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-FINAL-

Site-Wide Human Health Risk Assessment

-EXECUTIVE SUMMARY-

Libby Asbestos Superfund Site
Libby, Montana

November 2015

CDM Smith

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EXECUTIVE SUMMARY

Introduction

Libby is a community in northwestern Montana that is located near a former vermiculite mine (**Figure ES-1**). The vermiculite mine near Libby began limited operations in the 1920s and was operated on a larger scale by the W.R. Grace Company (Grace) from approximately 1963 to 1990. Vermiculite from the mine contains varying concentrations of amphibole asbestos, referred to as "Libby amphibole asbestos" or LA. Epidemiological studies revealed that workers at the mine had an increased risk of developing asbestos-related lung disease (McDonald *et al.* 1986a, 1986b, 2004; Amandus and Wheeler 1987; Amandus *et al.* 1987a,b; Whitehouse 2004; Sullivan 2007). Additionally, radiographic abnormalities were observed in 17.8 percent (%) of the general population of Libby, including former workers, family members of workers, and other residents of Libby and Troy, Montana (Peipins *et al.* 2003; Whitehouse *et al.* 2008; Antao *et al.* 2012; Larson *et al.* 2010, 2012a, 2012b).

In October 2002, the Libby Asbestos Superfund Site (Site) was listed on the U.S. Environmental Protection Agency (EPA) National Priorities List (NPL). The Site includes homes and businesses that may have become contaminated with LA as a result of the vermiculite mining and processing conducted in and around Libby, as well as other areas that may have been affected by mining-related releases of LA. In addition to vermiculite mining and processing activities, LA contamination also occurred as a consequence of use of LA-contaminated vermiculite as building insulation in residential and commercial buildings and as soil amendments (e.g., gardens and flowerbeds), use of LA-contaminated building materials (e.g., mortar, chinking), and other uses.

The purpose of this document is to quantify potential human health risks from exposures to LA at the Site under current and future conditions. This risk assessment differs from other "typical" Superfund risk assessments in that extensive interior and exterior removal actions have been conducted at the Site for more than 10 years, prior to the completion of the risk assessment, to allow for the timely removal of LA contamination while awaiting the necessary exposure and toxicity data needed complete a quantitative assessment of human health risk. Results of this risk assessment are intended to help Site managers determine if past removal actions have been sufficient to mitigate risk, if additional remedial actions are necessary to address risks, and if so, which exposure scenarios would need to be addressed in future remedial actions.

Exposure Assessment

Conceptual Site Model

Historical mining, milling, and processing operations, use of vermiculite in building materials, transport of mining-related materials, tailings, and waste, and runoff from the mine site are known to have released LA to the environment. People may be exposed to LA by two exposure routes: inhalation and ingestion. Of these two exposure routes, inhalation exposure of LA is considered to be of greatest concern.

Asbestos fibers in source materials are typically not inherently hazardous, unless the asbestos is released from the source material into air where it can be inhaled (EPA 2008). Asbestos fibers may become airborne in a number of ways. This may include natural forces, such as wind blowing over a contaminated soil, or human activities that disturb contaminated sources, such as soil or indoor dust.

Figure ES-2 presents the conceptual site model (CSM) that depicts how LA in source media can be transported in the environment to exposure media that humans may encounter at the Site. The two main types of exposure media are indoor air and outdoor air. **Table ES-1** summarizes the inhalation exposure scenarios and populations that will be evaluated in the human health risk assessment (HHRA).

Exposure Parameters

The risk assessment evaluates potential inhalation exposures for several exposure populations, including residents, recreational visitors, teachers/students, and several types of workers (indoor workers, local tradespeople, outdoor workers). Exposure estimates in the risk assessment do not seek to evaluate exposures for specific individuals. Rather, risk estimates are calculated for representative members of the exposure population, calculating risks based on both members of the population with "typical" levels of exposure and members of the population with "high-end" exposures. These two exposure estimates are referred to as central tendency exposure (CTE) and reasonable maximum exposure (RME), respectively.

For each exposure scenario evaluated in the risk assessment, information on estimated exposure time (ET, in hours per day), exposure frequency (EF, in days per year), and exposure duration (ED, in years) is used to derive a lifetime time-weighting factor (TWF) as follows:

$$TWF = (ET/24 \cdot EF/365 \cdot ED/70)$$

The value of the TWF ranges from zero to one, and describes the average fraction of a lifetime during which the specific exposure scenario occurs.

Exposure Point Concentrations

Predicting the LA levels in air based on measured LA levels in source media is extremely difficult. For this reason, EPA recommends an empiric approach for investigating asbestos-contaminated Superfund sites, where concentrations of asbestos in air from source disturbances are measured rather than predicted (EPA 2008). This type of sampling is referred to as activity-based sampling (ABS).

To date, more than two dozen different ABS investigations have been conducted at the Site to evaluate potential exposures to LA from various disturbances of source media. These studies have included a wide range of activities, including, but not limited to, dusting and vacuuming inside residences, raking/mowing/digging in yard soil, riding all-terrain vehicles (ATVs), bicycling and driving on roads, and various worker activities. In total, more than 3,100 ABS air samples have been collected at the Site since 2001. In addition, more than 1,500 outdoor ambient air samples have been collected at the Site.

All ABS and ambient air samples have been analyzed by transmission electron microscopy (TEM). During the analysis, detailed information for each observed asbestos structure (e.g., asbestos type, structure type, length, width) is recorded. For the purposes of computing risk estimates, it is necessary to use the results from the TEM analysis to estimate what would have been detected had the sample been analyzed by phase contrast microscopy (PCM). This is because available toxicity information is based on workplace studies that used PCM as the primary method for analysis. For convenience, structures detected under TEM that meet the recording rules for PCM are referred to as PCM-equivalent (PCME) structures. TEM analysis results for air samples are expressed as PCME LA structures per cubic centimeter of air (s/cc).

In accordance with EPA asbestos risk assessment guidance (EPA 2008), exposure point concentrations (EPCs) for each exposure scenario are calculated as the sample mean, evaluating non-detect samples at a concentration value of zero. In cases where air filters required the use of indirect preparation techniques prior to TEM analysis, the reported PCME LA air concentration was adjusted (decreased) by a factor of 2.5 to avoid potentially biasing calculated EPCs high due to the effect of indirect preparation.

Toxicity Assessment

The adverse effects of asbestos exposure in humans have been the subject of a large number of studies and publications. Exposure to asbestos may induce several types of both non-cancer and cancer effects. A detailed summary of the cancer and non-cancer effects of asbestos is provided in the Agency for Toxic Substances and Disease Registry (ATSDR) *Toxicological Profile for Asbestos* (ATSDR 2001) and in EPA's *Airborne Asbestos Health Assessment Update* (EPA 1986). A detailed summary of effects related specifically to LA is provided in the *Toxicological Review for Libby Amphibole Asbestos* (EPA 2014).

Cancer Effects

Many epidemiological studies have reported increased mortality from cancer in workers exposed to asbestos, especially from lung cancer and mesothelioma (tumor of the thin membrane that covers and protects the internal organs of the body). In addition, a number of studies suggest asbestos exposure may increase risk of cancer of the larynx (commonly called the voice box) and ovarian cancer (IARC, 2012). Based on these findings, and supported by extensive data from animal studies, EPA has classified asbestos as a known human carcinogen.

Cancer risk from inhalation exposure is determined based on an inhalation unit risk (IUR) value, which is defined as the excess lifetime cancer risk estimated to result from continuous exposure to one asbestos fiber per cubic centimeter of air (1 f/cc). The LA-specific IUR, referred to as IUR_{LA}, is derived from a group of workers employed at the vermiculite mining and milling operation in and around Libby, referred to as the "Libby worker cohort". The IUR_{LA} is 0.17 $(PCM\ f/cc)^{-1}$ (EPA 2014).

Non-Cancer Effects

Non-cancer effects from asbestos exposure include asbestosis (formation of scar tissue in the lung parenchyma) and several types of abnormalities in the pleura (the membrane surrounding the lungs), such as pleural effusions (excess fluid accumulation in the pleural space), pleural plaques (collagen deposits and calcification), and pleural thickening.

Non-cancer hazard from inhalation exposure is determined based on a reference concentration (RfC) value. The RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure that is likely to be without an appreciable risk of deleterious effects in humans (including sensitive subgroups) during a lifetime (EPA 2009). The LA-specific RfC, referred to as RfC_{LA}, is derived from a group of workers employed at the O.M. Scott Plant in Marysville, Ohio. This plant utilized vermiculite that originated from the mine in Libby from 1959 to 1980 in their lawn care products. Localized pleural thickening was selected as the critical effect endpoint for the derivation of the RfC_{LA}. The RfC_{LA} is 0.00009 PCM f/cc (EPA 2014).

Risk Characterization

Basic Equations

The basic equation used to estimate excess lifetime cancer risk from inhalation of LA is:

$$Risk = EPC \cdot TWF \cdot IUR_{LA}$$

where:

Risk = Lifetime excess risk of developing cancer (lung cancer or mesothelioma) as a consequence of LA exposure.

EPC = Exposure point concentration of LA in air (PCME LA s/cc). The EPC is an estimate of the long-term average concentration of LA in inhaled air for the specific activity being assessed.

TWF = Time-weighting factor for the specific activity being assessed.

IUR_{LA} = LA-specific inhalation unit risk $(0.17 \text{ PCM s/cc})^{-1}$

The basic equation used for characterizing non-cancer hazards from inhalation exposures to LA is as follows:

$$HQ = EPC \cdot TWF / RfC_{LA}$$

where:

HQ = Hazard quotient for non-cancer effects from LA exposure

EPC = Exposure point concentration of LA in air (PCME LA s/cc)

TWF = Time-weighting factor

RfC_{LA} = LA-specific reference concentration (0.00009 PCM s/cc)

Risk Interpretation

In general, EPA considers cumulative excess cancer risks[1] that are less than 1E-06 to be negligible, and risks greater than 1E-04 to be sufficiently large that some form of remedial action is desirable. Excess cancer risks that range between 1E-04 and 1E-06 are generally considered to be acceptable, although this is evaluated on a case-by-case basis, and EPA may determine that risks lower than 1E-04 are not sufficiently protective and warrant remedial action.

For non-cancer, if the cumulative HQ (referred to as the hazard index [HI]) is less than or equal to 1, then remedial action is generally not warranted. If the HI exceeds 1, there is some possibility that non-cancer effects may occur, although an HI greater than 1 does not indicate an effect will definitely occur. However, the larger the HI value, the more likely it is that an adverse effect may occur.

1 Note that excess cancer risk can be expressed in several formats. A cancer risk expressed in a scientific notation format as 1E-06 is equivalent to 1 in 1,000,000 (one in a million) or 1×10^{-6}. Similarly, a cancer risk of 1E-04 is equivalent to 1 in 10,000 (one in ten thousand) or 1×10^{-4}.

Scenario-Specific Risk Characterization

Risks from Exposures to Ambient Air

In the past (circa 1970s), ambient air concentrations as high as 1.5 PCM f/cc were measured in downtown Libby when the mine was in operation. Beginning in 2006, there have been several long-term outdoor ambient air monitoring studies conducted in Libby, Troy, and at the mine site. These data show that average ambient air concentrations in the Libby community and in Troy are less than 0.00001 PCME LA s/cc under current conditions. Current ambient air concentrations at the Site are greatly improved relative to historical conditions and are consistent with asbestos levels that have been measured in ambient air in Eureka and Helena, Montana, as well as across the country (SRC, Inc. 2013).

Data from the recent ambient air monitoring studies at the Site were used to calculate EPCs for use in evaluating potential exposures to LA in ambient air. All individuals at the Site have the potential to be exposed to LA in ambient air. However, for simplicity, risk estimates from exposures to ambient air were calculated for each exposure area based on the maximally-exposed receptor (e.g., residential exposure scenario in Libby). RME cancer risks are less than or equal to 1E-06 and non-cancer HQs are less than 0.1 for all Site exposure locations; CTE cancer risks and non-cancer HQs are even lower. These results indicate that exposures to LA in ambient air are not likely to be of concern to individuals at the Site and are not likely to contribute significantly to cumulative risks.

Risks from Exposures During Soil/Duff Disturbances

Overview

Potential exposures to LA during disturbances of soil/duff can occur for a wide range of receptor types and exposure scenarios. More than 80 different types of exposures during soil/duff disturbances were evaluated, encompassing multiple disturbance activities, exposure populations, exposure locations, and LA concentrations. In reviewing the risk estimates for exposures during soil/duff disturbance activities, there are a number of general conclusions that can be drawn:

- Estimated cancer risks and non-cancer HQs span more than four orders of magnitude depending upon the exposure scenario.
- For a given exposure scenario, non-cancer HQs can exceed 1 even when cancer risks are less than 1E-04, which indicates that non-cancer exposure is a more sensitive metric of potential concern. (For LA, a non-cancer HQ of 1 is approximately equivalent to a cancer risk of 1E-05.)
- There were only a few soil/duff disturbance exposure scenarios where risks from the exposure scenario alone had the potential to be above a level of concern based on RME, including residential and outdoor worker exposures during disturbances of yard soils with detected LA at properties in Libby and Troy, outdoor worker exposures during disturbances of subsurface soils with LA contamination at properties in Libby and Troy, and rockhound exposures in the disturbed area of the mine.
- Quantitative risks were not calculated for potential exposures to workers exposed to residual LA in subsurface soils in the former Screening Plant and Export Plant areas; however, these exposure scenarios could result in potentially unacceptable exposures and risks because LA concentrations greater than 1% are present in subsurface soil beneath the cover fill in some areas.

- Exposure to LA in outdoor air during yard soil disturbances has the potential to be an important exposure scenario. Even when only trace levels of LA are present in the soil, this exposure scenario, when considered alone, could yield non-cancer HQs greater than 1, depending upon the spatial extent of the LA in soil and the frequency and intensity that these soils are disturbed.

Extrapolation to Properties without ABS

As noted above, exposure to LA in outdoor air during yard soil disturbances has the potential to be an important exposure scenario. There are more than 5,000 residential/commercial properties in Libby and Troy. Because it is not feasible to evaluate risks by conducting outdoor ABS at every property, it is necessary to use the measured ABS data from the properties where ABS has been performed to draw risk conclusions about properties where ABS has not been performed. This is accomplished by assuming that properties without ABS data, but having the same LA soil level and similar disturbance activities, will have similar outdoor air concentrations as properties with ABS data.

Table ES-2 presents estimated RME cancer risks and non-cancer HQs from exposures to LA during soil disturbances for a range of LA soil levels at residential properties in Libby and Troy. In interpreting these risk estimates, it is important to understand that these calculations are intended to represent a given LA soil concentration. However, a specified exposure area for a property may have varying LA soil concentrations with differing spatial extents. The evaluation of risk at a property is based on the average exposure across the entire exposure area. Thus, for exposure areas that encompass varying soil concentrations, it is necessary to derive a spatially-weighted average risk estimate for the entire exposure area. **Figure ES-3** presents a simplified example of this approach.

Background LA Concentrations in Soil

EPA has conducted several investigations at the Site to characterize LA in soil from areas that are thought to be representative of "background" conditions, meaning that the soils are not expected to be affected by anthropogenic releases from vermiculite mining and processing activities. LA structures have been consistently detected in background soils within the Kootenai Valley. However, potential exposures and risks from LA in background soil are likely to be low.

Risks from Exposures to Indoor Air

There are a wide range of different activities that could occur inside buildings (residences, businesses, schools, etc.) at the Site that could result in exposures to LA. There have been several indoor ABS investigations to evaluate LA concentrations in air during various indoor disturbance scenarios, including indoor exposures inside residences, schools, and commercial and industrial buildings in Libby and Troy. In general, ABS air samples were collected under two representative conditions – active and passive behaviors. Active behaviors include indoor activities in which a person is moving about the building and potentially disturbing indoor sources; such activities have included walking from room to room, sitting down on upholstered chairs, sweeping, and vacuuming. Passive behaviors are minimally energetic actions, such as sitting and reading a book, watching television, and working at a desk, that will have low tendency to disturb any indoor source materials. In addition, air samples were also collected to evaluate potential exposures to local tradespeople (e.g., carpenter, electrician, plumber) from high intensity disturbances of vermiculite insulation (VI) or other asbestos-containing building materials.

With the exception of indoor exposures at properties under "pre-removal" conditions and during tradesperson activities (discussed below), estimated RME cancer risks were less than 1E-04 and non-cancer HQs were less than 1 for all indoor exposure scenarios.

Estimated RME non-cancer HQs were greater than 1 for both residential exposures and indoor worker exposures to LA inside "pre-removal" properties (these are properties where an interior removal has been deemed necessary, but a removal had not been completed at the time of the ABS). Activities associated with active disturbance behaviors contributed most to total exposures. Non-cancer HQs were less than 1 for properties where an interior removal has been completed ("post-removal") and for properties where an interior removal was deemed not to be necessary ("no removal required"). These results demonstrate that interior investigations and removals have been effective at identifying and mitigating sources of LA inside properties.

Exposures of local tradespeople to LA while working inside buildings have the potential to result in RME cancer risks greater than or equal to 1E-04 and non-cancer HQs greater than 1 for all the activities investigated, which included active disturbances of VI (e.g., wall demolition, attic detailing, cleaning living space areas with visible VI). These results indicate that local tradesperson exposures have the potential to be significant and result in risks above a level of concern if appropriate personal protective measures are not employed to mitigate exposures during active disturbances of indoor source materials. There is the potential for tradesperson exposures to occur, even for properties that have had an interior removal or where no interior removal has been deemed necessary, if source materials have been left in place (e.g., VI contained within walls).

Risks from Exposures during Disturbances of Wood-Related Materials

Extensive data have been collected in the forested area near the mine site (CDM Smith 2015) and in the forested area near the current Site NPL boundary (CDM Smith 2013). These data show that LA structures are present on the outer bark surface of trees at the Site. If LA-containing trees or wood-related materials (e.g., woodchips, mulch) are disturbed, people may be exposed to LA that is released to air from the wood. If LA-containing trees are used as a source of firewood (e.g., in a residential woodstove), studies have shown that LA fibers can become concentrated in the resulting ash (Ward *et al.* 2009; EPA 2012), which itself can become a source of potential LA exposure.

A number of ABS studies have been performed at the Site to provide measured data on LA concentrations in air during a variety of disturbances of wood-related materials, including ABS studies during residential wood harvesting activities, commercial logging activities, wood chipping activities, forest maintenance activities, woodchip/mulch disturbance activities, and woodstove ash disturbance activities. With the exception of activities related to commercial logging and the removal of ash from a woodstove (discussed below), estimated RME cancer risks were less than 1E-04 and non-cancer HQs were less than 1 for all wood-related exposure scenarios.

When commercial logging activities were conducted in an area located near the mine with higher concentrations of LA in tree bark and duff, estimated RME cancer risks for all commercial logging activities were less than 1E-04, but non-cancer HQs were greater than or equal to 1 during timber skidding and site restoration activities. However, when commercial logging activities were conducted in an area further from the mine, where concentrations of LA in tree bark and duff were lower, estimated RME cancer risks were less than 1E-04 and non-cancer HQs were less than 1 for all commercial logging activities.

Estimated RME non-cancer HQs for activities associated with the removal of ash from a woodstove differed depending on the source of the firewood that was burned. The estimated HQ was greater than 1 when firewood was collected from a location near the mine (where tree bark LA levels are highest), but HQs were less than 1 when firewood was collected from a location intermediate or far from the mine. RME cancer risks from exposure to LA in woodstove ash were less than 1E-04 regardless of the wood source. These risk estimates demonstrate that exposures to LA in woodstove ash may be an important contributor to cumulative exposures, if the ash is derived from a wood source in close proximity to the mine.

Risks from Exposures during Fire-Related Activities

ABS studies have been performed at the Site to provide measured data on LA concentrations in air during fire-related activities to provide information on potential exposures to fire fighters during an understory burn and to forest workers during a slash pile burn. Estimated RME cancer risks were less than 1E-04, but non-cancer HQs were greater than or equal to 1 for several fire-related exposure scenarios. The RME non-cancer HQs were greater than 1 during slash pile building activities and were greater than or equal to 1 during mop-up activities for the understory burn (when mop-up activities were conducted by hand) for both “wet” and “dry” mop-up scenarios. These risk estimates demonstrate that fire-related exposures have the potential to be significant near the mine if appropriate personal protective measures are not employed to mitigate exposures.

Cumulative Risk Characterization

Basic Approach

The calculation of cumulative risks is complicated by the fact that the exposure pattern of each individual at the Site may be unique. However, EPA does not typically perform risk calculations for specific individuals, but rather for generic classes of receptor populations with common exposure patterns. Thus, the goal of the cumulative risk assessment is to illustrate how risk depends on different types of disturbance activities, LA levels in the source media, and exposure locations.

Cumulative risk from asbestos is expressed as the sum of all the cancer risks or non-cancer HQs from various types of asbestos exposure scenarios. Exposure-specific TWF values for use in the cumulative assessment were selected by specifying the fraction of the lifetime spent engaging in each exposure scenario, taking care to ensure that the cumulative TWF is equal to 1.0. This approach is illustrated in **Figure ES-4**.

Cumulative Risk Examples

There are essentially an infinite number of possible exposure scenario combinations that could be evaluated in the cumulative risk assessment for the Site. The choice of which combinations to evaluate is a matter of judgment. For the purposes of this risk assessment, several alternate cumulative exposure scenario combinations were evaluated, representing a wide range of potential cumulative risks. These examples help to identify which exposure scenarios that tend to have the largest contribution to cumulative risk.

Figure ES-5 presents a graphical illustration of the cumulative assessment for one example receptor scenario. In this figure, the upper panel illustrates the fraction of time that each exposure scenario contributes to the total lifetime (i.e., a 70-year lifetime). The lower panel illustrates the contribution of each exposure scenario to the cumulative HI. The table below the figures provides a tabular presentation of the information shown in the two figures. (Note: This figure only presents cumulative HIs as the non-cancer endpoint appears to be the more sensitive metric of potential risk.)

In reviewing the cumulative exposure scenarios, several general observations can be made:

- Cumulative HI estimates were less than 1 when exposures occurred at properties and locations with lower levels of LA. However, cumulative HI estimates were greater than 1 when exposures occurred at properties and locations with higher levels of LA.

- Exposure scenarios that contributed the most time to the total lifetime exposure do not necessarily contribute most to the cumulative HI. In some cases, exposure scenarios that contribute little to the total lifetime exposure time can contribute significantly to the cumulative HI. For example, in **Figure ES-5**, exposures to LA in outdoor air during disturbances of yard soil (exposure scenario "D") contributes about 3% to the total lifetime exposure time, but about 14% to the cumulative HI.

- When cumulative exposure includes exposure scenarios that actively disturb LA-contaminated source materials (e.g., hiking along lower Rainy Creek near the mine, riding ATVs in the disturbed areas of the mine, disturbing yard soils with detected LA, performing timber skidding operations near the mine site, or disturbing VI during tradesperson activities), these pathways are important risk drivers for cumulative HI estimates.

- It is possible to reduce cumulative exposures and risks, without altering activity behavior patterns, by lowering LA levels in source media where disturbance activities are performed (e.g., removing yard soil with LA) (see **Figure ES-6**) and/or by changing the locations where the activities are performed (e.g., collecting firewood or performing logging in areas further from the mine site) (see **Figure ES-7**).

- As illustrated in **Figure ES-8**, it is not necessary to address every single exposure scenario to significantly lower cumulative risk. Addressing exposures for a small subset of the potential exposure scenarios, focusing on risk drivers, will have the greatest impact in lowering cumulative exposures and risks.

- It is possible for individual exposure scenario HQs to be less than 1, but the cumulative HI across all exposure scenarios to be greater than 1. Thus, risk managers should consider both cumulative risks and individual exposure scenario risks to identify potential risk drivers to guide decisions on future remedial levels and/or institutional controls.

Uncertainty Assessment

As with all HHRAs, uncertainties exist due to limitations in the exposure and toxicity assessments and our ability to accurately determine cumulative exposure and risk from multiple sources over a lifetime. This risk assessment has used the best available science to evaluate potential human health exposures and risks from LA at the Site; however, there are number of sources of uncertainty that affect the risk estimates that must be considered when making risk management decisions. The most important of these uncertainties are listed below.

- Uncertainty in true long-term average LA concentrations in air

- Uncertainty in the EPC due to non-detects

- Uncertainty due to air filter preparation methods

- Uncertainty due to analytical methods

- Uncertainty due to field collection methods
- Uncertainty in human exposure patterns
- Uncertainty in toxicity values used in risk characterization
- Uncertainty in the cumulative risk estimates

Because of these uncertainties, the cancer risks and non-cancer HQs for individual exposure scenarios are uncertain, and consequently all estimates of cumulative cancer risks and non-cancer HI values presented in this HHRA are also uncertain, and should be considered to be approximate. Actual risks may be either higher or lower than estimated.

Executive Summary References

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TABLES AND FIGURES

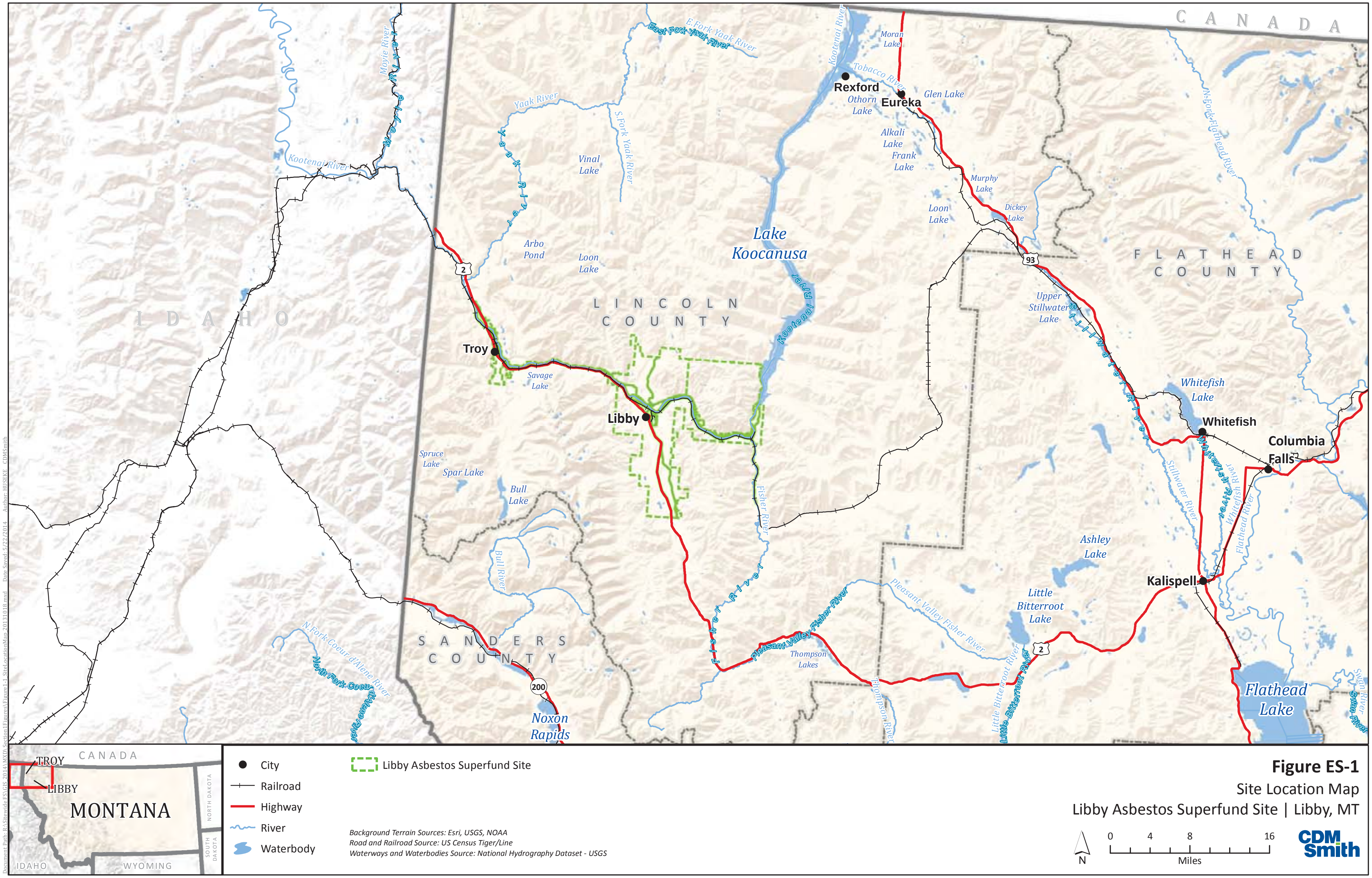


Figure ES-1
Site Location Map
Libby Asbestos Superfund Site | Libby, MT

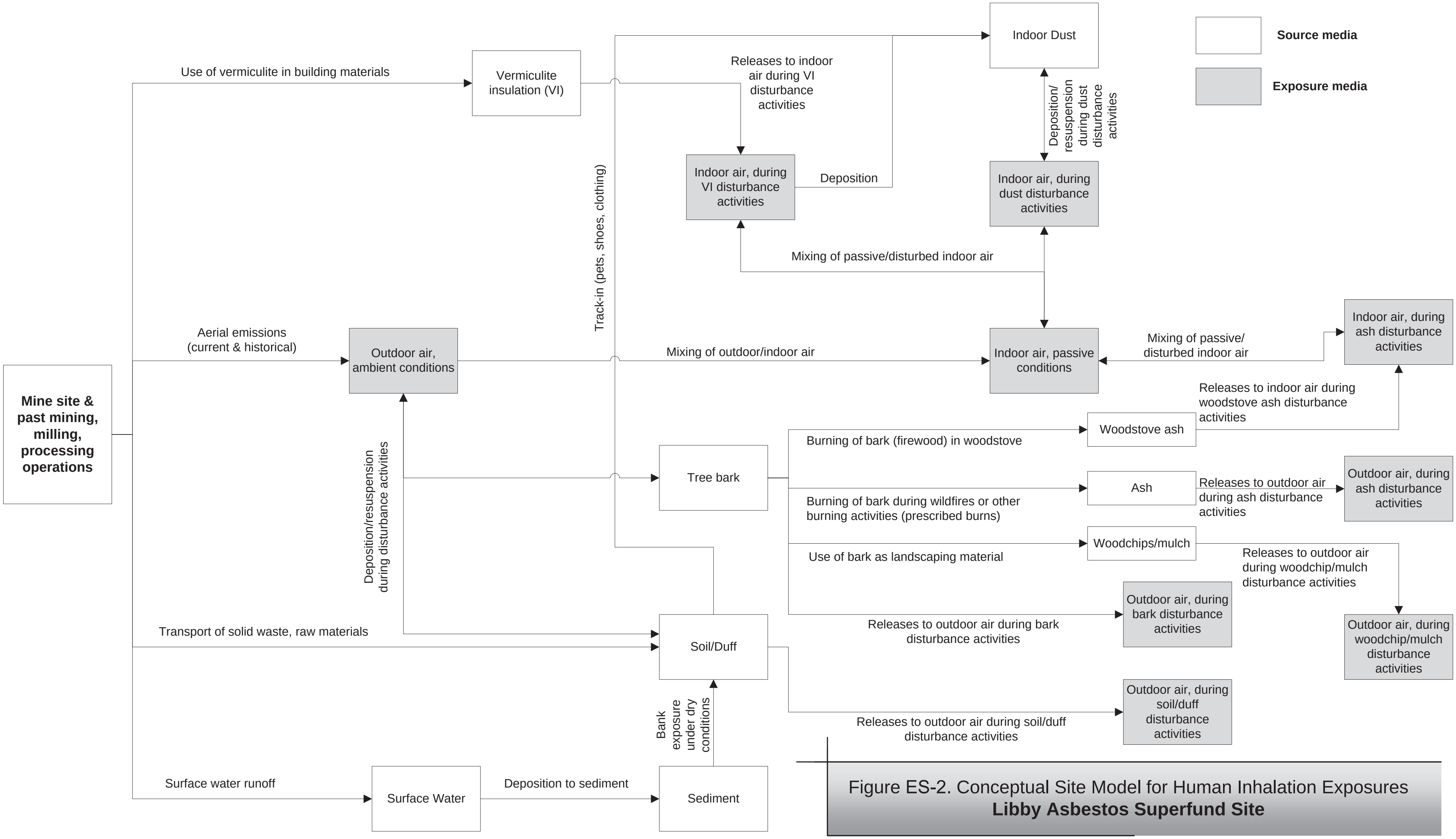


Figure ES-2. Conceptual Site Model for Human Inhalation Exposures
Libby Asbestos Superfund Site

FIGURE ES-3
Example of Exposure Area Spatial-Weighting Approach

Panel A: Exposure Area Soil Concentrations

Soil Sample #1: **Non-detect**	
Soil Sample #2: **Trace (<0.2%)**	Soil Sample #3: **1%**

Panel B: Estimated HQs* for Each Subarea

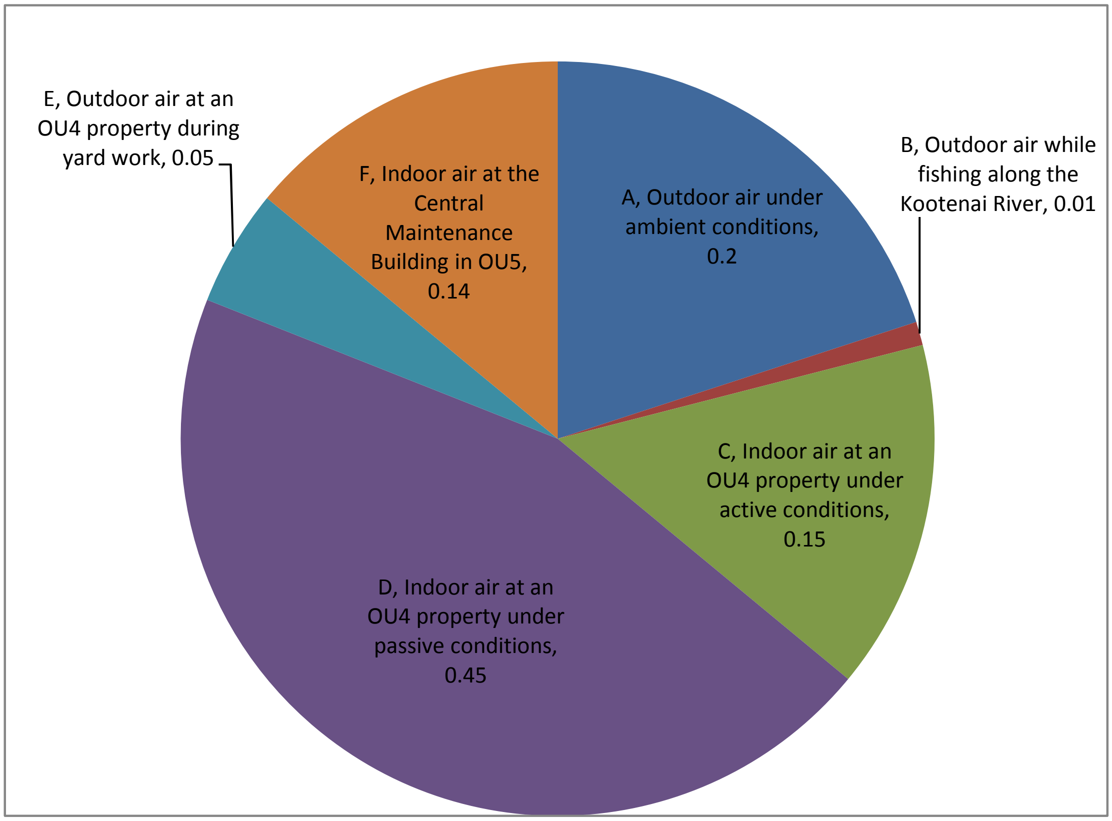
Non-detect Soil Concentration HQ = 0.1	
Trace (<0.2%) Soil Concentration HQ = 2	**1%** Soil Concentration HQ = 7

Panel C: Estimated Average HQ for the Entire Exposure Area

Exposure Area HQ = (0.1 · 0.5) + (2 · 0.25) + (7 · 0.25) = **2**

*Based on Libby Yard Soil Disturbance Residential HQs (see **Table ES-2**)
HQ = hazard quotient

FIGURE ES-4. ILLUSTRATION OF CUMULATIVE ASSESSMENT TWF APPROACH



Exposure Scenario		TWF	% of total
A	Outdoor air under ambient conditions	0.20	20%
B	Outdoor air while fishing along the Kootenai River	0.03	3%
C	Indoor air at an OU4 property under active conditions	0.15	15%
D	Indoor air at an OU4 property under passive conditions	0.48	48%
E	Outdoor air at an OU4 property during yard work	0.03	3%
F	Indoor air at the Central Maintenance Building in OU5	0.11	11%
	cumulative:	**1.00**	

Notes:

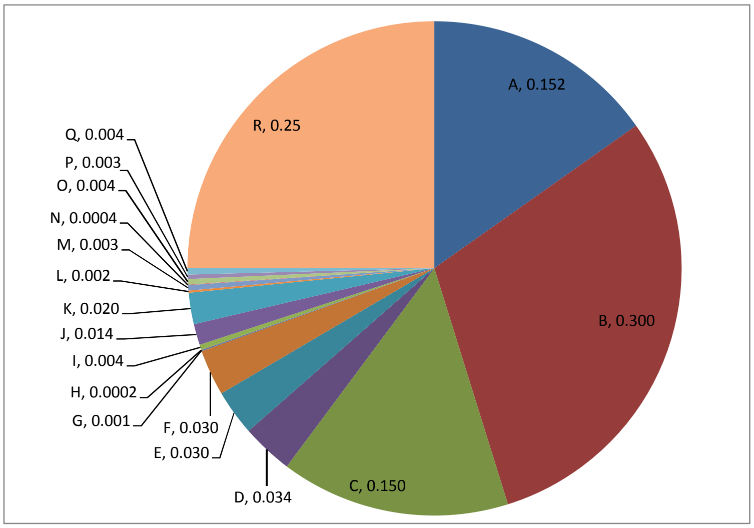
% - percent

OU - Operable Unit

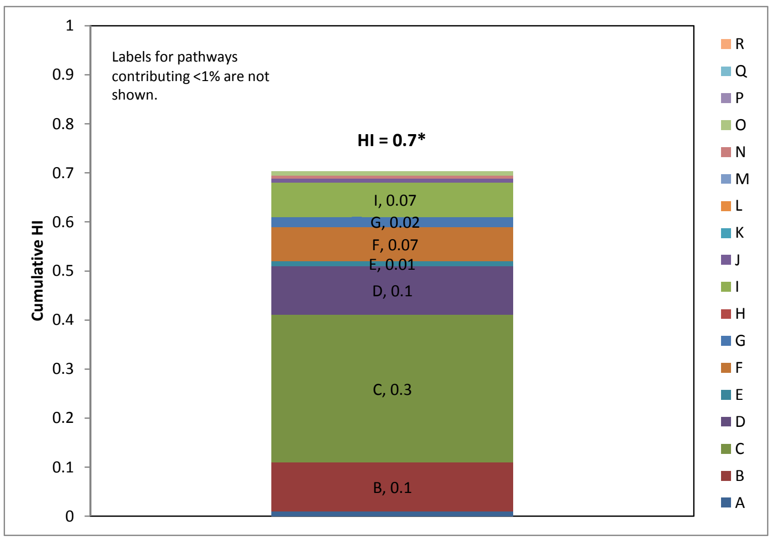
TWF - time-weighting factor

FIGURE ES-5. CUMULATIVE ASSESSMENT FOR RECEPTOR EXAMPLE 1

Panel A: Exposure Scenario Contribution to Cumulative TWF



Panel B: Exposure Scenario Contribution to Cumulative HI



	Exposure Scenario	TWF		Risk Estimates		
		Value	**% of total**	**Risk**	**HQ**	**% of total**
A	Ambient air, OU4	0.15	15%	2E-07	0.01	1%
B	Indoor air, OU4, post-removal, resident, passive	0.30	30%	2E-06	0.1	14%
C	Indoor air, OU4, post-removal, resident,active	0.15	15%	5E-06	0.3	43%
D	Outdoor air, yard soil, curb-to-curb	0.034	3%	2E-06	0.1	14%
E	Indoor air, OU4, no removal, worker, passive	0.030	3%	2E-07	0.01	1%
F	Indoor air, OU4, no removal, worker, active	0.030	3%	1E-06	0.07	10%
G	Outdoor air, OU4, Libby Middle, student	0.00070	0.07%	2E-07	0.02	3%
H	Outdoor air, OU4, Koot. Valley HS, student	0.00021	0.02%	0E+00	0	0%
I	Outdoor air, OU4, Libby Elem., student	0.0035	0.4%	1E-06	0.07	10%
J	Indoor air, OU4, student, Elem. School	0.014	1%	1E-07	0.009	1%
K	Outdoor air, OU7, Golf course, adult	0.02	2%	0E+00	0	0%
L	Outdoor air, OU4, biking, adult	0.0016	0.2%	0E+00	0	0%
M	Outdoor air, OU5, MotoX, participant	0.0034	0.3%	0E+00	0	0%
N	Outdoor air, OU4, LUA soil, ATV, A	0.00036	0.04%	7E-08	0.005	0.7%
O	Outdoor air, OU3, forest, hiking, far	0.0036	0.4%	1E-07	0.009	1%
P	Outdoor air, OU3, Kootenai, fishing	0.0029	0.3%	0E+00	0	0%
Q	Outdoor air, OU8, Driving in Libby	0.0041	0.4%	0E+00	0	0%
R	Offsite	0.25	25%	0E+00	0	0%
	cumulative*:	**1.000**		**1E-05**	**0.7**	

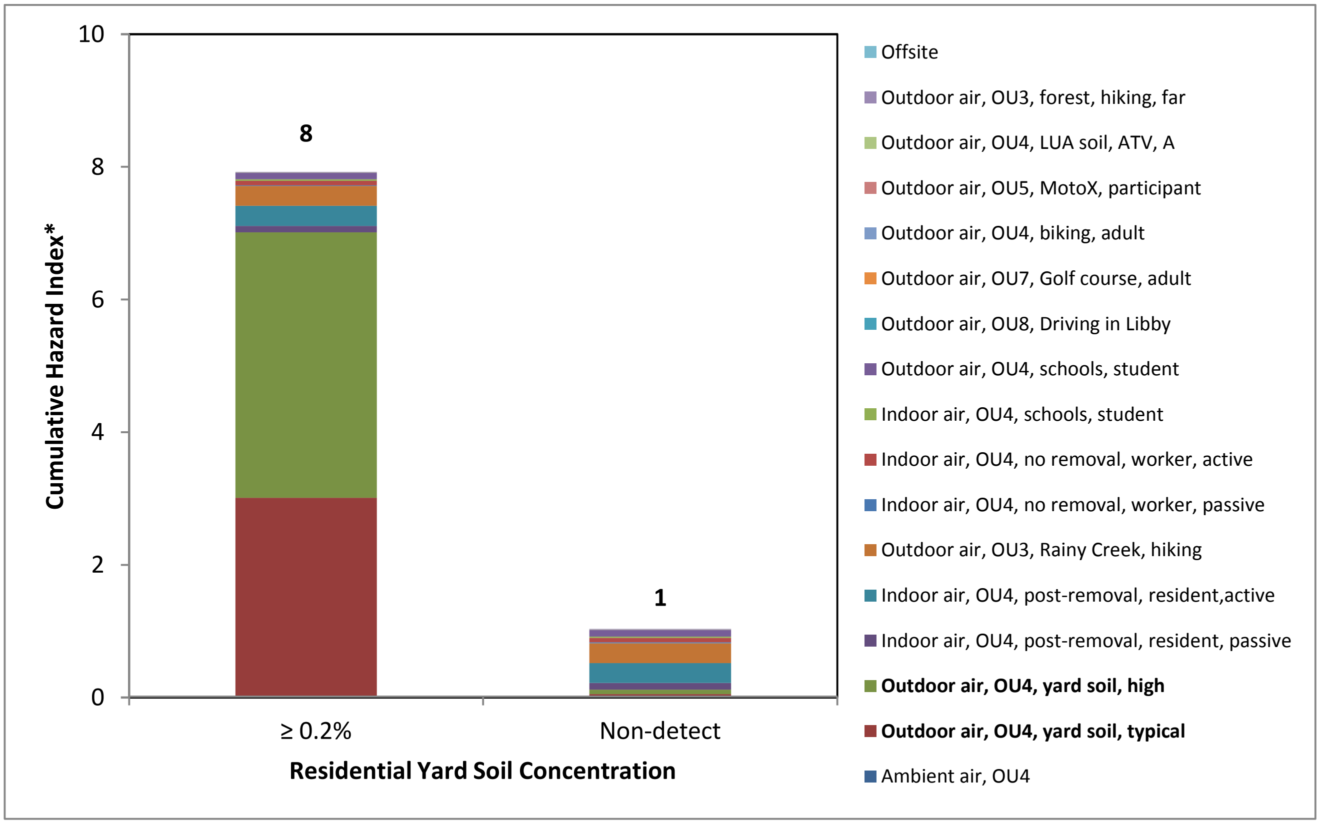
* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown in the table.

Notes:

% - percent
< - less than
ATV - all-terrain vehicle
HI - hazard index
HQ - hazard quotient
LUA - limited use area
MotoX - motorcross
OU - Operable Unit
TWF - time-weighting factor

FIGURE ES-6. ILLUSTRATION OF CUMULATIVE HI FOR DIFFERENT YARD SOIL CONCENTRATIONS

Libby Asbestos Superfund Site



* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown.

Notes:

% - percent

ATV - all-terrain vehicle

HI - hazard index

HQ - hazard quotient

LUA - limited use area

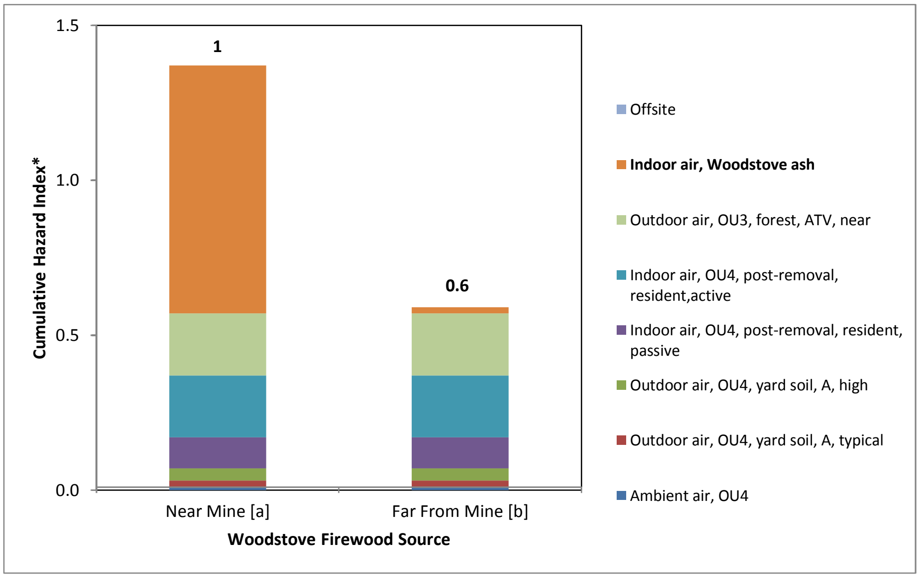
MotoX - motorcross

OU - Operable Unit

PLM - polarized light microscopy

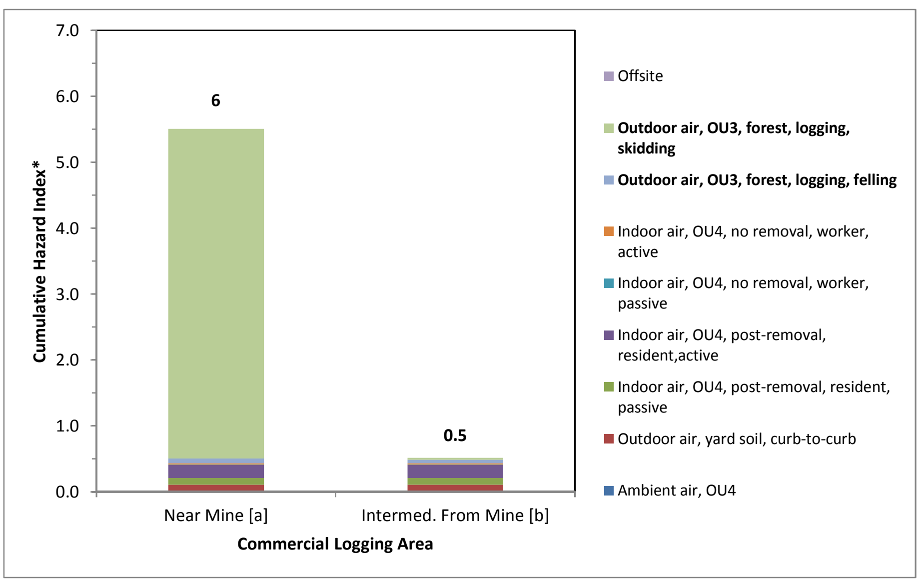
FIGURE ES-7. ILLUSTRATION OF CUMULATIVE HI FOR DIFFERENT ACTIVITY LOCATIONS *Libby Asbestos Superfund Site*

Panel A: Woodstove Firewood Source



[a] Near mine: firewood collected approximately one mile downwind of the mine site
[b] Far from mine: firewood collected approximately 10 miles south of Libby and outside the current NPL boundary

Panel B: Commercial Logging Area



[a] Near mine: Logging activities performed within 1 mile of the mine
[b] Intermed. from mine: Logging activities performed about 4 miles from the mine

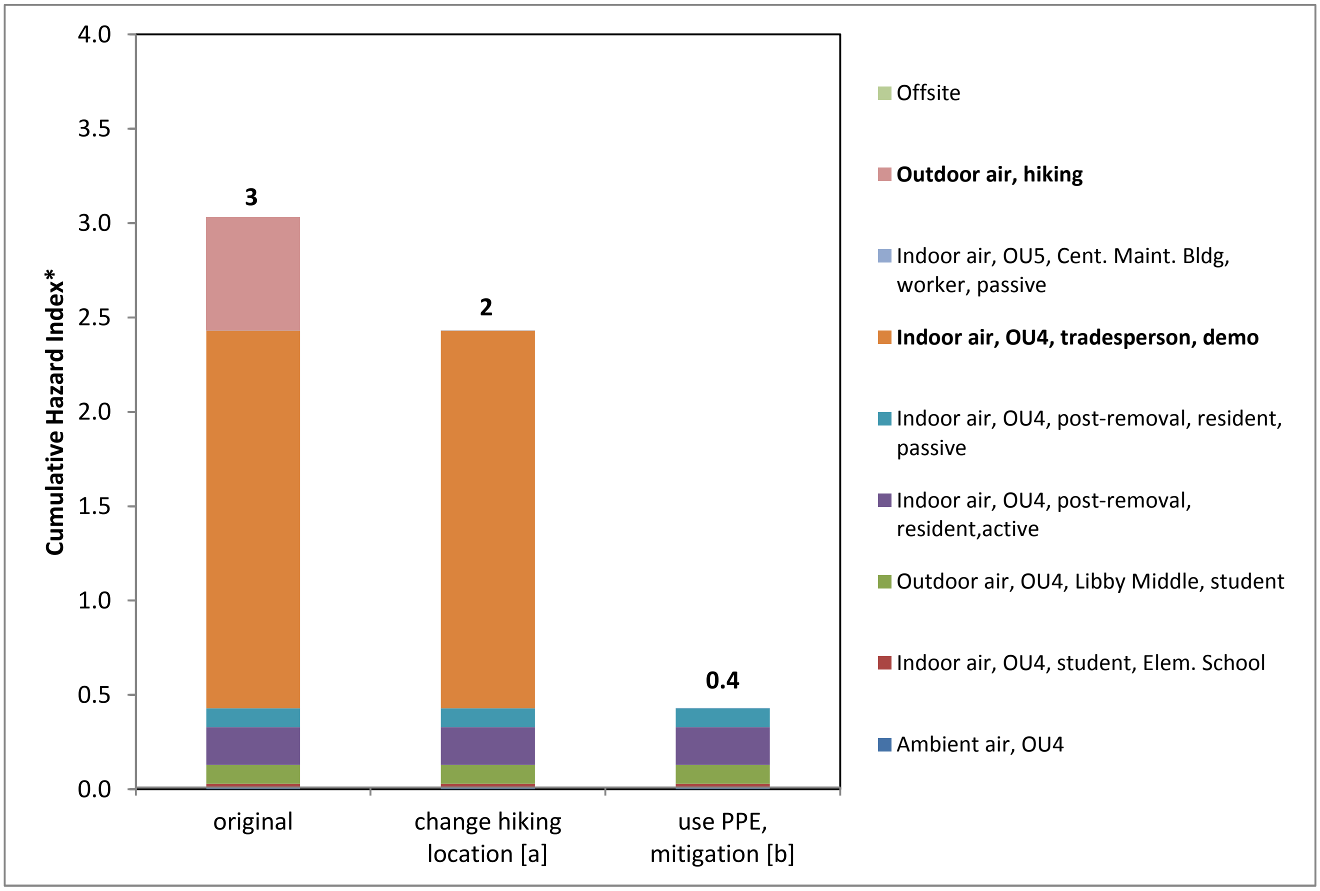
* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown.

Notes:

ATV - all-terrain vehicle
HI - hazard index
HQ - hazard quotient
NPL - National Priorities List
OU - Operable Unit

FIGURE ES-8. ILLUSTRATION OF CUMULATIVE HI CHANGE WHEN ADDRESSING MAIN RISK DRIVERS

Libby Asbestos Superfund Site



[a] Change hiking location from along Rainy Creek to along the Kootenai River

[b] Use appropriate personal protective equipment and employ dust mitigation measures during tradesperson

* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown.

Notes:

HI - hazard index

HQ - hazard quotient

OU - Operable Unit

PPE - personal protective equipment

TABLE ES-1
Conceptual Site Model, Exposure Scenarios and Populations
Libby Asbestos Superfund Site

Exposure Media	Exposure Locations	Operable Unit	Disturbance Description	Exposure Population[a]					
							Worker		
				Resident	Recreational Visitor	Teachers/ students	Indoor Worker	Tradesperson	Outdoor Worker
Outdoor air, ambient conditions	Outdoor	All	---	●	●	●	●	●	●
Outdoor air, during soil/duff disturbance activities	Parks	OU1, OU4, OU7	lawn/park maintenance						●
			park use		●				
	Road ROW	OU2, OU8	mowing/brush-hogging						●
	Kootenai River	OU2, OU3	hiking on trails/paths		●				
			fishing/boating		●				
	Mine Site, Rainy Creek	OU3	hiking, ATV riding, rockhound		●				
	Forested Areas	OU3, OU4	hiking		●				
			building campfires		●				
			ATV riding		●				
			USFS forest maintenance						●
			cutting firelines						●
	Residential/Commercial Properties	OU2, OU4, OU7	yard work	●					●
			gardening	●					●
			playing on driveways	●					
			ATV riding in LUAs	●					
	Schools	OU4, OU7	outdoor maintenance						●
			playing on playgrounds			●			
	Bike Trails/Paths	OU4, OU5, OU7	riding bicycles		●				
	Roads	OU3, OU8	driving cars	●	●	●	●	●	●
	Motocross Track	OU5	motocross participant/spectator		●				
	Industrial Properties	OU5	site maintenance						●
	Railyard/Railroad Corridors	OU6	RR maintenance						●
Outdoor air, during tree bark disturbance activities	Forested Areas	OU3, OU4	local wood harvesting	●					
			commercial logging						●
			campfire burning		●				
			wildfire, prescribed burns	●	●	●	●	●	●
	Landfills	OU4, OU7	woodchipping						●
Outdoor air, during woodchip/mulch disturbance activities	Residential/Commercial Properties	OU2, OU4, OU7	gardening/landscaping	●					●
	Woodchip Piles	OU5	pile maintenance						●
Outdoor air, during ash disturbance activities	Forested Areas	OU3, OU4	after wildfire, prescribed burns						●
			after campfires		●				
Indoor air, passive conditions	Residential/Commercial Properties	OU4, OU7	---	●			●		
	Industrial Properties	OU5	---				●		
	Schools	OU4, OU7	---			●			
Indoor air, during VI disturbance activities	Residential/Commercial Properties	OU4, OU7	attic use, routine property maintenance	●				●	
			construction/demolition	●				●	
Indoor air, during indoor dust disturbance activities	Residential/Commercial Properties	OU4, OU7	cleaning (sweeping, dusting, vacuuming)	●					
	Commercial/Industrial Buildings	OU1, OU5	general				●		
	Schools	OU4, OU7	general			●			
Indoor air, during woodstove ash disturbance activities	Residential/Commercial Properties	OU4, OU7	woodstove ash removal	●					

[a] Note that a given individual may be a member of several exposure populations. For example, an individual may live in OU7, work in OU4, and recreate in OU3. In this example, aspects of the exposure scenarios for a resident, indoor worker, and recreational visitor would apply to the individual. The cumulative assessment addresses cumulative exposures that span multiple exposure scenarios.

Notes:

ATV - all-terrain vehicle
LUAs - limited-use areas
OU - operable unit
ROW - right-of-way
USFS - United States Forest Service
VI - vermiculite insulation
RR - railroad

TABLE ES-2
Estimated Risks from Residential Exposures to LA During Soil Disturbance Activities
Libby Asbestos Superfund Site

Location	Expsoure Scenario & Soil Concentration	Yard ABS Script Intensity	EPC	RME Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Libby (OU4)	**Yards (Mowing, Raking, Digging)**								
	Non-detect	**high intensity**	0.0040	0.3	60	52	0.0015	**1E-06**	**0.07**
		typical intensity	0.00011	6.3	60	52	0.032	**6E-07**	**0.04**
							TOTAL	**2E-06**	**0.1**
	Trace (<0.2%)	**high intensity**	0.061	0.3	60	52	0.0015	**2E-05**	**1**
		typical intensity	0.0024	6.3	60	52	0.032	**1E-05**	**0.9**
							TOTAL	**3E-05**	**2**
	≥ 0.2%	**high intensity**	0.21	0.3	60	52	0.0015	**5E-05**	**4**
		typical intensity	0.0080	6.3	60	52	0.032	**4E-05**	**3**
							TOTAL	**1E-04**	**7**
	Gardens (Rototilling)								
	Trace (<0.2%)	---	0.039	2	2	52	0.00034	**2E-06**	**0.1**
	Gardens (Digging)								
	Non-detect	---	0.00020	3.3	40	52	0.011	**4E-07**	**0.03**
	Trace (<0.2%)	---	0.00066	3.3	40	52	0.011	**1E-06**	**0.08**
	≥ 0.2%	---	0	3.3	40	52	0.011	**0E+00**	**0**
	Driveway (Playing & Digging)								
	Non-detect	---	0	2	225	15	0.011	**0E+00**	**0**
	Trace (<0.2%)	---	0.0057	2	225	15	0.011	**1E-05**	**0.7**
	≥ 0.2%	---	0.0050	2	225	15	0.011	**9E-06**	**0.6**
	LUAs (ATV-riding)								
	Non-detect	---	0.0012	2	20	52	0.0034	**7E-07**	**0.05**
	Trace (<0.2%)	---	0.0014	2	20	52	0.0034	**8E-07**	**0.05**
Troy (OU7)	**Yards (Mowing, Raking, Digging)**								
	Non-detect	**typical intensity**	0.000062	6.6	60	52	0.034	**4E-07**	**0.02**
	Trace (<0.2%)	**typical intensity**	0	6.6	60	52	0.034	**0E+00**	**0**
	Residential, Outdoor Gardens (Digging & Rototilling)[++]								
	Non-detect	---	0.000023	5.3	42	52	0.019	**7E-08**	**0.005**
	Trace (<0.2%)	---	0	5.3	42	52	0.019	**0E+00**	**0**
	Residential, Outdoor Driveway (Playing & Digging)								
	Non-detect	---	0.000079	2	225	15	0.011	**1E-07**	**0.01**
	Trace (<0.2%)	---	0.000085	2	225	15	0.011	**2E-07**	**0.01**

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
[++] Exposure time and frequency have been summed because the EPC is based on a combination of the activities.

Notes:
ABS - activity-based sampling
ATV - all- terrain vehicle
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
LUA - limited use areas
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor
% - percent
< - less than