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U.S. Environmental Protection Agency, Region 8
Attn.: Christina Progess, OU3 Project Manager, Superfund Remedial Program
1595 Wynkoop Street
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Subject: Preliminary Responses to EPA's FS Study Area Delineation and Comments on the Draft Risk Management Approach for the Phase 1 Focus Area for Libby Asbestos Superfund Site - Operable Unit 3

Dear Christina:

On April 29, 2016[1], the U.S. Environmental Protection Agency (EPA) provided review comments in a letter to W.R. Grace & Co.—Conn. (Grace) approximately six months after receipt of the document titled: *Proposed Approach for Defining Boundary of OU3* (dated October 19, 2015). Under separate cover on April 29, 2016[2], EPA also provided review comments on the document titled: *Draft Risk Management Approach for the Phase 1 Focus Area of OU3 (dated February 22, 2016).* This letter provides Grace's preliminary responses to the key issues raised in the two EPA letters. The responses contained herein pertain to both EPA's approach to the delineation of the OU3 study area boundary and EPA's position on several risk management strategy (RMS) issues. Due to the importance of these topics, and the abbreviated time period allowed for Grace's response, the comments/responses contained herein should be considered preliminary in nature and are intended to foster the ongoing discussion and development of the OU3 FS study area boundary and RMS. Grace has identified a number of concerns with the approaches presented in the April 29, 2016 documents.

EPA's comments on the Draft RMS trigger the schedule requirements in Section 10 of the revised December 2015 Scope of Work (SOW) of the Administrative Settlement Agreement and Order on Consent (AOC) (Docket No. CERCLA-08-2007-0012) between Grace and the EPA. Specifically, the Revised Draft RMS is due 45 days after receipt of EPA's comments on the Draft RMS, and the Draft Feasibility Study (FS) Development and Screening of Alternatives Technical Memorandum (Phase 1 FS Memo #2) is due 60 days after receipt of EPA comments on the Draft RMS. However, in both April 29, 2016 letters, EPA granted a two-week extension to the AOC schedule where it pertains to

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[1] April 29, 2016a refers to the EPA letter Re: Comments on the Draft Risk Management Approach for the Phase 1 Focus Area of OU3 for the Libby Asbestos Site, submitted by Grace on October 19, 2015.
[2] April 29, 2016b refers to the EPA letter Re: FS Study Area Delineation for Libby Asbestos Superfund Site – Operable Unit 3, submitted by Grace on February 22, 2016.

the RMS and the Phase 1 FS Memo #2 to allow Grace to review and respond to EPA's OU3 FS study area delineation and RMS information.

Grace is concerned with the SOW schedule requirements given that EPA took six months to review Grace's OU3 boundary memorandum and nine weeks to review Grace's Draft RMS, but is only allowing Grace two weeks to review and respond to EPA's OU3 boundary and RMS information. In addition, considering the significant disparities between Grace's and EPA's approach for both the OU3 boundary and RMS, which are outlined in this letter, we request a schedule extension for submittal of the Draft Final RMS so that consensus can be reached on this important component of the FS. As presented in the remainder of this letter, the request for an extension to the schedule for delivery of the Draft Final RMS is based on: (1) the need for a substantial amount of additional data that is scheduled for collection during the summer of 2016, and (2) lack of alignment regarding EPA's approach and methods for delineating the OU3 FS study area and EPA's approach for several RMS issues including:

- Kriging methodology,
- Assumption of linear relationship between media concentrations and ABS data,
- Addition of an unsubstantiated forest fire buffer around the study area,
- Rejection of air dispersion/deposition modeling data to help inform boundary determination,
- Rejection of area-weighting for fire wood collection,
- Assertion that all of a forest worker's career would be spent within the OU3 study area,
- Use of an HQ of greater than or equal to 0.6 to guide risk decisions,
- Suggestion that an RAL established for residential soils in OU4 through OU8 may be applicable to soil and sediment in OU3,
- Rejection of HQ regression fitting process,
- Inclusion of all watersheds within the new study area boundary,
- Failure to incorporate shared responsibility for impacts within the Kootenai River,
- Attempt to define waste at the site as principal threat waste, and
- Lack of definition of the migration preliminary remedial objective (PRAO).

We believe that resolving these issues is necessary before a meaningful Draft Final RMS can be prepared.

The remainder of this letter presents Grace's comments regarding the OU3 Boundary and RMS topics included in EPA's April 29, 2016 letters. Various topics are presented below under the broad categories of OU3 FS Study Area Boundary Determination, Air Dispersion/Deposition Modeling, and RMS Approach. More detailed analyses of these topics are provided in attachments, as needed.

OU3 FS STUDY AREA BOUNDARY DETERMINATION

In the April 29, 2016 letter, the EPA requested that an alternate boundary determination methodology be used for the site. Grace has significant reservations about the proposed alternative method, which are set forth below. However, in the interim while the RMS is revised and the boundary determination methodology is negotiated, Grace agrees to use EPA's proposed OU3 FS boundary to guide the continuation of the Phase 1 Feasibility Study under the existing schedule.

The following concepts are critical considerations for boundary determination at the site:

- The Framework document (EPA, 2008) states that the relationship between the concentration of asbestos in a source material and the concentration of fibers in air that results when that source is disturbed is very complex and dependent on a wide range of variables. To date, no method has been found that reliably predicts the concentration of asbestos in air given the concentration of asbestos in the source.

- Significant data gaps in environmental media and ABS data exist within the OU3 RI study area.

- Impacted media analytical data are not normally distributed and do not follow a linear trend with regard to distance from the center of the former mine.

EPA has presented an alternate approach to boundary determination that is based on an assumed linear correlation between bark and duff concentrations and ABS results, assumption of uniform distribution of LAA levels around the former mine area, and inclusion of a fire management area around the proposed boundary for which there is no basis or rationale. Specific boundary-area determination topics are presented below. However, as mentioned by Lynn Woodbury, CDM-Smith, "these issues will not be resolved until additional ABS and bark/duff data are collected" (Woodbury, 2016). Grace is still waiting for delivery of the U.S. Forest Service's East Tub Gulch investigation and the Wildfire Modeling Report, as well as EPA's proposed sampling and analysis plan (SAP) for additional data collection developed by CDM-Smith for the 2016 data collection period without input from Grace.

Kriging Process

This section presents a summary of the concerns related to the kriging process performed by EPA. The EPA utilized ordinary kriging to interpolate PCME LAA concentrations for both tree bark and duff. Kriging is a geostatistical interpolation technique that utilizes statistical models to provide a prediction surface. Grace has the following concerns about the kriging work performed by the EPA and would like to request a technical meeting with EPA's kriging expert to discuss and further evaluate these items collaboratively.

- **Failure to perform standard data transformation.** Based on an evaluation of the tree bark and duff data, it was noted that both datasets exhibited data distributions with a high positive skew. One of the underlying assumptions of kriging is that of stationarity. Stationarity assumes that all data values come from distributions that have the same variability. With the assumption of stationarity, the autocorrelation of the data can then be examined and quantified. Transformations can be used to make a dataset more normally distributed and help satisfy the assumption of equal variability of the data. Log transformations are often used when a dataset has a positively skewed distribution and very large values. The EPA stated in the April 29, 2016 documents (EPA's Attachment B) that log transformation of bark and duff data resulted in a noticeable improvement in model predictions. However, EPA chose to use only non-transformed data in the kriging analysis without further explanation. **Grace requests an explanation for why data transformation was not performed.**

- **Inconsistent reporting of software used to create the ordinary kriging surfaces – Surfer or ESRI ArcGIS Spatial Analyst Extension**.
    - EPA's Attachment B states that the program Surfer was utilized to create the kriging surfaces. In addition, it was stated the kriging effort was repeated using ESRI ArcGIS Spatial Analyst Extension, but that the kriging surfaces generated did not match.
    - EPA's April 29, 2016b letter states that the kriging was performed using the ESRI ArcGIS Spatial Analyst Extension and does not mention the use of Surfer.
    - Inconsistent reporting of methodologies used to create ordinary kriging surfaces makes it difficult to assess and compare the approach. Grace requests an explanation for the inconsistencies.
- **Inconsistent reporting of kriging model settings used – linear/custom or spherical/default software settings.**
    - EPA's Attachment B describes a linear semi-variogram model, with custom parameters set, and the number of sample points to be used in the interpolation process.
    - EPA's April 29, 2016b letter states that a spherical semi-variogram model was combined with default software settings with the exception of the number of sample locations to be used in the interpolation.
    - Inconsistent reporting of methodologies used to create spatial models makes it difficult to assess and compare the approach. Grace requests an explanation for the inconsistencies.
- **Several model parameters described in EPA's Attachment B are of potential concern**:
    - Failure to use model that fit the data: A linear model was selected to represent the spatial correlation of the non-transformed data, which does not seem to be the best fit based on the variogram graphs that were provided.
    - Failure to consider critical data in model fit: Range, lag size, number of lags, sill, nugget, anisotropy are all additional model parameters that should be more closely considered prior to fitting a model.
    - Use of linear model for both duff and bark data: Linear model of slope of 1 is stated, but is only shown in the duff model (Figure 3b) not the tree bark model (Figure 3a), which is unusual and confusing. Was a linear model applied to the tree bark data with a slope > 1? A Gaussian or spherical approach seems more likely based on initial exploratory analysis of the data.
    - Spatial data range appears in error: Range was set to 999,999 (unit unknown), which seems quite large. This is basically saying that the data contain spatial correlation up to very large distances. The range is used to acknowledge that sample locations closer together are more likely to be similar than sample locations farther apart. Data beyond the range value are assumed to have no spatial correlation, thus limiting their effect on the model.
    - Insufficient data to support data trend assumptions. Anisotropy seems to have been considered. This assumes that there is a directional influence in the data in addition to distance of data points to one another. There is very limited dialogue discussing

global or local trends in the data to justify the approach. Assuming isotropy is the software default.
  - Failure to include model selection analysis: Grace requests an explanation of how the model parameters were selected.

- **No demonstration was provided that kriging was the correct tool to use or how spatial autocorrelation in the duff and bark data were determined**. Spatial autocorrelation can be statistically tested by calculating Global Moran's I, which measures the degree of dispersed, random, or cluster patterns in a dataset. The IDW "exploratory analysis" is not a substitute for calculation of spatial autocorrelation. Grace requests a copy of the spatial autocorrelation evaluation that was performed and a justification for why ordinary kriging was selected over other kriging approaches, which may provide a better fit for the data?
- **A standard demonstration of kriging results reliability was not presented**. Kriging provides a measurement of error for every predicted value. The ordinary kriging results should be assessed for the degree of error based on confidence or uncertainty.
- **The kriging model was not validated (in accordance with standard statistical evaluations)**. The report should include a comparison of the LAA measurements versus modeled results (e.g. residual error). A discussion of residual error is necessary to understand performance of the semi-variogram model. A cross validation analysis should also be performed on both the bark and duff data. Grace requests a copy of the model validation that was performed for this analysis.
- The rationale for kriging PCME tree bark at >0.6 Ms/cm^2 and PCME duff at >135 Ms/g is not discussed.
- **Data Inconsistencies**
  - Data were provided in two different coordinate systems and in three formats. This does not affect modeling once rectified, but shows inconsistent nature of data management and potential errors in its application.
  - Grace identified 14 locations relevant to the tree bark dataset and 10 locations relevant to the duff dataset that were excluded from the EPA kriging model.

Comparative Kriging Maps

Grace performed additional analyses of the tree bark data kriging effort. A series of maps was prepared using the bark dataset and the ESRI ArcGIS Spatial Analyst. EPA ordinary kriging settings were duplicated as described in EPA's Attachment B, with the exception of the number of points being used in the interpolation, which were reduced to the software default setting of 12 to aid in computing time and facilitate a timely response to EPA. Initial comparative models utilized the EPA documented setting of 136, but the reduction down to the software default of 12 did not have a significant effect on extent. The maps, which are presented in Attachment A, are described below:

- Figure A-1: Presents the EPA bark PCME kriged surface (based on the PDF submitted by EPA that was then georectified to display in GIS).

- Figure A-2a: Presents a re-creation of the kriging plots based on the raw EPA data (n=138) overlaid on the original EPA surfaces. A correlation of extent was observed between the two surfaces, but PCME concentration breaks in the EPA plot is undefined.

- Figure A-2b: All available data were included in Grace's kriging model (EPA neglected to include 14 data points), which was then overlaid on the EPA surfaces. The modeled plots are similar, however, the additional data result in a slightly smaller area overall.

- Figure A-3: Log transformation of the tree bark data was performed to optimize the kriging analysis. A constant (0.5 * minimum value) was applied prior to the log transformation to account for non-detect values and then later removed at the end of the modeling process.

- Figure A-4: The kriging analysis using the log transformed data overlaid on the original EPA surfaces. As can be observed, an area more consistent with air deposition modeling results was generated by the kriged model using the log transformed data.

Concerns with the Use of Data Obtained from Soils Analyzed by the Fluidized Bed Asbestos Segregator Method

Grace has a number of concerns with the use of the non-peer reviewed and unsubstantiated soil analytical method referred to as the fluidized bed asbestos segregator method (FBAS), with the use of the fluidized bed data in Libby (where soil types appear inconsistent with the use of this method), and with EPA's contention that the methodology supports a linear relationship between diverse media concentrations (i.e., soil, duff and bark) and ABS/HQ data. As set forth in Attachment C, while there appears to be a linear relationship between spiked percentages and structures per cubic centimeter in a lab-prepared mixture of Libby amphibole/soil/sand, "there are no correlations between the concentrations of LA in the air (i.e., the ABS values) and the LA content in the soil…when using the FBAS on natural soils."

Grace's concerns regarding the absence of a linear relationship between asbestos in natural soils and releasable asbestos, as set forth in EPA's 2014 analysis, are more fully addressed in Attachment C, which was prepared by Dr. Mickey Gunter, who is Chair and University Distinguished Professor of Geological Sciences and Acting Interim Chair of Geography at the University of Idaho. As set forth in the attached Curriculum Vitae (Attachment D), Dr. Gunter has conducted extensive analysis of LAA and geological traits of the Kootenai Valley.

Of further concern is the addition of another variable to the application of the FBAS correlation: environmental media. The correlations that exist when applying the FBAS method to laboratory-prepared samples (Januch, 2013) no longer exist when expanding the method to natural samples (USEPA, 2014) as described above. This supposed correlation was applied by EPA to both tree bark and duff when defining the Remedial Action Levels that were utilized to define the OU3 FS Study Area. The application of the FBAS correlation does not apply to the transition from laboratory-prepared soil samples to natural soil samples. Gunter posits the biggest issue is the difference in the size ranges of the particles for the laboratory-prepared samples as compared to the natural samples. Further extrapolation of the use and application of the FBAS laboratory-prepared soil sample correlation to the other environmental media of tree bark and duff adds another layer of incongruity and error to its application (especially when considering the relative difference in size ranges between the 0.9 mm sand and tree bark and duff samples). The magnitude of this error is significant.

Forest Fire Buffer

Grace will not have comprehensive comments on this topic until EPA provides Grace with, and Grace has the opportunity to review, the Wildfire Modeling Report. However, several topics are worth noting at this juncture and are discussed below.

As discussed on Page 10 of the EPA FS Study Area Delineation memorandum, the approximately one-mile wildfire mitigation zone is allegedly based on topography and other ground features around the forest duff area of potential concern. If true, it is unclear why the boundary extends past the forest bark area of potential concern. For example, if the forest bark area of potential concern is greater than one mile outside of the forest duff area of potential concern, then the FS study area boundary should coincide with the forest bark area of potential concern. The FS study area is drawn considerably larger than the criterion dictates.

Fire behavior represents the integration of vegetation, i.e., living and dead available fuel, weather, and terrain. This triplet of environmental factors is commonly referred to as the fire environment concept (Countryman 1973) and defines the fire's potential at a place and time. In addition to these three variables, actual fire behavior varies with the position on the fire front: head vs. flank vs. rear – relatively high vs. intermediate vs. relatively low, respectively (Catchpole et al. 1982, see also Finney 2001 and Ryan 2002).

The spatial arrangement of stands, i.e., patches of discernibly dissimilar vegetation, can be expected to also affect fire behavior at the local scale (Finney and Cohen 2003). In more robust fuels fire behavior often does not achieve its full potential for short distances uphill or downwind from lighter fuels, the so called "shadow effect," e.g., Finney (2002a). The probability of burning and the consequences of a given burn, i.e., "local scale effects" must be critically evaluated in any effective fuel treatment program (Finney 2001, 2002a,b; Finney 2005; Hyde et al. 2006; Finney et al. 2007).

In an analysis of landscape fire potential in the Colorado Rockies, Hann and Strohm (2003) used a one-mile buffer around developed (residential) lands, reflecting an attempt to evaluate potential wildfire threats to multiple mountain communities. Their buffer was an intelligent guess at what might possibly be needed to protect homes in a worst-case scenario. In their defense, the data and analytical models for a more scientific approach were non-existent at that time.

Hann and Strohm's (2003) arbitrary "rule of thumb" has been used by fire modeling teams deployed to support major wildland fire incidents. Its occasional use in an emergency management situation where time and resources for more rigorous analyses are lacking may have some merit. However, simple "rules-of thumb" are wholly unjustified for application in the OU3 FS.

The fire environment will not support extreme fire behavior everywhere on the landscape. This is a fundamental factor leading to commonly observed fire mosaics on the landscape (see, e.g., Ryan 2002). Vegetation maps clearly delineate areas of differing fuels (www.landfire.gov). Terrain data clearly indicate that slope is rarely uniform over significant distances in mountain areas. Wind roses reflect the fact that wind speeds and directions are neither uniform nor randomly distributed. Failure to recognize differences in fire potential is a recipe for a failed fuels treatment program (see, e.g., Finney 2002b, 2003; Finney and Cohen 2003; Finney et al. 2007).

AIR DISPERSION/DEPOSITION MODELING

This section presents a summary of the concerns related to the air dispersion modeling performed by EPA, its use in aiding EPA in the definition of OU3 FS study area boundary, and the limitations of use brought up by CDM Smith.

- **Comment Memorandum Attachment to the April 29, 2016a EPA letter, Page 3, "Aerial Dispersion Modeling" Comment:**

  Aerial dispersion modeling was employed to estimate ground-level air concentrations of LA, in units of micrograms of LA per cubic meter of air (µg/m3), resulting from historical emissions at the dry mill (located at the mine; OU3), the Screening Plant (OU2), and the Export Plant (OU1). A detailed description of the aerial dispersion modeling is provided in the Technical Memorandum: Aerial Dispersion of Libby Amphibole Asbestos (CDM Smith 2015b). This modeling indicated historical ground-level air concentrations were dominated by releases from the dry mill but contributions from the Screening Plant and Export Plant were minimal, even in areas near these other emission sources (CDM Smith 2015b).

  The original aerial dispersion modeling assumed there was no particle deposition, which likely overestimated the potential extent of LA dispersion. Since the completion of the original modeling, the aerial dispersion predictions for the dry mill have been updated to include deposition (i.e., assuming a fraction of the LA settled out as it traveled through the air), as this is likely to be more representative of actual aerial dispersion conditions. This update to the aerial dispersion modeling addresses comments from Grace during the November 19, 2015 meeting. The input parameters used in the model were consistent with the deposition assumptions presented in Grace's "Proposed Approach for Defining Boundary of OU3" memorandum (dated October 19, 2015).

  Based on the results of this modeling, estimated historical ground-level air concentrations were highest near and centered on the former Zonolite Mine (see Figure 1). The predicted historical LA aerial plume generally extended to the northeast and southwest, which are the predominant local wind directions (based on local meteorological data), up to a distance of about 8 miles in each direction. In the crosswind directions, the LA plume extended to a distance of about 6 miles to the northwest and about 5 miles to the southeast. Thus, the aerial modeling demonstrates that the extent of potential LA contamination in the forest due to aerial releases from historical mining activities would be oval in shape, extending further in the northeast/southwest directions than in the northwest/southeast directions. The pattern of spatial contamination also appears to depend upon topography; to the northeast, the plume appears to follow the contours of the lower elevation valleys.

  Grace Response: Grace agrees that deposition should be enabled in the dispersion modeling analysis. Since the purpose of this analysis is to assess the amount of LAA deposited at a particular location, the appropriate output from dispersion modeling is average annual deposition rate (i.e., g/m^2-year), not historical ground-level air concentrations (µg/m^3). In other words, modeled air concentrations at the time the facilities were in operation are not necessarily relevant to current conditions and potential risk drivers in the affected media.

Moreover, if EPA chooses to continue to illustrate historical ambient air concentrations, it is noted that 1 µg/m^3 corresponds to approximately 0.033 f/cc (approximately one-third of the 8-hour PEL of 0.1 f/cc). Both the green isopleth and the blue isopleth correspond to levels that are less than one third of the 8-hour PEL. Illustrating these low level concentrations in these documents is contrary to historical data, unrealistically conservative, and implies risks where none existed, which ultimately risks significantly misinforming the public.

Moreover, it is not clear how EPA used the historical ground-level air concentrations from the Aerial Dispersion Model to assist in defining the OU3 FS study area.

- **<u>Comment Memorandum Attachment to the April 29, 2016a EPA letter, Page 3, "Use of Air Deposition Modeling" Comment</u>:**
  As described in Section 6.2.2 and 6.2.3, once the critical distances for duff/soil (1.85 miles) and ash (1.35 miles) were determined from the HQ regression, these distances were used to identify a threshold air deposition rate for LA, which in turn was used to identify areas potentially above the risk-based threshold. However, all dispersion and deposition models of this type are subject to numerous limitations and uncertainties, and the results are very unlikely to be sufficiently accurate to support such an extrapolation, especially in a complex terrain such as the mountainous and forested area around the mine. Identification of areas that exceed the risk-based threshold should be based on empiric measurements of LA in ABS air and/or source media (soil, duff, bark).

  <u>Grace Response</u>: Grace recognizes that air dispersion modeling has uncertainties and limitations, as do all modeling efforts. This is one of the primary reasons that Grace's boundary definition approach utilized multiple lines of evidence, including ABS data and impacted media levels, in conjunction with the air dispersion modeling. EPA is critical of the use of air dispersion modeling due to "complex terrain such as the mountainous and forested areas around the mine" and prefers the use of kriging. However, EPA also used an air dispersion model as a line-of-evidence in formulating the OU3 FS study area boundary. EPA discusses in the FS Study Area Delineation memorandum how the pattern of spatial contamination appears to depend upon topography, which supports the use of the air dispersion/deposition model. Also, it is important to note that *kriging does not consider "complex terrain" or the actual atmospheric processes through which LAA was transported and deposited*. Consequently, the detailed contours produced by kriging may infer false accuracy and is considered by Grace to be an inferior approach when compared to an air dispersion/deposition model, which better considers complex terrain such as the mountainous and forested areas around the mine and complex spatial distribution.

RMS APPROACH

On February 22, 2016, Grace submitted to EPA the document titled: *Draft Risk Management Approach for the Phase 1 Focus Area of OU3* (Draft RMS). Grace's Draft RMS document outlines the many factors to be considered when evaluating the feasibility of remedial alternatives. The RMS synthesizes the unacceptable risks, site conditions, and land use in order to establish areas requiring remedial action and remedial criteria. The RMS is critical to the FS process because it must provide adequate protection of human health, but also should not be unrealistically conservative. Upon review of EPA's comments received on April 29, 2016 on the Draft RMS, Grace has identified RMS topics where there are large differences between Grace's and EPA's risk management approach. These topics are discussed below with the goal of pointing out these differences, but also with the intent of moving toward consensus on these critical RMS components.

Woodstove Ash

The use of the area- or spatially-weighted assessment of potential exposure to residential woodstove ash was based on the reasonable exposure assumptions used in the Site-wide HHRA (EPA 2015). In Section 8.2.2 of the Site-wide HHRA, EPA states that "The wood-related risk estimates presented in Table 8-5 [which includes residential woodstove ash removal] assume the entire exposure time is spent within the EPC grouping locations (e.g., near, intermediate, far from the mine). However, *it is likely long-term receptor exposure could encompass multiple EPC grouping locations*" (emphasis added). In the Draft RMS, Grace used the HHRA's spatially-weighted results to assess potential long-term exposures to LAA in residential woodstove ash because the spatially-weighted results are more representative of potential exposures using data encompassing multiple EPC locations.

EPA's assessment of potential risk to LAA in woodstove ash and the corresponding proposed remedial action level for tree bark is not supportable because it relies on data collected *from only two data points* (two deadwood trees obtained within approximately 1-mile north of the mine site). Additional paired PCME data for tree bark and ABS data for woodstove ash cleaning are needed from appropriate OU3 firewood harvesting locations to better understand the relationship between LAA concentrations in tree bark and potential exposures associated with long-term residential firewood gathering. By filling this data gap, a scientifically appropriate and health-protective risk-management zone for tree bark can be defined. This will augment the RMS for Phase I of the OU3 study area.

Hazard Quotient (HQ)

The risk-based remedial criterion used in the Draft RMS to identify the FS Study Area was defined as a reasonable maximum exposure non-cancer hazard that *exceeds* 0.6. In EPA's April 29, 2016 letter to Grace, the risk-based criterion was changed to greater than *or equal to* 0.6. Typically, EPA non-cancer risk-based remedial criteria are set to an HQ=1. Also, under EPA's guidance, where the non-cancer hazard is equal than or less than 1, no action is required. It is only when the non-cancer hazard exceeds the threshold of 1 that remedial action is evaluated further. Even in residential areas of Libby, EPA utilized the risk-based remedial criterion of greater than 0.6 for soil remedial action levels and remediation clearance criteria. See *Record of Decision for the Libby Asbestos Superfund Site, Libby and Troy Residential and Commercial Properties, Parks and Schools, Transportation Corridors, and Industrial Park, Operable Units 4 through 8* (EPA 2016), the FS for Operable Units 4, 5, 6, 7, and 8 (CDM Smith 2015b), and the Site-Wide HHRA (CDM Smith 2015a). The Draft RMS definition of the risk-based remedial criterion is appropriate and protective for the OU3 FS study area.

In addition, the risk-based remedial criterion of >0.6 is consistent with reported non-cancer hazards related to background soils (see Table 6-24 in CDM Smith 2015a). It is contrary to EPA guidance to set cleanup criteria to levels below background. Because it is standard practice to use one significant figure in expressing HQs, the use of a criterion greater than or equal to 0.6 could result in requiring cleanup at areas where the health risk is below background health risks, which is not supported by CERCLA and the NCP. The risk-based remedial criterion of >0.6 as proposed in the Draft RMS is appropriate and health protective.

Remedial Action Levels (RALs)

EPA's April 29, 2016b letter to Grace implies that the RAL established for soils in OU4 through OU8 (LAA ≥ 0.2%) may be applicable to soil and sediment in OU3. EPA points out that "this threshold is consistent with Grace's Proposed Approach for Defining Boundary of OU3 memorandum." While the Grace Boundary memorandum does employ the threshold of ≥ 0.2%, it was used only as a measure to define a conservative boundary of OU3 within which all remedial action would occur and not as an "action level" as EPA implies.

The use of ≥ 0.2% as an RAL for soil for OU3 is inappropriate because the basis for this RAL is residential exposure, which is not occurring or likely to occur in the foreseeable future within OU3. Moreover, EPA states in its comments, "There are no known LA concentrations ≥ 0.2% in mine waste or soil outside of the KDC boundary." This implies that if a soil RAL from another OU is used in OU3, then a more appropriate RAL would be the RAL applied to industrial property and transportation corridor soils. The RAL for industrial property and transportation corridor soils is Bin C or >1%. Exposures (frequency, duration, etc.) to soils in OU3 are more comparable to those modeled for the industrial properties and transportation corridors in OU5 and OU8, and are not similar to the exposure parameters used to model exposure to residential areas. CERCLA, the NCP and EPA guidance does not support the application of a residential-based RAL to the OU3 soils and is not justifiable.

HQ Regression Fitting

Several of EPA's criticisms of Grace's approach of using power function regressions to characterize the relationships of declining HQ values and LAA media concentrations with increasing distance from the mine site center are misinformed. Grace did not log-transform either the PCME LAA concentration data or the HQ results for these analyses. As described in the presentation of these analyses to EPA at the March 3, 2016 meeting in Denver, Grace took a conservative approach and performed these regressions only on detected results from the OU3 sampling campaigns. All "zero" value duff data, and all data from the nature and extent sampling program were excluded from these regressions. Instead of decreasing the relative weight of high values and increasing the relative weight of low values, the opposite effect was observed.

Before fitting the HQ and duff PCME concentration data to a power function without justification, as has been asserted, Grace evaluated exponential, linear, logarithmic, power, moving average, and polynomial trend lines for these data. Based on R^2 values and visual fit, Grace determined that the best fit regressions for both is provided by the power function.

Grace is also criticized for using all duff data (i.e., data from upwind, downwind, and crosswind sampling locations) to describe the relationship of duff concentrations with distance. EPA states that only the downwind duff concentrations should have been compared to HQ data derived from downwind ABS locations. To explore the merits of this comment, Grace conducted a sensitivity analysis by restricting the duff PCME concentration data to only those samples located in the northeast direction from the mine and reanalyzing the regressions. To also address concerns raised by the mistaken assumption that log-transformed data were modeled, this sensitivity analysis substituted a value equivalent to one-half of the lowest reported duff concentration in the directional data set for the 22 duff results that were reported as zero.

The results of this sensitivity analysis are shown on Figure B-1, which is included in Attachment B. The power curve shown in black depicts the original analysis of PCME duff concentrations with distance as shown in the draft RMS Figures 6-1 and 6-2. The power curve of HQ with distance is shown in orange and is identical to the analysis shown in the draft RMS at Figure 6-2. The power curve shown in blue is the sensitivity analysis of duff PCME concentrations with distance, but only includes data collected in the northeast direction from the mine. Clearly, the duff concentrations drop dramatically with distance from the mine, regardless of direction, and this decline in PCME concentrations and HQ values occurs in a nonlinear fashion. The exercise of censuring the duff data so that only those data located in the northeast direction from the mine results in very little difference in the shape of the power regression curve from that shown in our original analysis.

Applicability of Comparing to all ABS HQ Data

The EPA questioned the comparison of HQ values from different ABS scenarios because: (1) the intensity of the different activities leads to different release rates when the source concentrations are the same; and (2) time-weighting factors (TWFs) used to calculate HQs from ABS air are not equal for all exposures scenarios. Each of these comments is addressed below.

With respect to the variability in LAA release rates between the heavy equipment uses projected in Figure 6-2 of the RMS document (i.e., bulldozing, skidding, and excavator operation), mean ABS PCME LAA air concentrations associated with bulldozing (site restoration), hooking and skidding and slash pile building (excavator) within one mile of the former mine were 0.032 s/cc, 0.12 s/cc, and 0.105 s/cc, respectively. While each of these concentrations represents the use of a different piece of machinery, they vary by as little as a factor of 1.1 and at most by only a factor of 3.75. This level of variability is comparable to the variability seen in replicate samples for the same activity/equipment. For example, the variability between the highest and lowest PCME LAA concentrations for slash pile building is a factor of 3.72. In fact, EPA acknowledges that variability spanning up to four orders of magnitude occurs among ABS results from the same scenario and source concentration, as they state in Section 10.1.5 of the Site-wide HHRA (CDM Smith, 2015a). Thus because the level of variability resulting from different heavy equipment is not different than the variability derived from multiple samples collected while operating the same piece of heavy equipment in the same general area, it is reasonable to use the HQ data from different pieces of heavy equipment to evaluate the potential impact of distance from the mine site on exposure potential.

The uncertainty introduced due to different TWFs is also relatively small. The TWFs for heavy equipment uses range from 0.0013 for slash pile building to 0.0047 for hooking and skidding and site restoration. The difference in TWF is only a factor 3.62, meaning that changes of TWFs with distance have minimal influence over the changing HQs with distance from the mine site. In contrast, the ABS PCME LAA concentrations across the same stations and scenarios decrease by several orders of magnitude due to the decrease in media LAA concentration with distance increased distance from the mine. This means that the ABS PCME LAA concentrations generated from heavy equipment use have a far greater overall impact on the HQs than do the differing TWFs among these activities. To further substantiate this point, Figures B-2 and B-3 present the ABS PCME LAA concentrations versus distance for the heavy equipment and hand tool ABS scenarios, respectively. The figures also show the corresponding HQs with distance. These figures show that the ABS PCME LAA concentrations trend with the HQs without regard to the method of duff agitation. This shows that a small variation in the TWFs does not have a significant effect on the relationship established in the Grace's Draft RMS. In short, the media concentration and HQ relationships derived in the draft RMS are valid.

Forest Worker

EPA made the comment that it was reasonable to assume that a forest worker could spend their entire career working strictly in the OU3 study area. The Kootenai 2015 Land Management Plan gives the following data in relation to timber production/harvest on the Kootenai National Forest.

- The total acres of suitable timber producing land on the Kootenai National Forest is 791,400 acres with an expected annual harvest of 47.5 MMBF per year (p. 166). So the average acre of suitable timber ground would have about 60.02 board feet of timber.

- The Kootenai National Forest covers over 2.2 million acres. The currently proposed area for the OU3 study area is greater than 20,000 acres.

Using simple percentages:

- OU3 is 0.0379% of the size of the available total timber producing acres on the Kootenai National Forest or about 4%.

- OU3 is 0.009% of the total forest acres on the Kootenai National Forest (20,000/2,200,000) or less than 1% of the total acres.

- The annual predicted volume sold for the Kootenai National Forest is 4,750,000 board feet per year, so the amount potentially available if every acre of the OU3 was producing the same timber would be about 1,200,400 board feet, across the entire OU3 (20,000* 60.02).

- A large portion of the Grace property and the Plum Creek lands have already been harvested and will not produce a significant amount of timber. Being generous, assuming 75% of the total area of the proposed OU3 was "average" then it can be assumed that the area would have roughly 900,300 board feet of timber available (1,200,400 * 0.75).

It is reasonable to assume that a person could spend their entire career in the forest over the entire Kootenai National Forest area, but <u>not</u> that a person could spend their entire career in only 4% of the total "suitable" timber ground for the forest or less than 1% of the total forest acres. One timber sale would be capable of harvesting all of the available timber in OU3.

Inclusion of all Watersheds within New OU3 FS Boundary

EPA's April 29, 2016b letter states *"it is also appropriate to include any potentially affected watersheds in the OU3 FS study area to ensure LA in ash is appropriately mitigated following a wildfire*." This statement is problematic because there are watersheds that straddle EPA's OU3 FS study area (i.e., part of the watershed is inside and part of the watershed is outside EPA's OU3 FS study area). Also, watersheds occur on various scales and essentially all watersheds are within larger watersheds. For example, the Rainy Creek watershed is one of many watersheds that comprise the Kootenai River watershed. Therefore, it is not realistic to expand EPA's already unrealistically conservative OU3 FS study area to include the entirety of adjacent overlapping watersheds. Moreover, the remedial actions selected following the CERCLA FS process (including migration-related remedial actions) are presumed to be effective. In other words, it is not necessary to include the entirety of adjacent overlapping watersheds because it is presumed that the selected remedy will effectively prevent LAA-impacted ash migration to areas outside of the OU3 FS study area.

Kootenai River

Two ABS events have been conducted to assess exposure risks for recreational visitors along the Kootenai River during low-flow periods to ascertain the risk associated with exposed, dry river sediments. For the first ABS event, hiking along an unmarked, unbeaten trail was completed along the Kootenai River immediately upstream of the confluence with Lower Rainy Creek in OU2. The activities included traversing both above and below the high water mark along the river frontage. No sediment samples were collected to correlate sediment concentration with HQ values for this ABS event (*OU2 Interim Post-Construction Human Health Risk Assessment* (CDM Smith 2014)). The second ABS event was conducted on a sand bar in the Kootenai River immediately downstream of the confluence of Lower Rainy Creek and was designed to simulate activities representative of actions that might be performed by local river guides and recreational visitors on the sand bar. The script included landing a boat on the sand bar, walking around and simulating an individual fishing along the edges of the sand bar, and departing by boat. The concentration of LAA in the sediment sample collected on the sand bar for second ABS event had LAA concentrations corresponding to Bin B2 or >0.2% to <1% (sample location KR-20 by PLM-VE). Both of these sediment-related ABS activities resulted in a non-cancer HQ value of 0. This indicates the absence of risk with Bin B2 LAA concentrations in sediment. Based on the available data and subsequent risk assessment, an action level of 0.2% in sediment is not substantiated. There is no reason to believe that under an extended drought or a dredging scenario where the river sediments would be accessible that the resultant HQ values would be different from those already calculated. The ABS events were aggressively conducted when the sediments were exposed and dry and the concentration of the sediments sampled during the second ABS event on the sand bar were representative of worst-case LAA sediment concentrations along the Kootenai River (from the upstream sample point UKR-3 to sample point #25 in the town of Troy). Furthermore, if a linear relationship between sediment concentration and risk could be established, cleanup of sediment materials would not be warranted regardless of the LAA concentration.

Moreover, application of a residential soil RAL to sediment is unjustified under CERCLA, the NCP and EPA guidance. Even if low river flow events cause sediment to be exposed from time to time, low flow conditions will not continue for a time period consistent with residential exposure. Also, access to the river is limited relative to access to residential properties, so exposure parameters used to evaluate recreational activities on the river will be lower than the residential exposure parameters used to develop the OU4 residential soil RAL.

Additional evaluation of the LAA concentrations along the Kootenai River from sample point UKR-3 (located approximately 8 miles upstream of the Lower Rainy Creek confluence) down to sample point #25 (located in the town of Troy), indicates that the maximum LAA concentration in sediment is Bin B2 (>0.2% to <1%). Based on the ABS activities conducted in sediment and the resulting HQ values of 0, these concentrations do not pose unacceptable risk.

As addressed in the RI in Section 2.11.1, multiple sources contributed to the presence of LAA in Kootenai River sediments (e.g., OU1, OU2, OU3, OU4, Flower Creek, Granite Creek, Pipe Creek, Libby Creek, and direct placement of LAA contaminated rip-rap along the Kootenai River by the U.S. Government). Many of these sources are not associated with OU3 or activities within OU3, and therefore are not the responsibility of Grace pursuant to the Settlement Agreement. Grace's position is that the responsibility for any response action within the Kootenai River would be shared due to the interspersed contribution of varying sources. Grace would like to initiate discussions with EPA to determine the best approach for determining responsibilities along the Kootenai River.

Principal Threat Waste

Gary Hazen's Comment #6 on the Draft RMS: *The non-OU3 FS identified soil and building materials as principal threat wastes (PTW). The rationale was as follows: soil and building materials* *for non-OU3 areas of the Site, containing LA above their respective remedial criteria, constitute source materials. These media act as a source for direct exposure to inhalation of LA when encountered. In addition, these source materials could present a significant risk to human health should exposure occur, and thus are classified as principal threat wastes. It should be noted that "A Guide to Principal Threat and Low Level Threat Wastes" (EPA 1991) states"...this concept of principal and low level threat waste should not necessarily be equated with the risks posed by site contaminants via various exposure pathways".*

As discussed in 1991 EPA guidance on Principal Threat Wastes (PTW) (EPA, 1991), the guidance for principal threat and low level threat wastes was developed to communicate the types of remedies that the EPA generally anticipates to find appropriate for specific types of wastes: "these expectations help to streamline and focus the remedial investigation/feasibility study (RI/FS) on appropriate waste management options." Clear direction is given in this guidance that supports the determination of principal threat and low level threat wastes at the RI/FS phase of the CERCLA process. Furthermore, Grace strongly holds, based on the supporting data provided in the Draft RMS (Integral, 2016), that the media within the Phase 1 boundary do not meet the threshold of a PTW. This may be a moot point, however, since the use of treatment technologies for LAA contaminated media is not practical or viable based on the initial screening of technologies presented in the Phase 1 Technical Memorandum #1. This was also the case for the non-OU3 ROD where treatment technologies were not employed even though a PTW determination was made in that case.

Migration PRAO

Gary Hazen's Comment #5 on the Draft RMS: *All potential routes of LA migration from source media initially identified in a remediation zone should be addressed since they can migrate to other media that pose unacceptable risks, even if the medium is a minor contributor.*

As discussed in the meeting in Denver on March 3, 2016, the migration Preliminary Remedial Action Objective (PRAO) requires additional definition. This comment illustrates how the lack of definition in the PRAO requires additional clarification as it can greatly affect the remedy evaluation and selection.

SUMMARY

In summary, Grace has several concerns with EPA's approach to delineating the OU3 FS study area and associated RMS details. Grace recognizes that the OU3 FS study area/RMS must provide adequate protection of human health. However, it also is important that the OU3 FS study area/RMS be based on defensible science and multiple lines of defensible evidence, because there are negative consequences to an unsupported and unrealistically conservative OU3 FS study area and RMS. For example, it would be detrimental (not to mention inconsistent with CERCLA and the NCP) to invoke remedial actions in sensitive ecosystems where it has not been conclusively demonstrated there are unacceptable risks. Therefore, we emphasize the importance of achieving consensus on the OU3 FS study area and RMS and request the following actions and path forward:

- Schedule a technical meeting as soon as possible to discuss how EPA and Grace have conducted kriging analyses.
- Delay schedule for submittal of the Draft Final RMS until 60 days after the receipt of final data from 2016 FS data collection while the issues identified in this letter are resolved. Again, to

keep the feasibility study moving forward, Grace will submit the second technical memorandum based on the boundary identified by EPA.

- Collect additional paired PCME data for tree bark and ABS data for woodstove ash cleaning from appropriate OU3 firewood harvesting locations to better understand the relationship between LAA concentrations in tree bark and potential exposures associated with long-term residential firewood gathering. Filling this data gap will allow a scientifically appropriate and health-protective risk management zone for tree bark to be delineated. Again, Grace requests the sampling and analysis plans for these data collection efforts so that Grace has sufficient time in 2016 to collect these data.
- Perform additional skidding ABS evaluations to better understand the variability of these data across the site.
- Reevaluate the approach to boundary determination based on the new data.

Grace appreciates the opportunity to review EPA's methodology to better understand EPA's viewpoint in going forward with both the OU3 FS study area boundary as well as the OU3 Phase 1 RMS. These documents will enhance our ability to discuss and come to a mutually agreed upon and defensible approach on the outstanding concerns that remain. Of utmost importance is concurrence that the Draft Final Phase 1 RMS can be delayed until an adequate review of EPA's approach to both the FS boundary and the RMS can be completed, consensus can be obtained on areas where significant disparities exist, and the additional data are received to fill important data gaps that are scheduled for collection during the summer of 2016. Grace believes that resolving these outstanding concerns is necessary before a meaningful Draft Final RMS can be prepared.

We appreciate your attention to this matter.

Sincerely,

Robert J Medler

Robert J. Medler
Director Remediation
W.R. Grace & Co. –Conn.

Attachments: Attachment A: Figures A-1 through A-5 illustrating additional analyses of the tree bark data kriging effort using ESRI ArcGIS Spatial Analyst Extension.

Attachment B: Figure B-1. Sensitivity analysis of Northeast Duff PCME LAA Concentrations by Distance and Duff and Soil Disturbance HQs by Distance.

Attachment C: Critique of Fluidized bed asbestos segregator (FBAS) for use in obtaining the content of "asbestos" in "asbestos-contaminated" soil by Dr. Mickey Gunter

Attachment D: CV of Dr. Mickey Gunter

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Libby Asbestos Superfund Site, OU3 Study Area Stakeholders

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Attachment A

Tree Bark Kriging Figures

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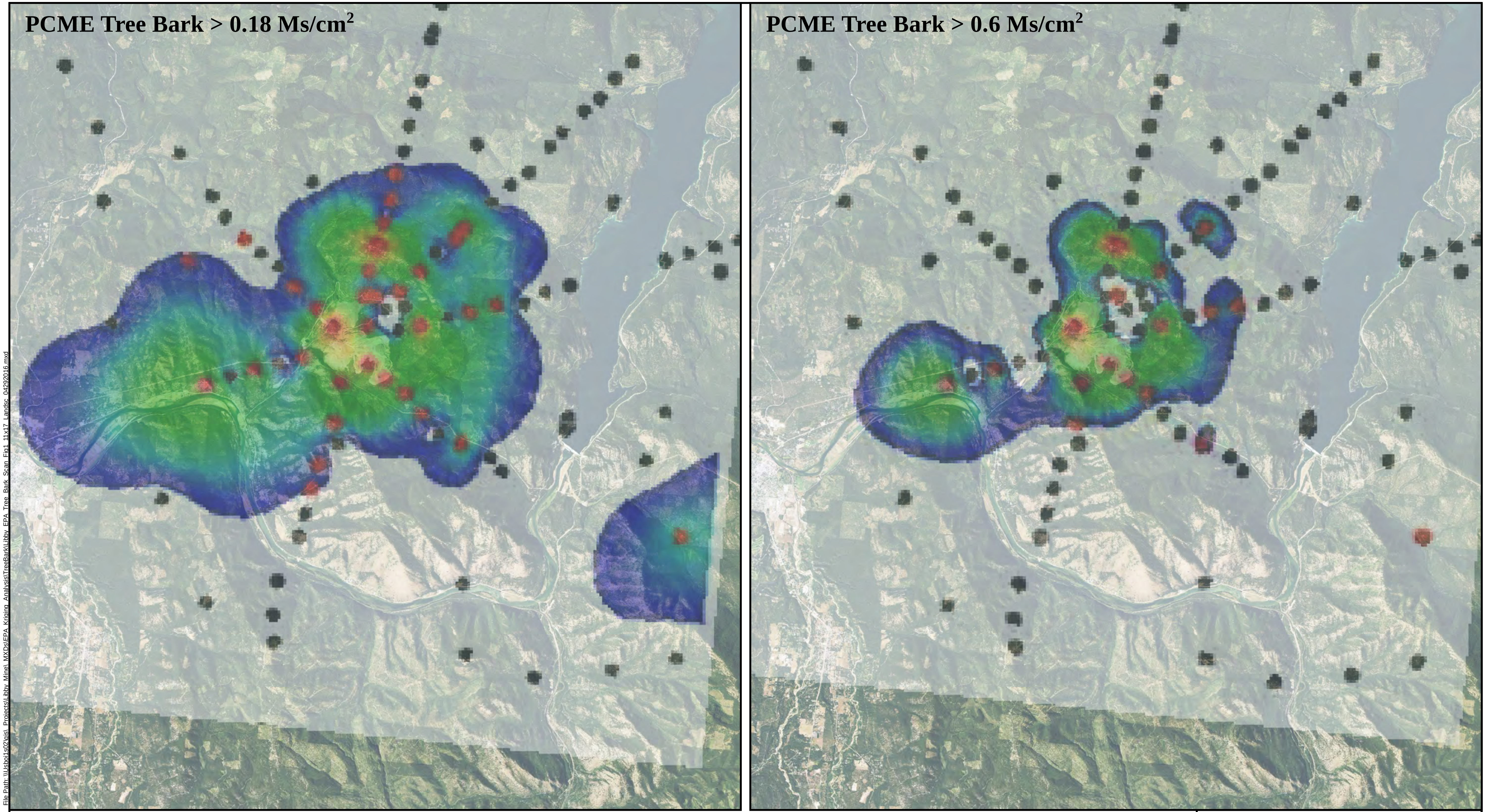

PCME Tree Bark > 0.18 Ms/cm^2

PCME Tree Bark > 0.6 Ms/cm^2

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● Sample Location (< Threshold)

● Sample Location (> Threshold)

Kriging Software: Surfer

Base Image: National Agriculture Imagery Program, 2013

Coordinate System: NAD 1983 HARN StatePlane Montana FIPS 2500 Feet Intl

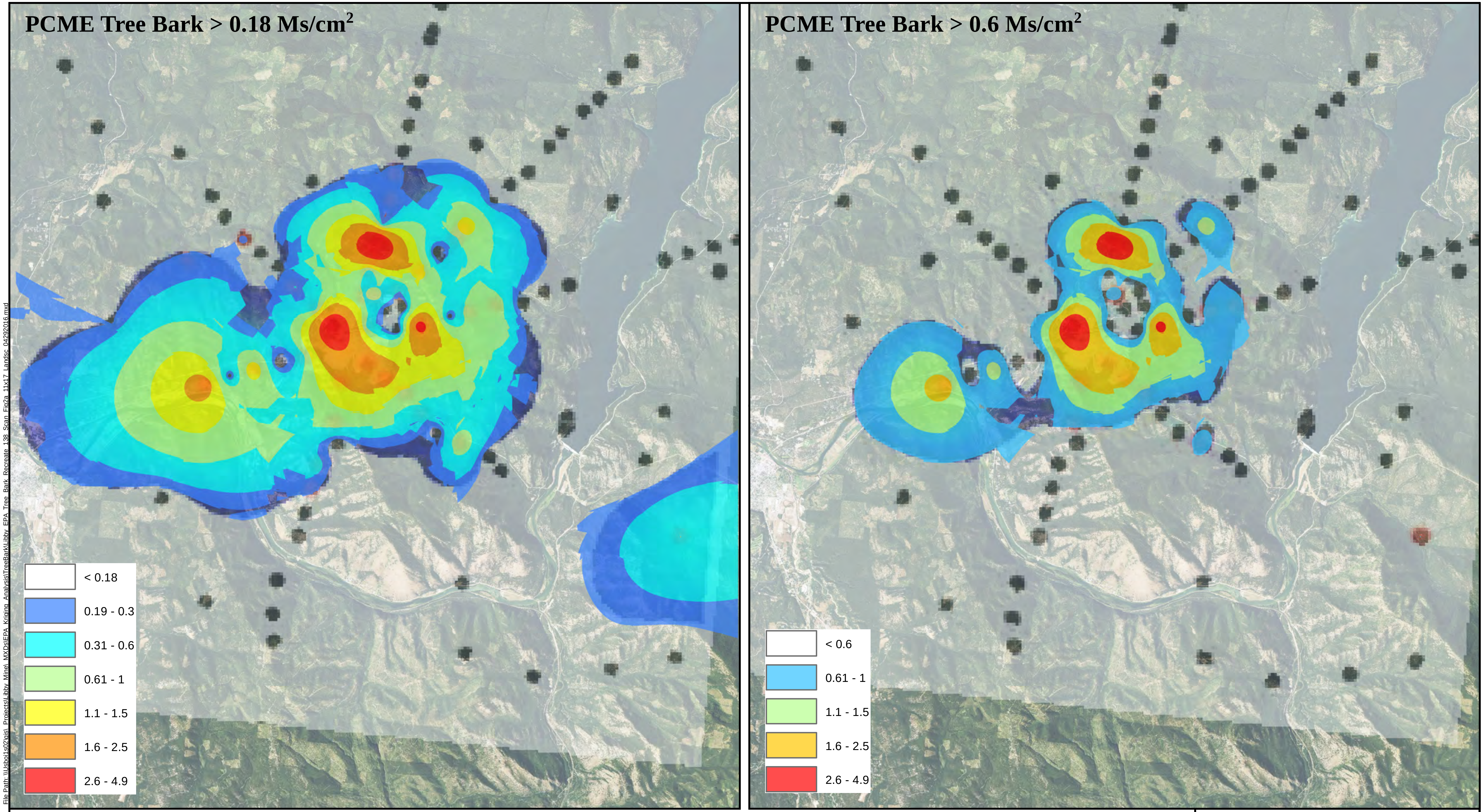
FIGURE A-1

Tree Bark PCME Concentration (EPA Rendering)

Libby Asbestos Superfund Site, OU3 Study Area
W.R. Grace & Co. - Conn.

Date Revised: 5/12/2016

MWH



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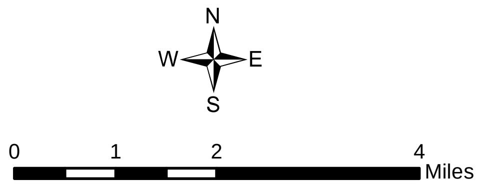
Spatial Analyst Extension



Base Image: National Agriculture Imagery Program, 2013

Coordinate System: NAD 1983 HARN StatePlane Montana FIPS 2500 Feet Intl

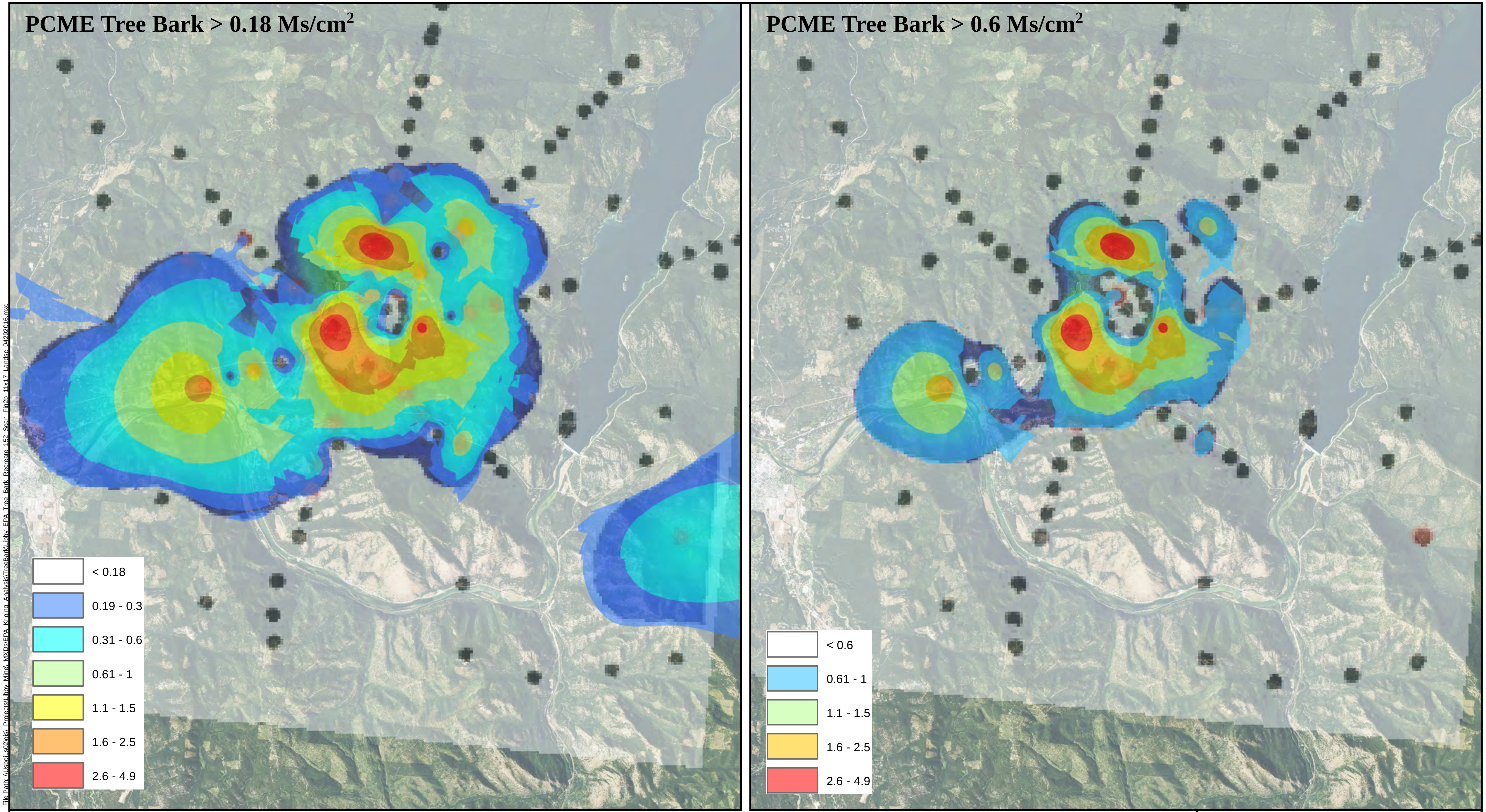
FIGURE A-2a

Tree Bark PCME Concentrations (EPA Raw Data with EPA Rendering in Background)

Libby Asbestos Superfund Site, OU3 Study Area
W.R. Grace & Co. - Conn.

Date Revised: 5/12/2016

MWH



PCME Tree Bark > 0.18 Ms/cm^2

PCME Tree Bark > 0.6 Ms/cm^2

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● Sample Location (> Threshold)

Kriging Software: ArcGIS 10.3.1
Spatial Analyst Extension

Base Image: National Agriculture Imagery Program, 2013

Coordinate System: NAD 1983 HARN StatePlane Montana FIPS 2500 Feet Intl

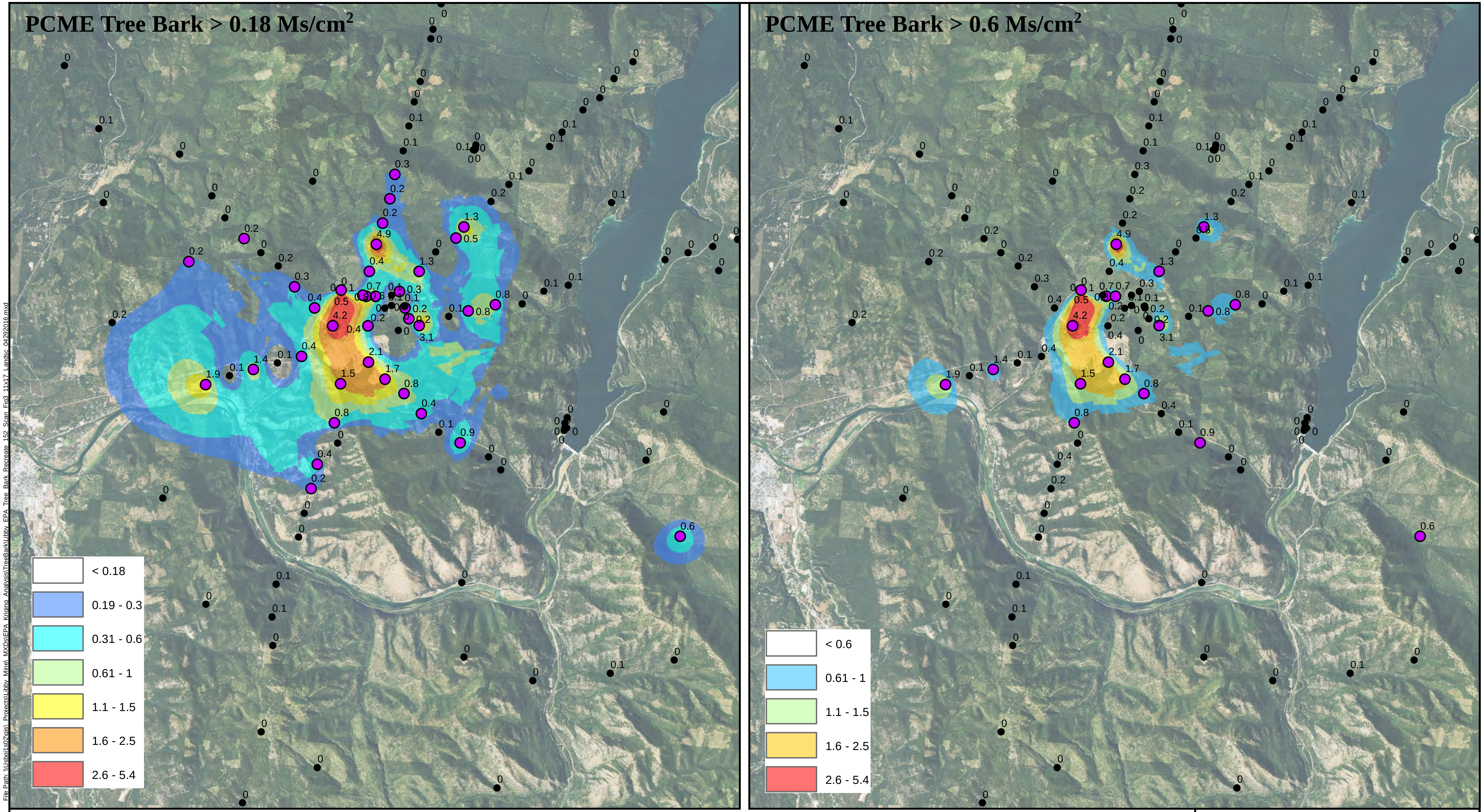
FIGURE A-2b

Tree Bark PCME Concentrations (MWH Raw Data with EPA Rendering in Background)

Libby Asbestos Superfund Site, OU3 Study Area
W.R. Grace & Co. - Conn.

Date Revised: 5/12/2016

MWH



PCME Tree Bark > 0.18 Ms/cm^2

PCME Tree Bark > 0.6 Ms/cm^2

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Legend

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● Sample Location (< Threshold)

Kriging Software: ArcGIS 10.3.1
Spatial Analyst Extension

Base Image: National Agriculture Imagery Program, 2013

Coordinate System: NAD 1983 HARN StatePlane Montana FIPS 2500 Feet Intl

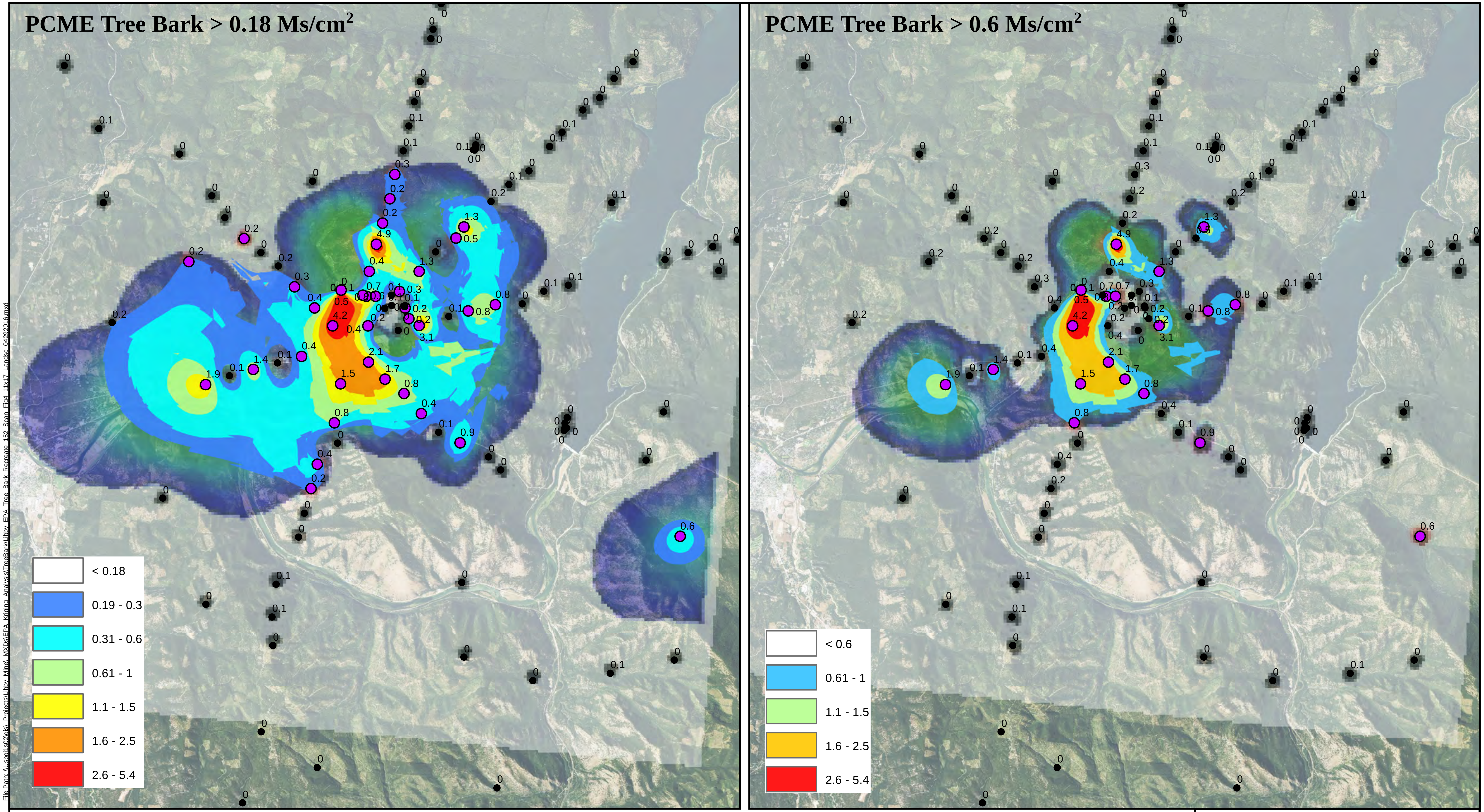
FIGURE A-3

Tree Bark PCME Concentrations (Log Transformed MWH Raw Data)

Libby Asbestos Superfund Site, OU3 Study Area
W.R. Grace & Co. - Conn.

Date Revised: 5/12/2016

MWH



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Legend

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● Sample Location (< Threshold)

Kriging Software: ArcGIS 10.3.1
Spatial Analyst Extension

N
W E
S

0 1 2 4 Miles

Base Image: National Agriculture Imagery Program, 2013

Coordinate System: NAD 1983 HARN StatePlane Montana FIPS 2500 Feet Intl

FIGURE A-4

**Tree Bark PCME Concentrations
(Log Transformed MWH Raw Data
with EPA Rendering in Background)**

Libby Asbestos Superfund Site, OU3 Study Area
W.R. Grace & Co. - Conn.

Date Revised: 5/12/2016

MWH

Attachment B

Analysis Figures

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Figure B-1. Northeast Duff PCME LA Concentrations by Distance and Duff and Soil Distrubance HQs by Distance

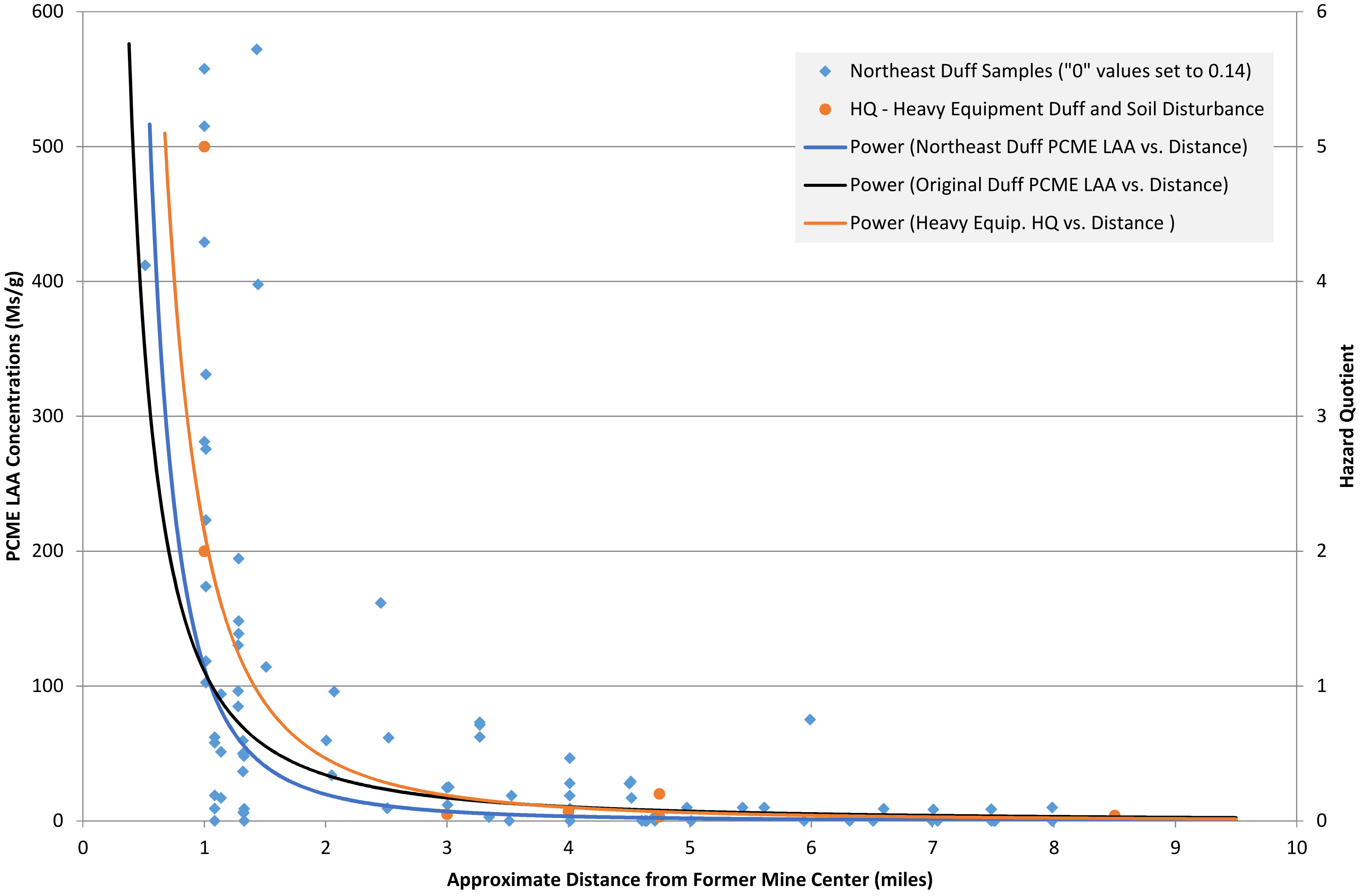


Figure B-2. Heavy Equipment ABS Mean PCME LAA Air Concentrations and Associated HQs vs. Distance

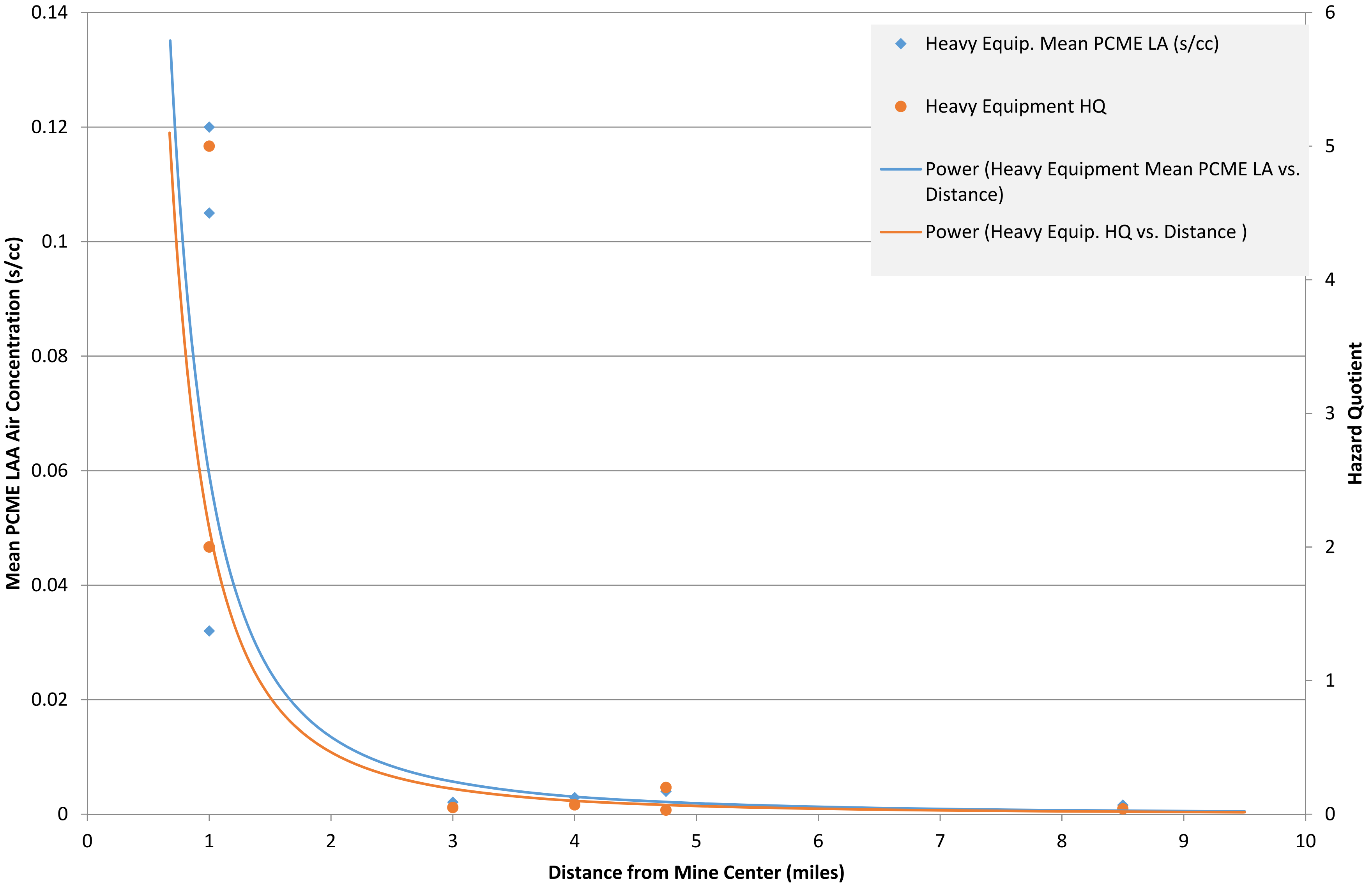
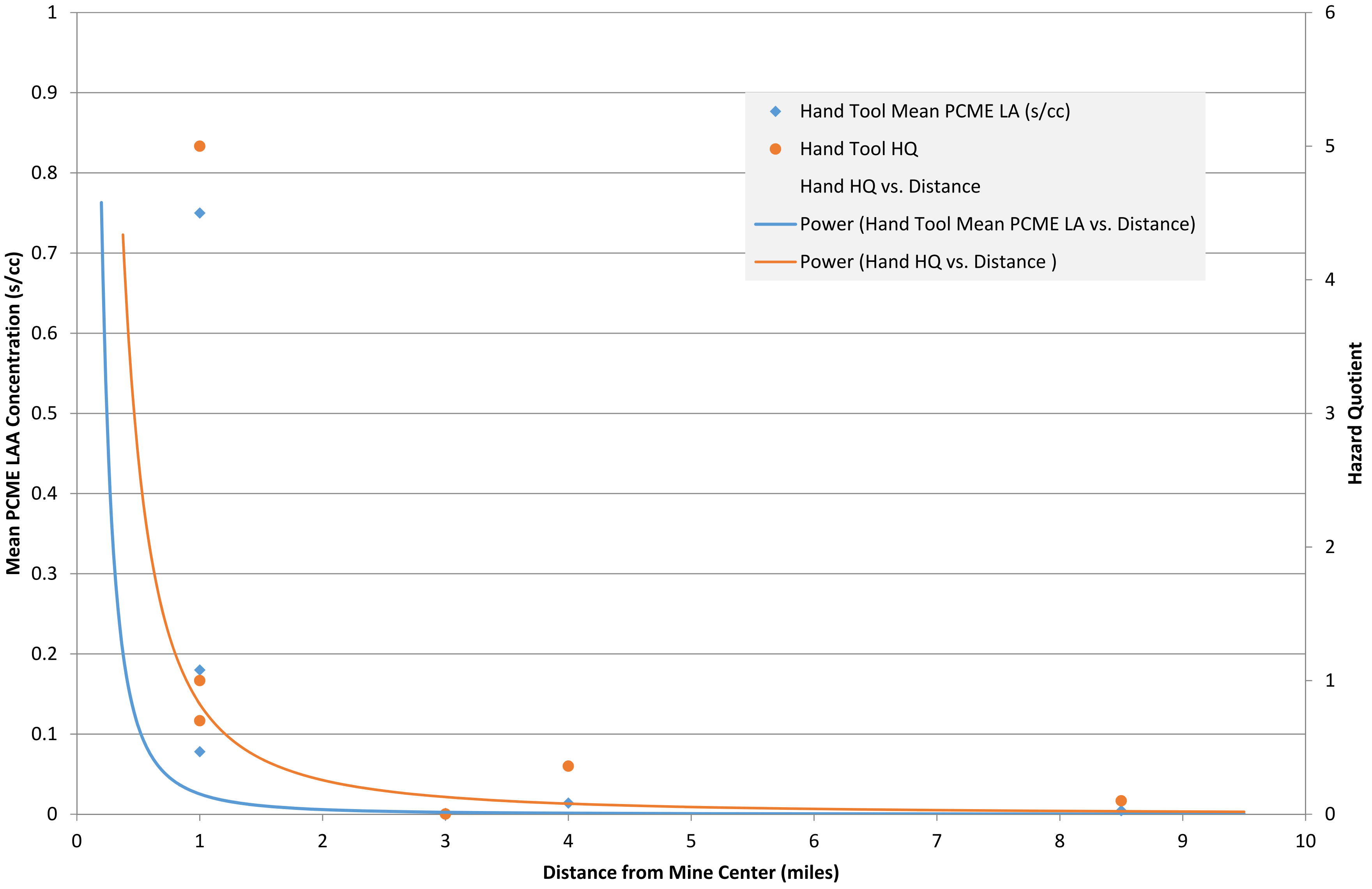


Figure B-3. Hand Tool ABS Mean PCME LAA Air Concentrations and Associated HQs vs. Distance



Attachment C

Critique of Fluidized Bed Asbestos Segregator (FBAS) for use in Obtaining the Content of "Asbestos" in "Asbestos-Contaminated" Soil

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Critique of fluidized bed asbestos segregator (FBAS) for use in obtaining the content of “asbestos” in “asbestos-contaminated” soil

Purpose: I was asked by WR Grace to:

> *Provide a formal review and critique of the proposed linear relationship between soil concentration and concentration of asbestos in air currently being held forth by EPA based on results of the Fluidized Bed Asbestos Separator (FBAS); please include*
> *a. whether the methodology is capable of being used for comparison to ABS activities; and*
> *b. the relationship of soil concentrations of asbestos, the results of ABS testing and the results of the FBAS as they relate to risk of asbestos inhalation.*

Specifically the above refers to soil and ABS testing given in USEPA (2014). Herein I will do all of this except discuss health-based implications as that is outside my field of expertise.

Introduction: The FBAS is a modified elutriation method based partially on the elutriator described in Webber et al. (2008). Webber et al. (2008) developed a method to remove (i.e., concentrate) the respirable amphibole fibers from a material referred to as Libby-six mix (Bellamy and Gunter, 2008). Their method was not intended to determine the amount of “asbestos” in the material, but to concentrate it for other health-based studies.

Januch et al. (2013) developed the FBAS with the intent of lowering the detection level of “asbestos” in different matrices; for our purposes we are concerned with soil as the matrix, and the “asbestos” of interest is “Libby amphibole.” They first created spiked samples of differing amounts of Libby amphibole added to a soil, and then sieved to pass 0.9 mm. Next 1-3 grams of the Libby amphibole / soil mixture was added to 19-17 grams of sand that was also sieved to the same size. However, the lower size limit for sand is approximately 0.6 mm; thus, the range of the sand size was much smaller than the range of the Libby amphibole / soil mixture. This method is then used on natural soils for several ABS scenarios associated with the Libby Asbestos Superfund site (USEPA, 2014).

Results: Table 1 (Januch et al., 2013) gives the results for the amount of Libby amphibole recovered in a mixture of amphibole / soil / sand for an unspiked sample and four spiked samples (i.e., 0.0001, 0.001, 0.005, and 0.01 mass % Libby amphibole). They directly observe s/g (i.e., structure per gram) by TEM and then calculate the recovered mass %.

In Figure 1 I have reproduced their Figure 2b that shows a linear relationship between spiked % and s/g. On the right hand side of Figure 1 I re-did their regression arriving at the same conclusion they make (i.e., there is a linear correlation between the spiked % and recovered s/g). Note we both arrived at the same regression statistics, but I plotted my results on a linear and not log scale. Also, note we both used a zero-intercept model. Figure 2 shows a correlation coefficient matrix, and pairwise plots, for the three parameters they list in Table 1 (Januch et al, 2013). As expected the data are all very highly correlated, with the mass % having a slightly lower r value than s/g, when compared to spiked %. This is logical as mass % was calculated from s/g.

Moving from the lab-based samples to natural samples there appears to be no correlation between soil concentration of LA (Libby amphibole) and s/g observed in ABS testing using the FBAS method. Figure 3 (left side) shows a plot of ABS and soil LA taken from USEPA (2014). The letters A-K are 11 sites in the Libby area where the FBAS method was used along with ABS in an attempt to correlate LA concentration in the soil to those found in air samples during ABS. Note that sample "A" has the highest ABS LA levels, yet the soil has one of the lowest, while sample "I" has one of the lowest ABS LA levels, yet the soil has the highest LA level.

To help quantify the observations made above, on the right side of Figure 3 is a correlation coefficient matrix, and pairwise plots, of the data given in USEPA (2014) Table 4-4 (i.e., the data used to produce the plot on the left side of Figure 3). Note there are no correlations between the concentrations of LA in the air (i.e., the ABS values) and the LA content in the soil. The only data that are correlated are the total LA and PCME LA, and since the latter is directly calculated from the former, this is to be expected. Figure 4 shows data from all 27 sampling events that are given in Tables 4-4, 4-5, and 4-7 (USEPA, 2014). Again there is no correlation between the LA in the air and soil when using the FBAS on natural materials.

Conclusions: Cleary the FBAS method shows a very high linear correlation for recovered "asbestos" for lab-prepared mixtures of Libby amphibole / soil / sand; this can be seen in Figures 1 and 2. However the method provides no correlation in natural samples; this can be seen in Figures 3 and 4. Probably the biggest issue is the difference in the size ranges of the particles for the lab-based samples as compared to the natural samples. Regardless, based upon analysis of the data in USEPA (2014), the FBAS is not capable of producing ABS results that correlate to LA in soil.

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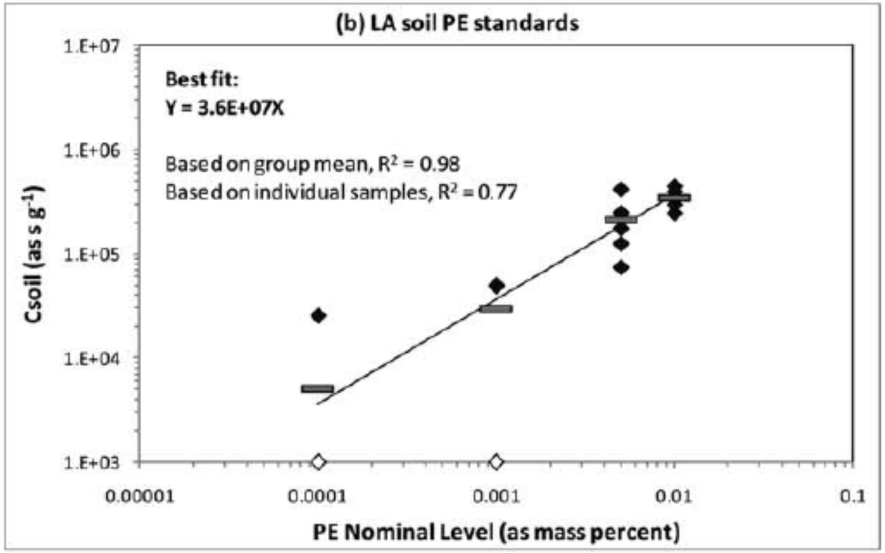
USEPA (2014) Background soil summary report Libby asbestos Superfund Site, Montana. U.S. Environmental Protection Agency, Region 8, pp. 190.

Webber, J.S., Blake, D.J., Ward, T.J., and Pfau, J.C. (2008) Separation and characterization of respirable amphibole fibers from Libby, Montana. Inhalation Toxicology, 733-740.

Figure 1. Plots and regression analysis from Table 1 (Januch et al., 2013) of Libby amphibole spiked "soils"



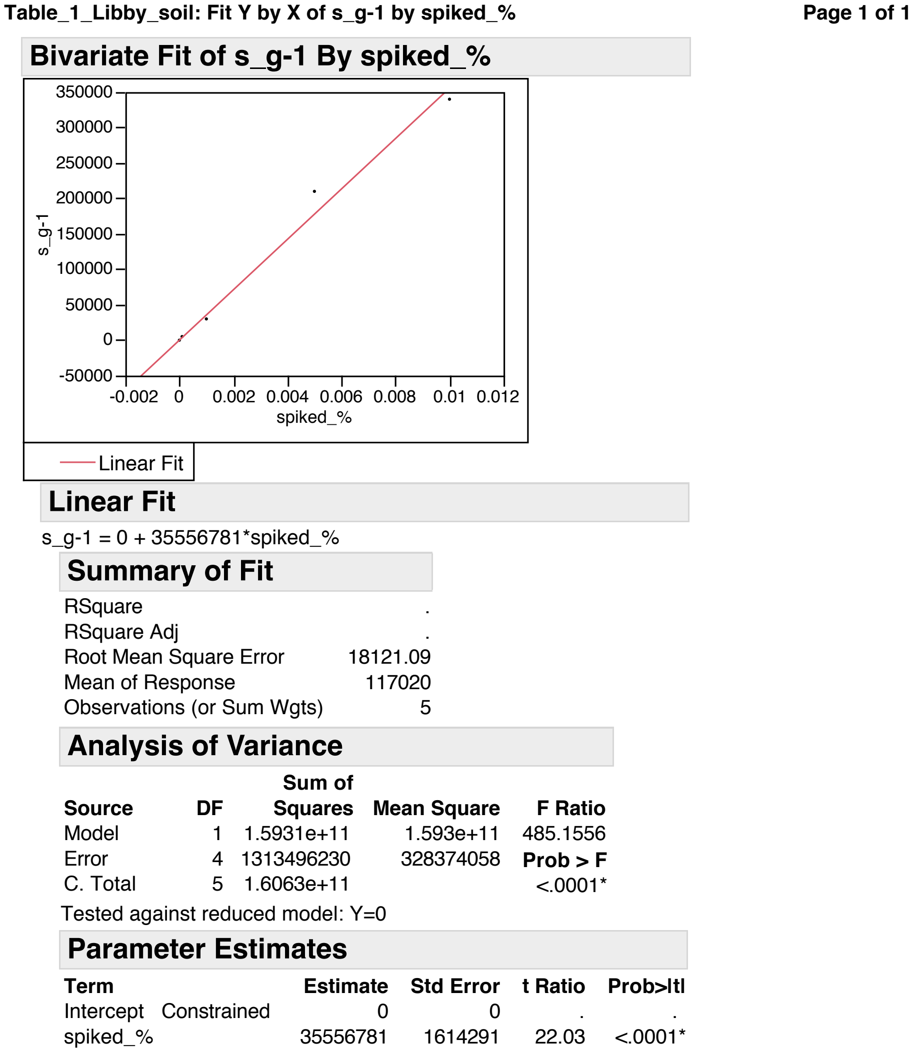


Table_1_Libby_soil: Fit Y by X of s_g-1 by spiked_%

Page 1 of 1

Bivariate Fit of s_g-1 By spiked_%

Linear Fit

s_g-1 = 0 + 35556781*spiked_%

Summary of Fit

RSquare	.
RSquare Adj	.
Root Mean Square Error	18121.09
Mean of Response	117020
Observations (or Sum Wgts)	5

Analysis of Variance

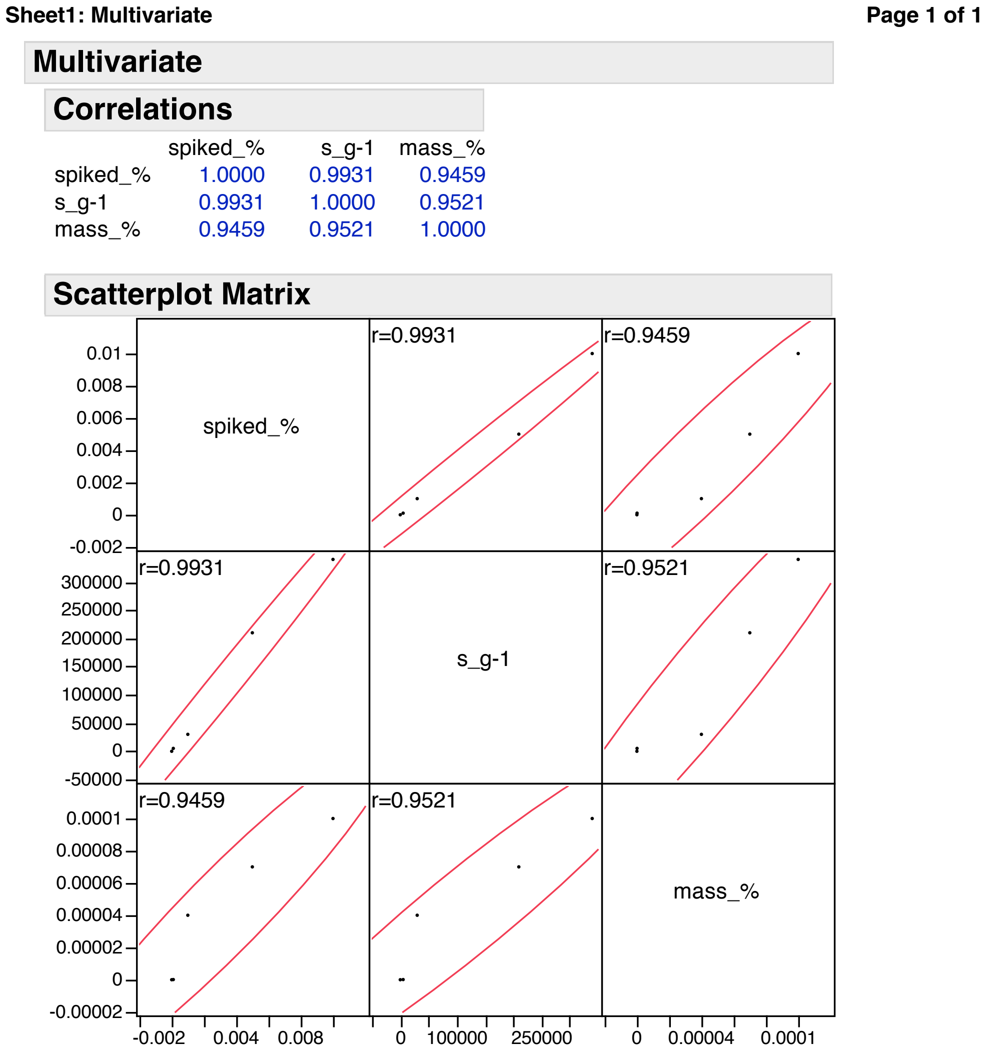
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Model	1	1.5931e+11	1.593e+11	485.1556
Error	4	1313496230	328374058	**Prob > F**
C. Total	5	1.6063e+11		<.0001*

Tested against reduced model: Y=0

Parameter Estimates

Term		**Estimate**	**Std Error**	**t Ratio**	**Prob>ltl**
Intercept	Constrained	0	0	.	.
spiked_%		35556781	1614291	22.03	<.0001*

Figure 2: Correlation coefficients from Table 1 (Januch et al., 2013) of Libby amphibole spiked “soils”



Sheet1: Multivariate **Page 1 of 1**

Multivariate

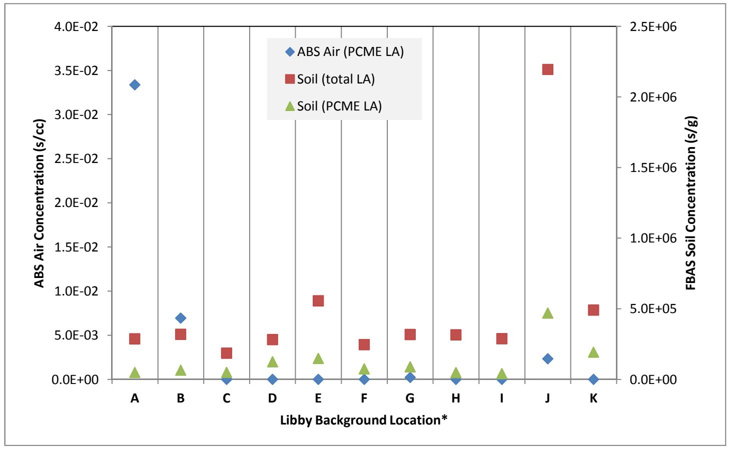
Correlations

	spiked_%	s_g-1	mass_%
spiked_%	1.0000	0.9931	0.9459
s_g-1	0.9931	1.0000	0.9521
mass_%	0.9459	0.9521	1.0000

Scatterplot Matrix

Figure 3. Figure 4-5 (USEPA, 2014) of background ABS soil results and correlation coefficients from data in Table 4-4 (USEPA, 2014)

FIGURE 4-5. 2011 Libby Background ABS Air and FBAS Soil Results



*See Figure 4-1 for a map of the Libby background locations.

ABS = activity-based sampling
FBAS = fluidized bed asbestos segregator
LA = Libby amphibole asbestos
PCME = phase contrast microscopy-equivalent
s/cc = structures per cubic centimeter
s/g = structures per gram

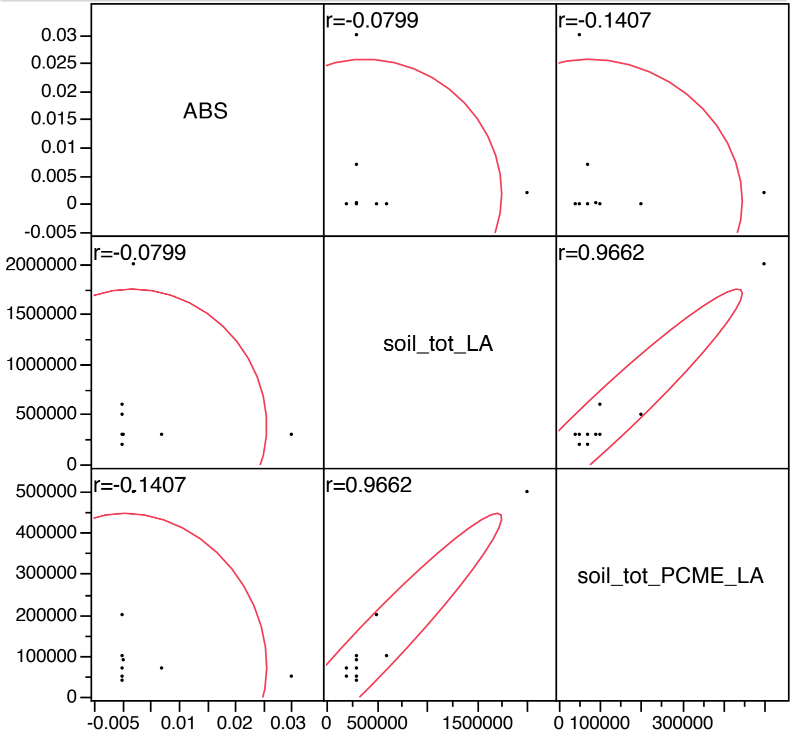
Table_4_4_Libby_background: Multivariate **Page 1 of 1**

Multivariate

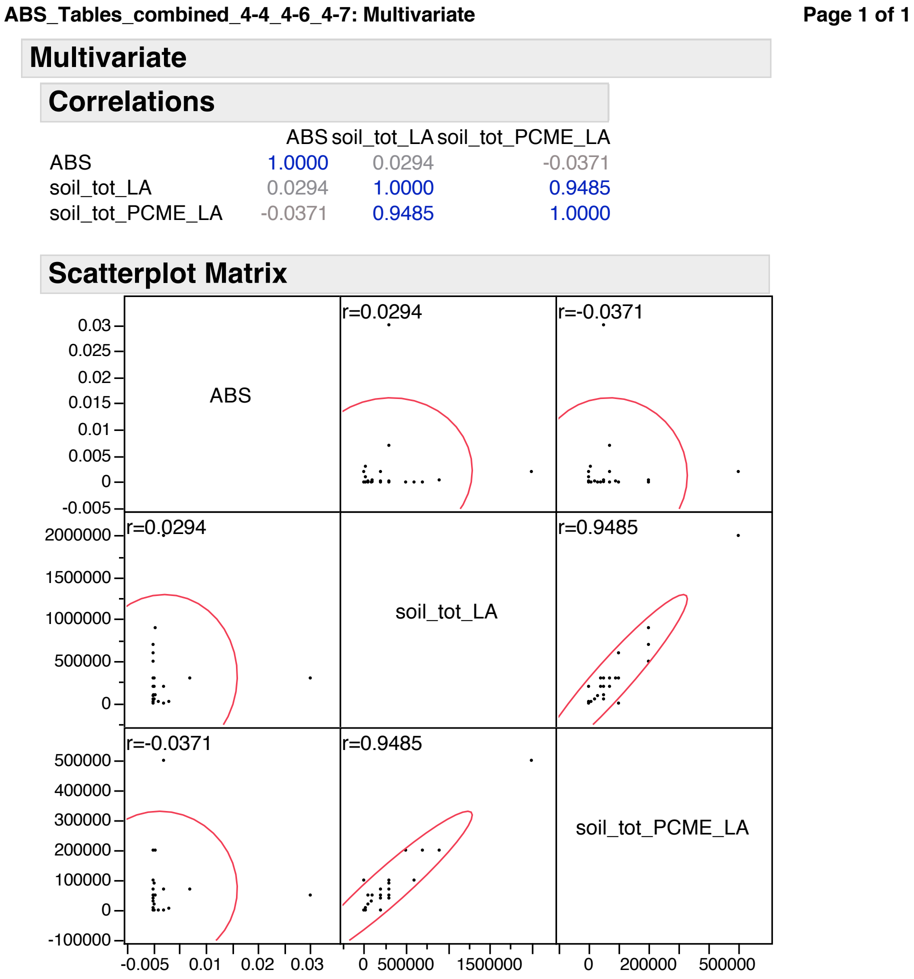
Correlations

	ABS	soil_tot_LA	soil_tot_PCME_LA
ABS	1.0000	-0.0799	-0.1407
soil_tot_LA	-0.0799	1.0000	0.9662
soil_tot_PCME_LA	-0.1407	0.9662	1.0000

Scatterplot Matrix



6 Figure 4. Correlation coefficients of ABS data from Tables 4-4, 4-6, and 4-7 (USEPA, 2014)



ABS_Tables_combined_4-4_4-6_4-7: Multivariate **Page 1 of 1**

Multivariate

Correlations

	ABS	soil_tot_LA	soil_tot_PCME_LA
ABS	1.0000	0.0294	-0.0371
soil_tot_LA	0.0294	1.0000	0.9485
soil_tot_PCME_LA	-0.0371	0.9485	1.0000

Scatterplot Matrix

Attachment D

Mickey E. Gunter Curriculum

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Curriculum Vitae of Mickey E. Gunter (5/13/16)

Professional Employment

2014 – Present	University Distinguished Professor, Geological Sciences, University of Idaho
2016 – Present	Acting / Interim Chair, Geography, University of Idaho
2008 – Present	Chair, Geological Sciences, University of Idaho
2008 – 2015	Marsh Professor-at-Large, University of Vermont
2007 - 2008	Acting / Interim Chair, Geological Sciences, University of Idaho
2007 (Fall)	Visiting Professor, Department of Earth Sciences, Sapienza University of Rome, Italy
2002 - 2014	Professor, Geological Sciences, University of Idaho
2002 - Present	Affiliate Professor, Materials Science, University of Idaho Affiliate Professor, Environmental Sciences, University of Idaho
2002 (Spring)	Visiting Professor, Graduate School of Human and Environmental Studies, Kyoto University, Japan
1996 (Fall)	Visiting Scientist, Laboratory for Crystallography, University of Bern, Switzerland
1995 - 2002	Associate Professor, Geological Sciences, University of Idaho
1989 - 1995	Assistant Professor, Geology, University of Idaho
1987 - 1989	Post-Doctoral Fellow, Geological Sciences, Virginia Tech
1986 - 1987	Design Engineer, Electro-Tec Corporation, Blacksburg, Virginia
1982 - 1984	Project Manager, Geology, Southern Illinois University
1981 - 1982	Researcher, Geology, Southern Illinois University
1981	Research Assistant, Geology, University of New Mexico

Education

Ph.D. (1987)	Virginia Tech Geological Sciences, Major field: Optical Mineralogy Dissertation: Refractometry by total reflection
M.S. (1982)	Virginia Polytechnic Institute and State University Geological Sciences, Major field: Optical Mineralogy Thesis: Optical, X-ray, and chemical properties of andalusite-kanonaite series
B.S. (1979)	Southern Illinois University at Carbondale Major: Geology, Minor: Mathematics

Awards, Honors, Scholarships

Best paper (as 2nd author), Microscopy and Microanalysis, Materials Applications category (2014)
Awarded University of Idaho Distinguished Professorship (2014)
Émile M. Chamot Award (presented by the State Microscopy Society of Illinois, 2012)
The new mineral gunterite ($\mathrm{Na_4(H_2O)_{16}(H_2V_{10}O_{28})}\square 6\mathrm{H_2O}$) named in my honor (2011)
Marsh Professor-at-Large position at the University of Vermont (2008-2015)
STAR Award (presented by the Moscow, Idaho Chamber of Commerce, 2005)
Mineralogical Society of America Distinguished Lecturer (2002-2003)
Most Popular Faculty Member (selected by UI students, 2001-2002)
Elected Fellow in Mineralogical Society of America (1999)
Faculty Recognition Award presented by UI Student-Athletes (1999)
Professor of the Month, University of Idaho KD Chapter (1998)
Teaching Excellence Award, University of Idaho (1998)
Faculty Excellence Award, NROTC, University of Idaho (1998, 2008, 2009)
Commencement Speaker, McLeansboro High School, McLeansboro, Illinois (1994)
Idaho Alpha Chapter of Pi Beta Phi, Faculty Excellence Award (1990, 1991, 1995)
Electro-Tec Fellowship (1986)
Virginia Mining Mineral Resource Research Institute Fellowship (1980)

Member Illinois Beta Association of Phi Beta Kappa (1979)
Outstanding Senior in Department of Geology, S.I.U. (1979)
National Association of Geology Teachers Summer Field Camp Scholarship (1978)
Leo Kaplan Memorial Scholarship (1978)
Mr. and Mrs. Richard J. Feeney Scholarship (1977)
Participant, National Science Foundation Undergraduate Research Program (1976)

Professional Organizations and Service

Talc methods expert panel (U.S. Pharmacopeial, 2016-)
ASBOG Council of Examiners (spring 2015)
Idaho State Board of Registration for Professional Geologists (2012-2017)
Board Member, International Medical Geology Institute. Ankara, Turkey (2012-2014)
Guest Associate Editor for "Minerals in the Human Body" virtual issue of the American Mineralogist (2011-)
Mineralogy Panel and Reviewer, Institute of Medicine and National Research Council, Workshop on the NISOH research roadmap on asbestos fibers and elongated mineral particles (2009)
Editorial Board, Periodico di Mineralogia (2008-2015)
Associate Editor, Handbook of Mineralogy, amphiboles and zeolites (2007-)
Executive Board Member and Secretary, Mineralogical Society of America (2007-2009, 2009-2011)
Member ATSDR expert panel on asbestos biomarkers (2006)
Member EPA review committee World Trade Center dust screening method (2005)
Co-organizer (with Scott Wood) of the 2005 Goldschmidt Conference
Councilor, Mineralogical Society of America (2003-2006)
Associate Editor, Canadian Mineralogist (1999-2002, 2003-2006)
Member: Geochemical Society, Geological Society of America, Mineralogical Society of America, Mineralogical Association of Canada, National Association of Geoscience Teachers, Yellowstone-Bighorn Research Association

University Service

Faculty Grand Marshal for UI commencement (2010-2015)
Idaho Geological Survey Advisory Board (2007-2017)
Space Governance Group (2006-2009)
IT Advisory Group (2006-2007)
Strategic Program Implementation Team (2006-2007)
Retirees Health Benefits Committee (2006-2007)
Established "Outstanding Staff Teamwork" endowment, University of Idaho (2006)
Budget and Finance Committee (2004-2007, chair 2006-2007)
University Promotions Committee (2002-2003)
Teaching-Learning Center Renovation (2001-2003)
Academic Technology Strategic Taskforce (2001-2003)
Institutional Planning and Budget Advisory Committee (2000-2002)
Faculty and Staff Campaign for Idaho (2000-2002)
Goldwater scholarship committee (1999-2002)
Radiation Safety Committee (2000-2002)
University Committee for General Education (1998-2001, 2002-2003)
Integrated Science Taskforce (1999-2000)
Retention Taskforce (1997-1999)
Instructional Media Services Advisory Committee (1998-2000)
Graduate Council (1997-2000)
Teaching Enhancement Committee (First chair 1993-1994)
Faculty Council (1991-1994, 2004-2007)
Five-year Planning Committee for Student Computer Fee (1993-1994)
Fiscal Emergency Committee (1991-1994)
Faculty Advisor, Geology Club (1989-2016)
Undergraduate Advisor, Department of Geological Sciences (1995-2017)

Books, book chapters, and electronic media

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Gunter, M.E. and Bloss, F.D. (1982) Andalusite-kanonaite series: Lattice and optical parameters. American Mineralogist, 67, 1218-1228.

Grants & Contracts

Acquisition of a dual beam FIB/SEM instrument with extended EBSD/EDS capabilities. M.J. Murdock Charitable Trust (Suat Ay – PI, co-PI with six others, 2015-2018, $444,377).

Development of a short course in advanced optical mineralogy. University of Rome, Tre, Rome, Italy (October 2010, 2,000 Euros = $2,800).

Acquisition of equipment to support environmental materials characterization. National Science Foundation (Greg Druschel - PI, co-PI with three others, 2009-2010, $207,000).

Scaffolding effective practice for use of animations in teaching mineralogy and physical geology. National Science Foundation (2009-2011, $28,826).

Redox ratios by Fe-XANES. National Science Foundation (2007-2011, $68,049).

Visiting professor, Department of Earth Sciences, Sapienza, University of Rome, Italy (September 2007, 3,707 Euros - $5,050).

Feldspars Forensics in northern Idaho. Stoney Forensics Incorporated, Clifton, Virginia (2006-2008, $72,137).

Acquisition of an inductively coupled plasma-atomic emission spectrometer and an ion chromatograph. National Science Foundation (Scott Wood - PI, co-PI with three others, 2006-2007, $127,711).

Development of a 3-D Interactive Mineralogy Textbook. National Science Foundation (M.D. Dyar - PI, co-PI with one other, 2002-2007, $417,244).

In situ use of microwaves to determine the water content of minerals. NASA (2004-2005, $15,000).

The lung: A reaction chamber for minerals. National Institutes of Health (with Scott Wood, 2002-2006, $146,000).

Small Travel Grant Program. University of Idaho (June 2002, $900).

Visiting faculty, Graduate School of Human and Environmental Sciences, Kyoto University, Kyoto, Japan (April 2002, 1,432,500 Japanese Yen - $11,460).

The lung: A reaction chamber for asbestos minerals. University of Idaho Research Council (with Scott Wood, July 2001, $8,000).

Mineralogical characterization of phosphate ore deposits. J.R. Simplot Co. (December 2000, $2,800).

Preparation of reference mineral sets (renewal). R.P. Cargille Laboratories (August 2000, $3,000).

Development of a 3-D Interactive Mineralogy Textbook. National Science Foundation (M.D. Dyar – PI, co-PI with one other, 2000-2001, $75,000).

Development of digital videos for in-class and web use. Office of Teaching Enhancement, University of Idaho (September 2000, $2,500).

Mineralogical characterization of southeast Idaho phosphate deposits. United States Geological Survey (October 1998, $39,500).

Characterization of natural and cation-exchanged clinoptilolite (renewal). British Nuclear Fuels Laboratory (July 1997, $91,192).

Preparation of reference mineral sets (renewal). R.P. Cargille Laboratories (August 1997, $3,000).

Small Travel Grant Program. University of Idaho (September 1996, $900).

IdaHOES - Idaho Hands On Elementary Science. Dwight D. Eisenhower Higher Education Competitive Grant Program (with Mike Odell, January 1996, $34,207).

Multimedia in a large lecture class: Computer Resources for Geol 101 and 102. Office of Teaching Enhancement, University of Idaho (with Dennis Geist, September 1995, $3,125).

Health effects of crystalline silica. Idaho State Board of Education (July 1995, $34,300).

Characterization of natural and cation-exchanged clinoptilolite. British Nuclear Fuels Laboratory (January 1995, $37,596).

North Idaho hands-on elementary science. Dwight D. Eisenhower Higher Education Competitive Grant Program (with Mike Odell, January 1995, $30,228).

Acquisition of a portable, in-class, video macroscope system. Office of Teaching Enhancement, University of Idaho (December 1994, $3,149).

Preparation of reference mineral sets (renewal). R.P. Cargille Laboratories (August 1994, $3,000).

Travel grant. Associated Western Universities - Department of Energy (November 1993, $1,500)

Small Travel Grant Program. University of Idaho (August 1993, $592).

Preparation of reference mineral sets (renewal). R.P. Cargille Laboratories (August 1993, $3,000).

Integrated science for elementary teachers. National Science Foundation (January 1993, $511,821, PI with four Co-PIs).

Preparation of reference mineral sets. R.P. Cargille Laboratories (August 1992, $3,000).

U.S. - Switzerland cooperative research on zeolite dehydration. National Science Foundation (July 1992, $5,000).

Visiting faculty, Laboratory for Chemical and Mineralogical Crystallography, University of Bern, Bern, Switzerland (May 1992, 5,500 Swiss Francs - $4,100).
Powder and single crystal x-ray diffractometers. M.J. Murdock Charitable Trust (with J. M. Shreeve, December 1991, $206,000,).
Critical risk assessment honors seminar. Honors Program, University of Idaho (December 1991, $750).
Small Travel Grant Program. University of Idaho (August 1991, $473).
Development of Bloss Automated Refractometer. McCrone Research Institute, Chicago, Illinois (August 1991, $3,000).
Gem feldspars and health hazards of zeolites. Idaho Mining and Minerals Resource Research Institute (May 1991, $5,000).
Partial support for two crystal chemical studies. Idaho Mining and Minerals Resource Research Institute (July 1990, $2,000).
Research Fellowship, Laboratory for Chemical and Mineralogical Crystallography, University of Bern, Switzerland (May 1990, 4,500 Swiss Francs - $3,350).
Establishment of a spindle stage light microscopy laboratory for mineral optical characterization. Idaho NSF-EPSCoR program (April 1990, $9,900).
Natrolite group zeolites: relationship between optical orientation and crystal chemistry. University of Idaho Research Council (July 1990, $4,950).
Small Travel Grant Program. University of Idaho (October 1989, $600).
Acquisition of an 80386 computer system. University of Idaho Research Council (July 1989, $4,701).
Development of techniques for obtaining and storing premium coal samples. Gas Research Institute, Chicago, Illinois (March 1983, $155,000).

Other Publications

Gunter, M.E. (2014) Book review: "A History of Geology and Medicine." Elements, 394.
McNamee, B.D. and Gunter, M.E. (2013) Cover photograph. The Microscope, 61.
Gunter, M.E. (2012) Forward to: "WWII, Mineralogy, and Me: A Memoir," by F. Donald Bloss. Mineralogical Society of America.
Gunter, M.E. (2009) Response to "A view from a different hilltop." Elements, 270.
Bellatreccia, F., Camara, F., Bindi, L., Della Ventura, G., Mottana, A., Gunter, M.E., and Sebastiani, M. (2009) La Fantappieite, nuovo minerale del gruppo cancrinite-sodalite. Il Cercapietre, 1-2, 6-15.
Mazziotti-Tagliani, S., Gianfagna, A., Andreozzi, G.B., Paoletti, L., Gunter, M.E., Pacella, A., and Burragato, F. (2009) Asbestos in terms of classical concept of standard reference materials. World Asbestos Conference, Taormina, Sicily.
Gunter, M.E. (2009) The need to apply mineralogical common sense to the definition of NOA and other misused terms when dealing with "asbestos" issues. World Asbestos Conference, Taormina, Sicily.
Gunter, M.E. and Gunter, M.A. (2009) Photographs and captions for "Grandma Deem's Marriage Notices." The Hamilton County Historical Society, McLeansboro, Illinois.
Gunter, M.E. (2007) Cover photograph. Journal of Geoscience Education, 55, #4.
Gunter, M.E. (2007) Book review: "Medical Mineralogy and Geochemistry, RiMG, 64." The Geochemical News, #133.
Gunter, M.E. (2005) Lattices and Crystal systems. AGI Datasheets, American Geological Institute, Alexandria, Virginia
Wood, S.A. and Gunter, M.E. (2005) Making a meeting of the minds: Reflections on the organization of the 2005 Goldschmidt Conference. Triple Point article, December, 2005, Elements.
Wood, S.A. and Gunter, M.E. (2005) Epilogue: The 15th Annual V.M. Goldschmidt Conference, May 20-25, 2005 University of Idaho, Moscow, Idaho, USA. The Geochemical News, #124, 5-11.
Crane, D., Ehrenfeld, F., Gunter, M.E., McConnell, E., Su, S.C., Webber, J., and Willhelmi, J. (2005) Peer review of the U.S. Environmental Protection Agency's "Final Report on the World Trade Center (WTC) dust screen study." EPA Contract # 68-C-02-060, USEPA, Washington DC, 114 p.
Gunter, M.E. (2005) A lucky break for polarization: The optical properties of calcite. µ•Notes, State Microscopical Society of Illinois, 5, 8-18 (republished with slight modifications from: ExtraLapis, Calcite, 4, 40-45, East Hampton, Connecticut)
Gunter, M.E. (2004) Cover photograph. Journal of Geoscience Education, 52, #1.
Gunter, M.E. (2003) Cover illustration. The Microscope, 51, #3.

Gunter, M.E. (2003) Book review: "Polarized Light Optics: The New Physics of the Photon." Canadian Mineralogist, 41, 1295-1296.

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Baumgart, D.M., Gammon, S.D., Gunter, M.E., Kearney, R.J., and Oliver, D.J. (1994) Developing an integrated science course for elementary education majors. Washington State Section of American Association of Physics Teachers. Pullman, Washington, October, 1994.

Bitterwolf, T.E., Gammon, S.D., Gunter, M.E., Kearney, R.J., Klowden, M.J., and Oliver, D.J. (1994) Developing an integrated science course for elementary education majors. Abstracts and Program for the 13th Biennial Conference on Chemical Education.

Weiszburg, T.G. and Gunter, M.E. (1994) Hydration effects on optical properties of heulandite-group zeolites. 16th General Meeting of the International Mineralogical Association, Pisa, Italy.

Gunter, M.E. (1993) Integration of analytical methods in introductory mineralogy. Geological Society of America Abstracts with Programs 25, #6, 348.

Gunter, M.E., Knowles, C.R. and Schalck, D.K. (1991) Intergrown natrolite/mesolite "single" crystals from the Columbia River Basalts. Geological Society of America Abstracts with Programs, 23, #5, 219.

Armbruster, T. and Gunter, M.E. (1991) Stepwise dehydration of a natural clinoptilolite: A single-crystal X-ray study at 100 K. American Geophysical Union Spring Meeting 1991.

Johnston, C.L., Gunter, M.E., and Knowles, C.R. (1991) Ponderosa Mine sunstone. International Gemological Symposium, Los Angeles, California.

Gunter, M.E. (1990) Variation in optical class and optical orientation: the rule not the exception. F.D. Bloss Symposium, Blacksburg, Virginia.

Gunter, M.E. and Ribbe, P.H. (1989) Zeolites: Structural and chemical interpretations of optical properties. Geological Society of America Abstracts with Programs, 21, #6, 117-118.

Gunter, M.E. (1988) Refractometry by total reflection. The Microscope, 36, 234.

Gunter, M.E. (1988) Dispersion equations and birefringence measurements. The Microscope, 36, 233.

Gunter, M.E. and Bloss, F.D. (1982) Andalusite-kanonaites: Optical and unit cell data. 13th General Meeting of the International Mineralogical Association, Varna, Bulgaria.

Courses Taught at UI (exclusive of thesis & dissertation credits and directed studies)

Sem	Class	Students	Credits	Numerical* evaluation
Sp 15	Geol 249, Mineralogy & Optical Mineralogy	18	4	4.0, 3.8
Sp 14	Geol 249, Mineralogy & Optical Mineralogy	19	4	4.0, 3.8
Sp '13	Geol 249, Mineralogy & Optical Mineralogy	23	4	3.8, 3.6
Sp '12	Geol 249, Mineralogy & Optical Mineralogy	21	4	3.9, 3.5
Sp '11	Geol 249, Mineralogy & Optical Mineralogy	29	4	3.8, 3.6
Sp '10	Geol 249, Mineralogy & Optical Mineralogy	16	4	3.8, 3.8

	Geol 550, Advanced Mineralogy	8	3	NA
Sp '09	Geol 249, Mineralogy & Optical Mineralogy	14	4	3.7, 3.3
Sp '08	Geol 249, Mineralogy & Optical Mineralogy	15	4	3.7, 3.5
Sp '07	Geol 249, Mineralogy & Optical Mineralogy	19	4	3.1, 3.0
Fa '06	Buyout to finish NSF-funded mineralogy book			
Sp '06	Geol 249, Mineralogy & Optical Mineralogy	9	4	4.0, 3.8
Fa '05	Geol 101, Physical Geology	294	4	3.6, 3.3
Sp 05	Geol 249, Mineralogy & Optical Mineralogy	14	4	4.0, 3.9
Fa '04	Geol 101, Physical Geology	261	4	3.7, 3.5
Sp '04	Geol 249, Mineralogy & Optical Mineralogy	20	4	3.8, 3.9
	Geol 201, Computer Geology	13	2	3.9, 3.7
Fa '03	Sabbatical leave			
Sp '03	Geol 249, Mineralogy & Optical Mineralogy	15	4	3.9, 3.9
	Core 201, Minerals and human health (honors)	15	3	3.8, 3.7
	Geol 301, Computer Geology -*N*	12	2	3.7, 3.5
Fa '02	Geol 550, Advanced Mineralogy -*T*	6	3	NA
Sp '02	Geol 249, Mineralogy & Optical Mineralogy	17	4	NA
Fa '01	Geol 101, Physical Geology	340	4	3.8, 3.5, 3.8, 3.7, 3.9
	Geol 550, Advanced Mineralogy -*T*	6	3	NA
Sp '01	Geol 249, Mineralogy & Optical Mineralogy	23	4	3.4, 3.1, 3.4, 3.4, 3.7
	Core 201, Minerals and human health -*N*	43	3	3.1, 3.4, 3.4, 3.4, 3.7
Fa '00	Geol 101, Physical Geology	324	4	3.5, 3.3, 3.3, 3.2, 3.4
	Geol 550, Advanced Mineralogy -*T*	8	3	NA
Su '00	Geol 101, Physical Geology-*T*	39	4	NA
	Geol 401, Field Camp – *T*	30	6	NA
Sp '00	Geol 249, Mineralogy & Optical Mineralogy	22	4	3.5. 3.4, 3.5, 3.5, 3.7
	Geol 552, X-ray analysis in geology -*T*	11	3	NA
Fa '99	Geol 101, Physical Geology	400	4	3.7, 3.3, 3.5, 3.5, 3.7
	Geol 499, X-ray diffraction of phosphates	1	1	NA
Su '99	Geol 101, Physical Geology-*T*	36	4	NA
	Geol 401, Field Camp – *T*	30	6	NA
Sp '99	Geol 249, Mineralogy & Optical Mineralogy	22	5	3.5, 3.4, 3.5, 3.5, 3.7
	Chem 565, X-ray diffraction - *N,T*	4	3	NA
Fa '98	Geol 101, Physical Geology	400	4	3.7, 3.5, 3.5, 3.4, 3.7
	Geol 550, Advanced Mineralogy- *N*	9	3	NA

Su '98	Geol 101, Physical Geology-*T*	39	4	NA
	Geol 401, Field Camp – *T*	30	6	NA
Sp '98	Geol 249, Mineralogy & Optical Mineralogy	18	5	3.0, 3.2, 3.1, 3.0, 3.4
Fa '97	Geol 101, Physical Geology	390	4	3.8, 3.6, 3.6, 3.5, 3.8
Su '97	Geol 101, Physical Geology	22	3	NA
	Geol 336, Juneau Ice Field	30	6	NA
	Geol 401, Field Camp – *T*	30	6	NA
Sp '97	Geol 249, Mineralogy & Optical Mineralogy	13	5	3.7, 3.5, 3.7, 3.8, 3.7
	Geol 504, Zeolite Crystallography - *N*	4	3	NA
Fa '96	Sabbatical leave			
Su '96	Geol 336, Juneau Ice Field	30	6	NA
	Geol 401, Field Camp – *T*	30	6	NA
Sp '96	Geol 249, Mineralogy & Optical Mineralogy	13	5	3.5, 3.6, 3.8, 3.5, 3.8
	Inter 103, Integrated Science - *O,T*	24	4	3.7, 3.8, 3.8, 3.7, 3.7
Fa '95	Geol 101, Physical Geology	400	3	3.8, 3.4, 3.7, 3.5, 3.8
	Inter 103, Integrated Science-*O,T*	20	4	3.5, 3.2, 3.6, 3.5, 3.7
Sp '95	Geol 249, Mineralogy & Optical Mineralogy	19	5	3.8, 3.7, 3.7, 3.4, 3.8
	Inter 103, Integrated Science - *O,T*	27	4	2.4, 2.7, 2.8, 2.7, 2.9
Su '95	Geol 336, Juneau Ice Field	30	6	NA
	Geol 401, Field Camp – *T*	30	6	NA
Fa '94	Geol 101, Physical Geology	400	3	3.8, 3.7, 3.7, 3.7, 3.8
	Inter 103, Integrated Science-*N,O,T*	25	4	3.0, 3.2, 3.2, 3.3, 3.5
	Inter 504, Integrated Science-*N,O,T*	5	2	NA
Su '94	Geol 101, Physical Geology	40	3	3.8, 3.4, 3.8, 3.5, 3.9
Sp '94	Geol 249, Mineralogy & Optical Mineralogy	24	5	3.6, 3.9, 3.8, 3.2, 3.9
Fa '93	Geol 101, Physical Geology	369	3	3.8, 3.3, 3.7, 3.4, 3.8
	Geol 504, Advanced Mineralogy-*N*	6	3	3.3, 3.5, 3.7, 4.0, 3.8
Su '93	Geol 101, Physical Geology	33	3	3.5, 3.4, 3.8, 3.8, 3.9
	Geology of the Salmon River (Conferences & Enrichment)	6	NA	NA
Sp '93	Geol 249, Mineralogy & Optical Mineralogy-*N*	16	5	3.8, 3.9, 3.7, 3.5, 3.8
	Geol 400, Honors Seminar-*N,O*	6	1	4.0, 4.0, 4.0, 3.5, 4.0
Fa '92	Geol 101(1), Physical Geology	147	3	3.9, 3.4, 3.7, 3.4, 3.9
	Geol 101(2), Physical Geology	268	3	3.8, 3.4, 3.7, 3.4, 3.8
Su '92	Geol 101, Physical Geology	21	3	3.4, 3.4, 3.8, 3.6, 3.8
	Geology of the Salmon River (Conferences & Enrichment)	18	NA	NA
Sp '92	Geol 251, Optical Mineralogy-*N*	14	3	3.7, 3.7, 3.7, 3.4, 3.8

Fa '91	Geol 101(1), Physical Geology	141	3	3.7, 3.3, 3.7, 3.4, 3.8
	Geol 101(2), Physical Geology	218	3	3.7, 3.3, 3.6, 3.4, 3.7
	Geol 250, Mineralogy	15	4	3.7, 3.3, 3.6, 3.5, 4.0
Su '91	Geology of the Salmon River (Conferences & Enrichment)	22	NA	NA
Sp '91	Geol 451, X-ray Diffraction	2	1	NA
Fa '90	Geol 101(1), Physical Geology	181	3	3.3, 3.6
	Geol 101(2), Physical Geology	214	3	3.2, 3.7
	Geol 250, Mineralogy-*N*	11	4	3.9, 4.0
Sp '90	Geol 101(1), Physical Geology-*N*	149	3	3.2, 3.5
	Geol 101(2), Physical Geology-*N*	171	3	3.1, 3.6
	Geol 451, X-ray Diffraction-*N*	3	1	NA
Fa '89	Geol 258, Minerals and Rocks-*N*	11	4	3.5, 3.6
	Geol 465, Optical Mineralogy-*N*	5	3	3.2, 3.8

N: New course for me or the department, *O:* Teaching overload, *T:* Team taught
* based on a scale of 0 to 4, with 4 the most positive response, new form: questions 1, 2, 3, 4, 5 old form: questions 1, 2, and then new web form 1, 2
NA: not yet available or course not evaluated
Geol 499/502 are Directed Studies