PROBABILISTIC RISK ASSESSMENT FOR THE CLIFTON SOIL PROGRAM

CLIFTON, ARIZONA

Prepared for

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RAMBOLL Bright ideas. Sustainable change.

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ACRONYMS AND ABBREVIATIONS

A.A.C.	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department Health Services
A.R.S.	Arizona Revised Statute
CSF	cancer slope factor
CSP	Clifton Soil Program
cm^2	square centimeter
Damian	Damian Applied Technology, LLC
dL	deciliter
DTSC	Department of Toxic Substances Control
ED_{ca}	carcinogen exposure duration
EFH	Exposure Factors Handbook
FMC	Freeport Minerals Corporation
HI	hazard index
HQ	hazard quotient
hr	hour
IEUBK	Integrated Exposure Uptake Biokinetic
IRIS	Integrated Risk Information System
kg	kilogram
m^3	cubic meter
µg	microgram
mg	milligram
NCP	National Contingency Plan
NHANES	National Health and Nutrition Examination Survey
ODEQ	Oregon Department of Environmental Quality
PRA	probabilistic risk assessment
Ramboll	Ramboll US Consulting, Inc.
RBA	relative bioavailability of arsenic
RBC	relative bioavailability of copper
RfC	reference concentration
RfD	reference dose
SAP	Sampling and Analysis Plan
SSRL	Site-specific soil remediation level
Site	properties included in CSP, Clifton, Arizona
TC	target constituent
TRW	Bioavailability Technical Review Work Group
URF	inhalation unit risk factor
USEPA	United States Environmental Protection Agency
VRP	Voluntary Remediation Program
yr	year

1. INTRODUCTION

This probabilistic risk assessment (PRA) report was prepared by Ramboll US Consulting, Inc. (Ramboll, formerly Ramboll US Corporation) on behalf of Freeport Minerals Corporation (Freeport; FMC) to evaluate site-specific soil remediation levels (SSRLs) proposed to support a soil sampling and remediation program planned for properties in and near the town of Clifton, Arizona that may be impacted by historical copper mining and smelting operations (the Site). In November 2019, FMC submitted a Sampling and Analysis Plan (SAP) for the Clifton Soil Program (CSP), a project enrolled in the Arizona Voluntary Remediation Program (VRP) [VRP Site Code; 513293-00]. A PRA was previously prepared by Damian Applied Technology, LLC (Damian) to assess cancer risks and noncancer hazards associated with the proposed SSRLs for arsenic, copper, and lead for the CSP (Damian 2019). This report updates the Damian 2019 PRA to address comments provided by the Arizona Department of Environmental Quality (ADEQ 2020a).

The remainder of this report is organized as follows:

- Section 2 - Background
- Section 3 - Exposure Assessment
- Section 4 - Toxicity Assessment
- Section 5 - Risk Characterization
- Section 6 - Uncertainty Analysis
- Section 7 - Summary and Conclusions
- Section 8 - References

2. BACKGROUND

Historical mining and smelting operations were located in and near the town of Clifton, Arizona. Three former copper smelter sites are located near Clifton as shown on **Figure 1**. Freeport plans to implement a soil sampling and remediation program, referred to as the Clifton Soil Program, at selected residential, publicly-owned, and commercial properties in and around the historical area of Clifton. Properties included in the CSP are collectively referred to in this report as the Site. The CSP will be performed with oversight by the ADEQ under the Voluntary Remediation Program. Data from previous investigations of the smelters within the Clifton area and the associated VRP projects in the Clifton area have been compared to screening levels to identify target constituents (TCs) for the CSP. Only arsenic and copper were detected at concentrations above screening levels. Since the Clifton Soil Program involves sampling residential properties, FMC has added lead to the list of TCs. Therefore, arsenic, copper, and lead are identified as TCs for the site characterization and remediation efforts to be completed for the CSP. This HHRA was completed to support development of SSRLs for the TCs. Future sampling will be completed to determine representative soil concentrations of TCs for comparison with the proposed SSRLs to determine the need for remediation at individual properties. The objective of the CSP is to identify and remediate any soils that may exceed applicable SSRLs for lead, arsenic, or copper. Soil samples will be collected from eligible properties and analyzed for TCs, and results compared to SSRLs, as described in the Sampling and Analysis Plan to be developed for the CSP. The purposes of this risk assessment report are twofold: First, to propose residential use SSRLs for lead, arsenic, and copper for use in implementing the CSP, and second, to demonstrate that these cleanup levels meet human health risk criteria established by the ADEQ using PRA methods.

Site-specific remediation levels for arsenic, copper, and lead of 30, 9,000, and 425 milligrams/kilogram (mg/kg), respectively, were previously approved by the ADEQ for residential properties that were sampled and remediated as part of VRP projects performed in the vicinity of FMC's Ajo and Bisbee smelter sites, hereinafter referred to as "Ajo/Bisbee". The same SSRLs were also approved by ADEQ for a similar soil sampling and remediation program in a portion of Douglas (ADEQ 2013) and Clarkdale (ADEQ 2015). The Ajo/Bisbee SSRLs were based on a site-specific risk assessment (URS 2007a,b; Brown and Caldwell 2009). Freeport proposes to apply these previously-approved SSRLs, which are summarized in **Table 1**, to the CSP.

Table 1: Site-specific Soil Remediation Levels Proposed for Clifton Soil Program

Target Constituent	**Proposed SSRL**
Arsenic	30 mg/kg
Copper	9,000 mg/kg
Lead	425 mg/kg

Damian reviewed the input parameters that were used in the Ajo/Bisbee, Douglas, and Clarkdale risk assessments to ensure that they remain applicable to the CSP, and prepared a report presenting the review, documentation, and risk results (Damian 2019). The Damian 2019 report used the same PRA methods that were used for the Ajo/Bisbee, Douglas, and Clarkdale risk assessments to assess cancer and noncancer hazard associated with the SSRLs proposed for the CSP.

The ADEQ provided comments in response to the Damian 2019 report in a letter dated February 11, 2020. The ADEQ comments requested revisions to the PRA model, including changes to some

exposure parameter distributions as well as exposure and risk calculations and report text (ADEQ 2020a). This report presents an updated evaluation of risks associated with the proposed SSRLs that is responsive to ADEQ comments on the Damian 2019 report. This report also incorporates comments from ADEQ on an initial draft prepared by Ramboll, provided in a letter dated September 17, 2020 (ADEQ 2020b), and FMC's response to ADEQ's comments, submitted on November 13, 2020 and approved by ADEQ on December 2, 2020.

Unlike deterministic risk assessment methods, PRA methods use exposure assumptions that are expressed as statistical distributions rather than as a single value (i.e., a constant or "point estimate"). For example, instead of expressing arsenic bioavailability in soil as a single value, it may be expressed as a statistical distribution specified by a minimum value, various percentiles, and a maximum value. The advantage of PRA methods is that they incorporate the likely range of uncertainty or variability in exposure parameters into the final risk estimates. ADEQ regulations specifically permit the use of PRA methods (Arizona Administrative Code [A.A.C.] R18-7-206.B). The PRA methods used in this report are also consistent with United States Environmental Protection Agency (USEPA) guidance on PRA (Volume III, Part A – Process for Conducting Probabilistic Risk Assessment [USEPA 2001a]) and Oregon Department of Environmental Quality (ODEQ) PRA guidance (ODEQ 1998).

This report presents some of the information previously used to support the arsenic, lead, and copper SSRLs at the Ajo/Bisbee, Douglas and Clarkdale sites (Brown and Caldwell 2009 and 2013; Damian 2015). The information that served as a basis for development of some input parameters for these previous assessments has recently been updated, and as a result, some input parameters for the CSP risk assessment have been modified from those used in the previous assessments. All input parameters used in the updated PRA are described in this report for completeness.

The circumstances of chemical exposure (i.e., the conceptual site model) at the CSP site are fundamentally the same as at Ajo/Bisbee, Douglas, and Clarkdale. At all of these sites, residential receptors are exposed to metals in soil, primarily arsenic, lead, and copper. Thus, the receptors (adult and child residents), exposure pathways (soil ingestion, dermal contact with soil, and inhalation of resuspended soil), and chemicals of concern are the same. None of the sites involves chemical exposure via water bodies or water supplies (e.g., dermal contact with water, drinking water ingestion).

Oracle's Crystal Ball software (Release 11.1.2.4.850) was used to complete the PRA. This software utilizes Monte Carlo simulation methods to randomly select values from exposure parameter distributions, repeating the process over many iterations to produce a distribution of risk estimates that represents the range of possible outcomes. For this PRA, a maximum of 10,000 iterations was selected to create the cancer risk and noncancer hazard distributions for arsenic and copper. As described in Section 4.3, the SSRL for lead was assessed using the USEPA's Integrated Exposure Uptake Biokinetic (IEUBK) model. The following section describes the exposure assumptions used to evaluate the health risks associated with the proposed residential use SSRLs.

3. EXPOSURE ASSESSMENT

As noted previously, the circumstances of potential chemical exposure for the CSP are fundamentally the same as in the previous risk assessments for Ajo/Bisbee, Douglas and Clarkdale. In all cases the potentially impacted population (receptor population) is nearby residents. The chemicals of concern are three metals: arsenic, copper and lead. Exposure is via soil, not drinking water or surface water, so the relevant exposure pathways are limited to soil ingestion, dermal contact with soil, and inhalation of resuspended soil. Additional details and the basis for each exposure assumption used in this risk assessment are presented below.

3.1 Receptor Populations

For purposes of developing the SSRLs, residential use is assumed. This use results in the most conservative cleanup levels and will allow the widest variety of future uses once the relevant property areas have been remediated. The relevant receptor populations for a residential use risk assessment are adult and child residents, where children are assumed to be 0 to 6 years old (USEPA 1989). For this assessment, all receptors were assumed to be exposed beginning at birth, which incorporates early childhood exposure in all cancer risk estimates.

For risk assessment, residents have historically been divided into two age groups: children aged 0-6 years and adults. More recent exposure data for parameters such as soil ingestion rate enable further distinction of exposure assumptions by age. For this PRA, residential receptors are characterized using three age categories: birth to <6 years, 6 to <12 years, and ages 12 and older.

3.2 Exposure Pathways

Exposure to metals in soil may occur via ingestion, dermal contact and inhalation. Soil ingestion is assumed to occur when individuals incidentally transfer soil on the hands to the mouth. A portion of soil ingestion is assumed to consist of indoor dust ingestion (discussed in Section 3.3.4 below). Dermal absorption of metals from soil may also occur. Although the dermal absorption of metals from soil is typically low, this pathway is evaluated where applicable information is available. Inhalation exposure to metals in soil occurs entirely via resuspension and subsequent inhalation of airborne dust since arsenic, copper and lead are non-volatile at ambient temperatures.

3.3 Exposure Assumptions

Several assumptions are used to calculate potential chemical exposure. These assumptions, which may be specified as single point estimates (i.e., constants), or as statistical distributions, describe the physical/physiological characteristics of the receptors (e.g., body weight, skin surface area, etc.), chemical-specific assumptions (e.g., oral bioavailability, dermal absorption efficiency) and receptor behavioral characteristics (e.g., length of time a person lives at their residence). The assumptions used in this risk assessment and their basis are summarized in **Table 2** and described in detail below.

Where available and applicable, current data summaries and recommendations in the USEPA's *Exposure Factors Handbook* (EFH; USEPA 2011) were used as a primary reference for exposure parameter distributions in this PRA. For some parameters, more recent data were available (i.e., soil ingestion rates and soil arsenic relative bioavailability). For several parameters, literature sources were obtained or distributions from the 1998 probabilistic risk assessment guidance published by the ODEQ were used. For some parameters, the ODEQ (1998) distributions represent the most current available data.

To enable incorporation of all potential values from a given distribution in risk estimate calculations, custom distributions defined by specified percentiles were entered as continuous distributions. In contrast, entering percentiles as discrete (weighted) values would result in only one of the discrete percentile values being selected for the specified exposure assumption in each model iteration. For example, a hypothetical exposure parameter distribution may have a 10^{th} percentile of 15 and a 25^{th} percentile of 40. Values between 15 and 40 exist within the distribution but are not included in the discrete percentile values. Using a continuous distribution allows, for example, a value of 30 to be selected for this hypothetical exposure parameter in one of the many iterations included in a particular model run. This approach results in a more complete characterization of the range of possible risk estimates.

3.3.1 Exposure Duration

Exposure duration is the number of years that an individual is assumed to have contact with exposure media. For noncancer hazard assessment, a custom probability distribution of exposure duration for children from 3 to 11 years was used with a maximum exposure duration of six years (ODEQ 1998). This dataset is the closest approximation for the standard child age range assumed in risk assessment for children of 0 to <6 years (USEPA 1989). Capping the noncancer exposure duration distribution at six years is conservative because the probabilities of selecting each percentile equal to and above the 60^{th} percentile (where the six year exposure duration occurs within the source distribution) are combined, while lower percentiles retain their individual probabilities based on the source distribution. For example, the 5^{th}, 10^{th}, and 15^{th} percentiles would each have a 5% chance of being selected in any given model iteration, while the 60^{th} percentile has a 45% chance of selection (5% for each percentile equal to and greater than 60^{th}). This assigns a higher overall probability to the maximum exposure duration relative to those less than 6 years.

To estimate cancer risks, continuous exposure beginning at birth was assumed as discussed in Section 3.1. A single distribution was therefore used to define the exposure duration for carcinogen assessment. Specifically, the exposure duration distribution for males and females combined, presented in Table 16-108 of the EFH, was used for this PRA. This distribution is based on a study of residential occupancy period, or time lived at the same residence, for the US population (Johnson and Capel 1992). A minimum value is not provided in Table 16-108; a minimum value of 0.01 years was specified based on the minimums specified for most age groups in Table 3-38 of ODEQ (1998).

3.3.2 Body Weight

As a receptor ages over the length of the exposure duration, body weight increases. Body weights of very young children can be substantially different from those of older children and adults. For this PRA, separate body weight distributions were defined for the three age groups identified in Section 3.1. The distributions are based on data presented in the EFH and are described below for each age category.

The USEPA used data collected between 1999 and 2006 as part of the National Health and Nutrition Examination Survey (NHANES) to develop distributions of body weight for different age categories. This information is presented for males and females combined in EFH Table 8-3 (USEPA 2011). For children ages 0 to <6 years old, separate distributions are presented for seven age groups (birth to <1 month, 1 to <3 months, 3 to <6 months, 6 to <12 months, 1 to <2 years, 2 to <3 years, and 3

to <6 years). For each percentile in these distributions, a weighted average was calculated to provide one value for each percentile in the distribution representing children from birth to <6 years.

Table 8-3 of USEPA (2011) includes a body weight distribution for children aged 6 to <11 years. Because this is the closest available approximation of body weight for children in the 6 to <12 year age category, this distribution was used to represent children from 6 to <12 years of age.

Finally, nine additional distributions are provided for body weight of receptors ages 11 and greater, up to those over 80 years old. Similar to the 0 to <6 year old distribution, the weighted average for each percentile across these distributions was calculated to provide one value for each percentile in the distribution representing residents aged 12 years or more.

3.3.3 Exposure Frequency

Exposure frequency is the number of days per year that a person is assumed to have contact with an exposure medium. The exposure frequency for a resident was specified as a uniform distribution with a minimum of 350 days per year and a maximum of 365 days per year (ODEQ 1998). This distribution incorporates the maximum possible value for exposure frequency and is considered a conservative representation of conditions at the CSP. Use of this distribution assumes that children and adults could spend several days away from home each year (e.g., on vacation or visiting relatives) and therefore some of the soil that they contact is not from the impacted area near their home. The USEPA (2002) central tendency and reasonable maximum exposure estimates for soil contact frequency are 40 and 350 days/year, respectively. The residential exposure frequency distribution is used here instead of these point estimates to account for potential exposure to indoor dust in addition to outdoor soil.

3.3.4 Ingestion of Outdoor Soil and Indoor Dust

The USEPA updated Chapter 5 of the EFH in 2017 to incorporate recent studies of soil and dust ingestion by children and adults in the general population. The term "soil" as applied by the USEPA when describing soil ingestion rates includes outdoor settled dust that may be ingested during incidental ingestion of soil. The term "dust" is used to describe indoor dust, for which separate ingestion rates are provided. Soil and dust ingestion rates recommended by the USEPA (2011) were updated as relevant based on the more recent studies presented in USEPA (2017). The recommended ingestion rates are point estimates representing central tendency and upper percentile values. These point estimates were derived by combining data distributions from multiple studies. The information reported in those studies was used in this PRA to develop soil and dust ingestion rate distributions, rather than using the point estimates presented in USEPA (2017).

Three new studies published since the 2011 EFH was completed were added to the assessment of soil and dust ingestion presented in the updated Chapter 5 (USEPA 2017). The three modeling studies used data from numerous studies for parameters such as time spent in different locations, microactivity data, surface/object soil/dust loading data, and other exposure factors (Ozkaynak et al. 2011); particle loading measures, particle fraction transferred to hands and the amount dissolved in saliva, hand surface areas and the fraction that may be mouthed or contact food, hand-to-mouth contact frequency, and exposure time (Wilson et al. 2013); and soil, dust, and child blood lead data and associated metadata from a Superfund site (von Lindern et al. 2016). These three studies were published within the last 10 years and represent the most recent assessments of available data. Additionally, the most recent tracer element-based mass-balance study (Davis & Mirick 2006) was

considered. The data from these four studies were used to develop soil and dust ingestion rate distributions for the three age groups evaluated in this PRA. The USEPA provides percentiles from two of the studies (Ozkaynak et al. 2011, von Lindern et al. 2016) in the updated EFH Chapter 5. For the other studies (Wilson et al. 2013, Davis & Mirick 2006), mean and standard deviations are provided. One distribution was generated from the data provided for each study as applicable for each age group. The distributions generated from each study were then combined to develop a single distribution for each age group. The methods used to generate and combine distributions for each age group are described below.

Percentiles from the von Lindern et al. (2016) study for the two soil/dust partitioning scenarios that best fit blood lead levels predicted by the IEUBK model to observed blood lead levels (Table 5-16 of USEPA 2017) were averaged across the years of age from 0.5 to <6 within each scenario, then the average values for each percentile were averaged between the two partitioning scenarios to create a single distribution (i.e., a single set of percentiles) based on this study. The EFH provides means and standard deviations, rather than percentiles, from the Wilson et al. (2013) study. To enable combination of the data from this study with the percentiles provided from the von Lindern et al. (2016) and Ozkaynak et al. (2011) studies, distributions were therefore defined using the parameters provided and then combined to generate percentiles. Mean and standard deviation values for soil and dust ingestion from the Wilson et al. (2013) data provided for infants (0 to 6 months) and toddlers (7 months to 4 years) in Table 5-14 of USEPA (2017) were each assigned to a normal distribution. Soil and dust distributions were summed for each age group, and infant and toddler distributions were then combined using a weighted average of the sums (based on the relative time represented by each age group) to develop a single distribution to represent soil and dust ingestion by the 0 to <6 year age group. This was done by generating a forecast distribution equal to the time-weighted average of the sums of soil and dust distributions for each age group (infants and toddlers). The soil and dust ingestion input distributions for each age group and the resulting combined forecast distribution, respectively, are shown in the Soil Ingestion Rate Supporting Distributions and Soil Ingestion Rate Supporting Forecasts sections of **Appendix A** using graphs and associated statistics identified by study author, age group, and type (i.e., soil/dust ingestion) as applicable. In cases where lower percentiles resulted in negative soil ingestion rates, these values were replaced by zeros in the distribution, which is consistent with the USEPA (2017) approach, before combining the percentiles with those from other studies. The percentiles comprising the single distribution provided in Table 5-12 of USEPA (2017) from the Ozkaynak et al. (2011) study for children aged 3 to <6 years were then combined with the percentiles of the distributions generated from the von Lindern et al. (2016) and Wilson et al. (2013) studies. Values for each percentile (i.e., 5^{th}, 10^{th}, 25^{th}, etc.) from the three distributions were averaged to develop a single soil/dust ingestion rate distribution for children in the 0 to <6 year age group. The resulting distribution is presented in the Assumptions section of **Appendix A**. Because percentiles from the von Lindern et al. (2016) and Ozkaynak et al. (2011) studies are provided in the EFH and it was not necessary to define distributions and generate percentiles using Crystal Ball, these distributions do not appear in **Appendix A**; rather, they are readily available in Tables 5-16 and 5-12 of USEPA (2017).

Data from the von Lindern et al. (2016) and Wilson et al. (2013) studies were used to develop a soil ingestion rate distribution for the 6 to <12 year age group. Using the same methods described above for the 0 to <6 year age group, the von Lindern et al. (2016) percentiles provided in USEPA (2017) Table 5-16 for ages 6 through <10 (oldest group included) were averaged across the relevant years of age and then between the two partitioning scenarios to create a single distribution based on that

study. Mean and standard deviation values for soil ingestion and dust ingestion from the Wilson et al. (2013) data provided for children aged 5 to 11 years in Table 5-14 of USEPA (2017) were each assigned to a normal distribution and the two distributions were summed to develop a single soil and dust ingestion distribution for the 6 to <12 year age group. The soil and dust ingestion input distributions for each age group and the resulting combined forecast distribution, respectively, are shown in the Soil Ingestion Rate Supporting Distributions and Soil Ingestion Rate Supporting Forecasts sections of **Appendix A**. As described for the 0 to <6 year age group, where lower percentiles resulted in negative soil ingestion rates, these values were replaced by zeros in the distribution prior to being combined with the percentiles from the von Lindern et al. (2016) study. The soil ingestion rate distribution defined for the 6 to <12 year age group is presented in the Assumptions section of **Appendix A**. The data provided in USEPA (2017) do not correspond exactly to this age group but represent the closest available approximation, and were used by the USEPA to develop recommended soil ingestion rates specific to children aged 6 to <12 years.

Data from Wilson et al. (2013) are provided in Table 5-14 of USEPA (2017) for teenagers (12 to 19 years), adults (20 to 59 years) and seniors (60+years). The means and standard deviations for soil and dust ingestion were assigned to normal distributions that were summed to develop a single soil/dust ingestion rate distribution for each age group. These three distributions were combined using a weighted average to represent the 12+ age group. This approach is consistent with the methods described above for the younger age groups to generate a single soil and dust ingestion rate distribution from the Wilson et al. (2013) data. This distribution was then combined with the adult data from Davis & Mirick (2006) which are provided in Table 5-9 of USEPA (2017). Similar to the Wilson et al. (2013) study, means and standard deviations from this study, rather than percentiles, are provided in the EFH. The mean and standard deviation values for mothers and fathers and aluminum and silicon tracer elements from Davis & Mirick (2006) were assigned to normal distributions and the four resulting distributions were averaged to develop a single combined ingestion rate distribution for adults. The resulting forecast distribution based on the Davis & Mirick (2006) data was combined with the forecast distribution developed from the Wilson et al. (2013) data by averaging values for each percentile to develop a single soil ingestion rate distribution for residents aged 12 and older. As described for the younger age groups, the distributions were truncated at zero prior to being combined. The original input and combined forecast distributions from each study, respectively, are shown in the Soil Ingestion Rate Supporting Distributions and Soil Ingestion Rate Supporting Forecasts sections of **Appendix A**. The final soil ingestion rate distribution defined for the 12+ age group is presented in the Assumptions section of **Appendix A**.

Of the total amount of soil and dust ingested each day, the USEPA assumes a composition of 45 percent soil and 55 percent dust (USEPA 2007, 2017). The contribution of arsenic in indoor dust from the outside soil was estimated using data from Tu et al. (2020) and Brattin and Griffin (2011). Both studies are primarily focused on lead, but Tu et al. (2020) also evaluated limited soil track-in data for arsenic, cadmium, and zinc. Both studies used ordinary linear regression and Bartlett's method to fit regression lines to soil and dust data collected from mining, smelting, and refining sites. The contribution of outdoor soil to indoor dust, which has numerous sources other than outdoor soil, is estimated based on the slope of the regression line. Tu et al. (2020) identified datasets with regression coefficients equal to or greater than 0.25 as indicating a good model fit. Twelve of the 22 datasets analyzed by Tu et al. (2020) and three of the nine analyzed by Brattin and Griffin (2011) met this criterion based on the ordinary linear regression analyses. Based on further communication (Tu 2020) two of the twelve datasets analyzed by Tu et al. (2020) were not included in this PRA due

to numerous complicating factors that likely influence the slope estimates, leaving a total of 13 values with regression coefficients equal to or greater than 0.25. The Crystal Ball software requires at least 15 data points to define a distribution; two additional values from Brattin and Griffin (2011) with regression coefficients just below the Tu et al. (2020) criterion of 0.25 (0.23 and 0.24) were therefore added to the dataset, and the best-fit distribution of all 15 values defined by the software was a logistic distribution with a mean of 0.25 and a scale of 0.08. The lower end of this distribution was truncated at zero.

The majority of available data used for estimating soil track-in are based on measurements of lead, which has more potential indoor sources than arsenic. While the data analysis completed by Tu et al. (2020) showed lower estimates for arsenic, model fits for arsenic were generally poor. Relying primarily on lead data is considered to be conservative for arsenic because bias in lead estimates due to indoor sources likely overestimates the contribution of outdoor soil to indoor dust concentrations for other metals.

3.3.5 Oral Bioavailability of Arsenic and Copper in Soil

The Bioavailability Technical Review Work Group (TRW) at USEPA has reviewed available in vivo data for soil arsenic bioavailability to identify "key studies" (USEPA 2012a,b). The purpose of this review is to support a default soil arsenic relative bioavailability (RBA) value less than the previous default value of 100% that could be applied at sites lacking site-specific data. The new default is 60% based on analyses of 103 RBA estimates from a total of 88 samples of soils and waste materials tested in swine, monkeys, and mice. More than half of these RBA estimates (65 of 103) and 54 of 88 samples tested were from mining and/or smelting sites. The rest include samples from orchard soils, cattle dip sites, pesticide and other manufacturing sites, railroad corridors and miscellaneous sites such as volcanic soils. Data from all sites included in the TRW study (USEPA 2012a,b), not just smelter sites, are appropriate for this PRA because the soil in the CSP area represents a combination of natural, smelter, and other anthropogenic influences.

The key studies included 64 RBA values from swine studies, 24 values from monkeys and 15 values for mice. Four test materials were tested in all three species. Seven additional test materials were tested in both swine and mice. The TRW used these RBA values to derive distributions for the swine dataset, the monkey dataset and the combined dataset. The combined dataset is summarized in two ways: 1) with each RBA value given equal weight, even if the sample was tested more than once (termed the "unweighted" dataset), and 2) with RBA values for the same sample averaged before generating summary statistics (termed the "weighted" dataset). The combined unweighted dataset has a minimum RBA of 4.1%, an arithmetic mean of 31%, a 50^{th} percentile of 28.5% and a maximum value of 78%. The 95^{th} percentile was 57%. The 95^{th} percentile is highest for the swine dataset. The 95^{th} percentile based on only the monkey data is substantially lower (33%). The 95^{th} percentile for mouse data is 50%. For this PRA, the distribution presented in Table 3 of USEPA (2012a) for the unweighted dataset for all species and soil samples was used to define the arsenic RBA parameter. This distribution was selected because results from different species based on the same sample provide different estimates of bioavailability, and no species was considered more representative than another. Therefore, each sample result was given equal weight. As noted earlier in this section, all soil samples were included to best represent the various influences to soil in the CSP area.

For copper, Golder Associates Inc. (2002) conducted a bioavailability study and evaluated data based on in vitro solubility analysis and electron microprobe analysis of samples from a mining site in New

Mexico. The study concluded, "the data strongly fit into a normal distribution," so the reported mean copper relative bioavailability (RBC) of 64% and standard deviation of 8.5% were assigned to a normal distribution for use in this PRA. The use of these data is consistent with the approved Ajo/Bisbee, Douglas and Clarkdale risk assessments (Brown and Caldwell 2013; Damian 2015; ADEQ 2013, 2015).

3.3.6 Dermal Exposure to Arsenic in Soil and Dust

For inorganic substances in soil, very little absorption occurs via the dermal pathway; however, it is included in this PRA for completeness. The USEPA has assigned default ABS_d values for only arsenic and cadmium (USEPA 2004).

For arsenic, the USEPA (2004) default ABS_d of 0.03 is highly conservative. This value is based on a 1993 study of rhesus monkeys that evaluated absorption of soluble arsenic in aqueous solution and soluble arsenic mixed with soil (Wester et al. 1993). However, this estimate is not representative of arsenic absorption from environmental media such as soil. Research on the geochemistry of arsenic suggests that for soils that are weathered in the environment, arsenic is likely to be present in more stable alteration phases that are tightly bound within the soil and would not be expected to behave like soluble arsenic (Lowney et al. 2005).

A 2007 *in vivo* mammalian study showed that dermal absorption of arsenic is negligible and highly overestimated by the USEPA default ABS_d value (Lowney et al. 2007). This study used the same animal model as the Wester et al. (1993) study with an "open-crossover" design that allowed the animals to serve as their own comparison controls. The abdomens of Rhesus monkeys were exposed to soil with elevated arsenic concentrations or to soluble arsenic. Specifically, soils with very high concentrations of arsenic were evaluated; one sample, containing 1,400 mg/kg arsenic, was collected adjacent to a pesticide production facility in New York and another sample, containing 1,230 mg/kg arsenic, was collected from a residential area in Denver, CO with a history of application of arsenical pesticides. Urine samples from the animals were collected 3 days prior to dosing to establish background and through day 7 after dosing. The results found that following application of wet and dry soil, urinary arsenic excretion could not be distinguished from background. For dermal absorption of arsenic in a variety of soil matrices, Lowney et al. (2007) estimated arsenic absorption to be 0.5 percent or less.

The findings of Lowney et al. (2007) of negligible dermal absorption of arsenic from soil are supported by a study by Wester et al. (2004) of dermal absorption of arsenic from copper chromated arsenic-treated wood residues showing that dermal absorption of arsenic could not be detected (i.e., does not result in urinary arsenic excretion above background levels). No additional *in vivo* studies of dermal arsenic absorption from soil have been identified. In vitro studies of dermal arsenic absorption (e.g., Abdel-Rahman et al. 1999, Abdel-Rahman et al. 2005, Hughes et al. 1995, Rahman and Hughes 1994) are not considered adequate to provide quantitative estimates for use in risk assessment.

For this PRA, the highest mean ABS_d value measured in the Lowney et al. (2007) study of 0.5 percent (0.005) and the associated standard deviation (0.44%) were assigned to a normal distribution that was used to estimate dermal absorption of arsenic. The lower end of this distribution was truncated at zero. For copper, dermal absorption is assumed to be zero (USEPA 2004).

The USEPA provides distributions for specified age groups for whole body skin surface area derived from their analysis of NHANES data from 1999-2006 for children and adults in Table 7-10 of the EFH (USEPA 2011). A weighted average of the percentiles of the seven age groups listed from birth to <6 years was used to represent the 0 to <6 year age group and the percentiles for 6 to <11 years were used to represent the 6 to <12 year age group in this PRA.

Table 7-8 of the EFH provides information regarding the fraction of whole-body skin surface area represented by individual body parts. The fraction of whole-body area comprised of the head, legs, feet, lower arms, and hands was calculated using the data provided for male children of the specific ages included in the table that are relevant to each age category included in this PRA. Because males tend to be larger, this provides a conservative estimate for male and female children. The most conservative (i.e., highest) age-specific fraction for each age group was used to adjust the whole-body distributions to represent the skin surface area of the head, legs, feet, lower arms, and hands, which may be exposed to soil while playing outdoors. This equated to 35.5% of the whole body for the 0 to <6 age group and 35.3% of the whole body for the 6 to <12 age group.

For ages 12 and older, the USEPA provides distributions of body part skin surface areas in Table 7-12 of the EFH (USEPA 2011). These distributions are based on USEPA 1985 and NHANES 2005-2006 data for adult males and conservatively represent both male and females in this PRA. A sum of the percentiles for head, hands, forearms, and lower legs was used in this PRA, which is consistent with USEPA's recommendations stating that children are assumed to have more sensitive body parts (i.e. feet) exposed, whereas adults are not (USEPA 2002, 2014).

Skin surface area distributions for each age group were correlated with the body weight distributions for the same group using a correlation coefficient of one.

Point estimates were used to quantify the amount of soil or dust assumed to adhere to the skin. The USEPA (2004) default value of 0.2 milligrams per square centimeter (mg/cm^2) was used for children in the 0 to <6 year age group. The default value of 0.07 mg/cm^2 is specified in USEPA (2002) guidance for receptors aged seven to 31 years. This value was therefore used for the 6 to <12 and 12 and older age groups.

3.3.7 Inhalation Exposure Time

While the USEPA (2011) provides activity pattern data reflecting the amount of time that residents spend indoors and outdoors, a point estimate of 24 hours (i.e. the whole day) was used to quantify particulate inhalation exposures for this PRA. This value conservatively assumes that residents spend the entire day at their home and are exposed to dust at all times both indoors and outdoors at the home.

3.3.8 Averaging Time

The averaging time is the period of the lifetime over which the exposure is averaged. Averaging time was represented using point estimates and no distribution was assumed for this exposure parameter. For carcinogenic risk evaluation, the standard averaging time is 70 years or 25,550 days (USEPA 1989). This value is also consistent with Arizona risk guidance (ADHS 2003).

For noncancer hazard evaluation, the averaging time is equal to the exposure duration in years times the number of days per year (365; USEPA 1989). For each model iteration, the value randomly

selected from the exposure duration distribution for children ages 0 to <6 years was therefore multiplied by 365 days/year to provide a noncancer averaging time equal to the exposure duration for each iteration.

4. TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to present the toxicity criteria used to calculate cancer and noncancer health risks, along with basic information about the potential health effects related to exposure to the chemicals of concern. Toxicity criteria include oral reference doses (RfDs) and inhalation reference concentrations (RfCs) for the evaluation of noncancer health risks, and oral cancer slope factors (CSFs) and inhalation unit risk factors (URFs) to calculate cancer risks. Note that in the case of lead, a unique toxicity criterion is used to evaluate health risks instead of an RfD or RfC. Lead health risks are evaluated based on the predicted blood lead concentration in potentially exposed children. A potential lead exposure in soil is considered acceptable if the predicted blood lead concentration resulting from that exposure will result in no more than 5 percent of the exposed children having a blood lead level greater than 10 micrograms/deciliter (µg/dL) (USEPA 2007).

Toxicity criteria for arsenic and copper were treated as point estimates or constants in this risk assessment; statistical distributions were not used for these parameters. The specific toxicity criteria used for arsenic, copper and lead are described in detail below.

4.1 Arsenic

Arsenic is considered by the USEPA and other government agencies to be carcinogenic via both oral and inhalation routes of exposure (USEPA 2020a). The CSF, URF, and RfD values were obtained from the USEPA's Integrated Risk Information System (IRIS) (USEPA 2020a) and the RfC was obtained from the California Environmental Protection Agency (CalEPA 2019). For the dermal pathway, route-to-route extrapolation was applied from the oral pathway using a gastrointestinal absorption factor of 1 (USEPA 2004). These toxicity values are shown in **Table 2**.

According to the Agency for Toxic Substances and Disease Registry (ATSDR), the most sensitive and characteristic noncancer health effects of arsenic exposure via the ingestion route are dermal effects, including hyperkeratosis (thickening of the skin) and hyperpigmentation (excess pigmentation of the skin) (ATSDR 2007a). At much higher exposure levels, gastrointestinal irritation, manifested as nausea, vomiting, diarrhea, and abdominal pain are typical. Other effects associated with ingestion exposure may include anemia, cardiovascular effects, and liver damage (ATSDR 2007a). The most common noncancer effect associated with inhalation exposure to arsenic is irritation of the respiratory tract.

4.2 Copper

Copper is not considered a carcinogen by the USEPA (USEPA 2020a). The oral RfD for copper was obtained from the USEPA's Regional Screening Levels tables (USEPA 2020b) and is derived from the USEPA's Health Effects Assessment Summary Tables (HEAST; USEPA 1997). The copper RfD is shown in **Table 2**.

According to ATSDR, the most sensitive noncancer health effect related to ingestion exposure to copper is gastrointestinal irritation, primarily nausea and diarrhea. At higher levels of exposure kidney damage may occur (ATSDR 2004). Inhalation exposure is primarily associated with irritation of the respiratory tract (ATSDR 2004).

4.3 Lead

Exposure to lead results in a wide range of noncarcinogenic health effects; however, a 'safe' level below which no adverse effects occur has not been identified (ACCLP 2012, CDC 2012). The primary and most sensitive noncancer effect associated with lead exposure is neurologic impairment (ATSDR 2007b). The USEPA does not have standard toxicity values for lead because a no-effect dose has not been identified. Instead, the USEPA's IEUBK model is used to estimate the percent chance of a child resident potentially having a blood lead level above 10 µg/dL from contacting Site soil. If, based on this model, this percentage is equal to or less than five percent (5%), lead risks are considered to be negligible. The IEUBK model estimates blood lead concentrations in children from birth to seven years of age. Use of this model to assess lead for older children is conservative.

The following section describes the calculation of cancer and noncancer hazard estimates for the proposed SSRLs.

5. RISK CHARACTERIZATION

To characterize cancer risks and noncancer hazards, quantitative estimates of exposure and toxicity are combined to yield numerical estimates. This section discusses how risk and hazard estimates were calculated for arsenic and copper (noncancer hazard only), and the resulting estimates.

5.1 Cancer Risk Characterization Methods

The cancer risk estimates derived using standard risk assessment methods are characterized as the incremental probability that an individual will develop cancer during his or her lifetime due to exposure to site-related chemicals resulting from the specific exposure scenarios that are going to be evaluated. The term "incremental" reflects the fact that the calculated risk associated with site-related exposure is in addition to the background risk of cancer experienced by all individuals. The USEPA refers to such estimates as lifetime excess cancer risk, or LECR, estimates.

Excess incremental lifetime cancer risks for ingestion/dermal and inhalation exposures, respectively, were calculated using the following equations:

$$Cancer\ Risk_{ingestion/dermal} = Intake\left({}^{mg}/_{kg\text{-}day}\right) \times SF\left({}^{mg}/_{kg\text{-}day}\right)^{-1}$$

$$Cancer\ Risk_{inhalation} = EC\left({}^{mg}/_{m^3}\right) \times URF\left({}^{mg}/_{m^3}\right)^{-1}$$

Where,

Intake	=	Estimated average daily intake of the chemical via the specified exposure route (mg/kg-day)
EC	=	Exposure concentration for the chemical (mg/m^3)
SF	=	Slope factor (mg/kg-day)$^{-1}$
URF	=	Inhalation unit risk factor (mg/m^3)$^{-1}$

Intake was calculated using age-adjusted factors as contact rates and certain exposure factors vary among the three age groups evaluated (0 to <6, 6 to <12, and 12+years).

The following equations were used for the ingestion pathway:

$$Intake_{ing} = C_{soil} \times \frac{IFS_{adj} \times (RBA \times FI_s + Dust\ Ratio \times RBA \times FI_d) \times EF \times CF1}{AT_{ca}}$$

If exposure duration (ED_{ca}) is 12 years or greater:

$$IFS_{adj} = \frac{6\ yr \times IR_{0-6}}{BW_{0-6}} + \frac{6\ yr \times IR_{6-12}}{BW_{6-12}} + \frac{(ED_{ca} - 12\ yr) \times IR_{12+}}{BW_{12+}}$$

If exposure duration (ED_{ca}) is greater than or equal to 6 years and less than 12 years:

$$IFS_{adj} = \frac{6\ yr \times IR_{0-6}}{BW_{0-6}} + \frac{(ED_{ca} - 6\ yr) \times IR_{6-12}}{BW_{6-12}}$$

If exposure duration (ED_{ca}) is less than 6 years:

$$IFS_{adj} = \frac{ED_{ca} \times IR_{0-6}}{BW_{0-6}}$$

Where,

$Intake_{ing}$	=	Estimated average daily intake of the chemical via ingestion (mg/kg-day)
C_{soil}	=	Proposed SSRL concentration in soil (mg/kg)
IFS_{adj}	=	Age-adjusted ingested fraction of soil (mg-year/kg-day)
RBA	=	Relative bioavailability of arsenic (unitless)
FI_s	=	Fraction of material ingested as soil (unitless)
FI_d	=	Fraction of material ingested as dust (unitless)
Dust ratio	=	Ratio of metal concentration in dust to metal concentration in soil (unitless)
EF	=	Exposure frequency (days/year)
CF1	=	Conversion factor (10^{-6} kg/mg)
AT_{ca}	=	Cancer averaging time (days)
IR	=	Soil ingestion rate (mg/day)
BW	=	Body weight (kg)
ED_{ca}	=	Cancer exposure duration (years)

The following equations were used for the dermal pathway:

$$Intake_{derm} = C_{soil} \times \frac{DFS_{adj} \times ABS_{derm} \times EV \times EF \times CF1}{AT_{ca}}$$

If exposure duration (ED_{ca}) is 12 years or greater:

$$DFS_{adj} = \frac{6\ yr \times SA_{0-6} \times AF_{0-6}}{BW_{0-6}} + \frac{6\ yr \times SA_{6-12} \times AF_{6-12}}{BW_{6-12}} + \frac{(ED_{ca} - 12\ yr) \times SA_{12+} \times AF_{12+}}{BW_{12+}}$$

If exposure duration (ED_{ca}) is greater than or equal to 6 years and less than 12 years:

$$DFS_{adj} = \frac{6\ yr \times SA_{0-6} \times AF_{0-6}}{BW_{0-6}} + \frac{(ED_{ca} - 6\ yr) \times SA_{6-12} \times AF_{6-12}}{BW_{6-12}}$$

If exposure duration (ED_{ca}) is less than 6 years:

$$DFS_{adj} = \frac{ED_{ca} \times SA_{0-6} \times AF_{0-6}}{BW_{0-6}}$$

Where,

$Intake_{derm}$ = Estimated average daily intake of the chemical via dermal contact (mg/kg-day)

DFS_{adj} = Age-adjusted dermal fraction of soil (mg-year/kg)

ABS_{derm} = Chemical-specific dermal absorption factor (unitless)

EV = Events per day (day^{-1})

SA = Skin surface area (cm^2)

AF = Soil-to-skin adherence factor (mg/cm^2)

The following equations were used for the particulate inhalation pathway:

$$EC = (C_{soil} \times \frac{1}{PEF}) \times \frac{ET \times EF \times ED_{ca}}{24\ hr/d \times AT_{ca}}$$

Where,

PEF = Particulate emission factor (m^3/kg)

ET = Exposure time (hrs/day)

5.2 Noncancer Hazard

Health risks other than cancer are characterized as the increased likelihood that an individual will suffer adverse health effects as a result of chemical exposure. To evaluate noncancer risks, the ratio of the average daily intake to the RfD or RfC is calculated. This ratio is referred to as the hazard quotient (HQ). Unlike cancer risk estimates, which are averaged over a receptor's lifetime, only children are typically included for evaluation of noncancer effects under a residential scenario due to their higher exposure. The assessment of noncancer hazards for children is also considered protective of adults. The HQ was calculated for the ingestion/dermal and inhalation pathways using the following equations:

$$HQ_{ingestion/dermal} = \frac{Intake\ (mg/kg\text{-}day)}{RfD\ (mg/kg\text{-}day)}$$

$$HQ_{inhalation} = \frac{EC\ (mg/m^3)}{RfC\ (mg/m^3)}$$

Where,

RfD = Reference dose for the chemical (mg/kg-day)

RfC = Reference concentration for the chemical (mg/m^3)

Intake was calculated as follows for the ingestion pathway:

$$Intake_{ing} = C_{soil} \times \frac{IR_{0-6} \times (RBA\ or\ RBC\ \times FI_s + Dust\ Ratio\ \times RBA\ or\ RBC \times FI_d) \times EF \times ED_{nc} \times CF1}{BW_{0-6} \times AT_{nc}}$$

Where,

RBC = Relative bioavailability of copper (unitless)

ED_{nc} = Noncancer exposure duration (years)

AT_{nc} = Noncancer averaging time (days)

Intake was calculated as follows for the dermal pathway:

$$Intake_{derm} = C_{soil} \times \frac{ABS_{derm} \times AF_{0-6} \times SA_{0-6} \times EV \times EF \times ED_{nc} \times CF1}{BW_{0-6} \times AT_{nc}}$$

Exposure concentration was calculated as follows for the inhalation pathway:

$$EC = (C_{soil} \times \frac{1}{PEF}) \times \frac{ET \times EF \times ED_{nc}}{24\ hr/d \times AT_{ca}}$$

For noncancer hazard, cumulative toxicity is accounted for by summing the HQs for all chemicals to obtain a hazard index (HI) (USEPA 1989; ADHS 2003). This HI can be refined further using the "segregation of Hazard Indices" approach per USEPA risk guidance (USEPA 1989). According to this method, only the HQs of chemicals which have a similar mechanism of toxicity, or which act on the same target organ, should be added to account for cumulative toxicity. For the proposed SSRLs the critical noncancer effects of arsenic (skin pigmentation and keratin changes, vascular effects [ATSDR 2007a, USEPA 2020a]) and copper (gastrointestinal irritation [ATSDR 2004]) at low doses do not affect the same target organ or act by a similar mechanism of toxicity, so it would not be appropriate to add the HQs related to these chemicals.

5.3 Lead Risks

A lead SSRL of 425 mg/kg was approved for similar sites by ADEQ in 2008, 2013 and 2015. This value was obtained using the USEPA's IEUBK lead model for children assuming all USEPA default values, except that the indoor dust lead concentration was assumed to be 273 mg/kg. This indoor dust lead concentration was derived based on a conversion factor developed by the USEPA (USEPA 2001b). To verify that the previously approved SSRL for lead of 425 mg/kg presents health risks related to lead in soil that the USEPA has determined to be protective, the IEUBK model was run using the same assumptions as specified above.

5.4 Results and Discussion

For known or suspected carcinogens, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) established that acceptable exposure levels are generally concentration levels that represent an incremental upper-bound lifetime cancer risk in the range from 10^{-4} to 10^{-6} or less (29 CFR 1910.120, 40 CFR 300.430, USEPA 1991). For systemic toxicants, the NCP established that acceptable exposure levels shall represent concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety. Therefore, noncancer hazards are compared to a protection goal of one (1). The state of Arizona has adopted this lifetime cancer risk range and noncancer hazard target in Arizona Revised Statute (A.R.S.) 49-175.B.2 & 49-152.B.2. For this PRA, the proposed arsenic and copper SSRLs were used as soil exposure concentrations to assess if they are protective at the risk and hazard levels identified as acceptable by the USEPA and ADEQ. In order to assess the protectiveness of the proposed SSRLs, the 95th percentile of the risk or hazard

distribution is compared to the corresponding regulatory target. This discussion therefore focuses on the 95th percentile LECR and HQ estimates resulting from exposure concentrations equal to the proposed arsenic and copper SSRLs. These results are summarized along with the proposed SSRLs and model input parameters in **Table 2**. The complete LECR and HQ distributions are provided in **Appendix A**.

The combination of exposure parameter distributions and point estimates used to develop the PRA model for the Site resulted in a 95th percentile LECR estimate of 1 x 10^{-5} based on the proposed arsenic SSRL of 30 mg/kg, which is within the range of LECR estimates considered acceptable by the USEPA and ADEQ. The 95th percentile HQ estimates for arsenic and copper based on the proposed SSRLs of 30 mg/kg and 9,000 mg/kg, respectively, are 0.3 and 0.9. Summing these chemical-specific HQ estimates results in an HI estimate of 1 (rounded to one significant figure), which meets the USEPA and ADEQ cumulative goal of 1. However, as discussed in Section 5.2 of this report, due to the difference in target organs affected by arsenic and copper, the HQ estimates for these two metals should not be summed. The individual HQ estimates based on the proposed SSRLs for each metal also meet the USEPA and ADEQ target of 1.

For lead, the IEUBK model run showed that the SSRL of 425 mg/kg will result in a 4.4% chance of a potentially exposed child having a blood lead concentration equal to or greater than 10 µg/dL. The IEUBK model output is included in **Appendix B**. The USEPA considers lead health risks to be protective when the chance of a child having a blood lead concentration of 10 µg/dL or greater is no more than 5%. Thus, the proposed lead SSRL will provide adequate protection of children with respect to potential lead exposure. Because children have greater exposure compared to adults, the proposed SSRL for lead will also be protective of adult residents.

The PRA and IEUBK results indicate that incremental excess lifetime cancer risks and noncancer hazards to residents resulting from potential exposure to metals in soil at the SSRLs proposed for the Clifton Townsite are within acceptable limits.

Table 2: Probabilistic Risk Assessment Input Parameters and Results

Parameter	Abbreviation	Value or Distribution Type	Description	Reference
Exposure Frequency (d/y)	EF	350, 365	Uniform distribution (minimum, maximum)	ODEQ 1998
Cancer Exposure Duration (y)	ED_c	Custom	Distribution from Table 16-108	USEPA 2011
Non-Cancer Exposure Duration ages 0 to <6 (y)	ED_{nc}	Custom	Distributions for ages 0 to 11, truncated at 6 years, from Table 3-38	ODEQ 1998
Soil Ingestion Rate ages 0 to <6 (mg/d)	IR	Custom	Distributions for ages 0 to < 6 from Tables 5-12, 5-14, and 5-16	USEPA 2017 (subreference Ozkaynak et al. 2011, von Lindern et al. 2016, Wilson et al. 2013)
Soil Ingestion Rate ages 6 to <12 (mg/d)	IR	Custom	Distributions for ages 6 to < 12 from Tables 5-14 and 5-16	USEPA 2017 (subreference von Lindern et al. 2016; Wilson et al. 2013)
Soil Ingestion Rate ages 12+ (mg/d)	IR	Custom	Distributions for ages 12 to 70 from Tables 5-14 and 5-9	USEPA 2017 (subreference Wilson et al. 2013; Davis & Mirick 2006)
Fraction Ingested soil (unitless)	FI_s	0.45	Fixed value	USEPA 2007
Fraction Ingested dust (unitless)	FI_d	0.55	Fixed value	USEPA 2007
Bioavailability of arsenic in soil and dust (unitless)	RBA	Custom	Distribution from Table 3	USEPA 2012
Bioavailability of copper in soil and dust (unitless)	RBC	0.64 (0.085)	Mean ± standard deviation of mining site data	Golder 2002
Ratio of concentration in dust to soil (unitless)	Dust-Ratio	Custom	Distribution derived from datasets with good regression model fit	Brattin & Griffin 2011; Tu et al. 2020
Skin Surface Area ages 0 to <6 (cm^2)	SSA	Custom	Distribution for ages 0 to < 6 from Table 7-10, adjusted by mean percentage of total SSA from Table 7-8	USEPA 2011
Skin Surface Area ages 6 to <12 (cm^2)	SSA	Custom	Distribution for ages 6 to < 11 from Table 7-10, adjusted by mean percentage of total SSA from Table 7-8	USEPA 2011
Skin Surface Area ages 12+ (cm^2)	SSA	Custom	Sum of distributions for head, forearms, hands, and lower legs from Table 7-12	USEPA 2011
Dermal absorption fraction of arsenic (unitless)	ABS_{dermal}	0.005 (0.0044)	Mean ± standard deviation of dataset with highest absorption	Lowney et al. 2007
Dermal Adherence Factor ages 0 to <6 (mg/cm^2)	AF	0.2	Fixed value	USEPA 2004
Dermal Adherence Factor ages 6+ (mg/cm^2)	AF	0.07	Fixed value	USEPA 2004
Body Weight ages 0 to <6 (kg)	BW	Custom	Distribution for ages 0 to < 6 from Table 8-3	USEPA 2011
Body Weight ages 6 to <12 (kg)	BW	Custom	Distribution for ages 6 to < 11 from Table 8-3	USEPA 2011
Body Weight ages 12+ (kg)	BW	Custom	Distribution for ages 11 to < 60 from Table 8-3	USEPA 2011
Exposure Time (particulate) (h/d)	ET	24	Fixed value	USEPA 2011
Conversion Factor (kg/mg)	CF1	0.000001	Fixed value	--
Cancer Averaging Time (d)	AT_c	25550	Fixed value	ADHS 2003; USEPA 2014
Non-Cancer Averaging Time (d)	AT_{nc}	ED_{nc} x 365	Fixed value	ADHS 2003; USEPA 2014
Particulate Emission Factor (m^3/kg)	PEF	1.396E+09	Fixed value	ADHS 2003
Event per day (event/d)	EV	1	Fixed value	USEPA 2004
Arsenic oral slope factor $((mg/kg/d)^{-1})$	SF_o	1.5	Fixed value	USEPA 2020a
Arsenic gastrointestinal absorption (unitless)	ABS_{GI}	1	Fixed value	USEPA 2004
Arsenic dermal slope factor $((mg/kg/d)^{-1})$	SF_{derm}	1.5	Fixed value	USEPA 2020a
Arsenic inhalation unit risk factor $((mg/m3)^{-1})$	IUR	4.3	Fixed value	USEPA 2020a
Arsenic oral reference dose (mg/kg-d)	RfD_o	0.0003	Fixed value	USEPA 2020a
Arsenic dermal reference dose (mg/kg-d)	RfD_{derm}	0.0003	Fixed value	USEPA 2020a
Arsenic reference concentration (mg/m^3)	RfC	0.000015	Fixed value	CalEPA 2019
Copper oral reference dose (mg/kg-d)	RfD_o	0.04	Fixed value	USEPA 1997
Arsenic Concentration (mg/kg)	C_{soil}	30	Proposed SSRL	URS 2007; Brown & Caldwell 2009; ADEQ 2013; ADEQ 2015
Copper Concentration (mg/kg)	C_{soil}	9,000	Proposed SSRL	URS 2007; Brown & Caldwell 2009; ADEQ 2013; ADEQ 2015
95th Percentile Cumulative LECR Estimate - Arsenic		**1E-05**		
Ingestion Pathway		1E-05		
Dermal Pathway		2E-06		
Inhalation Pathway		4E-08		
95th Percentile Cumulative HQ Estimate - Arsenic		**0.3**		
Ingestion Pathway		0.2		
Dermal Pathway		0.04		
Inhalation Pathway		0.001		
95th Percentile Cumulative HQ Estimate - Copper		**0.9**		
Ingestion Pathway		0.9		

Notes:
LECR: Lifetime Excess Cancer Risk
HQ: Noncancer Hazard Quotient
ADEQ: Arizona Department of Environmental Quality
ODEQ: Oregon Department of Environmental Quality
USEPA: US Environmental Protection Agency
ADHS: Arizona Department of Health Services
CalEPA: California Environmental Protection Agency
SSRL: Site-specific soil remediation level
--: not applicable

6. UNCERTAINTY ANALYSIS

Uncertainty is an important component of risk assessment. Understanding uncertainty can help with interpretation of risk estimates and decision-making. Probabilistic risk assessment provides distributions of estimated risks that incorporate variability in exposure parameters and other assumptions and help to clarify the role of uncertainty in the risk assessment process. In deterministic risk assessment, uncertainty and variability are addressed by assigning conservative point estimates, usually from the upper end of available datasets. Including a more complete representation of the possible range of input parameters and risk estimates allows for a better understanding of the effects of uncertainty on the outcome of the assessment. Some of the factors contributing to uncertainty in the PRA model are discussed below.

For many exposure parameters, the USEPA breaks available data into specific age groups, which are not the same for every parameter. For this PRA, distributions provided by the USEPA for the age groups closest to those defined to characterize residents were used. In some cases the data used to characterize exposure for children in a particular age class correspond to children in a slightly younger class. For example, data for children aged 6 to <11 years were used to characterize exposure for children aged 6 to <12 years. These relatively minor differences are unlikely to have a large effect on outcomes, but may result in slight overestimates of exposure and risk. One example that may introduce a slight low bias to the cancer risk estimates is that the body weight distribution for the 12+ age group was based on the full range of data for teens and adults up to age 80+ years. In some probabilistic model iterations where exposure duration exceeds 12 years, this may overestimate body weight for the receptor in this age group (i.e., if exposure does not extend beyond the teenage/young adult years).

Point estimates were used instead of distributions for some parameters, such as toxicity values. Point estimates are conservative, upper end values that do not incorporate the variability associated with the parameter and likely result in overestimation of risks. Toxicity values are particularly conservative because they incorporate numerous uncertainty and modifying factors. Additionally, chronic (i.e., based on exposures seven years or greater) noncancer toxicity values were used to calculate HQ estimates for child residents whose exposure duration is a maximum of six years. While subchronic toxicity values may not be sufficiently protective of children, the approach of using chronic toxicity values may be overly conservative (USEPA 1996).

The studies used by the USEPA to develop exposure parameter distributions include various types of uncertainty. Several studies used 24-hour diaries to extrapolate activity patterns to a longer timeframe, and in some cases survey questions had a limited set of potential responses that may not characterize the full range of actual activity patterns. Other studies used modeling to predict a pattern based on available data. For some parameters, such as RBA, all data reported in a study were considered applicable and used rather than only using a specific subset of data to ensure an adequately protective distribution was selected. The various types of uncertainty associated with the underlying data used to develop exposure parameter distributions for this PRA may result in under- or overestimation of exposure and risks.

As shown in **Table 2**, the ingestion pathway contributes most to the cumulative arsenic cancer risk and noncancer hazard estimates for residential receptors, followed in each case by the dermal pathway and lastly the inhalation pathway. **Appendix A** provides the Crystal Ball risk forecasts and

sensitivity charts for each exposure pathway. The sensitivity chart displays the rankings of each input parameter assumption according to their contribution to variability in the risk forecast. The variability of each parameter is shown, with higher input parameter variability driving variability in the risk forecast. Because the soil ingestion pathway contributes most to the overall risk and hazard estimates for each receptor, the discussion of model sensitivity in this section focuses on the ingestion pathway. The sensitivity chart for the ingestion pathway for the arsenic cancer risk forecast shows that the exposure duration distribution has the greatest influence on the variability in risk estimates. Distributions for soil ingestion rate (particularly for ages 0 to 6) and relative bioavailability contribute most of the remaining variability in cancer risk estimates. For arsenic noncancer HQ estimates, the same soil ingestion rate distribution contributes most to the variability, followed by relative bioavailability. This soil ingestion rate distribution is also the main parameter to influence variability for copper noncancer HQ estimates.

The cancer exposure duration distribution is based on US census data and reflects the high variability in residential occupancy reported among the US population. The contribution of this parameter to variability in risk estimates is therefore a result of measured variability with relatively low uncertainty resulting from extrapolation from the US population to the Clifton, Arizona population. Arsenic relative bioavailability measurements can vary substantially between different soil types and between test species. Similar to the study used to develop the RBA distribution for this PRA, different soil types present at the Site are also likely to have variable levels of arsenic bioavailability. Including data measured in multiple test species provides a broader database, lowering the overall uncertainty by accounting for differences between species. Soil ingestion rate distributions likely add the greatest uncertainty to the PRA, due to limitations associated with the available methods to estimate ingestion. Incorporation of multiple studies that used different methods to estimate soil ingestion rates may reduce this uncertainty to some degree.

While uncertainty can only be reduced through further study, acknowledging uncertainties that exist within the available information is important for understanding and interpreting results. While the goal of using distributions is to better reflect available information, where uncertainty is greater the general trend leans toward more conservative assumptions. This is particularly true when underlying assumptions are considered. For example, while data are available to quantify whole body or body part surface areas, assumptions must be made regarding body parts that are likely to be exposed to soil. Where necessary such assumptions tend to be conservative, such as assuming the entire legs and head are always exposed to soil. Similarly, the underlying assumption that residents will contact soil during every day they spend at home adds conservatism to the already conservative assumption that residents will be home on all or almost all days of the year. Such assumptions, when combined with available data, ensure a reasonable and health-protective characterization of risks.

7. SUMMARY AND CONCLUSIONS

Potential cancer risks and noncancer hazards to residents that could result from exposure to soil containing arsenic and copper at the proposed SSRL concentrations across the Clifton Townsite were assessed using probabilistic methods. Exposure data compiled by the USEPA, ODEQ, and others were combined with the proposed SSRLs as exposure concentrations to estimate exposure. Exposure estimates based on a combination of parameter distributions and point estimates were then combined with toxicity values to provide distributions of risk and hazard estimates that take into account both variability and uncertainty. Blood lead modeling was also completed based on the proposed SSRL for lead. The proposed SSRLs, associated risk and hazard estimates for arsenic and copper, and lead modeling results are summarized in **Table 3**.

Table 3: Proposed Site-specific Soil Remediation Levels and Risk Assessment Results

Target Constituent	**Proposed SSRL**	**Results**
Arsenic	30 mg/kg	LECR: 1 x 10^{-5}; HQ: 0.3
Copper	9,000 mg/kg	HQ: 0.9
Lead	425 mg/kg	4.4% chance of child blood lead ≥ 10 µg/dL

The 95th percentile LECR estimate of 1 x 10^{-5} based on the proposed arsenic SSRL of 30 mg/kg is within the USEPA and ADEQ acceptable risk range of 1 x 10^{-6} to 1 x 10^{-4}. The respective HQ estimates of 0.3 and 0.9 based on the arsenic and copper proposed SSRLs of 30 mg/kg and 9,000 mg/kg meet the USEPA and ADEQ criteria (less than or equal to 1) for noncancer hazards. For lead, the predicted chance of a child having a blood lead level equal to or greater than the target of 10 µg/dL based on potential exposure to lead in soil at the proposed SSRL of 425 mg/kg is 4.4%, which meets the USEPA's goal of less than 5%.

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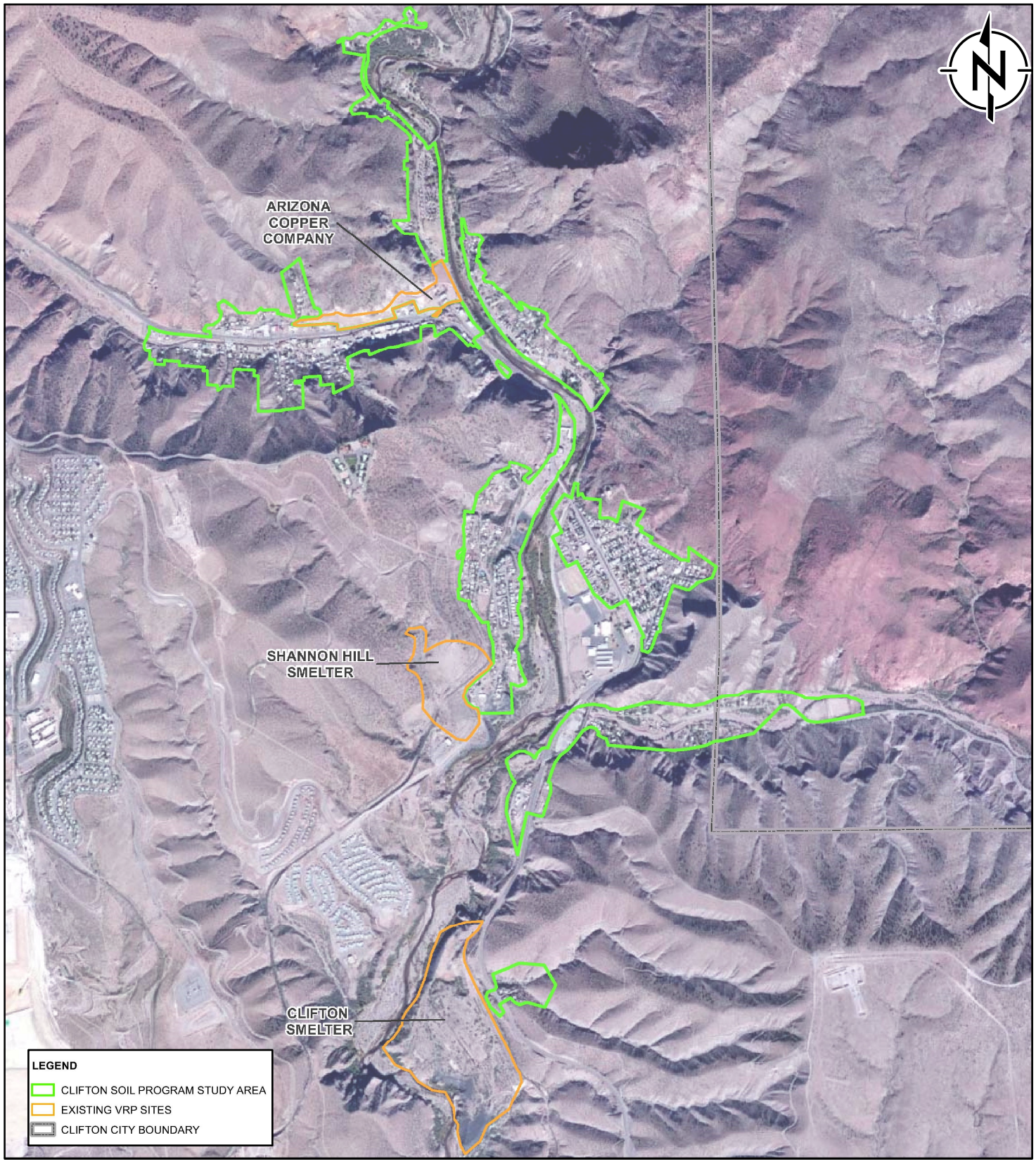
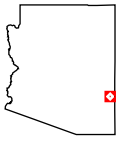
FIGURES



Notes:
VRP = Voluntary Remediation Program
Source: Modified from Damian (2019)

SOURCE:
© 2020 Microsoft Corporation © 2020 Maxar ©CNES (2020) Distribution Airbus DS.
Map Scale: 1:1:25,940; Spatial Reference: ;
Map Center: 109°17'51"W 33°2'48"N

0 2,000 4,000
Scale in Feet


KEY MAP

RAMBOLL

Clifton Soil Program Study Area
Freeport Minerals Corporation
Clifton, Arizona

FIGURE
1

DRAFTED BY :SLEICK | DATE: 6/23/2020 | PROJECT: 1690017244

C:\Users\sleick\OneDrive - Ramboll\Documents\Working\GIS\Clifton\Figure1.aprx\Figure 01-Site Location Map

APPENDIX A
CRYSTAL BALL REPORT

Crystal Ball Report - Full
Simulation started on 1/7/2021 at 9:47 AM
Simulation stopped on 1/7/2021 at 9:50 AM

Run preferences:	
Number of trials run	10,000
Monte Carlo	
Random seed	
Run statistics:	
Total running time (sec)	44.79
Trials/second (average)	223
Random numbers per sec	7,145
Crystal Ball data:	
Assumptions	31
Correlations	3
Correlation matrices	3
Decision variables	0
Forecasts	13

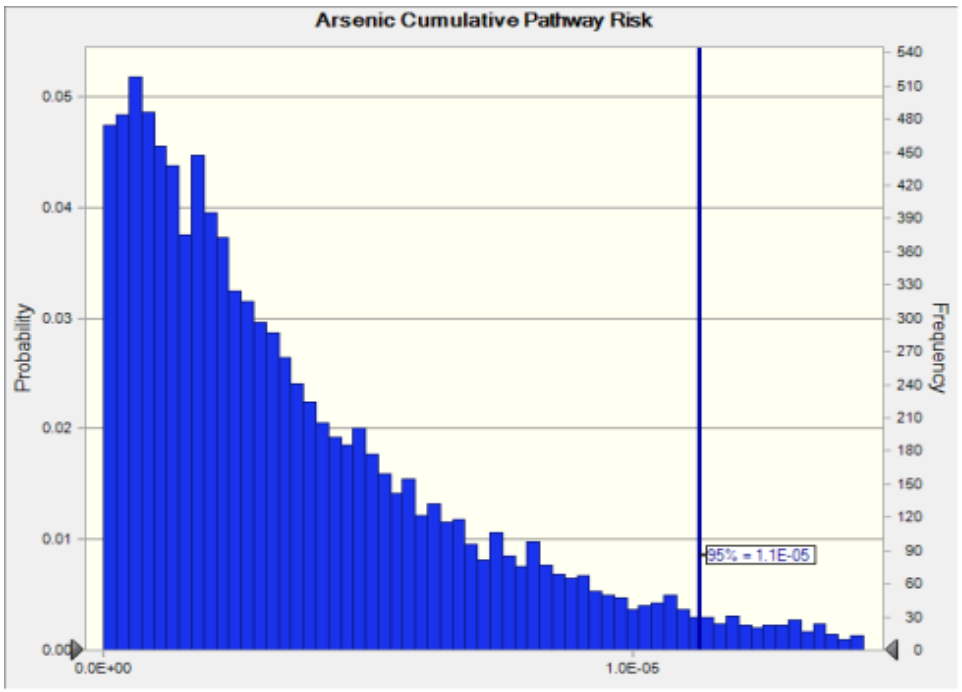
Forecasts

Worksheet: [REH MC_table_Clifton_HRA_20201221.xlsx]REH HRA

Risk and HQ Forecasts

Forecast: Arsenic Cumulative Pathway Risk **Cell: K18**

Summary:
Entire range is from 3.0E-09 to 3.1E-05
Base case is 4.9E-06
After 10,000 trials, the std. error of the mean is 3.7E-08



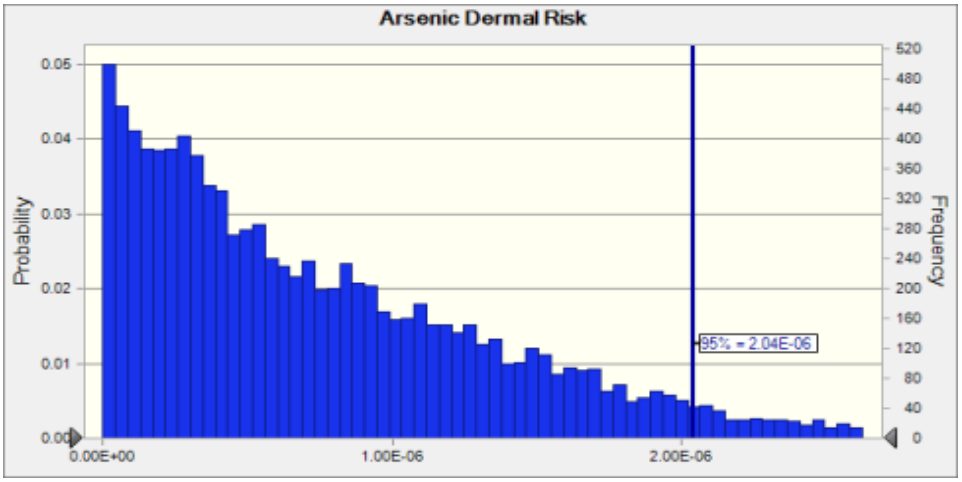
Statistics:	Forecast values
Trials	10,000
Base Case	4.9E-06
Mean	3.9E-06
Median	2.8E-06
Mode	---
Standard Deviation	3.7E-06
Variance	1.4E-11
Skewness	1.90
Kurtosis	8.14
Coeff. of Variation	0.9593
Minimum	3.0E-09
Maximum	3.1E-05
Range Width	3.1E-05
Mean Std. Error	3.7E-08

Forecast: Arsenic Cumulative Pathway Risk (cont'd)

Percentiles:	Forecast values
0%	3.0E-09
10%	4.9E-07
20%	9.7E-07
30%	1.5E-06
40%	2.1E-06
50%	2.8E-06
60%	3.6E-06
70%	4.7E-06
80%	6.2E-06
90%	8.7E-06
100%	3.1E-05

Forecast: Arsenic Dermal Risk **Cell: K14**

Summary:
Entire range is from 1.05E-11 to 4.80E-06
Base case is 9.01E-07
After 10,000 trials, the std. error of the mean is 6.62E-09



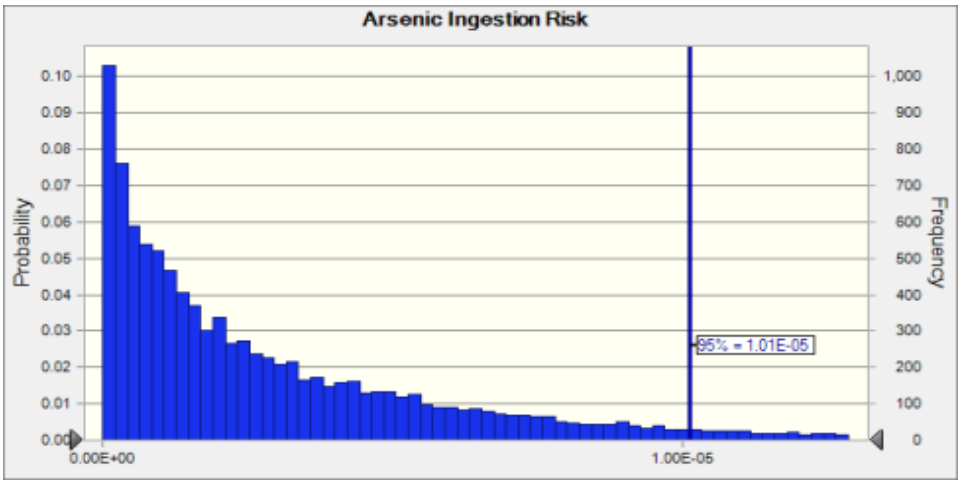
Statistics:	Forecast values
Trials	10,000
Base Case	9.01E-07
Mean	7.73E-07
Median	5.95E-07
Mode	---
Standard Deviation	6.62E-07
Variance	4.38E-13
Skewness	1.2866
Kurtosis	5.02
Coeff. of Variation	0.86
Minimum	1.05E-11
Maximum	4.80E-06
Range Width	4.80E-06
Mean Std. Error	6.62E-09

Forecast: Arsenic Dermal Risk (cont'd) **Cell: K14**

Percentiles:	Forecast values
0%	1.05E-11
10%	9.21E-08
20%	2.01E-07
30%	3.12E-07
40%	4.36E-07
50%	5.95E-07
60%	7.90E-07
70%	1.01E-06
80%	1.28E-06
90%	1.69E-06
100%	4.80E-06

Forecast: Arsenic Ingestion Risk **Cell: K12**

Summary:
Entire range is from 3.44E-10 to 2.86E-05
Base case is 3.99E-06
After 10,000 trials, the std. error of the mean is 3.48E-08



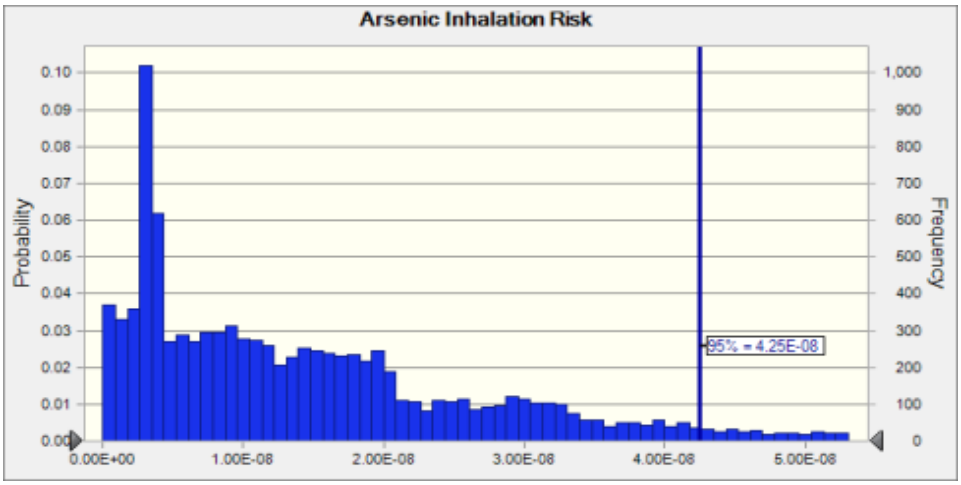
Forecast: Arsenic Ingestion Risk (cont'd) **Cell: K12**

Statistics:	Forecast values
Trials	10,000
Base Case	3.99E-06
Mean	3.11E-06
Median	1.91E-06
Mode	---
Standard Deviation	3.48E-06
Variance	1.21E-11
Skewness	2.13
Kurtosis	9.31
Coeff. of Variation	1.12
Minimum	3.44E-10
Maximum	2.86E-05
Range Width	2.86E-05
Mean Std. Error	3.48E-08

Percentiles:	Forecast values
0%	3.44E-10
10%	2.04E-07
20%	4.91E-07
30%	8.78E-07
40%	1.31E-06
50%	1.91E-06
60%	2.65E-06
70%	3.69E-06
80%	5.15E-06
90%	7.62E-06
100%	2.86E-05

Forecast: Arsenic Inhalation Risk **Cell: K16**

Summary:
Entire range is from 1.37E-11 to 7.61E-08
Base case is 1.52E-08
After 10,000 trials, the std. error of the mean is 1.35E-10



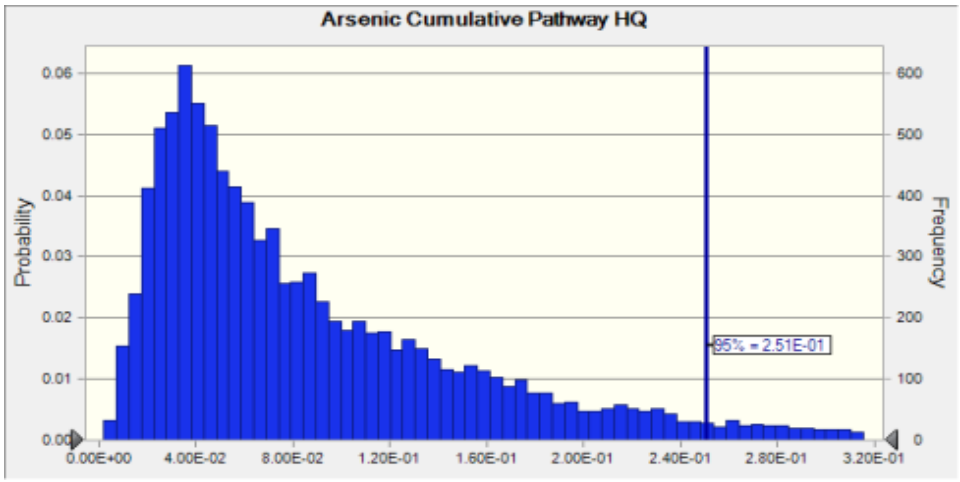
Forecast: Arsenic Inhalation Risk (cont'd) **Cell: K16**

Statistics:	Forecast values
Trials	10,000
Base Case	1.52E-08
Mean	1.51E-08
Median	1.14E-08
Mode	---
Standard Deviation	1.35E-08
Variance	1.83E-16
Skewness	1.38
Kurtosis	4.88
Coeff. of Variation	0.8942
Minimum	1.37E-11
Maximum	7.61E-08
Range Width	7.61E-08
Mean Std. Error	1.35E-10

Percentiles:	Forecast values
0%	1.37E-11
10%	2.52E-09
20%	3.44E-09
30%	5.34E-09
40%	8.39E-09
50%	1.14E-08
60%	1.51E-08
70%	1.88E-08
80%	2.50E-08
90%	3.36E-08
100%	7.61E-08

Forecast: Arsenic Cumulative Pathway HQ **Cell: K32**

Summary:
Entire range is from 2.15E-03 to 6.30E-01
Base case is 9.35E-02
After 10,000 trials, the std. error of the mean is 7.94E-04

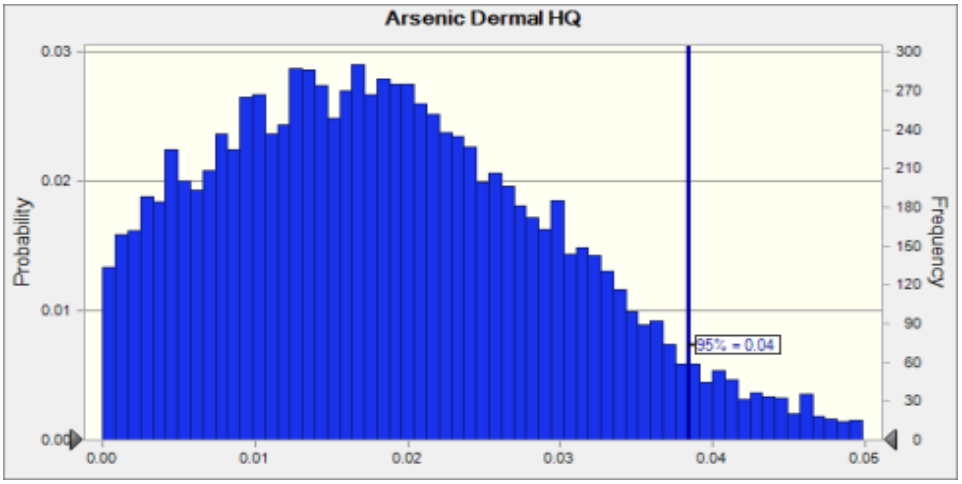


Statistics:	Forecast values
Trials	10,000
Base Case	0.093
Mean	0.093
Median	0.067
Mode	---
Standard Deviation	0.079
Variance	0.006
Skewness	2.00
Kurtosis	8.39
Coeff. of Variation	0.8554
Minimum	0.002
Maximum	0.630
Range Width	0.628
Mean Std. Error	0.001

Percentiles:	Forecast values
0%	0.002
10%	0.024
20%	0.034
30%	0.043
40%	0.053
50%	0.067
60%	0.084
70%	0.108
80%	0.140
90%	0.194
100%	0.630

Forecast: Arsenic Dermal HQ **Cell: K28**

Summary:
Entire range is from 0.00 to 0.07
Base case is 0.02
After 10,000 trials, the std. error of the mean is 0.00

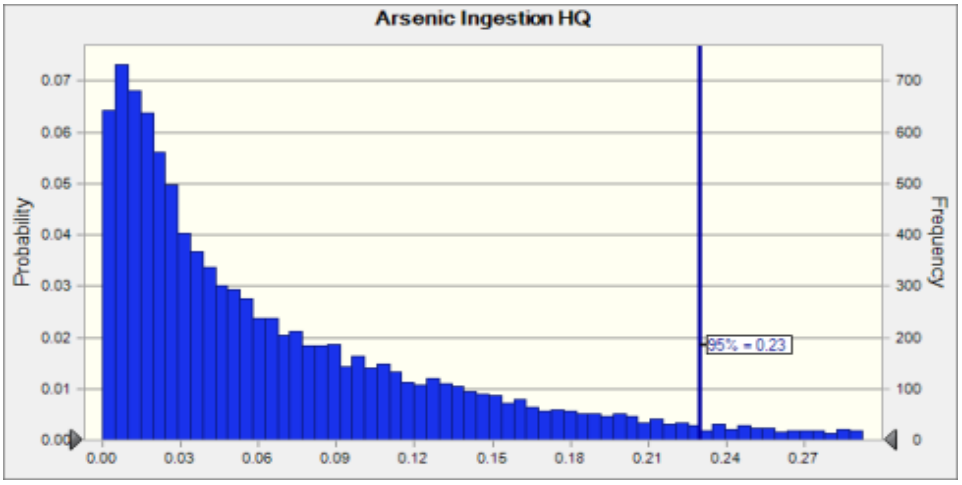


Statistics:	Forecast values
Trials	10,000
Base Case	0.02
Mean	0.02
Median	0.02
Mode	---
Standard Deviation	0.01
Variance	0.00
Skewness	0.5262
Kurtosis	2.96
Coeff. of Variation	0.5899
Minimum	0.00
Maximum	0.07
Range Width	0.07
Mean Std. Error	0.00

Percentiles:	Forecast values
0%	0.000
10%	0.005
20%	0.009
30%	0.012
40%	0.015
50%	0.018
60%	0.021
70%	0.024
80%	0.028
90%	0.034
100%	0.071

Forecast: Arsenic Ingestion HQ **Cell: K26**

Summary:
Entire range is from 0.00 to 0.61
Base case is 0.07
After 10,000 trials, the std. error of the mean is 0.00

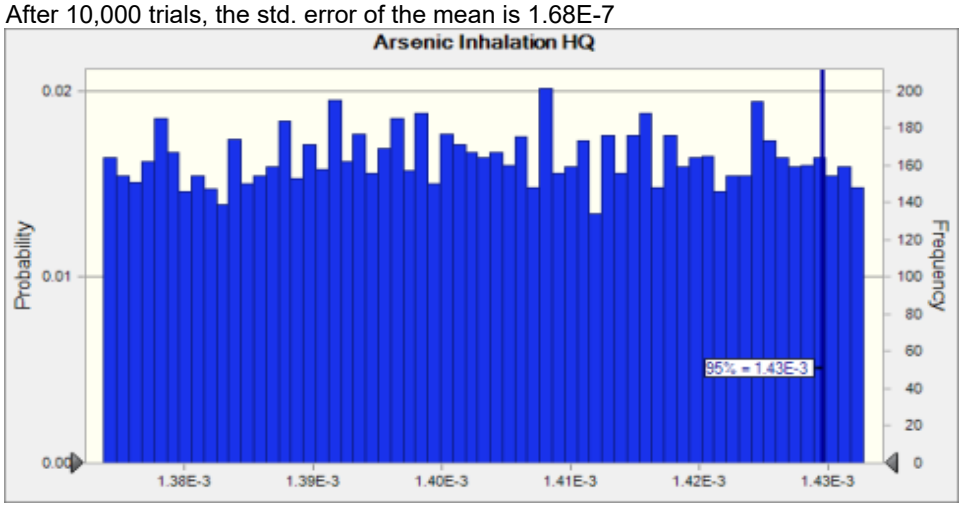


Statistics:	Forecast values
Trials	10,000
Base Case	0.07
Mean	0.07
Median	0.05
Mode	---
Standard Deviation	0.08
Variance	0.01
Skewness	2.06
Kurtosis	8.62
Coeff. of Variation	1.08
Minimum	0.00
Maximum	0.61
Range Width	0.61
Mean Std. Error	0.00

Percentiles:	Forecast values
0%	0.000
10%	0.007
20%	0.014
30%	0.022
40%	0.032
50%	0.045
60%	0.063
70%	0.087
80%	0.120
90%	0.174
100%	0.612

Forecast: Arsenic Inhalation HQ **Cell: K30**

Summary:
Entire range is from 1.37E-3 to 1.43E-3
Base case is 1.40E-3
After 10,000 trials, the std. error of the mean is 1.68E-7

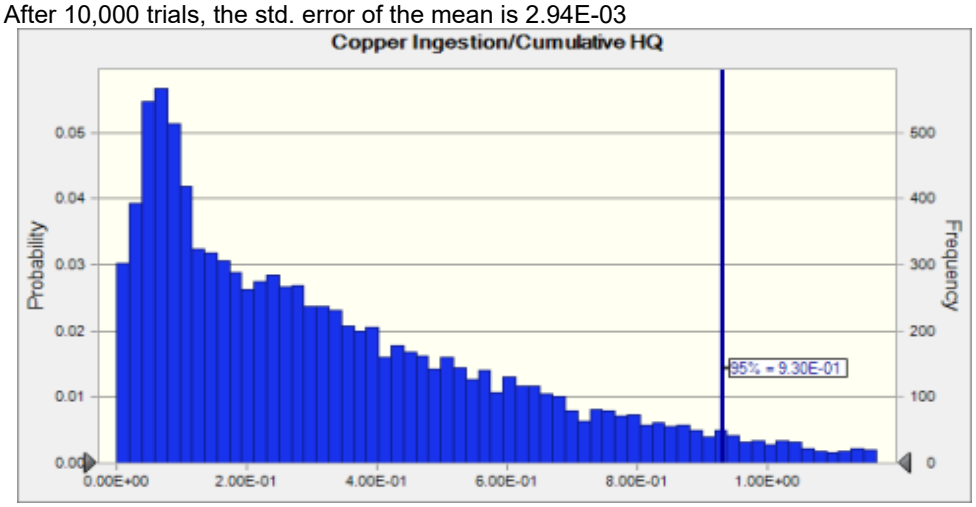


Statistics:	Forecast values
Trials	10,000
Base Case	1.40E-3
Mean	1.40E-3
Median	1.40E-3
Mode	---
Standard Deviation	1.68E-5
Variance	2.83E-10
Skewness	-0.0031
Kurtosis	1.82
Coeff. of Variation	0.0120
Minimum	1.37E-3
Maximum	1.43E-3
Range Width	5.89E-5
Mean Std. Error	1.68E-7

Percentiles:	Forecast values
0%	1.37E-3
10%	1.38E-3
20%	1.39E-3
30%	1.39E-3
40%	1.40E-3
50%	1.40E-3
60%	1.41E-3
70%	1.41E-3
80%	1.42E-3
90%	1.43E-3
100%	1.43E-3

Forecast: Copper Ingestion/Cumulative HQ **Cell: K38**

Summary:
Entire range is from 1.07E-04 to 1.96E+00
Base case is 3.45E-01
After 10,000 trials, the std. error of the mean is 2.94E-03



Statistics:	Forecast values
Trials	10,000
Base Case	3.45E-01
Mean	3.43E-01
Median	2.64E-01
Mode	---
Standard Deviation	2.94E-01
Variance	8.67E-02
Skewness	1.24
Kurtosis	4.48
Coeff. of Variation	0.8596
Minimum	1.07E-04
Maximum	1.96E+00
Range Width	1.96E+00
Mean Std. Error	2.94E-03

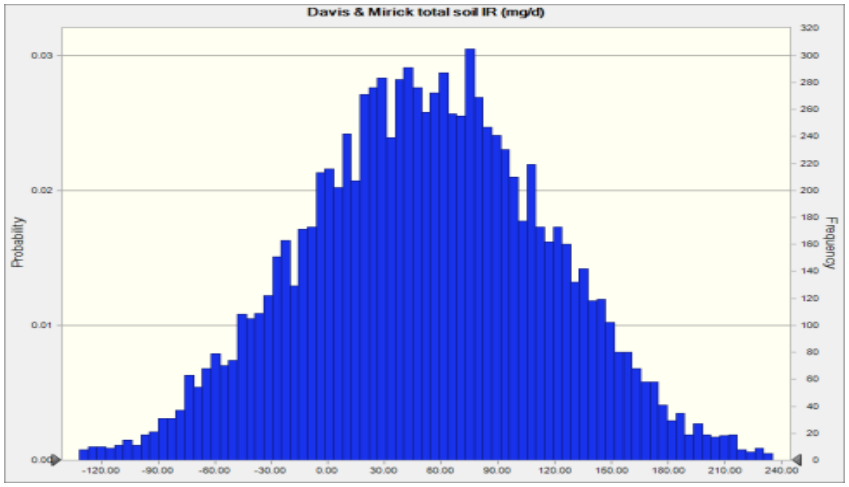
Percentiles:	Forecast values
0%	1.07E-04
10%	4.93E-02
20%	8.36E-02
30%	1.31E-01
40%	1.93E-01
50%	2.64E-01
60%	3.41E-01
70%	4.42E-01
80%	5.70E-01
90%	7.64E-01
100%	1.96E+00

Worksheet: [REH MC_table_Clifton_HRA_20201221.xlsx]4-14 App B IR

Soil Ingestion Rate Supporting Forecasts

Forecast: Davis & Mirick total soil IR (mg/d) **Cell: E302**

Summary:
Entire range is from -236.58 to 319.21
Base case is 52.25
After 10,000 trials, the std. error of the mean is 0.66



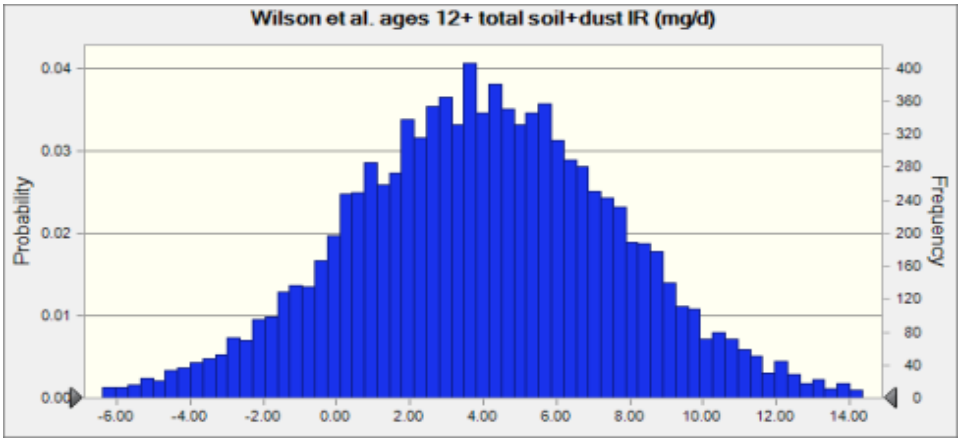
Statistics:	Forecast values
Trials	10,000
Base Case	52.25
Mean	51.88
Median	52.00
Mode	---
Standard Deviation	65.53
Variance	4,294.80
Skewness	-0.0085
Kurtosis	2.95
Coeff. of Variation	1.26
Minimum	-236.58
Maximum	319.21
Range Width	555.79
Mean Std. Error	0.66

Forecast: Davis & Mirick total soil IR (mg/d) (cont'd) **Cell: E302**

Percentiles:	Forecast values
0%	-236.58
10%	-32.66
20%	-3.31
30%	17.88
40%	35.17
50%	52.00
60%	69.35
70%	86.35
80%	107.61
90%	136.28
100%	319.21

Forecast: Wilson et al. ages 12+ total soil+dust IR (mg/d) **Cell: G346**

Summary:
Entire range is from -8.83 to 18.18
Base case is 4.06
After 10,000 trials, the std. error of the mean is 0.04



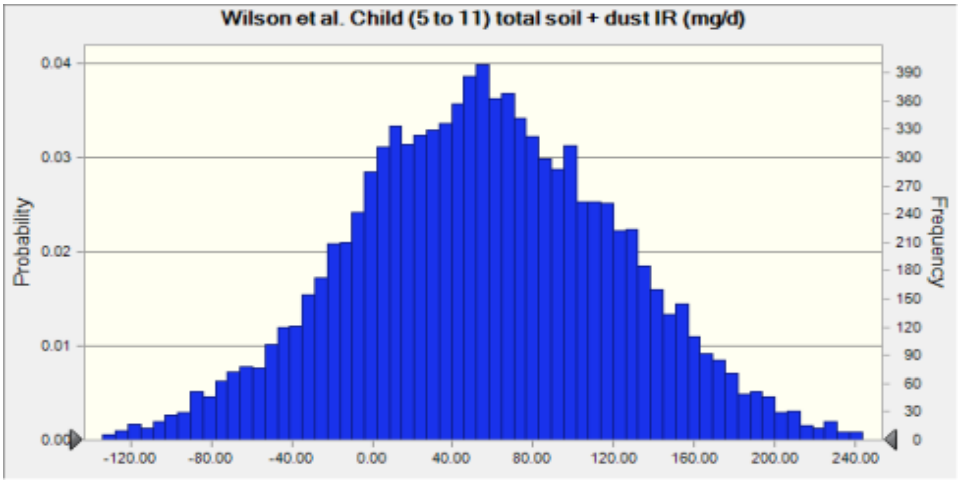
Statistics:	Forecast values
Trials	10,000
Base Case	4.06
Mean	3.98
Median	3.97
Mode	---
Standard Deviation	3.70
Variance	13.66
Skewness	-0.0050
Kurtosis	2.98
Coeff. of Variation	0.9283
Minimum	-8.83
Maximum	18.18
Range Width	27.01
Mean Std. Error	0.04

Forecast: Wilson et al. ages 12+ total soil+dust IR (mg/d) (cont'd) **Cell: G346**

Percentiles:	Forecast values
0%	-8.83
10%	-0.71
20%	0.89
30%	2.06
40%	3.05
50%	3.96
60%	4.91
70%	5.90
80%	7.08
90%	8.69
100%	18.18

Forecast: Wilson et al. Child (5 to 11) total soil + dust IR (mg/d) **Cell: F230**

Summary:
Entire range is from -198.92 to 321.58
Base case is 55.00
After 10,000 trials, the std. error of the mean is 0.67



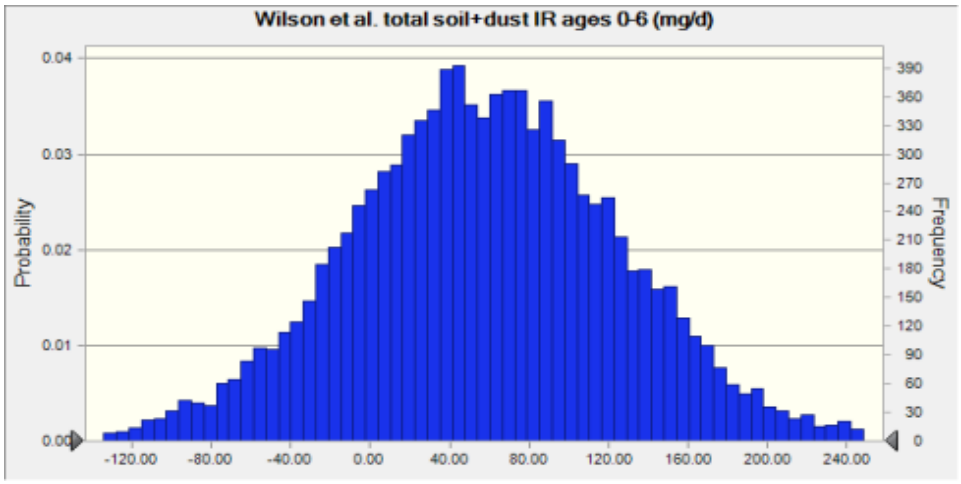
Statistics:	Forecast values
Trials	10,000
Base Case	55.00
Mean	54.80
Median	54.15
Mode	---
Standard Deviation	67.38
Variance	4,539.63
Skewness	-0.0087
Kurtosis	3.01
Coeff. of Variation	1.23
Minimum	-198.92
Maximum	321.58
Range Width	520.50
Mean Std. Error	0.67

Forecast: Wilson et al. Child (5 to 11) total soil + dust IR (mg/d) (cont'd) **Cell: F230**

Percentiles:	Forecast values
0%	-198.92
10%	-29.89
20%	-1.27
30%	18.68
40%	37.50
50%	54.13
60%	70.98
70%	90.46
80%	112.65
90%	141.28
100%	321.58

Forecast: Wilson et al. ages 0 to 6 total soil+dust IR (mg/d) **Cell: F100**

Summary:
Entire range is from -195.20 to 316.28
Base case is 57.88
After 10,000 trials, the std. error of the mean is 0.68



Statistics:	Forecast values
Trials	10,000
Base Case	57.88
Mean	57.07
Median	56.60
Mode	---
Standard Deviation	68.25
Variance	4,657.60
Skewness	-0.0028
Kurtosis	3.02
Coeff. of Variation	1.20
Minimum	-195.20
Maximum	316.28
Range Width	511.47
Mean Std. Error	0.68

Forecast: Wilson et al. ages 0 to 6 total soil+dust IR (mg/d) (cont'd) **Cell: F100**

Percentiles:	Forecast values
0%	-195.20
10%	-28.95
20%	0.41
30%	21.86
40%	39.79
50%	56.59
60%	73.87
70%	92.02
80%	114.50
90%	145.17
100%	316.28

End of Forecasts

Assumptions

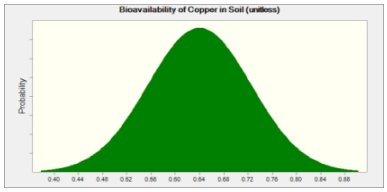
Worksheet: [REH MC_table_Clifton_HRA.xlsx]REH HRA

Assumption: Bioavailability in soil of copper (unitless) **Cell: E13**

Normal distribution with parameters:

Mean	0.64
Std. Dev.	0.09

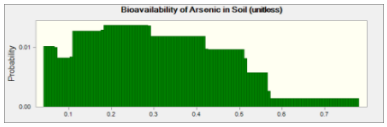
Selected range is from 0.00 to ∞



Assumption: Bioavailability of Arsenic in soil (unitless) **Cell: E12**

Custom distribution with parameters:

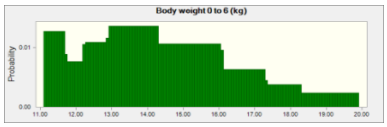
Min	Max	Percentile
0.041	0.071	5
	0.108	10
	0.18	25
	0.291	50
	0.42	75
	0.515	90
	0.568	95
	0.78	100



Assumption: Body Weight ages 0 to 6 (kg) **Cell: E26**

Custom distribution with parameters:

Min	Max	Percentile
11.1	11.7	10
	12.2	15
	12.9	25
	14.3	50
	16.1	75
	17.3	85
	18.3	90
	19.9	95

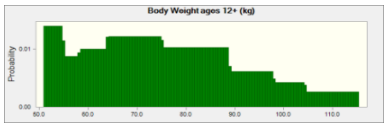


Correlated with:	Coefficient
Skin Surface Area 0 to 6 (cm2) (E17)	1.00

Assumption: Body Weight ages 6 to 12 (kg) **Cell: E27**

Custom distribution with parameters:

Min	Max	Percentile
19.7	21.3	10
	22.3	15
	24.4	25
	29.3	50
	36.8	75
	42.1	85
	45.6	90
	52.5	95

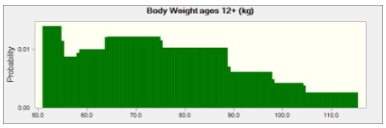


Correlated with: Coefficient
Skin Surface Area 6 to 12 (cm2) (E18) 1.00

Assumption: Body Weight ages 12+ (kg) **Cell: E28**

Custom distribution with parameters:

Min	Max	Percentile
50.9	54.9	10
	58.1	15
	63.7	25
	75.2	50
	88.8	75
	97.9	85
	104.5	90
	115.3	95



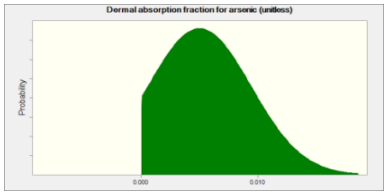
Correlated with: Coefficient
Skin Suface Area 12+ (cm2) (E19) 1.00

Assumption: Dermal absorption fraction for arsenic (unitless) **Cell: E20**

Normal distribution with parameters:

Mean	0.005
Std. Dev.	0.004

Selected range is from 0.00 to ∞

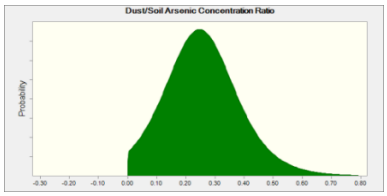


Assumption: Dust/Soil Concentration Ratio **Cell: E14**

Logistic distribution with parameters:

Mean	0.25
Scale	0.08

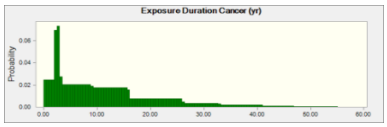
Selected range is from 0.00 to ∞



Assumption: Exposure Duration Cancer (yr) **Cell: E6**

Custom distribution with parameters:

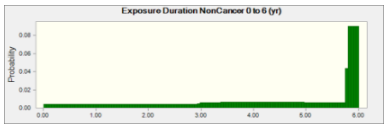
Min	Max	Percentile
0.01	2	10
	3	25
	9	50
	16	75
	26	90
	33	95
	41	98
	47	99
	51	99.5
	55	99.8
	59	99.9



Assumption: Exposure Duration NonCancer ages 0 to 6 (yr) **Cell: E5**

Custom distribution with parameters:

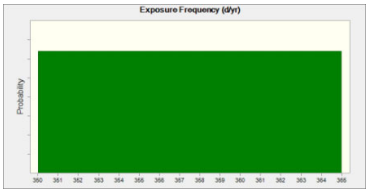
Min	Max	Percentile
0.01	0.59	5
	1.18	10
	1.77	15
	2.36	20
	2.96	25
	3.37	30
	3.76	35
	4.16	40
	4.56	45
	4.95	50
	5.37	55
	5.78	60
	6	100



Assumption: Exposure Frequency (d/yr) **Cell: E4**

Uniform distribution with parameters:

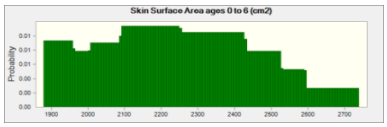
Minimum	350
Maximum	365



Assumption: Skin Surface Area ages 0 to 6 (cm2) **Cell: E17**

Custom distribution with parameters:

Min	Max	Percentile
1879.37	1959.245	10
	2006.815	15
	2089.53	25
	2253.185	50
	2430.685	75
	2525.825	85
	2596.115	90
	2738.47	95

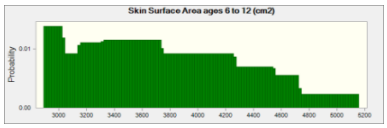


Correlated with:	Coefficient
Body Weight 0 to 6 (kg) (E26)	1.00

Assumption: Skin Surface Area ages 6 to 12 (cm2) **Cell: E18**

Custom distribution with parameters:

Min	Max	Percentile
2894.6	3035.8	10
	3141.7	15
	3318.2	25
	3741.8	50
	4271.3	75
	4553.7	85
	4730.2	90
	5153.8	95

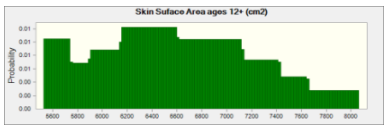


Correlated with:	Coefficient
Body Weight 6 to 12 (kg) (E27)	1.00

Assumption: Skin Suface Area ages 12+ (cm2) **Cell: E19**

Custom distribution with parameters:

Min	Max	Percentile
5530	5740	10
	5900	15
	6150	25
	6600	50
	7130	75
	7430	85
	7660	90
	8060	95

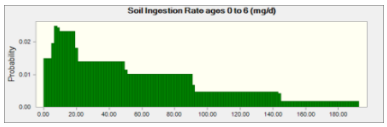


Correlated with:	Coefficient
Body Weight 12+ (kg) (E28)	1.00

Assumption: Soil Ingestion Rate ages 0 to 6 (mg/day) **Cell: E7**

Custom distribution with parameters:

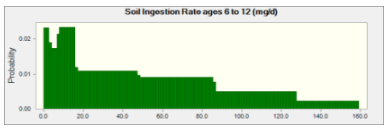
Min	Max	Percentile
0.01	5.63	5
	9.00	10
	19.84	25
	49.46	50
	90.86	75
	143.59	90
	192.07	95



Assumption: Soil Ingestion Rate ages 6 to 12 (mg/day) **Cell: E8**

Custom distribution with parameters:

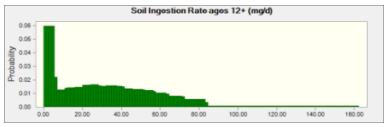
Min	Max	Percentile
0.01	3.00	5
	7.00	10
	16.09	25
	48.06	50
	87.35	75
	128.64	90
	160.22	95



Assumption: Soil Ingestion Rate 12+ (mg/day) **Cell: E9**

Custom distribution with parameters:

Min	Max	Percentile
0	4.59	25
	9.97	30
	14.45	35
	19.11	40
	23.50	45
	27.98	50
	32.38	55
	37.13	60
	41.32	65
	46.13	70
	51.33	75
	57.35	80
	64.39	85
	72.49	90
	84.41	95
	168.69	100

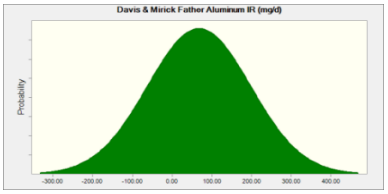


Worksheet: [REH MC_table_Clifton_HRA_20201221.xlsx]4-14 App B IR

Soil Ingestion Rate Supporting Distributions

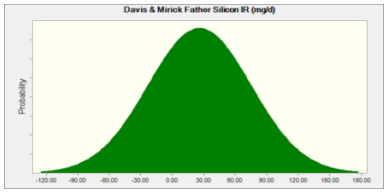
Assumption: Davis & Mirick Father Aluminum IR (mg/d) **Cell: E299**

Normal distribution with parameters:
Mean 68.00
Std. Dev. 130.00



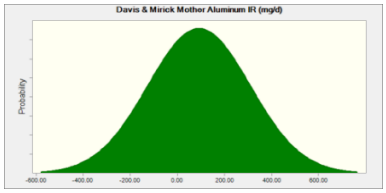
Assumption: Davis & Mirick Father Silicon IR (mg/d) **Cell: E300**

Normal distribution with parameters:
Mean 26.00
Std. Dev. 49.00



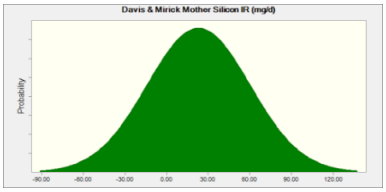
Assumption: Davis & Mirick Mother Aluminum IR (mg/d) **Cell: E295**

Normal distribution with parameters:
Mean 92.00
Std. Dev. 218.00



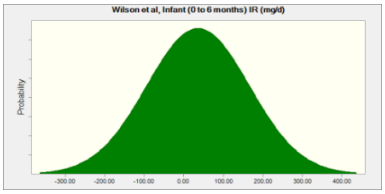
Assumption: Davis & Mirick Mother Silicon IR (mg/d) **Cell: E296**

Normal distribution with parameters:
Mean 23.00
Std. Dev. 37.00



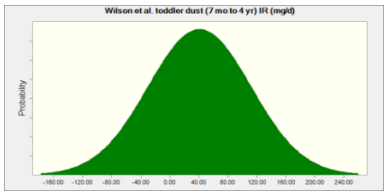
Assumption: Wilson et al. Infant (0 to 6 months) IR (mg/d) **Cell: F95**

Normal distribution with parameters:
Mean 36.00
Std. Dev. 130.00



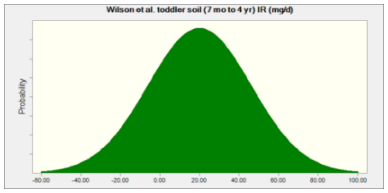
Assumption: Wilson et al. Toddler (7 mo to 4 yr) dust IR (mg/d) **Cell: F96**

Normal distribution with parameters:
Mean 41.00
Std. Dev. 71.00



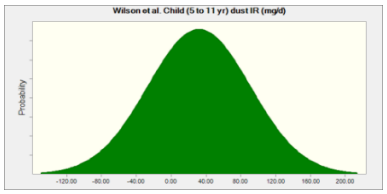
Assumption: Wilson et al. Toddler (7 mo to 4 yr) soil IR (mg/d) **Cell: F97**

Normal distribution with parameters:
Mean 20.00
Std. Dev. 26.00



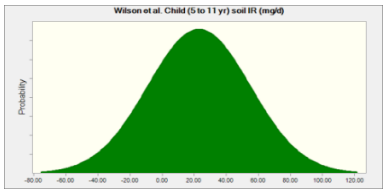
Assumption: Wilson et al. Child (5 to 11 yr) dust IR (mg/d) **Cell: F229**

Normal distribution with parameters:
Mean 32.00
Std. Dev. 59.00



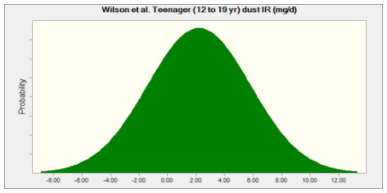
Assumption: Wilson et al. Child (5 to 11 yr) soil IR (mg/d) **Cell: F228**

Normal distribution with parameters:
Mean 23.00
Std. Dev. 32.00



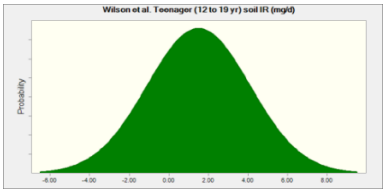
Assumption: Wilson et al. Teenager (12 to 19 yr) dust IR (mg/d) **Cell: G340**

Normal distribution with parameters:
Mean 2.20
Std. Dev. 3.60



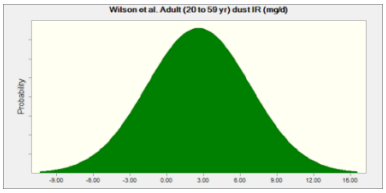
Assumption: Wilson et al. Teenager (12 to 19 yr) soil IR (mg/d) **Cell: G339**

Normal distribution with parameters:
Mean 1.50
Std. Dev. 2.60



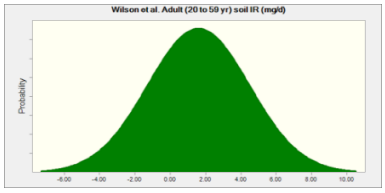
Assumption: Wilson et al. Adult (20 to 59 yr) dust IR (mg/d) **Cell: G342**

Normal distribution with parameters:
Mean 2.60
Std. Dev. 4.20



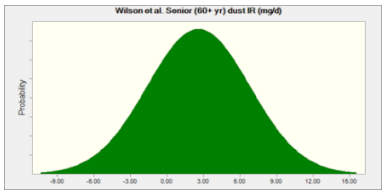
Assumption: Wilson et al. Adult (20 to 59 yr) soil IR (mg/d) **Cell: G341**

Normal distribution with parameters:
Mean 1.60
Std. Dev. 2.90



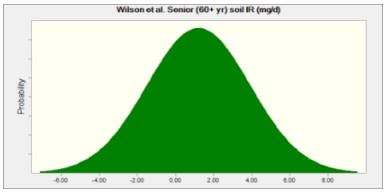
Assumption: Wilson et al. Senior (60+ yr) dust IR (mg/d) **Cell: G344**

Normal distribution with parameters:
Mean 2.60
Std. Dev. 4.20



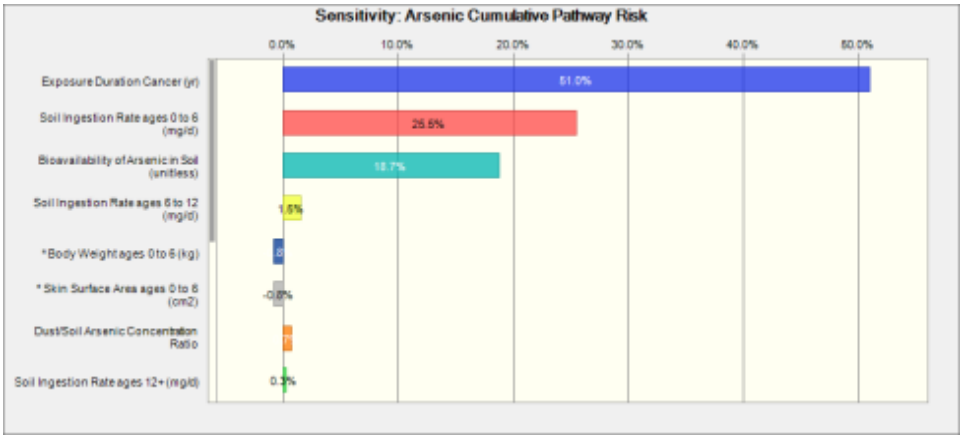
Assumption: Wilson et al. Senior (60+ yr) soil IR (mg/d) **Cell: G343**

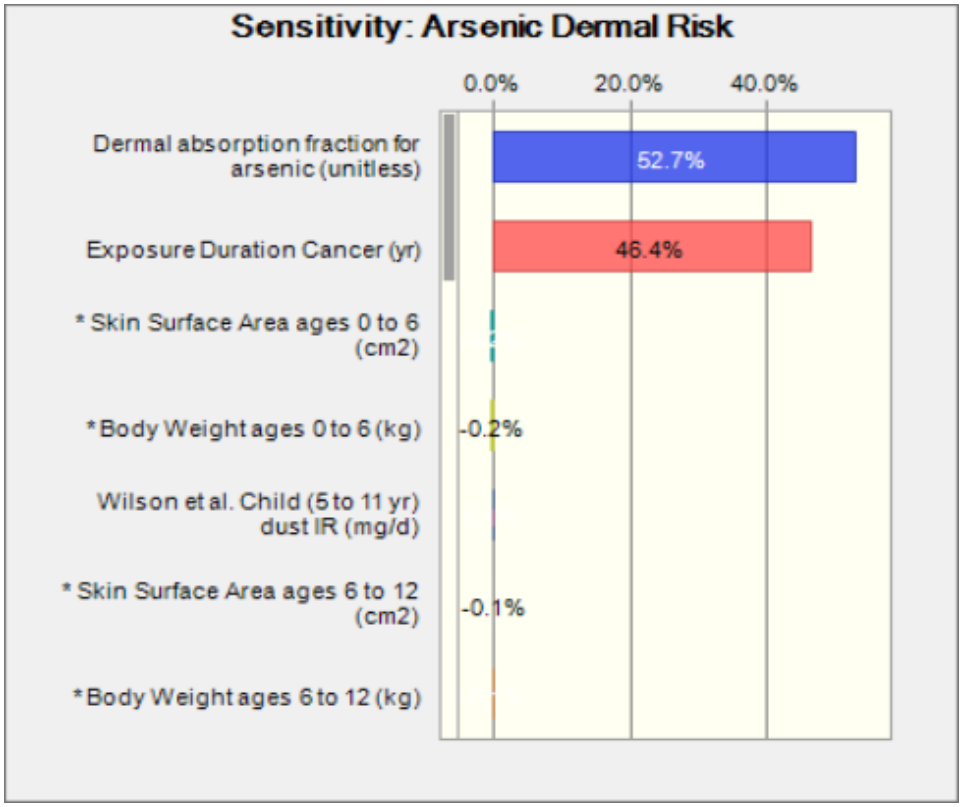
Normal distribution with parameters:
Mean 1.20
Std. Dev. 2.70

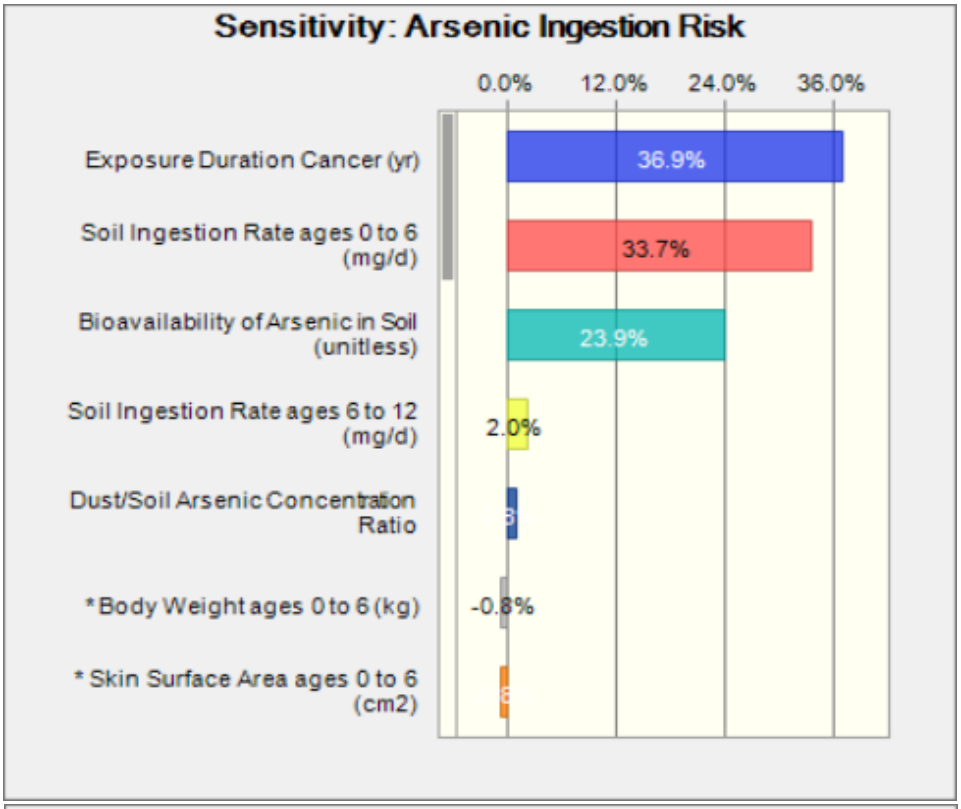


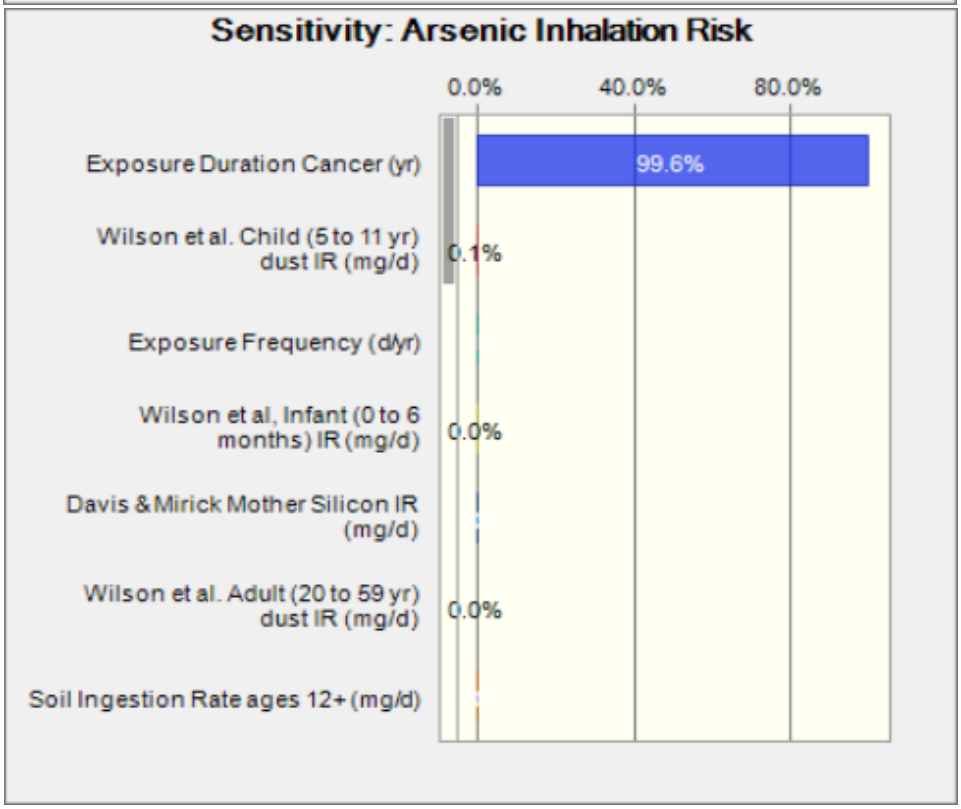
End of Assumptions

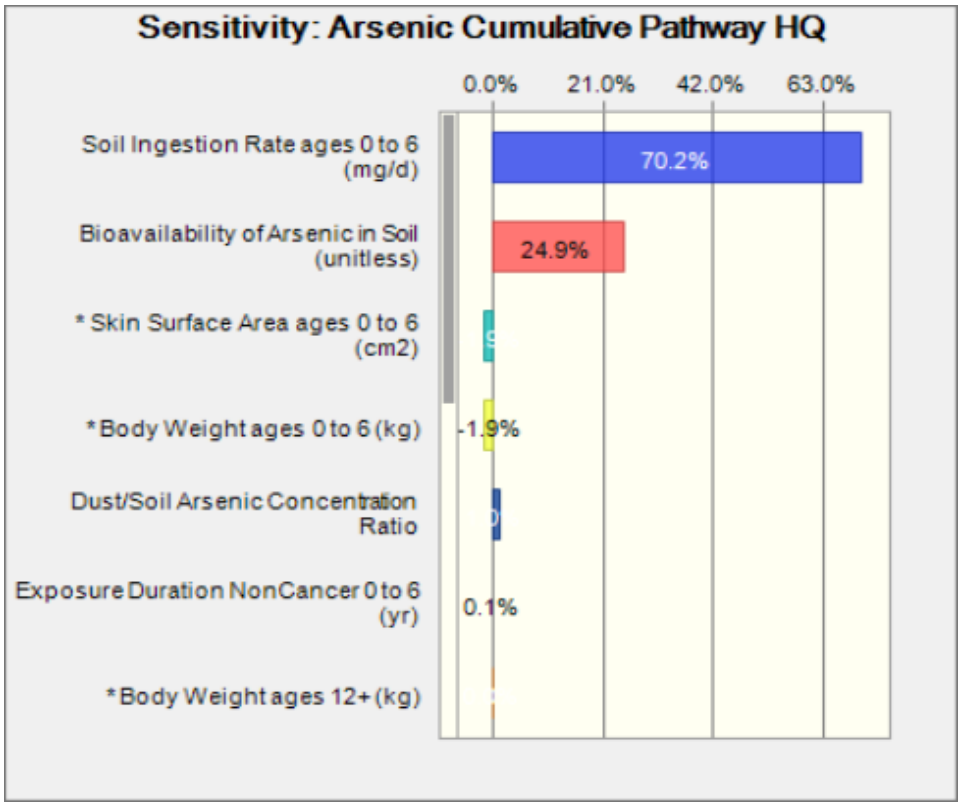
Sensitivity Charts

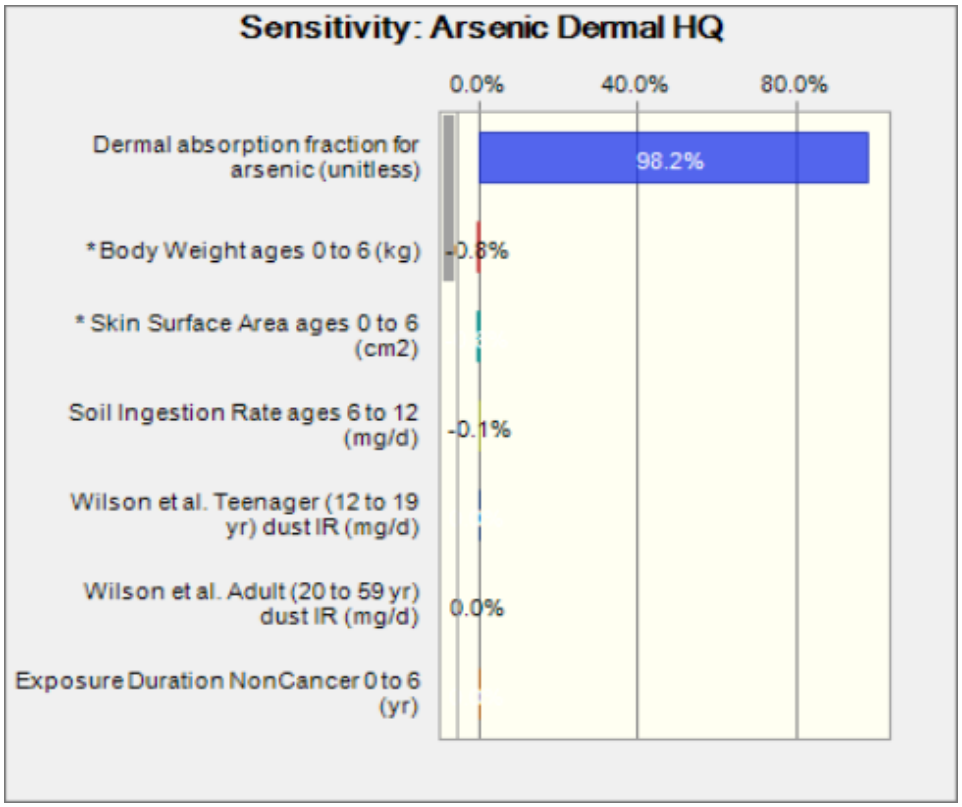


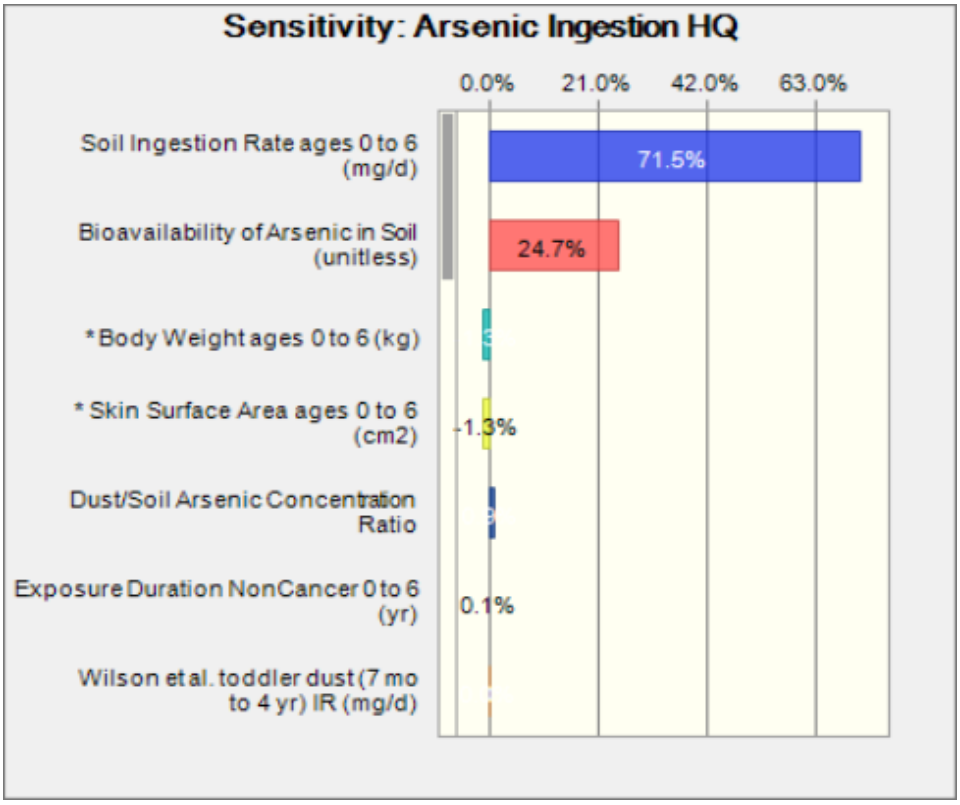


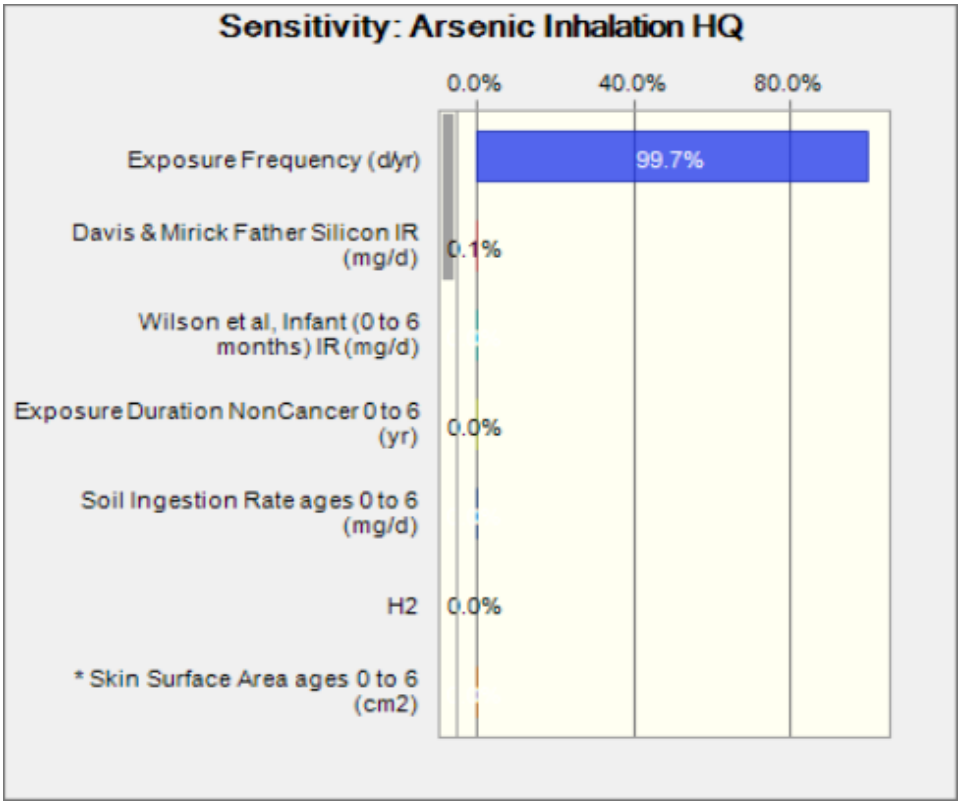

Sensitivity: Arsenic Ingestion Risk
0.0%
12.0%
24.0%
36.0%
Exposure Duration Cancer (yr)
36.9%
Soil Ingestion Rate ages 0 to 6 (mg/d)
33.7%
Bioavailability of Arsenic in Soil (unitless)
23.9%
Soil Ingestion Rate ages 6 to 12 (mg/d)
2.0%
Dust/Soil Arsenic Concentration Ratio
* Body Weight ages 0 to 6 (kg)
-0.8%
* Skin Surface Area ages 0 to 6 (cm2)

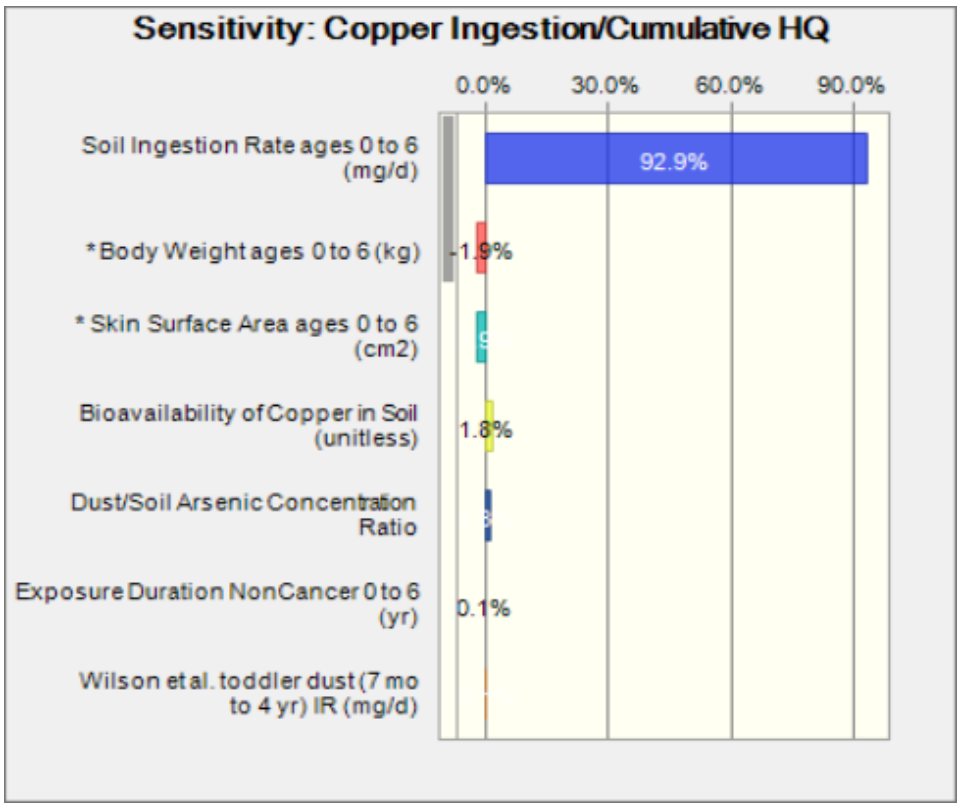

Sensitivity: Arsenic Inhalation Risk
0.0%
40.0%
80.0%
Exposure Duration Cancer (yr)
99.6%
Wilson et al. Child (5 to 11 yr) dust IR (mg/d)
0.1%
Exposure Frequency (d/yr)
Wilson et al, Infant (0 to 6 months) IR (mg/d)
0.0%
Davis & Mirick Mother Silicon IR (mg/d)
Wilson et al. Adult (20 to 59 yr) dust IR (mg/d)
0.0%
Soil Ingestion Rate ages 12+ (mg/d)


Sensitivity: Arsenic Cumulative Pathway HQ
0.0%
21.0%
42.0%
63.0%
Soil Ingestion Rate ages 0 to 6 (mg/d)
70.2%
Bioavailability of Arsenic in Soil (unitless)
24.9%
* Skin Surface Area ages 0 to 6 (cm2)
*Body Weight ages 0 to 6 (kg)
-1.9%
Dust/Soil Arsenic Concentration Ratio
Exposure Duration NonCancer 0 to 6 (yr)
0.1%
*Body Weight ages 12+ (kg)


Sensitivity: Arsenic Dermal HQ
0.0%
40.0%
80.0%
Dermal absorption fraction for arsenic (unitless)
98.2%
*Body Weight ages 0 to 6 (kg)
-0.8%
* Skin Surface Area ages 0 to 6 (cm2)
Soil Ingestion Rate ages 6 to 12 (mg/d)
-0.1%
Wilson et al. Teenager (12 to 19 yr) dust IR (mg/d)
Wilson et al. Adult (20 to 59 yr) dust IR (mg/d)
0.0%
Exposure Duration NonCancer 0 to 6 (yr)


Sensitivity: Arsenic Ingestion HQ
0.0%
21.0%
42.0%
63.0%
Soil Ingestion Rate ages 0 to 6 (mg/d)
71.5%
Bioavailability of Arsenic in Soil (unitless)
24.7%
*Body Weight ages 0 to 6 (kg)
* Skin Surface Area ages 0 to 6 (cm2)
-1.3%
Dust/Soil Arsenic Concentration Ratio
Exposure Duration NonCancer 0 to 6 (yr)
0.1%
Wilson et al. toddler dust (7 mo to 4 yr) IR (mg/d)


Sensitivity: Arsenic Inhalation HQ
0.0%
40.0%
80.0%
Exposure Frequency (d/yr)
99.7%
Davis & Mirick Father Silicon IR (mg/d)
0.1%
Wilson et al, Infant (0 to 6 months) IR (mg/d)
Exposure Duration NonCancer 0 to 6 (yr)
0.0%
Soil Ingestion Rate ages 0 to 6 (mg/d)
H2
0.0%
* Skin Surface Area ages 0 to 6 (cm2)

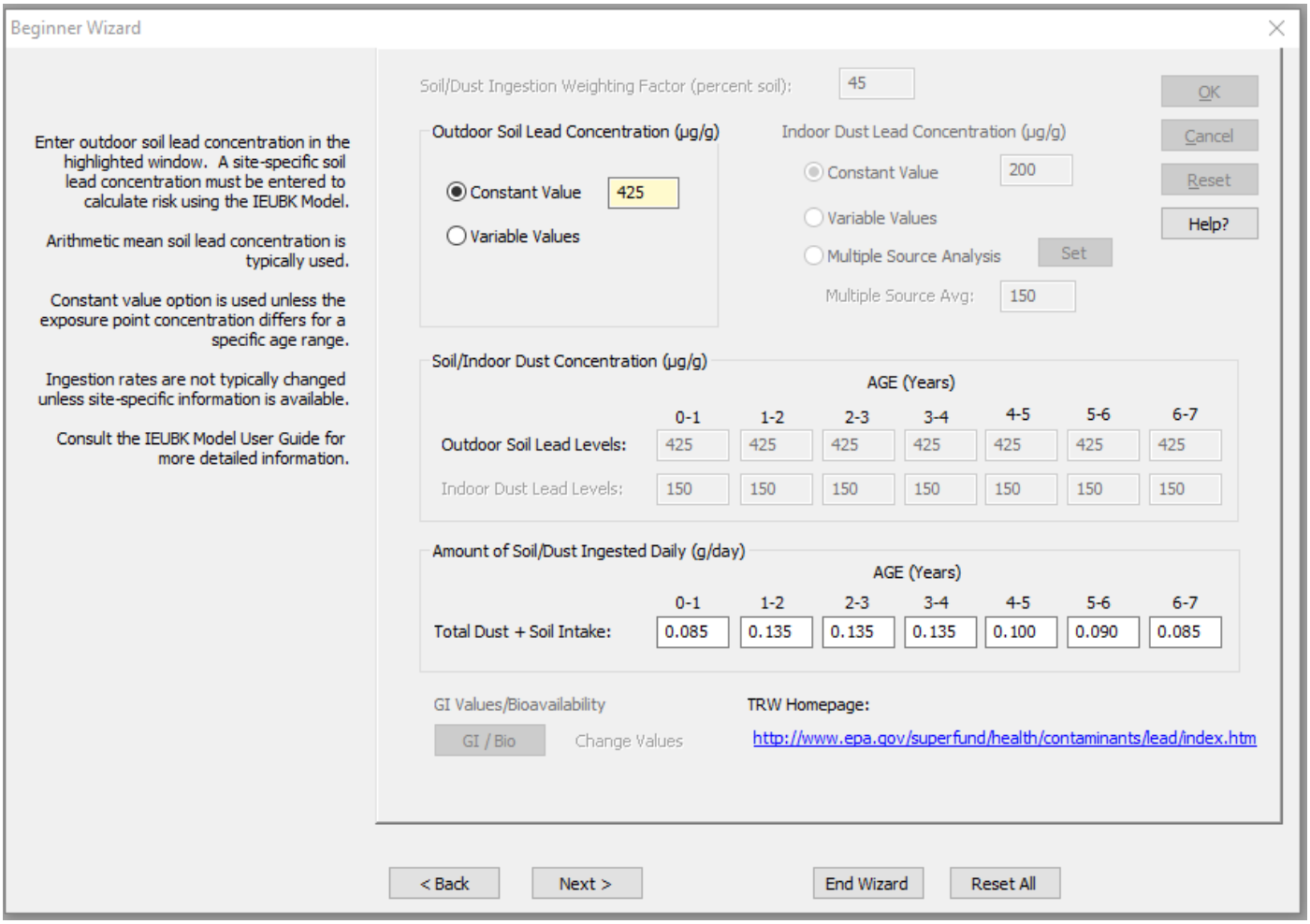


End of Sensitivity Charts

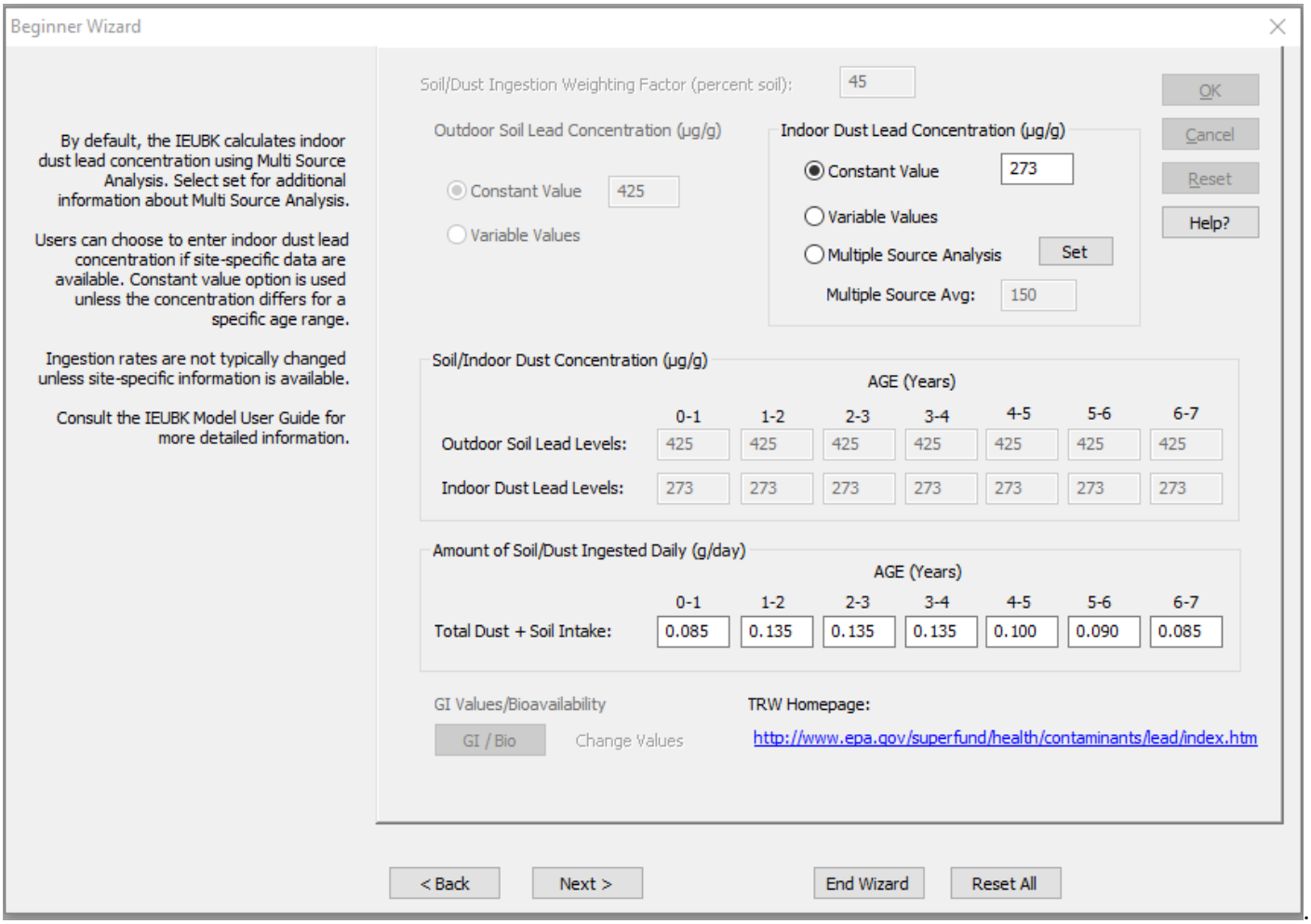
APPENDIX B
IEUBK MODELING

Clifton HHRA IEUBK Model Parameters

Step 1: Update Outdoor Soil Lead Concentration to 425 mg/kg

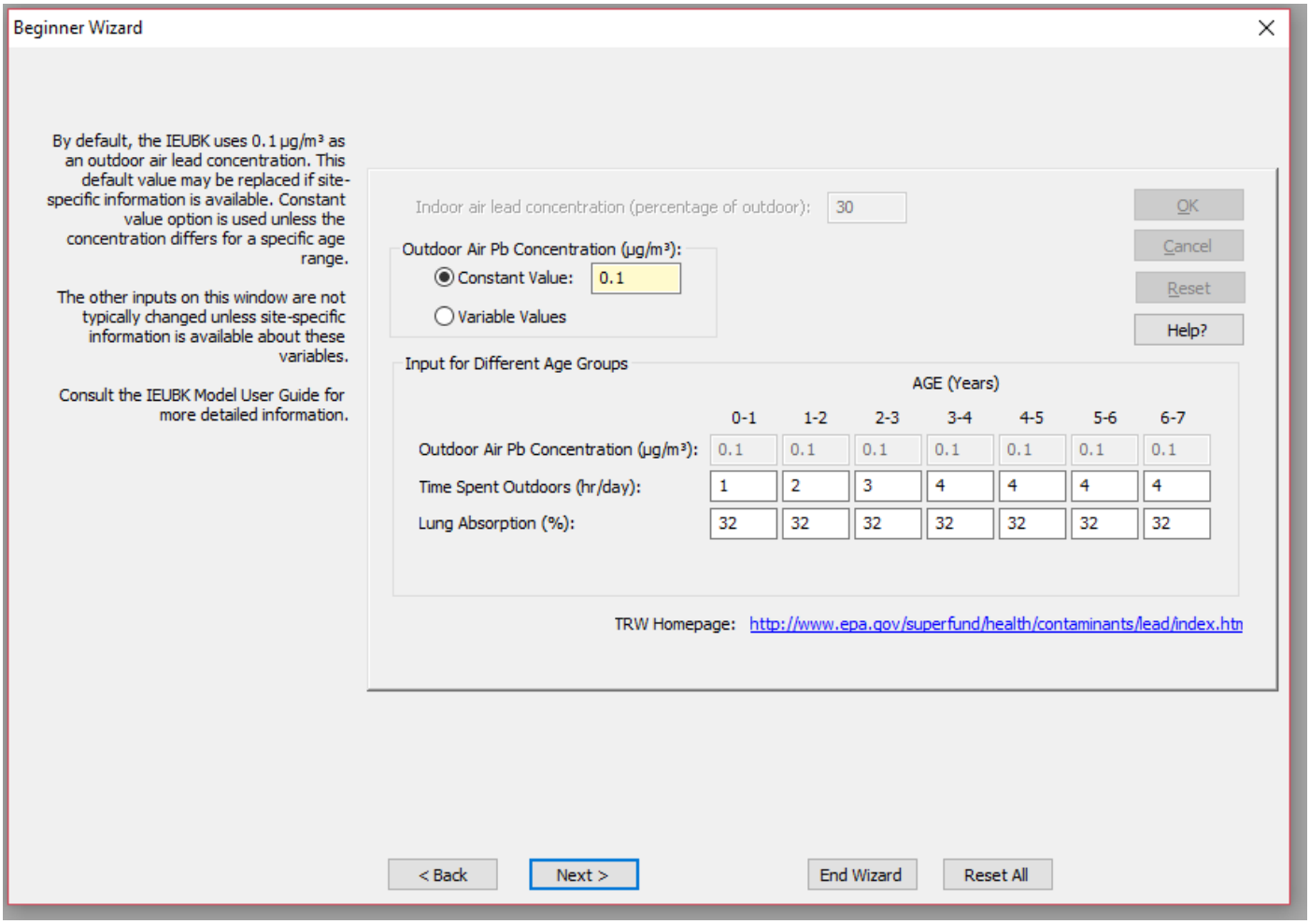


Step 2: Update Indoor Dust Lead Concentration to 273 mg/kg

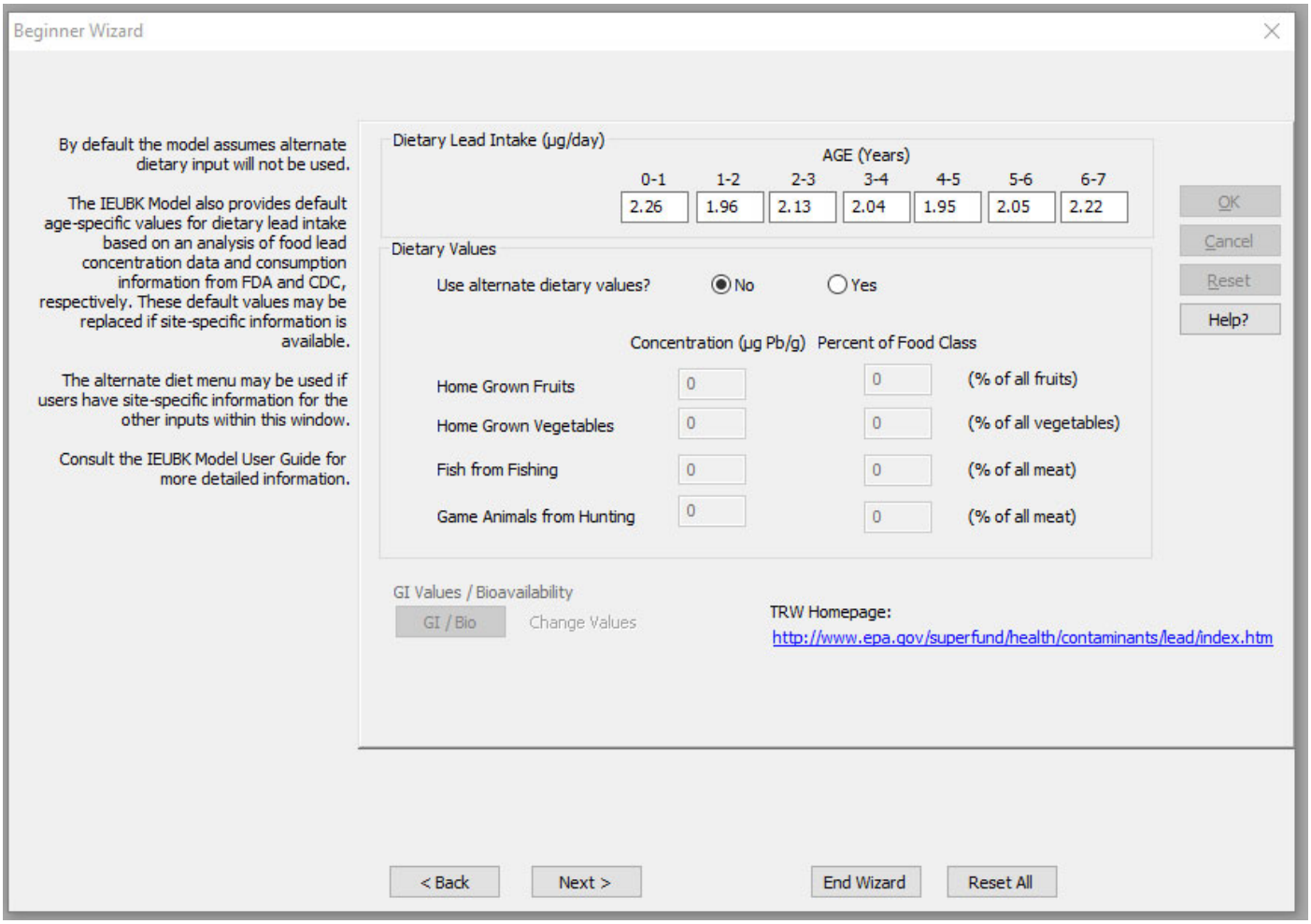


Clifton HHRA IEUBK Model Parameters

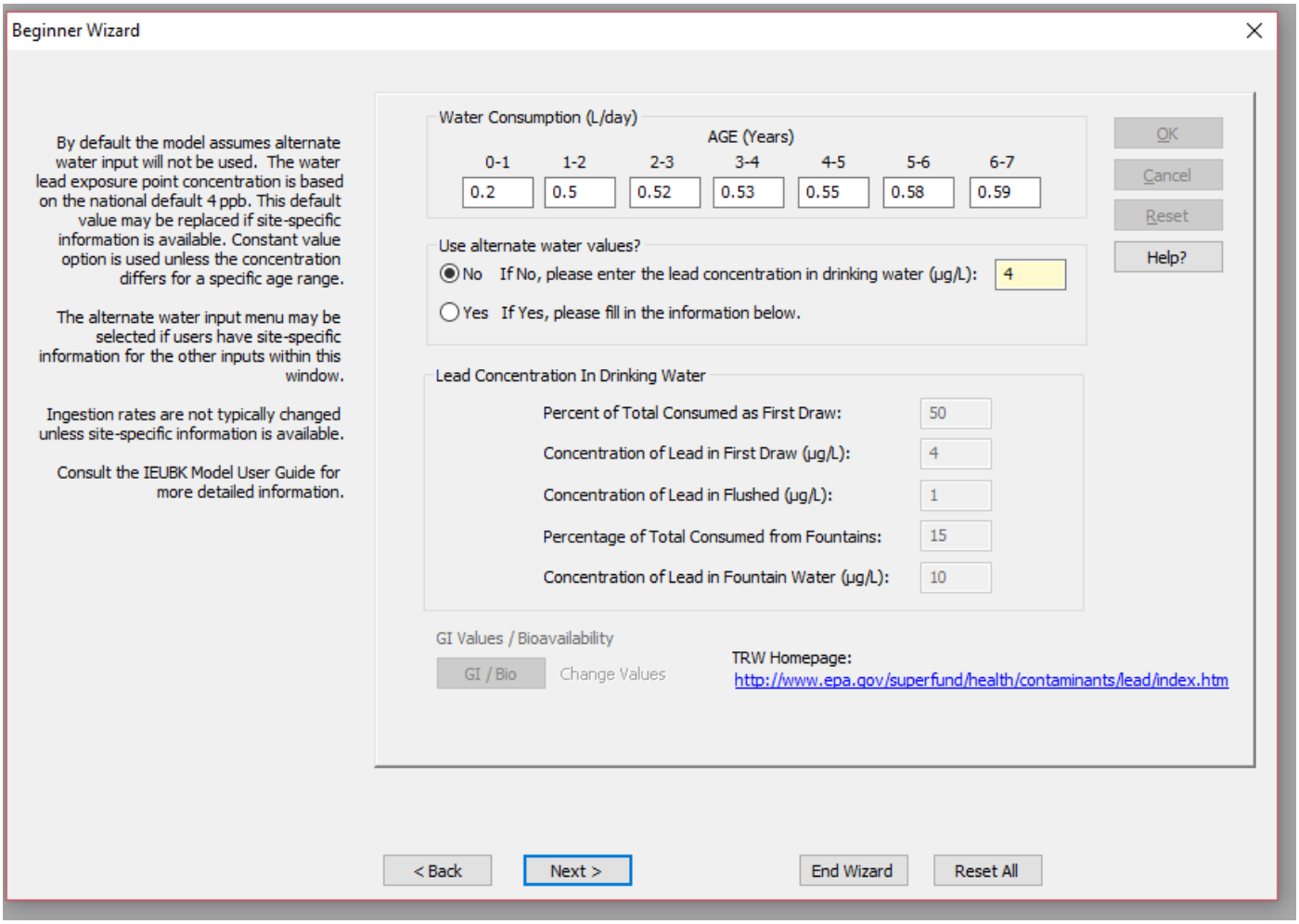
All other values were assumed to be USEPA default values.



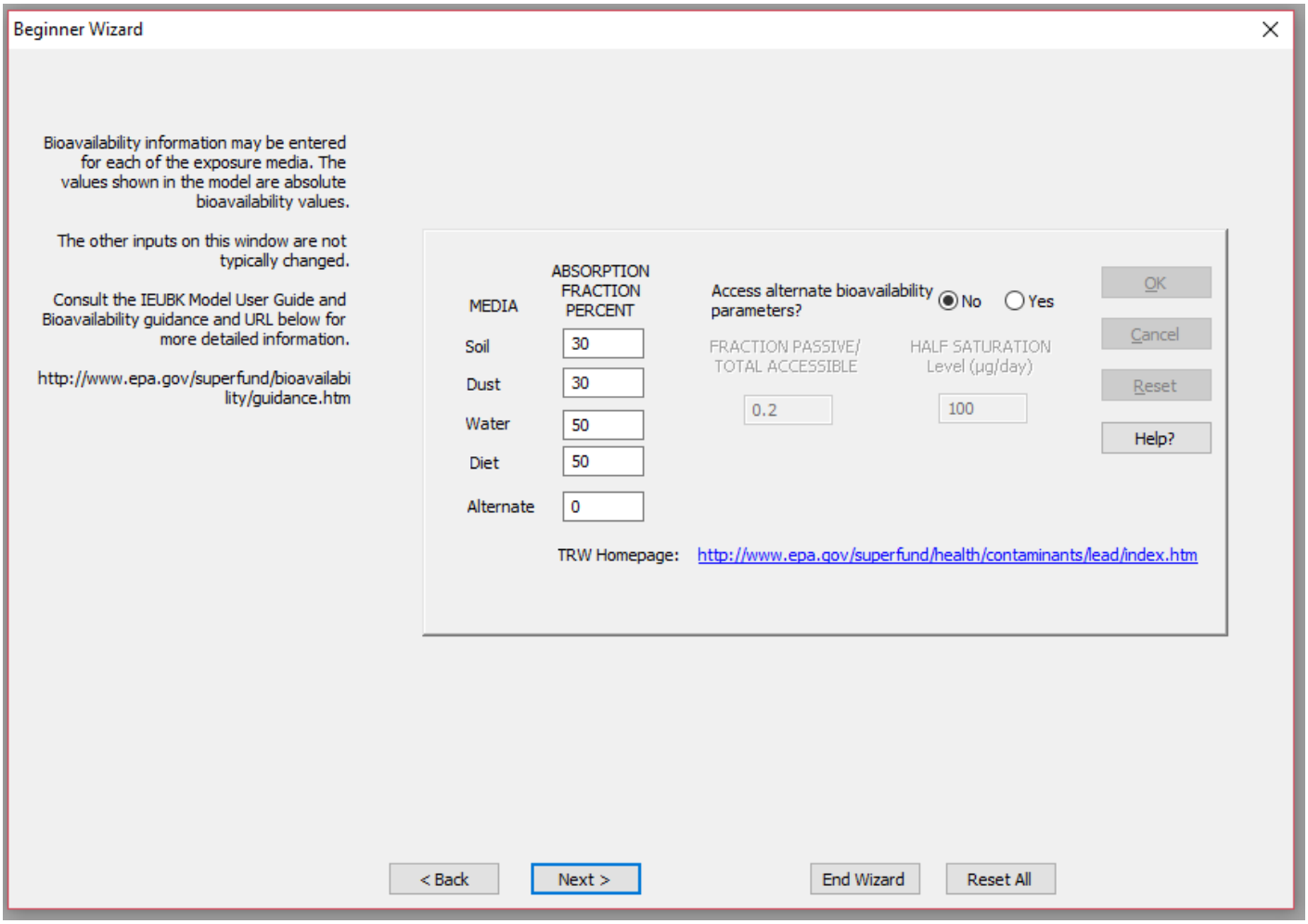
Clifton HHRA IEUBK Model Parameters

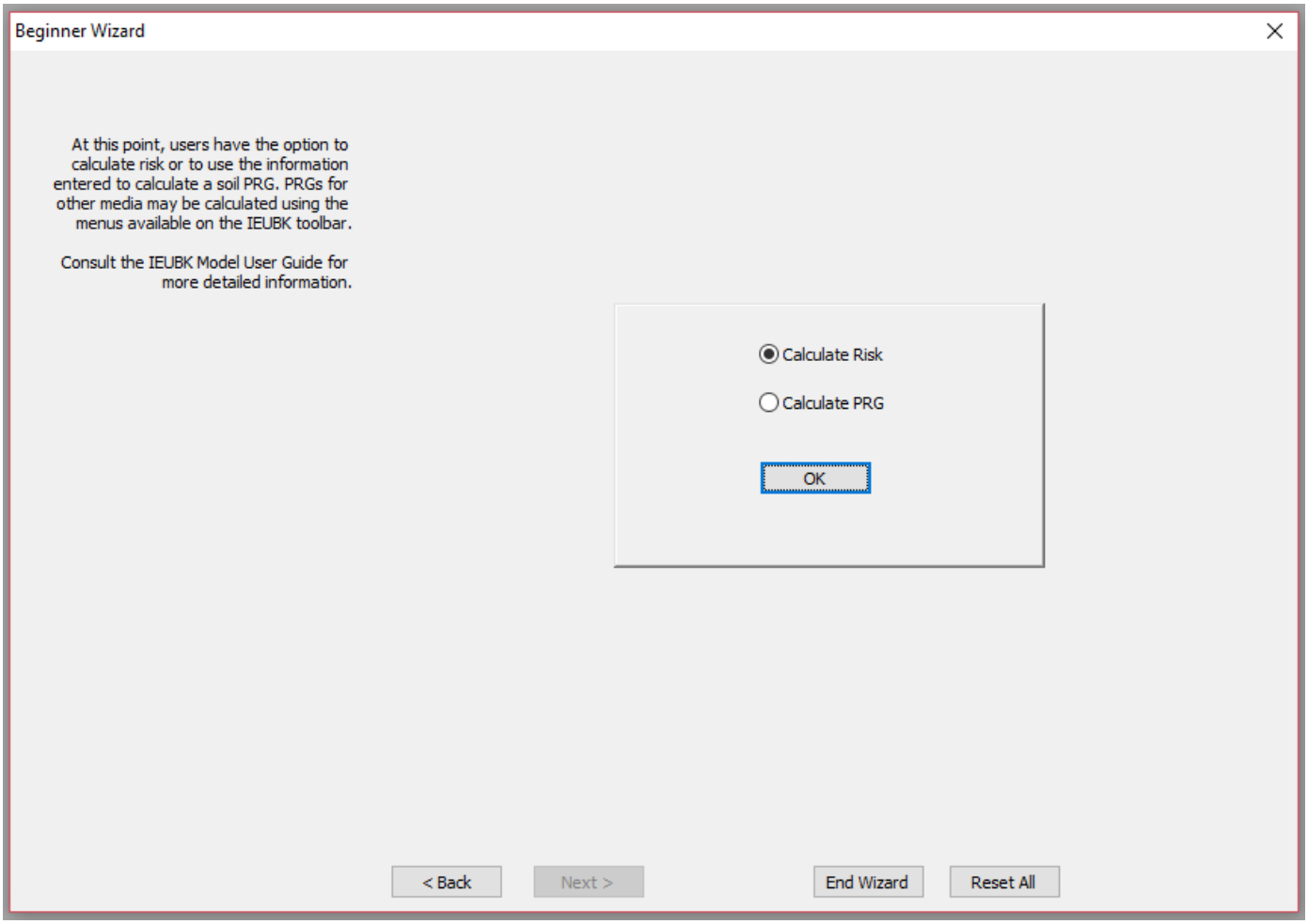


Clifton HHRA IEUBK Model Parameters



Clifton HHRA IEUBK Model Parameters




Beginner Wizard
At this point, users have the option to calculate risk or to use the information entered to calculate a soil PRG. PRGs for other media may be calculated using the menus available on the IEUBK toolbar.
Consult the IEUBK Model User Guide for more detailed information.
Calculate Risk
Calculate PRG
OK
< Back
Next >
End Wizard
Reset All

Clifton IEUBK Model Output and Results

LEAD MODEL FOR WINDOWS Version 2.0

These IEUBK Model results are valid as long as they were produced with an official, unmodified version of the IEUBK Model with a software certificate.

==========

Model Version: 2.0 Build1

User Name:

Date:

Site Name:

Operable Unit:

Run Mode: Research

==========

****** Air ******

Indoor Air Pb Concentration: 30.000 percent of outdoor.

Other Air Parameters:

Age	Time Outdoors (hours)	Ventilation Rate (m^3/day)	Lung Absorption (%)	Outdoor Air Pb Conc (µg Pb/m^3)
6-12	1.000	3.216	32.000	0.100
12-24	2.000	4.970	32.000	0.100
24-36	3.000	6.086	32.000	0.100
36-48	4.000	6.954	32.000	0.100
48-60	4.000	7.682	32.000	0.100
60-72	4.000	8.318	32.000	0.100

72-84	4.000	8.887	32.000	0.100

****** Diet ******

Age	Diet Intake(µg/day)
6-12	2.660
12-24	5.030
24-36	5.210
36-48	5.380
48-60	5.640
60-72	6.040
72-84	5.950

****** Drinking Water ******

Water Consumption:

Age	Water (L/day)
6-12	0.400
12-24	0.430
24-36	0.510
36-48	0.540
48-60	0.570
60-72	0.600
72-84	0.630

Drinking Water Concentration: 0.900 µg Pb/L

Clifton IEUBK Model Output and Results

****** Soil & Dust ******

Age	Soil (µg Pb/g)	House Dust (µg Pb/g)
6-12	425.000	273.000
12-24	425.000	273.000
24-36	425.000	273.000
36-48	425.000	273.000
48-60	425.000	273.000
60-72	425.000	273.000
72-84	425.000	273.000

****** Alternate Intake ******

Age	Alternate (µg Pb/day)
6-12	0.000
12-24	0.000
24-36	0.000
36-48	0.000
48-60	0.000
60-72	0.000
72-84	0.000

****** Maternal Contribution: Infant Model ******

Maternal Blood Concentration: 0.600 µg Pb/dL

****

Clifton IEUBK Model Output and Results

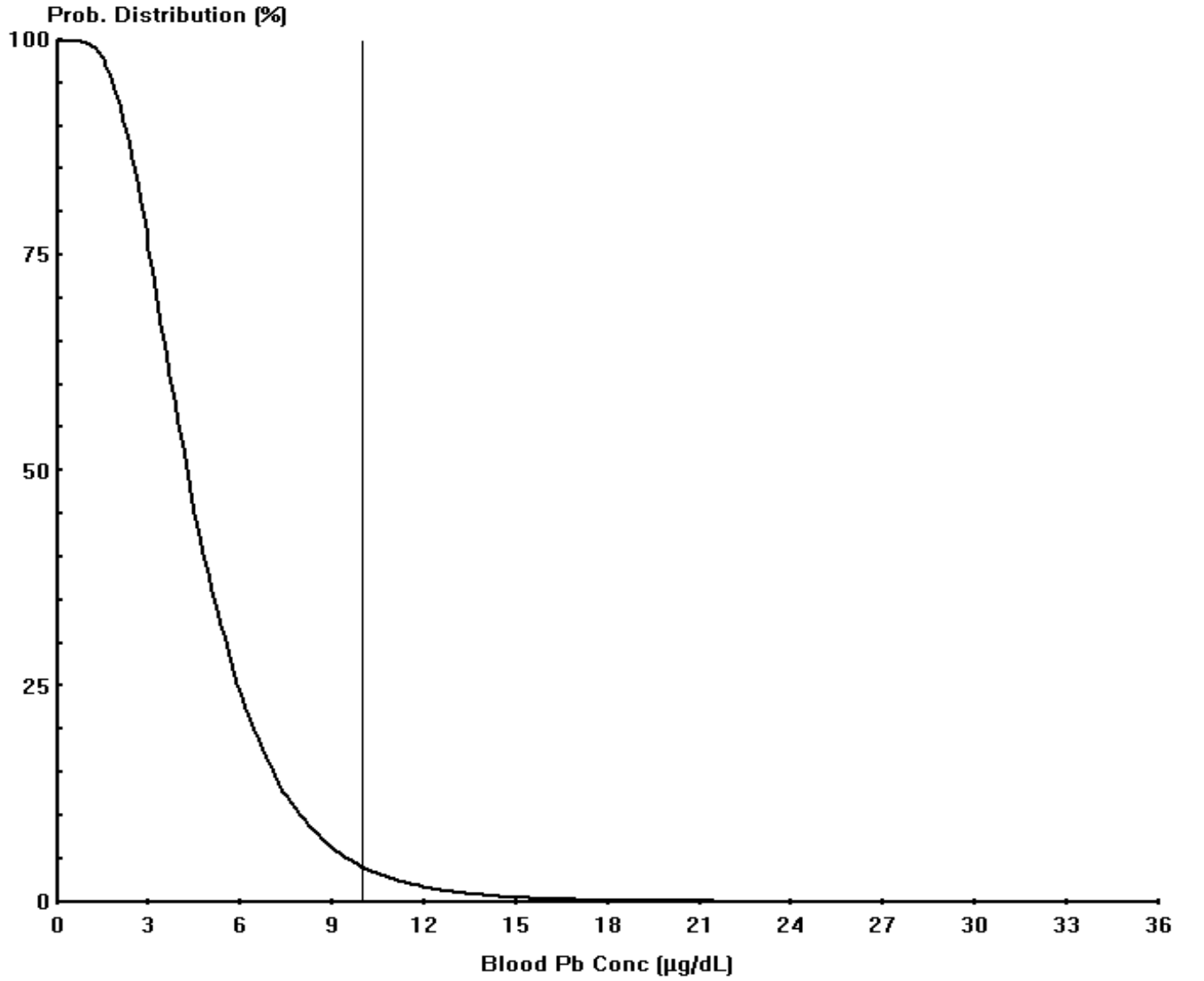
CALCULATED BLOOD LEAD AND LEAD UPTAKES:

****

Year	Air (µg/day)	Diet (µg/day)	Alternate (µg/day)	Water (µg/day)
6-12	0.034	1.196	0.000	0.162
12-24	0.057	2.279	0.000	0.175
24-36	0.075	2.435	0.000	0.214
36-48	0.093	2.542	0.000	0.230
48-60	0.102	2.678	0.000	0.244
60-72	0.111	2.901	0.000	0.259
72-84	0.118	2.864	0.000	0.273

Year	Soil+Dust (µg/day)	Total (µg/day)	Blood (µg/dL)
6-12	7.918	9.309	4.9
12-24	8.723	11.234	4.7
24-36	6.414	9.138	3.6
36-48	6.099	8.963	3.2
48-60	6.516	9.540	3.1
60-72	5.116	8.387	2.7
72-84	5.422	8.678	2.5

Clifton IEUBK Model Output and Results



Cutoff = 10.000 µg/dl
Geo Mean = 4.485
GSD = 1.600
% Above = 4.398

Age Range = 0 to 84 months

Run Mode = Research