Health Consultation

Public Health Implications of Exposure to Metals
Associated with an Unpermitted Gold Mill in
Southwestern Colorado

RED ARROW MINE AND MILL SITE
MANCOS, MONTEZUMA COUNTY, COLORADO

Prepared by the
Colorado Department of Public Health and Environment

SEPTEMBER 4, 2014

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Foreword
The Colorado Department of Public Health and Environment's (CDPHE) Colorado Cooperative Program for Environmental Health Assessments (CCPEHA) has prepared this health consultation under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the United States Department of Health and Human Services and is the principal federal public health agency responsible for the health issues related to hazardous waste. This health consultation was prepared in accordance with the methodologies and guidelines developed by ATSDR.

The purpose of this health consultation is to identify and prevent harmful health effects resulting from exposure to hazardous substances in the environment. Health consultations focus on health issues associated with specific exposures so that the state or local department of public health can respond quickly to requests from concerned citizens or agencies regarding health information on hazardous substances. The CCPEHA evaluates sampling data collected from a hazardous waste site, determines whether exposures have occurred or could occur in the future, reports any potential harmful effects, and then recommends actions to protect public health.

The findings in this report are relevant to conditions at the site during the time this health consultation was conducted and should not necessarily be relied upon if site conditions or land use changes in the future.

For additional information or questions regarding the contents of this health consultation, please contact the author of this document or the Principal Investigator/Program Manager of the CCPEHA:

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Table of Contents

List of Abbreviations and Acronyms

AOC	Area of Concern
APCD	Air Pollution Control Division
ASGM	Artisanal and Small-Scale Gold Mining
ATSDR	Agency for Toxic Substances and Disease Registry
CCPEHA	Colorado Cooperative Program for Environmental Health Assessments
CDC	Centers for Disease Control and Prevention
CDPHE	Colorado Department of Public Health and Environment
COPC	Contaminant of Potential Concern
CTE	Central Tendency Exposures
CV	Comparison Value
DNR	(Colorado) Department of Natural Resources
DRMS	(Colorado) Division of Reclamation, Mining and Safety
EPA	(United States) Environmental Protection Agency
EPC	Exposure Point Concentration
ESAT	Environmental Services Assistance Team
ft.	foot or feet
HI	Hazard Index
HQ	Hazard Quotient
in.	inch or inches
LOAEL	Lowest Observed Adverse Effect Level
ng/m^3	nanograms per cubic meter
NIOSH	National Institute for Occupational Safety and Health
NOAEL	No Observed Adverse Effect Level
OSHA	Occupational Safety and Health Administration
PVC	Poly Vinyl Chloride
µg/L	microgram per liter
$\mu g/cm^2$	microgram per square centimeter
mg/kg	milligram per kilogram
RME	Reasonable Maximum Exposures
SPLP	Synthetic Precipitation and Leaching Procedure
TAL	Target Analyte List (metals)
TCLP	Toxicity Characteristic Leaching Procedure
UCL	Upper Confidence Limit

List of Tables and Figures

Main Text Tables

Appendix A. Additional Tables and Figures

Appendix B. Additional Exposure Dose Information

Summary and Statement of Issues

Introduction

The Colorado Cooperative Program for Environmental Health Assessments' (CCPEHA) and the Agency for Toxic Substances and Disease Registry's (ATSDR) top priority is to ensure that all stakeholders have the best health information possible to protect the public from past, current, and future health hazards associated with previous operations and the resulting environmental hazards posed by the Red Arrow Mine and Mill Site in Montezuma County, Colorado.

In September 2013, the Colorado Department of Natural Resources, Division of Reclamation, Mining, and Safety (DRMS) contacted the CCPEHA for assistance in evaluating the potential health hazards associated with an unpermitted milling facility located just outside the limits of the Town of Mancos, Colorado. Based on evidence gathered at the mill during a DRMS inspection, it appears that the operators of the mill were using mercury amalgamation to extract gold from fine ore concentrates. The elemental mercury used in the amalgamation process is highly toxic and could present a potential hazard to human health and the environment.

Due to the immediate concern for public health and the environment, DRMS issued a Cease and Desist Order on June 19, 2013. DRMS then contracted with Walter Environmental and Engineering Group, Incorporated (referred to as Walter) to conduct an initial site investigation to identify potential contamination at the Red Arrow Mine and Mill site. Walter conducted sampling activities on June 25-26, 2013 and the Evaluation Summary Report that detailed the findings of their investigation was completed on August 1, 2013.

In addition to the use of mercury for amalgamation and ore benefication, the Walter's report identified several tailings piles containing heavy metals in the storage yard of the unpermitted mill; at two nearby, offsite locations; and at the Red Arrow Mine, located approximately 10 miles northeast of the mill. Once the findings of the Walter's report became available to community members, people were concerned about the potential health implications of mercury use at the unpermitted mill site and the heavy metals in the tailings piles. At this point, DRMS contacted CCPEHA to address these concerns by conducting a health consultation. The purpose of this health consultation is to examine the available data to evaluate the potential risks to public health associated with unpermitted milling operations at the Red Arrow Mine and Mill site.

It should be noted that since CCPEHA was initially contacted, two other major actions have taken place at the site. First, DRMS mobilized to the site during the week of October 28, 2013 to conduct a removal action consisting of excavating the tailings piles and consolidating the tailings at the unpermitted mill. During the same week, the Environmental Protection Agency (EPA) Superfund Technical Assessment and Response Team (START) contractor (Weston Solutions) arrived onsite to further investigate the vertical and distal extent of contamination associated with the mill.

At this time, no exposures are thought to be occurring. Mercury use at the mill ceased prior to June 19, 2013, and the tailings piles are now consolidated at the unpermitted mill under a temporary polyvinyl chloride (PVC) barrier to prevent water infiltration and wind erosion until the tailings can be disposed of properly.

Overview

Based on the information available at the time this evaluation was conducted, CCPEHA and ATSDR have reached six conclusions regarding exposure to site-related contamination in soil (0-1 foot) at the Red Arrow Mine and Mill site. It is important to note that the following conclusions are not based on the evaluation of surface soil (0-3 inches) per ATSDR guidance; however, this uncertainty is not likely to impact the conclusions because of the fairly homogeneous nature of contamination in tailings piles from where many of the samples were collected to evaluate site-related exposures. The conclusions of this evaluation are listed below.

Conclusion 1

Past exposures (1-day acute) to mill tailings in the storage yard of the unpermitted mill are not likely to harm the health of trespassers or visitors.

Basis of Decision

This conclusion was reached because the estimated non-cancer hazards from exposure to multiple metal contaminants found in surface soil and tailings at the unpermitted mill are below levels of concern (i.e., below the health-based guidelines). This indicates that the potential for harmful, non-cancer health effects from exposure to contaminants in surface soil and tailings is very low.

Conclusion 2

Past exposures occurring over a period of one year to mill tailings at the Western Excelsior Plant is not likely to harm the health of Western Excelsior employees.

Basis of Decision

This conclusion was reached because the estimated non-cancer hazards from exposure to arsenic and chromium in mill tailings are below levels known to cause harmful health effects (i.e., below the health-based guidelines) for all scenarios considered in this evaluation. In addition, the estimated cumulative cancer risks from exposure to both arsenic and chromium in mill tailings at the Western Excelsior Plant are not elevated for any of the exposure scenarios considered. Overall, these findings indicate that the increased risk of developing harmful non-cancer health effects and cancer is very low for Western Excelsior employees that may have come into contact with tailings (up to 52 days) over a period of one year.

Conclusion 3 *Past exposures occurring over a period of one year to mill tailings at the Dana Farm is not likely to harm the health of child and adult residents and/or visitors.*

Basis of Decision This conclusion was reached because the estimated non-cancer hazards for both children and adults from exposure to arsenic and chromium in mill tailings at the Dana Farm are below levels known to cause harmful health effects (i.e., below the health-based guidelines) for all exposure scenarios considered in this evaluation. In addition, the estimated cumulative cancer risks from exposure to both arsenic and chromium in tailings at the Dana Farm are not elevated for any of the exposure scenarios considered in this evaluation. Overall, these findings indicate that the increased risk of developing harmful non-cancer health effects and cancer is very low for children and adults that may have come into contact (up to 52 days) with the tailings at the Dana Farm over a period of one year.

Conclusion 4 *CCPEHA and ATSDR cannot conclude whether past mercury emissions from the unpermitted mill could harm people's health.*

Basis of Decision This conclusion was reached because the information needed to make a decision is not available and cannot be obtained. No air monitoring data are available for the concentration of mercury released to the atmosphere during operations at unpermitted mill site. It is also not possible to reconstruct the concentration of mercury in air using modeling techniques based on the information that is currently available. However, based on the qualitative evaluation of currently available environmental and biological data, the potential for ambient exposures through inhalation pathway appears to be low.

Conclusion 5 *Current and future exposures to tailings associated with the unpermitted mill are not likely to harm people's health.*

Basis of Decision This conclusion was reached because the tailings have been excavated and consolidated at the mill site. The excavated tailings, located at the mill, are covered with a temporary PVC liner to prevent wind erosion and water infiltration. The mill is also fenced and secured. Therefore, as long as these remedies are in place, exposure to the consolidated mill tailings pile is considered an incomplete exposure pathway for current and future exposures. However, it is recommended that EPA continues to take the necessary actions as some areas remained to be backfilled (noted below under "Next Steps").

Conclusion 6

Current and future exposures to mercury in ambient air associated with the unpermitted mill operations are not likely to harm people's health.

Basis of Decision

This conclusion was reached because there have been no operations at the unpermitted mill since at least June 2013. The Mercury Building at the mill has been closed and no public access is allowed. Furthermore, the available environmental data show mercury levels well below levels of health concern. These findings indicate a very low potential for current exposures to mercury associated with past operations at the unpermitted mill. There is also a very low potential for future exposures to mercury since EPA plans to clean up the mercury building prior to the mill buildings being reoccupied.

Next Steps

EPA is planning to take the following measures to protect public health at the Red Arrow Mine and Mill site:

- Remove the consolidated tailings pile from behind the mill and dispose of properly.
- Complete backfilling of excavations with clean soil in all areas that have yet to be backfilled. This action will eliminate the surface soil exposure pathway.
- Decontaminate the Mercury Building at the mill prior to re-occupancy to protect the health of future users of the mill property.
- Confirm the location of the mercury that is believed to be stored in the rental storage facility and dispose of it properly.

CCPEHA commits to the following actions as a result of this evaluation:

- CCPEHA will present the findings of this evaluation in a public meeting and health education materials will be made available regarding the findings of this health consultation.
- As requested, CCPEHA will also review any additional environmental data collected from the site and will update the health consultation as necessary.

For More Information

If you have immediate concerns about your health, contact your health care provider. For questions or concerns regarding this evaluation, please contact Thomas Simmons at 303-692-2961 or Dr. Raj Goyal at 303-692-2634.

Purpose

In October 2013, CCPEHA was contacted by the Colorado Division of Reclamation, Mining, and Safety (DRMS) to assist with community concerns over an illegal and unpermitted milling operation in Mancos, Colorado. The unpermitted mill was using mercury for amalgamation of gold and one of the primary concerns of the local citizenry was inhalation of mercury vapors emanating from the mill. In addition, citizens were concerned about the potential impact of mine tailings found at the mill and two nearby, offsite locations. The purpose of this health consultation is to examine the available environmental data to evaluate the potential public health risks associated with former activities at the Red Arrow Mine and Mill site (Site).

Background

The Red Arrow Mine is a permitted gold mine located approximately 10 miles northeast of the unpermitted mill that was used to process ore from the mine. The mine is in a mountainous and wooded area with a creek running through the site (Walter 2013). The Red Arrow Mine is also known by the name Out West Mine (DRMS 2013). The road leading to the mine is currently closed and the site is not accessible. A tailings pile was discovered at the mine site during the DRMS site inspection in June 2013 (DRMS 2013). The tailings pile is located in an equipment shed and has been covered with a tarp (Figure A1). The mine is a permitted site that is technically under the authority of other agencies. Therefore, the permitted Red Arrow Mine is not the focus of this evaluation and will not be discussed further in this health consultation. For more information on the Red Arrow Mine, please refer to the Walter report (Walter 2013).

The site background information presented in the following sections consists of data that were used for this evaluation. For more complete background and historical data, please refer to Walter 2013, Weston 2014, and other sources referenced in this section. These reports and other site-related documents can be found on the Internet at: epaosc.org/RedArrowMill.

Site Description

The focus of this evaluation is the unpermitted mill site and the associated offsite areas that have been impacted by wastes generated by former milling operations. Overall, Areas of Concern (AOCs) have been divided into three primary components: the unpermitted mill and two offsite properties (Dana Farm and Western Excelsior) where tailings appear to have been transferred. In this evaluation, “tailings” describes any ore or solid material that has been mined and is at various stages of processing. Each Area of Concern (AOC) is discussed in more detail below.

Unpermitted Mill

The unpermitted mill is at 1000 W. Grand Avenue, just west of the city limits of Mancos, Colorado (Figure A2). The immediate area surrounding the unpermitted mill is mixed-use commercial/industrial, agricultural, and residential. To the immediate north of the mill is storage lot that is used to store Recreational Vehicles (RVs), boats and other similar items; to the east is a field that separates a mobile home park, located less than 1,000 feet away; to the south is Western Excelsior, an erosion control manufacturer; and to the west a rental storage facility.

The unpermitted mill contains two industrial-type buildings and a storage yard (Figure A3). The lot is approximately 2/3 acre and each building is approximately 1,500 square feet in size (Montezuma 2013). The buildings are situated side-by-side, oriented in an east/west direction. The property and buildings were being leased by Red Arrow Gold Corporation at the time DRMS was notified of the unpermitted mill (DRMS 2013). During the initial assessment of the site, the Walter team included a mining geologist that provided his interpretation of the operations that may have occurred at the unpermitted mill. According to the Walter report, the westernmost building (Non-mercury Building) was likely used for processing ore into fine-grained materials. No evidence of mercury or mercury use was present in the west building (Walter 2013). The easternmost building (Mercury Building), however, did contain evidence of elemental mercury and mercury use. It appears that the west building was used to mill the ore and the east building was used for further refinement and amalgamation with mercury. The three areas of the unpermitted mill (Mercury Building, Non-mercury Building, and Storage Yard) are briefly discussed below.

Mercury Building

When DRMS and Walter inspected the site, the Mercury Building contained separation equipment, including gravitation settling tanks and a concentration belt and hopper. A ball mill, drying kiln, and a retort heater were also present along with an empty plastic bucket labeled "21.5# Mercury" (DRMS 2013). Beads of mercury were present in the ball mill's discharge chute at the time of the inspections. The retort heater (also referred to as a roaster) was fixed with an inverted, galvanized wash tub that appeared to have been used as a fume hood to catch mercury vapors emanating from the retort. Retort is the process of heating the mercury to the boiling point and recovering the leftover gold particles. Walter surmised that amalgamation took place in the ball mill (or the amalgamator) and that the retort heater was likely used for vaporizing mercury and recovering gold after amalgamation (Walter 2013). A stacked pair of blue 55-gallon drums were also present, which appears to be the catchment system for the mercury after retorting. At the time of the DRMS inspection, the lower amalgamation drum had mercury beads clinging to the drain spout leading from the drum (DRMS 2013). The top drum was sampled and revealed elevated levels of arsenic and mercury at respective concentrations of 56.1 milligrams per kilogram (mg/kg) and 114 mg/kg. Low concentrations of chromium, copper, nickel, and zinc were also detected (Walter 2013).

Also inside the Mercury Building there were a number of various sized tanks containing sediment and several 5-gallon orange buckets labeled "~ 250# Concentrates Ready for Amalgamation" (DRMS 2013). A drum located next to the amalgamator was labeled "Hg #3" on the side. Records found inside the mill indicate that 1 to 2 ounces of gold were being produced per day when the mill was operational (DRMS 2013). Sampling of liquids, indoor air, and indoor surfaces conducted by Walter and Weston indicated mercury contamination of this building (Walter 2013, Weston 2014). For example, five liquid samples were collected at various locations within the mercury building, with mercury at concentrations ranging from 109 micrograms per liter (µg/L) to 2,450 µg/L (Walter 2013). The aqueous sample collected from an orange plastic bucket located in the northeast corner of the building had the highest concentration of mercury (Walter 2013). Air monitoring for mercury vapors was also conducted using a Lumex® mercury-vapor detector (Ohio Lumex Co. Inc, Twinsburg, OH). No elevated concentrations of mercury vapor were present outside of the storage units to the west, where mercury is thought to be stored, or in the onsite septic system (Weston 2013). In September

2013, EPA's On-scene Coordinator conducted air monitoring for mercury vapors prior to entering the buildings. At that time, airborne mercury concentrations in the Mercury Building exceeded the Lumex® monitor's detection capabilities of 50,000 nanograms per cubic meter of air (ng/m^3) (EPA 2014a). In addition, surface wipe mercury samples collected by Walter and Weston also indicated mercury contamination inside the Mercury Building (Walter 2013, Weston 2014).

At this time, public access to the mercury building is prohibited and no current exposures to mercury inside the Mercury Building are thought to be occurring. However, it should be noted that occupational exposure to mercury inside the Mercury Building most likely occurred based on the available evidence. Past occupational exposures are not the focus of this health consultation as ATSDR and CDPHE do not have the authority to evaluate occupational exposures. Occupational exposures are covered under the Occupational Safety and Health Administration (OSHA).

Non-mercury Building

Operations inside the Non-mercury Building likely pertained to gradational separation by mechanical and flotation techniques (Walters 2013). Tailings-type materials were found in various containers in the Non-mercury Building. This material is likely the result of the initial milling stages or waste from the initial stages. Six large tanks were also present and contained water at the time of the inspection by DRMS and Walter (DRMS 2013, Walter 2013). An open trailer that had been sealed to hold water was also present (DRMS 2013).

Storage Yard

Material that appears to be tailings piles is located in the storage yard surrounding the buildings (Figure A4). The dimensions of each pile were measured and recorded. Nine tailings piles in the storage yard of the mill site, which total approximately 250 cubic yards of material, were documented in the Walter Report (Walter 2013). In addition, a 55-gallon metal drum containing tailings was located near one of the tailings piles. At the time of the DRMS and Walter inspections, the tailings piles did not have ground protection and were found uncovered (DRMS 2013, Walter 2013).

The storage yard also contained an unlabeled drum, several 5-gallon buckets, and 1-gallon containers of what appeared to be waste oil or spent petroleum-based products. In addition, two round farm tanks were present on the northeast corner of the Non-mercury Building. The tanks were void of liquid at the time of the DRMS and Walter inspections, but did contain dried sediment (DRMS 2013, Walter 2013).

Dana Farm

What has been termed the "Dana Farm" is a residential property, located approximately 1,000 feet west/southwest of the mill (Figure A5). During the Walter site inspection, tailings were discovered at the Dana Farm (Walter 2013). The tailings were located in a horse pasture along the northern edge of the property. The estimated volume of waste material at the farm was approximately 33 cubic yards.

Western Excelsior

Tailings were also transferred from the mill to the Western Excelsior plant located directly south and across the highway from the mill (Figure A5). The tailings were apparently being used by Western Excelsior as a fire suppressor and fire barrier in the area around their incinerator, which is located towards the southern end of the property (Walter 2013). The dimensions of the fill materials at the lumberyard equated to an area of approximately 3,342 square feet at an estimated depth of 1 foot. The estimated volume of waste material at the lumberyard is 124 cubic yards.

Site History

According to Red Arrow's webpage, the company was formed in 1988 and preliminary work at the Red Arrow Mine began in March of that year (Red Arrow 2010). It appears that mining and milling activity fluctuated at the Red Arrow Mine during the 1990's and early 2000's due to low precious metal prices and litigation over access, or easement rights (Red Arrow 2010). Precious metal prices began to increase in 2005 and the Red Arrow Mine was reopened in May 2006. Litigation regarding easement rights was settled in November 2007, which paved the way for full scale production at the mine (Red Arrow 2010). Over the following years, it appears that Red Arrow continued exploration activities and site work at the Red Arrow Mine, which required major upgrades following years of inactivity. Additional information is very limited on other Red Arrow activities that took place at the site between 2007 and 2013.

In June 2013, DRMS was informed of potentially illegal activities occurring at the mill. DRMS inspectors responded to the site on June 18, 2013 and noted several violations, including the use of elemental mercury for amalgamation and ore beneficiation (DRMS 2013). Following the DRMS' initial inspection, a series of actions took place at the site starting with a Cease and Desist Order issued by DRMS. The Cease and Desist was issued on June 19, 2013, which ceased all mining and milling activity associated with Red Arrow. However, it should be noted that Red Arrow had not been mining or milling at the site since a receiver took control of the properties in April 2013.

DRMS then hired Walter Environmental and Engineering Group, Inc. (Walter) to conduct an initial assessment of the site conditions and potential levels of environmental contamination found at the site. Walter arrived onsite June 25, 2013 to begin sampling and assessment activities, which occurred over a two-day period. The results of Walter's activities were published in an "Evaluation Summary Report" dated August 1, 2013 (Walter 2013). This material was presented to the Mancos community. Shortly thereafter, a number of health and environmental concerns were raised by community members. DRMS then contacted the CCPEHA for assistance in addressing these concerns by conducting a health consultation at this site. It is important to note that a record of the amount of mercury used and how it was used at the site has not been found. Based on the DRMS estimates, it appears that unpermitted mill operated anywhere from 6 to 11 months (personal communication with Ms. Loretta Pineda, Director of the Colorado Department of Natural Resources (DNR), October 15, 2013)

During the week of October 28, 2013, DRMS mobilized a contractor to the site to conduct a temporary stabilization action that included excavating the tailings from two off-site properties where they had been deposited and consolidating all tailings at the mill. Tailings were scattered throughout the mill storage yard with some discrete piles also present. These tailings piles were also excavated and consolidated with the other piles. The consolidated tailings pile is currently located behind the mill site buildings and is covered with a temporary polyvinyl chloride (PVC) barrier to prevent water infiltration and windblown erosion of the pile. Approximately 1,100 cubic yards of tailings and the subsoil immediately underlying the excavated tailings are temporarily stored under the PVC barrier.

That same week, the EPA Emergency Response and Removal Program arrived at the site with their contractor, Weston Solutions, Inc. (Weston), to conduct additional site characterization activities. This included additional environmental sampling beneath the tailings piles and an analysis of mercury vapor levels inside the mill buildings. The results of this sampling activity were published in the Weston Solutions Letter Report (Trip Report) dated December 5, 2013. During the week of December 10, 2013, Weston returned to the site to conduct additional background soil sampling and further assess the extent of contamination inside the mercury building. The results of this sampling event were combined with the Letter Report and published in February 2014 under the title Removal Evaluation Report (Weston 2014).

On December 10, 2013, CCPEHA personnel conducted a site visit of the unpermitted mill with members of ATSDR Region 8, EPA, and the DRMS. The group examined and discussed the major site features of the mill. That evening, a public meeting was held by the EPA to present the findings of the Weston Trip Report. CCPEHA and ATSDR Region 8 personnel also attended the meeting to introduce the health consultation and collect community health concerns. Concerns cited by the community during this meeting and those collected from other sources of information are discussed in more detail in the Community Health Concerns section.

Demographics

As mentioned previously, the unpermitted mill is located on Grand Avenue just west of the city limits of Mancos, Colorado (Figure A2). Mancos, Colorado is a relatively small town of 1,336 people in southwestern Colorado (U.S. Census 2010). The median age is 38 years old, which is slightly higher than the rest of the state. Nineteen percent of the population is 62 years or older compared to the state, which 14 percent of the population is 62 or older. There are more females (711) than males (625) and 19.8% females are of child-bearing age (age 15-44 years). The population of Mancos consists of whites (85.4%), American Indian or Alaska Native (6.3%), Asian (0.7%), and African American (0.1%). The remaining 3.1% of individuals reported two or more races of the above combinations. Twelve percent of the population reported being Hispanic or Latino. Sixty percent of households are owner occupied units and 40% of households are renter occupied units. No striking demographic characteristics appear to exist in Mancos that would have an impact on this evaluation.

Community Health Concerns

As part of the health consultation process, CCPEHA and ATSDR specifically evaluate community health concerns regarding site-related contamination and exposures. The majority of information regarding community health concerns has been gathered by CCPEHA personnel thorough personal communication with DRMS and EPA, a review of media reports on the site, a letter expressing concerns that was sent to the Director of DNR from two community members, and personal communication with community members at the site visit and public meeting conducted in December 2013, which CCPEHA personnel attended.

Following the discovery of the illegal milling operation in June 2013, a public meeting was held by DRMS to relay the findings of the Walter Report to the public. At this meeting a number of community members expressed health concerns related to the site, which range from contaminated soil and groundwater to inhalation of mercury vapors. A health assessment was specifically requested by community members in a follow-up letter to the Director of Colorado Department of Natural Resources (DNR). The letter expressed environmental and health concerns including the amount of mercury that was released into the atmosphere, leachate from tailings piles contaminating surface and ground waters, and the need for a risk assessment of the site to determine the potential health implications of exposures associated with the unpermitted mill. The letter also requested an evaluation of all women of child-bearing age and children in the surrounding area for evidence of environmental mercury contamination.

In December 2013, CCPEHA staff attended a public meeting to introduce the health consultation that was to be conducted and to gather community health concerns. Many of the same concerns noted previously were expressed at this meeting including past mercury inhalation exposures, the need for biomonitoring for mercury exposure, potential ground water contamination from tailings piles, and occupational exposures to the former workers of the mill. To the extent possible, this evaluation attempts to address these concerns; however, as mentioned previously, the evaluation of occupational exposure of the former mill workers is beyond the scope of this health consultation. It should be noted, however, that there is a potential for mill workers to transfer mercury from the facility while it was operational. Mercury could have been transferred via contaminated clothing, shoes, and other personal items to the workers' homes where children and other family members could have been exposed. These potential exposures cannot be evaluated due to a lack of data and information on work practices and families of workers at the millsite.

For more information, on how community concerns are addressed in this health consultation, please see Attachment 1.

Discussion

The overall goal of this health consultation is to determine if exposure to contamination related to the Red Arrow Unpermitted Mill Site poses a public health hazard and, if so, make recommendations to protect public health. The first steps of the health consultation process include an examination of the currently available environmental data and how individuals could be exposed to site-related contaminants of potential concern (COPCs). If people can come into contact with COPCs, exposure doses are estimated and compared to health-based guidelines established by the ATSDR, EPA, or other state agencies. This is followed by a more in-depth evaluation if the estimated exposure doses exceed health-based guidelines.

Exposure Assessment

Environmental Data

Data Description

As mentioned previously, two primary environmental site assessments have been conducted at the site since the unpermitted mill was discovered in June 2013. This includes the Walter Report prepared for DRMS (Walter 2013) and the Weston Report prepared for EPA Region 8 (Weston 2014). Various types of environmental samples were collected in order to characterize the source, type, and extent of contamination at the unpermitted mill and the two offsite disposal locations.

Sampling for the Walter Report was conducted on June 25th and 26th of 2013 and the report was finalized on August 1, 2013. Samples were collected from tailings, gravitational settling tanks, and sedimentation basins (farm tanks); two surface soil samples were collected from behind the unpermitted mill buildings, waste oil samples were collected from the unpermitted mill, and various samples were collected from drums and buckets of what has been described as pre-milling ore (Walter 2013). During the site evaluation by Walter, samples were collected from 6 of the 9 tailings piles surrounding the exterior of both buildings at the unpermitted mill facility (Figure A4) from a depth of 0-8 inches (in.) below the ground surface (Walter 2013, Personal Communication with DRMS, Mr. Steve Renner, January 2014). Tailings samples were analyzed for priority pollutant metals as well as mercury and cyanide. In addition, wipe samples for mercury were collected from the ball mill and the makeshift vent hood in the Mercury Building. All samples were labeled and maintained on ice prior to shipment to the analytical laboratory. The analytical laboratory used in the Walter Report was Accutest Laboratories in Wheat Ridge, Colorado. Sample coolers were shipped via overnight carrier to the laboratory (Walter 2013).

The EPA and Weston deployed to the site during the week of October 27, 2013 to sample site soils and waste piles (Weston 2013). During the week of December 10, 2013, Weston returned to the mine site to collect additional background soil data from a field west of the site and to further evaluate the extent of contamination in the mercury building at the mill. For the mercury assessment, Weston collected tailings and aqueous samples from containers inside the mercury building as well as wipe samples for mercury from a number of surfaces in the building and at two outdoor locations to the immediate east of the building (Weston 2014). The purpose of the Weston sampling event was to further characterize the vertical and horizontal extent of contamination associated with the unpermitted mill. For this reason, the sampling strategy differed from the Walter sampling event, where the purpose was to identify the contamination and its chemical composition. It should be noted that both Walter and Weston collected soil samples prior to the DRMS excavation actions. Therefore, the sub-surface soils sampled by Weston were most likely excavated after the sampling occurred and are now contained in the PVC covered temporary repository.

The majority of sampling in the Weston Report was focused on tailings piles at the mill, the Dana Farm, and the Western Excelsior Plant. Background sampling was also conducted by Weston at locations that represent background conditions and areas of concern if the potential contamination mobilized. Three tailings samples were also collected inside the mercury building at the mill. All samples were analyzed for Target Analyte List (TAL) metals. Weston collected soil samples from 4 of the 9 tailings piles located in the storage yard of the mill (Figure A6). Outdoor tailings samples were collected from depths of 1 feet (ft.) and 1.5 ft. at each location, which is deeper than the samples collected in the Walter report. The sampling conducted during the Weston event was collected from beneath the tailings piles. Therefore, the metal concentrations found in the depth samples are most indicative of metals that have leached from the tailings piles, not the actual tailings. It should also be noted that the samples were collected at different periods in time by different people, which could also have an effect on the analytical results. However, the time between events was short (4 months) and the same general sampling techniques and analytical methods were used in both sampling events.

In summary, the primary difference is that tailings were collected during the Walter site evaluation and subsurface soil samples were collected during the Weston site evaluation. The results of the subsurface soil samples show lower concentrations of heavy metals in all cases with the exception of chromium. Overall, it is important to note that chromium levels are the lowest in the tailings in comparison to subsurface soil samples and background soil samples.

Data Results

The environmental data that were utilized in this health consultation are discussed below. For additional information on the complete set of environmental data collected during the environmental assessments conducted by Walter and Weston, see the original reports (Walter 2013, Weston 2014).

Unpermitted Mill site (Onsite)

The Walter sampling results from the tailings piles in the storage yard at the unpermitted mill are shown in Table A1. The concentration of arsenic ranged from 46.7 mg/kg to 299 mg/kg. Mercury was detected in all of the tailings piles, but only the sample collected from pile 7 appears unique with a concentration of 55.7 mg/kg. The concentration of mercury in the other tailings piles ranged from 0.061 to 1.1 mg/kg, which is near the reporting limit of the analytical method. The concentration of antimony and copper in pile 2 was also elevated in respect to the other samples. Antimony was detected at a concentration of 38.5 mg/kg in pile 2, but ranged from 3.3 mg/kg to 18.3 mg/kg in all other samples. Copper was found at a concentration of 575 mg/kg in pile 2, but ranged from 73.2 mg/kg to 311 mg/kg in all other tailings samples. Cyanide was only detected in tailings pile 3 at a concentration of 0.58 mg/kg, which is very close to laboratory reporting limit of the analytical method of 0.5 mg/kg. In two other samples collected from pile 3 (one duplicate sample and one additional sample), cyanide was not detected above the reporting limit. This casts some doubt on the actual presence of cyanide in the sample. If cyanide is present, it is present only at very low levels near the reporting limit of analytical method. It should also be noted that no other evidence exists to indicate that cyanide was being utilized at the unpermitted mill for ore beneficiation. The concentration of lead in the tailings was relatively low with a range of 13.5 mg/kg to 133 mg/kg. This is somewhat unusual in relation to mine tailings found at other Colorado mining sites, which typically contain a fair amount of lead.

Weston’s sampling results from the tailings piles found in the storage yard at the unpermitted mill are presented in Table A2. The arsenic concentration in the piles was markedly different from the levels found in the Walters report. Arsenic concentrations ranged from 4.6 to 43.2 mg/kg in the samples collected at depth. The highest concentration of arsenic was found in an area where tailings had washed under the fence near the northern property line of the mill (Sample 22). At three tailings piles, samples were collected in both the Walter and the Weston Solutions investigations (Piles 2, 6, 7). In pile 2, arsenic was detected at a concentration of 299 mg/kg in the 0-8 in. sample collected in the Walter report compared to 5.2 mg/kg in the 1 ft. depth sample, and 6.2 mg/kg in the 18 in. depth sample collected for the Weston Report. The depth samples from this pile are near background levels of arsenic. The same is true for piles 6 and 7. However, in pile 7, arsenic was still detected at relatively high levels in the depth samples, albeit much lower than the concentration found in the Walter samples. The concentration of arsenic in the Walter sampling event (0-8 in.) was 194 mg/kg versus 24.9 mg/kg (duplicate sample showed 21.5 mg/kg) at 1 foot deep, and 23.3 mg/kg (duplicate sample showed 10.4 mg/kg) at the sample collected from 18 in. deep during the Weston evaluation. In contrast, the levels of chromium in piles 2 and 6 were higher in the depth samples than the samples collected from the tailings. For instance, in pile 2 the concentration of chromium found in the tailings sample from the Walter report was 1.6 mg/kg compared to 7.5 mg/kg and 8.1 mg/kg in the samples collected during the Weston report from depths of 1 ft. and 18 in., respectively. The same is true for pile 6. In pile 7, the levels of chromium in the tailings and depth samples are roughly equivalent. This could indicate that background levels of chromium are higher than the levels found in the tailings. Other metals were detected in the subsurface samples, but at relatively low concentrations. Mercury was detected in the subsurface samples at levels near the reporting limit of the analytical method (generally 0.1 mg/kg). The exception is at pile 7 where mercury was detected at a maximum concentration of 13.4 mg/kg in the sample collected from 1 foot and 6 mg/kg in the 18 in. sample.

During the Walter sampling event, two surface soil samples were collected from behind the mill buildings in order to assess any potential surface soil impacts (Figure A4). These samples were analyzed for priority pollutant metals and cyanide (Walter 2013). The surface soil sampling data collected from behind the mill buildings is shown in Table A3. Arsenic was detected in both samples at a concentration of 97.4 mg/kg and 112 mg/kg, which is elevated. Mercury was also detected in both samples, but it was found at low concentrations of 0.88 mg/kg and 2.7 mg/kg. Antimony, cadmium, chromium, copper, lead, and zinc were also detected in both samples. However, the concentration of each of these contaminants was low.

Offsite Disposal Areas

Soil samples were collected from the Dana Farm and the Western Excelsior facility in both the Walter and Weston sampling events. The sampling locations for the Offsite Disposal Areas are shown in Figures A5 and A6.

Dana Farm

A composite sample (0-8 inches) was collected from the tailings pile that was discovered at the Dana Farm and submitted for laboratory analysis of priority pollutant metals and cyanide (Walter 2013). Sample results for data collected during the Walter sampling event from the Dana Farm are presented in Table A4. The sample collected from the tailings pile located in the Dana Farm horse pasture has an arsenic concentration of 119 mg/kg, which is elevated in comparison to background. Mercury was detected in this sample, but only at a concentration of 0.78 mg/kg. Other metals such as antimony, cadmium, chromium, copper, lead, and zinc were also detected at low concentrations.

In addition, Weston sampled at depths of 1 ft. and 1.5 ft. Both samples were submitted for TAL metals and mercury analyses (Weston 2014). During the Weston sampling event soil was collected from three locations at the Dana Farm as described previously. A duplicate sample was collected from location 14 and sample location 31 was collected from tailings that had washed under the fence of the pasture. The exact areas that were sampled for the Walters and Weston sampling event are not clear, but it appears that sample location 15 from the Weston report is closest to the area sampled in the Walters event according to figures in the reports. The other locations were identified during the DRMS removal event and the Weston October 2013 sampling event, which were occurring simultaneously at the farm. The data results for soil samples collected from the Dana Farm during the Walter and Weston sampling events are shown in Table A4.

Western Excelsior

A composite sample (0-8 inches) was also collected from the tailings that were deposited as a fire suppressor/fire barrier around the incinerator at the Western Excelsior plant across the street from mill. This sample was also submitted for laboratory analysis of priority pollutant metals and cyanide (Walter 2013). Sampling results for sample collected during the Walter investigation at the Western Excelsior facility are shown in Table A5. This sample collected from the Western Excelsior Plant was very similar to the tailings at the Dana Farm. Arsenic was found at a concentration of 107 mg/kg. Mercury had a concentration of 1.9 mg/kg. In addition, antimony, cadmium, chromium, copper, lead, and zinc were also detected at nearly identical concentrations. This information suggests that the tailings that were transferred from the mill are fairly uniform in chemical composition.

Weston sampled the tailings pile at Western Excelsior Plant at depths of 1 ft. and 1.5 ft. and analyzed for TAL metals and mercury (Weston 2014). The soil sampling results collected from the Western Excelsior facility during the Weston sampling event are shown in Table A5. Arsenic was again detected in all of the samples collected during the Weston sampling event, but at much lower concentrations than were found in the tailings sample from the Walters report. The concentration of arsenic ranged from 4.1 mg/kg to 17.7 mg/kg. The highest two concentrations were found in location 31 (17.7 mg/kg) and location 15 (9.8 mg/kg at 1 foot deep). In contrast, the sample collected from tailings in the Walters report had a concentration of 119 mg/kg. Chromium levels were also elevated in the depth samples relative to the tailings. However, the concentrations of chromium found in the Weston sampling event, which range from 7.1 mg/kg to 8.8 mg/kg, appear to be consistent with background levels. In the Walters sampling event, chromium was detected at a concentration of 2.7 mg/kg in this area. Mercury was not detected above background in any sample collected at depth. At the Western Excelsior facility, a composite sample was collected from a depth of 1 ft. (Location 11). The sample results, shown in Table A5, indicated the concentration of arsenic was 8.1 mg/kg and the concentration of chromium was 4.3 mg/kg. In comparison, the concentrations of arsenic and chromium found in the Walters investigation were 107 mg/kg and 2.7 mg/kg, respectively.

Background Soil Samples

During Weston's sampling activities, site-specific background surface soil samples were collected from locations within one-quarter mile of the millsite that were not thought to be impacted by site-related waste (Figure A6). The objective of collecting the background samples was to determine the levels of naturally occurring metal concentrations in soil and if the contamination had mobilized. All background samples were submitted for laboratory analysis of TAL metals and mercury (Weston 2014). A total of 20 background samples were grab sampled from a depth of 0-2 inches below the surface. Soil samples that were considered background samples in this evaluation include sample numbers #12, 13, 17 to 21, 23 to 30, and 52 to 56 (Weston 2014). Summary statistics for the background data results are shown in Table A6.

A number of heavy metals were also found in the background, which is to be expected since heavy metals are a naturally occurring component of soils. Arsenic, chromium, and mercury are the primary metals that have been identified in the tailings piles associated with the unpermitted mill. The concentration of arsenic in background samples ranged from 3.7 to 8 mg/kg with a mean concentration of 5.3 mg/kg over the 20 samples. Chromium was detected in each background sample at a concentration range of 5 to 8.5 mg/kg with a mean concentration of 7.0 mg/kg. Mercury was only detected in one sample at a concentration of 0.11 mg/kg, which is near the reporting limit of the analytical method. The reporting limit for mercury in background samples ranged from 0.089 to 2.9 mg/kg with a mean of 0.11 mg/kg. Thus, if mercury is actually present in the sample, it is equivalent to the mean concentration of the reporting limit of the analytical method (i.e., very low concentration).

Outdoor Mercury Surface Wipe Samples

Weston collected two outdoor samples from a table located near the eastern property line and from fence running along the eastern property line (Weston 2014). The surface wipe samples were submitted to the EPA Region 8 Environmental Services Assistance Team laboratory in Golden, Colorado for mercury analysis. The concentration of mercury in both wipe samples collected outdoors appears to be very low based on a qualitative evaluation by EPA Region 8 (Weston 2014).

Selection of Contaminants of Potential Concern

To identify soil contaminants of potential concern (COPCs), all of the soil data were screened against comparison values established by the ATSDR and EPA. The screening values from both agencies were reviewed and the more conservative value was selected as the Comparison Value (CV). The resulting CVs used to identify COPCs in soil were derived for residential soil exposures and are shown in Table A7. Using these CVs for screening is considered conservative and protective of individuals that might come into contact with soil contaminants at the Red Arrow site because people are not living in the areas under consideration. Therefore, if the maximum concentration of a particular contaminant is below the CV, no further evaluation is made. If the maximum concentration of the contaminant is above the CV it is generally retained for further analysis as a COPC. However, exceeding the CV does not indicate that a health hazard exists, only that additional evaluation is warranted.

Soil COPCs that exceed the residential soil screening value are shown in bold in the data Tables A1-A6 and the results of the screening process are summarized below for each area of concern.

Unpermitted Mill (Onsite)

The data summary for the unpermitted mill is shown in Table A8. The concentration of antimony, arsenic, chromium, copper, lead, and mercury exceeded the residential CVs. It is, however, important to note that lead was only detected in one location at a concentration greater than the EPA screening level of 400 mg/kg. The concentration of lead beneath Pile 7 at a depth of 1 ft. was 403 mg/kg. The duplicate sample collected from this location had a concentration of lead just below the EPA screening level at 394 mg/kg. The samples collected from 1.5 ft. beneath Pile 7 were approximately one-half of the lead concentration at 1 ft. All other samples were practically devoid of lead with an overall mean concentration of 75 mg/kg, which is well below the current screening value from EPA.

It should be noted that the Centers for Disease Control and Prevention has recently revised their reference blood lead level based on information showing the blood lead levels less than 10 micrograms per deciliter have been associated with adverse health effects. As more information becomes available on the health effects of lower blood lead levels, it seems possible that there is no safe level of lead in blood. For more information, please refer to CDC 2012a and CDC 2012b. However, an overall site mean concentration of 75 mg/kg is less than one-fourth of the current EPA screening value for lead of 400 mg/kg. In addition, running the IEUBK model using CDC recommended blood lead level of 5µg /dL indicates soil screening level about 150-200 mg/kg for lead (vs. average of 75 mg/kg at this site).Therefore, lead was not considered further as a COPC. Antimony, arsenic, chromium, copper, and mercury were retained as COPCs at the Unpermitted Mill AOC.

Offsite Disposal Areas

As mentioned previously, the data for Dana Farm and Western Excelsior are shown in Appendix Tables A4 and A5, respectively. Arsenic and chromium were the only contaminants that exceeded the residential CVs at the Dana Farm and Western Excelsior plant.

Background Areas

The data for the background surface soils samples collected within one-quarter mile of the millsite are shown in Table A6. Background sampling locations are shown in Figure A6. Arsenic and chromium were the only contaminants in background soil samples that exceeded the CVs.

Conceptual Site Model

A conceptual site model helps people to visualize how contaminants of potential concern move in the environment at the site and how people might come into contact with these contaminants. A conceptual site model identifies the 5 components of a completed exposure pathway, which include:

- A *source* of contamination.
- A *release mechanism* into water, soil, air, food chain or transfer between media (i.e., the fate and transport of environmental contamination).
- An *exposure point* or area (e.g., drinking water well, residential yard).
- An *exposure route* (e.g., ingestion, dermal contact, inhalation).
- A *potentially exposed population* (e.g., residents, children, workers).

Exposure pathways are classified as complete, potential or incomplete based on the available information and the likelihood of a particular pathway actually occurring. The Conceptual Site Model summarizes the elements of each exposure pathway that was considered in this evaluation (Appendix Table A9). A large amount of information that would help CCPEHA clarify complete, potential, and incomplete exposure pathways is lacking, especially, for mercury in ambient air.

Mercury in Ambient Air

Potential sources of community exposure to mercury include inhalation of metallic mercury vapor in ambient air, and ingestion of inorganic mercury contaminated soil as a result of deposition of mercury from the atmosphere. Mercury exposures through the ingestion of mercury-contaminated soil are addressed under surface soil exposures.

Very little is known about exposures to mercury in ambient air that may have occurred offsite due to operations at the unpermitted mill. No ambient air monitoring data are available for inhalation exposures to mercury while the mill was operational. Based on the available data for the Mercury Building discussed in the site description section, it appears that mercury was used for amalgamation at the unpermitted mill. However, it is not clear what the exact process was, how long mercury was used for, how much mercury was used, and how much might have entered the atmosphere. It should be noted that the mill is thought to have been in operation for approximately 6-11 months. However, it is not clear if mercury was being used the entire time that Red Arrow occupied the mill buildings. Without this information, it is not possible to estimate ambient air levels of mercury using a modeling approach. A qualitative discussion of wind directions by the Air Pollution Control Division (APCD) of CDPHE is provided in Appendix E. This analysis indicates a potential for mercury exposures based on wind directions from the mill towards inhabited areas. However, the magnitude of those exposures cannot be quantified. Therefore, ambient air exposure to mercury from the mill is considered a potential exposure pathway (Table A9). In addition, it is important to note that the unpermitted mill is located in the Four Corners region where environmental mercury levels are higher than other areas of Colorado. Please refer to Appendix E for more details.

Surface Soil and Tailings

As mentioned previously, data were generated from soil collected at depths of 1 ft. and 1.5 ft. in the Weston sampling event and from 0-8 in. depth in the Walter sampling event. It does not seem likely that the people considered in this evaluation would be coming into contact with soil below a depth of 1ft. based on the information currently available regarding land-use at the site. For this reason, surface soil in this evaluation includes soil, tailings, milled mining materials, and wastes collected from the 0-1 ft. depth range. Surface soil is the primary environmental medium under consideration in this health consultation. It should be noted that ATSDR typically prefers surface soil samples collected from 0-3 in. below ground surface (ATSDR 2005). This is a small source of uncertainty since many of the samples are collected from tailings piles, which are fairly homogenous throughout the pile. Thus, this approach likely reflects the type of material that a person could be exposed to (a mix of tailings and soil) and this uncertainty is not likely to have a substantial impact on the conclusions of this evaluation.

Three routes of exposure to soil contaminants are likely to occur under any given scenario: 1) incidental ingestion of surface soil, 2) dermal contact with surface soil, and 3) inhalation of soil particles suspended in air (fugitive dust). For most metals, dermal exposures are considered a relatively insignificant exposure pathway due to the limited ability of metal contaminants to cross the skin barrier and enter the bloodstream. In general, dermal exposure to metals is not evaluated and remains a minor source of uncertainty. However, dermal exposures to arsenic are potentially relevant and will be evaluated in this assessment. Inhalation of re-suspended soil particulates (dust) is typically not considered an important pathway in terms of public health unless there is evidence to suggest a significant mechanical disturbance of the soil such as in

ATV riding and/or very high, sustained winds. At this site, no such evidence exists now and into the future. Therefore, this pathway was also not quantitatively evaluated in this health consultation. While there may be some additional exposure from inhalation of fugitive dusts, this pathway is not likely to appreciably alter the doses estimated for incidental ingestion. Therefore, this exposure pathway is not quantitatively evaluated. Incidental ingestion of surface soil is considered the primary pathway of exposure to soil contaminants at the Red Arrow Unpermitted Mill site.

Information regarding how often people come into contact with site-related soil contamination is minimal at the site. However, the general consensus among site assessment teams and those familiar with the site is that the public did not come into contact with site-related contaminants in soil very often. In lieu of site-specific information, professional judgment is often times used to determine the appropriate exposure factors that are used in the dose estimations. The purpose of developing exposure factors for a particular site is to account for the majority of exposures that occur at the site. It is recognized that some people may come into contact with site-related contaminants more, or less frequently than the exposure factors used to develop exposure doses. This could potentially result in an over-or underestimation of risk. Professional judgment is based on the best available information regarding land-use, the types of contamination, the location of the contamination, and physical barriers such as snow cover, fencing, PVC covers, etc.

Since the potential exposures in each area are not well defined, CCPEHA used a range of values to estimate potential exposure frequencies under a Central Tendency Exposure (CTE) and a Reasonable Maximum Exposure (RME) scenario for the Dana Farm and the Western Excelsior Plant. Once again, it is estimated that the mill was operational for a period of approximately one year from the time that DRMS was notified of the illegal operation and issued the Cease and Desist Order. The CTE scenario is intended to describe the 50th percentile exposures (i.e. average exposure frequency) and the RME scenario is intended to describe exposures above the 90th percentile (i.e., high-end exposure frequency). The CTE scenario accounts for 26 days of exposure over a period of 1 year and the RME scenario accounts for 52 days of exposure of a period of 1 year (Table B1). The exposure frequencies used in this evaluation are based on professional judgment and account for exposures occurring approximately 2 times per month (CTE) and 1 time per week (RME) over the course of the year that the mill was operating. Based on what is known about the site, these exposure frequencies are thought to be protective of individuals that may have come into contact with tailings from the mill. In addition, an acute scenario, which accounts for exposures occurring over a period of 1-day, was evaluated in all areas of concern. The CTE and RME scenarios were not included at the mill because the site is fenced and secured and there is no evidence to suggest that people were visiting the mill that frequently. Therefore, the acute scenario was the only exposure scenario considered at the mill. The various exposure scenarios are discussed below by area of concern. Additional information on the exposure factors used in this evaluation is included in Appendix B. It should be noted that all exposure scenarios were also evaluated using background data collected from 20 locations (Appendix B).

Unpermitted Millsite

At the mill, soil samples were collected from tailings piles, surface soil behind the buildings, tailings in buckets inside the mill that are in various stages of refining, sedimentation basins, etc.

As mentioned previously, mill workers are not considered in this evaluation. Therefore, tailings material inside the mill buildings does not appear relevant to the general public. If the general public were at the mill, it is possible that they came into contact with the tailings piles and surface soil in the storage yard through incidental ingestion and dermal exposure. It seems reasonable that acute exposure to mine and mill material is the most likely scenario that may have occurred at the mill because there is no apparent reason for anyone to be at the site regularly where they could have been exposed and if it did occur, it was only for a short period of time (i.e. 1-day). Therefore, a short-term (1-day) acute exposure was the only exposure scenario evaluated at the mill site. Adults were the only receptors evaluated at the unpermitted mill because no evidence exists that young children were onsite.

Dana Farm (Offsite Repository)

The tailings pile at the Dana Farm is located in a horse pasture. It is unclear if, or how often people may have entered the pasture and potentially come into contact with the tailings pile stored there. Anecdotal information suggests horses were present at the time the tailings were transferred to the farm. It is unclear how often people tended the horses or if they came into contact with tailings while doing so. Based on anecdotal information collected during the public meeting on December 10, 2013, it appears that children occasionally visit the farm to ride horses. However, it is unclear if this has occurred in the pasture that contained the tailings and if the children could have contacted contaminated materials while riding. The horses were reportedly relocated when the owner returned to the property. After that time, it seems unlikely that people were entering the area and coming into contact with tailings materials. Therefore, a range of exposures varying from 1-day to 52 days over a period of one year were evaluated at the Dana Farm (see Appendix B for details). Based on the available site-specific information indicating that young children were not residing or visiting the Dana farm, children were assumed to be of the age 6-11 years in this evaluation. Therefore, children (ages 6-11 years) and adults were evaluated at the Dana Farm.

Western Excelsior (Offsite, Fire Barrier)

The tailings that were transferred to the Western Excelsior Plant were used as a fire barrier on the southeastern corner of their property. The tailings were arranged in a horseshoe pattern around the incinerator. It does not appear that people were handling the tailings on a regular basis. However, it is possible that workers frequented this area and could have inadvertently ingested tailings material. It is unknown how often the incinerator was used or how frequently people were in the area. Therefore, a short-term (1 day) acute exposure scenario will be evaluated at the Western Excelsior Plant. Therefore, a range of exposures varying from 1-day to 52 days over a period of one year were evaluated at the Western Excelsior (see Appendix B for details). Adult workers were evaluated at the Western Excelsior Plant.

Groundwater

There was also a community concern regarding the potential for groundwater contamination stemming from the tailings. Currently, there is no groundwater data. The potential for groundwater contamination from leaching of metals from the piles was evaluated by Toxicity Characteristic Leaching Procedure (TCLP) and Synthetic Precipitating Leaching Procedure (SPLP) metals analyses of soil samples collected from beneath the tailings piles. It should be noted that the sampling results from the TCLP and SPLP analysis showed the potential for contaminants to leach from the tailings into surface and ground water (Weston 2014). This includes one of the onsite tailings piles and at two locations on the Dana Farm. Therefore, EPA's hydrogeologist reviewed the site reports and data and found little reason to believe that sampling of groundwater is necessary at this time (EPA 2014b). The short time the facility operated and the short time the mill tailings were on the ground behind the facility, the low amount of precipitation in this area, the rapidly decreasing mercury and low arsenic values (at 1.5 ft. depth), when viewed as a whole, do not indicate any reason for groundwater concerns. There are also no registered drinking water wells down gradient of the site for over a mile, according to Colorado's Office of the State Engineer (EPA 2014b). Thus, potential exposures to groundwater are not discussed further in this health consultation.

Surface water

No data are available for surface water. However, the information provided above for the potential for groundwater contamination does not indicate a reason for surface water concerns (See Attachment 1, EPA 2014b).

Exposure Point Concentrations

The exposure point concentration (EPC) is an estimate of the concentration of a contaminant in soil the people are exposed to in a particular area of concern. In general, the EPC estimate is a high-end average concentration of a contaminant in a particular area (i.e. unpermitted mill). Average concentrations are normally used because people typically move throughout an area and are exposed to varying levels of contamination in different spots within the area. That is, people are neither exposed to the highest, nor the lowest, concentration of contamination. In this case, the 95% Upper Confidence Limit on the mean (average) concentration is used as the EPC. In cases where there are fewer than 10 samples available from a particular area, the EPC estimation becomes unreliable and the maximum detected concentration is typically used as the EPC for that area. This is the case for the two offsite areas (Dana Farm and Western Excelsior). However, EPCs were estimated for the unpermitted mill and background exposure areas. A summary of sample identification numbers, depth of samples and other details are provided in Table B2. The soil EPCs used in this evaluation are shown in Appendix Table B3.

Public Health Implications

The public health implications of exposure to surface soil contaminants at the Red Arrow Unpermitted Mill site are determined using exposure dose estimations based on the exposure parameters described above. As discussed earlier, the contaminants of potential concern are selected by screening against the comparison values. To assess the public health implications of contaminants of potential concern, the estimated doses for non-cancer health effects are divided by the appropriate health-based guidelines to calculate the Hazard Quotient (HQ). The health-based guidelines used in this evaluation are shown in Appendix C, Table C1. The cumulative non-cancer hazard (or hazard index; HI) of multiple contaminants is estimated by adding all HQs together. A HQ or HI greater than one indicates the estimated exposure exceeds the non-cancer health-based guideline and requires further evaluation by comparison of estimated exposure doses or concentrations with reference levels observed in animal and/or human studies (see Appendix C for more details). These non-cancer levels are referred to as the No-Observed-Adverse-Effect Level (NOAEL) and the Lowest-Observed-Adverse-Effect Level (LOAEL).

Cancer risks are averaged over a lifetime and the results of the exposure dose estimation are multiplied by the Oral Slope Factors established by EPA or state health agencies (Table C3).

This calculation estimates the theoretical cancer risk, which is compared to EPA's target cancer risk range of 1 excess cancer case per million people exposed over a lifetime to 100 excess cancer cases per million people exposed over a lifetime (1×10^{-6} to 1×10^{-4}). In addition, it is important to note that EPA has recently recommended a default value of 60% Relative Bioavailability for arsenic in soil (EPA 2012). This assumption is applied in the estimation of doses for arsenic exposure via soil ingestion pathway.

It should be noted that because of the uncertainties regarding exposure conditions and the adverse health effects associated with environmental levels of exposure, definitive answers on whether health effects actually will occur or will not occur are not possible. The evaluation only serves as a means of gaining a better perspective on how strongly the available toxicological information in the scientific literature suggests potential for harmful exposures (i.e., could harm people's health). Appendix B contains additional information on the exposure doses calculated for this evaluation using the Central Tendency Exposure (CTE) and Reasonable Maximum Exposure (RME) assumptions. Appendix C contains additional information on the toxicological evaluation and toxicity values used in this evaluation.

The following two sections discuss:

1) The estimated risks from exposure to soil COPCs in each area of potential concern (unpermitted mill; Western Excelsior, and Dana Farm). In addition, the estimated risks for background areas are also discussed
2) The qualitative evaluation of health implication of potential exposures to ambient air mercury

Exposure to Soil Contaminants (Quantitative Evaluation)

Unpermitted Mill

As described above, an acute exposure scenario occurring over a period of 1-day was used to evaluate adults coming into contact with tailings at the mill. The non-cancer exposure doses and the associated hazard quotients are shown in Table 1. It should be noted that acute health-based guidelines are only available for arsenic, copper, and mercury. Therefore, long-term health-based guidelines were conservatively used to evaluate acute exposures to hexavalent chromium (ATSDR Intermediate Minimal Risk Level) and antimony (EPA chronic Reference Dose). It should also be noted that the type of chromium found in tailings and soil has not been determined. To be conservative, it was assumed that all of the chromium found in tailings and soil is the more toxic hexavalent chromium.

The hazard quotient (HQ) for each contaminant of potential concern is well below the benchmark level of one, which indicates that the estimated exposure dose for each contaminant is well below the associated health-based guideline. The highest estimated non-cancer HQ of 0.07 is a result of exposure to antimony in the tailings. This indicates that the estimated exposure dose for antimony is more than 14 times lower than the chronic health-based guideline for antimony. In addition, the total combined HQ (Hazard Index, or HI) of 0.14, which takes into account the additive effect of all contaminants of potential concern, is also well below one. Together, these data indicate that the estimated exposure to soil contaminants occurring over a period of one-day at the unpermitted mill are not likely to result in adverse non-cancer health effects.

Table 1. Acute (1-day) Non-Cancer Dose Calculations and Estimated Hazard Quotients for Adults at the Unpermitted Mill

Contaminants of Potential Concern	EPC (mg/kg)	Ingestion Pathway		Dermal Pathway		Combined Hazard Quotients
		Adult Non-cancer Dose*	Hazard Quotient	Adult Non-cancer Dose*	Hazard Quotient	
Antimony	19.7	0.000028	0.07	--	--	0.07
Arsenic	116.3	0.0001	0.02	0.00002	0.0023	0.022
Chromium (hexavalent)	7.6	0.000011	0.0022	--	--	0.0022
Copper	223.6	0.00032	0.032	--	--	0.032
Inorganic Mercury	38.1	0.000054	0.0078	--	--	0.0078
Hazard Index	--	--	**0.13**	--	**0.004**	**0.14**

NOTE: EPC = Exposure Point Concentration (Calculated Concentration, *n*= 17), mg/kg = milligram per kilogram, * Dose in units of milligram per kilogram body weight per day

Dana Farm

Residential adults and children were evaluated at the Dana Farm. Children were also added to the evaluation of this area because unconfirmed reports suggest that children used at least a portion of the farm for horseback riding. Yet it is still unclear how often children or adults were exposed to contaminated soils at the Dana Farm. Arsenic and chromium are the only contaminants selected as COPCs at the farm. Once again, all chromium was considered as hexavalent chromium. For each scenario considered in this evaluation, the estimated non-cancer health hazards and estimated cancer risks at the Dana Farm are well below a level of concern.

The estimated non-cancer exposure doses for acute exposures are shown in Table B4. For both children and adults, the estimated doses over a period of 1-day are below the health-based guidelines for arsenic and chromium. The greatest potential risk stems from children's exposure to arsenic in contaminated soil. The combined child (ingestion and dermal) HQ for arsenic is 0.11, or 9 times lower than the acute health-based guideline for arsenic. The combined HQs from incidental ingestion and dermal exposures are also lower than the health-based guidelines for both contaminants of concern. In addition, the estimated child cumulative HI from exposure to arsenic and chromium is 0.12 (chromium was not found to be a major contributor to the total risk). This information indicates that non-cancer adverse health effects are not expected from a 1-day acute exposure to the tailings and soil found at the Dana Farm.

For the CTE scenario, the non-cancer and cancer dose estimates are shown in Table B5. The non-cancer dose estimates for children and adults are well below the health-based guidelines for arsenic and chromium. The estimated cumulative non-cancer HI for children is 0.13 and the HI for adults is 0.029. This indicates that non-cancer health effects are not likely to occur in children or adults from exposure to tailings at the Dana Farm for 26 days over a period of one year. Moreover, the estimated cancer risks shown in Table B5 are lower than the EPA target cancer risk range of 1 in a million to 100 in a million, or $1x10^{-4}$ to $1x10^{-6}$. For children, the estimated cancer risks from exposure to arsenic and chromium for the CTE exposure scenario are less than one excess cancer case per million exposed children ($8.4 x10^{-7}$). The cancer risk estimations for the adult CTE exposure scenario are even lower at $1.9 x10^{-7}$excess cancer cases per million people exposed. This indicates a very low increased risk of developing cancer from exposure to tailings and soil at the Dana Farm for 26 days over a period of one year.

The non-cancer and cancer dose estimations for the RME scenario are shown in Table B6. The non-cancer dose estimates for children and adults are well below the health-based guidelines for arsenic and chromium. The estimated cumulative non-cancer HI for children is 0.26 and the HI for adults is 0.058. This indicates that non-cancer health effects are not likely to occur in children or adults from exposure to tailings and soil at the Dana Farm for 52 days over a period of one year. The estimated cancer risks for children, shown in Table B6, are at the low-end of the EPA target cancer risk range with approximately 2 excess cancer cases per million people exposed, or $1.7x10^{-6}$. For adults, the estimated cancer risks from exposure to arsenic and chromium for the RME exposure scenario are less than one excess cancer case per million exposed people ($3.8x10^{-7}$). This indicates that children and adults have a very low increased risk of developing cancer from exposure to tailings and soil at the Dana Farm for 52 days over a period of one year.

Summary of Dana Farm Public Health Implications

Overall, the results of this evaluation indicate a very low risk of developing adverse non-cancer health effects and/or cancer from exposure to arsenic and chromium at the Dana Farm. All results for the Dana Farm are summarized in Table 2.

Table 2. Summary of the Total Estimated Risks of Incidental Ingestion and Dermal Exposure to Soil at the Dana Farm and Background AOCs

Dana Farm and Background Non-cancer Risk Estimates												
Scenario	**Arsenic**		**Chromium***		**Combined**		**Arsenic**		**Chromium***		**Combined**	
	Child Background Non-cancer HQs	**Dana Farm Child Non-cancer HQs**	**Child Background Non-cancer HQs**	**Dana Farm Child Non-cancer HQs**	**Child Background Non-cancer HQs**	**Dana Farm Child Non-cancer HQs**	**Adult Background Non-cancer HQs**	**Dana Farm Adult Non-cancer HQs**	**Adult Background Non-cancer HQs**	**Dana Farm Adult Non-cancer HQs**	**Adult Background Non-cancer HQs**	**Dana Farm Adult Non-cancer HQs**
Acute	0.0052	*0.11*	0.0093	*0.0094*	0.015	*0.12*	0.0012	*0.024*	0.0021	*0.0021*	0.0033	*0.027*
CTE	0.0062	*0.13*	0.00066	*0.00067*	0.0068	*0.13*	0.0014	*0.029*	0.00015	*0.00015*	0.0016	*0.029*
RME	0.012	*0.25*	0.0013	*0.0013*	0.014	*0.26*	0.0028	*0.058*	0.0003	*0.00031*	0.0031	*0.058*

Dana Farm and Background Cancer Risk Estimates												
Scenario	**Arsenic**		**Chromium***		**Combined**		**Arsenic**		**Chromium***		**Combined**	
	Child Background Cancer Risks	**Dana Farm Child Cancer Risks**	**Child Background Cancer Risks**	**Dana Farm Child Cancer Risks**	**Child Background Cancer Risks**	**Dana Farm Child Cancer Risks**	**Adult Background Cancer Risks**	**Dana Farm Adult Cancer Risks**	**Adult Background Cancer Risks**	**Dana Farm Adult Cancer Risks**	**Adult Background Cancer Risks**	**Dana Farm Adult Cancer Risks**
CTE	$4.0x10^{-8}$	*$8.2x10^{-7}$*	$2.4x10^{-8}$	*$2.4x10^{-8}$*	$6.3x10^{-8}$	*$8.4x10^{-7}$*	$9.1x10^{-9}$	*$1.9x10^{-7}$*	$5.4x10^{-9}$	*$5.5x10^{-9}$*	$1.4x10^{-8}$	*$1.9x10^{-7}$*
RME	$8.0x10^{-8}$	*$1.6x10^{-6}$*	$4.7x10^{-8}$	*$4.8x10^{-8}$*	$1.3x10^{-7}$	*$1.7x10^{-6}$*	$1.8x10^{-8}$	*$3.7x10^{-7}$*	$1.1x10^{-8}$	*$1.1x10^{-8}$*	$2.9x10^{-8}$	*$3.8x10^{-7}$*

NOTES: HQ = Hazard Quotient, CTE = Central Tendency Exposure, RME = Reasonable Maximum Exposure, Background calculations are based off the site-specific background soil samples collected within one-quarter mile of the site, bolded values exceed the health-based guideline or target cancer risk range, * All chromium in soil was conservatively assumed to be hexavalent chromium for the health evaluation

Western Excelsior

Three exposure scenarios were considered at the Western Excelsior facility. This includes an acute, 1-day scenario; a 26-day CTE scenario; and a 52-day RME scenario for adult workers through ingestion and dermal contact. In addition, a default exposure scenario that evaluates the potential risks based on 250 days of exposure per year is included in Appendix C. The estimated exposure doses and the resulting hazard quotients for each scenario are shown in Table B7 (acute), Table B8 (CTE), and Table B9 (RME). Arsenic and chromium were the only contaminants selected as COPCs in the Western Excelsior AOC. Once again, all chromium was considered hexavalent chromium.

In all cases the estimated exposure to arsenic and chromium is well below a level of concern for non-cancer and carcinogenic health risks. For the acute exposure scenario, the combined HQ for incidental ingestion and dermal exposures to arsenic and chromium is 0.02 and 0.0012, respectively (Table B7). This means that the estimated dose of arsenic is 50 times lower than the acute health-based guideline for arsenic and the estimated dose of chromium is over 800 times lower than the intermediate health-based guideline for chromium. In addition, the cumulative HI for acute exposure to both arsenic and chromium is 0.022, which is well below the benchmark of 1(i.e., below health-based guidelines). This indicates that acute, one-day exposures to arsenic and chromium in tailings at the Western Excelsior facility are not likely to result in harmful health effects.

The estimated non-cancer health hazards for the CTE scenario are also well below the health-based guidelines for arsenic and chromium. The combined HQs for incidental ingestion and dermal exposure to arsenic and chromium are 0.024 and 0.00009, respectively (Table B8). The cumulative HI is 0.024 as chromium is only a minor contributor to the overall health hazard at the Western Excelsior AOC. This indicates that harmful non-cancer health effects are not likely to occur in adult workers from exposure to tailings at the Western Excelsior facility for 26 days over a period of one year. The estimated cancer risks for the CTE worker scenario are also lower than EPA's target cancer risk range of 1 excess cancer case per million people to 100 excess cancer cases per million people exposed for a lifetime ($1x10^{-6}$ to $1x10^{-4}$). The combined (incidental ingestion and dermal contact) cancer risks for arsenic and chromium are $1.6x10^{-7}$ and $3.1x10^{-9}$, respectively. The cumulative estimated cancer risk from exposure to both contaminants is $1.6\ x10^{-7}$, or less than 1 excess cancer case per million people exposed. This indicates a very low increased risk of developing cancer following exposure to tailings while working at the Western Excelsior facility for 26 days over a period of one year.

The estimated non-cancer health hazards and the cancer risks for the RME scenario are approximately two times higher than the estimated risks for the CTE scenario, but are still well below a level of concern. The combined HQs for incidental ingestion and dermal exposure to arsenic and chromium are 0.049 and 0.00018, respectively (Table B9). The estimated cumulative HI from exposure to arsenic and chromium is 0.049. This indicates that harmful non-cancer health effects are not likely to occur in adult workers from exposure to tailings at the Western Excelsior facility for 52 days over a period of one year. The estimated combined cancer risks for adult workers from incidental ingestion and dermal exposure to arsenic and chromium are $3.1\ x10^{-7}$ and $6.3x10^{-9}$, respectively. The estimated cumulative cancer risk from exposure to both contaminants is $3.2\ x10^{-7}$, or less than 1 excess cancer case per million people exposed. This indicates a very low increased risk of developing cancer following exposure to mining-related material at the Western Excelsior facility for 52 days over a period of one year.

Summary of Western Excelsior Public Health Implications

Overall, the results of this evaluation at the Western Excelsior facility indicate a very low risk of developing adverse non-cancer health effects and/or cancer from exposure to arsenic and chromium at the Western Excelsior facility. All results for the Western Excelsior facility are summarized in Table 3.

Table 3. Summary of the Total Estimated Risks of Incidental Ingestion and Dermal Exposure to Soil at the Western Excelsior Facility and Background AOCs

Western Excelsior and Background Non-cancer Risk Estimates						
Scenario	**Arsenic**		**Chromium***		**Combined**	
	Background Non-cancer HQs	**Western Excelsior Non-cancer HQs**	**Background Non-cancer HQs**	**Western Excelsior Non-cancer HQs**	**Background Non-cancer HQs**	**Western Excelsior Non-cancer HQs**
Acute	0.0011	*0.018*	0.0021	*0.0012*	0.0033	*0.02*
CTE	0.0013	*0.024*	0.00015	*0.000088*	0.0015	*0.024*
RME	0.0026	*0.049*	0.0003	*0.00018*	0.0029	*0.049*

Western Excelsior and Background Cancer Risk Estimates						
Scenario	**Arsenic**		**Chromium***		**Combined**	
	Background Cancer Risks	**Western Excelsior Cancer Risks**	**Background Cancer Risks**	**Western Excelsior Cancer Risks**	**Background Cancer Risks**	**Western Excelsior Cancer Risks**
CTE	$8.5x10^{-9}$	*$1.6x10^{-7}$*	$5.4x10^{-9}$	*$3.1x10^{-9}$*	$1.4x10^{-8}$	*$1.6x10^{-7}$*
RME	$1.7x10^{-8}$	*$3.1x10^{-7}$*	$1.1x10^{-8}$	*$6.3x10^{-9}$*	$2.8x10^{-8}$	*$3.2x10^{-7}$*

NOTES: HQ = Hazard Quotient, CTE = Central Tendency Exposure, RME = Reasonable Maximum Exposure, Background calculations are based off the site-specific background soil samples collected within one-quarter mile of the site, * All chromium in soil was conservatively assumed to be hexavalent chromium for the health evaluation

Site-Specific Background Areas

The estimated CTE and RME risks of exposure to COPCs (arsenic and chromium) in site-specific background surface soil samples (0-2inches) are shown in Tables B10 to B15 for the exposure areas of potential concern (Dana Farm and Western Excelsior). The estimated background risks are also summarized next to the estimated risks for the Dana Farm and Western Excelsior AOCs in Tables 2 and 3 for comparison purposes. The estimated risks under all exposure scenarios (i.e., acute, CTE, and RME) are well below the benchmark level of one for non-cancer hazards and the low-end of EPA's target cancer risk level of $1x10^{-6}$. For example, the highest estimated, background, non-cancer hazard index is 0.014 (Table 2, residential child, Dana Farm). In comparison, the same hazard index from site-related contamination in this area is 0.26 (Table 2, RME residential child, Dana Farm). This indicates that the estimated non-cancer health hazards from exposure to site-related soil at the Dana Farm AOC is approximately 19 times higher than exposure to background levels of arsenic and chromium. Similarly, the highest estimated total cancer risk for site-specific background soil exposures is 1.3×10^{-7} compared to the estimated risks from exposure to site-related contamination of 1.7×10^{-6} (Table 2, RME residential child, Dana Farm).

Overall, the estimated background risks are notably lower than the estimated risks associated with exposure to site-related contaminants. However, the estimated risks from exposure to chromium in background samples are generally higher than what was found in site-related contamination. This indicates that the levels of naturally occurring chromium are higher in the background samples than the tailings from the mill. Arsenic and chromium were the only contaminants that exceeded the screening levels in background samples and both of these metals are naturally occurring and are not related to the site. Thus, it appears that site-related contamination has remained localized in areas that it was deposited and has not mobilized to the surrounding background areas via various mechanisms (e.g., wind transport, physical movement by people, and wet and dry deposition of ambient air mercury). For more information on background levels of arsenic in EPA Region 8, see: http://www2.epa.gov/region8/hh-exposure-assessment.

Potential Exposure to Mercury in Ambient Air (Qualitative Evaluation)

Residents and community members living and working in the vicinity of the unpermitted mill might have experienced mercury exposures stemming from operations at the mill. As already mentioned above, the potential for past, current, and future exposures to mercury is evaluated qualitatively because ambient air data for past emissions during the unpermitted mill operations is not available. The overall potential for adverse health effects from exposure to mercury in ambient air is dependent on the rate of release, fate and transport, frequency and duration of exposure, and individual factors (e.g., age, life style, health status, and family history). Therefore, Appendix E provides details on the following topics: environmental sources of mercury, fate and transport of mercury, health effects, reference levels of mercury, and environmental burden of mercury at a local and regional level (i.e., in the Mesa Verde National Park/Four Corners region). These topics are briefly discussed below.

Mercury is a highly toxic metal and occurs in the environment as a result of natural and anthropogenic (man-made) activities. In nature, mercury exists in three forms: elemental, organic, and inorganic salts. All forms of mercury are harmful to humans and can produce a wide range of health effects depending on the type of mercury, the dose, and duration of exposure. High levels of any form of mercury can permanently damage the brain, kidneys, and a developing fetus. Mercury enters the body via inhalation, ingestion, and absorption through the skin. Potential sources of general population exposure to mercury include inhalation of metallic mercury vapor in ambient air, ingestion of inorganic mercury contaminated soil, and dietary intake of methyl mercury contaminated fish and other sea food and foodstuffs. Common sources of mercury exposure include household items that can release mercury when they are improperly disposed of, broken, or mishandled (e.g., thermometers, light bulbs, pesticides, antibacterials, and fungicides). People can also be exposed when participating in hobbies involving mercury containing products (e.g., antique collection, painting); performing rituals with mercury containing products; and taking certain herbal medications. All people have at least some amount of mercury in their body (CDC 2013).

Potential Sources of Mercury Exposure in the Vicinity of the Unpermitted Mill Site

Mercury vapor in the atmosphere represents the major pathway of regional and global transport of mercury because it can reside in the atmosphere for about a year, and eventually be converted to a water soluble form and returned to the earth's surface as rainwater. The unpermitted mill site is located in the vicinity of the Mesa Verde National Park in the Four Corners region of southwestern Colorado. Mercury is a growing threat in the Four Corners region of Colorado due to a large number of coal-fired power plants for energy generation and increases in forest fires which may greatly contribute to the transport of mercury from terrestrial sites to area water bodies (Peltz et al. 2011). The information provided in Appendix D indicates that mercury levels continue to increase in Colorado, but have risen faster in the Mesa Verde National Park region over the last decade, especially over the last 5 years. The available scientific knowledge supports a plausible link between mercury emissions from anthropogenic combustion and industrial sources and methylmercury concentrations in freshwater fish (EPA 1997). Various reservoirs with fish advisories in the Four Corner region and their distance from the unpermitted mill site are shown in Appendix D (Table D2 and Figure D4).

A significant correlation was also found between total gaseous mercury in air in the small-scale gold mining area and mercury concentrations in soil (Garcia-Sanchez 2006). In this study, an air and soil mercury measurement was carried out at a mill site up to a distance of 1000 meters (approximately two-thirds of a mile), and it was observed that the air mercury concentration and mercury soil concentration decreased with increasing distance from the mill site. Exposures from artisanal and small-scale gold mining (ASGM) can also affect the communities surrounding the processing centers. Based on the current epidemiological studies conducted in ASGM communities in multiple countries on three continents (South America, Asia, and Africa), mercury exposure in ASGM communities is associated with adverse health effects including kidney dysfunction, autoimmune dysfunction, and neurological symptoms (WHO 2013). A recent investigation conducted in the US (Alaska) found only one out of eighteen participants with urine mercury level (106.07 microgram per gram (µg/g) creatinine) above the health reference level (20 µg/L or 20 µg/g creatinine) (ATSDR 2013). This one participant had been regularly heating gold samples in recent months for 90 hours/month for a few months; however, this participant was asymptomatic. It is, however, important to note that the magnitude of exposure and the potential for adverse health effects can vary based on a variety of factors, including distance of communities from the source, meteorological conditions, exposure duration, and individual factors (e.g., health status, genetics, life style, age, and gender).

Environmental Levels of Mercury in the Vicinity of the Unpermitted Mill

As discussed above in the site description section, the overall available data for mercury (surface wipe samples, air samples, water samples, soil samples, and indoor air) collected from inside the mercury building indicate elevated levels of mercury and past use of mercury in the building (Walter 2013 and Weston 2014). The site-specific environmental data that are available to evaluate the potential for current and future community exposures to mercury in the vicinity of the unpermitted mill includes surface soil mercury levels (from the Dana farm, Western

Excelsior, and 20 background locations), surface wipe samples from the eastern fence line of the mill, and Lumex® air samples. These sampling results are discussed below to qualitatively evaluate the potential for past, current, and future exposures to mercury.

Past Exposures

As mentioned, no ambient air and soil data are available to quantitatively evaluate past exposures during the time period when the unpermitted mill was operational. However, analysis of meteorological conditions by the APCD of CDPHE indicates the possibility of transportation of mercury emissions from the unpermitted mill site towards the town of Mancos and inhabited areas, as discussed in APCD document provided in Appendix F.

Current and Future Exposures

After the unpermitted mill was shut down, surface wipe samples were collected from inside and outside the mercury building of the unpermitted mill site. The outdoor samples are qualitatively evaluated by comparison to interior surfaces. According to Weston (2014), the indoor levels of mercury are much higher than the levels found in exterior surface samples. It is, however, important to note that the potential for outdoor mercury exposures cannot be evaluated based on the results of wipe samples. It is important to note that the interior wipe samples indicate high levels of mercury inside the Mercury Building that will require cleaning prior to re-occupancy.

In October 2013, Weston (2014) conducted mercury vapor monitoring for EPA Region 8 with a Lumex® mercury vapor detector outdoors at the unpermitted mill. No elevated concentrations of mercury vapor (data not available) were found escaping from the units of the storage facility to the west of the unpermitted mill or the Septic system on the unpermitted mill (Weston 2014).

Mercury released into the atmosphere from natural and anthropogenic sources deposits mainly as inorganic mercury, and the affinity of mercury species for soil results in soil acting as a large reservoir for anthropogenic mercury emissions (EPA 1997). Furthermore, a significant correlation was found between total gaseous mercury in air in the small-scale gold mining area and mercury concentrations in soil (Garcia-Sanchez 2006). It was also observed that the air mercury concentration and mercury soil concentration decreased with increasing distance from the ASGM site. Therefore, surface soil samples collected from background locations and areas of potential concern can be used to qualitatively evaluate potential exposures to mercury. In this evaluation, mercury is not even selected as a contaminant of potential concern for offsite areas of potential concern and background areas, with the maximum detected concentration of 0.76 mg/kg, 1.9 mg/kg, and 0.11 mg/kg at the Dana Farm, Western Excelsior, and background areas, respectively (Table A4 through A6). It should be noted that surface soil samples collected from background areas in the vicinity of the unpermitted mill site do not indicate mercury deposition as a result of emissions during the past operations at the unpermitted mill (Table A6). Mercury was only detected in one background soil sample at a concentration of 0.11 mg/kg, which is equivalent to the mean reporting limit if all background mercury samples collected. Overall, soil samples for mercury collected from areas of potential concern as well as background locations indicate very low levels of mercury in soil (i.e., below residential health guideline of 10 mg/kg for elemental mercury and 23 mg/kg for inorganic mercury); thereby, indicating a very low potential for current and future exposures to mercury.

Surveillance of blood and urinary mercury levels

Colorado has a mercury surveillance system which is built on a reporting requirement from clinical laboratories. Colorado law requires clinical laboratories to report to CDPHE all elevated blood (>5 µg/L) and urinary (>20 µg/L) mercury results for Colorado residents. The overall goal of the mercury surveillance program is to identify the potential sources of mercury exposure in elevated cases and provided targeted health education materials so that people can take steps to reduce exposures to mercury. Due to the potential concerns regarding potentially elevated mercury levels in biological samples, CCPEHA reviewed the mercury surveillance data for the years 2012, 2013, and 2014. No reportable blood or urinary mercury results were identified from anyone living in or near Mancos, Colorado.

Summary of findings for potential mercury exposures

Overall, the above information indicates the possibility of past community exposures through inhalation of mercury emissions from the unpermitted mill but the magnitude of past exposures cannot be quantified because the concentration of mercury in ambient air during mill operations is unknown. However, it is known that mercury contamination is currently localized inside the Mercury Building based on the exterior surface wipe sampling at the unpermitted mill. This finding is further supported by very low levels of mercury measured in 20 soil samples in relation to increasing distance from the unpermitted mill (i.e., background areas), especially, east of the site halfway between the site and the neighboring homes (locations 29 and 30), southwest of the site at the Dana Farm (at locations 27 and 28), and west of the site along the western edge perimeter of the storage area (at locations 52 to 56). Since June 2013, there are no operations at the unpermitted mill and the Mercury Building has been closed with no public access. EPA will clean up the Mercury Building prior to re-occupancy. Overall, these findings indicate a very low potential for current and future exposures to mercury associated with past operations at the unpermitted mill. In addition, for people not associated with the mill, the potential for past exposures appears to be low based on the current levels of mercury in the available environmental samples and biological samples (i.e. mercury surveillance data).

However, it is important to note that the unpermitted mill site is located in the vicinity of the Mesa Verde National Park, which has higher levels of mercury in the environment than other regions of Colorado because of mercury emissions from anthropogenic combustion and industrial sources. In addition, fish advisories are in place at six reservoirs with distances ranging from 7 to 55 miles from the unpermitted mill site in Mancos. The latest information regarding fish consumption advisories in Colorado can be found at CDPHE's Fish Consumption Program website (http://www.colorado.gov/cs/Satellite/CDPHE-WQ/CBON/1251595874901). Evaluation of mercury exposures from sources other than the unpermitted mill site is beyond the scope of this health consultation, but it should be noted that individuals living in the vicinity of the unpermitted mill may already be exposed to other sources of mercury through personal house hold use and higher regional mercury levels in the Four Corners region.

Uncertainty and Limitations

In general, the uncertainties associated with any risk-based health consultation are likely to over- or underestimate environmental exposures and the associated health hazards because all aspects of the actual exposure are typically unknown. This section of the discussion is not intended to be an in-depth description of all the uncertainties associated with this evaluation. Rather, the focus is to highlight the major assumptions and limitations that are specific to this evaluation and result in uncertainty.

- There are no land-use data to support the exposure frequency and/or exposure duration assumptions used in this assessment. This is a major source of uncertainty because these assumptions are vital components of the exposure dose calculations and the resulting public health implications of exposure to site-related contamination. This includes the possibility that young children (ages 0-6 years) could have come into contact with tailings at the millsite and Dana Farm, a scenario that was not considered in this evaluation based on the current knowledge of land-use (i.e. no one has suggested that young children were exposed to tailings). However, based on the current knowledge, health protective/conservative assumptions were made which are likely to overestimate health risks for the exposure scenarios considered in this evaluation.

- A limited amount of soil data is available for the Dana Farm and Western Excelsior. This limitation is addressed by using the maximum detected concentration as the exposure point concentration for the Dana Farm and Western Excelsior, which may result in over- or under-estimation of risk because the true maximum value might not have been achieved in a small sample size.

- Chromium speciation has not been conducted at the Unpermitted Mill site. Therefore, the species of chromium was conservatively assumed to be hexavalent (VI) chromium because of the availability of an oral cancer slope factor for hexavalent chromium (NJDEP 2009). This assumption is likely to overestimate cancer risk for chromium because hexavalent chromium degrades to trivalent chromium in the environment.

- Metals (e.g., selenium and thallium) that were not detected are not evaluated quantitatively. The impact of this uncertainty is likely to be insignificant because the detection limits were below the health-based CVs. It should be noted that the reporting limit of the analytical method for thallium exceeds the residential CV in all locations (including background); however, thallium was not detected in any sample collected from all off-post and on-post locations. Since thallium was not detected in any sample and the detection limit of 0.52 mg/kg is below the residential CV (0.78 mg/kg), thallium was not evaluated as a COPC.

- The assumption of additivity to estimate cumulative cancer and non-cancer risks can over- or under-estimate risk due to synergistic and antagonistic interactions. However, it is not considered a major source of uncertainty because the cumulative non-cancer hazards are much lower (greater than 10 times) lower than the acceptable level of one and the estimated cancer risks are primarily attributable to a single contaminant (arsenic).

- There is some uncertainty (i.e., over- or under-estimation of risk) due to the use of 0-1 foot depth interval data (versus 0-2 inches) to represent surface soil exposures in the areas of potential concern (unpermitted mill, Dana farm, and Western Excelsior). However, this uncertainty is not likely to impact the conclusions of this evaluation because many of the samples are collected from tailings piles, which are typically fairly homogenous throughout the pile. Thus, this approach accurately reflects the type of material that a person could be exposed to (a mix of tailings and soil).

- Health guidelines (or reference toxicity values) are not available for subchronic or intermediate (short-term) exposures for chromium and arsenic and therefore chronic (long-term) health guidelines are used to estimate short-term risks which may result in over-estimation of non-cancer hazards. Similarly, acute (1-14 days) health guidelines are available only for arsenic, copper, and inorganic mercury and therefore subchronic or chronic health guidelines are used for antimony and hexavalent chromium to estimate acute risks which may result in over-estimation of risk. In addition, the estimation of cancer risk for short-term exposures (e.g., 26 or 52 days) using the current methodology for cancer risk assessment is associated with uncertainty and may result in over- or under-estimation of cancer risk.

- It should be noted that in this evaluation, oral toxicity values were used to evaluate dermal exposures since dermal toxicity values are not available. This could result in an over or underestimation of risk; however, the resulting uncertainty is presumably low and this method for evaluating dermal risk is standard procedure in risk assessments.

- The largest uncertainty is associated with the evaluation of past mercury inhalation exposures because no ambient air data are available. In addition, the information is not available to estimate past ambient exposures by applying modeling approaches. These data gaps cannot be filled. Therefore, this uncertainty is addressed by qualitative evaluation of potential exposures to mercury. Furthermore, no information is available regarding potential exposures to the mill workers family members; this also remains a data gap.

Child Health Considerations

In communities faced with air, water, or food contamination, the many physical differences between children and adults demand special emphasis. Children could be at greater risk than are adults from certain kinds of exposure to hazardous substances. Children play outdoors and sometimes engage in hand-to-mouth behaviors that increase their exposure potential. Children are shorter than are adults; this means they breathe dust, soil, and vapors close to the ground. A child’s lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing, for access to medical care, and for risk identification. Thus adults need as much information as possible to make informed decisions regarding their children’s health.

In this health consultation, children and the embryo/fetus of pregnant women are the most sensitive receptor population of mercury exposure. However, past airborne mercury exposures from the unpermitted mill are not well defined and cannot be quantitatively evaluated. The only area of concern that included children (age 6 to 11 years) in this evaluation is the Dana Farm AOC. Mercury was not selected as a COPC at the Dana Farm and children’s exposure to all other site-related contaminants at the Dana Farm are below levels of health concern. It should be noted, however, that there is a potential for mill workers to transfer mercury from the facility while it was operational. Mercury could have been transferred via contaminated clothing, body, shoes, and other personal items to the workers home where children could have been exposed. Again, no information is available to evaluate potential exposures to the mill workers family members.

Conclusions

CCPEHA and ATSDR have reached six conclusions regarding past, current and future exposures to soil (0-1 foot) at the Red Arrow Mine and Mill Site. It is important to note that the following conclusions are not based on the evaluation of what is defined as surface soil (0-3 inches) as per ATSDR guidance. However, this uncertainty is not likely impact the conclusions because of fairly homogeneous nature of contamination in tailings piles from where many of the samples were collected to evaluate site-related exposures:

Past Exposures (2012-2013)

- *Past exposure (1-day acute) to mill tailings in the storage yard of the unpermitted mill are not likely to harm the health of trespassers or visitors.* This conclusion was reached because the estimated non-cancer exposure doses are well below the acute health-based guidelines for all contaminants of potential concern. In addition, the cumulative hazard index is also lower than 1, which indicates that the additive effect of all contaminants is below levels of concern known to cause harmful health effects. Therefore, the potential for non-cancer health effects is very low.

- *Past exposure over a period of one year to mill tailings at the Western Excelsior Plant is not likely to harm the health of workers under the assumptions used in this evaluation.* This conclusion was reached because the estimated non-cancer exposure doses (arsenic and chromium) for the acute, average (CTE), and high-end (RME) exposure scenarios are below levels known to cause harmful health effects (i.e., below the health-based guidelines). The non-cancer hazard index for cumulative exposure to arsenic and chromium is also below the benchmark level of one (i.e., below health guidelines) for all exposure scenarios considered in this evaluation. In addition, the estimated cumulative cancer risks for the CTE and RME exposure scenarios are lower than the low-end of EPA target cancer risk range (i.e., one excess cancer case per million people exposed). Overall, this indicates that the increased risk of developing harmful non-cancer health effects and cancer is very low for Western Excelsior employees that may have come into contact with the tailings for up to 52 days over a period of one year.

- *Past exposure over a period of one year to mill tailings at the Dana Farm is not likely to harm the health of children or adults residents and/or visitors under the assumptions used in this evaluation.* This conclusion was reached because the estimated non-cancer exposure doses for the acute, average (CTE), and high-end (RME) scenarios are below the health-based guidelines for arsenic and chromium for both children and adults at the Dana Farm. The non-cancer hazard index for cumulative exposure to arsenic and chromium is also below the benchmark level of one (i.e., below health guidelines) for each exposure scenario considered in this evaluation. In addition, the estimated cumulative cancer risks for the CTE and RME exposure scenarios for children and adults are lower than, or at the low-end of the EPA target cancer risk range (i.e., one excess cancer case per million people exposed). The highest estimated cancer risk is for the RME child, which equates to about 2 excess cancer cases per million people exposed, or 1.7×10^{-6}. Overall, this indicates that the increased risk of developing harmful non- cancer and cancer is very low for children and adults at the Dana Farm that may have come into contact with the tailings for up to 52 days over a period of one year.

- *CCPEHA and ATSDR cannot conclude whether past mercury emissions from the unpermitted mill could harm people's health.* This conclusion was reached because the information needed to make a decision is not available and cannot be obtained. No data are available on the ambient air concentration of mercury since it was an unpermitted mill site using illegal procedures and no air monitoring was conducted. In addition, no other information is available to use air modeling to estimate air concentrations. However, based on the qualitative evaluation of currently available surface soil data and biological samples collected from the state-wide mercury surveillance system, the potential for ambient exposures through inhalation pathway appears to be low. It should be noted that the area in the vicinity of the unpermitted mill is likely to have higher potential for mercury exposure than other regions in Colorado due to various other sources in the Four Corners region as demonstrated by the number of fish advisories and the available regional mercury deposition data.

Current and Future Exposures

- *Current and future exposures to tailings associated with the unpermitted mill are not likely to harm people's health.* This conclusion was reached because the tailings have been excavated and moved to the mill site. The excavated tailings, located at the mill, are covered with a temporary PVC liner to prevent wind erosion and water infiltration. The mill is also fenced and secured. Therefore, exposure to the consolidated mill tailings pile is also considered an incomplete exposure pathway for current and future exposures. It should be noted that this conclusion is contingent upon the EPA's continued removal actions such as removing the consolidated tailings pile and disposing of it properly (as outlined in the recommendations section).

- *Current and future exposures to mercury in the ambient air associated with the unpermitted mill operations are not likely to harm people's health.* This conclusion was reached because there have been no operations at the unpermitted mill since at least June 2013. The mercury building has been closed and no public access is allowed. Furthermore, the available environmental data show mercury levels well below levels of health concern. These findings indicate a very low potential for current exposures to mercury associated with past operations at the unpermitted mill. There is also a very low potential for future exposures to mercury since EPA plans to clean up the mercury building prior to the mill buildings being reoccupied.

Recommendations

CCPEHA recommends that EPA continue to reduce the potential for current and future exposures at the Red Arrow Mine and Mill Site. Specifically, EPA is planning to take the following protective public health measures to protect public health:

- Remove the consolidated tailings pile from behind the mill and dispose of properly.
- Complete backfilling excavations with clean soil in all areas that have yet to be backfilled. This action will eliminate the surface soil exposure pathway.
- Decontaminate the Mercury Building prior to re-occupancy to protect the health of future users of the mill property.
- No further removal action appears to be necessary at the Dana Farm and Western Excelsior.

Public Health Action Plan

The public health action plan for the site contains a description of actions that have been or will be taken by CCPEHA and other governmental agencies at the site. The purpose of the public health action plan is to ensure that this public health consultation both identifies public health hazards and provides a plan of action designed to mitigate and prevent harmful human health effects resulting from breathing, drinking, eating, or touching hazardous substances in the environment. Included is a commitment on the part of CCPEHA to follow up on this plan to be sure that it is implemented.

- CCPEHA will present the findings of this health consultation to the community through a public meeting and health education materials will be provided in a local repository for site-related document and will also be available on the internet.

- Upon request, CCPEHA will review any additional environmental data collected from the site to evaluate any remaining potential health concerns. If warranted by the new data, CCPEHA will amend this health consultation.

- CCPEHA will help answer any future health concerns regarding the removal of tailings and re-occupancy of the mercury contaminated mill building.

Report Preparation

This Health Consultation for the Red Arrow Unpermitted Mill site was prepared by the Colorado Department of Public Health and Environment under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry. It is in accordance with approved agency methodology and the procedures existing at the time the health consultation was initiated. Editorial review was completed by the cooperative agreement partner. The Agency for Toxic Substances and Disease Registry has reviewed this health consultation and concurs with its findings based on the information presented in this report. ATSDR's approval of this document has been captured in an electronic database, and the approving reviewers are listed below.

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Attachment 1. Responses to Community Concerns

These responses seek to address the primary health concerns and other important topics related to the Red Arrow Unpermitted Millsite. Some of the information has been gathered from previous fact sheets produced by the Colorado Department of Natural Resources and the Environmental Protection Agency.

1) **Is there a risk from coming into contact with contaminated soil and tailings?**

   RESPONSE: Based on the results of this evaluation, the estimated health hazards and cancer risks from incidental ingestion and dermal (skin) contact with contaminated soil are not expected to harm people's health from past exposures over a period of one year.

2) **Is there potential for ground water and surface water contamination from leaching of heavy metals found in the tailings piles?**

   RESPONSE: EPA's hydrogeologist reviewed the site reports and data and found little reason to believe that sampling of groundwater is necessary at this time. The short time the facility operated, the short time the mill tailings were on the ground behind the facility, the low amount of precipitation in this area, and the rapidly decreasing mercury and low arsenic values (at 1.5 ft. depth), when viewed as a whole, do not indicate any reason for groundwater concerns (EPA 2014b).

3) **Am I at risk from breathing mercury vapors emitted from the mill?**

   RESPONSE*:* This question cannot be answered definitively since there is no way of estimating what the concentration of mercury in ambient air was, how far it travelled, and how long mercury was released. It has been estimated that the mill was operational for approximately 6-11 months. However, it is not clear is mercury was used the entire time that Red Arrow occupied the mill buildings. Based on the qualitative analysis included in this document, it seems that some mercury was emitted from the unpermitted millsite. However, any potential exposures to mercury in air cannot be quantified. Based on the qualitative evaluation of currently available surface soil data and biological samples collected from the state-wide mercury surveillance system, the potential for ambient exposures through inhalation pathway appears to be low. It should be noted that the area in the vicinity of the unpermitted mill is likely to have higher potential for mercury exposure than other regions in Colorado due to various other sources in the Four Corners region as demonstrated by the number of fish advisories and the available regional mercury deposition data. If you are concerned for your health or are experiencing health effects that have been associated with mercury exposure, it is best to consult with your physician. More information on possible sources of mercury exposure and common health effects of mercury can be found here:

   - http://www.atsdr.cdc.gov/ToxProfiles/tp46-c1-b.pdf
   - http://www.atsdr.cdc.gov/tfacts46.pdf
   - http://www.atsdr.cdc.gov/mercury/docs/InfoHealthCareProviders.pdf

4) **What other ways can I be exposed to mercury?**

RESPONSE*:* People can come into contact with mercury in a variety of ways. The most common ways are through ingestion of fish containing high amounts of mercury and inhalation of mercury in air during occupational activities, small-scale gold mining, and other hobbies that utilize mercury. Through mercury surveillance activities in Colorado, it appears that the primary mercury exposure pathway in Colorado that results in elevated mercury levels in the body is consumption of fish species containing high amounts of methylmercury. It should also be noted that the data gathered for this evaluation indicate that people living in the Four Corners Region are exposed to higher levels of mercury in air than many places due to the number of coal burning power plants in the region.

5) **Should I have the levels of mercury in my body tested?**

RESPONSE*:* The Colorado Cooperative Program for Environmental Health Assessments consulted with an Agency for Toxic Substances and Disease Registry Medical Officer (Michelle Watters, M.D., MSPH). Due to a relatively short half-live of about 60 days for elemental mercury in the body, no urinalysis for mercury was recommended because it is likely that most, if not all, mercury in the body as a result of past mill operations would have been eliminated since the mill operations stopped in at least June 2013. However, the decision to get a urinalysis for mercury is personal and we would encourage those interested in testing to seek the advice of their physician. In addition, Dr. Watters has provided and can continue to provide consultation to physicians on an as-needed basis and shared educational materials. Please see the following weblinks:

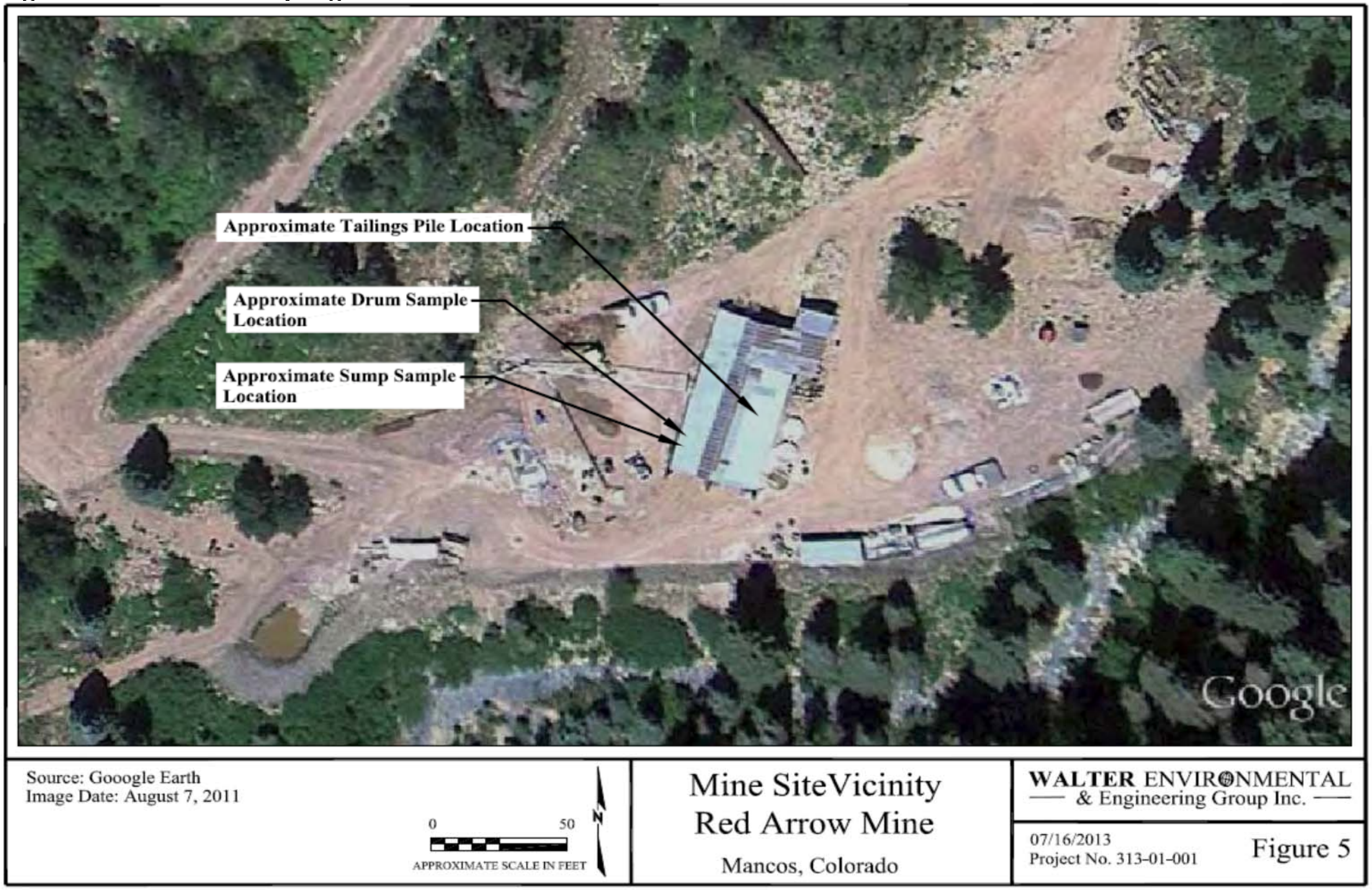
- http://www.atsdr.cdc.gov/toxfaqs/tfacts46_metallic_mercury.pdf
- http://www.atsdr.cdc.gov/mercury/docs/InfoHealthCareProviders.pdf
- http://www.kuskokwimcouncil.org/documents/mercury.pdf

6) **Were the workers of the unpermitted millsite at risk of disease from exposure to mercury?**

RESPONSE*:* CCPEHA and ATSDR do not have the authority to evaluate mill worker exposures, which come under the purview of the Occupational Health and Safety Administration. High levels of mercury contamination inside the “Mercury Building” of the millsite have been documented in the Walter (2013) and Weston (2014) Reports. However, it is not known what types of personal protective equipment mill workers were using during operations. It is also not known how they handled mercury and what potential exposures could have occurred inside the mill. ATSDR Region 8 contacted the National Institute for Occupational Safety and Health to evaluate potential mill worker health concerns. Further study was not feasible since no one was working at the mill at the time and a large amount of time had passed since the mill was closed. It is possible that mill workers were exposed to unacceptable levels of mercury in the mill. It is also possible that mercury could have been transferred to their homes on clothing, body, shoes, and other materials that were used at the mill during site operations. This could have resulted in exposure to family members. However, these exposures cannot be quantified based on the information that is available.

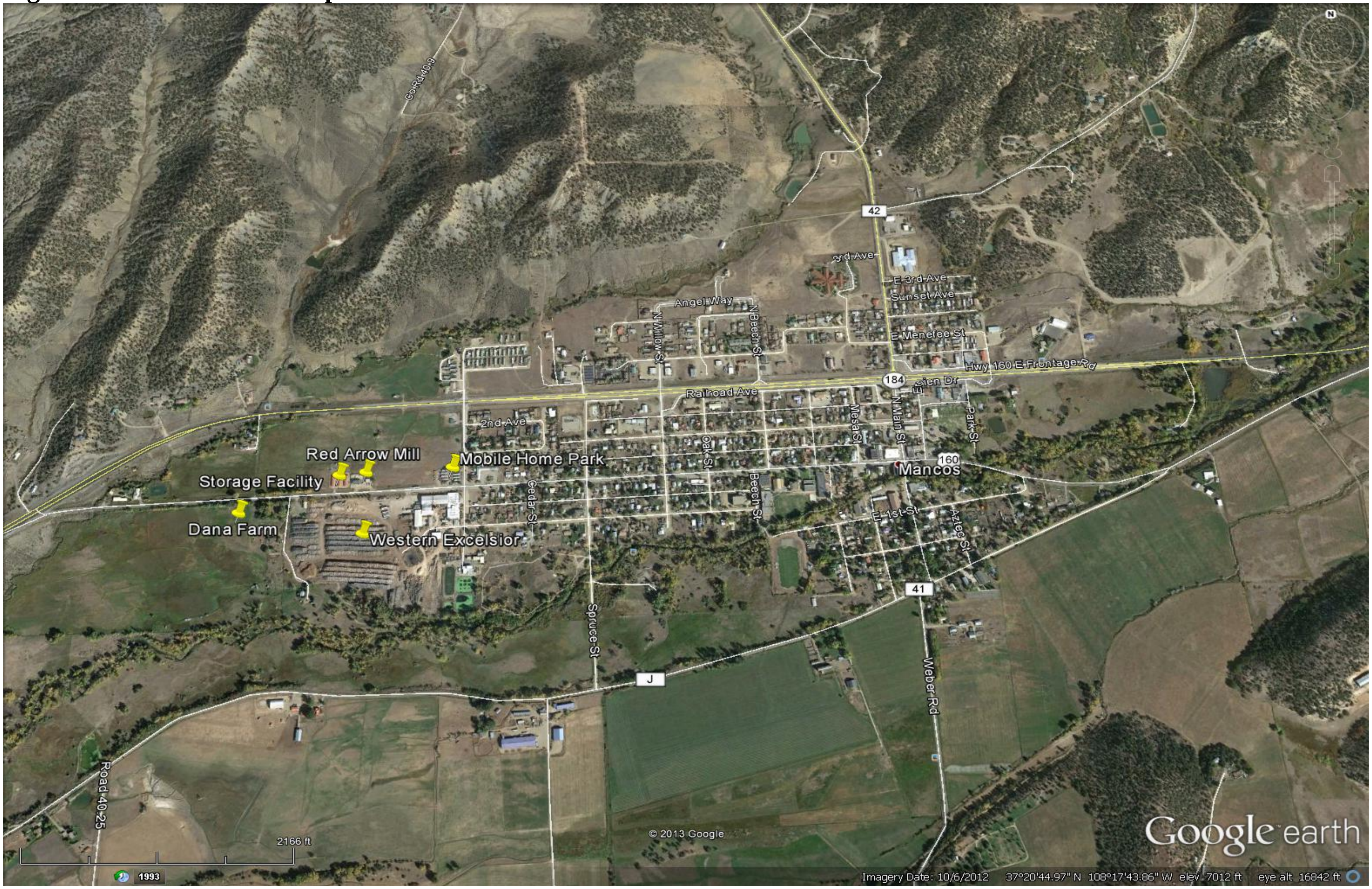
Appendix A. Additional Tables and Figures

Figure A1. Walters' Sampling Locations at the Red Arrow Mine



SOURCE: Walters 2013

Figure A2. Site Location Map

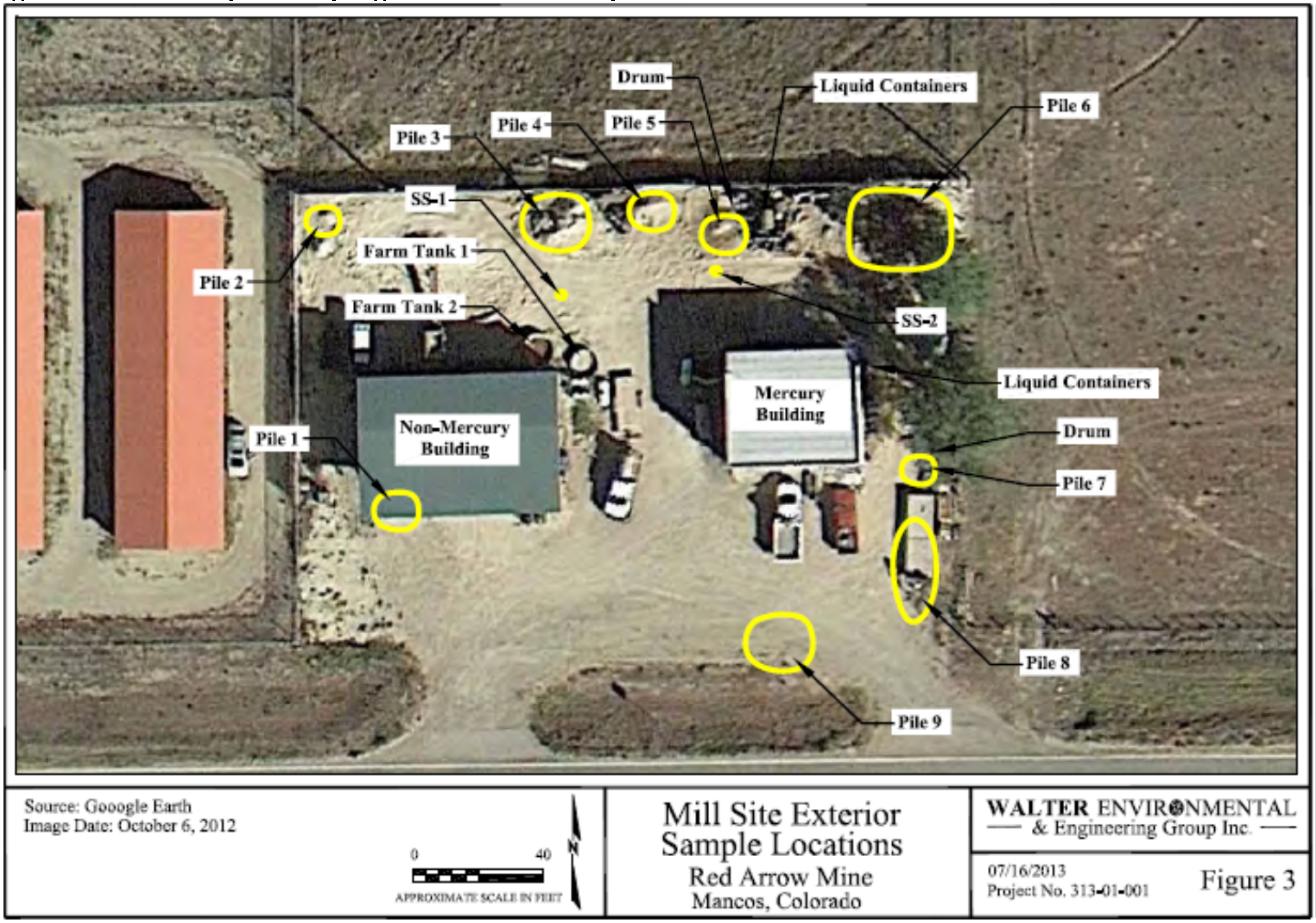


SOURCE: Google Earth

Figure A3. Layout of the Unpermitted Mill

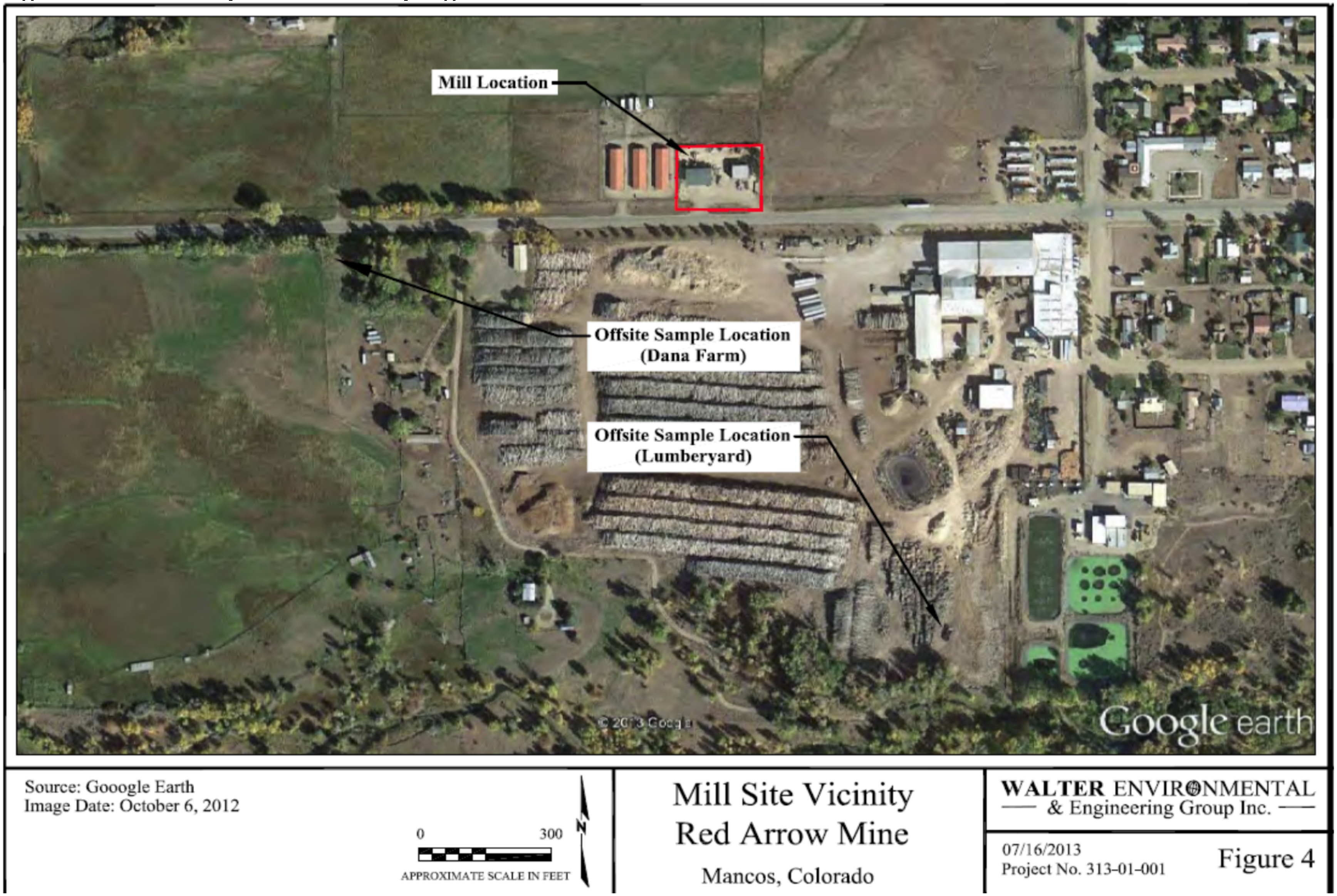
SOURCE: Walter 2013

Figure A4. Walter Report Sampling Locations at the Unpermitted Mill



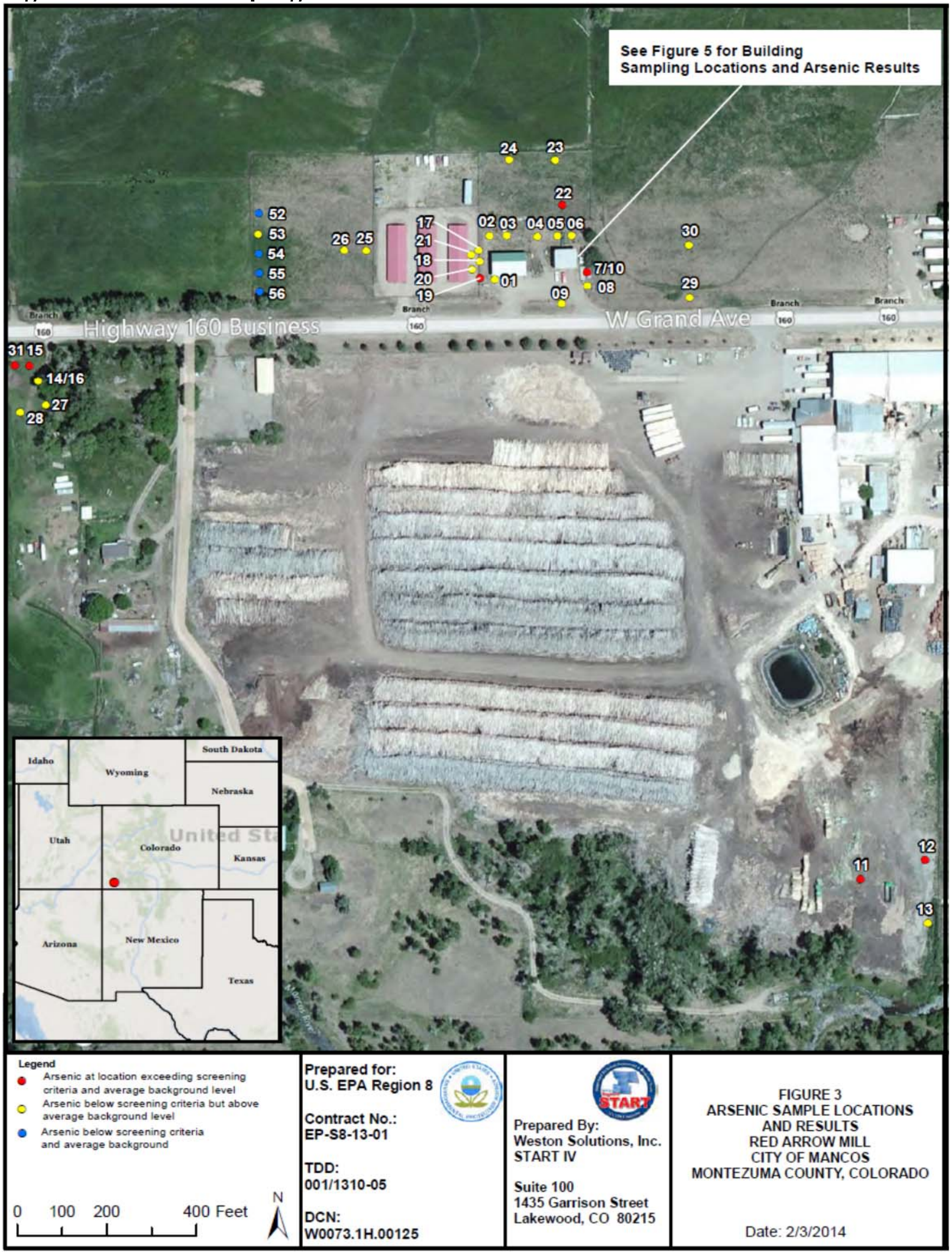
Source: Walters 2013

Figure A5. Walter Report Offsite Sampling Locations



SOURCE: Walters 2013

Figure A6. Weston Sampling Locations



SOURCE: Weston 2014

Table A1. Results of Tailings Data Collected from the Millsite for the Walter Report (Walter 2013)

Location	**Millsite Pile #1**	**Millsite Pile #1**	**Millsite Pile #2**	**Millsite Pile #3**	**Millsite Pile #3**	**Millsite Pile #3 (Dup)**	**Millsite Pile #5**	**Millsite Pile #6**	**Millsite Pile #7**	**Comparison Value***
Depth-Sample Type	**Surface-Grab**	**Surface-Grab**	**Surface-Composite**	**Surface-Composite**	**Surface-Composite**	**Surface-Composite**	**Surface-Composite**	**Surface-Composite**	**Surface-Composite**	
Analyte/Sample ID	*Walters-UM-TS1001*	*Walters-UM-TS1002*	*Walters-UM-TS2001*	*Walters-UM-TS3001*	*Walters-UM-TS3002*	*Walters-UM-TS3100*	*Walters-UM-TS5001*	*Walters-UM-TS6001*	*Walters-UM-TS7001*	
Antimony	8.3	5.3	**38.5**	3.3	11.9	12	11.5	7.3	18.3	20
Arsenic	**89.8**	**58.8**	**299**	**46.7**	**125**	**140**	**96.6**	**80.8**	**194**	**0.47**
Beryllium	ND(<1)	ND(<1)	ND(<1)	ND(<0.99)	ND(<1)	ND(<0.98)	ND(<1)	ND(<1.1)	ND(<0.98)	100
Cadmium	ND(<1)	ND(<1)	2.7	ND(<0.99)	1.3	1.3	1	ND(<1.1)	1.5	5
Chromium	**1.2**	**2.3**	**1.6**	**1.3**	**1.7**	**1.6**	**2.1**	**2.9**	**10.4**	**0.29****
Copper	166	114	575	73.2	257	271	205	162	311	500
Lead	23	16.1	41.3	13.5	29.9	35.7	20.2	19.8	133	400
Mercury	0.25	0.061	0.3	0.051	0.33	0.39	0.96	1.1	**55.7**	**10**
Nickel	ND(<3)	ND(<3)	ND(<3)	ND(<3)	ND(<3)	ND(<2.9)	ND(<3.1)	ND(<3.2)	7.9	820
Selenium	ND(<5)	ND(<5)	ND(<5)	ND(<4.9)	ND(<5)	ND(<4.9)	ND(<5.2)	ND(<5.3)	ND(<4.9)	250
Silver	ND(<3)	ND(<3)	3.2	ND(<3)	ND(<3)	ND(<2.9)	ND(<3.1)	ND(<3.2)	3.9	250
Thallium	ND(<1)		ND(<5)	ND(<4.9)	ND(<1)	ND(<4.9)	ND(<1)	ND(<1.1)	ND(<0.98)	0.78
Zinc	82.5	ND(<5) 89.8	142	84.8	102	104	68.9	91.3	119	15,000
Cyanide, Total	ND(<0.52)	ND(<0.51)	ND(<0.5)	0.58	ND(<0.51)	ND(<0.51)	ND(<0.51)	ND(<0.53)	ND(<0.5)	22

NOTE: all sample results in milligram per kilogram, ND = Not Detected (Reporting Limit), bolded values exceed the comparison values used in this evaluation. Thallium was never detected and the detection limit of 0.52 mg/kg is lower than the conservative residential soil screening value, * refer to Table A7 for more information on screening values used in this evaluation, ** screening value is for hexavalent chromium

Table A2. Results of Composite Tailings Data Collected from the Millsite for the Weston Report (Weston 2014)

Location	Millsite Pile #2	Millsite Pile #2	Millsite Pile #6	Millsite Pile #6	Millsite Pile #7	Millsite Pile #7 (Dup of 7-1)	Millsite Pile #7	Millsite Pile #7 (Dup of 7-2)	Millsite Pile #9	Millsite Pile #9	Pile along North fence line of the mill	Pile along North fence line of the mill	Comparison Value*
Depth	**1 foot**	**1.5 feet**	**1 foot**	**1.5 feet**	**1 foot**	**1 foot**	**1.5 feet**	**1.5 feet**	**1 foot**	**1.5 feet**	**1 foot**	**1.5 feet**	
Analyte/ Sample ID	*Weston-RAM-SO-02-01*	*Weston-RAM-SO-02-02*	*Weston-RAM-SO-06-01*	*Weston-RAM-SO-06-02*	*Weston-RAM-SO-07-01*	*Weston-RAM-SO-10-01*	*Weston-RAM-SO-07-02*	*Weston-RAM-SO-10-02*	*Weston-RAM-SO-09-01*	*Weston-RAM-SO-09-02*	*Weston-RAM-SO-22-01*	*Weston-RAM-SO-22-02*	
Aluminum	8,640	9,170	8,460	8,680	7,250	7,220	7,090	7,240	8,640	9,220	6,220	5,730	50,000
Antimony	3.4	3.3	3.2	3.3	3.3	3.1	3	3.2	3.3	3.4	3.1	3.2	20
Arsenic	**5.2**	**6.2**	**5.9**	**6.7**	**24.9**	**21.5**	**23.3**	**10.4**	**4.6**	**6.2**	**12.2**	**43.2**	**0.47**
Barium	142	134	126	130	856	878	1,110	479	130	137	278	758	10,000
Beryllium	1.1	1.1	1.1	1.1	1.1	1	1	1.1	1.1	1.1	1	1.1	100
Cadmium	1.1	1.1	1.1	1.1	1.2	1.1	1.1	1.1	1.1	1.1	1	1.1	5
Calcium	2,590	2,370	3,020	2,860	3,300	3,630	2,950	2,980	2,900	2,940	3,050	2,430	NV
Chromium	**7.5**	**8.1**	**7.7**	**7.2**	**8.1**	**7.3**	**7.6**	**7.2**	**6.6**	**7.2**	**7**	**6.2**	**0.29****
Cobalt	5.4	5.8	5.5	5.6	5.2	4.8	5	5.4	4.9	5.1	5.1	6.1	23
Copper	15.5	15.3	19.4	17	61.4	59.2	63.9	32.1	15.9	18.9	29.6	90.3	500
Iron	11,700	11,800	11,300	12,700	11,500	11,500	10,700	10,400	12,100	11,800	10,700	11,800	55,000
Lead	33.3	13.8	18.2	13.7	**403**	394	207	142	12.7	19.8	17.2	19.5	**400**
Magnesium	2,110	2,180	2,030	2,570	1,880	1,820	1,780	1,800	1,900	2,190	1,900	1,570	NV
Manganese	149	130	378	450	515	466	451	562	382	363	365	1,210	1,800
Mercury	0.1	0.1	0.09	0.091	9.6	**13.4**	3.4	6	0.094	0.095	0.089	0.18	**10**
Nickel	9.3	9.9	9.3	9	10	9.4	9.1	9.4	8	9.4	8.7	8.6	820
Potassium	1,600	1,930	1,740	1,510	1,790	1,780	1,810	1,790	1,480	1,590	1,570	1,230	NV
Selenium	5.7	5.5	5.3	5.5	5.4	5.2	5	5.3	5.5	5.6	5.2	5.3	250
Silver	3.4	3.3	3.2	3.3	3.3	3.1	3	3.2	3.3	3.4	3.1	3.2	250
Sodium	52.8	44	48.6	52.2	78.9	80.8	48.7	48.5	57.4	56.7	69.6	42	NV
Thallium	ND (<1.1)	ND (<1.1)	ND (<1.1)	ND (<1.1)	ND (<1.1)	ND (<1)	ND (<1)	ND (<1.1)	ND (<1.1)	ND (<1.1)	ND (<1)	ND (<1.1)	0.78
Vanadium	19.8	21.2	18.6	22.1	17.4	17.1	17.3	16.9	19.3	19.3	15.4	15.2	390
Zinc	46.3	45.3	54.9	61.3	178	177	121	98.2	46.7	45.4	54.9	66.8	15,000

NOTE: All results presented in units of milligram per kilogram, NV = No value available from the Agency for Toxic Substances and Disease Registry or Environmental Protection Agency, ND = Not Detected (Reporting Limit), bolded values exceed the comparison values used in this evaluation, Thallium was never detected and the detection limit of 0.52 mg/kg is lower than the conservative residential soil screening value, * refer to Table A7 for more information on screening values used in this evaluation, ** screening value is for hexavalent chromium

Table A3. Results of Grab Surface Soil Data collected from the Millsite for the Walter Report (Walter 2013)

Location	Behind West Building	Behind East Building	Comparison Value*
Depth-Sample Type	**Surface-Grab**	**Surface-Grab**	
Analyte/Sample ID	*Walters-UM-SS001*	*Walters-UM-SS002*	
Antimony	12.1	9.4	20
Arsenic	**112**	**97.4**	**0.47**
Beryllium	ND(<0.99)	ND(<0.97)	100
Cadmium	1.2	1.1	5
Chromium	**2.7**	**2.6**	**0.29****
Copper	227	201	500
Lead	42.1	25.3	400
Mercury	0.68	2.7	**10**
Nickel	ND(<3)	ND(<2.9)	820
Selenium	ND(<5)	ND(<4.9)	250
Silver	5.1	ND(<2.9)	250
Thallium	ND (<0.99)	ND (<0.97)	0.78
Zinc	97.6	74.7	15,000
Cyanide, Total	ND(<0.5)	ND(<0.51)	22

NOTE: all sample results in milligram per kilogram, ND = Not Detected (Reporting Limit), bolded values exceed the comparison values used in this evaluation. Thallium was never detected and the detection limit of 0.52 mg/kg is lower than the conservative residential soil screening value, * refer to Table A7 for more information on screening values used in this evaluation, ** screening value is for hexavalent chromium

Table A4. Results of Data collected from the Dana Farm for the Walter Report and Weston Report (Walter 2013, Weston 2014)

Location	**Dana Farm**	**Dana Farm Pile #1**	**Dana Farm Pile 1 (Dup of 14-1)**	**Dana Farm Pile #1**	**Dana Farm Pile 1 (Dup of 14-2)**	**Dana Farm Pile #2**	**Dana Farm Pile #2**	**Dana Farm Under Fence**	**Comparison Value***
Depth	**0-8 inch-Composite**	**1 foot-Composite**	**1 foot-Composite**	**1.5 feet-Composite**	**1.5 feet-Composite**	**1 foot-Composite**	**1.5 feet-Composite**	**1 foot-Grab**	
Analyte/Sample ID	*Walters-UM-TS004*	*Weston-RAM-SO-14-01*	*Weston-RAM-SO-16-01*	*Weston-RAM-SO-14-02*	*Weston-RAM-SO-16-02*	*Weston-RAM-SO-15-01*	*Weston-RAM-SO-15-02*	*Weston-RAM-SO-31-01*	
Aluminum	NA	8,180	7,460	8,290	9,020	7,220	8,070	7,070	50,000
Antimony	4.7	3.6	3.8	3.6	3.7	3.7	3.7	3.9	20
Arsenic	**119**	**4.1**	**4.3**	**4.3**	**5.5**	**9.8**	**6.1**	**17.7**	**0.47**
Barium	NA	145	154	152	156	349	169	505	10,000
Beryllium	1	1.2	1.3	1.2	1.2	1.2	1.2	1.3	100
Cadmium	1.1	1.2	1.3	1.2	1.2	1.2	1.2	1.3	5
Calcium	NA	9,930	9,940	10,600	7,360	8,010	4,890	22700	NV
Chromium	**2.7**	**7.3**	**7.1**	**8**	**8.8**	**7.5**	**8.3**	**7.4**	**0.29****
Cobalt	NA	4.7	4.3	5.1	5.2	4.4	6.9	5.1	23
Copper	261	18.5	18	16.2	16.6	28.5	17.1	40.9	500
Iron	NA	10,200	11,000	12,500	12,800	10,500	12,800	10,800	55,000
Lead	27.3	12.7	11.9	11.7	11.8	12.7	11.6	14.9	400
Magnesium	NA	2,790	2,760	2,600	2,610	2,460	2,380	3,440	NV
Manganese	NA	354	358	367	354	417	511	577	1,800
Mercury	0.76	0.1	0.11	0.1	0.099	0.11	0.1	0.1	10
Nickel	3.1	8.5	7.6	8.5	9.1	8.1	9.3	7.6	820
Potassium	NA	3,710	3,530	3,540	3,830	3,060	2,520	4,920	NV
Selenium	5.1	6	6.4	6	6.2	6.2	6.1	6.4	250
Silver	3.1	3.6	3.8	3.6	3.7	3.7	3.7	3.9	250
Sodium	NA	157	145	106	101	179	142	546	NV
Thallium	ND (<1)	ND (<1.2)	ND (<1.3)	ND (<1.2)	ND (<1.2)	ND (<1.2)	ND (<1.2)	ND (<1.3)	0.78
Vanadium	NA	17.6	17.7	19.9	20.8	17.2	21.2	17.3	390
Zinc	88.6	50.9	50.6	44.5	46.5	47.5	46.2	49.8	15,000

NOTE: All results presented in units of milligram per kilogram, NA = Not analyzed, ND = Not Detected (Reporting Limit), bolded values exceed the comparison values used in this evaluation, NV = No value available from the Agency for Toxic Substances and Disease Registry or Environmental Protection Agency. Thallium was never detected and the detection limit of 0.52 mg/kg is lower than the conservative residential soil screening value, * refer to Table A7 for more information on screening values used in this evaluation, ** screening value is for hexavalent chromium

Table A5. Results of Data collected from the Western Excelsior Facility for the Walter Report and Weston Report (Walter 2013, Weston 2014)

Depth	**0-8 inch-Composite**	**1 foot-Composite**	**Comparison Value***
Analyte / Sample Number	*Walters-UM-TS005*	*Weston-RAM-SO-11-01*	
Aluminum	NA	3,430	50,000
Antimony	5.3	4.4	20
Arsenic	**107**	**8.1**	**0.47**
Barium	NA	369	10,000
Beryllium	1.1	1.5	100
Cadmium	1.3	1.5	5
Calcium	NA	14,000	NV
Chromium	**2.1**	**4.3**	**0.29****
Cobalt	NA	2.4	23
Copper	257	24.7	500
Iron	NA	5,130	55,000
Lead	31.7	8.9	400
Magnesium	NA	1,740	NV
Manganese	NA	251	1,800
Mercury	1.9	0.54	10
Nickel	3.2	4.4	820
Potassium	NA	4,130	NV
Selenium	5.4	7.3	250
Silver	3.2	4.4	250
Sodium	NA	126	NV
Thallium	ND (<1.1)	ND (<1.5)	0.78
Vanadium	NA	8.9	390
Zinc	84.2	153	15,000

NOTE: All results presented in units of milligram per kilogram, NA = Not analyzed, ND = Not Detected (Reporting Limit), bolded values exceed the comparison values used in this evaluation, NV = No value available from the Agency for Toxic Substances and Disease Registry or Environmental Protection Agency. Thallium was never detected and the detection limit of 0.52 mg/kg is lower than the conservative residential soil screening value, * refer to Table A7 for more information on screening values used in this evaluation, ** screening value is for hexavalent chromium

Table A6. Summary Statistics of Background Surface Soil Results (Weston 2014)

Analyte	Minimum (mg/kg)	Mean (mg/kg)	Maximum (mg/kg)	Detection Frequency	Number of Samples (*n*)	Comparison Value* (mg/kg)	COPC
Aluminum	4,490	7,093	8,900	100%	20	50,000	
Antimony	ND (<3.0)	N/a	ND (<10)	0%	20	20	
Arsenic	**3.7**	**5.3**	**8**	**95%**	**20**	**0.47**	**X**
Barium	86.3	130	182	100%	20	10,000	
Beryllium	ND (<0.99)	N/a	ND (<3.4)	0%	20	100	
Cadmium	ND (<0.99)	N/a	ND (<3.4)	0%	20	5	
Calcium	3,000	7,302	29,000	100%	20	NV	
Chromium	**5**	**7.0**	**8.5**	**100%**	**20**	**0.29****	**X**
Cobalt	2.9	4.7	5.9	100%	20	23	
Copper	14.2	25.8	121	100%	20	500	
Iron	5,690	11,552	16,100	100%	20	55,000	
Lead	ND (<17)	15.3	37	95%	20	400	
Magnesium	1,920	2,383	3,910	100%	20	NV	
Manganese	87	290	465	100%	20	1,800	
Mercury	ND (0.089)	0.09	0.11	5%	20	10	
Nickel	ND (<10)	8.7	10.6	95%	20	820	
Potassium	874	2,267	5,260	100%	20	NV	
Selenium	ND (<4.9)	N/a	ND (<17)	0%	20	250	
Silver	ND (<3.0)	N/a	ND (<10)	0%	20	250	
Sodium	ND (<45)	201	516	65%	20	NV	
Thallium	ND (<0.99)	N/a	ND (<3.4)	0%	20	0.78	
Vanadium	11.2	18.7	30	100%	20	390	
Zinc	37.4	60.4	124	100%	20	15,000	

NOTE: mg/kg = milligram per kilogram, COPC = Contaminant of Potential Concern, ND = Not Detected (Reporting Limit), N/a = Not Applicable, bolded chemicals exceed the comparison values used in this evaluation, NV = No value available from the Agency for Toxic Substances and Disease Registry or Environmental Protection Agency. Thallium was never detected and the detection limit of 0.52 mg/kg is lower than the conservative residential soil screening value, * refer to Table A7 for more information on screening values used in this evaluation, ** screening value is for hexavalent chromium

Table A7. Screening Values for Residential Soil Exposures

Analyte	ATSDR Comparison Value for Soil (mg/kg)	Source	EPA Regional Screening Level* (mg/kg)	Basis
Aluminum	**50,000**	cEMEG	77,000	non-cancer
Antimony	**20**	cRMEG	31	non-cancer
Arsenic	**0.47**	CREG	0.61	cancer
Barium	**10,000**	cEMEG	15,000	non-cancer
Beryllium	**100**	cEMEG	160	non-cancer
Cadmium	**5**	cEMEG	70	non-cancer
Calcium	NA	--	NV	non-cancer
Chromium (hexavalent)	45	cEMEG	**0.29**	cancer
Cobalt	500	Int. cEMEG	**23**	non-cancer
Copper	**500**	Int. cEMEG	3,100	non-cancer
Cyanide	30	cRMEG	22	non-cancer
Iron	NA	--	**55,000**	non-cancer
Lead	NA	--	**400**	non-cancer
Magnesium	NA	--	NV	non-cancer
Manganese	2,500	cRMEG	**1,800**	non-cancer
Elemental Mercury	NA	--	**10**	non-cancer
Nickel	1,000	cRMEG	**820**	non-cancer
Potassium	NA	--	NV	non-cancer
Selenium	**250**	cEMEG	390	non-cancer
Silver	**250**	cRMEG	390	non-cancer
Sodium	NA	--	NV	non-cancer
Thallium	NA	--	**0.78**	non-cancer
Vanadium	500	Int. cEMEG	**390**	non-cancer
Zinc	**15,000**	cEMEG	23,000	non-cancer

NOTE: All results presented in units of milligram per kilogram (mg/kg), Bolded values were selected for use in this evaluation, cEMEG = Child Environmental Media Evaluation Guide, cRMEG = Child Reference Dose Media Evaluation Guide, CREG = Cancer Risk Evaluation Guide, Int. cEMEG = Intermediate Child Environmental Media Evaluation Guide, NA = screening value not available, NV = No value available from the Agency for Toxic Substances and Disease Registry or Environmental Protection Agency.

* Source: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/docs/master_sl_table_run_NOV2013.pdf

Table A8. Data Summary and Selection of Contaminants of Concern at the Unpermitted Mill Area of Concern

Analyte	Minimum (mg/kg)	Mean (mg/kg)	Maximum (mg/kg)	Detection Frequency	Number of Samples *(n)*	Screening Value* (mg/kg)	COPC
Aluminum	6,220	7,738	8,640	100%	6	50,000	
Antimony	**ND(<3.1)**	**12.5**	**38.5**	**64.7%**	**17**	**20**	**X**
Arsenic	**4.6**	**83.2**	**299**	**100%**	**17**	**0.47**	**X**
Barium	126	402	878	100%	6	10,000	
Beryllium	ND(<0.97)	N/a	ND(<1.1)	0%	17	100	
Cadmium	ND(<0.99)	1.4	2.7	52.9%	17	5	
Calcium	2,590	3,082	3,630	100%	6	NV	
Chromium	**1.2**	**4.4**	**10.4**	**100%**	**17**	**0.29******	**X**
Cobalt	4.8	5.2	5.5	100%	6	23	
Copper	**15.5**	**163**	**575**	**100%**	**17**	**500**	**X**
Iron	10,700	11,467	12,100	100%	6	55,000	
Lead	**12.7**	**75**	**403**	**100%**	**17**	**400**	**X**
Magnesium	1,820	1,940	2,110	100%	6	NV	
Manganese	149	376	515	100%	6	1,800	
Mercury	**ND(<0.089)**	**6.6**	**55.7**	**76.5%**	**17**	**10**	**X**
Nickel	ND(<2.9)	8.9	10	41.2%	17	820	
Potassium	1,480	1,660	1,790	100%	6	NV	
Selenium	ND(<4.9)	N/a	ND(<5.7)	0%	17	250	
Silver	ND(<2.9)	4.1	5.1	17.7%	17	250	
Sodium	48.6	64.7	80.8	100%	6	NV	
Thallium	ND(<0.97)	N/a	ND(<5.0)	0%	17	0.78	
Vanadium	15.4	17.9	19.8	100%	6	390	
Zinc	46.3	95.0	178	100%	17	15,000	

NOTE: COC = Potential Contaminant of Concern, mg/kg = milligrams per kilogram, ND = Not Detected (Reporting Limit), N/a = Not applicable, bolded chemicals exceed the comparison values used in this evaluation, NV = No value available from the Agency for Toxic Substances and Disease Registry or Environmental Protection Agency, Thallium was never detected and the detection limit of 0.52 mg/kg is lower than the conservative residential soil screening value, * refer to Table A7 for more information on screening values used in this evaluation, ** screening value is for hexavalent chromium

Table A9. Conceptual Site Model

Area of Exposure	Probable Source	Affected Environmental Medium	Potentially Exposed Population	Timeframe of Exposure	Route of Exposure	Pathway Designation
Unpermitted Mill	Source of the mine workings is unknown, but potentially include workings from the Red Arrow Mine and Millsite, the Freda Mine, the Johnston Mine, and other prospective mine sites/tailings piles	*Surface Soil (0-1 ft.)*	*Adult Trespasser/Visitor*	*Past*	Incidental ingestion and Dermal contact	Complete
				Current and Future	The area is fenced, the tailings are covered, and potential for ground water contamination has been minimized	Incomplete
	Elemental Mercury Used in the Amalgamation Process. The amount of elemental mercury used for amalgamation is unknown. However, a bucket labeled 22.5# mercury was found at the mill	*Air:* ambient air in close proximity to the mill	*Commercial Workers:* Possibly Storage Center employees, Dana farm workers, neighboring farmer to the north, and Western Excelsior employees *Residents/Visitors:* Dana Farm and Mobile Home Park	*Past*	Inhalation	Potential
				Current	Inhalation	Potential
				Future	Inhalation	Potential, but Incomplete once building is cleaned
Off-site Areas (Dana Farm and Western Excelsior Plant)	*Unpermitted Mill:* Spent tailings from the milling process that appear to have been used as fill material	*Surface Soil (0-1 ft.)*	*Industrial/commercial Workers:* Dana farm, Storage area and Western Excelsior employees *Residents/Visitors:* Dana Farm	*Past*	Incidental ingestion and Dermal contact	Complete
				Current/Future	The tailings piles have been excavated and moved to the millsite. Some of the excavated areas were backfilled with clean fill.	Incomplete

Groundwater: Incomplete exposure pathway based on the available information discussed under site description

Appendix B. Exposure Dose Estimation

This section provides additional information on the exposure parameters and exposure doses that were used to evaluate the public health implications of soil and tailings exposures at the Red Arrow Unpermitted Mill site. Three primary areas of concern were outlined in this health consultation. This includes the unpermitted mill, the Dana Farm and the Western Excelsior Plant. Most stakeholders believe that people are not coming into contact with tailings and soil on a frequent basis in these areas. However, detailed site-specific information regarding exposure to these materials is very limited. CCPEHA used what is known about the site, along with professional judgment, to establish a range of exposure scenarios in each area of concern.

Exposure Parameters

The purpose of developing exposure factors for a particular site is to account for the majority of exposures that occur at the site. It is recognized that people may come into contact with site-related contaminants more, or less frequently than the exposure factors used to develop exposure doses at this site. This could potentially result in an over-or underestimation of risk. In lieu of site-specific information, professional judgment is often times used to determine the appropriate exposure factors. Professional judgment is based on the best available information regarding land-use, the types of contamination, the location of the contamination, and physical features such as snow cover, fencing, PVC barriers, etc. Further rationale supporting the use of these exposure factors is presented in the main document.

The proposed RME and CTE exposure scenarios and site-specific exposure parameters are shown below in Table B1. In order to further address the uncertainty associated with the lack of site-specific information on exposure parameters, residential and commercial default exposure parameters were also evaluated for each receptor. This default scenario is evaluated separately in Appendix C.

Unpermitted Mill

The exposure factors were set at 100 mg/day soil ingestion and an exposed skin surface area of 3,300 cm^2 (EPA 2004), which assumes they have a short-sleeved shirt, pants, and shoes on. The exposure point concentration will be based on the samples collected from the exterior tailings piles and the surrounding surface soil.

Dana Farm

At the Dana Farm AOC, an exposure scenario consisting of 26 days of exposure over a period of 1 year (approximately 2 days per month) and 52 days of exposure over a period of 1 year (approximately 4 days per month) was used to evaluate central tendency and reasonable maximum exposures. Exposure parameters for children (ages 6-11) were set at 200 mg/day soil ingestion and an exposed skin surface area of 3,800 cm^2 (EPA 2004). The exposure parameters for adult residents and commercial workers were set at 100 mg/day soil ingestion and an exposed skin surface area of 5,700 cm^2 for residents and 3300 cm^2 for commercial workers (EPA 2004). Exposure parameters for all scenarios (i.e., acute, CTE, RME, and default) are shown below in Table B1.

Western Excelsior

An exposure scenario consisting of 26 days of exposure over a period of 1 year and 52 days of exposure over a period of 1 year was used to evaluate central tendency and reasonable maximum exposures, respectively. The exposure parameters for adult workers were set at 100 mg/day soil ingestion and an exposed body area of 3,300 cm^2 (EPA 2004). Exposure parameters for all scenarios (i.e., acute, CTE, RME, and default) are shown below in Table B1.

Table B1. Exposure Factors

Area of Potential Concern	Receptor	Exposure Frequency in days		Body Weight (kg.)	Exposure Duration in years	Soil Ingestion Rate (mg/day)	Non-cancer Averaging Time (days)	Cancer Averaging Time (days)	Exposed Surface Area (cm^2)	Soil Adherance Factor (mg/cm^2)
		CTE	RME							
Dana Farm	Child Resident or Visitor (6-11 years)	26	52	33	1	200 (EPA 2002)	365	25,550 (EPA 1989)	3,800 (EPA 2004)	0.2 (EPA 2004)
Dana Farm	Adult Resident or Visitor	26	52	70	1	100 (EPA 2002)	365	25,550 (EPA 1989)	5,700 (EPA 2004)	0.07 (EPA 2004)
Western Excelsior Plant	Adult Commercial Worker	26	52	70	1	100 (EPA 2002)	365	25,550 (EPA 1989)	3,300 (EPA 2004)	0.07 (EPA 2004)
Exposure parameter for Acute Scenarios										
Millsite	Adult Trespasser	1	N/a	70	1 day	100 (EPA 2002)	1	N/a	3,300 (EPA 2004)	0.07 (EPA 2004)
Dana Farm	Child Resident or Visitor (6-11 years)	1	N/a	33	1 day	200 (EPA 2002)	1	N/a	3,800 (EPA 2004)	0.2 (EPA 2004)
Dana Farm	Adult Resident or Visitor	1	N/a	70	1 day	100 (EPA 2002)	1	N/a	5,700 (EPA 2004)	0.07 (EPA 2004)
Western Excelsior Plant	Adult Commercial Worker	1	N/a	70	1 day	100 (EPA 2002)	1	N/a	3,300 (EPA 2004)	0.07 (EPA 2004)

NOTE: kg. = kilogram, mg/day = milligrams per day, cm^2 = square centimeters, N/a = not applicable

SOURCES:

EPA 1989 = Environmental Protection Agency, Risk Assessment Guidance for Superfund, Part A

EPA 2011 = Environmental Protection Agency, Exposure Factors Handbook

EPA 2002 = Environmental Protection Agency, Supplemental Guidance for Developing Soil Screening Levels at Superfund Sites

EPA 2004 = Environmental Protection Agency, Risk Assessment Guidance for Superfund, Part E. Supplemental Guidance for Dermal Exposure

Exposure Point Concentrations

The exposure point concentration (EPC) is an estimate of the concentration of a contaminant in soil the people are exposed to in a particular area of concern. In general, the EPC estimate is a high-end average concentration of a contaminant in a particular area (i.e. unpermitted mill). Average concentrations are normally used because people typically move throughout an area and are exposed to varying levels of contamination in different spots within the area. That is, people are neither exposed to the highest, nor the lowest concentration of contamination. In this case, the 95% Upper Confidence Limit (UCL) on the mean concentration is used as the EPC. In cases where there are fewer than 10 samples available from a particular area, the EPC UCL estimation becomes unreliable and it is typical to use the maximum detected concentration as the EPC for that area. This is the case for the two offsite areas. However, a sufficient number of samples were available at the unpermitted mill and background exposure areas, so EPCs were estimated using ProUCL software. A summary of sample identification numbers, depth of samples and other details are provided in Table B2. The soil EPCs used in this evaluation are shown in Table B3.

Table B2. Samples used for EPC estimation for each Area of Concern

Area of Concern	Applicable Sample ID's	Source*	Depth
Millsite	UM-TS1001, UM-TS1002, UM-TS2001, UM-TS3001, UM-TS3002, UM-TS3100, UM-TS5001, UM-TS6001, UM-TS7001, UM-SS-001, UM-SS-002	Walters	0-8 inches
	RAM-SO-02-01, RAM-SO-06-01, RAM-SO-07-01, RAM-SO-09-01, RAM-SO-10-01, RAM-SO-22-01	Weston	1 foot
Dana Farm	UM-TS-004	Walters 2013	0-8 inches
	RAM-SO-14-01, RAM-SO-15-01, RAM-SO-16-01, RAM-SO-31-01	Weston	1 foot
Western Excelsior	UM-TS005	Walters	0-8 inches
	RAM-SO-11-01	Weston	1 foot
Background	RAM-SO-12-00, RAM-SO-13-00, RAM-SO-17-00, RAM-SO-18-00, RAM-SO-19-00, RAM-SO-20-00, RAM-SO-21-00, RAM-SO-23-00 (North Field), RAM-SO-24-00 (North Field), RAM-SO-25-00, RAM-SO-26-00, RAM-SO-27-00, RAM-SO-28-00, RAM-SO-29-00 (East Field), RAM-SO-30-00 (East Field) RAM-SO-52-00 (West Field), RAM-SO-53-00 (West Field), RAM-SO-54-00 (West Field), RAM-SO-55-00 (West Field), RAM-SO-56-00 (West Field)	Weston	0-2 inches

*Source: Walters 2013 and Weston 2014

Table B3. Exposure Point Concentrations for all Areas of Concern

Area of Concern	Contaminant of Concern	Exposure Point Concentration (mg/kg)	Residential Screening Value (mg/kg)	Basis	Applicable Sample Number	Depth
Millsite	Antimony	14.6	20	95% Adjusted Gamma KM-UCL	N/a	0-1 ft.
Millsite	Arsenic	116.3	0.47	Calculated: 95% Student's-t UCL	N/a	0-1 ft.
Millsite	Chromium	7.6	0.29†	Calculated: 95% Chebyshev (Mean, Sd) UCL	N/a	0-1 ft.
Millsite	Copper	223.6	500	Calculated: 95% Student's-t UCL	N/a	0-1 ft.
Millsite	Lead*	207.1	400	Calculated: 95% Chebyshev (Mean, Sd) UCL	N/a	0-1 ft.
Millsite	Mercury	38.1	10	99% KM (Chebyshev) UCL	N/a	0-1 ft.
Dana Farm	Arsenic	119	0.47	Maximum Detected Value of All Samples	Walters-UM-TS004	0-8 in.
Dana Farm	Chromium	7.5	0.29†	Maximum Detected Values of All Samples	Weston-RAM-SO-15-01	1 ft.
Western Excelsior	Arsenic	107	0.47	Maximum Detected Values of All Samples	Walters-UM-TS005	0-8 in.
Western Excelsior	Chromium	4.3	0.29†	Maximum Detected Values of All Samples	Weston-RAM-SO-11-01	1 ft.
Background	Antimony	3.8	20	Mean reporting limit for all undetected background samples	Weston Bkgd Samples	1 ft.
Background	Arsenic	5.8	0.47	Calculated: 95% KM(t) UCL	Weston Bkgd Samples	0-2 in.
Background	Chromium	7.4	0.29†	Calculated: 95% Student's-t UCL	Weston Bkgd Samples	0-2 in.
Background	Copper	49.5	500	Calculated: 95% Chebyshev (Mean, Sd) UCL	Weston Bkgd Samples	0-2 in.
Background	Mercury	0.11	10	Only detected background sample available	Weston Bkgd Samples	0-2 in.

NOTE: * Lead was not carried forward as a COPC because the calculated Exposure Point Concentration (EPC) and the average concentration of 75 mg/kg (used in lead models) are lower than the residential soil screening value. In addition, suitable models are not available to evaluate lead risks for acute exposure scenario. †Chromium RSL based on hexavalent chromium; N/a = Not Applicable, UCL = Upper Confidence Interval on the mean concentration

To calculate the estimated exposure doses for each receptor, the appropriate variable from Tables B1 and B3 is inserted into the following equations. The resulting dose is in units of milligrams of contaminant per kilogram body weight a day (mg/kg-day). The resulting non-cancer dose estimations are shown in Tables B4-B15. Two items worth noting are related to the bioavailability of arsenic in soil and dermal exposure to arsenic. As mentioned previously in the text, the relative bioavailability of arsenic in soil was assumed to be 60% based on recent guidance by USEPA (2012). Therefore, for all incidental ingestion exposures, the exposure point concentration must be multiplied by 60%. The bioavailability fraction of arsenic is not applied to dermal exposures, nor does it apply to any other COPCs. Dermal exposure to metals is typically not considered a major exposure pathway due to the limited ability of metals to penetrate the skin barrier. However, variables that are required to estimate dermal exposure to arsenic are available, namely the Dermal Absorption Fraction. The Dermal Absorption Fraction (ABS_D) essentially describes the amount of arsenic that is absorbed through the skin from dermal exposures. The ABS_D is unitless and the value for arsenic is 0.03.

Equation 1. Non-Cancer Soil Ingestion Dose

Non-Cancer Dose = (C_s * RBA * IRS * CF * EF * ED) / (BW * AT_{NC})

Where:
C_s = Chemical Concentration in Soil (in mg/kg or milligrams contaminant per kilogram of soil) Soil exposure point concentrations are found in Table B3
RBA = Relative Bioavailability of Arsenic (Only applies to arsenic, 60 percent)
IRS = Ingestion Rate of Soil (in milligrams of soil per day)
CF = Conversion Factor (in kilograms per milligram)
EF = Exposure Frequency (in days per year)
ED = Exposure Duration (in years)
BW = Body Weight (in kilograms)
AT_{NC} = Non-Cancer Averaging Time (in days)

Example: CTE Western Excelsior Worker, Non-cancer ingestion dose of Arsenic, Table B8 =>
(107 mg/kg * 60% * 100 mg/day * 10^{-6} kg/mg * 26 days per year * 1 years) / (70 kg. * 365 days) =
$6.5 * 10^{-6}$ (6.5E-06) mg/kg-day

Equation 2. Non-Cancer Dermal Absorbed Dose from Soil

$$\textbf{DA event (DAev) = } C_s \text{ * CF * AF * } ABS_d$$

$$\text{DAD (mg/cm}^2\text{-event)} = \frac{\text{DAev * EF * ED * SA}}{\text{BW * } AT_{NC}}$$

Where:
DAev = Absorbed dose per event (in milligrams per square centimeter event)
C_s = Chemical concentration in soil (in milligrams contaminant per kilogram soil)
CF = Conversion factor (in kilograms per milligram)
AF = Adherence Factor (milligram per square centimeter event)
ABS_d = Dermal Absorption Fraction (chemical specific; e.g., arsenic =0.03 (EPA 2004)
EF = Exposure Frequency (in days per year)
ED = Exposure Duration (in years)
SA = Skin Surface Area (in square centimeters)
BW = Body Weight (in kilograms)
AT_{NC} = Non-Cancer Averaging Time (in days)

Example: CTE Adult at Dana Farm, Non-cancer dermal absorbed dose of Arsenic (Table B5) =>

DA_{ev} = 119 mg/kg * 10^{-6} kg/mg * 0.07 mg/cm^2-event * 0.03 =
2.50 * 10^{-7} mg/cm^2-event

DAD = (2.50 * 10^{-7} mg/cm^2-event * 26 days * 1 years * 5,700 cm^2) / (70 kg. * 365 days) =
1.4 * 10^{-6} mg/kg-day

The equation used to calculate the exposure dose for cancer risks is similar to the non-cancer exposure dose equation shown above. The primary difference between the two is that non-cancer exposure doses are averaged over the time period of exposure and cancer exposures are averaged over a lifetime (70 years). As mentioned previously, it was assumed that the chromium detected in surface soil is hexavalent chromium because site-specific speciation of the chromium valency has not been performed. Therefore, the conservative assumption that chromium in site soils is hexavalent was made to be prudent of public health. In reality, it is more likely that the majority of chromium found onsite is trivalent chromium, which is not classified as a human carcinogen. Equation 3 was used to calculate surface soil ingestion doses for cancer for all receptors in this evaluation. The resulting carcinogenic exposure doses from incidental ingestion of soil are shown below in Table B4-B15.

Equation 3. Carcinogenic Soil Ingestion Dose Calculation

Cancer Dose = (C_s * RBA * CF * IRS * EF * ED) / (BW * AT_C)

Where:
C_s = Chemical Concentration in Soil (in mg/kg or milligrams contaminant per kilogram of soil)
RBA = Relative Bioavailability (Only applies to arsenic ingestion pathway, 60 percent)
CF = Conversion Factor (in kilograms per milligram)
IRS = Soil Ingestion Rate (in milligrams of soil-year per kilogram body weight)
EF = Exposure Frequency (in days per year)
ED = Exposure Duration (in years)
BW = Body weight (kg)
AT_C = Cancer Averaging Time (in days)

Example: Estimated Cancer Dose of Chromium for the CTE Child at the Dana Farm, Table B5 =>
(7.5 mg/kg * 10^{-6} kg/mg * 200 mg/day * 26 days/year * 1 year) / (31.8 kg. * 25,550 days)
= 4.8 * 10^{-8} mg/kg/day

Equation 4. Carcinogenic Dermal Exposure to Soil Dose Calculation

$$\textbf{DA event (DAev)} = C_s * CF * AF * ABS_d$$

$$\textbf{DAD (mg/cm}^2\textbf{-event)} = \frac{DAev * EF * ED * SA}{AT_C * BW}$$

Where:
DAev = Absorbed dose per event (in milligrams per square centimeter event)
C_s = Chemical concentration in soil (in milligrams contaminant per kilogram soil)
CF = Conversion factor (in kilograms per milligram)
AF = Adherence Factor (milligram per square centimeter event)
ABS_d = Dermal Absorption Fraction (chemical specific; e.g., arsenic = 0.03)
EF = Exposure Frequency (in days per year)
ED = Exposure Duration (in years)
SA = Skin Surface Area (in square centimeters)
AT_C = Cancer Averaging Time (in days)
BW = Body Weight (in kilograms)

Example: Arsenic Dermal Cancer Dose for the CTE Adult at Dana Farm (Table B5) =>

DA_{ev} = 119 mg/kg * 10^{-6} kg/mg * 0.07 mg/cm^2-event * 0.03 =
2.5 * 10^{-7} mg/cm^2-event

DAD = (2.5*10^{-7} mg/cm^2-event * 26 days * 1 years * 5,700 cm^2)/ (70 * 25,550 days) =
2.1*10^{-8} mg/kg-day

Table B4. Dana Farm Acute Exposure Dose Calculations Estimated Risks for Residential Children and Adults

Non-Cancer Dose Calculations and Hazard Quotients											
Contaminants of Potential Concern	**EPC (in mg/kg)**	**Ingestion Pathway**		**Dermal Pathway**		**Combined Hazard Quotients**	**Ingestion Pathway**		**Dermal Pathway**		**Combined Hazard Quotients**
		Child Non-cancer Dose*	Hazard Quotient	Child Non-cancer Dose*	Hazard Quotient		Adult Non-cancer Dose*	Hazard Quotient	Adult Non-cancer Dose*	Hazard Quotient	
Arsenic	119	0.00045	0.09	0.000085	0.017	0.11	0.0001	0.02	0.00002	0.0041	0.024
Chromium**	7.5	0.000047	0.0094	--	--	0.0094	0.000011	0.0021	--	--	0.0021
Hazard Index	**--**	**--**	**0.099**	**--**	**0.017**	**0.12**	**--**	**0.023**	**--**	**0.0041**	**0.027**

NOTE: EPC = Exposure Point Concentration (Maximum Detected Concentration of 5 samples, See Table 10), mg/kg = milligram per kilogram, * Dose in units of milligram per kilogram per day, ** All chromium in soil was conservatively assumed to be hexavalent chromium for the health evaluation

Table B5. Dana Farm Central Tendency Exposure Dose Calculations and Estimated Risks for Residential Children and Adults

Non-Cancer Dose Calculations and Hazard Quotients

Contaminants of Potential Concern	EPC (in mg/kg)	Ingestion Pathway		Dermal Pathway		Combined Hazard Quotients	Ingestion Pathway		Dermal Pathway		Combined Hazard Quotients
		Child Non-cancer Dose*	Hazard Quotient	Child Non-cancer Dose*	Hazard Quotient		Adult Non-cancer Dose*	Hazard Quotient	Adult Non-cancer Dose*	Hazard Quotient	
Arsenic	119	0.000032	0.11	0.0000061	0.02	0.13	0.0000073	0.024	0.0000014	0.0048	0.029
Chromium**	7.5	0.0000034	0.00067	--	--	0.00067	0.00000076	0.00015	--	--	0.00015
Hazard Index	--		**0.11**	--	**0.02**	**0.13**	**--**	**0.024**	**--**	**0.0048**	**0.029**

Cancer Dose Calculations and Estimated Cancer Risks

Contaminants of Potential Concern	-- EPC (in mg/kg)	Ingestion Pathway		Dermal Pathway		Combined Cancer Risks	Ingestion Pathway		Dermal Pathway		Combined Cancer Risks
		Child Cancer Dose*	Cancer Risk	Child Cancer Dose*	Cancer Risk		Adult Cancer Dose*	Cancer Risk	Adult Cancer Dose*	Cancer Risk	
Arsenic	119	0.00000046	6.9×10^{-7}	0.00000009	1.3×10^{-7}	8.2×10^{-7}	0.0000001	1.6×10^{-7}	0.00000002	3.1×10^{-8}	1.9×10^{-7}
Chromium**	7.5	0.000000048	2.4×10^{-8}	--	--	2.4×10^{-8}	0.00000001	5.5×10^{-9}	--	--	5.5×10^{-9}
Total Cancer Risk	--		**7.1×10^{-7}**	**--**	**1.3×10^{-7}**	**8.4×10^{-7}**	**--**	**1.6×10^{-7}**	**--**	**3.1×10^{-8}**	**1.9×10^{-7}**

NOTE: EPC = Exposure Point Concentration (Maximum Detected Concentration of 5 samples, See Table B3), mg/kg = milligram per kilogram, * Dose in units of milligram per kilogram per day, ** All chromium in soil was conservatively assumed to be hexavalent chromium for the health evaluation

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Table B6. Dana Farm Reasonable Maximum Exposure Dose Calculations and Estimated Risks for Residential Children and Adults

Non-Cancer Dose Calculations and Hazard Quotients

Contaminants of Potential Concern	EPC (in mg/kg)	Ingestion Pathway		Dermal Pathway		Combined Hazard Quotients	Ingestion Pathway		Dermal Pathway		Combined Hazard Quotients
		Child Non-cancer Dose*	Hazard Quotient	Child Non-cancer Dose*	Hazard Quotient						
Arsenic	119	0.000064	0.21	0.000012	0.041	0.25	0.000015	0.048	0.0000029	0.0097	0.058
Chromium**	7.5	0.0000067	0.0013	--	--	0.0013	0.0000015	0.00031	--	--	0.00031
Hazard Index	--		**0.21**	--	**0.041**	**0.26**	**--**	**0.049**	**--**	**0.0097**	**0.058**

Cancer Dose Calculations and Estimated Cancer Risks

Contaminants of Potential Concern	-- EPC (in mg/kg)	Ingestion Pathway		Dermal Pathway		Combined Cancer Risks	Ingestion Pathway		Dermal Pathway		Combined Cancer Risks
		Child Cancer Dose*	Cancer Risk	Child Cancer Dose*	Cancer Risk		Adult Cancer Dose*	Cancer Risk	Adult Cancer Dose*	Cancer Risk	
Arsenic	119	0.00000091	$1.4x10^{-6}$	0.00000017	$2.6x10^{-7}$	$1.6x10^{-6}$	0.00000021	$3.1x10^{-7}$	0.00000004	$6.2x10^{-8}$	$3.7x10^{-7}$
Chromium**	7.5	0.0000001	$4.8x10^{-8}$	--	--	$4.8x10^{-8}$	0.00000002	$1.1x10^{-8}$	--		$1.1x10^{-8}$
Total Cancer Risk	**--**	--	**$1.4x10^{-6}$**	**--**	**$2.6x10^{-7}$**	**$1.7x10^{-6}$**	**--**	**$3.2x10^{-7}$**	**--** --	**$6.2x10^{-8}$**	**$3.8x10^{-7}$**

NOTE: EPC = Exposure Point Concentration (Maximum Detected Concentration of 5 samples, See Table B3), mg/kg = milligram per kilogram, * Dose in units of milligram per kilogram per day, ** All chromium in soil was conservatively assumed to be hexavalent chromium for the health evaluation

Table B7. Western Excelsior Acute Non-cancer Dose Calculations and Hazard Quotients for Adult Commercial Workers

Contaminants of Potential Concern	EPC (in mg/kg)	Ingestion Pathway		Dermal Pathway		Combined Hazard Quotients
		Adult Non-cancer Dose*	Hazard Quotient	Adult Non-cancer Dose*	Hazard Quotient	
Arsenic	107	0.000092	0.018	0.000011	0.0021	0.02
Chromium**	4.3	0.0000061	0.0012	--	--	0.0012
Hazard Index	--	--	**0.02**	--	**0.0021**	**0.022**

NOTE: EPC = Exposure Point Concentration (Maximum Detected Concentration of 2 samples, See Table B3), mg/kg = milligram per kilogram, * Dose in units of milligram per kilogram per day, ** All chromium in soil was conservatively assumed to be hexavalent chromium for the health evaluation

Table B8. Western Excelsior Central Tendency Exposure Dose Calculations Estimated Risks for Adult Commercial Workers

Non-Cancer Dose Calculations and Hazard Quotients						
Contaminants of Potential Concern	**EPC (in mg/kg)**	**Ingestion Pathway**		**Dermal Pathway**		**Combined Hazard Quotients**
		Adult Non-cancer Dose*	Hazard Quotient	Adult Non-cancer Dose*	Hazard Quotient	
Arsenic	107	0.0000065	0.022	0.00000075	0.0025	0.024
Chromium**	4.3	0.00000044	0.000088	--	--	0.000088
Hazard Index	**--**	**--**	**0.022**	**--**	**0.0025**	**0.024**

Cancer Dose Calculations and Estimated Cancer Risks						
Contaminants of Potential Concern	**EPC (in mg/kg)**	**Ingestion Pathway**		**Dermal Pathway**		**Combined Cancer Risks**
		Adult Cancer Dose*	Cancer Risk	Adult Cancer Dose*	Cancer Risk	
Arsenic	107	0.000000093	1.4×10^{-7}	0.000000011	1.6×10^{-8}	1.6×10^{-7}
Chromium**	4.3	0.000000006	3.1×10^{-9}	--	--	3.1×10^{-9}
Total Cancer Risk	**--**	**--**	$\mathbf{1.4 \times 10^{-7}}$	**--**	$\mathbf{1.6 \times 10^{-8}}$	$\mathbf{1.6 \times 10^{-7}}$

NOTE: EPC = Exposure Point Concentration (Maximum Detected Concentration of 2 samples, See Table B3), mg/kg = milligram per kilogram, * Dose in units of milligram per kilogram per day, ** All chromium in soil was conservatively assumed to be hexavalent chromium for the health evaluation

Table B9. Western Excelsior Reasonable Maximum Exposure Dose Calculations Estimated Risks for Adult Commercial Workers

Non-Cancer Dose Calculations and Hazard Quotients						
Contaminants of Potential Concern	**EPC (in mg/kg)**	**Ingestion Pathway**		**Dermal Pathway**		**Combined Hazard Quotients**
		Adult Non-cancer Dose*	Hazard Quotient	Adult Non-cancer Dose*	Hazard Quotient	
Arsenic	107	0.000013	0.044	0.0000015	0.005	0.049
Chromium**	4.3	0.0000009	0.00018	--	--	0.00018
Hazard Index	--	--	**0.044**	--	**0.005**	**0.049**

Cancer Dose Calculations and Estimated Cancer Risks						
Contaminants of Potential Concern	**EPC (in mg/kg)**	**Ingestion Pathway**		**Dermal Pathway**		**Combined Cancer Risks**
		Adult Cancer Dose*	Cancer Risk	Adult Cancer Dose*	Cancer Risk	
Arsenic	107	0.00000019	$2.8x10^{-7}$	0.000000022	$3.2x10^{-8}$	$3.1x10^{-7}$
Chromium**	4.3	0.00000001	$6.3x10^{-9}$	--	--	$6.3x10^{-9}$
Total Cancer Risk	--	--	**$2.9x10^{-7}$**	--	**$3.2x10^{-8}$**	**$3.2x10^{-7}$**

NOTE: EPC = Exposure Point Concentration (Maximum Detected Concentration of 2 samples, See Table B3), mg/kg = milligram per kilogram, * Dose in units of milligram per kilogram per day, ** All chromium in soil was conservatively assumed to be hexavalent chromium for the health evaluation

Table B10. Background Acute Exposure Dose Calculations and Estimated Risks for Adults (Unpermitted Mill and Western Excelsior)

Non-Cancer Dose Calculations and Hazard Quotients						
Contaminants of Potential Concern	**EPC (in mg/kg)**	**Ingestion Pathway**		**Dermal Pathway**		**Combined Hazard Quotients**
		Adult Non-cancer Dose*	Hazard Quotient	Adult Non-cancer Dose*	Hazard Quotient	
Antimony	3.5	0.000005	0.013	--	--	0.013
Arsenic	5.8	0.000005	0.00099	0.00000057	0.00011	0.0011
Chromium**	7.4	0.000011	0.0021	--	--	0.0021
Copper	49.5	0.000071	0.0071	--	--	0.0071
Mercury	0.11	0.0000002	0.000022	--	--	0.000022
Hazard Index	--	**--**	**0.023**	**--**	**0.00011**	**0.023**

NOTE: EPC = Exposure Point Concentration (ProUCL Calculated Concentration of 20 samples, See Table B3), mg/kg = milligram per kilogram, * Dose in units of milligram per kilogram per day, ** All chromium in soil was conservatively assumed to be hexavalent chromium for the health evaluation

Table B11. Background Acute Exposure Dose Calculations and Estimated Risks for Child and Adult Residents (Dana Farm)

Non-Cancer Dose Calculations and Hazard Quotients												
Contaminants of Potential Concern	**EPC (in mg/kg)**	**Ingestion Pathway**		**Dermal Pathway**		**Combined Hazard Quotients**	**Ingestion Pathway**		**Dermal Pathway**		**Combined Hazard Quotients**
		Child Non-cancer Dose*	Hazard Quotient	Child Non-cancer Dose*	Hazard Quotient		Adult Non-cancer Dose*	Hazard Quotient	Adult Non-cancer Dose*	Hazard Quotient	
Arsenic	5.8	0.000022	0.0044	0.0000042	0.00083	0.0052	0.000005	0.00099	0.000001	0.0002	0.0012
Chromium**	7.4	0.000047	0.0094	--	--	0.0094	0.000011	0.0021	--	--	0.0021
Hazard Index	**--**	**--**	**0.014**	**--**	**0.00083**	**0.015**	**--**	**0.0031**	**--**	**0.0002**	**0.0033**

NOTE: EPC = Exposure Point Concentration (ProUCL Calculated Concentration of 20 samples, See Table B3), mg/kg = milligram per kilogram, * Dose in units of milligram per kilogram per day, ** All chromium in soil was conservatively assumed to be hexavalent chromium for the health evaluation

Table B12. Background Central Tendency Exposure Dose Calculations and Estimated Risks for Child and Adult Residents (Dana Farm)

Non-Cancer Dose Calculations and Hazard Quotients

Contaminants of Potential Concern	EPC (in mg/kg)	Ingestion Pathway		Dermal Pathway		Combined Hazard Quotients	Ingestion Pathway		Dermal Pathway		Combined Hazard Quotients
		Child Non-cancer Dose*	Hazard Quotient	Child Non-cancer Dose*	Hazard Quotient		Adult Non-cancer Dose*	Hazard Quotient	Adult Non-cancer Dose*	Hazard Quotient	
Arsenic	5.8	0.0000016	0.0052	0.0000003	0.00099	0.0062	0.00000035	0.0012	0.000000071	0.00024	0.0014
Chromium**	7.4	0.0000033	0.00066	--	--	0.00066	0.00000075	0.00015	--	--	0.00015
Hazard Index	--	--	**0.0059**	--	**0.00099**	**0.0068**	--	**0.0013**	--	**0.00024**	**0.0016**

Cancer Dose Calculations and Estimated Cancer Risks

Contaminants of Potential Concern	EPC (in mg/kg)	Ingestion Pathway		Dermal Pathway		Combined Cancer Risks	Ingestion Pathway		Dermal Pathway		Combined Cancer Risks
		Child Cancer Dose*	Cancer Risk	Child Cancer Dose*	Cancer Risk		Adult Cancer Dose*	Cancer Risk	Adult Cancer Dose*	Cancer Risk	
Arsenic	5.8	0.000000022	3.3x10^{-8}	0.000000004	6.3x10^{-9}	4.0x10^{-8}	0.0000000051	7.6x10^{-9}	0.000000001	1.5x10^{-9}	9.1x10^{-9}
Chromium**	7.4	0.000000047	2.4x10^{-8}	--	--	2.4x10^{-8}	0.000000011	5.4x10^{-9}	--	--	5.4x10^{-9}
Total Cancer Risk	--	--	**5.7x10^{-8}**	--	**6.3x10^{-9}**	**6.3x10^{-8}**		**1.3x10^{-8}**		**1.5x10^{-9}**	**1.4x10^{-8}**

NOTE: EPC = Exposure Point Concentration (ProUCL Calculated Concentration *n* = 20 samples, Table B3), mg/kg = milligram per kilogram, * Dose in units of milligram per kilogram per day, ** All chromium in soil was conservatively assumed to be hexavalent chromium for the health evaluation

Table B13. Background Reasonable Maximum Exposure Dose Calculations and Estimated Risks for Child and Adult Residents (Dana Farm)

Non-Cancer Dose Calculations and Hazard Quotients

Contaminants of Potential Concern	EPC (in mg/kg)	Ingestion Pathway		Dermal Pathway		Combined Hazard Quotients	Ingestion Pathway		Dermal Pathway		Combined Hazard Quotients
		Child Non-cancer Dose*	Hazard Quotient	Child Non-cancer Dose*	Hazard Quotient		Adult Non-cancer Dose*	Hazard Quotient	Adult Non-cancer Dose*	Hazard Quotient	
Arsenic	5.8	0.0000031	0.01	0.00000059	0.002	0.012	0.00000071	0.0024	0.00000014	0.00047	0.0028
Chromium**	7.4	0.0000066	0.0013	--	--	0.0013	0.0000015	0.0003	--	--	0.0003
Hazard Index	--	--	**0.012**	--	**0.002**	**0.014**	--	**0.0027**	--	**0.00047**	**0.0031**

Cancer Dose Calculations and Estimated Cancer Risks

Contaminants of Potential Concern	EPC (in mg/kg)	Ingestion Pathway		Dermal Pathway		Combined Cancer Risks	Ingestion Pathway		Dermal Pathway		Combined Cancer Risks
		Child Cancer Dose*	Cancer Risk	Child Cancer Dose*	Cancer Risk		Adult Cancer Dose*	Cancer Risk	Adult Cancer Dose*	Cancer Risk	
Arsenic	5.8	0.000000045	$6.7x10^{-8}$	0.0000000085	$1.3x10^{-8}$	$8.0x10^{-8}$	0.00000001	$1.5x10^{-8}$	0.000000002	$3.0x10^{-9}$	$1.8x10^{-8}$
Chromium**	7.4	0.000000095	$4.7x10^{-8}$	--	--	$4.7x10^{-8}$	0.000000022	$1.1x10^{-8}$	--	--	$1.1x10^{-8}$
Total Cancer Risk	--	--	**$1.1x10^{-7}$**	--	**$1.3x10^{-8}$**	**$1.3x10^{-7}$**	--	**$2.6x10^{-8}$**	--	**$3.0x10^{-9}$**	**$2.9x10^{-8}$**

NOTE: EPC = Exposure Point Concentration (ProUCL Calculated Concentration *n* = 20 samples, Table B3), mg/kg = milligram per kilogram, * Dose in units of milligram per kilogram per day, ** All chromium in soil was conservatively assumed to be hexavalent chromium for the health evaluation

Table B14. Background Central Tendency Exposure Dose Calculations and Estimated Risks for Adult Commercial Workers (Western Excelsior)

Non-Cancer Dose Calculations and Hazard Quotients

Contaminants of Potential Concern	**EPC (in mg/kg)**	**Ingestion Pathway**		**Dermal Pathway**		**Combined Hazard Quotients**
		Adult Non-cancer Dose*	Hazard Quotient	Adult Non-cancer Dose*	Hazard Quotient	
Arsenic	5.8	0.00000035	0.0012	0.000000041	0.00014	0.0013
Chromium**	7.4	0.00000075	0.00015	--	--	0.00015
Hazard Index	--	--	**0.0013**	--	**0.00014**	**0.0015**

Cancer Dose Calculations and Estimated Cancer Risks

Contaminants of Potential Concern	**EPC (in mg/kg)**	**Ingestion Pathway**		**Dermal Pathway**		**Combined Cancer Risks**
		Adult Cancer Dose*	Cancer Risk	Adult Cancer Dose*	Cancer Risk	
Arsenic	5.8	0.0000000051	$7.6x10^{-9}$	0.00000000058	$8.8x10^{-10}$	$8.5x10^{-9}$
Chromium**	7.4	0.000000011	$5.4\ x10^{-9}$	--	--	$5.4x10^{-9}$
Total Cancer Risk	--	--	**$1.3x10^{-8}$**	--	**$8.8x10^{-10}$**	**$1.4x10^{-8}$**

NOTE: EPC = Exposure Point Concentration (ProUCL Calculated Concentration, *n*= 20), mg/kg = milligram per kilogram, * Dose in units of milligram per kilogram per day, ** All chromium in soil was conservatively assumed to be hexavalent chromium for the health evaluation

Table B15. Background Reasonable Maximum Exposure Dose Calculations and Estimated risks for Adult Commercial Workers (Western Excelsior)

Non-Cancer Dose Calculations and Hazard Quotients						
Contaminants of Potential Concern	**EPC (in mg/kg)**	**Ingestion Pathway**		**Dermal Pathway**		**Combined Hazard Quotients**
		Adult Non-cancer Dose*	Hazard Quotient	Adult Non-cancer Dose*	Hazard Quotient	
Arsenic	5.8	0.00000071	0.0024	0.000000082	0.00027	0.0026
Chromium**	7.4	0.0000015	0.0003	--	--	0.0003
Hazard Index	--	--	**0.0027**	--	**0.00027**	**0.0029**

Cancer Dose Calculations and Estimated Cancer Risks						
Contaminants of Potential Concern	**EPC (in mg/kg)**	**Ingestion Pathway**		**Dermal Pathway**		**Combined Cancer Risks**
		Adult Cancer Dose*	Cancer Risk	Adult Cancer Dose*	Cancer Risk	
Arsenic	5.8	0.00000001	1.5×10^{-8}	0.0000000012	1.8×10^{-9}	1.7×10^{-8}
Chromium**	7.4	0.000000022	1.1×10^{-8}	--	--	1.1×10^{-8}
Total Cancer Risk	--	--	$\mathbf{2.6 \times 10^{-8}}$	--	--	$\mathbf{2.8 \times 10^{-8}}$

NOTE: EPC = Exposure Point Concentration (ProUCL Calculated Concentration, *n*= 20, Table B3), mg/kg = milligram per kilogram, * Dose in units of milligram per kilogram per day, ** All chromium in soil was conservatively assumed to be hexavalent chromium for the health evaluation

Appendix C. Toxicological Evaluation

The basic objective of a toxicological evaluation is to identify what adverse health effects a chemical causes, and how the appearance of these adverse effects depends on dose. The toxic effects of a chemical also depend on the route of exposure (oral, inhalation, dermal), the duration of exposure (acute, subchronic, chronic or lifetime), the health condition of the person, the nutritional status of the person, and the life style and family traits of the person.

The Agency for Toxic Substances and Disease (ATSDR) and the U.S. Environmental Protection Agency (EPA) have established minimal risk levels (MRL) and oral reference doses (RfD) for non-cancer effects. A MRL is the dose of a compound that is an estimate of daily human exposure that is likely to be without an appreciable risk of adverse non-cancer effects of a specified duration of exposure. The acute, intermediate, and chronic MRLs address exposures of 14 days or less, 14 days to 364 days, and 1-year to lifetime, respectively. A RfD is the daily dose in humans (with uncertainty spanning perhaps an order of magnitude), including sensitive subpopulations, that is likely to be without an appreciable risk of non-cancer, adverse health effects during a lifetime of exposure to a particular contaminated substance. The health-based guidelines for the contaminants of potential concern for this evaluation are listed below in Table C1.

Table C1. Non-cancer Toxicity Values

Analyte	Acute Health-based Guideline (mg/kg-day)	Source	Intermediate Health-based Guideline (mg/kg-day)	Source	ATSDR Chronic Health-based Guideline (mg/kg-day)	EPA Chronic Health-based Guideline (mg/kg-day)
Antimony	NA	N/a	NA	N/a	NA	**0.0004**
Arsenic	**0.005**	Oral Acute MRL	NA	N/a	**0.0003**	0.0003
Hexavalent Chromium	NA	N/a	**0.005**	Oral Intermediate MRL	**0.0009**	0.003
Copper	**0.01**	Oral Acute MRL	**0.01**	Oral Intermediate MRL	NA	**0.04**
Inorganic Mercury	**0.007**	Oral Acute MRL for Mercuric Chloride	**0.002**	Oral Intermediate MRL for Mercuric Chloride	NA	**0.0003**

NOTE: mg/kg-day = milligram per kilogram per day, ATSDR = Agency for Toxic Substances and Disease Registry, EPA = Environmental Protection Agency, MRL = Minimal Risk Level, **bolded** values were selected for use in this evaluation, NA = not available, N/a = Not applicable

The toxicity assessment process is usually divided into two parts: the first characterizes and quantifies the non-cancer effects of the chemical, while the second addresses the cancer effects of the chemical. This two-part approach is employed because there are typically major differences in the risk assessment methods used to assess cancer and non-cancer effects. For example, cancer risks are expressed as a probability of suffering an adverse effect (cancer) during a lifetime and non-cancer hazards are expressed, semi-quantitatively, in terms of the hazard quotient (HQ), defined as the ratio between an individual's estimated exposure and the health guideline (MRL or RfD). HQs are not an estimate of the likelihood that an effect will occur, but rather an indication of whether there is potential cause for concern for adverse health effects. If the HQ exceeds one, which indicates that the estimated dose is greater than the health-based guideline, the chemical exposure is examined in greater detail using the In-depth approach noted below.

Methodology for in-depth evaluation of potential for non-cancer health Effects

- *The estimated non-cancer exposure doses are compared with observed effect levels* reported in the **critical toxicological and/or epidemiologic study** used to derive the health guideline in ATSDR Tox Profile and/or EPA IRIS database. In addition, the larger toxicological/epidemiological database is also evaluated, especially for critical chemicals with high concentrations in all media in order to gain a better understanding of the range of effect levels rather than focusing on a single dose level which is used to derive the health guideline.

- When the estimated dose approaches or exceeds a Lowest-Observed -Adverse-Effect- Level (LOAEL), it is considered *to cause harm* for longer term exposures, but requires further evaluation for acute exposures based on other factors listed below.

  The relevance of the critical study is carefully evaluated in relation to site-specific exposure conditions by taking into consideration the following factors:
  - Animal or human study (adults or children)
  - Relevance of effects observed in animals to humans
  - High bolus dose or low/medium dose levels, dose regimens, and method of dosing
  - Bioavailability of metals (arsenic, lead, copper) in the study matrix versus the environmental media evaluated (e.g., soil and water)
  - Level of confidence in the critical study and uncertainties/limitations in supporting studies

Toxicity Assessment for Cancer Effects

For cancer effects, the toxicity assessment process has two components. The first is a qualitative evaluation of the weight of evidence that the chemical does or does not cause cancer in humans. Typically, this evaluation is performed by the EPA, using the system summarized in Table C2 below:

Table C2. Cancer Classifications

Category	Meaning	Description
A	Known human carcinogen	Sufficient evidence of cancer in humans.
B1	Probable human carcinogen	Suggestive evidence of cancer incidence in humans.
B2	Probable human carcinogen	Sufficient evidence of cancer in animals, but lack of data or insufficient data from humans.
C	Possible human carcinogen	Suggestive evidence of carcinogenicity in animals.
D	Cannot be evaluated	No evidence or inadequate evidence of cancer in animals or humans.

For chemicals which are classified in Group A, B1, B2, or C, the second part of the toxicity assessment is to describe the carcinogenic potency of the chemical. This is done by quantifying how the number of cancers observed in exposed animals or humans increases as the dose increases. Typically, it is assumed that the dose response curve for cancer has no threshold, arising from the origin and increasing linearly until high doses are reached. Thus, the most convenient descriptor of cancer potency is the slope of the dose-response curve at low dose (where the slope is still linear). This is referred to as the Slope Factor (SF), which has dimensions of risk of cancer per unit dose.

Estimating the cancer SF is often complicated by the fact that observable increases in cancer incidence usually occur only at relatively high doses, frequently in the part of the dose-response curve that is no longer linear. Thus, it is necessary to use mathematical models to extrapolate from the observed high dose data to the desired (but unmeasurable) slope at low dose. In order to account for the uncertainty in this extrapolation process, EPA typically chooses to employ the upper 95th confidence limit of the slope as the SF. That is, there is a 95% probability that the true cancer potency is lower than the value chosen for the SF. This approach ensures that there is a margin of safety in cancer risk estimates. The Cancer SFs used in this evaluation are shown below in Table C3.

Table C3. Cancer Toxicity Values

Analyte	Oral Slope Factors $(mg/kg\text{-}day)^{-1}$	Source
Antimony	N/a	N/a
Arsenic	1.5	IRIS
Hexavalent Chromium	0.5	New Jersey/EPA RSL
Copper	N/a	N/a
Mercury	N/a	N/a

NOTE: $mg/kg\text{-}day^{-1}$ = per milligram per kilogram per day, N/a = Not Applicable, IRIS = Integrated Risk Information System, EPA = Environmental Protection Agency, RSL = Regional Screening Level Table

For additional information of the toxic potential of the primary contaminants of potential concern in this health consultation, please see the ATSDR ToxFAQs at the following web addresses:

Arsenic - *http://www.atsdr.cdc.gov/toxfaqs/TF.asp?id=19&tid=3*

Chromium - *http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=61&tid=17*

Mercury - *http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=113&tid=24*

Appendix D. Mercury Exposures

Background

Mercury is a highly toxic metal and occurs in the environment as a result of natural and anthropogenic activities. Human exposure can occur in occupational settings, or from sources such as fish consumption, dental amalgams, pharmaceuticals, cosmetics, folk medicines, and some household products (thermometers and compact fluorescent light bulbs). All people have at least some amount of mercury in their body. Mercury enters the body via inhalation, ingestion and absorption through the skin. Potential sources of general population exposure to mercury include inhalation of metallic mercury vapor in ambient air, ingestion of inorganic mercury contaminated soil, and dietary intake of methyl mercury contaminated fish and other sea food and foodstuff contaminated with elemental mercury. The Centers for Disease Control and Prevention (CDC) reports that the geometric mean blood mercury concentration in the U.S. population age 20 years and older is 1.04 (95% Confidence Interval = 0.956-1.14) micrograms mercury per liter of blood (µg/L) from the updated tables of the National Health and Nutrition Examination Survey for the year 2009-2010 (CDC 2013). In the United States, humans are exposed to methyl mercury mostly through fish consumption and elemental and inorganic mercury through certain occupations (CDC 1996).

Sources, Fate and Transport of Mercury

Sources, fate, and transport of mercury in the environment have been thoroughly discussed in various reports, such as Global Mercury Assessment and the accompanying Technical Background Report by the United Nations Environment Program (UNEP 2013); Toxicological Profile for Mercury by the Agency for Toxic Substances and Disease Registry (ATSDR 1999); and Mercury Study Report to Congress by the US Environmental Protection Agency (USEPA, 1997). A brief summary of the findings from these reports is provided below.

Sources of mercury emission in the US are ubiquitous and include: (1) natural mercury emissions; (2) anthropogenic mercury emissions; and (3) re-emitted mercury. Natural sources of mercury create background environmental levels. Some of the major natural sources of mercury include, natural weathering of mercury containing rocks, eruption of volcanoes, and geothermal activity. The major anthropogenic sources of atmospheric mercury include coal burning, mining, industrial activities that process ores to produce various metals, waste incineration, cement/brick factories, and chlorine production. In the US, coal-fired power plants are the largest source of mercury emission to the air. Artisanal and small scale gold mining (ASGM) is a major source of mercury emission worldwide, in which mercury is used to extract gold from rocks, soils, and sediments (UNEP 2013). However, calculating emissions from this source is particularly challenging because it is typically widely dispersed and often unregulated and illegal; therefore, uncertainties regarding emission estimates are high (UNEP 2013). Mercury previously deposited from air onto soil, vegetation and water bodies from past emissions can emit back to the air. Re-emission occurs as a result of natural processes that convert inorganic and organic forms of mercury to elemental mercury, which is a volatile form and returns to the air. Re-emitted mercury may include both natural and anthropogenic mercury, but it is difficult to distinguish. Mercury may be deposited and re-emitted several times as it cycles through the environment.

Once mercury is released to the environment as a result of natural and human activities, it cycles between air, soil, and water until it is removed from the system. Mercury exists in three primary forms in the environment: gaseous elemental mercury, gaseous oxidized mercury, and particulate bound mercury. However, the oxidized and particulate mercury are less common forms and are deposited relatively rapidly after their formation, leading to a residence time of hours to months. Most mercury in the air exists in the gaseous elemental form and may be transported long distances by wind for a year or longer. Elemental mercury has an average residence time of one year in the atmosphere. Mercury released into the atmosphere from natural and anthropogenic sources deposits mainly as inorganic (HgII) mercury. This inorganic mercury results from either direct deposition of emitted inorganic mercury or from conversion of emitted elemental mercury to inorganic mercury through ozone mediated reduction. The former process results in elevated deposition rates around atmospheric emission sources and the latter process results in regional/global transport followed by deposition. Once deposited, the inorganic mercury species are subject to a wide variety of chemical and biological reactions. The affinity of mercury species for soil results in soil acting as a large reservoir for anthropogenic mercury emissions (EPA 1997). Furthermore, EPA (1997) states that even if anthropogenic emissions were to stop, leaching of mercury from soil would not be expected to diminish for many years. The majority of total mercury (97-99%) can be considered largely inorganic mercury complexes, although a small fraction of mercury in typical soils will be elemental mercury and about 1-3% of the total mercury in surface soil will be methylmercury (EPA 1997).

Environmental Mercury Levels in the Mesa Verde National Park/Four Corners Region

The unpermitted mill site is in the vicinity of the Mesa Verde National Park which is in the Four Corners region. The Mercury Deposition Network is the mercury wet deposition monitoring arm of the National Atmospheric Deposition Program (NADP). The NADP is a cooperative program comprised of federal and state agencies, academic institutions, Native American tribal government, and private organizations. The NADP mercury monitor (SITE CO99) is approximately 14.5 miles from the unpermitted mill site. The NADP mercury monitor has been in place since 2002 in Mesa Verde National Park. Although mercury deposition is not a direct ambient air monitoring technique, deposition can be used to identify long-term patterns and provides data to estimate wet deposition rates locally or between sites. Trends for mercury deposition in Mesa Verde National Park are shown in Figures D1 and D2 which indicate that three-year averages over the last decade for this monitor have increased significantly by about 2.4 times (2002-2004 vs. 2010-2012). The NADP Mercury Deposition Network also has another Colorado site located on Buffalo Pass at Summit Lake near Steamboat Springs, Colorado that has been in operation since 1998 that can be used to compare mercury trends in Colorado over the long-term. It is apparent from Figure D3 that mercury levels continue to increase in both regions, but have risen faster in the Mesa Verde National Park region over the last decade, especially over the last 5 years.

The Mesa Verde National Park is geographically located near a center for coal-fired power plants and oil and gas production. There are currently 13 major power plants within 200 miles of the

Four Corners region generating approximately 9,062 Mega Watt (MW) as of January 2014, making it one of the most industrially dense areas of the United States (Table D1). For perspective, according to 2012 data, sources in the south central region of Colorado that emit mercury include the CFI Steel Mill (emits about 200 lbs of mercury annually), the Comanche Power Plant (emits about 50 lbs of mercury annually), the Holcim and GCC Rio Grande Cement Plants (about 8 lbs of mercury annually).

Table D1. List of Existing Power Plants within 200 miles of Mesa Verde National Park

1. Navajo Generating Station (2,250 MW) near Page, Arizona
2. Cholla Power Plant (1,021 MW) near Joseph City, Arizona
3. Coronado Generating Station (773 MW) near St. Johns, Arizona
4. Delta-Person Generating Station (132 MW) near Albuquerque, New Mexico
5. Reeves Generating Station (154 MW) in Albuquerque, New Mexico
6. Santa Fe/Rio Grande Power Plant (340 MW), New Mexico
7. Prewitt Escalante Generating Station (250 MW) near Grant, New Mexico
8. TA-3 Steam Plant (20 MW) near Los Alamos, New Mexico
9. Algodones Generating Station (45 MW), New Mexico - CLOSED
10. Animas/Bloomfield Power Plant (51 MW) near Farmington, New Mexico
11. Milagro Cogeneration Plant (121 MW) near Bloomfield, New Mexico
12. San Juan Generating Station (1,800 MW) near Farmington, New Mexico
13. Four Corners Power Plant (2,040 MW) in Fruitland, New Mexico
14. Nucla Station (110 MW), Colorado

The available scientific knowledge supports a plausible link between mercury emissions from anthropogenic combustion and industrial sources and methylmercury concentrations in freshwater fish (EPA 1997). Various reservoirs with fish advisories in the Four Corner region and their distance from the unpermitted mill site are shown below in Table D2 and Figure D4.

Table D2.Mercury fish advisories in the vicinity of the unpermitted mill site

Site with Fish Consumption Advisory	Approximate Distance from Mancos Site of Concern in Miles
Puett Reservoir	7.4
Totten Reservoir	12.5
Narraguinnep Reservoir	20.1
McPhee Reservoir	20.6
Vallecito Reservoir	41.6
Navajo Reservoir	55

Health Effects of Mercury

In nature, mercury exists in three forms: elemental, organic and inorganic salts. In humans, the urine and feces are the major pathways for metallic and inorganic mercury with a half-life of about 1-2 months (ATSDR 1999). Excretion through expired air is negligible after inhalation exposure.

All forms are harmful to humans and can produce a wide range of health effects depending on the dose and duration of exposure. High levels of any form of mercury can permanently damage the brain, kidneys and a developing fetus. Yet, there are major differences in the biological response to inorganic and organic mercury, as well as its route of exposure (ATSDR, 2006). Please see http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=113&tid=24 for ATSDR's mercury health effects fact sheet.

Metal mercury vapors and methyl mercury are the most harmful because both can access the central nervous system. Mercury accumulates in the body and causes delayed neurological effects. The neuro-developmental effects are the most sensitive and well-documented health effect in humans. Other health impacts include cardiovascular disease, immune deficiency and reproductive complications. Early clinical symptoms include paresthesia (tingling and numbness in the toes, fingers, mouth and lips), ataxia (lack of coordination of muscle movement), generalized weakness, vision and auditory difficulties, muscle spasms and tremors (Olsen 2009).

Artisanal and Small Scale Gold Mining: Mercury Exposure and Health Impacts

Artisanal and Small Scale Gold Mining (ASGM) community uses mercury to extract gold from ore by forming "amalgam" because it is cheaper than most alternative methods. Globally, ASGM is responsible for about 37% of mercury emissions (WHO 2013). Mercury vapors in the air around amalgam burning sites can be alarmingly high and almost always exceed the WHO limit for public exposure of 1.0 $\mu g/m^3$ (WHO 2013). ASGM industry is found primarily in East and Southeast Asia, Sub-Saharan Africa, and South America. A significant correlation has also been found between total gaseous mercury in air in the small-scale gold mining area and mercury concentrations in soil (Garcia-Sanchez 2006). In this study, an air and soil mercury measurement was carried out at a mill site up to a distance of 1000m (about two-thirds of a mile) and it was observed that the air mercury concentration and mercury soil concentration decreased with increasing distance from the mill site.

The ASGM exposures can also affect the communities surrounding the processing centers. Based on the current epidemiological studies conducted in ASGM communities in multiple countries on three continents, South America, Asia, and Africa, WHO (2013) concluded, "Mercury exposure in ASGM communities is associated with adverse health effects including kidney dysfunction, autoimmune dysfunction, and neurological symptoms. Urinary mercury concentrations in ASGM communities are above the concentrations that have been associated with neurologic and kidney effects." It is, however, important to note that the magnitude of exposure and the potential for adverse health effects can vary based on a variety of factors, including distance of communities from the source, meteorological conditions, exposure duration, and individual factors (e.g., health status, genetics, life style, age, and gender). For example, a recent study conducted in Alaska (ATSDR 2013) found only one (Participant A) out of eighteen participants with urine mercury level (106.07 µg/g creatinine) above the health reference level (20 µg/L or 20 µg/g creatinine). This one participant had been regularly heating gold samples in recent months for 5,400 minutes/month for a few months; however, this participant was asymptomatic. Two other participants (Participant A's neighbors living in the same household, a quadruplex) had urine mercury levels (5.39 and 6.38 µg/g creatinine) considerably higher than those for most US residents based on the National Health and Nutrition Examination Survey (NHANES) 95th percentile (< 2.5 µg/g creatinine approximately), but well below the health reference level. It is, however, important to note that having a urine mercury level above the NHANES 95th percentile does not imply that adverse health effects will occur, but it does indicate higher mercury exposure than most of the US population (ATSDR 2013).

Reference Levels for Mercury in Biological Samples

Nationally, professional groups and federal programs maintain their own guidelines. The CDC only considers blood or urine mercury levels above 10 µg/L as of potential concern) (Belson et al. 2005). The American Conference of Governmental Industrial Hygienists (ACGIH) uses a Biological Exposure Index which sets the occupational exposure limit for serum inorganic mercury toxicity at 15 µg/L and urine levels at 20 µg/L. For elemental mercury, the Agency for Toxic Substances and Disease Registry (ATSDR 2006) reported no clinical or subclinical effects for urine mercury levels below 20 µg/L In addition, no reports of effects have been documented for people in a range of 21-39 µg/L but this does not rule out the possibility of harmful effects in sensitive subpopulations (ATSDR 2006).

Colorado's Mercury Surveillance System

The State of Colorado "Regulations Pertaining to the Detection, Monitoring, and Investigation of Environmental and Chronic Diseases (6 CCR 1009-7)" require that within 30 days of the test all clinical laboratories in the state report any blood and urine tests where mercury levels exceed 5µg/L for blood and 20µg/L for urine. This is intended for the protection of the developing fetus based on the available toxicological health information.

Colorado maintains a mercury surveillance system which is built on the above-mentioned reporting requirement that includes the collection of sufficient information about tested individuals. The system further depends on follow-up conducted by the program staff or health care providers to identify the source of exposure. Once the source has been identified, the goal is to reduce exposure to mercury in these individuals through health education.

Since 2013, CDPHE has not received any elevated blood or urine mercury report from Mancos.

References for Appendix D

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Figure D1: Annual Mercury Deposition at Mesa Verde NP (NADP, 2014)

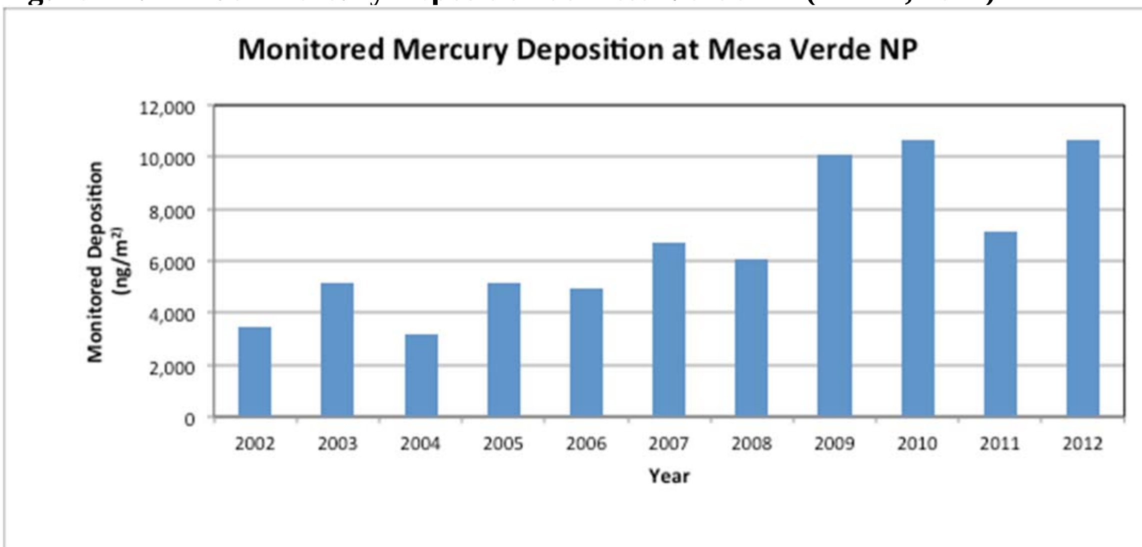


Figure D2: 3-Year Averages of Monitoring Mercury Deposition in Mesa Verde NP (NADP, 2014)

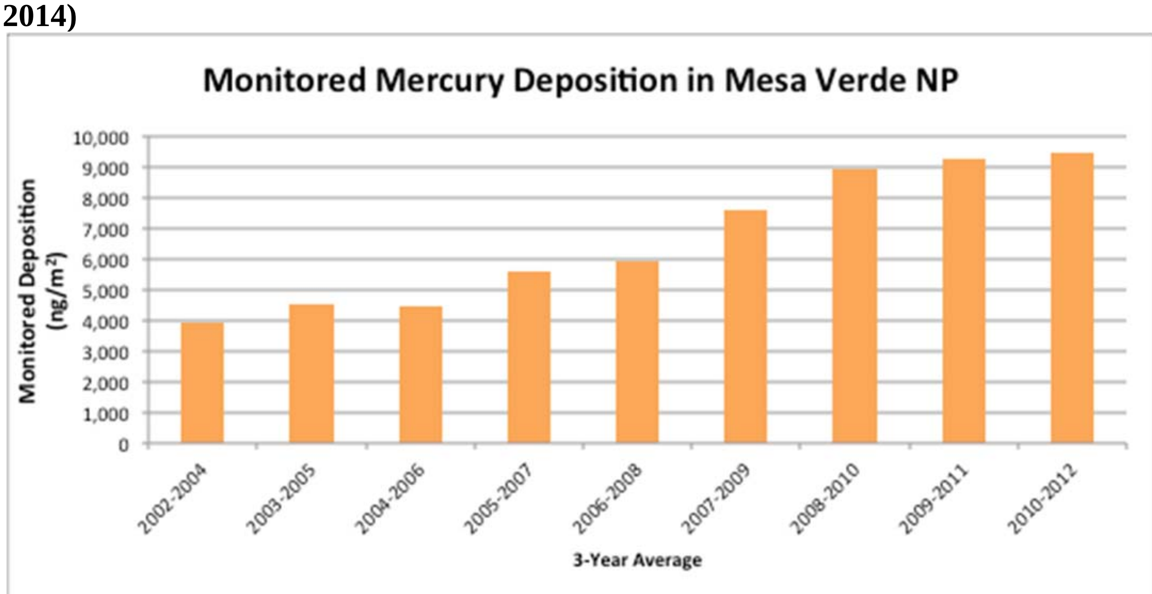


Figure D3: Three-Year Average of Annual Mercury Deposition in Colorado at Mesa Verde NP and Buffalo Pass (NADP, 2014)

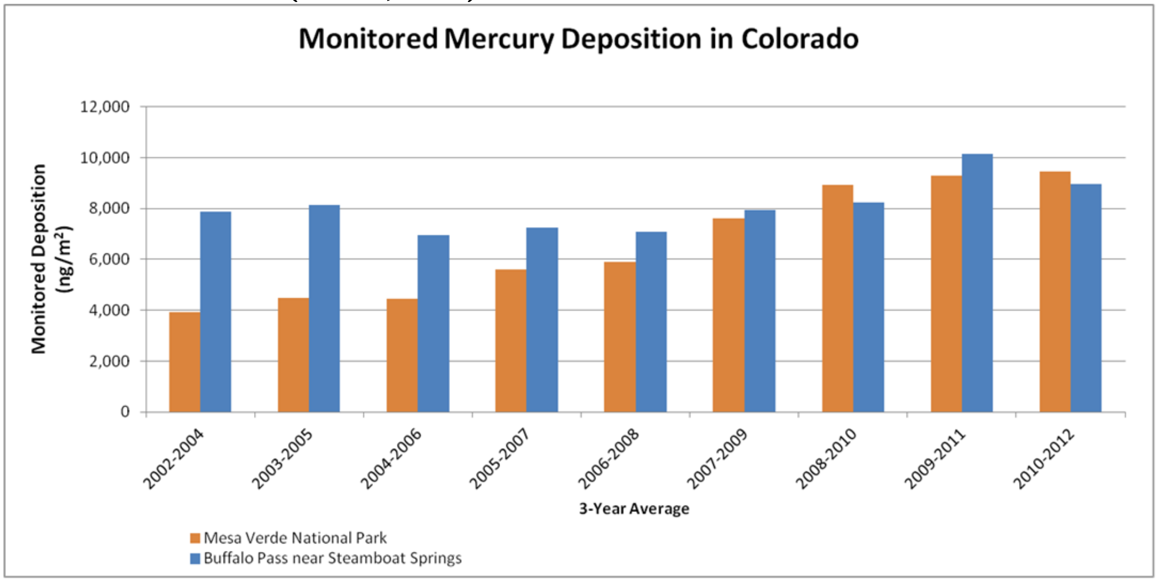
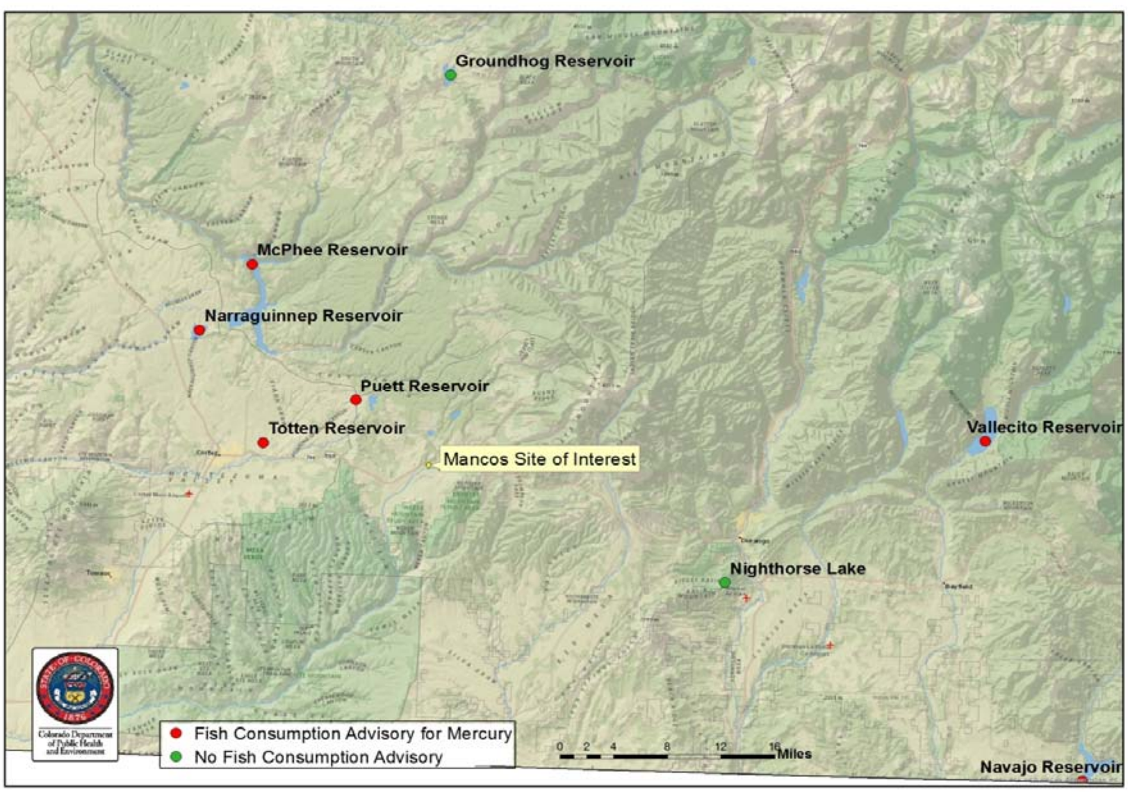


Figure D4. Fish mercury advisories in the Four Corner Region in the vicinity of the unpermitted mill site.



Appendix E: Expected Meteorological Conditions, Transport and Dispersion for the Unpermitted Mill Site

Expected Meteorological Conditions, Transport and Dispersion for site at
37.345213° N, 108.305262° W

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Air Pollution Control Division
Technical Services Program
Modeling, Meteorology, and Emission Inventory Unit

February 7, 2014

Summary

A plume emitted from the site at 37.345213° N / 108.305262° W will be transported towards the town of Mancos during the late morning (about 9 or 10 AM) until near sunset (one to two hours either side of sunset), approximately 5 – 13 hours total depending on the season. There will be additional periods when a plume emitted from the site will be transported towards the town of Mancos, such as when a strong weather system moves through the area and when there are thunderstorms nearby. From the evening through the night into the early morning (approximately 9 -17 hours total depending on the season), a plume will be transported west/ southwest from the site towards inhabited areas. When the wind direction changes from east/northeast to west/southwest within 1-2 hours of sunset and from west/southwest to east/northeast in the late morning, a plume emitted from the site will be transported in many directions, including to areas surrounding the site that are inhabited or used for industry. Thunderstorms will have strong gusty winds that could move a plume in any direction.

Analysis

This analysis provides general information about the probable direction of plume transport during different times of the day. It does not provide estimates of deposition rates or ambient concentration levels that might have occurred from an emissions release. For that, a dispersion modeling study would be necessary.

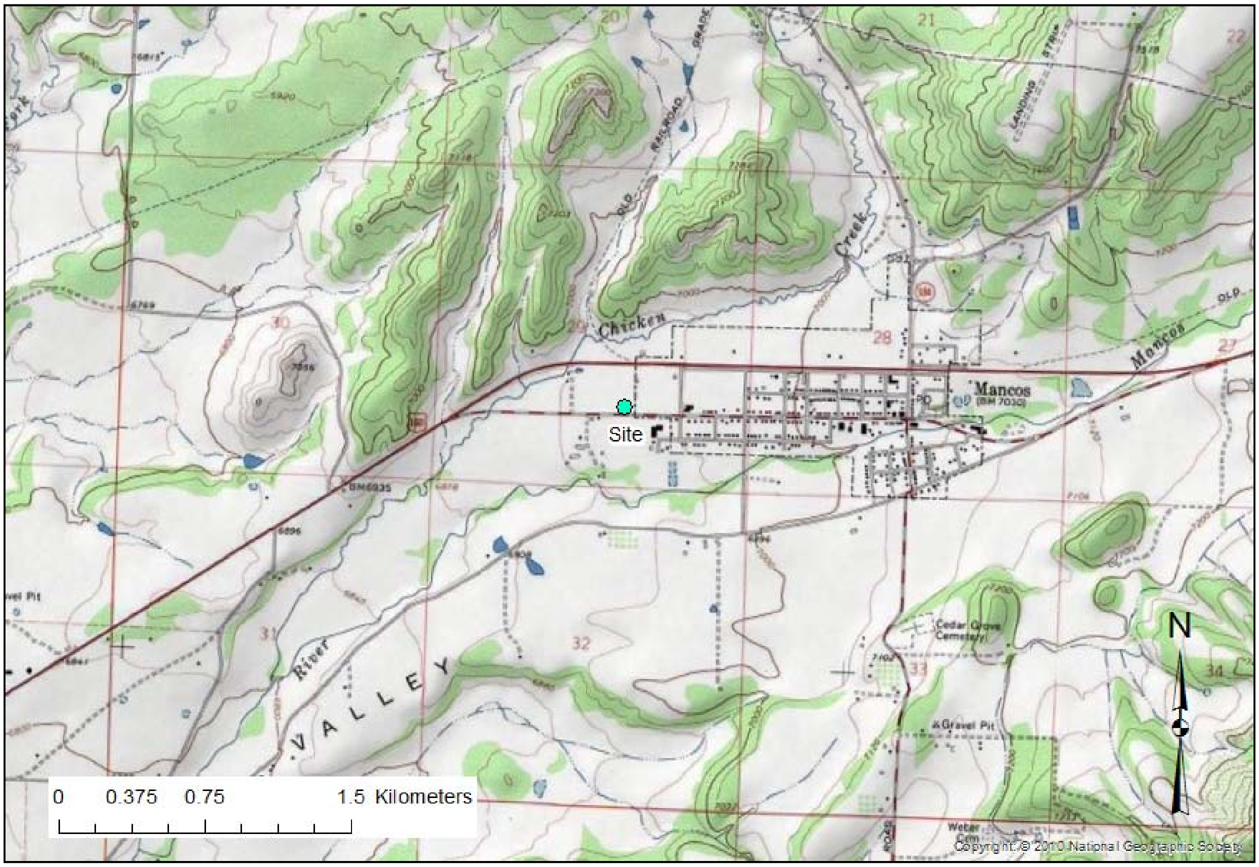
The site at 37.345213° N / 108.305262° W is between Chicken Creek and the Mancos River in the Mancos Valley. The valley has an east to west orientation but turns to the southwest near the site. The site is at an elevation of 2,115 m (6,937 ft) with valley walls rising to 2,196 m (7,202 ft) about 1 km to the north and to 2,186 m (7,170 ft) about 2.2 km to the south. Where the Chicken Creek and Mancos River valleys merge about 2 km to the northwest of the site, a mesa rises sharply to over 2,256 (7,400 ft) m. These elevation changes can be seen in the USGS topographical map in Figure E1 and the USGS National Elevation Data (NED) in Figures E2 and E3. The Mancos Valley floor slopes upward about 25 m per km from the Site to the east and downward from the site at about 17 m per km to the southwest.

For the majority of the time, the winds at the site will be driven by the diurnal heating and cooling of the valley and surrounding higher terrain rather than by large scale weather features. The diurnal heating will cause the winds to flow up Mancos Valley from the late morning to near sunset as seen in Figure E2. The winds will flow down Mancos Valley from the evening till a few hours after sunrise as seen in Figure E3. There will be a period of 1 to 3 hours during the transition from up valley to down valley or the reverse when the winds will be calm to light and variable (3 mph or less). During these transition periods, the wind direction will generally be up or down the Mancos Valley but could be from any direction.

The up valley wind speeds will generally be lighter than the down valley winds. The up valley wind speeds, when not enhanced by a strong weather system moving across the area, will be in the 1 to 5 mph range. The down valley wind speeds can be expected to be in the 3 to 8 mph range. It is expected the up valley wind direction could vary from about 220^o to 280^o. The down valley winds are expected to be from 45^o to 135^o.

In the winter and the spring, strong weather systems can move across the Mancos area. It is not uncommon for these storms to have strong southwest winds associated with them. These strong southwest winds could get channeled in the Mancos Valley. This would cause the up valley winds to last for extended periods and reach wind speeds of 10 to 20 mph with gusts of 20 to 40 mph. In recent years, these types of storms have occurred from 3 to over 12 times per year. Most years, these types of storms occur from late February or March into late April or early May. These storms can occur as late as June and in the fall.

Figure E1. Topographic map, the site is located at the blue dot



Summer thunderstorms may also cause strong gusty winds. These winds will be short in duration.

The transport and dispersion of pollutants from a plume emitted from the site depend on the time of day. During the late evening into the early morning hours, the plume would move down valley in an arc between 220^o to 280^o, the plume will turn to match the orientation of Mancos Valley as seen in Figure 3. After an hour or two of downwind transport, the plume would be well mixed within Mancos Valley.

Depending on the amount of cloud cover and the time of year, the transition to up valley flow will occur from mid to late morning and last 1 to 3 hours. If it is cloudy, the up valley flow may not develop and the winds will remain light and variable until the down valley redevelops in the evening. During the transition to up valley flow, the area affected by the plume would be more like a circle. The constraints to the area impacted by the plume would be the distance to the valley side walls and the distance light wind speeds could transport the pollutant up or down Mancos Valley.

Once the up valley flow develops, the plume will travel up valley in an arc between 45° and 135° as seen in Figure 2. Some of the up valley flow will move up adjacent valleys of Chicken Creek Valley, West Mancos River Valley, and other unnamed valleys that intersect with Mancos Valley. The portion of the plume moving up these side valleys will vary depending on the distance from the site, and the size of the side valley. Generally, a majority of the plume will stay in the largest valley, Mancos Valley. The transition conditions will develop once again in the late afternoon into the evening when the down valley flow starts. The transition period from up valley to down valley flow could last 1 to 3 hours but is generally shorter than the transition from down valley to up valley flow.

During strong large scale storms with winds of 10 to 20 mph with gusts of 20 to 40 mph, the plume would be dispersed over large distances, in and out of the Mancos Valley. Thunderstorms would disperse plumes in patterns that would vary in direction, area, and by event.

Figure E2. USGS National Elevation Data (NED), upslope flow, the site is located at the blue dot

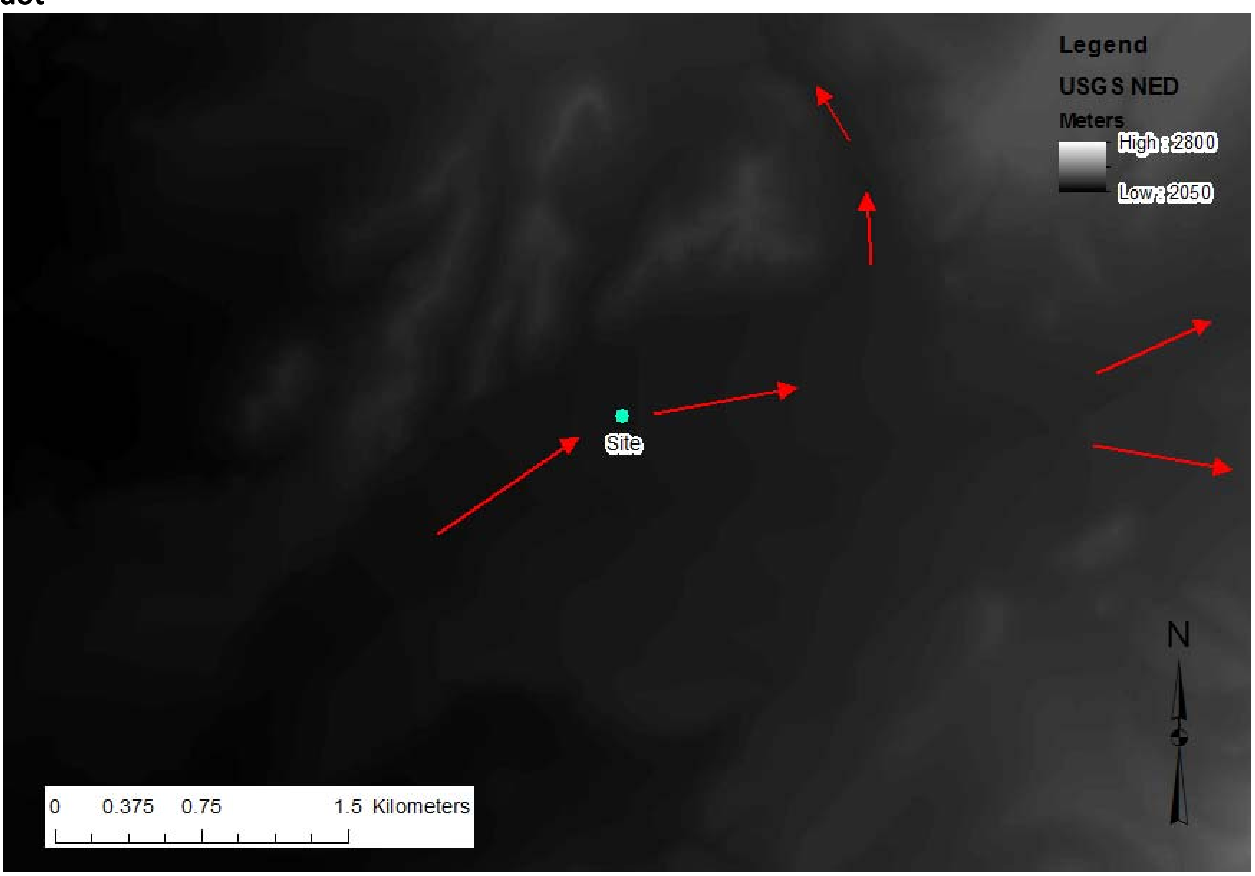


Figure E3. USGS National Elevation Data (NED), downslope flow, the site is located at the blue dot