Health Consultation

FORMER BONANZA MINE SITE
1299 BONANZA MINE ROAD
SUTHERLIN, OREGON 97479

EPA FACILITY ID: ORN001001174

Prepared by
Oregon Health Authority

MAY 3, 2017

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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HEALTH CONSULTATION

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Public Health Division
Under Cooperative Agreement with
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry (ATSDR)

Foreword

The Environmental Health Assessment Program (EHAP) within the Oregon Health Authority, Public Health Division prepared this Health Consultation (HC) report under cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to exposures to toxic substances.

In order to prepare a HC, ATSDR and its cooperative agreement partners review available information about hazardous substances at sites and evaluate whether exposure to them might cause any harm to people. An HC is not the same as a medical exam or a community health study. EHAP prepared this HC in accordance with ATSDR's approved methods, policies, and procedures existing at the date of publication. ATSDR has reviewed this document, and based on the information presented, concurs with its findings.

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Summary

Introduction

The Environmental Health Assessment Program (EHAP) within the Oregon Health Authority, Public Health Division prepared this Health Consultation (HC) under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

In November 2013, EHAP learned that children were living in a contaminated area of the former Bonanza Mine site. As a result, the Oregon Department of Environmental Quality (DEQ) collected soil, spring water, and well water samples to better characterize the contamination. After reviewing the data, the U.S. Environmental Protection Agency (EPA) and DEQ remediated the soil at the site. In addition, EHAP chose to evaluate the health risks posed to children and adults from drinking spring and well water from the former Bonanza Mine property since we received new information about residents' possible use of the well for drinking should the spring run dry at certain times of the year.

In this HC, EHAP evaluated spring and well water samples from the Bonanza Mine property that were collected on December 16, 2013, March 12, 2014, January 14, 2015, and September 17, 2015. The well water samples were for two wells that serviced five residences as a secondary water source when the spring runs dry. Based on our analysis of these data, EHAP concluded that the well water at the former Bonanza Mine property is contaminated with arsenic at levels of health concern. The arsenic levels in the well water could cause non-cancer health effects in children and adults who drink it for a short period of time (acute, 14-day exposure). Additionally, it could pose an increased risk of cancer to children and adults who regularly drink water from these wells. As a result, EHAP strongly advises people not to use well water from the former Bonanza Mine property for drinking or any other purpose.

EHAP does not expect the levels of arsenic and mercury in the spring water on the property to harm the health of children and adults who drink it. However, springs are susceptible to contamination from microorganisms, nitrates, and other contaminants from upland sources, and therefore, we recommend the spring be tested for these contaminants.

Conclusions

EHAP reached three conclusions in this HC:

Conclusion 1

EHAP concludes that the arsenic concentrations in the water from well #1 at the former Bonanza Mine property could harm the health of children and adults.

Basis for decision

Water from well #1 at the former Bonanza Mine property is contaminated with arsenic at levels of health concern. The maximum arsenic concentration from this well (630 parts per billion [ppb]) is above ATSDR's oral health-based comparison values (0.016, 2.1, and 35 ppb [cancer, chronic, and acute screening levels, respectively]) and EPA's Maximum Contaminant Level (MCL) (10 ppb) for drinking water. All of the non-cancer, acute exposure dose estimates are higher than ATSDR's Minimal Risk Level for acute oral exposure (0.005 mg/kg/day), which indicates there may be a risk of experiencing adverse health effects from drinking this water for even a period of 14 days. The cancer risk estimates show that exposure to this level of arsenic could pose an increased risk of cancer to children and adults who regularly drink, cook, or prepare beverages/food with this well water.

Further, because the level of arsenic is higher than 500 ppb, this water is unsuitable for any other purpose. According to guidance from the Oregon Health Authority's Public Health Division, this includes watering gardens, bathing/showering, washing dishes, or doing laundry (1).

The water samples from well #1 were tested for only mercury and arsenic, and we could not draw conclusions about nitrates, bacteria, or other compounds that could potentially be present in this water.

Conclusion 2

EHAP concludes that the arsenic concentrations in the water from well #2 at the former Bonanza Mine property could harm the health of children and adults if this water is used for drinking, cooking, preparing beverages/food, or watering gardens.

Basis for decision

EHAP evaluated a single water sample from well #2 with an arsenic concentration of 205 ppb. Like well #1, exposure to this level of arsenic may pose a risk of cancer and/or non-cancer health effects to children and adults that use the water for drinking, cooking, preparing beverages/food, or watering gardens (1) (2). In contrast to well #1, there may be a low risk of adverse health effects from bathing/showering, washing dishes, and doing laundry with well #2 water (1). However, EHAP cannot be certain of the risks associated with any of these uses without more data on this well. Therefore, it would be prudent for people to avoid, if possible, using water from well #2 until more data are collected.

EHAP could not draw conclusions about mercury, nitrates, bacteria, or other compounds that could potentially be present in the well #2 water since the samples from this well were analyzed for only arsenic.

Conclusion 3

EHAP concludes that the mercury and arsenic concentrations in the spring water at the former Bonanza Mine property are not expected to harm the health of children and adults.

Basis for decision	First, the levels of mercury in the spring water samples were below EPA's MCL (2 ppb). Second, arsenic was not detected in any of the spring water samples. The spring water samples were analyzed for only mercury and arsenic, and so we could not draw conclusions about nitrates, bacteria, or other compounds.
Next steps	A list of actions that can be taken to protect the health of children and adults who live at or visit the former Bonanza Mine property is provided below: • EHAP strongly advises people not to use water from well #1 for drinking, cooking, preparing beverages/food, or any other purpose. • EHAP recommends people not use the water from well #2 for drinking, cooking, preparing beverages/food, or watering gardens. We also advise people to avoid, if possible, using well #2 water for bathing/showering, washing dishes, and doing laundry. • Because people may use well water from the former Bonanza Mine property, EHAP recommends water from both wells undergo additional arsenic testing. We also recommend well #2 water be tested for mercury, since this well was tested for only arsenic. • If people have questions about the health risks associated with using the arsenic-contaminated well water and how to prevent exposure, they can contact EHAP for answers. • EHAP recommends the spring water and well water be tested for other contaminants, especially bacteria and nitrates, since both are susceptible to contamination from upland sources. • If additional well or spring water data from the former Bonanza Mine site are collected, EHAP will review the data and communicate the results to the property owner and others living at the site.
For more information	If you have questions about this report, you can contact EHAP at 971-673-0977 or toll free at 1-877-290-6767 or via email: ehap.info@state.or.us.

Background and Statement of Issues

The Environmental Health Assessment Program (EHAP) within the Oregon Health Authority, Public Health Division prepared this Health Consultation (HC) under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

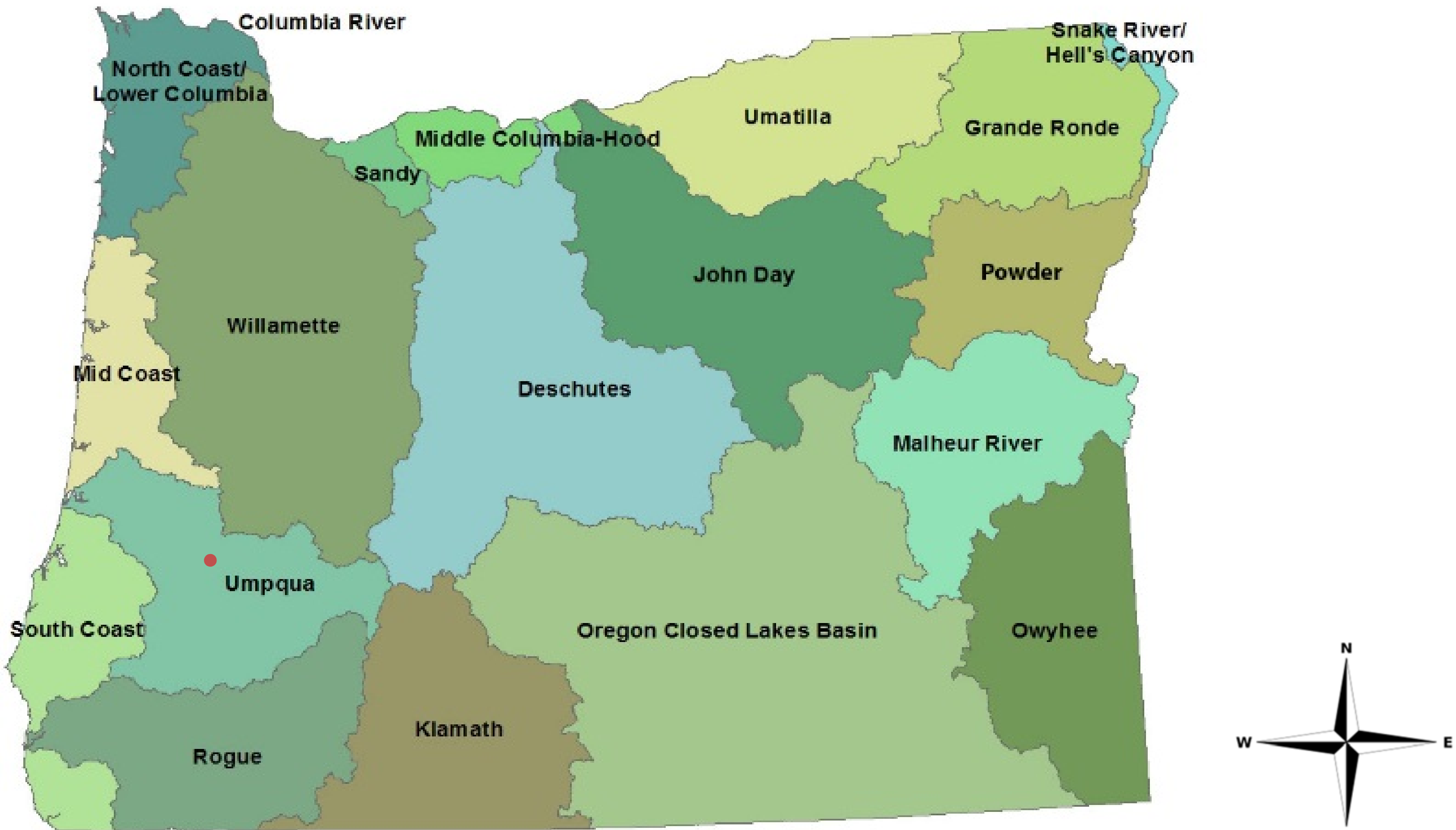
In November 2013, EHAP learned that children were living in a contaminated area of the former Bonanza Mine site. As a result, the Oregon Department of Environmental Quality (DEQ) collected soil, spring water, and well water samples to better characterize the contamination. After reviewing the data, the U.S. Environmental Protection Agency (EPA) and DEQ remediated the soil at the site. In addition, EHAP chose to evaluate the health risks posed to children and adults from drinking spring and well water from the former Bonanza Mine property since we received new information about residents' possible use of the well for drinking should the spring run dry at certain times of the year.

Arsenic in Oregon's Groundwater

High arsenic concentrations have been found in groundwater in many western states, including Oregon (3). Arsenic occurs naturally in rocks and soil and it is a byproduct of some agricultural and industrial activities (4). Arsenic can get into drinking water when groundwater flows through rocks and soil that contain the element (5). It can also enter drinking water as runoff into surface water (4).

In Oregon, evidence of high arsenic levels in groundwater and soil has been observed in areas near the former Bonanza Mine site. The town of Sutherlin is located in the Umpqua Basin and it is approximately eight miles west of the former Bonanza Mine site (Figure 1). In a 2008 study of the Sutherlin area, 144 private wells were tested and 33 percent (n=48) of them had concentrations of arsenic that were equal to or higher than the U.S. Environmental Protection Agency's (EPA) Maximum Contaminant Level (MCL) of 10 parts per billion (ppb), with levels as high as 4,600 ppb (6). In a study of the nearby Willamette Basin, arsenic concentrations of 50 ppb in groundwater were found to be widespread (Figure 1) (7). This study also showed that some of the highest levels of arsenic were in south central and eastern Lane County, which is located approximately 12 miles from the former Bonanza Mine site (7). The arsenic levels observed in these areas are likely due to volcanic material that contains high concentrations of the naturally-occurring element (6) (7).

Figure 1. Map of water basins in Oregon.



● Approximate location of the former Bonanza Mine site	0 50 100 200 Approximate scale in miles	Source: Oregon Department of Environmental Quality (31)

Site Location and Characteristics

The Bonanza Mine site is approximately eight miles east of the town of Sutherlin in Douglas County, Oregon. The property is 41.8 acres in size and it is zoned as farm/forest land, timberland resource, and grazing land (8).

The Bonanza Mine site was once a mercury mine and mercury processing mill that operated from about 1865 to 1960. Historic operations contaminated much of the site. Past investigations by EPA and DEQ revealed that there were high concentrations of arsenic and mercury in surface and roadway soil, the tailings pile and waste rock pile, and creek sediment from mining and processing activities on the site. See Appendix A for more information about the site's mining history, EPA and DEQ's clean-up investigations and actions, and EHAP's activities.

Currently, only one home remains from the site's mining period; additionally, four trailer homes have been placed on the Bonanza property. The mill buildings and their concrete foundations are no longer present; EPA removed the foundations during the 2014 removal action. The tailings pile and waste rock pile, along with contaminated soil and other debris from the 2014 removal action, were consolidated into a large repository, which is located near the former mill and smelter area on a hillside just below and outward from the mine (9). There are 12 open mine adits with more than three miles of subterranean tunnels and shafts. Two of these adits are located on the former Bonanza Mine property and the others are on neighboring properties (10).

Figure 2. Storage tank that holds spring water on the former Bonanza Mine property in Sutherlin, Oregon.

All five residences on the Bonanza property receive their water from a spring that is located west of the property. The untreated spring water is diverted into an aboveground storage tank situated near the entrance of the site (Figure 2) (10). In addition, there are two groundwater wells on the property; one is located on the eastern edge of the property (well #1) and the other is adjacent to the storage tank that holds spring water (well #2) (Figure 3). The former joins to the southernmost home while the latter connects to the four northern residences. The Oregon Water Resources Department's (OWRD's) well log indicates that well #1 was installed in 1980 and it is 185 feet in depth with a static water level of 36 feet below ground surface (9) (11). Similar information (i.e., completion date, depth, static water level) on well #2 cannot be found because there is no record of this well in OWRD's well log. Additionally, it's unknown if the two well are hydrogeologically connected. See Appendix B for a map of the site, which includes the locations of the residences, the spring water storage tank, and the groundwater wells.

Figure 3. The two groundwater wells on the former Bonanza Mine property in Sutherlin, Oregon.

Figure 3a. The well house for well #1 on October 9, 2014.

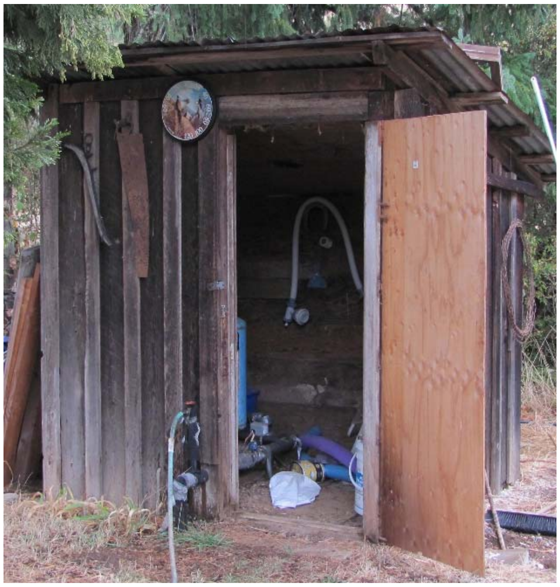


Figure 3b. Inside the well house for well #1 on October 9, 2014.

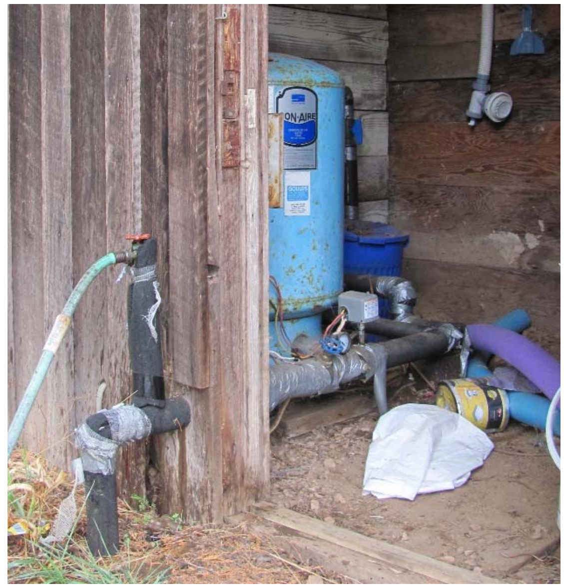


Figure 3c. The well house for well #2 on September 17, 2015.

Past Investigations

In 2000, a water sample was collected from well #1 on the former Bonanza Mine property and it showed an arsenic concentration of 53.6 ppb. EHAP reviewed and discussed this sample result in a 2012 HC (12). This result was higher than ATSDR's Cancer Risk Evaluation Guide (CREG) (0.016 ppb), ATSDR's chronic and acute Environmental Media Evaluation Guide (EMEG) for a child (2.1 ppb and 35 ppb, respectively), and the MCL (10 ppb). However, EHAP eliminated contact with the well water as an exposure pathway and we did not further evaluate the risk to residents.[1,2,3] This was because information from past investigations indicated that residents did not use the well for domestic purposes, but may have used it for gardening (9) (12). Further, the level of arsenic was shown to be between 10 and 99 ppb, which is the range that arsenic-contaminated water can be safely used for bathing/showering, washing dishes, doing laundry, and irrigating (1). Based on this information, EHAP stated that they did not expect the well water to harm people's health.

Since 2012, when the HC was released, EHAP received new data on the spring and well water; these data were collected in December 2013, March 2014, January 2015, and September 2015. EHAP also received new information about residents' possible use of the well for drinking should the spring run dry at certain times of the year. As a result, EHAP chose to reevaluate the risks posed to human health from drinking the spring and well water.

Discussion

Environmental Data Evaluation

In this HC, EHAP evaluated spring and well water samples from the Bonanza Mine property that were collected on December 16, 2013, March 12, 2014, January 14, 2015, and September 17, 2015. In December 2013, the Oregon Department of Human Services collected two water samples; one sample was taken from the tank that holds spring water and the other sample was taken at well #1. Six water samples were collected in March 2014 by the DEQ environmental contractor that carried out the time critical removal. Among these samples, one was collected at well #1, one was taken from the spring water storage tank, and four spring water samples were taken from four homes on the site (one sample from each home). DEQ visited the site in January 2015 and collected one sample from the tank containing spring water and another sample from well #1. Later that same year (September 2015), DEQ returned to the property to gather additional water samples. During this visit, they learned there was a second groundwater well (well #2) and so they collected one sample from this source. They also took two samples from well #1.[4] No spring water samples were collected in September 2015. The locations of the spring water storage tank and the groundwater wells are shown in Figure 4.

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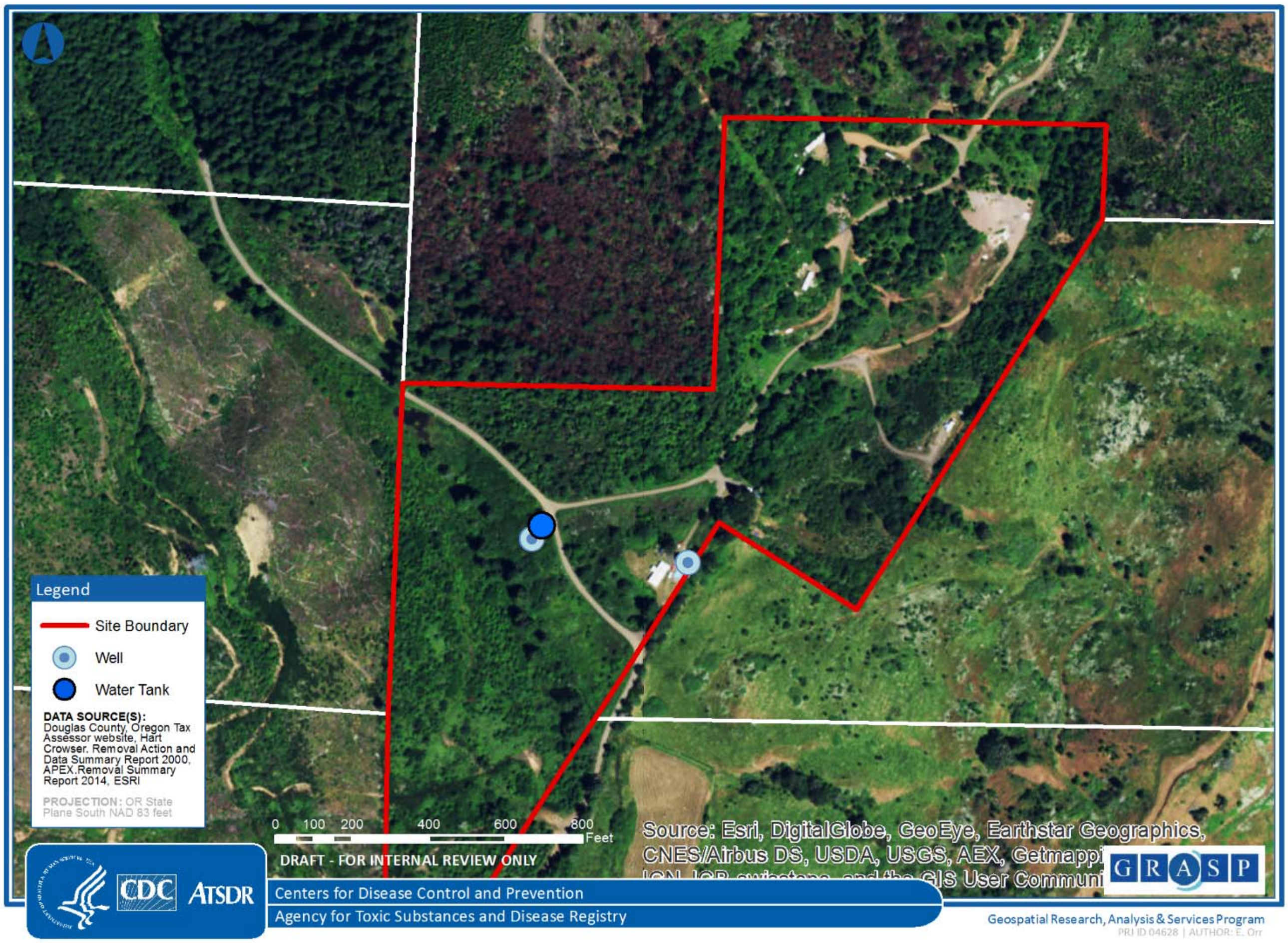
[1] Cancer Risk Evaluation Guides (CREGs) are estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10^{-6}) persons exposed during their lifetime. Concentrations greater than CREGs do not necessarily mean that people will develop cancer from exposures, but further evaluation is necessary to assess the risk of cancer.

[2] Environmental Media Evaluation Guides (EMEGs) are estimated contaminant concentrations that are not expected to result in adverse non-cancer health effects. EMEGs are available for children and adults. Like CREGs, concentrations greater than EMEGs do not necessarily mean that people will develop non-cancer health effects from exposures, but further evaluation is necessary to assess the risk of non-cancer health effects.

[3] Maximum Contaminant Levels (MCLs) are the highest chemical concentrations that are allowed in public drinking water systems. MCLs are not strictly health-based like ATSDR CVs. They are determined by a broader range of factors, like the availability of monitoring and treatment technologies, costs, and potential adverse health effects.

[4] DEQ collected two samples from well #1 on September 17, 2015; one sample was taken while draining the pressure tank and another sample was taken after the pressure tank was emptied.

Figure 4. Location of the spring water storage tank and groundwater wells on the former Bonanza Mine property in Sutherlin, Oregon.



The spring water samples were collected from a pipe that comes from the spring and pours into the top of the storage tank (B. Thoms, personal communication, January 20, 2015). The well water samples were collected from the pressure tank. All of the samples were analyzed for arsenic and mercury, except for the January and September 2015 samples; these samples were tested for only arsenic.

Note: Several samples from December 2013 and March 2014 had concentrations of arsenic that were below the detection limit. The EPA analytical method 6010B was used to identify the levels of arsenic in these samples. Using this method was problematic since its detection limit is 20 ppb, which is higher than the CREG (0.016 ppb), the chronic EMEG for a child (2.1 ppb), and the MCL (10 ppb) for arsenic. As a result, EHAP could not discern whether the arsenic concentrations in the December 2013 and March 2014 spring water samples were above or below these screening values. In order to better understand whether the arsenic levels, especially in the spring water, could harm the health of residents, more water samples were collected in January and September 2015 and more sensitive analytical methods (EPA Method 6020 and Standard Methods 3113B, respectively) were used.

Exposure Pathways

In order for a contaminant to harm human health, there must be a way for people to come into contact with the chemical. To determine if, and how, people could be exposed to water-related contamination at the Bonanza Mine site, EHAP conducted an exposure pathway analysis. An exposure pathway analysis describes how a chemical moves from its source and comes into physical contact with people. An exposure pathway has the following five elements:

1) A source where the chemicals originate from
2) A medium (e.g., air, soil, water) for chemicals to move through the environment to a place where people could come into contact with them
3) A location (point or area) where people come into contact with the chemicals
4) A route by which people have contact with the chemicals (e.g., breathing it, swallowing it, absorbing it through the skin)
5) A population that comes into contact with the chemicals

Depending on the extent to which these five elements are satisfied, an exposure pathway is considered completed, potential, or eliminated. In a completed exposure pathway, all five of these elements are present. A completed pathway means there is a strong likelihood that people have been, are currently being, or will be exposed to a chemical. However, it does not necessarily mean that the chemical is harming people's health. In a potential exposure pathway, it is unknown whether one or more of these elements is present. In an eliminated exposure pathway, one or more of the five elements is absent. This means that exposure to a chemical is unlikely.

EHAP identified one completed exposure pathway and one potential exposure pathway during our evaluation of the Bonanza Mine spring and well water. The pathways and elements are summarized in Table 1. We considered contact with spring water a completed exposure pathway since residents reported using it as their primary water source for drinking, cooking, bathing/showering, etc. We considered contact with well water a potential exposure pathway because we do not know for certain if people use the well water for domestic or other purposes (e.g., irrigation, swimming) at any time during the year.

Table 1. Exposure pathways.

Completed exposure pathway						
Pathway	Time	Contaminant Source	Media and Transport	Point of Exposure	Route of Exposure	Exposed Population
Contact with contaminated groundwater (spring)	Past Current Future	Historic operations from the former Bonanza Mine, a mercury mine and mill; naturally occurring arsenic	Groundwater	Spring located at the former Bonanza Mine site (1299 Bonanza Mine Road, Sutherlin, Oregon 97479)	Drinking or swallowing (Ingestion)	People that use the spring located at the former Bonanza Mine property (1299 Bonanza Mine Road, Sutherlin, Oregon 97479)
Contact with contaminated groundwater (private wells)	Past Current Future	Historic operations from the former Bonanza Mine, a mercury mine and mill; naturally occurring arsenic	Groundwater	Private wells located at the former Bonanza Mine site (1299 Bonanza Mine Road, Sutherlin, Oregon 97479)	Drinking or swallowing (Ingestion)	People that use the private wells located at the former Bonanza Mine property (1299 Bonanza Mine Road, Sutherlin, Oregon 97479)

Health Effects Evaluation

Environmental Guideline Comparison

When evaluating environmental data, EHAP compares the maximum concentration of each contaminant that is found in each medium to ATSDR comparison values (CVs). ATSDR CVs are screening tools to identify contaminants of potential concern at a site. The CVs represent the contaminant levels in soil, water, or air that people could be exposed to on a daily basis and not experience harmful health effects. CVs are not environmental clean-up levels, and chemicals that exceed their CVs will not necessarily pose health risks. In some instances, like when there is no ATSDR CV for a contaminant, we consider environmental screening values from other sources.

In this case, EHAP used three ATSDR CVs and the EPA MCL to screen the December 2013, March 2014, January 2015, and September 2015 water data. Specifically, we compared the levels of arsenic to the ATSDR CREG, the ATSDR chronic (lasting one year or longer) and acute (lasting up to 14 days) EMEG for a child, and the EPA MCL (drinking water standard).[5] For mercury, we compared the concentrations to *only* the EPA MCL.[6] More information about these screening values is provided in the text box to the right and Appendix D.

What is an ATSDR CREG?
Cancer Risk Evaluation Guides (CREGs) are estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10^{-6}) persons exposed during their lifetime. Concentrations greater than CREGs do not necessarily mean that people will develop cancer from exposures, but further evaluation is necessary to assess the risk of cancer.

What is an ATSDR EMEG?
Environmental Media Evaluation Guides (EMEGs) are estimated contaminant concentrations that are not expected to result in adverse non-cancer health effects. EMEGs are available for children and adults. Like CREGs, concentrations greater than EMEGs do not necessarily mean that people will develop non-cancer health effects from exposures, but further evaluation is necessary to assess the risk of non-cancer health effects.

What is an EPA MCL?
Maximum Contaminant Levels (MCLs) are the highest chemical concentrations that are allowed in public drinking water systems. MCLs are not strictly health-based like ATSDR CVs. They are determined by a broader range of factors, like the availability of monitoring and treatment technologies, costs, and potential adverse health effects.

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[5] EHAP compared the levels of arsenic to the ATSDR CREG (0.016 ppb), the ATSDR chronic EMEG for a child (2.1 ppb), the ATSDR acute EMEG for a child (35 ppb), and the EPA MCL (10 ppb). We used this screening value to evaluate arsenic in the spring and well water because it is the drinking water standard. In addition, EHAP is housed under the same agency as the program that enforces this standard in Oregon and our evaluation of drinking water at the former Bonanza Mine property should not result in conflicting messages from our agency about its safety.

[6] Like arsenic, EHAP compared the levels of mercury in the spring and well water to the EPA MCL since EHAP is housed under the same agency as the program that enforces the drinking water standard in Oregon and our evaluation of drinking water at the former Bonanza Mine property should not result in conflicting messages from our agency about its safety. Unlike arsenic, the EPA MCL was the *only* value that we used to screen mercury in the spring and well water because it is lower than the ATSDR CVs that are available for this contaminant; the EPA MCL (for inorganic mercury) is 2 ppb whereas the ATSDR chronic Reference Dose Media Evaluation Guide (RMEG) for a child (for mercuric chloride) is 2.1 ppb and the ATSDR acute EMEG for a child (for mercuric chloride) is 49 ppb.

When the highest contaminant level at the site is below or equal to the environmental screening value (e.g., ATSDR's CVs, EPA's MCL, etc.), the chemical does not require further evaluation since it is not expected to harm human health. If the highest contaminant level is above the environmental screening value, it requires further analysis to evaluate the likelihood of harmful health effects.

Spring water

Samples were collected from the spring and four homes that were using the spring water in December 2013, March 2014, and January 2015; spring water samples were not collected in September 2015. All of the samples were analyzed for arsenic and mercury except for the January 2015 sample; this sample was analyzed for only arsenic.

All of the December 2013 and March 2014 samples had arsenic concentrations that were below the detection limit (Table 2). However, these samples were analyzed using an EPA analytical method that had a detection limit of 20 ppb, which is higher than the CREG (0.016 ppb), the chronic EMEG for a child (2.1 ppb), and the MCL (10 ppb) for arsenic. As a result, it is unknown whether the actual concentrations of arsenic are higher or lower than any of these screening values. A more sensitive analytical method was used to identify the level of arsenic in the January 2015 spring water sample; the detection limit for this method is 0.25 ppb, which is also higher than the CREG. This sample result showed the contaminant was not detected. If this sample result is representative of typical values, EHAP does not expect arsenic in the spring water to harm people's health.

The highest level of mercury that was detected among the spring samples was 0.28 ppb (collected December 2013; Table 2). This concentration is below the MCL of 2 ppb, and therefore, EHAP does not expect mercury in the spring water to harm people's health.

Refer to Table 2 for more information about the data and the environmental screening values that EHAP used for this evaluation.

Table 2. Spring water samples from December 16, 2013, March 12, 2014, and January 14, 2015.

	Sample date: December 16, 2013					
	Arsenic			Mercury		
Sample location	Level (ppb)	Comparison value ¥ (ppb)	Contaminant of Potential Concern?	Level (ppb)	Comparison value ǂ (ppb)	Contaminant of Potential Concern?
Spring	ND (<20)‡	0.016/2.1/10/35	Unknown/No †	0.28	2	No

	Sample date: March 12, 2014					
	Arsenic			Mercury		
Sample location	Level (ppb)	Comparison value ¥ (ppb)	Contaminant of Potential Concern?	Level (ppb)	Comparison value ǂ (ppb)	Contaminant of Potential Concern?
Spring	ND (<20)‡	0.016/2.1/10/35	Unknown/No †	ND (<0.20)§	2	No
Location 1 (Spring)	ND (<20)‡	0.016/2.1/10/35	Unknown/No †	ND (<0.20)§	2	No
Location 2 (Spring)	ND (<20)‡	0.016/2.1/10/35	Unknown/No †	ND (<0.20)§	2	No
Location 3 (Spring)	ND (<20)‡	0.016/2.1/10/35	Unknown/No †	ND (<0.20)§	2	No
Location 4 (Spring)	ND (<20)‡	0.016/2.1/10/35	Unknown/No †	ND (<0.20)§	2	No

	Sample date: January 14, 2015					
	Arsenic			Mercury		
Sample location	Level (ppb)	Comparison value ¥ (ppb)	Contaminant of Potential Concern?	Level (ppb)	Comparison value ǂ (ppb)	Contaminant of Potential Concern?
Spring	ND (<0.25)*	0.016/2.1/10/35	Unknown/No €	-	-	-

Abbreviations: ppb = parts per billion (also expressed as µg/L or microgram per liter); ND = not detected; < = less than

¥ The following sources were used to screen arsenic: 1) the ATSDR CREG (0.016 ppb), 2) the ATSDR chronic EMEG for a child (2.1 ppb), 3) the EPA MCL (10 ppb), and 4) the ATSDR acute EMEG for a child (35 ppb).

ǂ The EPA MCL (for inorganic mercury) was used to screen mercury.

‡ The detection limit for arsenic is 20 ppb; this detection limit is based on EPA analytical method 6010B.

* The detection limit for arsenic is 0.25 ppb; this detection limit is based on EPA analytical method 6020.

§ The detection limit for mercury is 0.20 ppb.

† It is unknown whether arsenic is a contaminant of potential concern when the detection limit for this sample result (20 ppb) is compared to the ATSDR CREG (0.016 ppb), the ATSDR chronic EMEG for a child (2.1 ppb), and the EPA MCL (10 ppb). However, arsenic is not a contaminant of potential concern when the detection limit for this sample result (20 ppb) is compared to the ATSDR acute EMEG for a child (35 ppb).

€ It is unknown whether arsenic is a contaminant of potential concern when the detection limit for this sample result (0.25 ppb) is compared to the ATSDR CREG (0.016 ppb). However, arsenic is not a contaminant of potential concern when the detection limit for this sample result (0.25 ppb) is compared to the ATSDR chronic EMEG for a child (2.1 ppb), the EPA MCL (10 ppb), and the ATSDR acute EMEG for a child (35 ppb).

Water from well #1

A total of five water samples were collected from well #1 in December 2013 (one sample), March 2014 (one sample), January 2015 (one sample), and September 2015 (two samples). The December 2013 and March 2014 samples were tested for arsenic and mercury and the January and September 2015 samples were tested for only arsenic.

Note: The concentration of arsenic in the January 2015 sample was 4.5 ppb. We excluded this result from our evaluation since it is not reliable. After this sample was collected and analyzed, we discovered that well #1 has two valves; one valve is for spring water and the other valve is for groundwater from well #1. These valves can be turned on and off to control which water source is used. When the January 2015 water sample was collected from well #1, the valve for spring water was open and the valve for well water was closed. As a result, DEQ collected spring water (with some residual well water from the pipes) rather than pure well water.

Among the four samples that EHAP evaluated, the highest concentration of arsenic was 630 ppb (Table 3). Since this result exceeded the CREG (0.016 ppb), the chronic and acute EMEG for a child (2.1 ppb and 35 ppb, respectively), and the MCL (10 ppb) for arsenic, EHAP further evaluated this contaminant in the well.

Among the two well water samples that were tested for mercury, both had levels below the detection limit of 0.20 ppb, which is less than the MCL of 2 ppb (Table 3). Based on these data, we do not expect mercury in the well to harm people's health.

Table 3. Groundwater samples from well #1 from December 16, 2013, March 12, 2014, and September 17, 2015.

	Arsenic			Mercury		
Sample date	Level (ppb)	Comparison value ¥ (ppb)	Contaminant of Potential Concern?	Level (ppb)	Comparison value ‡ (ppb)	Contaminant of Potential Concern?
December 16, 2013	**110**	**0.016/2.1/10/35**	**Yes**	ND (<0.20)§	2	No
March 12, 2014	**630 ***	**0.016/2.1/10/35**	**Yes**	ND (<0.20)§	2	No
September 17, 2015	**95 †**	**0.016/2.1/10/35**	**Yes**	-	-	-
	120 €	**0.016/2.1/10/35**	**Yes**	-	-	-

Abbreviations: ppb = parts per billion (also expressed as µg/L or microgram per liter); ND = not detected; < = less than

¥ The following sources were used to screen arsenic: 1) the ATSDR CREG (0.016 ppb), 2) the ATSDR chronic EMEG for a child (2.1 ppb), 3) the EPA MCL (10 ppb), and 4) the ATSDR acute EMEG for a child (35 ppb).

‡ The EPA MCL (for inorganic mercury) was used to screen mercury.

* This sample result was flagged with a B qualifier. This qualifier means arsenic was found in the associated method blank as well as in the sample. However, the concentration of arsenic in the sample is more than 10 times the blank concentration.

† This sample was collected while the pressure tank for well #1 was draining.

€ This sample was collected after the pressure tank for well #1 was emptied.

§ The detection limit for mercury is 0.20 ppb.

Cells with bolded text and red shading denote when a contaminant level is above the ATSDR CREG, the ATSDR chronic and acute EMEG for a child, and the EPA MCL.

Water from well #2

Only one sample was collected from well #2 during the period of our investigation and it was taken in September 2015.[7] The sample was tested for only arsenic and it contained 205 ppb of this chemical (Table 4). Like well #1, EHAP further evaluated arsenic in well #2 since the concentration exceeded the CREG (0.016 ppb), the chronic and acute EMEG for a child (2.1 ppb and 35 ppb, respectively), and the MCL (10 ppb).

Table 4. Groundwater sample from well #2 from September 17, 2015.

	Arsenic		
Sample date	Level (ppb)	Comparison value ¥ (ppb)	Contaminant of Potential Concern?
September 17, 2015	**205**	**0.016/2.1/10/35**	**Yes**

Abbreviations: ppb = parts per billion (also expressed as µg/L or microgram per liter)

¥ The following sources were used to screen arsenic: 1) the ATSDR CREG (0.016 ppb), 2) the ATSDR chronic EMEG for a child (2.1 ppb), 3) the EPA MCL (10 ppb), and 4) the ATSDR acute EMEG for a child (35 ppb).

Cells with bolded text and red shading denote when a contaminant level is above the ATSDR CREG, the ATSDR chronic and acute EMEG for a child, and the EPA MCL.

Evaluation of non-cancer and cancer risk

Residents at the former Bonanza Mine property report that they use the spring for their primary source of domestic water, which showed low levels of arsenic and mercury. However, a past investigation states that residents reportedly use well #1 for gardening (9). EHAP also received anecdotal information that residents may use the wells for domestic purposes during times when the spring runs dry. While it's not completely certain if and how residents use the wells, EHAP decided to further evaluate the health risks associated with drinking the water, because the arsenic concentrations in the wells are much higher than the MCL (10 ppb) and arsenic is a toxic metal that can cause cancer and other health problems.

EHAP calculated the risk of developing cancer and non-cancer health effects (health problems other than cancer) from drinking arsenic-contaminated water from wells #1 and #2 on the property. We calculated these risk estimates for several age groups (e.g., birth to <1 year, 1 to <2 years, 2 to <6 years, 6 to <11 years, 11 to <16 years, 16 to <21years, and ≥21 years), since a multi-generational family that has included children, teenagers, young adults, and elderly persons has lived on the property since at least 1990. For every age group that we evaluated, we calculated average (central tendency exposure or CTE) and high (reasonable maximum exposure or RME) water intake scenarios.

Since EHAP is not certain if and how people use the wells, it is difficult to estimate the health risks posed from drinking the water. However, we used the available data and made

[7] Despite years of involvement at the site, EHAP and DEQ discovered there was a second groundwater well (well #2) on the property on September 17, 2015. This information was revealed during a follow-up meeting with the property owner to discuss past spring and well water results and provide health education on the range of potential health effects that children and adults can experience from drinking arsenic-contaminated water.

conservative assumptions about people's exposure to understand the health risks. For instance, EHAP assumed people would be exposed to the most heavily contaminated water from wells #1 and #2 (630 and 205 ppb, respectively). We also assumed people might drink the arsenic-contaminated water for up to 14 days per year during periods when the spring runs dry. Refer to Appendix C for more information about all the assumptions and values used to calculate the non-cancer and cancer risks.

a) Non-cancer risk from acute exposure to arsenic
EHAP evaluated the non-cancer risks associated with a one-time, acute exposure. An acute exposure is defined by ATSDR as contact with a chemical that occurs once or for only a short period of time (less than 14 days). For this non-cancer assessment, we defined acute exposure as drinking the well water for 14 days.

To determine the non-cancer risk of acute arsenic exposure, we calculated a Hazard Quotient (HQ). An HQ is a way to quantify non-cancer risk where an exposure dose is compared to a health guideline (the amount of a chemical that is not expected to harm health). When an HQ is less than or equal to 1.0 (the exposure dose is lower than or equal to the health guideline), it is unlikely that non-cancer health effects will occur. If it is greater than 1.0 (the dose is higher than the health guideline), an exposed person could experience adverse health effects that are not cancer.

For this analysis, all of the HQs for well #1 and most of the HQs for well #2 were higher than 1.0, which means the estimated doses for these wells exceeded the health guideline (Minimal Risk Level [MRL] for acute oral exposure) of 0.005 mg/kg/day (Table 5). Additionally, the HQs were highest among young children (birth to <1 years, 1 to <2 years, 2 to <6 years, and 6 to <11 years) and lowest among older children (11 to <16 years and 16 to <21 years). The doses and HQs for young children are higher than those of older children and adults because young children drink more water in relationship to their size (body weight) than other age groups.

What is an ATSDR MRL?
Minimal Risk Levels (MRLs) are estimates of daily human exposure to a hazardous substance. They represent the amount of a substance that is *not* expected to cause noncancer health effects. Exposure doses that are greater than MRLs do not necessarily mean that people will experience the associated adverse effects.

To better understand the potential risk to residents, EHAP also compared the estimated exposure doses that exceeded the MRL to the dose that the health guideline is based on. In this instance, the health guideline is based on the lowest observed adverse effect level (LOAEL) of 0.05 mg/kg/day (2) (13). A LOAEL is the lowest dose of a chemical that has been tested and shown to cause adverse health effects in either people or animals. This LOAEL is based on a study of 220 people that consumed approximately 0.05 mg/kg/day of arsenic-contaminated soy sauce for 2-3 weeks. The initial health effects associated with this LOAEL included swelling of the face (generally the eyelids); nausea, vomiting, and diarrhea; and upper respiratory symptoms (2) (13). Skin lesions (overgrowths of skin on the palms of the hands, soles of the feet, and torso; the formation of corns or warts; and discoloration of the skin) and neuropathy developed later (2) (13). Other health effects included mild anemia and leukopenia, hepatic dysfunction (swollen and tender liver), mild degenerative liver lesions, abnormal electrocardiogram, and ocular lesions (2) (13).

Among the exposure doses that exceeded the MRL, all of them are below the LOAEL, except for one; the dose we calculated for children from birth to <1 year who are exposed to water from well #1 and have a high water intake (0.090 mg/kg/day) is above the LOAEL (Table 5).

While most of the estimated doses are below the LOAEL, people who drink well water from the former Bonanza Mine property for 14 days could experience non-cancer health effects. This is because the study that the health guideline was based on did not report a no observed adverse effect level (NOAEL). A NOAEL is the highest dose of a chemical that has been tested and has not shown adverse health effects in either people or animals. In addition, the health guideline is based on one uncertainty factor, which is for using the LOAEL, and the health effects observed at the LOAEL in the study were severe.

Note: EHAP has not heard reports from either the property owner or residents of health effects attributed to drinking arsenic-contaminated water associated the LOAEL.

More information about the assumptions EHAP made, the values we used, and steps we took to calculate non-cancer dose and risk estimates for acute exposure can be found in Appendix C.

Table 5. Non-cancer, acute exposure dose and Hazard Quotient calculations for wells #1 and #2 ¥.

Age group	Well #1				Well #2			
	Exposure dose (mg/kg/day)		Hazard quotient		Exposure dose (mg/kg/day)		Hazard quotient	
	Average water intake (CTE)	High water intake (RME)	Average water intake (CTE)	High water intake (RME)	Average water intake (CTE)	High water intake (RME)	Average water intake (CTE)	High water intake (RME)
Birth to <1 year	0.041	0.090	8.1	18.0	0.013	0.029	2.6	5.9
1 to <2 years	0.017	0.049	3.4	9.9	0.0055	0.016	1.1	3.2
2 to <6 years	0.014	0.035	2.7	7.1	0.0044	0.012	0.9	2.3
6 to <11 years	0.010	0.028	2.0	5.6	0.0033	0.0091	0.7	1.8
11 to <16 years	0.0071	0.022	1.4	4.4	0.0023	0.0071	0.5	1.4
16 to <21 years	0.0068	0.022	1.4	4.3	0.0022	0.0070	0.4	1.4
≥21 years	0.0097	0.024	1.9	4.9	0.0031	0.0079	0.6	1.6

Abbreviations: < = less than; ≥ = greater or equal to; mg/kg/day = milligram per kilogram per day; CTE = central tendency exposure; RME = reasonable maximum exposure

¥ See Appendix C for more information about the assumptions EHAP made, the values we used, and steps we took to calculate non-cancer dose and risk estimates.

b) Cancer risk of arsenic

EHAP estimated people's risk of developing cancer from drinking arsenic-contaminated water. To estimate cancer risk, we used four different exposure scenarios. We assumed people would drink the well water for 14 days (2 weeks) per year for 12 or 33 years. We also assumed residents were exposed from birth (birth to 12 years and birth to 33 years) or as adults (21-33 years and 21 to 54 years).

The lifetime cancer risks from a 12- or 33-year exposure to arsenic through ingestion of well water are presented in Table 6. The numbers show that cancer risk is greater among people with a higher than average water intake. Risk also increases as the exposure duration gets longer and when people are exposed from birth as compared to those that are exposed only as adults.

The cancer that is most often associated with ingesting arsenic is skin cancer and there is growing evidence that chronic oral exposure can cause bladder and lung cancer (2). Based on our analysis of well #1, the highest cancer risk number is approximately 30 in 10,000 (for birth to 33 years and high water intake) and the lowest risk number is approximately 3 in 10,000 (for 21-33 years and average water intake)(Table 6). For people using well #2, the highest cancer risk value is approximately 8 in 10,000 (for birth to 33 years and high water intake) and the lowest risk value is approximately 1 in 10,000 (for 21-33 years and average water intake)(Table 6). All of the cancer risk numbers presented in Table 6 show that arsenic exposure from drinking water from wells #1 and #2 poses a public health risk.

These values do not predict if cancer will occur. Rather, they are probabilities that represent the number of additional cancer cases above the population background lifetime risk of 4,000 cases per 10,000 people. They are generated based on the assumption that everyone in the population receives the same exposure for a certain period of time.

Refer to Appendix C for additional information about the assumptions EHAP made, the values we used, and steps we took to calculate cancer risk.

Table 6. Cancer dose and risk calculations for wells #1 and #2 ¥.

Exposure duration	Exposure period	Cancer risk from well #1‡		Cancer risk from well #2‡	
		Average water intake (CTE)	High water intake (RME)	Average water intake (CTE)	High water intake (RME)
12 years	Birth to 12 years	5 in 10,000	10 in 10,000	2 in 10,000	4 in 10,000
	21-33 years	3 in 10,000	8 in 10,000	1 in 10,000	3 in 10,000
33 years	Birth to 33 years	10 in 10,000	30 in 10,000	3 in 10,000	8 in 10,000
	21-54 years	9 in 10,000	20 in 10,000	3 in 10,000	7 in 10,000

Abbreviations: CTE = central tendency exposure; RME = reasonable maximum exposure

¥ See Appendix C for more information about the assumptions EHAP made, the values we used, and steps we took to calculate cancer dose and risk estimates.

‡ Red bars show the degree of cancer risk among the values presented in the table. Long bars mean there is a higher risk of cancer where short bars mean there is a lower risk of cancer as compared to the values in this table.

Well water and other uses

While we do not recommend someone drink, cook, or prepare beverages/food with water that has arsenic concentrations greater than 10 ppb, people can use water containing less than 500 ppb arsenic for other purposes. According to guidance from the Oregon Health Authority's Public Health Division, water that contains less than 100 ppb of arsenic can be used for watering gardens (1). They also say that activities like bathing/showering, washing dishes, and doing laundry can be done with water containing less than 500 ppb arsenic (1).[8] However, water that contains 500 ppb or more of arsenic should not be used for any purpose. (Refer to Table 7 for more information about using water with arsenic.)

Table 7. Possible increased health risk from water use by arsenic level (1).

Water use categories	**Arsenic levels** 0 to <10 ppb	10 to <100 ppb	100 to <500 ppb	500 ppb or above
Category 1 Drinking, mixing into beverages, cooking, and washing fruits and vegetables	Low Risk	High Risk	High Risk	High Risk
Category 2 Watering gardens	Low Risk	Low Risk	High Risk	High Risk
Category 3 Bathing/showering, washing dishes, and doing laundry	Low Risk	Low Risk	Low Risk	High Risk

Abbreviations: < = less than; ppb = parts per billion (also expressed as µg/L or microgram per liter)
Cells with blue shading indicate when there is a low risk and cells with red shading indicate when there is a high risk.

EHAP evaluated the risk associated with using the well water from the Bonanza Mine property for other purposes than drinking and we found two things:

- Water from well #1 is unsuitable for <u>any</u> purpose.
  The arsenic level that we evaluated in well #1 was 630 ppb. This concentration is higher than all of the range levels for potential use (Table 7). Therefore, there is a high risk of someone experiencing adverse health effects if this water is used. This includes cooking,

[8] The most important route of exposure for people bathing/showering with arsenic-contaminated water is through incidental ingestion since there is little exposure from this pathway through dermal absorption and volatilization.

washing fruits and vegetables, irrigating, bathing/showering, washing dishes, and doing laundry.

- Water from well #2 is unsuitable for some purposes.
  Well #2 contained 205 ppb arsenic. This concentration is higher than some of the arsenic range levels for potential use (0 to <10 and 10 to <100 ppb; Table 7). As a result, we do not recommend well #2 be used for cooking, washing fruits and vegetables, and watering gardens. However, this level is below 500 ppb, and so there is a low risk associated with using this water for bathing/showering, washing dishes, and doing laundry.

Uncertainties and Data Gaps

There are some data gaps with the Bonanza Mine spring and well water that limit EHAP's ability to evaluate the health risks associated with drinking water from these sources. First, EHAP's assessment and conclusions are based exclusively on two contaminants, arsenic and mercury, in the spring and well water at the Bonanza Mine site. Springs are generally fed by shallow groundwater, and therefore they are more susceptible to contamination from microorganisms, nitrates, and other contaminants from upland sources. As a result, EHAP recommends the spring water and well water be tested for other contaminants.

Similarly, our evaluation of the water from well #2 includes only arsenic and it is unknown if mercury is present at levels that could harm human health. Therefore, we recommend well #2 be tested for this contaminant.

Second, to be protective of health, EHAP used the highest arsenic concentration among the December 2013, March 2014, and September 2015 well #1 water samples to calculate exposure doses and risk estimates. However, it is unknown whether this concentration (630 ppb) is representative of what people could actually be exposed to. The arsenic levels among these four samples fluctuated a great deal; the arsenic concentrations ranged between 95 and 630 ppb. To better understand whether the fluctuations are seasonal or the result of something else, additional water samples from well #1 would be needed.

Third, EHAP evaluated one sample from well #2; this sample is the only known sample collected from well #2 since our involvement at the Bonanza Mine site. A single sample may not represent the contaminant levels that people are exposed to. For instance, contaminant concentrations can fluctuate, which is something that we observed in reviewing the arsenic levels from the well #1. To better understand if and when arsenic levels fluctuate, EHAP recommends additional water samples be taken from well #2.

Fourth, it is not possible for EHAP to know exactly how much water each child and adult at the site drinks every day. In the absence of this specific information, we used default values developed by EPA that are based on studies that measure how much water people drink. EHAP used the average amount and high amount of water that children and adults drink assuming these values would be representative of people at the site. Refer to Appendix C for more information about these and other assumptions made in calculating dose and risk estimates.

Children's Health

EHAP and ATSDR recognize that infants and children may be more vulnerable than adults to exposures with contaminated air, water, soil, or food. This vulnerability is a result of the following factors:

- Children are smaller, resulting in higher doses of chemical exposure per body weight
- Children are more likely to mouth soil and contaminated objects and ingest more water and soil compared to adults
- The developing body systems of children can sustain permanent damage if toxic exposures occur during critical stages of growth

Because children depend on adults for risk identification and management decisions, EHAP and ATSDR are committed to evaluating their special interests at and around the Bonanza Mine site. It is important to note that the health-based screening values EHAP used for water were derived from health guidelines that incorporate a high levels of protectiveness for children and other sensitive individuals.

In this HC, EHAP evaluated children and adults' risk of cancer and non-cancer health effects from drinking arsenic-contaminated well water from the Bonanza Mine property. EHAP found that people exposed to this water from birth had a greater risk of cancer than people exposed only as adults (21 years or older) (Table 6). We also determined that young children (birth to <11 years) had the highest risk of experiencing non-cancer health effects from an acute exposure (Table 5).

Children are at risk of experiencing the same adverse health effects as adults as well as some other health effects. A few studies have reported that children who are chronically exposed to doses of arsenic ranging between 0.0017 and 0.005 mg/kg/day did poorer than other children on neurobehavioral tests including intellectual performance (2) (14) (15) (16). This suggests that children may be more susceptible than adults to other health effects, like learning disabilities and declines in IQ, if arsenic exposure occurs during critical stages of growth and development.

Conclusions

EHAP reached three conclusions in this HC:

Conclusion 1: *EHAP concludes that the arsenic concentrations in the <u>water from well #1</u> at the former Bonanza Mine property could harm the health of children and adults.*

Water from well #1 at the former Bonanza Mine property is contaminated with arsenic at levels of health concern. The maximum arsenic concentration from this well (630 parts per billion [ppb]) is above ATSDR's oral health-based comparison values (0.016, 2.1, and 35 ppb [cancer, chronic, and acute screening levels, respectively]) and EPA's Maximum Contaminant Level (MCL) (10 ppb) for drinking water. All of the non-cancer, acute exposure dose estimates are higher than ATSDR's Minimal Risk Level for acute oral exposure (0.005 mg/kg/day), which indicates there may be a risk of experiencing adverse health effects from drinking this water for even a period of 14 days. The cancer risk estimates show that exposure to this level of arsenic could pose an increased risk of cancer to children and adults who regularly drink, cook, or prepare beverages/food with this well water.

Further, because the level of arsenic is higher than 500 ppb, this water is unsuitable for any other purpose. According to guidance from the Oregon Health Authority's Public Health Division, this includes watering gardens, bathing/showering, washing dishes, or doing laundry (1).

The water samples from well #1 were tested for only mercury and arsenic, and we could not draw conclusions about nitrates, bacteria, or other compounds that could potentially be present in this water.

Conclusion 2: *EHAP concludes that the arsenic concentrations in the <u>water from well #2</u> at the former Bonanza Mine property could harm the health of children and adults if this water is used for drinking, cooking, preparing beverages/food, or watering gardens.*

EHAP evaluated a single water sample from well #2 with an arsenic concentration of 205 ppb. Like well #1, exposure to this level of arsenic may pose a risk of cancer and/or non-cancer health effects to children and adults that use the water for drinking, cooking, preparing beverages/food, or watering gardens (1) (2). In contrast to well #1, there may be a low risk of adverse health effects from bathing/showering, washing dishes, and doing laundry with well #2 water (1). However, EHAP cannot be certain of the risks associated with any of these uses without more data on this well. Therefore, it would be prudent for people to avoid, if possible, using water from well #2 until more data are collected.

EHAP could not draw conclusions about mercury, nitrates, bacteria, or other compounds that could potentially be present in the well #2 water since the samples from this well were analyzed for only arsenic.

Conclusion 3: *EHAP concludes that the mercury and arsenic concentrations in the <u>spring water</u> at the former Bonanza Mine property are not expected to harm the health of children and adults.*

First, the levels of mercury in the spring water samples were below EPA's MCL (2 ppb). Second, arsenic was not detected in any of the spring water samples.

The spring water samples were analyzed for only mercury and arsenic, and so we could not draw conclusions about nitrates, bacteria, or other compounds.

Recommendations

Based on EHAP's review of the December 2013, March 2014, January 2015, and September 2015 spring and well water data, we recommend the following actions to protect the health of children and adults that live at or visit the former Bonanza Mine site:

- People are strongly advised not to use water from well #1 for drinking, cooking, preparing beverages/food, or any other purpose.
- People are discouraged from using well #2 for drinking, cooking, preparing beverages/food, or watering gardens. We also advise people to avoid, if possible, using well #2 water for bathing/showering, washing dishes, and doing laundry.
- Because people may use well water from the former Bonanza Mine property, EHAP recommends water from both wells undergo additional arsenic testing. The levels of arsenic from past well #1 water samples vary a great deal and the well #2 water was tested only one time for arsenic. These data provide an incomplete picture of arsenic levels in the well water on the property. Collecting more data could help better discern the risk to people. Specifically, these new data would help determine whether there are possible safe uses of the well water.
- We recommend well #2 water be tested for mercury. This well was tested for only arsenic and it is unknown if mercury is present at levels that could harm human health.
- We recommend the spring water and well water be tested for other contaminants, especially bacteria and nitrates, since both are susceptible to contamination from microorganisms, nitrates, and other contaminants from upland sources.

Public Health Action Plan

A Public Health Action Plan describes the specific actions EHAP has taken and will take to implement the recommendations outlined in this report, with the goal of preventing and reducing people's exposure to hazardous substances in the environment. EHAP has carried out or will carry out the actions listed below in collaboration with community members and partner agencies.

Completed Public Health Actions

To date, EHAP has taken the following actions:

- Worked in collaboration with DEQ to obtain and analyze the December 2013, March 2014, January 2015, and September 2015 spring and well water data
- Recommended additional sampling be conducted, after reviewing the December 2013, March 2014, and January 2015 data

Planned Public Health Actions

EHAP will take the following public health actions:

- Release this HC and share it with the property owner and other people living at the former Bonanza Mine site as well as with EPA, DEQ, the Oregon Department of Human

Services, the Douglas County Health Department, the Northwest Pediatric Environmental Health Specialty Unit, and the Oregon Poison Center

- Communicate with the property owner and others living at the site in a manner that ensures the findings and recommendations are clearly understood
- Be available to answer questions about the health risks associated with using the arsenic-contaminated well water and how to prevent exposure
- Review additional water data from the site, if they become available

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Report Preparation

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Authors

Lauren Karam, MPH
Program Coordinator/Health Assessor
Environmental Health Assessment Program

Julie Early Sifuentes, MS
Principal Investigator/Program Manager
Environmental Health Assessment Program

David G. Farrer, PhD
Public Health Toxicologist
Environmental Public Health

Renee Hackenmiller-Paradis, MPH, PhD
Section Manager
Environmental Public Health

Karen Bishop, MPH
Health Educator
Environmental Health Assessment Program

Other State Agency Reviewers

Tara Chetock, MHA
Program Coordinator
Domestic Well Safety Program
Oregon Health Authority, Public Health Division

Bryn Thoms, RG
Western Region Hydrogeologist
Oregon Department of Environmental Quality

Susan Turnblom, MS
Western Region Toxicologist
Oregon Department of Environmental Quality

ATSDR Reviewers

Audra Henry, MS
Technical Project Officer

Trent LeCoultre, MSEH, REHS
Acting Cooperative Agreement Coordinator

Alan Parham, MPH, REHS
Technical Project Officer

Tina Forrester, PhD
Acting Division Associate Director for Science

Michelle Watters, MD, PhD, MPH
Acting Western Branch Associate Director for Science

Ileana Arias, PhD
Division Director

Appendix A. Additional background information on the former Bonanza Mine site.

This appendix provides additional background information on the former Bonanza Mine site. It provides a brief history about the former mine, outlines past clean-up investigations and actions conducted by EPA and DEQ, and summarizes activities conducted by EHAP.

Site History

Bonanza Mine operated between 1865 and 1870 and mining started at the Glory Hole. A small Scott furnace was erected to process the ore in 1870 (9). Over the next several decades, the mine underwent additional development and expanded. It is reported that the mine produced 15 flasks of mercury in 1887; this is the first and only record of production before 1937 (9). By 1934, the mine expanded to five adits and production increased to 36—40 tons per day three years later (9). In 1939, the main (north) ore body was discovered and the mill produced 5,733 flasks of mercury the following year, which made it the second largest production in the United States (9). By the end of 1944, the mine became the all-time largest producer of mercury in Oregon (9).

Other than some short closures from 1949 to 1951 and in 1954, the mine operated continuously until October 1960 when minable reserves were exhausted and the mine closed (9). By the time of its closure, the mine had 12 adits with 17,500 feet of tunnels and shafts on 12 levels, and total recorded production was 39,540 flasks (or 3,005,040 pounds) of mercury (9).

Past Clean-up Investigations and Actions by EPA and DEQ

In order to understand the extent of contamination at the Bonanza Mine site and to address the public health and environmental risks associated with this contamination, several investigations and actions were taken. These investigations and actions extend beyond the mine site itself, to Red Rock Road, a 17-mile railroad grade that runs through part of Sutherlin and was constructed of mine tailings from Bonanza Mine. Table 8 summarizes the major environmental investigations and actions carried out by EPA and DEQ at the site.

Table 8. Summary of EPA and DEQ environmental investigations and actions at the former Bonanza Mine site.

Year	Investigation	Purpose	Major findings and outcomes
May 1999	EPA Preliminary Assessment of Red Rock Road	Determine whether Red Rock Road poses a risk to human health and the environment; determine whether contaminants are being released into the environment; and determine whether Red Rock Road should be placed on the National Priorities List	An estimated 316,000 cubic yards of tailings were used in the construction of Red Rock Road. The Bonanza Mine property was identified as the potential source of the contaminated tailings. The preliminary assessment recommended additional investigation (17).
May 2000	EPA Site Inspection	Collect soil samples from Red Rock Road and the Bonanza Mine property as well as sediment samples from surrounding watersheds to determine whether contaminants are present at concentrations that could pose a risk to human health and the environment	Samples collected from Bonanza Mine showed high concentrations of mercury (74 – 12,000 mg/kg), arsenic (71.3 – 246 mg/kg), and lead (6.5 – 1,240 mg/kg) in surface soils at the former mill site, and arsenic and mercury in the mine tailings pile, waste rock pile, and roadway soil (10).
September 2000	DEQ Removal Assessment and Removal Action	Gather additional data from the Bonanza Mine property, with a focus on the former mill area, to delineate the extent of metal contamination and remove highly contaminated soil to reduce the risk to human health and the environment	Prior to the removal, 31 samples were collected from surface and near-surface soil at the former mill site. The results indicated the following contaminant levels (9): • Mercury 67.7—12,000 mg/kg • Arsenic 20.3—314 mg/kg • Lead <70 mg/kg, except for one sample (1,040 mg/kg) Approximately 240 cubic yards of mercury-contaminated soil was removed from the former mill site and transported it to a lined and covered, temporary storage cell located near the base of the waste rock pile (9). In addition to the samples collected at the former mill site, soil samples were collected from other areas of the property (surrounding hillside, tailings pile, waste rock pile, roads, driveways, and cell base) and water samples were collected from an on-site well (well #1) and an

Year	Investigation	Purpose	Major findings and outcomes
			aboveground storage tank that holds spring water. The soil concentrations of mercury in these samples were between 1.53 and 220 mg/kg, except for four samples that exceeded the cleanup goal of 230 mg/kg. The arsenic concentrations in these samples ranged from 11.2—246 mg/kg. Among the two water samples that were collected, well #1 had elevated levels of arsenic (53.6 ppb) (9).
December 2013	DEQ Soil Assessment	Collect soil samples from the Bonanza Mine property to identify areas where contaminant concentrations in soil are below residential screening values so a "clean" parcel of the property can be created for residential use	DEQ analyzed 118 soil samples with X-ray Fluorescence (XRF) and collected nine discrete samples for off-site lab analysis. The highest concentrations of mercury and arsenic were 1,200 and 471 mg/kg, respectively. This assessment revealed that mercury and arsenic contamination was widespread in the northern section of the property and the contamination extended down into the southern section of the property (10) (18). One water sample was collected from well #1 and one from the storage tank that holds spring water. The concentration of arsenic in this well was 110 ppb. These results are the subject of this health consultation and they are discussed in detail in this document.
March 2014	DEQ Time Critical Removal	Excavate soil with high concentrations of arsenic and mercury in discrete locations of the Bonanza Mine property that are in close proximity to where people live	Based on the results of the December 2013 DEQ Soil Assessment, six priority areas were identified on the Bonanza Mine property. Among the six areas, areas 1, 2 and 4 were the largest, making up approximately 16 of the 40-acre site. These three areas included the former mill site and the tailings pile. The soil from these areas was not removed due to the large size of the area and waste piles and the difficult site topography. As a result, areas 1 and 2 were fenced off to restrict access. It was determined that area 4 did not impose an immediate hazard since black berries covered the area. The remaining areas (3, 4a, 5, and 6) were discrete spots of contamination near the two most

Year	Investigation	Purpose	Major findings and outcomes
			southern residences. These areas were excavated and backfilled with clean soil, sand, gravel, or crushed rock. Approximately 60 cubic yards of contaminated soil, gravel, and firebrick was removed from these four areas and the hazardous material was stored in lined and covered stockpiles near the waste rock pile in area 1 (19). Six water samples were taken around the time of the Time Critical Removal; one sample was collected from well #1, one sample was collected from the storage tank that receives spring water, and samples were collected from four of the residences. The level of arsenic in the well was 630 ppb. These results are the subject of this health consultation and are discussed in further detail in this document.
August—November 2014	EPA Time Critical Removal	Conduct a removal action to address contamination on the Bonanza Mine property that was not dealt with in previous removal actions; and mitigate human health risks associated with open mine adits	EPA excavated 40,000 cubic yards of mercury and arsenic-contaminated soil from areas 1, 2, and 4 and removed the mill pad from area 1. Contaminated soil and other materials were transported to an on-site repository that is located against the tailings and waste rock piles. The repository was covered with a liner and 2—6 feet of clean soil and then vegetation was placed on top. EPA replaced the two residences in the northern section of the property, installed new septic systems for these two homes, and replaced the water lines for the entire property. In addition, they closed two adits (Bryn Thoms, personal communication, November 20, 2014).

Abbreviations: EPA = U.S. Environmental Protection Agency; DEQ = Oregon Department of Environmental Quality; mg/kg = milligrams per kilogram (same as parts-per-million); ppb = parts per billion)

EHAP Activities

In 2003, the Oregon Environmental Health Assessment Program (EHAP) conducted an exposure investigation to determine the levels of arsenic and mercury in the urine of Bonanza Mine residents. At the time, there were at least a dozen people living in five residences on the site, including several young adults and one toddler. Six adults provided urine samples for the investigation, but only five of the six samples were tested for mercury and arsenic (one sample did not have enough volume for urinalysis). All samples had levels of mercury and arsenic below the reference ranges for these contaminants. Based on these findings, the investigators determined that the Bonanza Mine residents whose urine was tested were “not being exposed to significant levels of arsenic and mercury” at the time of the testing (20).

The 2003 exposure investigation had important limitations. First, the urine tests for mercury and arsenic are typically used to screen for exposure to high levels of these contaminants (e.g., mercury spills, occupational exposures, etc.). In contrast, the residents at the Bonanza Mine site (at the time of the investigation) were exposed to lower levels of these contaminants over a long period of time. Second, the urine tests provided information about only recent levels of exposure and did not provide information on past exposures to mercury and arsenic at the site. Lastly, the investigators were able to test only a small number of adults living on the site. Therefore, while the investigation did not find significant levels of exposure at the time, it is possible that residents had increased health risks from past or ongoing low-level exposures to arsenic and mercury at the site.

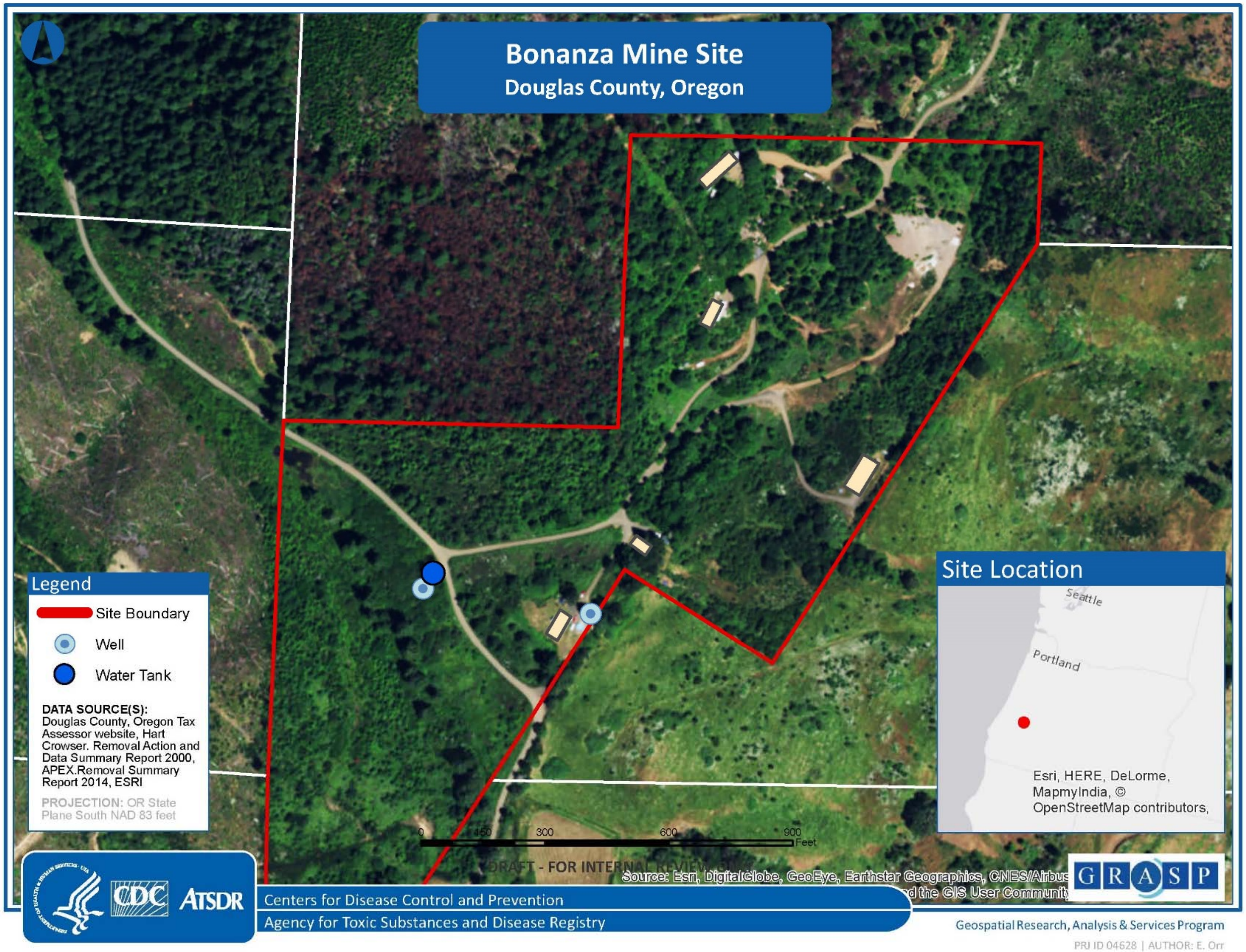
In 2011, DEQ planned to partition the property into one or two clean parcels that adult residents could live on (12). As a result, EHAP evaluated the health risks to adult residents (18 years and older) from breathing, accidentally swallowing, and touching soil on the proposed clean parcel. This evaluation did not include children because EHAP received information that children were not expected to live on the site.

Six soil samples (three from the road and three from non-road locations) from the property and three samples from Red Rock Road were assessed. Among the nine samples, the highest concentrations of arsenic and mercury were used to calculate dose and risk estimates for a high exposure scenario. EHAP also calculated dose and risk estimates for an average exposure scenario by using average regional background levels. EHAP found that adult residents living on the clean parcel were not expected to have an increased risk for non-cancer health effects from contact with these contaminants in soil (12). We also found that long-term contact with arsenic-contaminated soil in the clean parcel was not expected to substantially increase cancer risk in adults (12).

Like the 2003 exposure investigation, there were some uncertainties and limitations to this evaluation. First, EHAP focused on only the clean parcel of land designated by DEQ, and we assumed residents would not live on or use other parts of the site that were not part of the clean parcel. Second, we assumed that only adults (and not children) would live on the site in the future. If children did live on the site, they could be at greater risk from exposure to site-related contaminants than adults on the site. Third, EHAP did not consider past exposure. The property owner and their family have lived on the site since at least 1990, and the levels of arsenic and mercury in the soil were probably higher in the past. Past exposures to these higher levels could have increased their risk. Lastly, EHAP evaluated only six soil samples from the property. There are some uncertainties related to the representativeness of environmental sampling data when there are too few data available for reliably estimating exposure doses.

In November 2013, EHAP learned that children were living on the property. As a result, we worked with other state agencies to communicate to the residents about the presence of contamination and ways to prevent and reduce exposure. In February 2014, EHAP developed a flyer for the residents that gave them information about the health effects of mercury and arsenic and actions they can take to avoid exposures, especially for the children.

Appendix B. Map of the former Bonanza Mine site.



Appendix C. Exposure dose and risk calculations for water ingestion

This appendix describes the equations and assumptions used to calculate doses and risk estimates for acute non-cancer health effects and cancer.

Dose calculations

The formula used to calculate an exposure dose is as follows:

$$D = \frac{C \times CF \times IR \times F \times ED}{BW \times AT}$$

Where:

Parameter	
Term	Description
D	= exposure dose
C	= contaminant concentration
CF	= conversion factor
IR	= ingestion rate of contaminated water
F	= frequency of exposure
ED	= exposure duration
BW	= body weight
AT	= averaging time†

†The method for calculating a non-cancer and cancer averaging time is different. For non-cancer, we multiply the exposure duration (ED) and 365 days/year. For cancer, we multiply adult lifetime (78 years) and 365 days/year. The value for adult lifetime is taken from Table 18-1 of the EPA Exposure Factor Handbook 2011 (21). For acute exposures, the averaging time is adjusted for the exposure duration.

Risk calculations

The formulas used to calculate the risk of non-cancer health effects and cancer are shown below:

Non-cancer risk

The formula used to calculate non-cancer risk is as follows:

$$HQ = \frac{D}{Health\ guideline}$$

Where:

Parameter	
Term	Description

Cancer risk

The formula used to calculate cancer risk is as follows:

$$Cancer\ risk = D \times Cancer\ slope\ factor$$

Where:

Parameter	
Term	Description

D	= exposure dose
HQ	= hazard quotient

D	= exposure dose

Assumptions
EHAP evaluated the risk of developing cancer and non-cancer health effects among people that drink arsenic-contaminated well water at the former Bonanza Mine site. We calculated these risk estimates for several age groups (e.g., birth to <1 year, 1 to <2 years, 2 to <6 years, 6 to <11 years, 11 to <16 years, 16 to <21years, and ≥21 years), since a multi-generational family has lived on the property since 1990. For every age group that we evaluated, we calculated average (central tendency exposure or CTE) and high (reasonable maximum exposure or RME) water intake scenarios.

EHAP is not certain if and how often people use the wells, and so it is difficult to estimate the health risks posed from drinking this water. However, we used the available data and made conservative assumptions about people's exposure to understand the health risks. EHAP assumed children and adults would be exposed to the most heavily contaminated well water (630 and 205 ppb arsenic in wells #1 and #2, respectively) in all non-cancer and cancer exposure scenarios.

For our non-cancer risk analysis, EHAP calculated risk values for a one-time acute exposure and we defined acute exposure as ingesting well water for 14 days.

For our cancer risk analysis, we assumed people would drink well water for 14 days (2 weeks) per year for 12 or 33 years. We also assumed residents were exposed from birth (birth to 12 years and birth to 33 years) or as adults (21-33 years and 21 to 54 years).

To estimate the cancer risk from exposure to arsenic-contaminated well water, EHAP used EPA staff's recommended cancer slope factor (CSF) of 5.7 per mg/kg-day instead of the current Integrated Risk Information System (IRIS) CSF for arsenic (1.5 per mg/kg-day). The IRIS CSF is based on the risk for developing skin cancer while the new CSF is based on the risk for lung and bladder cancer. We chose to use the higher CSF since it is based on a more complete set of endpoints (22) (23).

See Tables 9-12 for a complete list of values we used to estimate the acute non-cancer health effects and cancer.

Table 9. Exposure factors for dose and risk calculations.

Parameter		Value		Unit	Source
Term	Description	Non-cancer acute	Cancer		
D	= exposure dose	Doses are shown in Tables 5, 13, and 14.	Doses are shown in Tables 15-22.	mg/kg/day	The doses are based on the values presented in this table and Tables 10-12.
C	= contaminant concentration	630 (Well #1) 205 (Well #2)		µg/L	Among all the samples results, these arsenic concentrations are the highest levels that were detected in wells #1 and #2.
CF	= conversion factor	0.001		mg/µg	---
IR	= ingestion rate of contaminated water	Multiple values are used for ingestion rate; see Table 10.		L/day	The water ingestion rate values are taken from Table 1 of ATSDR's Exposure Dose Guidance for Water Ingestion (November 2014) and Table 3-1 of the EPA Exposure Factor Handbook 2011 (21) (24).
F	= frequency of exposure	14		days/year	We assumed residents might use water from the well no more than 14 days per year (or 2 weeks per year) since they use the spring as their primary water source. This frequency parameter is based on professional judgment.
ED	= exposure duration	---	12 (CTE) 33 (RME)	years	The central tendency and reasonable maximum (95th percentile) for residential exposure is 12 and 33 years, respectively. These values are taken from ATSDR's Exposure Dose Guidance: Determining Life Expectancy and Exposure Factor to Estimate Exposure Doses and Table 16-5 of the EPA Exposure Factor Handbook 2011 (21) (25).
BW	= body weight	Multiple values are used for body weight; see Table 12.		kg	The body weight values are taken from Table 1 of ATSDR's Exposure Dose Guidance for Water Ingestion (November 2014) and Table 8-1 of the EPA Exposure Factor Handbook 2011 (21) (24).
AT	= averaging time	14 days	78 years x 365 days/year	days	The method for calculating a non-cancer and cancer averaging time is different. For non-cancer, we multiply the exposure duration (ED) and 365 days/year. For cancer, we multiply adult lifetime (78 years) and 365 days/year. The value for adult lifetime is taken from Table 18-1 of the EPA Exposure Factor Handbook 2011

Parameter		Value		Unit	Source
Term	Description	Non-cancer acute	Cancer		
					(21). For acute exposures, the averaging time is adjusted for the exposure duration.
HQ	= hazard quotient	Hazard quotients are shown in Tables 5, 13, and 14.	---	---	The hazard quotients are based on the values presented in this table and Tables 10-12.
Health guideline		0.005	---	mg/kg/day	The arsenic health guidelines are ATSDR's Minimal Risk Levels for acute oral exposure (2).
Cancer risk		---	Cancer risk values are shown in Tables 6 and 15-22.	---	The cancer risk values are based on the values presented in this table and Tables 10-12.
Cancer slope factor		---	5.7	$(mg/kg\text{-}day)^{-1}$	The EPA Science Advisory Board Arsenic Review Panel recommends using a cancer slope factor of 5.7 $(mg/kg/day)^{-1}$ for arsenic. While this value differs from the cancer slope factor in EPA's Integrated Risk Information System of 1.5 $(mg/kg/day)^{-1}$, EHAP chose this value since it reflects more recent evaluations by EPA staff. Additionally, this value is based on the combined risk of lung and bladder cancer, which are more serious endpoints than skin cancer (23) (26).

Abbreviations: CTE = central tendency exposure; RME = reasonable maximum exposure; mg/kg/day = milligram per kilogram per day; µg/L = microgram per liter; mg/µg = milligram per microgram; L/day = liters per day; kg = kilogram; EPA = U.S. Environmental Protection Agency

Table 10. Age-specific water ingestion rates (IR) †.

Age range	Central tendency exposure (L/day)	Reasonable maximum exposure (L/day)
Birth to <1 year	0.504 ǂ	1.113 ǂ
1 to <2 years	0.308	0.893
2 to <6 years	0.376 ǂ	0.977 ǂ
6 to <11 years	0.511	1.404
11 to <16 years	0.637	1.976
16 to <21 years	0.770 ǂ	2.444 ǂ
≥21 years	1.227	3.092

Abbreviations: L/Day = liters per day; < = less than; ≥ = greater or equal to

† Ingestion rates for combined direct and indirect water from community water supply. These values are taken from Table 1 of ATSDR's Exposure Dose Guidance for Water Ingestion (November 2014) and Table 3-1 of the EPA Exposure Factor Handbook 2011 (21) (24).

ǂ The water ingestion rate is a time-weighted average that is based on values from Table 3-1 of the EPA Exposure Factor Handbook 2011 (21).

Table 11. Age-specific exposure durations (ED) for cancer dose and risk estimates †.

Age range	12 years of exposure‡		33 years of exposure‡	
	Birth to 12 years old (years)	21-33 years old (years)	Birth to 33 years old (years)	21-54 years old (years)
Birth to <1 year	1	0	1	0
1 to <2 years	1	0	1	0
2 to <6 years	4	0	4	0
6 to <11 years	5	0	5	0
11 to <16 years	1	0	5	0
16 to <21 years	0	0	5	0
≥21 years	0	12	12	33
Total	**12**	**12**	**33**	**33**

Abbreviations: < = less than; ≥ = greater or equal to

† The exposure durations are distributed over the age ranges to reflect exposures from birth (to 12 and 33 years of age) and as an adult (21-33 years old and 21-54 years old).

‡ The central tendency and reasonable maximum (95th percentile) for residential exposure is 12 and 33 years, respectively. These values are taken from ATSDR's Exposure Dose Guidance: Determining Life Expectancy and Exposure Factor to Estimate Exposure Doses and Table 16-5 of the EPA Exposure Factor Handbook 2011 (21) (25).

Table 12. Age-specific body weights (BW) †.

Age range	Body weight (kg)
Birth to <1 year	7.8 ǂ
1 to <2 years	11.4
2 to <6 years	17.4 ǂ
6 to <11 years	31.8
11 to <16 years	56.8
16 to <21 years	71.6
≥21 years	80

Abbreviations: kg = kilogram; < = less than; ≥ = greater or equal to

† These values are taken from Table 1 of ATSDR's Exposure Dose Guidance for Water Ingestion (November 2014) and Table 8-1 of the EPA Exposure Factor Handbook 2011 (21) (24).

ǂ The body weight is a time-weighted average that is based on values from Table 8-1 of the EPA Exposure Factor Handbook 2011 (21).

Dose and risk calculations

Non-cancer, acute exposure

Table 13. Non-cancer, acute exposure (14 days) dose and risk estimates for well #1 ¥.

Age group	Concentration (µg/L)	Conversion factor	Ingestion rate (L/day)		Frequency of exposure (days/year)	Body weight (kg)	Averaging time (days)		Exposure dose (mg/kg/day)		Health guideline (mg/kg/day)	Hazard quotient‡	
			CTE	RME			CTE	RME	CTE	RME		CTE	RME
Birth to <1 year	630	0.001	0.504	1.113	14	7.8	14	14	0.0407	0.0899	0.005	8.1	18.0
1 to <2 years	630	0.001	0.308	0.893	14	11.4	14	14	0.0170	0.0494	0.005	3.4	9.9
2 to <6 years	630	0.001	0.376	0.977	14	17.4	14	14	0.0136	0.0354	0.005	2.7	7.1
6 to <11 years	630	0.001	0.511	1.404	14	31.8	14	14	0.0101	0.0278	0.005	2.0	5.6
11 to <16 years	630	0.001	0.637	1.976	14	56.8	14	14	0.0071	0.0219	0.005	1.4	4.4
16 to <21 years	630	0.001	0.770	2.444	14	71.6	14	14	0.0068	0.0215	0.005	1.4	4.3
≥21 years	630	0.001	1.227	3.092	14	80	14	14	0.0097	0.0243	0.005	1.9	4.9

Abbreviations: < = less than; ≥ = greater or equal to; µg/L = microgram per liter; L/day = liters per day; kg = kilogram; mg/kg/day = milligram per kilogram per day; CTE = central tendency exposure; RME = reasonable maximum exposure

¥ See Tables 9-12 for more information about the values and sources used to calculate the exposure doses and hazard quotients.

‡ Red shading denotes when the hazard quotient is greater than 1.0 and an exposed person could experience adverse health effects that are not cancer.

Table 14. Non-cancer, acute exposure (14 days) dose and risk estimates for well #2 ¥.

Age group	Concentration (µg/L)	Conversion factor	Ingestion rate (L/day)		Frequency of exposure (days/year)	Body weight (kg)	Averaging time (days)		Exposure dose (mg/kg/day)		Health guideline (mg/kg/day)	Hazard quotient‡	
			CTE	RME			CTE	RME	CTE	RME		CTE	RME
Birth to <1 year	205	0.001	0.504	1.113	14	7.8	14	14	0.0132	0.0293	0.005	2.6	5.9
1 to <2 years	205	0.001	0.308	0.893	14	11.4	14	14	0.0055	0.0161	0.005	1.1	3.2
2 to <6 years	205	0.001	0.376	0.977	14	17.4	14	14	0.0044	0.0115	0.005	0.9	2.3
6 to <11 years	205	0.001	0.511	1.404	14	31.8	14	14	0.0033	0.0091	0.005	0.7	1.8
11 to <16 years	205	0.001	0.637	1.976	14	56.8	14	14	0.0023	0.0071	0.005	0.5	1.4
16 to <21 years	205	0.001	0.770	2.444	14	71.6	14	14	0.0022	0.0070	0.005	0.4	1.4
≥21 years	205	0.001	1.227	3.092	14	80	14	14	0.0031	0.0079	0.005	0.6	1.6

Abbreviations: < = less than; ≥ = greater or equal to; µg/L = microgram per liter; L/day = liters per day; kg = kilogram; mg/kg/day = milligram per kilogram per day; CTE = central tendency exposure; RME = reasonable maximum exposure

¥ See Tables 9-12 for more information about the values and sources used to calculate the exposure doses and hazard quotients.

‡ Red shading denotes when the hazard quotient is greater than 1.0 and an exposed person could experience adverse health effects that are not cancer.

Cancer

Table 15. Cancer, chronic intermittent exposure (14 days per year for 12 years from birth to <12 years old) dose and risk estimates well #1 ¥.

Age group	Concentration (ug/L)	Conversion factor	Ingestion rate (L/day)		Frequency of exposure (days/year)	Exposure duration (years)		Body weight (kg)	Averaging time (days)		Exposure dose (mg/kg/day)		Cancer slope factor (mg/kg-day)$^{-1}$	Cancer risk	
			CTE	RME		CTE	RME		CTE	RME	CTE	RME		CTE	RME
Birth to <1 year	630	0.001	0.504	1.113	14	1	1	7.8	28470	28470	2.0E-05	4.4E-05	5.7	1.1E-04	2.5E-04
1 to <2 years	630	0.001	0.308	0.893	14	1	1	11.4	28470	28470	8.4E-06	2.4E-05	5.7	4.8E-05	1.4E-04
2 to <6 years	630	0.001	0.376	0.977	14	4	4	17.4	28470	28470	2.7E-05	7.0E-05	5.7	1.5E-04	4.0E-04
6 to <11 years	630	0.001	0.511	1.404	14	5	5	31.8	28470	28470	2.5E-05	6.8E-05	5.7	1.4E-04	3.9E-04
11 to <12 years	630	0.001	0.637	1.976	14	1	1	56.8	28470	28470	3.5E-06	1.1E-05	5.7	2.0E-05	6.1E-05
						12									
													Total	**4.8E-04**	**1.2E-03**

Abbreviations: < = less than; ≥ = greater or equal to; µg/L = microgram per liter; L/day = liters per day; kg = kilogram; mg/kg/day = milligram per kilogram per day; CTE = central tendency exposure; RME = reasonable maximum exposure

¥ See Tables 9-12 for more information about the values and sources used to calculate the exposure doses and cancer risks.

Table 16. Cancer, chronic intermittent exposure (14 days per year for 12 years from 21 to <33 years old) dose and risk estimates well #1 ¥.

Age group	Concentration (ug/L)	Conversion factor	Ingestion rate (L/day)		Frequency of exposure (days/year)	Exposure duration (years)		Body weight (kg)	Averaging time (days)		Exposure dose (mg/kg/day)		Cancer slope factor (mg/kg-day)$^{-1}$	Cancer risk	
			CTE	RME		CTE	RME		CTE	RME	CTE	RME		CTE	RME
21 to <33 years	630	0.001	1.227	3.092	14	12	12	80	28470	28470	5.7E-05	1.4E-04	5.7	3.3E-04	8.2E-04
						12									
													Total	**3.3E-04**	**8.2E-04**

Abbreviations: < = less than; ≥ = greater or equal to; µg/L = microgram per liter; L/day = liters per day; kg = kilogram; mg/kg/day = milligram per kilogram per day; CTE = central tendency exposure; RME = reasonable maximum exposure

¥ See Tables 9-12 for more information about the values and sources used to calculate the exposure doses and cancer risks.

Table 17. Cancer, chronic intermittent exposure (14 days per year for 33 years from birth to <33 years old) dose and risk estimates well #1 ¥.

Age group	Concentration (ug/L)	Conversion factor	Ingestion rate (L/day)		Frequency of exposure (days/year)	Exposure duration (years)		Body weight (kg)	Averaging time (days)		Exposure dose (mg/kg/day)		Cancer slope factor $(mg/kg\text{-}day)^{-1}$	Cancer risk	
			CTE	RME		CTE	RME		CTE	RME	CTE	RME		CTE	RME
Birth to <1 year	630	0.001	0.504	1.113	14	1	1	7.8	28470	28470	2.0E-05	4.4E-05	5.7	1.1E-04	2.5E-04
1 to <2 years	630	0.001	0.308	0.893	14	1	1	11.4	28470	28470	8.4E-06	2.4E-05	5.7	4.8E-05	1.4E-04
2 to <6 years	630	0.001	0.376	0.977	14	4	4	17.4	28470	28470	2.7E-05	7.0E-05	5.7	1.5E-04	4.0E-04
6 to <11 years	630	0.001	0.511	1.404	14	5	5	31.8	28470	28470	2.5E-05	6.8E-05	5.7	1.4E-04	3.9E-04
11 to <16 years	630	0.001	0.637	1.976	14	5	5	56.8	28470	28470	1.7E-05	5.4E-05	5.7	9.9E-05	3.1E-04
16 to <21 years	630	0.001	0.770	2.444	14	5	5	71.6	28470	28470	1.7E-05	5.3E-05	5.7	9.5E-05	3.0E-04
21 to <33 years	630	0.001	1.227	3.092	14	12	12	80	28470	28470	5.7E-05	1.4E-04	5.7	3.3E-04	8.2E-04
						33									
													Total	**9.8E-04**	**2.6E-03**

Abbreviations: < = less than; ≥ = greater or equal to; µg/L = microgram per liter; L/day = liters per day; kg = kilogram; mg/kg/day = milligram per kilogram per day; CTE = central tendency exposure; RME = reasonable maximum exposure

¥ See Tables 9-12 for more information about the values and sources used to calculate the exposure doses and cancer risks.

Table 18. Cancer, chronic intermittent exposure (14 days per year for 33 years from 21 to <54 years old) dose and risk estimates well #1 ¥.

Age group	Concentration (ug/L)	Conversion factor	Ingestion rate (L/day)		Frequency of exposure (days/year)	Exposure duration (years)		Body weight (kg)	Averaging time (days)		Exposure dose (mg/kg/day)		Cancer slope factor $(mg/kg\text{-}day)^{-1}$	Cancer risk	
			CTE	RME		CTE	RME		CTE	RME	CTE	RME		CTE	RME
21 to <54 years	630	0.001	1.227	3.092	14	33	33	80	28470	28470	1.6E-04	4.0E-04	5.7	8.9E-04	2.3E-03
						33									
													Total	**8.9E-04**	**2.3E-03**

Abbreviations: < = less than; ≥ = greater or equal to; µg/L = microgram per liter; L/day = liters per day; kg = kilogram; mg/kg/day = milligram per kilogram per day; CTE = central tendency exposure; RME = reasonable maximum exposure

¥ See Tables 9-12 for more information about the values and sources used to calculate the exposure doses and cancer risks.

Table 19. Cancer, chronic intermittent exposure (14 days per year for 12 years from birth to <12 years old) dose and risk estimates well #2 ¥.

Age group	Concentration (ug/L)	Conversion factor	Ingestion rate (L/day)		Frequency of exposure (days/year)	Exposure duration (years)		Body weight (kg)	Averaging time (days)		Exposure dose (mg/kg/day)		Cancer slope factor (mg/kg-day)$^{-1}$	Cancer risk	
			CTE	RME		CTE	RME		CTE	RME	CTE	RME		CTE	RME
Birth to <1 year	205	0.001	0.504	1.113	14	1	1	7.8	28470	28470	6.5E-06	1.4E-05	5.7	3.7E-05	8.2E-05
1 to <2 years	205	0.001	0.308	0.893	14	1	1	11.4	28470	28470	2.7E-06	7.9E-06	5.7	1.6E-05	4.5E-05
2 to <6 years	205	0.001	0.376	0.977	14	4	4	17.4	28470	28470	8.7E-06	2.3E-05	5.7	5.0E-05	1.3E-04
6 to <11 years	205	0.001	0.511	1.404	14	5	5	31.8	28470	28470	8.1E-06	2.2E-05	5.7	4.6E-05	1.3E-04
11 to <12 years	205	0.001	0.637	1.976	14	1	1	56.8	28470	28470	1.1E-06	3.5E-06	5.7	6.4E-06	2.0E-05
						12									
													Total	**1.5E-04**	**4.0E-04**

Abbreviations: < = less than; ≥ = greater or equal to; µg/L = microgram per liter; L/day = liters per day; kg = kilogram; mg/kg/day = milligram per kilogram per day; CTE = central tendency exposure; RME = reasonable maximum exposure

¥ See Tables 9-12 for more information about the values and sources used to calculate the exposure doses and cancer risks.

Table 20. Cancer, chronic intermittent exposure (14 days per year for 12 years from 21 to <33 years old) dose and risk estimates well #2 ¥.

Age group	Concentration (ug/L)	Conversion factor	Ingestion rate (L/day)		Frequency of exposure (days/year)	Exposure duration (years)		Body weight (kg)	Averaging time (days)		Exposure dose (mg/kg/day)		Cancer slope factor (mg/kg-day)$^{-1}$	Cancer risk	
			CTE	RME		CTE	RME		CTE	RME	CTE	RME		CTE	RME
21 to <33 years	205	0.001	1.227	3.092	14	12	12	80	28470	28470	1.9E-05	4.7E-05	5.7	1.1E-04	2.7E-04
						12									
													Total	**1.1E-04**	**2.7E-04**

Abbreviations: < = less than; ≥ = greater or equal to; µg/L = microgram per liter; L/day = liters per day; kg = kilogram; mg/kg/day = milligram per kilogram per day; CTE = central tendency exposure; RME = reasonable maximum exposure

¥ See Tables 9-12 for more information about the values and sources used to calculate the exposure doses and cancer risks.

Table 21. Cancer, chronic intermittent exposure (14 days per year for 33 years from birth to <33 years old) dose and risk estimates well #2 ¥.

Age group	Concentration (ug/L)	Conversion factor	Ingestion rate (L/day)		Frequency of exposure (days/year)	Exposure duration (years)		Body weight (kg)	Averaging time (days)		Exposure dose (mg/kg/day)		Cancer slope factor $(mg/kg\text{-}day)^{-1}$	Cancer risk	
			CTE	RME		CTE	RME		CTE	RME	CTE	RME		CTE	RME
Birth to <1 year	205	0.001	0.504	1.113	14	1	1	7.8	28470	28470	6.5E-06	1.4E-05	5.7	3.7E-05	8.2E-05
1 to <2 years	205	0.001	0.308	0.893	14	1	1	11.4	28470	28470	2.7E-06	7.9E-06	5.7	1.6E-05	4.5E-05
2 to <6 years	205	0.001	0.376	0.977	14	4	4	17.4	28470	28470	8.7E-06	2.3E-05	5.7	5.0E-05	1.3E-04
6 to <11 years	205	0.001	0.511	1.404	14	5	5	31.8	28470	28470	8.1E-06	2.2E-05	5.7	4.6E-05	1.3E-04
11 to <16 years	205	0.001	0.637	1.976	14	5	5	56.8	28470	28470	5.7E-06	1.8E-05	5.7	3.2E-05	1.0E-04
16 to <21 years	205	0.001	0.770	2.444	14	5	5	71.6	28470	28470	5.4E-06	1.7E-05	5.7	3.1E-05	9.8E-05
21 to <33 years	205	0.001	1.227	3.092	14	12	12	80	28470	28470	1.9E-05	4.7E-05	5.7	1.1E-04	2.7E-04
						33									
													Total	**3.2E-04**	**8.5E-04**

Abbreviations: < = less than; ≥ = greater or equal to; µg/L = microgram per liter; L/day = liters per day; kg = kilogram; mg/kg/day = milligram per kilogram per day; CTE = central tendency exposure; RME = reasonable maximum exposure

¥ See Tables 9-12 for more information about the values and sources used to calculate the exposure doses and cancer risks.

Table 22. Cancer, chronic intermittent exposure (14 days per year for 33 years from 21 to <54 years old) dose and risk estimates well #2 ¥.

Age group	Concentration (ug/L)	Conversion factor	Ingestion rate (L/day)		Frequency of exposure (days/year)	Exposure duration (years)		Body weight (kg)	Averaging time (days)		Exposure dose (mg/kg/day)		Cancer slope factor $(mg/kg\text{-}day)^{-1}$	Cancer risk	
			CTE	RME		CTE	RME		CTE	RME	CTE	RME		CTE	RME
21 to <54 years	205	0.001	1.227	3.092	14	33	33	80	28470	28470	5.1E-05	1.3E-04	5.7	2.9E-04	7.3E-04
						33									
													Total	**2.9E-04**	**7.3E-04**

Abbreviations: < = less than; ≥ = greater or equal to; µg/L = microgram per liter; L/day = liters per day; kg = kilogram; mg/kg/day = milligram per kilogram per day; CTE = central tendency exposure; RME = reasonable maximum exposure

¥ See Tables 9-12 for more information about the values and sources used to calculate the exposure doses and cancer risks.

Appendix D. List of Abbreviations and Glossary of Terms

This appendix lists abbreviations and defines words used in this Health Consultation. An abbreviation with an asterisk is defined in the glossary of terms.

The definitions in the glossary are not a complete dictionary of environmental health terms. If you have questions or comments, call the Centers for Disease Control and Prevention's toll-free telephone number, 1-800-CDC-INFO (1-800-232-4636).

Abbreviations

AT*	averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
BW	body weight
CREG*	Cancer Risk Evaluation Guide
CSF*	cancer slope factor
CTE*	central tendency exposure
CV*	comparison value
DEQ	(Oregon) Department of Environmental Quality
ED*	exposure duration
EHAP	(Oregon) Environmental Health Assessment Program
EMEG*	Environmental Media Evaluation Guide
EPA	(U.S.) Environmental Protection Agency
HC*	Health Consultation
HQ*	hazard quotient
IR*	ingestion rate
IRIS	Integrated Risk Information System
LOAEL*	lowest observed adverse effect level
MCL*	Maximum Contaminant Level
mg/kg	milligrams per kilogram
ND	not detected
NOAEL*	no observed adverse effect level
OWRD	Oregon Water Resources Department
ppb	parts per billion
RME*	reasonable maximum exposure
µg/L	microgram per liter
XRF	X-ray fluorescence

*Abbreviations with an asterisk are defined in the glossary that follows this section.

Glossary of Terms

Absorption:	The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.
Acute exposure:	Contact with a substance that occurs once or for only a short time (up to 14 days).
Adverse health effect:	A change in body function or cell structure that might lead to disease or health problems.
Averaging time (AT):	The period over which the exposure is averaged to arrive at a time-weighted exposure factor. For assessing cancer risks, AT is averaged over a lifetime (78 years); for assessing non-cancer risks, AT is averaged over the exposure duration (years), which may or may not be a lifetime.
Background level:	An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.
Cancer:	Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.
Cancer risk:	A theoretical risk for getting cancer if exposed to a substance every day for 78 years (a lifetime exposure). The true risk might be lower.
Cancer Risk Evaluation Guides (CREGs):	The estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10-6) persons exposed during their lifetime (78 years). The Agency for Toxic Substances and Disease Registry's CREGs are calculated from the U.S. Environmental Protection Agency's (EPA's) cancer slope factors for oral exposures or unit risk values for inhalation exposures. These values are based on EPA's evaluations and assumptions about hypothetical cancer risks at low levels of exposure.
Cancer slope factor (CSF):	A value used to estimate the risk of cancer associated with exposure to a cancer-causing substance. It is based on the probability of the risk of cancer over a person's lifetime (78 years).
Carcinogen:	A substance that causes cancer.
Central tendency exposure (CTE):	CTE refers to individuals who have average or typical exposure to a contaminant.

Comparison value (CV):	Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.
Completed exposure pathway:	See exposure pathway.
Concentration:	The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.
Contaminant:	A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.
Dermal contact:	Contact with (touching) the skin (see route of exposure).
Detection limit:	The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.
Dose:	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.
Environmental media:	Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants. Environmental media is the second part of an exposure pathway.
Environmental Media Evaluation Guides (EMEGs):	The estimated contaminant concentrations that are not expected to result in adverse non-cancer health effects based on the Agency for Toxic Substances and Disease Registry’s (ATSDR’s) evaluation. EMEGs are based on ATSDR’s Minimal Risk Levels and conservative assumptions about exposure, such as intake rate, exposure frequency and duration, and body weight.

Exposure:	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term (acute exposure), of intermediate duration, or long-term (chronic exposure).
Exposure duration (ED):	The number of years that an exposure occurred.
Exposure pathway:	The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: 1) a source of contamination, 2) an environmental media, 3) a point of exposure, 4) a route of exposure, and 5) a receptor population. When all five parts are present, the exposure pathway is termed a completed exposure pathway.
Frequency of exposure (F):	How often a person is exposed to a chemical over time; for example, every day, once a week, or twice a month.
Health Consultation (HC):	A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical.
Health guideline:	See Minimal Risk Level (MRL).
Hazard quotient (HQ):	A value used to quantify non-cancer risk where an exposure dose is compared to a health guideline. Specifically, the value is the result of dividing an exposure dose by a health guideline. When an HQ is less than or equal to 1.0 (the exposure dose is lower than or equal to the health guideline), it is unlikely that non-cancer health effects will occur. If the HQ is greater than 1.0 (the exposure dose is higher than the health guideline), an exposed person could experience adverse health effects that are not cancer.
Ingestion:	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way (see route of exposure).

Ingestion rate (IR):	The amount of soil, sediment, or water that is swallowed in a day. It is usually expressed as liters per day or L/day for water and grams/day or g/day for soil and sediment.
Inhalation:	The act of breathing. A hazardous substance can enter the body this way (see route of exposure).
Intermediate duration exposure:	Contact with a substance that occurs for more than 14 days and less than a year.
kg	Kilogram or 1000 grams. Usually used here as part of the dose unit mg/kg/day meaning mg (contaminant)/kg (body weight)/day.
Lowest observed adverse effect level (LOAEL):	The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.
Maximum Contaminant Levels (MCLs):	The maximum permissible level of a contaminant in water which is delivered to any user of a public water system. MCLs are derived by EPA as enforceable standards for public water systems. These standards are not strictly health-based, but they are set as close to the maximum contaminant level goals (MCLGs) as is feasible. MCLs are based on considerations of health, available treatment technologies, costs (affordability), and other feasibility factors, such as the availability of analytical methods, treatment technology and costs for achieving various levels of removal. There are MCLs for about 88 contaminants.
µg	Microgram or 1 millionth of 1 gram. Usually used here as part of the concentration of contaminants in water (µg/liter).
mg	Milligram or 1 thousandth of 1 gram. Usually used here as in a concentration of contaminant in soil mg contaminant/kg soil or as in the dose unit mg/kg/day meaning mg (contaminant)/kg (body weight)/day.
Minimal Risk Level (MRL):	An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects.

No observed adverse effect level (NOAEL):	The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.
Point of exposure:	The place where someone can come into contact with a substance present in the environment (see exposure pathway).
Population:	A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).
Potential exposure pathway:	See exposure pathway.
Reasonable maximum exposure (RME):	RME refers to people who are at the high end of the exposure distribution (approximately the 95th percentile). The RME scenario is intended to assess exposures that are higher than average, but are still within a realistic range of exposure. The RME scenario is derived using both high end and average exposure factors.
Receptor population:	People who could come into contact with hazardous substances (see exposure pathway).
Reference Dose Media Evaluation Guides (RMEGs):	Values that represent the concentration in water or soil at which daily human exposure is unlikely to result in adverse non-cancer health effects. The Agency for Toxic Substances and Disease Registry derives RMEGs from the U.S. Environmental Protection Agency's (EPA's) oral reference doses, which are based on EPA's evaluations.
Risk:	The probability that something will cause injury or harm.
Route of exposure:	The way people come into contact with a hazardous substance. The three routes of exposure are: 1) breathing (inhalation), 2) eating or drinking (ingestion), and 3) contact with the skin (dermal contact).
Source (of contamination):	The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Special populations:	People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.
Substance:	A chemical, element, metal, or radiation.