The final data set included blood lead values from 39 children who are less than or equal to 84 months of age, who reside in or visit the Study Area, and for whom both soil and indoor dust lead concentrations were available. Inclusion of visitors is expected to increase the GSD, since the other exposures that the visitor children experience (at home or elsewhere) could include environmental concentrations that vary from those found at the residence where they visit. Two of the children in this group were twins (housecode 27, personcode 64 and 65). EPA requested that twins not be included in the GSD analysis, therefore one of the twins (personcode 65) was removed from the dataset prior to the statistical analysis.

We also reviewed the results of the Environmental and Exposure questionnaires conducted in Reading at the time of the blood lead study to determine if any children had any unusual exposures that could affect the value of the GSD. No PbB values were excluded as a result of this review.

5.2.2 Methodology

The Reading child blood lead data were analyzed using the approach described in EPA's Lead Guidance Manual, Appendix A (USEPA, 1994). Briefly, this approach segregates the PbB values into "boxes" according to the child's age (in years), average yard soil lead concentration, and indoor dust lead concentration. GSDs are calculated for each box, and the median GSD for all boxes (weighted by the degrees of freedom) is used as the final GSD to be used in the model. One goal of this segregation is to minimize the range of soil and dust lead concentrations in each box, while maximizing the number of PbB values in each box. This approach reduces uncertainty in the resulting GSD value.

The soil and dust data were segregated into "bins" by concentration[6] (Table 6). Four soil bins were used in this analysis, in increments of 500 mg/kg, from 0 to 2000 mg/kg. The soil bins were named with the midpoint of the soil concentration range they represent, *i.e.,* soil bin SB250 includes soil concentrations from 0 to 500 mg/kg. Seven dust bins were used in this analysis. The first four bins had ranges of 500 mg/kg, and the last three bins had wider ranges (Table 6). The dust bins were named with the midpoint of the dust concentration range they represent, *i.e.,* dust bin DB250 includes dust concentrations from 0 to 500 mg/kg. A total of eight age bins were used, using the age of the child in years from ages 0 to 7 years. The child age in years was rounded down to the nearest whole year, *i.e.*, a child age 83 months, or 6.9 years, was considered to be 6 years old.

[6] Note that, as used here, a "bin" and a "box" are distinct from one another. Bins are media-specific, and are used to segregate the soil, dust, and age data into ranges. For example, a soil concentration of 120 mg/kg is assigned to soil bin SB250, which contains soil concentrations between 0 and 500 mg/kg. A "box" is a unique combination of soil bin, dust bin, and age bin. Thus a "box" contains blood lead values for children of the same age, who are exposed to similar soil and dust concentrations.

Table 6
Soil and Dust Bins Used for GSD Analysis

	Bin Name	low conc. (mg/kg)	high conc. (mg/kg)	midpoint conc. (mg/kg)
Soil Bin	SB250	0	500	250
	SB750	500	1000	750
	SB1250	1000	1500	1250
	SB1750	1500	2000	1750
Dust Bin	DB250	0	500	250
	DB750	500	1000	750
	DB1250	1000	1500	1250
	DB1750	1500	2000	1750
	DB2500	2000	3000	2500
	DB4500	4000	5000	4500
	DB8000	7000	9000	8000

Each blood lead value was assigned to a box based on the child's age, and the soil and dust concentrations at his or her residence. Summary statistics were calculated for the blood lead values in each box: number of blood lead values in the box (N), mean, standard deviation (SD), geometric mean (GM), and GSD. Next, the overall weighted median GSD was calculated from the "within-box" GSDs; where within-box GSDs were weighted by the degrees of freedom (N-1) for the box. GSDs were calculated only for boxes with two or more blood lead values.

5.2.3 Results

The GSD analysis was performed four different ways. The results are presented in Tables in Appendix D. Tables D-1 and D-2 present results for residents and visitors combined, while Tables D-3 and D-4 present results for residents only. Tables D-1 and D-3 used one-year age groups. Tables D-2 and D-4 used two-year age groups, *i.e.*, the age bins consisted of combined age groups – ages 0-1 year, 2-3 years, 4-5 years, and 6-7 years. We combined the ages into these groupings due to similarities in behavior among children of these ages. Four analyses were performed as a method to assess the uncertainty associated with the site-specific GSD, particularly in light of the small sample size.

The GSD results from each analysis are summarized in Table 7. The four calculations of the weighted median GSD yield estimates of the site-specific GSD that are substantially lower than the EPA's proposed default value of 1.6. Median weighted GSDs range from 1.33 to 1.51. Comparing analyses with residents and visitors to those with only residents, we find that the GSD decreases when visitor children are excluded from the analysis. This result is expected because visitor children likely have broader environmental lead exposures (*i.e.*, environmental lead levels at their primary residence are unknown, and may not be within the concentration ranges established for the box in which the visitor was analyzed). The use of the 2-year age bins (Tables D-3 and D-4) increased the number of boxes with multiple PbB values, and thus gave a greater number of GSD values. The analyses that included only residents yielded very similar GSDs (1.33 and 1.34 in Tables D-2 and D-4).

Table 7
Summary of GSD Analyses

Population **Age bins**	**Table D-1 Residents/Visitors** **1-yr**	**Table D-2 Residents** **1-yr**	**Table D-3 Residents/Visitors** **2-yr**	**Table D-4 Residents** **2-yr**
Number of PbB values	38	30	38	30
Number of GSD values	5	5	7	5
Median GSD	1.49	1.33	1.63	1.34
Weighted Median GSD	1.49	1.33	1.51	1.34

5.2.4 Conclusion

Analysis of the child blood lead data from residents of the Study Area in Reading indicates that there is uncertainty in the site-specific GSD, with a low-end estimate of 1.34, and a high-end estimate of 1.51. The EPA-recommended default GSD of 1.6 will be used in the risk assessment, while the low-end GSD estimate of 1.34 will be used to assess uncertainty in the risk assessment.

5.3 IEUBK Model Analysis Using Alternate Input Values

In order to examine the effect of uncertainty on the model-predicted PbBs, the model was run with various combinations of the alternate input values discussed above, using the same batch file as was used for the run with default input values. Predicted and observed PbBs are compared for each of the model runs.

5.3.1 Inputs

Five batch-mode runs of the IEUBK Model were conducted using different combinations of the alternate input values, summarized in Table 8. The model was run with the Palmerton and Amherst soil ingestion rates, and the site-specific GSD of 1.34 as well as the default GSD of 1.6.

Table 8
Summary of IEUBK Model Runs with Alternate Input Values

Parameter	Input	1	2	3	4	5	6
Soil Ingestion Rate	Default	X	X				
	Palmerton			X	X		
	Amherst					X	X
GSD	Default 1.6	X		X		X	
	1.34		X		X		X

Run 1 used the default soil ingestion rate and the default GSD, as previously described in Section 4.2. Run 2 used the default soil ingestion rate and the site-specific GSD. Runs 3 and 4 used the Palmerton soil ingestion rate and the default and site-specific GSD. Runs 5 and 6 used the Amherst soil ingestion rates and the default and site-specific GSD. The site-specific GSD of 1.34 does not affect the predicted geometric mean PbB for each child but does affect the exceedance probabilities (*i.e.,* the blood lead distribution), and therefore the predictive capability of the model.

5.3.2 Results

The results of the batch mode runs of the IEUBK model using the alternate input values are summarized in Table 9. The batch output files are provided in Appendix E. Table 9 presents the GM of all the predicted PbBs, as well as the mean of all the predicted probabilities of exceeding a PbB of 10 µg/dL. The mean probability of exceeding a PbB of 10 µg/dL is what the model predicts would be the percent of the population with blood leads above 10 µg/dL, given these environmental exposures. All five of the alternate runs have predicted GMs that are higher than the observed GM. Runs 5 and 6, which use the Amherst soil ingestion rate, have the GM PbB (3.4 µg/dL) that is closest to the GM for the observed data (2.4 µg/dL). Run 6, which uses the site-specific GSD, has a mean probability of having a PbB greater than 10 µg/dL of 4%. This is the lowest exceedance probability, but it still exceeds the observed probability of 0%.

Table 9
Summary of Results from Batch Runs of IEUBK Model Using Alternate Input Values

Run Number	Soil Ingestion Rate	GSD	GM of all $PbB_{predicted}$	Mean Probability > 10 µg/dL
Observed			2.4	0%
1	Default	1.6	7.9	38%
2	Default	1.34	7.9	36%
3	Palmerton	1.6	5.5	21%
4	Palmerton	1.34	5.5	17%
5	Amherst	1.6	3.4	7%
6	Amherst	1.34	3.4	4%

Exceedance probability distributions for the alternate runs are presented in Figure 2, in addition to the distributions for the model default run and the observed PbB data. Figure 2 indicates that the model tends to overpredict PbB for all runs including the model default. Runs 5 and 6 provide the closest agreement to the observed data, and provide better agreement than the model default run.

5.4 Soil Action Levels Using IEUBK Model with Alternate Inputs

The IEUBK model was run in the "Find Blood Lead Concentration" mode, to calculate soil action levels for children ages 0 to 84 months. The target GM PbB is 4.6 µg/dL for a GSD of 1.6, and 6.2 µg/dL for the site-specific GSD of 1.34. The drinking water lead concentration was set to 1 µg/L, the median value for Reading. Table 10 presents the soil action levels calculated using the alternative inputs, and the model defaults. The soil lead action levels range from 420 to 1900 mg/kg.

Table 9 and the exceedance probability plot in Figure 2 indicate that the Amherst soil ingestion rate together with the site-specific GSD of 1.34 provides the closest agreement to the observed PbB data. These inputs were used in Run 6 in Table 10. Run 6 yields a soil lead action level of 1900 mg/kg.

Table 10
Soil Lead Action Levels for Children Ages 0-84 Months

Run Number	Soil Ingestion Rate	M_{SD}	GSD	Target GM	Soil Lead Action Level (mg/kg)
1	Default	0.70	1.6	4.6	420
2	Default	0.70	1.34	6.2	620
3	Palmerton	0.70	1.6	4.6	680
4	Palmerton	0.70	1.34	6.2	1000
5	Amherst	0.70	1.6	4.6	1300
6	Amherst	0.70	1.34	6.2	1900

5.5 Other Sources of Uncertainty

One source of uncertainty in this community is the relationship between soil lead and dust lead. Figure 3 presents a plot of dust lead *vs*. soil lead. The different symbols represent houses in four categories, corresponding to whether or not the house has had recent remodeling, and whether or not the house had any interior paint readings greater than 1 mg/cm^2. The regression line is drawn through all the symbols, and has the equation:

$$\text{Dust Lead} = 0.18*(\text{Soil Lead}) + 1443$$

The correlation between soil and dust is poor, as evidenced by the fact that the line has a correlation coefficient (r^2) of only 0.001. The high residual (intercept) of 1443 indicates that there could be another source of lead in housedust besides soil. In addition, there is no clear trend within the house categories in this figure, except for the fact that houses without lead paint (Categories 3 and 4) generally have dust lead concentrations below 1000 mg/kg. Houses in Category 1, which have both lead paint *and* recent remodeling, do not have uniformly high dust leads.

We also investigated whether dust lead could be influenced by parental occupational exposure to lead. The environmental survey identified four houses where parental occupational exposure to lead was a potential issue. Thus, for these four houses, some of the lead in interior housedust could have come from the parent's clothing. These houses are shown with red symbols on Figure 3. Three of these houses have dust lead levels below 1000 mg/kg, and one has a dust lead level of 5000 mg/kg, thus there does not appear to be a defined trend for this parameter.

Because the relationship between dust and soil lead is unclear, another source of uncertainty is the possibility that the different sources of lead in dust *e.g.*, paint and soil, have different relative bioavailabilities (higher or lower) than the 60% assumed in the IEUBK model.

Because dust lead can be a young child's primary route of exposure, the uncertain relationship between soil lead and dust lead contributes to uncertainty in whether the implementation of any particular soil lead cleanup level will have the expected impact on blood lead levels.

6 Summary and Conclusions

Soil lead action levels for residential properties in the Study Area range from 420 to 1900 mg/kg. With a few exceptions where access could not be obtained, exposure areas with average soil lead concentrations greater than 1200 mg/kg, that represent the area immediately around a residential dwelling, have been remediated. The closest model agreement to the observed PbB data was found for inputs that include the Amherst soil ingestion rate together with the site-specific GSD of 1.34. These inputs yield a soil lead action level of 1900 mg/kg, above the 1200 mg/kg that has been used as the interim value. Therefore, no further soil remediation may be necessary.

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Figure 1
Exceedance Probability for Default Run

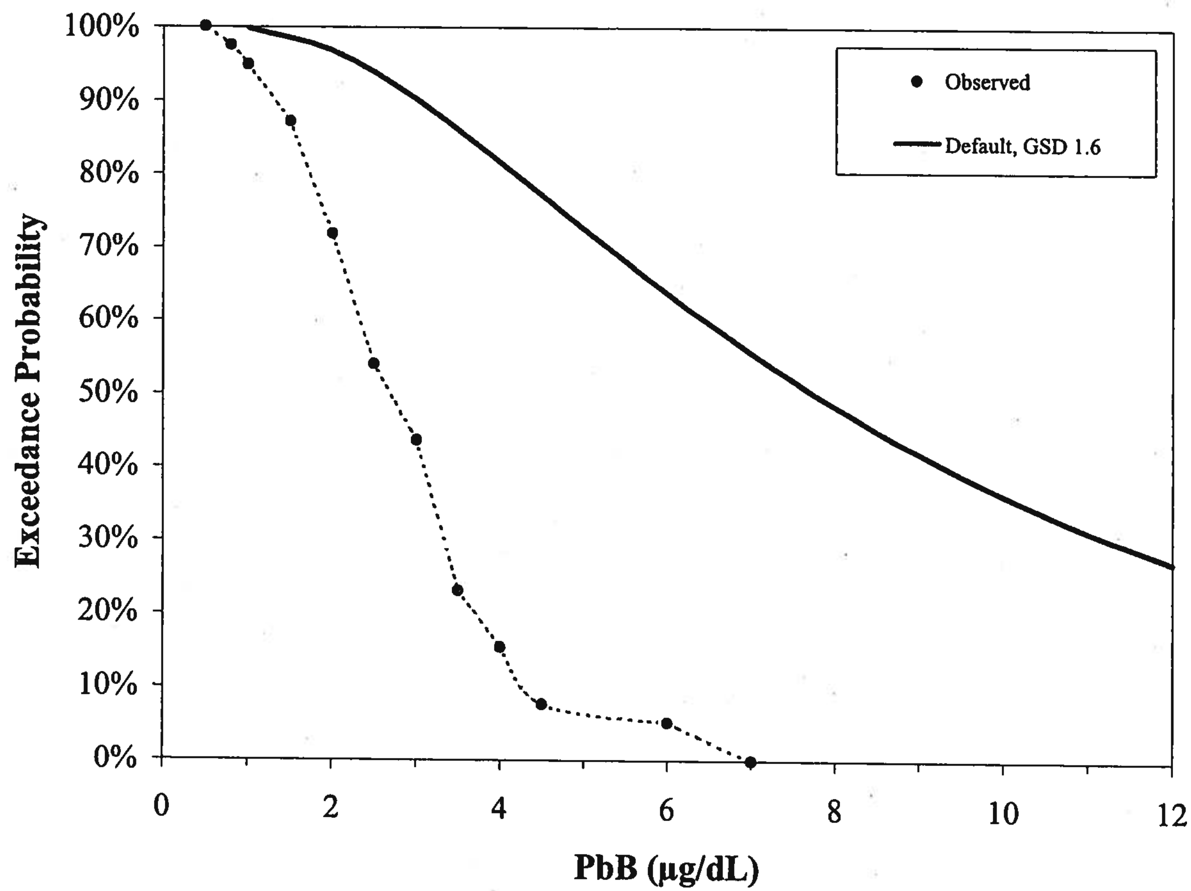


Figure 2
Exceedance Probabilities for Alternate Runs

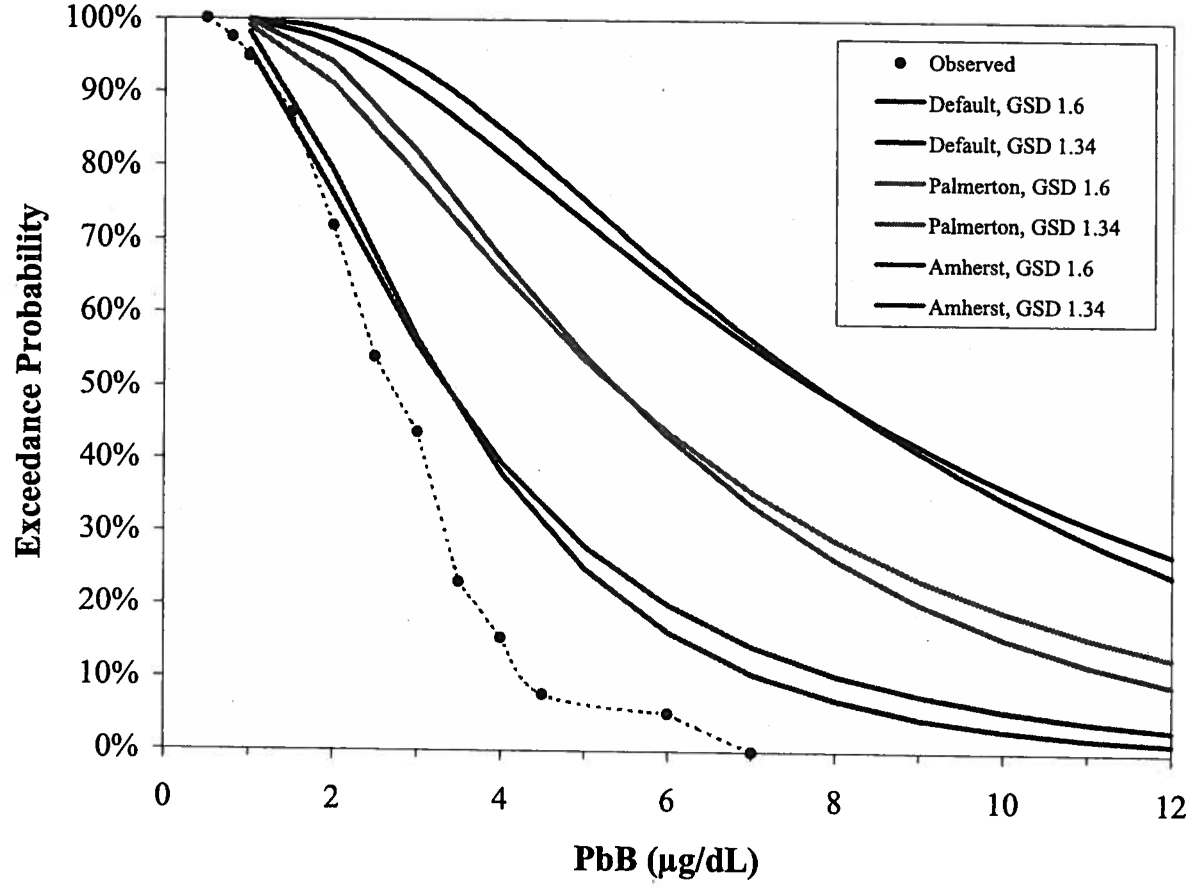
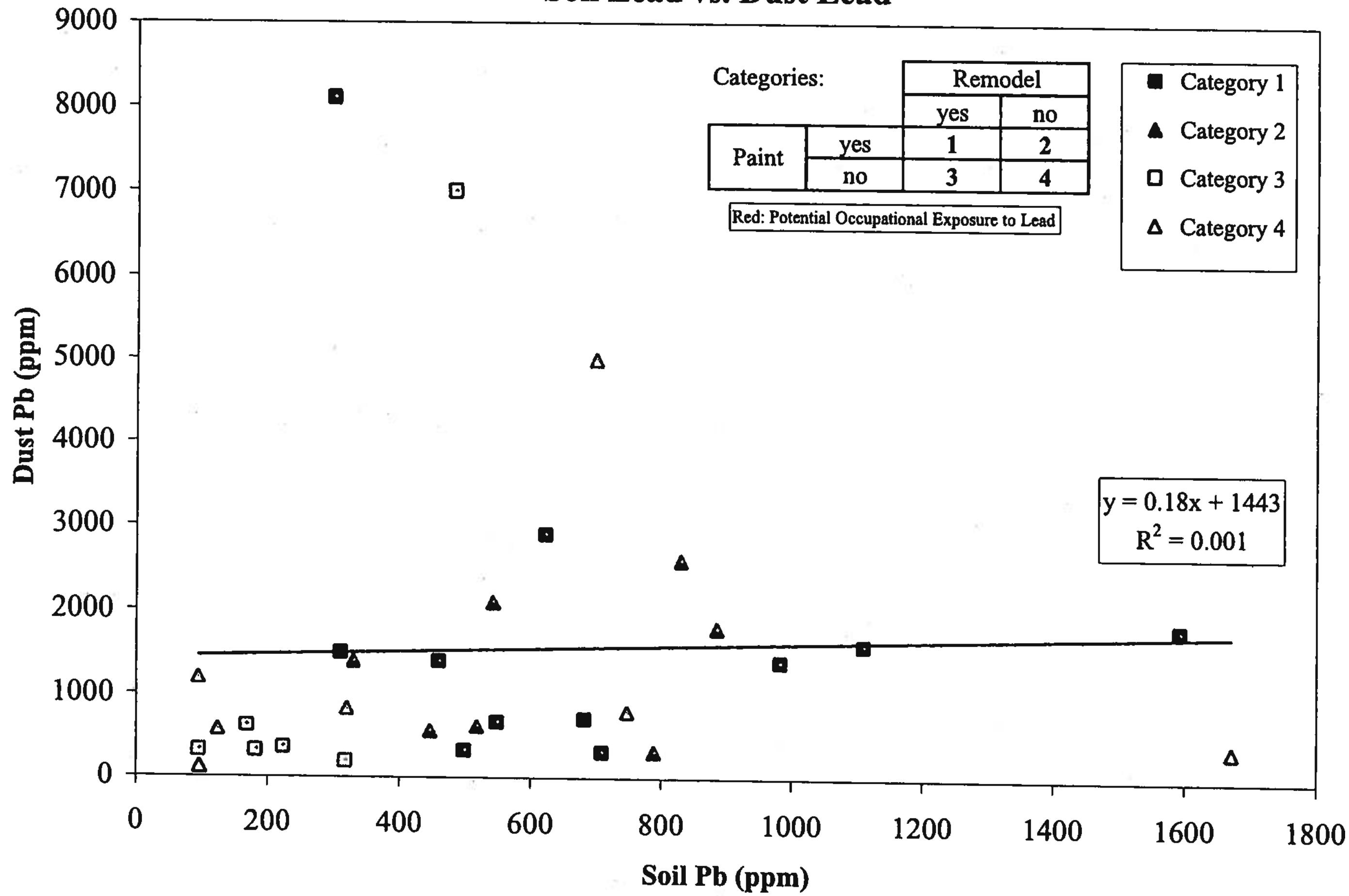


Figure 3
Soil Lead vs. Dust Lead



Appendix A

Blood Lead, Soil, and Dust Data

Appendix A

House Code	Person Code	Type	PbB1 (µg/dL)	PbB2 (µg/dL)	Avg PbB (µg/dL)	Age (yr)	Age (mo)	Avg Soil Pb (mg/kg)	Dust Pb (mg/kg)	Water Pb (mg/L)	Exterior Paint Max (mg/cm²)	Exterior Paint Avg (mg/cm²)	Interior Paint Max (mg/cm²)	Interior Paint Avg (mg/cm²)	Remediation Status
1	1	R	0.5	0.5	0.5	4	55	542	2100	0.001	13.4	8.4	22.3	6.4	Retained for Future
1	2	R	3	2	2.5	2	26	542	2100	0.001	13.4	8.4	22.3	6.4	Retained for Future
2	5	R	3	4	3.5	4	49	96	120	0.002	0.4	0.4	0.4	0.3	No Further Action
3	6	V	4	4	4	5	72	298	8100		19.3	12.1	20.4	4.3	No Further Action
4	8	R	1	2	1.5	5	71	518	620	0.001	5.6	2.0	17.5	3.3	Retained for Future
4	11	R	2	2	2	4	54	518	620	0.001	5.6	2.0	17.5	3.3	Retained for Future
5	12	R	2	1	1.5	3	46	1593	1800		3.8	2.3	22.5	8.7	Cleanup
6	16	R	1	1	1	6	78	682	710	0.002	16.5	11.5	14.9	3.7	Retained for Future
7	20	R	2	1	1.5	5	66	549	670	0.001	2.6	1.0	6.0	1.2	Retained for Future
8	22	R	2	1	1.5	6	82	622	2900		9	6.4	5.2	1.0	Retained for Future
9	24	R	3	3	3	5	71	446	560		14.7	9.3	4.3	1.8	No Further Action
10	27	R	2	2	2	5	71	498	330	0.025	2	1.2	15.2	3.3	No Further Action
12	32	R	3	3	3	6	76	351							Retained for Future
13	35	R	4	5	4.5	4	51	309	1500	0.004	4.5	1.8	13.3	3.2	No Further Action
14	37	R	3	3	3	2	32	655							Retained for Future
15	40	V	2	1	1.5	5	66	829	2600	0.002	26.5	13.7	23.9	4.8	Retained for Future
15	41	V	0.5	1	0.75	3	45	829	2600	0.002	26.5	13.7	23.9	4.8	Retained for Future
17	44	V	7	7	7	5	61	1023							Retained for Future
17	46	V	14	14	14	2	29	1023							Retained for Future
18	47	R	3		3	5	60	982	1400		22.3	18.2	11.4	3.2	Retained for Future
19	49	R	6	6	6	2	25	789	320		21.2	13.9	6.8	2.1	Retained for Future
20	50	R	1	1	1	4	53	329	1400		0.4	0.3	2.8	0.5	No Further Action
20	52	R	2	1	1.5	2	35	329	1400		0.4	0.3	2.8	0.5	No Further Action
20	53	R	2	2	2	1	11	329	1400		0.4	0.3	2.8	0.5	No Further Action
23	56	V	4	4	4	4	59	60							No Further Action
24	59	V	4	3	3.5	4	59	181	320		0.3	0.2	0.4	0.3	No Further Action
25	60	R	2	2	2	3	41	317	190		3.2	1.3	0.3	0.2	No Further Action
26	61	V	3	3	3	6	83	699	5000		5.3	3.5	0.4	0.3	Retained for Future
27	63	R	2	2	2	5	70	124	580	0.001	0.4	0.4	0.5	0.3	Retained for Future
27	64	R	2	3	2.5	2	34	124	580	0.001	0.4	0.4	0.5	0.3	Retained for Future
27	65	R	3	2	2.5	2	34	124	580	0.001	0.4	0.4	0.5	0.3	Retained for Future
29	66	R	3	3	3	2	34	94	1200		0.3	0.3	0.4	0.3	No Further Action
31	69	R	3	3	3	1	19	168	620	0.001	0.2	0.2	0.5	0.3	No Further Action
32	73	R	1	1	1	4	58	223	360	0.001			0.4	0.2	No Further Action
33	75	V	3	3	3	5	64	747	800		0.3	0.3	0.4	0.2	Retained for Future
33	76	V	3	3	3	3	40	747	800		0.3	0.3	0.4	0.2	Retained for Future

Appendix A

House Code	Person Code	Type	PbB1 (µg/dL)	PbB2 (µg/dL)	Avg PbB (µg/dL)	Age (yr)	Age (mo)	Avg Soil Pb (mg/kg)	Dust Pb (mg/kg)	Water Pb (mg/L)	Exterior Paint Max (mg/cm²)	Exterior Paint Avg (mg/cm²)	Interior Paint Max (mg/cm²)	Interior Paint Avg (mg/cm²)	Remediation Status
34	79	R	2	2	2	4	55	602	1000U	0.001	7.2	5.7	7.2	1.3	Retained for Future
34	80	R	3	3	3	2	34	602	1000U	0.001	7.2	5.7	7.2	1.3	Retained for Future
35	81	R	3	2	2.5	6	74	709	310		22.3	12.8	11.3	1.8	Retained for Future
35	82	R	7	7	7	2	34	709	310		22.3	12.8	11.3	1.8	Retained for Future
36	83	V	2	2	2	3	70	1110	1600		2.7	1.8	3.4	2.1	Cleanup
36	84	V	2	2	2	5	46	1110	1600		2.7	1.8	3.4	2.1	Cleanup
38	86	R	3	3	3	5	68	885	1800		27.1	19.1	3.7	1.4	Retained for Future
39	87	R	4	4	4	3	36	572	4000U	0.002	0.6	0.3	0.6	0.3	Retained for Future
40	90	R	3	5	4	6	84	460	1400	0.002	4.4	2.7	7.9	1.8	Retained for Future
41	92	R	6	6	6	3	47	1671	370	0.001	16	7.5	0.3	0.3	Cleanup
41	93	R	4	4	4	6	72	1671	370	0.001	16	7.5	0.3	0.3	Cleanup
42	94	R	3	4	3.5	4	54	319	830	0.001	1.7	1.2	0.3	0.1	No Further Action

Notes: Missing person codes are from duplicate or split samples not listed here.
Blanks indicate that no data were collected.
U means not detected, with value representing the detection limit.

Appendix B

IEUBK Batch Input File

Appendix B

ID	FAM	BLOCK	AGE	SOIL	DUST	WATER	AIR	PAINT	PBB
1	1	R	55	542	2100	1	.	0	0.5
2	1	R	26	542	2100	1	.	0	2.5
5	2	R	49	96	120	2	.	0	3.5
6	3	V	72	298	8100	***1***	.	0	4
8	4	R	71	518	620	1	.	0	1.5
11	4	R	54	518	620	1	.	0	2
12	5	R	46	1593	1800	***1***	.	0	1.5
16	6	R	78	682	710	2	.	0	1
20	7	R	66	549	670	1	.	0	1.5
22	8	R	82	622	2900	***1***	.	0	1.5
24	9	R	71	446	560	***1***	.	0	3
27	10	R	71	498	330	25	.	0	2
35	13	R	51	309	1500	4	.	0	4.5
40	15	V	66	829	2600	2	.	0	1.5
41	15	V	45	829	2600	2	.	0	0.75
47	18	R	60	982	1400	***1***	.	0	3
49	19	R	25	789	320	***1***	.	0	6
50	20	R	53	329	1400	***1***	.	0	1
52	20	R	35	329	1400	***1***	.	0	1.5
53	20	R	11	329	1400	***1***	.	0	2
59	24	V	59	181	320	***1***	.	0	3.5
60	25	R	41	317	190	***1***	.	0	2
61	26	V	83	699	5000	***1***	.	0	3
63	27	R	70	124	580	1	.	0	2
64	27	R	34	124	580	1	.	0	2.5
65	27	R	34	124	580	1	.	0	2.5
66	29	R	34	94	1200	***1***	.	0	3
69	31	R	19	168	620	1	.	0	3
73	32	R	58	223	360	1	.	0	1
75	33	V	64	747	800	***1***	.	0	3
76	33	V	40	747	800	***1***	.	0	3
81	35	R	74	709	310	***1***	.	0	2.5
82	35	R	34	709	310	***1***	.	0	7
83	36	V	70	1110	1600	***1***	.	0	2
84	36	V	46	1110	1600	***1***	.	0	2
86	38	R	68	885	1800	***1***	.	0	3
90	40	R	84	460	1400	2	.	0	4
92	41	R	47	1671	370	1	.	0	6
93	41	R	72	1671	370	1	.	0	4
94	42	R	54	319	830	1	.	0	3.5

Water concentrations in bold italics are the median water concentration for the community, used for houses where tap water data was not collected.

Appendix C

Data Set for GSD Analysis

Appendix C

house	person	agemon	type	ageint	soil	dust	PbB
1	1	55	R	4	542	2100	0.5
1	2	26	R	2	542	2100	2.5
1	4	360	R	30	542	2100	1
2	5	49	R	4	96	120	3.5
3	6	72	V	6	298	8100	4
3	7	96	V	8	298	8100	2
4	8	71	R	5	518	620	1.5
4	10	360	R	30	518	620	1
4	11	54	R	4	518	620	2
5	12	46	R	3	1593	1800	1.5
5	13	360	R	30	1593	1800	2
5	14	360	R	30	1593	1800	1
6	15	118	R	9	682	710	0.5
6	16	78	R	6	682	710	1
7	19	89	R	7	549	670	1.25
7	18	116	R	9	549	670	1
7	20	66	R	5	549	670	1.5
8	21	106	R	8	622	2900	2
8	22	82	R	6	622	2900	1.5
9	23	128	R	10	446	560	2
9	24	71	R	5	446	560	3
10	26	105	R	8	498	330	3
10	27	71	R	5	498	330	2
11	28	90	R	7	95	320	2
11	29	144	R	12	95	320	2
12	30	170	R	14	351		2
12	31	131	R	10	351		2
12	32	76	R	6	351		3
13	34	409	R	34	309	1500	0.75
13	35	51	R	4	309	1500	4.5
14	37	32	R	2	655		3
15	38	512	V	42	829	2600	1
15	39	134	V	11	829	2600	0.75
15	40	66	V	5	829	2600	1.5
15	41	45	V	3	829	2600	0.75
17	43	281	V	23	1023		3
17	44	61	V	5	1023		7
17	46	29	V	2	1023		14
18	47	60	R	5	982	1400	3
18	48	132	R	11	982	1400	1
19	49	25	R	2	789	320	6
20	50	53	R	4	329	1400	1
20	52	35	R	2	329	1400	1.5
20	53	11	R	0	329	1400	2
21	54	360	R	30	483	7000	3
23	55	169	V	14	60		2.5
23	56	59	V	4	60		4
24	57	154	V	12	181	320	2.5
24	58	137	V	11	181	320	2.5
24	59	59	V	4	181	320	3.5
25	60	41	R	3	317	190	2
26	61	83	V	6	699	5000	3

Appendix C

house	person	agemon	type	ageint	soil	dust	PbB
27	63	70	R	5	124	580	2
27	64	34	R	2	124	580	2.5
27	65	34	R	2	124	580	2.5
29	66	34	R	2	94	1200	3
29	67	360	R	30	94	1200	1
29	68	360	R	30	94	1200	2
31	69	19	R	1	168	620	3
32	71	151	R	12	223	360	1.5
32	72	92	R	7	223	360	1
32	73	58	R	4	223	360	1
33	75	64	V	5	747	800	3
33	76	40	V	3	747	800	3
34	79	55	R	4	602		2
34	80	34	R	2	602		3
35	81	74	R	6	709	310	2.5
35	82	34	R	2	709	310	7
36	83	70	V	5	1110	1600	2
36	84	46	V	3	1110	1600	2
37	85	98	V	8	1058		4
38	86	68	R	5	885	1800	3
39	87	36	R	3	572		4
40	88	338	R	28	460	1400	2
40	89	96	R	8	460	1400	4.5
40	90	84	R	7	460	1400	4
41	91	97	R	8	1671	370	17
41	92	47	R	3	1671	370	6
41	93	72	R	6	1671	370	4
42	94	54	R	4	319	830	3.5

Blanks indicate that data are missing either because sample was not collected or result was a non-detect.

Appendix D

GSD Analysis Results

Table D-1
GSD Analysis Using One-Year Age Bins
Residents and Visitors

			Blood Lead Levels (µg/dL)				
Age (yr)	Soil Bin	Dust Bin	N	Mean	SD	GM	GSD
0	250	1250	1	2.00	.	2.00	.
1	250	750	1	3.00	.	3.00	.
2	250	750	1	2.50	.	2.50	.
2	250	1250	2	2.25	1.06	2.12	1.63
2	750	250	2	6.50	0.71	6.48	1.12
2	750	2500	1	2.50	.	2.50	.
3	250	250	1	2.00	.	2.00	.
3	750	750	1	3.00	.	3.00	.
3	750	2500	1	0.75	.	0.75	.
3	1250	1750	1	2.00	.	2.00	.
3	1750	250	1	6.00	.	6.00	.
3	1750	1750	1	1.50	.	1.50	.
4	250	250	3	2.67	1.44	2.31	2.06
4	250	750	1	3.50	.	3.50	.
4	250	1250	1	1.00	.	1.00	.
4	250	1750	1	4.50	.	4.50	.
4	750	750	1	2.00	.	2.00	.
4	750	2500	1	0.50	.	0.50	.
5	250	250	1	2.00	.	2.00	.
5	250	750	2	2.50	0.71	2.45	1.33
5	750	750	3	2.00	0.87	1.89	1.49
5	750	1250	1	3.00	.	3.00	.
5	750	1750	1	3.00	.	3.00	.
5	750	2500	1	1.50	.	1.50	.
5	1250	1750	1	2.00	.	2.00	.
6	250	8000	1	4.00	.	4.00	.
6	750	250	1	2.50	.	2.50	.
6	750	750	1	1.00	.	1.00	.
6	750	2500	1	1.50	.	1.50	.
6	1750	250	1	4.00	.	4.00	.
7	250	1250	1	4.00	.	4.00	.

Number of PbB values	38
Number of boxes	31
Number of GSD values (within-box)	5
Minimum GSD	1.1
Maximum GSD	2.1
Median GSD - weighted by DF	**1.49**
Median GSD - unweighted	1.49

Table D-2
GSD Analysis Using One-Year Age Bins
Residents Only

			Blood Lead Levels (µg/dL)				
Age (yr)	Soil Bin	Dust Bin	N	Mean	SD	GM	GSD
0	250	1250	1	2.00	.	2.00	.
1	250	750	1	3.00	.	3.00	.
2	250	750	1	2.50	.	2.50	.
2	250	1250	2	2.25	1.06	2.12	1.63
2	750	250	2	6.50	0.71	6.48	1.12
2	750	2500	1	2.50	.	2.50	.
3	250	250	1	2.00	.	2.00	.
3	1750	250	1	6.00	.	6.00	.
3	1750	1750	1	1.50	.	1.50	.
4	250	250	2	2.25	1.77	1.87	2.43
4	250	750	1	3.50	.	3.50	.
4	250	1250	1	1.00	.	1.00	.
4	250	1750	1	4.50	.	4.50	.
4	750	750	1	2.00	.	2.00	.
4	750	2500	1	0.50	.	0.50	.
5	250	250	1	2.00	.	2.00	.
5	250	750	2	2.50	0.71	2.45	1.33
5	750	750	2	1.50	0.00	1.50	1.00
5	750	1250	1	3.00	.	3.00	.
5	750	1750	1	3.00	.	3.00	.
6	750	250	1	2.50	.	2.50	.
6	750	750	1	1.00	.	1.00	.
6	750	2500	1	1.50	.	1.50	.
6	1750	250	1	4.00	.	4.00	.
7	250	1250	1	4.00	.	4.00	.

Number of PbB values	30
Number of boxes	25
Number of GSD values (within-box)	5
Minimum GSD	1.0
Maximum GSD	2.4
Median GSD - weighted by DF	**1.33**
Median GSD - unweighted	1.33

Table D-3
GSD Analysis Using Two-Year Age Bins
Residents and Visitors

			Blood Lead Levels (µg/dL)				
Age Bin	Soil Bin	Dust Bin	N	Mean	SD	GM	GSD
0-1	250	750	1	3.00	.	3.00	.
0-1	250	1250	1	2.00	.	2.00	.
2-3	250	250	1	2.00	.	2.00	.
2-3	250	750	1	2.50	.	2.50	.
2-3	250	1250	2	2.25	1.06	2.12	1.63
2-3	750	250	2	6.50	0.71	6.48	1.12
2-3	750	750	1	3.00	.	3.00	.
2-3	750	2500	2	1.63	1.24	1.37	2.34
2-3	1250	1750	1	2.00	.	2.00	.
2-3	1750	250	1	6.00	.	6.00	.
2-3	1750	1750	1	1.50	.	1.50	.
4-5	250	250	4	2.50	1.22	2.22	1.81
4-5	250	750	3	2.83	0.76	2.76	1.34
4-5	250	1250	1	1.00	.	1.00	.
4-5	250	1750	1	4.50	.	4.50	.
4-5	750	750	4	2.00	0.71	1.92	1.39
4-5	750	1250	1	3.00	.	3.00	.
4-5	750	1750	1	3.00	.	3.00	.
4-5	750	2500	2	1.00	0.71	0.87	2.17
4-5	1250	1750	1	2.00	.	2.00	.
6-7	250	1250	1	4.00	.	4.00	.
6-7	250	8000	1	4.00	.	4.00	.
6-7	750	250	1	2.50	.	2.50	.
6-7	750	750	1	1.00	.	1.00	.
6-7	750	2500	1	1.50	.	1.50	.
6-7	1750	250	1	4.00	.	4.00	.

Number of PbB values	38
Number of boxes	26
Number of GSD values (within-box)	7
Minimum GSD	1.1
Maximum GSD	2.3
Median GSD - weighted by DF	**1.51**
Median GSD - unweighted	1.63

Table D-4
GSD Analysis Using Two-Year Age Bins
Residents Only

			Blood Lead Levels (µg/dL)				
Age Bin	Soil Bin	Dust Bin	N	Mean	SD	GM	GSD
0-1	250	750	1	3.00	.	3.00	.
0-1	250	1250	1	2.00	.	2.00	.
2-3	250	250	1	2.00	.	2.00	.
2-3	250	750	1	2.50	.	2.50	.
2-3	250	1250	2	2.25	1.06	2.12	1.63
2-3	750	250	2	6.50	0.71	6.48	1.12
2-3	750	2500	1	2.50	.	2.50	.
2-3	1750	250	1	6.00	.	6.00	.
2-3	1750	1750	1	1.50	.	1.50	.
4-5	250	250	3	2.17	1.26	1.91	1.87
4-5	250	750	3	2.83	0.76	2.76	1.34
4-5	250	1250	1	1.00	.	1.00	.
4-5	250	1750	1	4.50	.	4.50	.
4-5	750	750	3	1.67	0.29	1.65	1.18
4-5	750	1250	1	3.00	.	3.00	.
4-5	750	1750	1	3.00	.	3.00	.
4-5	750	2500	1	0.50	.	0.50	.
6-7	250	1250	1	4.00	.	4.00	.
6-7	750	250	1	2.50	.	2.50	.
6-7	750	750	1	1.00	.	1.00	.
6-7	750	2500	1	1.50	.	1.50	.
6-7	1750	250	1	4.00	.	4.00	.

Number of PbB values	30
Number of boxes	22
Number of GSD values (within-box)	5
Minimum GSD	1.1
Maximum GSD	1.9
Median GSD - weighted by DF	**1.34**
Median GSD - unweighted	1.34

Appendix E

IEUBK Batch Output Files

Exide Reading Children <=84 months

Model Version: 1.0 Build 254
User Name:
Date:
Site Name:
Operable Unit:
Run Mode:

* : signify default values used in place of missing input data.
# : signify surrogate values entered (determined) by user.
---: signify missing input data.
PBB & PRED are the observed and predicted blood Pb levels in ug/dL.

Soil Ingestion Rate	Default

Sorted by Residents/Visitors

Percent exceedance was calculated using values of GSD and PbB Cutoff as follows:
GSD = 1.6
PbB Cutoff (C) = 10 ug/dL

ID	FAM	BLK	AGE (mon)	SOIL (ug/g)	DUST (ug/g)	WATER (ug/L)	AIR (ug/m^3)	Other (ug/day)	PBB (ug/dL)	PRED (ug/dL)	P(PbB>C) (%)
1	1	R	55	542	2100	1	0.10*	0	0.5	12.1	66.0
2	1	R	26	542	2100	1	0.10*	0	2.5	15.6	82.6
5	2	R	49	96	120	2	0.10*	0	3.5	2.1	0.0
8	4	R	71	518	620	1	0.10*	0	1.5	4.9	6.2
11	4	R	54	518	620	1	0.10*	0	2	6.1	14.5
12	5	R	46	1593	1800	1	0.10*	0	1.5	17.0	87.0
16	6	R	78	682	710	2	0.10*	0	1	5.3	9.0
20	7	R	66	549	670	1	0.10*	0	1.5	5.4	9.5
22	8	R	82	622	2900	1	0.10*	0	1.5	11.3	60.5
24	9	R	71	446	560	1	0.10*	0	3	4.4	4.0
27	10	R	71	498	330	25	0.10*	0	2	5.4	9.7
35	13	R	51	309	1500	4	0.10*	0	4.5	10.1	50.6
47	18	R	60	982	1400	1	0.10*	0	3	10.3	52.7
49	19	R	25	789	320	1	0.10*	0	6	7.6	28.4
50	20	R	53	329	1400	1	0.10*	0	1	9.0	41.5
52	20	R	35	329	1400	1	0.10*	0	1.5	11.1	58.4
53	20	R	11	329	1400	1	0.10*	0	2	10.2	51.2
60	25	R	41	317	190	1	0.10*	0	2	3.9	2.1
63	27	R	70	124	580	1	0.10*	0	2	3.5	1.2
64	27	R	34	124	580	1	0.10*	0	2.5	5.5	10.3
65	27	R	34	124	580	1	0.10*	0	2.5	5.5	10.3
66	29	R	34	94	1200	1	0.10*	0	3	9.0	41.5
69	31	R	19	168	620	1	0.10*	0	3	6.7	20.1
73	32	R	58	223	360	1	0.10*	0	1	3.4	1.0
81	35	R	74	709	310	1	0.10*	0	2.5	4.1	2.9
82	35	R	34	709	310	1	0.10*	0	7	6.8	20.7
86	38	R	68	885	1800	1	0.10*	0	3	10.3	52.1
90	40	R	84	460	1400	2	0.10*	0	4	6.7	19.3
92	41	R	47	1671	370	1	0.10*	0	6	11.1	58.6
93	41	R	72	1671	370	1	0.10*	0	4	7.3	25.4
94	42	R	54	319	830	1	0.10*	0	3.5	6.3	16.3
6	3	V	72	298	8100	1	0.10*	0	4	23.8	96.7
40	15	V	66	829	2600	2	0.10*	0	1.5	12.9	70.4
41	15	V	45	829	2600	2	0.10*	0	0.8	17.7	88.8
59	24	V	59	181	320	1	0.10*	0	3.5	3.0	0.5
61	26	V	83	699	5000	1	0.10*	0	3	16.3	85.1
75	33	V	64	747	800	1	0.10*	0	3	6.7	19.7
76	33	V	40	747	800	1	0.10*	0	3	9.6	46.4
83	36	V	70	1110	1600	1	0.10*	0	2	10.0	50.2
84	36	V	46	1110	1600	1	0.10*	0	2	14.6	78.9

ID	FAM	BLK	AGE (mon)	SOIL (ug/g)	DUST (ug/g)	WATER (ug/L)	AIR (ug/m^3)	Other (ug/day)	PBB (ug/dL)	PRED (ug/dL)	P(PbB>C) (%)
									Obs	**Pred**	
							RESIDENTS	N	31	31	
								Mean	2.7	7.7	
								GM	2.3	6.9	
								min	0.5	2.1	
								max	7.0	17.0	
							mean prob of exceeding 10		0%	29%	
							VISITORS	N	9	9	
								Mean	2.5	12.7	
								GM	2.3	11.1	
								min	0.8	3.0	
								max	4.0	23.8	
							mean prob of exceeding 10		0%	60%	

Exide Reading Children <=84 months

Model Version: 1.0 Build 254
User Name:
Date:
Site Name:
Operable Unit:
Run Mode:

* : signify default values used in place of missing input data.
# : signify surrogate values entered (determined) by user.
---: signify missing input data.
PBB & PRED are the observed and predicted blood Pb levels in ug/dL.

Soil Ingestion Rate	Default

Percent exceedance was calculated using values of GSD and PbB Cutoff as follows:
GSD = 1.6
PbB Cutoff (C) = 10 ug/dL

ID	FAM	BLK	AGE (mon)	SOIL (ug/g)	DUST (ug/g)	WATER (ug/L)	AIR (ug/m^3)	Other (ug/day)	PBB (ug/dL)	PRED (ug/dL)	P(PbB>C) (%)
1	1	R	55	542	2100	1	0.10*	0	0.5	12.1	66.0
2	1	R	26	542	2100	1	0.10*	0	2.5	15.6	82.6
5	2	R	49	96	120	2	0.10*	0	3.5	2.1	0.0
6	3	V	72	298	8100	1	0.10*	0	4	23.8	96.7
8	4	R	71	518	620	1	0.10*	0	1.5	4.9	6.2
11	4	R	54	518	620	1	0.10*	0	2	6.1	14.5
12	5	R	46	1593	1800	1	0.10*	0	1.5	17.0	87.0
16	6	R	78	682	710	2	0.10*	0	1	5.3	9.0
20	7	R	66	549	670	1	0.10*	0	1.5	5.4	9.5
22	8	R	82	622	2900	1	0.10*	0	1.5	11.3	60.5
24	9	R	71	446	560	1	0.10*	0	3	4.4	4.0
27	10	R	71	498	330	25	0.10*	0	2	5.4	9.7
35	13	R	51	309	1500	4	0.10*	0	4.5	10.1	50.6
40	15	V	66	829	2600	2	0.10*	0	1.5	12.9	70.4
41	15	V	45	829	2600	2	0.10*	0	0.8	17.7	88.8
47	18	R	60	982	1400	1	0.10*	0	3	10.3	52.7
49	19	R	25	789	320	1	0.10*	0	6	7.6	28.4
50	20	R	53	329	1400	1	0.10*	0	1	9.0	41.5
52	20	R	35	329	1400	1	0.10*	0	1.5	11.1	58.4
53	20	R	11	329	1400	1	0.10*	0	2	10.2	51.2
59	24	V	59	181	320	1	0.10*	0	3.5	3.0	0.5
60	25	R	41	317	190	1	0.10*	0	2	3.9	2.1
61	26	V	83	699	5000	1	0.10*	0	3	16.3	85.1
63	27	R	70	124	580	1	0.10*	0	2	3.5	1.2
64	27	R	34	124	580	1	0.10*	0	2.5	5.5	10.3
65	27	R	34	124	580	1	0.10*	0	2.5	5.5	10.3
66	29	R	34	94	1200	1	0.10*	0	3	9.0	41.5
69	31	R	19	168	620	1	0.10*	0	3	6.7	20.1
73	32	R	58	223	360	1	0.10*	0	1	3.4	1.0
75	33	V	64	747	800	1	0.10*	0	3	6.7	19.7
76	33	V	40	747	800	1	0.10*	0	3	9.6	46.4
81	35	R	74	709	310	1	0.10*	0	2.5	4.1	2.9
82	35	R	34	709	310	1	0.10*	0	7	6.8	20.7
83	36	V	70	1110	1600	1	0.10*	0	2	10.0	50.2
84	36	V	46	1110	1600	1	0.10*	0	2	14.6	78.9
86	38	R	68	885	1800	1	0.10*	0	3	10.3	52.1
90	40	R	84	460	1400	2	0.10	0	4	6.7	19.3
92	41	R	47	1671	370	1	0.10*	0	6	11.1	58.6
93	41	R	72	1671	370	1	0.10*	0	4	7.3	25.4
94	42	R	54	319	830	1	0.10*	0	3.5	6.3	16.3

Notes:
0.10* Program fills in missing value.

	Obs	Pred
N	40	40
GM	2.3	7.7
min	0.5	2.1
max	7.0	23.8
mean prob of exceeding 10	0%	36%

Exide Reading Children <=84 months

Model Version: 1.0 Build 254
User Name:
Date:
Site Name:
Operable Unit:
Run Mode: Research

* : signify default values used in place of missing input data.
# : signify surrogate values entered (determined) by user.
---: signify missing input data.
PBB & PRED are the observed and predicted blood Pb levels in ug/dL.

Soil Ingestion Rate Amherst

Percent exceedance was calculated using values of GSD and PbB Cutoff as follows:
GSD = 1.6
PbB Cutoff (C) = 10 ug/dL

ID	FAM	BLK	AGE (mon)	SOIL (ug/g)	DUST (ug/g)	WATER (ug/L)	AIR (ug/m^3)	Other (ug/day)	PBB (ug/dL)	PRED (ug/dL)	P(PbB>C) (%)
1	1	R	55	542	2100	1	0.10*	0	0.5	5.0	7.1
2	1	R	26	542	2100	1	0.10*	0	2.5	6.9	21.1
5	2	R	49	96	120	2	0.10*	0	3.5	1.1	0.0
6	3	V	72	298	8100	1	0.10*	0	4	10.7	55.7
8	4	R	71	518	620	1	0.10*	0	1.5	2.1	0.0
11	4	R	54	518	620	1	0.10*	0	2	2.5	0.2
12	5	R	46	1593	1800	1	0.10*	0	1.5	7.4	26.0
16	6	R	78	682	710	2	0.10*	0	1	2.3	0.1
20	7	R	66	549	670	1	0.10*	0	1.5	2.3	0.1
22	8	R	82	622	2900	1	0.10*	0	1.5	4.6	4.9
24	9	R	71	446	560	1	0.10*	0	3	1.9	0.0
27	10	R	71	498	330	25	0.10*	0	2	3.5	1.3
35	13	R	51	309	1500	4	0.10*	0	4.5	4.3	3.6
40	15	V	66	829	2600	2	0.10*	0	1.5	5.4	9.2
41	15	V	45	829	2600	2	0.10*	0	0.8	7.8	29.9
47	18	R	60	982	1400	1	0.10*	0	3	4.2	3.2
49	19	R	25	789	320	1	0.10*	0	6	3.2	0.8
50	20	R	53	329	1400	1	0.10*	0	1	3.7	1.7
52	20	R	35	329	1400	1	0.10*	0	1.5	4.7	5.3
53	20	R	11	329	1400	1	0.10*	0	2	4.4	4.1
59	24	V	59	181	320	1	0.10*	0	3.5	1.4	0.0
60	25	R	41	317	190	1	0.10*	0	2	1.7	0.0
61	26	V	83	699	5000	1	0.10*	0	3	6.8	20.9
63	27	R	70	124	580	1	0.10*	0	2	1.5	0.0
64	27	R	34	124	580	1	0.10*	0	2.5	2.4	0.1
65	27	R	34	124	580	1	0.10*	0	2.5	2.4	0.1
66	29	R	34	94	1200	1	0.10*	0	3	3.8	2.0
69	31	R	19	168	620	1	0.10*	0	3	2.9	0.4
73	32	R	58	223	360	1	0.10*	0	1	1.5	0.0
75	33	V	64	747	800	1	0.10*	0	3	2.8	0.3
76	33	V	40	747	800	1	0.10*	0	3	4.0	2.6
81	35	R	74	709	310	1	0.10*	0	2.5	1.8	0.0
82	35	R	34	709	310	1	0.10*	0	7	2.9	0.4
83	36	V	70	1110	1600	1	0.10*	0	2	4.1	2.8
84	36	V	46	1110	1600	1	0.10*	0	2	6.2	15.7
86	38	R	68	885	1800	1	0.10*	0	3	4.2	3.2
90	40	R	84	460	1400	2	0.10	0	4	2.7	0.3
92	41	R	47	1671	370	1	0.10*	0	6	4.6	5.0
93	41	R	72	1671	370	1	0.10*	0	4	3.0	0.5
94	42	R	54	319	830	1	0.10*	0	3.5	2.6	0.2

	Obs	Pred
N	40	40
GM	2.3	3.3
min	0.5	1.1
max	7.0	10.7
mean prob of exceeding 10	0%	6%

Exide Reading Children <=84 months

Model Version: 1.0 Build 254
User Name:
Date:
Site Name:
Operable Unit:
Run Mode: Research

* : signify default values used in place of missing input data.
# : signify surrogate values entered (determined) by user.
---: signify missing input data.
PBB & PRED are the observed and predicted blood Pb levels in ug/dL.

Soil Ingestion Rate	Palmerton

Percent exceedance was calculated using values of GSD and PbB Cutoff as follows:
GSD = 1.6
PbB Cutoff (C) = 10 ug/dL

ID	FAM	BLK	AGE (mon)	SOIL (ug/g)	DUST (ug/g)	WATER (ug/L)	AIR (ug/m^3)	Other (ug/day)	PBB (ug/dL)	PRED (ug/dL)	P(PbB>C) (%)
1	1	R	55	542	2100	1	0.10*	0	0.5	8.4	35.1
2	1	R	26	542	2100	1	0.10*	0	2.5	11.1	58.5
5	2	R	49	96	120	2	0.10*	0	3.5	1.5	0.0
6	3	V	72	298	8100	1	0.10*	0	4	17.2	87.5
8	4	R	71	518	620	1	0.10*	0	1.5	3.3	0.9
11	4	R	54	518	620	1	0.10*	0	2	4.1	3.0
12	5	R	46	1593	1800	1	0.10*	0	1.5	12.0	65.3
16	6	R	78	682	710	2	0.10*	0	1	3.6	1.6
20	7	R	66	549	670	1	0.10*	0	1.5	3.7	1.6
22	8	R	82	622	2900	1	0.10*	0	1.5	7.8	29.5
24	9	R	71	446	560	1	0.10*	0	3	3.0	0.5
27	10	R	71	498	330	25	0.10*	0	2	4.4	3.9
35	13	R	51	309	1500	4	0.10*	0	4.5	7.0	22.1
40	15	V	66	829	2600	2	0.10*	0	1.5	8.9	40.0
41	15	V	45	829	2600	2	0.10*	0	0.8	12.6	68.9
47	18	R	60	982	1400	1	0.10*	0	3	7.0	22.7
49	19	R	25	789	320	1	0.10*	0	6	5.3	8.6
50	20	R	53	329	1400	1	0.10*	0	1	6.2	15.2
52	20	R	35	329	1400	1	0.10*	0	1.5	7.7	28.6
53	20	R	11	329	1400	1	0.10*	0	2	7.1	23.6
59	24	V	59	181	320	1	0.10*	0	3.5	2.1	0.0
60	25	R	41	317	190	1	0.10*	0	2	2.7	0.3
61	26	V	83	699	5000	1	0.10*	0	3	11.4	61.1
63	27	R	70	124	580	1	0.10*	0	2	2.4	0.1
64	27	R	34	124	580	1	0.10*	0	2.5	3.8	2.0
65	27	R	34	124	580	1	0.10*	0	2.5	3.8	2.0
66	29	R	34	94	1200	1	0.10*	0	3	6.2	15.7
69	31	R	19	168	620	1	0.10*	0	3	4.7	5.2
73	32	R	58	223	360	1	0.10*	0	1	2.3	0.1
75	33	V	64	747	800	1	0.10*	0	3	4.5	4.6
76	33	V	40	747	800	1	0.10*	0	3	6.6	18.8
81	35	R	74	709	310	1	0.10*	0	2.5	2.8	0.3
82	35	R	34	709	310	1	0.10*	0	7	4.7	5.3
83	36	V	70	1110	1600	1	0.10*	0	2	6.8	20.8
84	36	V	46	1110	1600	1	0.10*	0	2	10.2	51.8
86	38	R	68	885	1800	1	0.10*	0	3	7.0	22.3
90	40	R	84	460	1400	2	0.10	0	4	4.5	4.6
92	41	R	47	1671	370	1	0.10*	0	6	7.6	28.2
93	41	R	72	1671	370	1	0.10*	0	4	5.0	6.8
94	42	R	54	319	830	1	0.10*	0	3.5	4.3	3.5

	Obs	**Pred**
N	40	40
GM	2.3	5.3
min	0.5	1.5
max	7.0	17.2
mean prob of exceeding 10	0%	19%