Health Consultation

Evaluation of Drinking Water and Drinking Water Sources at
Residences Near Ore Knob Mine NPL Site

ORE KNOB MINE NPL SITE
ASHE COUNTY, NORTH CAROLINA

Prepared by
North Carolina Department of Health and Human Services

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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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Summary

The Ore Knob Mine site was listed on the National Priorities List (NPL) in 2009 (EPA ID: NCN000409895). A North Carolina Division of Public Health's (N.C. DPH) priority is to make sure the community near the Ore Knob Mine NPL site has the best science information available to safeguard its health. To ensure that the affected community continues to receive updated information following the site's listing on the U.S. Environmental Protection Agency's (EPA) National Priority List, the N.C. DPH performed a comprehensive evaluation of available environmental analytical data associated with the Ore Knob Mine NPL site collected from 2010-2013 by the U.S. EPA. The EPA collected drinking water source samples to delineate the extent of groundwater contamination due to the mine near the site and identify drinking water sources that need to be prioritized for treatment. EPA also samples whole-house well treatment systems[1] annually to make sure the treatment systems are working properly. This health consultation (HC) evaluates potential public health hazards related to current exposures to drinking water from private wells at residential properties near the site. This is the DPH's second document evaluating potential health effects related to the mine for nearby residents (ATSDR 2011 PHA).

N.C. DPH reached two important conclusions about drinking water for residences near the Ore Knob Mine NPL site.

Conclusion 1: Drinking water from some groundwater sources near the Ore Knob Mine NPL site can harm the health of residents drinking the water daily over many years.

Basis for conclusion 1: Concentrations of manganese, iron, cadmium, cobalt, and copper were elevated in several untreated water samples. All five metals were also detected at elevated concentrations in treated samples (i.e. samples taken after the water went through a whole-house treatment system) from multiple drinking water source wells, posing a possible health risk for residents in the area consuming the water on a daily basis over many years.

Next steps: The N.C. DPH recommends:

- EPA more frequently monitor the functional capacity of treatment systems at residential wells OK702, OK706, OK711, OK727, OK737, OK750, and OK774, as each of these locations had concentrations of at least one metal in treated water elevated at a level that may pose a health risk for residents consuming the water over many years.
- EPA resamples the water source at residential well OK755 because the water has not been tested since 2010, and the copper health guideline value was

[1] The EPA has performed an extensive evaluation of whole house treatment systems and drinking water options for this community. Questions regarding whole house water treatment systems can be directed to the EPA. The most commonly used treatment system near the site are ion exchange water systems, which operate by displacing sodium sorbed to a resin or zeolite bed with divalent cations such as manganese, cobalt, and ferrous iron. The sodium is released into the treated water.

exceeded for bottle-fed infants. If impacted, a whole-house water treatment system should be installed.

- The HACE unit in DPH will contact individual well owners to review their specific well water results. Discussions will include their exposures, the status of their wells and filter systems, and recommendations for long-term reduction of exposure, such as connecting to a municipal water system.

Conclusion 2: Even drinking water treated by a well maintained treatment system can harm the health of individuals on a sodium restricted diet, but is not expected to harm the general population's health.

Basis for conclusion 2: Treatment systems were largely effective at reducing or eliminating exposure to toxic metals in the groundwater. However, treatment systems at several locations failed to eliminate risk of adverse health effects for one or more metals on a long-term or permanent basis. Additionally, the use of ion exchange water systems resulted in high concentration of sodium in treated drinking water. Treatment systems require regular maintenance and testing to ensure they function properly.

Next steps: The N.C. DPH recommends:

- EPA continues to monitor levels of metal contamination in private residential wells on an annual basis at minimum. More frequent testing would be recommended if measured concentrations of metals approach or exceed comparison values.
- Residents are connected to water lines from a nearby municipality to eliminate the risk of private residence treatment system failures or improper maintenance and to protect individuals on a sodium restricted diet, who may be adversely impacted by the ion exchange water systems installed at affected residences near the site. The EPA has proposed this solution, but action has not yet been taken.
- Drinking water sources identified in this assessment as having elevated metal concentrations continue to use whole-house treatment systems and monitor the effectiveness of the systems to remove metals before consumption until they are able to connect to the municipal system.

For more information: If you have concerns about your health, you should contact your health care provider. Please call the N.C. Division of Public Health at (919) 707-5900, or send an email to nchace@dhhs.nc.gov and ask for information on the Ore Knob Mine NPL site.

Background and Statement of Issues

The Ore Knob Mine NPL site (EPA ID NCN000409895) is located in Ashe County, North Carolina. The site is located about 12 miles south of the Virginia state line, 10 miles east of the town of West Jefferson, and 30 miles north of the city of Boone (Figure 1). The site was mined intermittently from 1855 through 1962, with most activity taking place from 1873 to 1883 and from 1957 and 1962. The site consists of three principal areas that were affected by mining, plus downstream surface waters, sediment, sediment porewater, and floodplain soils (EPA 2008). The three principal areas include the 19th century operations area, 1950s mine and mill area, and a 20-acre tailings impoundment (Figure 2). The 19th century operations area includes a series of barren and nearly barren areas near the top of Ore Knob (about 5 acres) that comprise dumps of waste rock from at least 11 mine shafts as well as areas (another 5 acres) where ore was roasted to drive off sulfur and smelted to recover the copper. The 1950s mine and mill area includes derelict ore bins, concrete mill foundations, a transformer building, and other ruins. The 20-acre tailings impoundment contains waste material left over after mining operations have extracted minerals from ore mined at the site and contains high levels of metals.

Prior site investigations have identified metal contamination in surface water, groundwater, sediment, and soil that could potentially harm people in the area (ATSDR 2011 PHA). Contaminated groundwater has been identified as the primary threat to public health, and residences in the area do not have access to a public water supply. Since 2010, the EPA has provided some households in the area with whole-house well treatment systems. EPA collected private drinking well water samples to assess whether site contamination might be affecting additional wells. EPA also samples whole-house treatment systems annually to make sure that the treatment systems are working properly. EPA is currently conducting an investigation to determine the feasibility of providing an alternative water source to people affected by groundwater contamination from the site.

The objective of this Health Consultation (HC) is to determine if exposure to groundwater near the site poses a current health hazard to the community. For the Ore Knob Mine NPL Site HC, N.C. DPH evaluated untreated and treated drinking water samples collected at nearby private residences from 2010-2013 (EPA 2013a, EPA 2013b). The information reviewed for the HC was taken from reports and analytical data generated by EPA and their contractors. Concentrations of contaminants in drinking water samples are compared to health comparison values to determine if they pose a health hazard to residents using each water source.

Discussion

The ATSDR health effects evaluation process

This section provides a summary of the ATSDR health effects evaluation process. A discussion of exposure dose equations and parameters is provided in Appendix C.

The first stage of the ATSDR health effects evaluation process involves screening environmental analytical data from a site by comparing site contaminant concentrations to comparison values. Comparison values (CVs) are developed by ATSDR as chemical concentrations in environmental media (e.g. groundwater) and are set at levels that are highly health protective, well below concentrations known or anticipated to result in adverse health effects. Contaminant concentrations at or below the CV may reasonably be considered safe and require no additional evaluation. When chemicals are found on a site at concentrations greater than the CV, it does not mean that adverse health effects would be expected, but it does identify that a more in-depth evaluation is warranted.

The second stage of the process is the "health guideline comparison" and involves looking more closely at site specific exposure conditions, estimating exposure doses, and comparing the dose estimates to dose-based health-effect comparison values, referred to as health guideline values. An exposure dose is an estimate of the amount of a substance a person may come into contact with in the environment during a specific time period, expressed relative to body weight. Health guideline values represent daily human exposure levels to a substance that is likely to be without appreciable risk of adverse health effects during a specified exposure duration. Important factors in determining exposure dose estimates include the concentration of the chemical, the duration and frequency of exposure, the route of exposure, and the health status of the exposed person or population. Highly health protective site-specific dose estimates[2] are developed for both children and adults. These values are then compared to ATSDR health guideline values.

To determine if adverse (negative) health effects are indicated for the site-specific exposure doses calculated for children and adults, these values are compared to data collected in human health effect and animal laboratory studies for the chemicals of concern. The health study data is generally taken from ATSDR or EPA references that summarize human and animal studies that have undergone extensive validation review. Comparisons are made on the basis of the exposure route (ingestion/eating, inhalation/breathing, or dermal/skin contact) and the length of the exposure. Preference is given to human study data and chemical doses or concentrations where no adverse health effects were observed. If no human data or no-adverse-effect data is available, animal data or the lowest chemical dose where adverse health effects were observed may be used.

Long term daily exposures were considered for children and adults living on or near the Ore Knob Mine property. There are limitations inherent to the public health assessment process. These include the availability of analytical data collected for a site, the type and quantity of health effect information, and the risk estimation process itself. To overcome some of these limitations, the parameters selected for exposure estimates (amount consumed, frequency of exposure, years or exposure) were all selected to be health protective by maximizing the selected

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[2] To remain protective of human health, DPH considers realistic high-end exposure scenarios including 95th percentile ingestion rate, daily exposure, and a long-term time frame, consistent with a permanent resident using tap water at their home as the main water source.

values to represent a realistic maximum potential for persons to be in contact with the environmental contamination that may exist on the site. Comparison values and health guideline values used in this HC were developed by the ATSDR for chronic (>1 year) daily exposure to a chemical, consistent with drinking water from a private well over many years living at a particular residence. Where ATSDR chronic CVs or health guidelines were unavailable, ATSDR intermediate exposure duration or EPA chronic exposure duration values were used. See Appendix B Tables 1 and 2 for a list of comparison values used for contaminants of concern at the Ore Knob Mine NPL site. See Appendix C for equations and exposure parameters used to estimate exposure doses for residents near the Ore Knob Mine NPL site. It should be noted that the exposure scenarios considered in this Health Consultation assumed year-round residence and daily ingestion for exposed populations (age-specific drinking water ingestion rates are provided in Appendix C). Many of the properties near the site are vacation homes that are not occupied year-round, reducing the potential for exposure to contaminants in the drinking water and thus decreasing the potential for health risks.

Exposure pathway analysis

An exposure to a chemical and the possibility of adverse (harmful) health effects requires persons to come into contact with the chemical through ingestion (eating or drinking), inhalation (breathing the chemical), or absorbing the chemical through the skin (dermal absorption). Having contact with a chemical does not necessarily result in adverse health effects. A chemical's ability to result in adverse health effects is influenced by a number of factors, including the amount of a chemical that a person is exposed to (dose), how often and how long a time a person is exposed to the chemical (frequency and duration), and the amount and type of damage the chemical can cause in the body (toxicity). Knowing or estimating the frequency with which people have contact with hazardous substances is essential to assessing the public health implications of these contaminants.

Responses of persons to potentially harmful substances may vary with the individual or group of individuals, such as children, the elderly, or persons with weakened immune responses, or other chronic health issues. These susceptible populations may have different or heightened responses as compared to most persons exposed at the same concentration to a particular chemical in the environment. Reasons for these differences include genetic makeup, age, health status, nutritional status, and exposure to other toxic substances (such as cigarette smoke or alcohol). These factors may limit a person's ability to detoxify or eliminate the harmful chemicals from their body, or may increase the effects of damage to their organs or physiological systems. Child-specific exposure situations and susceptibilities are considered in our health evaluations.

The exposure pathway (how people may come into contact with contaminants in their environment) is evaluated to determine if people have come into contact with site contaminants, or if they may in the future. An exposure pathway is one that contains a source of contamination, the movement of the contaminant through environmental media such as groundwater, a point of exposure where people come in contact with the contaminated media such as drinking water, a route of exposure like drinking contaminated well water, and a population of persons that can come in contact with the contaminants.

This health consultation focuses on the population of people living near and down gradient of the Ore Knob Mine NPL site that rely on private wells for residential drinking water. This population may be exposed to site related contaminants via ingestion of drinking water. The EPA sampled sites where groundwater contamination is thought to be the highest, as well as additional sites to delineate the extent of groundwater contamination, because tracking of groundwater movement in the mountains is more complex than for other geological structures. While there is potential for past exposure to contaminants at the Ore Knob Mine NPL site, there is insufficient data to evaluate past exposures via drinking water. A thorough discussion of potential past exposures can be found in the 2011 Public Health Assessment [ATSDR 2011 PHA]. This HC will focus on samples collected from 2010-2013.

Review of environmental analytical data

N.C. DPH reviewed all available analytical data generated by the EPA. Data sets evaluated for this Health Consultation include:

- Private well water samples collected by the EPA and its contractors over several sampling events, occurring periodically from 2010-2013. Untreated water sources were sampled at 81 different stations (Figure 3).

- Treated water in private residences near the site collected by the EPA and its contractors over several sampling events, occurring periodically from 2010-2013. Treated water samples were collected from 20 stations.

Samples collected and analyzed by EPA and its contractors used EPA-approved protocols (EPA 2008). Although site contaminants are thought to be primarily limited to metals, to make a broader statement about the safety of potable sources each water source sample was submitted for at least one full suite of analyses including metals, cyanide, semi-volatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), and volatile organic compounds (VOCs). Certain water sources, selected for proximity to historical mining operations, were analyzed for acidity, alkalinity, and sulfate (EPA 2013a). Chemical analytes are discussed below. Measured pH in untreated and treated water samples near the Ore Knob Mine site range from 4.32- 7.98. Acidic groundwater is not unexpected in the vicinity of mining sites. For pH in drinking water, the EPA has set a National Secondary Drinking Water Regulation (NSDWR) level range of 6.5-8.5. NSDWRs are not enforceable, and are set for contaminants not considered to present a risk to human health. pH levels outside of the 6.5-8.5 range may contribute to the taste of the water, as well as corrosion of distribution system pipes and household fixtures, but are not expected to pose a risk to public health.

The following discussions of analytical data will focus only on substances detected in a particular sample set and those that exceed ATSDR-defined comparison values (CVs). Comparison values were not available for 3 of the metals detected in most of the samples (calcium, magnesium, and potassium). These metals are essential nutrients[3] and are not typically harmful under most environmental exposure scenarios (ATSDR 2005).

In 112 untreated water samples collected from 81 stations, 19 wells were found to have exceedances of CVs for metals, primarily manganese, cobalt, and iron. The data for untreated water samples are summarized in Appendix B Table 1.

Sixty-six treated water samples were collected from 20 stations near the Ore Knob Mine NPL site. Seven stations had metal concentrations in exceedance of comparison values, primarily for manganese, cobalt, and iron. The data for treated samples are summarized in Appendix B Table 2.

There were 22 detections of organic compounds at 10 wells. Beta-hexachlorocyclohexane (beta-BHC) was in exceedance of the ATSDR Cancer Risk Evaluation Guide (CREG) of 0.019 µg/L [4] in untreated water collected from OK739 in May 2010. Treated water from this station collected during the same sampling event and during subsequent sampling events detected no beta-BHC. No other organic compounds exceeded comparison values. There is no pattern of organic compound contamination that would indicate an association with site activities.

Sulfate was detected in 126 samples. Forty-one samples (13 untreated and 28 treated) from 10 sampling stations exceeded the N.C. 2L groundwater standard of 250 mg/L for sulfate.

Evaluation of potential public health issues

Metals

Twenty wells have at least one metal at levels above comparison values (CVs), and are evaluated in depth below for potential public health hazards. Appendix B Tables 1 and 2 summarize the metals detected and list comparison values used for ingestion exposures.

Iron

Untreated water from OK738, OK761, and OK779 had measured iron levels above the environmental comparison value of 2500 µg/L, but maximum estimated doses did not exceed the EPA chronic reference dose (RfD) of 0.7 mg/kg/day (Tables 14, 18, 22). Additionally, treated water samples from these sources did not exceed the CV for iron, and no other metals were elevated above CVs in any samples collected from these three drinking water sources. These water sources are considered to have no risk of adverse health effects.

[3] Essential nutrients are required for normal body functioning and must be obtained from dietary sources
[4] µg/L = micrograms of compound per liter of water

Sodium

Untreated water from OK748 and OK707 were found to have sodium levels in excess of the EPA Drinking Water Advisory level of 20 mg/L. Treated water from OK702, OK706, OK707, OK708, OK709, OK710, OK711, OK712, OK719, OK723, OK727, OK739, OK750, OK762, OK774, and OK779 had sodium levels above 20 mg/L, with a maximum of 250 mg/L at OK702. These excess sodium levels in treated water samples are likely due to the ion exchange water treatment systems in place at these residences. The EPA guidance level of 20 mg/L was developed for those individuals restricted to a total sodium intake of 500 mg/day and should not be extrapolated to the entire population (EPA 2003b). Sodium concentrations in exceedance of this guidance may pose a health risk to individuals who are on a sodium restricted diet. The EPA Drinking Water Advisory recommends that the sodium concentration in drinking water not exceed a range of 30 to 60 mg/L because of effects on taste at higher concentrations, but no adverse health effects are anticipated for people not on a sodium restricted diet.

OK702

Untreated water samples collected from OK702 in 2010 had concentrations of manganese, iron, cadmium, and cobalt elevated above CVs. Estimated exposure doses were greater than health guideline (HG) values for all four metals (Table 3), with the highest doses estimated for bottle-fed infants. Treated drinking water from this source sampled during the same sampling event and during subsequent events had no iron, cadmium, or cobalt detected, and concentrations of manganese were below the CV. Treated samples from OK702 taken in 2010 and 2011 exceeded the CV for copper, and estimated doses were greater than the HG of 0.01 mg/kg/day[5], but remain below the no observed adverse effects level (NOAEL) for intermediate duration oral exposure to copper (Table 23). The highest doses were estimated for bottle-fed infants. The most recent treated sample, collected in 2012, had levels of all metals below their respective CVs and thus does not indicate the potential for adverse health effects.

OK706

Sampling station OK706 exceeded CVs for manganese, iron, cadmium, cobalt, and copper in untreated and treated samples in 2010. Estimated doses exceeded HG values for all five metals (Table 4), with the highest doses expected for bottle-fed infants. Estimated doses of manganese received by persons exposed to treated water at this site in 2010 are greater than doses shown to have negative neurological effects in children (Table 23). Subsequent sampling events in 2011 and 2012 detected no iron, cadmium, cobalt, or copper in treated water samples, and measured manganese concentrations were below the CV. Treated water from this source is not anticipated to cause adverse health effects for residents consuming the water from 2011 onward if the treatment system continues to function properly, as indicated in the 2011 and 2012 sampling events.

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[5] mg/kg/d = milligrams of compound per kilogram of body weight ingested per day

OK707

Untreated water samples from OK707 exceeded the CVs for manganese and cobalt, and estimated exposure doses exceeded the HG values for both metals, with maximum estimated doses 4.5 and 13.8 times higher than the HG for manganese and cobalt, respectively (Table 5). Maximum estimated doses of manganese received from untreated water exceed levels doses shown to have negative neurological effects in children (Table 23). However, treated water collected during the same sampling event and subsequent sampling events detected no metals. Consumption of treated water from this source is not anticipated to result in adverse health effects.

OK708

Station OK708 had elevated levels of manganese and iron in untreated water collected in 2010. Estimated exposure doses for bottle-fed infants exceeded the HG value for manganese, but no other age group had estimated doses greater than the HG (Table 6). Estimated exposure doses for children up to age six exceeded the HG value for iron. Treated water collected during the same sampling event and subsequent sampling events had no detectable manganese or iron. No other metals exceeded CVs for any samples collected from this site. Ingestion of treated water from this source is not anticipated to result in adverse health effects.

OK709

Untreated water collected in 2010 from station OK709 had concentrations of manganese, cadmium, cobalt, copper, and aluminum greater than the CV for each metal. Estimated exposure doses were above HG values for all age groups for manganese, cadmium, cobalt, and copper (Table 7). Maximum estimated doses of manganese and copper received from untreated water exceed levels doses shown to have negative health effects, indicating the importance of maintaining a treatment system to remove these metals (Table 23). Estimated exposure doses from untreated water only exceeded the aluminum HG value for bottle-fed infants. All treated samples collected from OK709 in 2010-2013 were below CVs for all metals tested. Ingestion of treated water from this source does not pose a risk to human health.

OK710

Health guideline values for manganese, iron, and cobalt were exceeded by maximum estimated exposure doses in untreated water collected from OK710 in 2010 (Table 8). Maximum estimated doses of manganese received from untreated water exceed levels doses shown to have negative neurological effects in children (Table 23). Treated water samples taken during the same event and subsequent events in 2011 and 2012 did not have detectable concentrations of these metals, indicating that the treated water at this site does not pose a public health risk.

OK711

Maximum estimated exposure doses for manganese, iron, cadmium, and cobalt from untreated water at OK711 exceeded HG values in samples collected in 2010. Maximum estimated exposure doses for manganese and cobalt from treated OK711 water collected during the same sampling event also exceeded HG values (Table 9). Maximum estimated doses of manganese received from untreated and treated water exceed levels doses shown to have negative neurological effects in children (Table 23). No health guideline values were exceeded for any metals in treated OK711 water collected in 2011, but manganese, iron, and cobalt HG values were exceeded in treated OK711 sampled in 2012. Estimated doses of manganese from this water sample indicate the possibility of adverse effects if the contaminated water is consumed over a long period of time. The water treatment system was adjusted and retested in 2013, at which time all metal concentrations were below comparison values and all estimated exposure doses were below HG values. Ingestion of treated water at this site is unlikely to pose a health risk if the treatment system is well maintained. Samples should be collected frequently (every six months) to ensure the treatment system continues to function properly.

OK712

Untreated water samples collected from the well at OK712 exceeded comparison values for manganese and iron during the 2010 sampling event. Estimated exposure doses exceeded health guidelines for manganese for infants and toddlers, aged birth to 2 years. Maximum estimated doses of manganese received from untreated water exceed levels doses shown to have negative neurological effects in children who consume manganese contaminated water over a long period of time (Table 23). Estimated exposure doses of iron exceeded health guidelines for bottle-fed infants only (Table 10). Treated water samples collected from this site during the 2010 event and in subsequent events (2011 and 2012) had no detectable levels of iron or manganese, indicating that the treated water at OK712 does not pose a public health risk.

OK723

Sampling station OK723 had concentrations of manganese, iron, cadmium, cobalt, and copper elevated above their respective comparison values in untreated water collected in 2010. Maximum estimated exposure doses exceeded health guideline values for all five metals in this sample (Table 11). Maximum estimated doses of manganese received from untreated water exceed levels doses shown to have negative neurological effects in children (Table 23). However, treated OK723 water collected during the same sampling event, as well as subsequent sampling events (2011 and 2012) had no detectable levels of any metal tested. Consumption of treated water at OK723 is not indicated to result in adverse health effects.

OK727

Treated and untreated water collected from OK727 over several sampling events exceeded comparison values for multiple metals. Untreated water collected in 2010 exceeded CVs for manganese, iron, cadmium, cobalt, and copper. Maximum estimated exposure doses for all five metals were greater than the respective health guideline values (Table 12). Although zinc concentrations were below its CV, the estimated dose received by bottle-fed infants exposed to untreated water exceeded the zinc health guideline level. Additionally, treated water collected during 2010, 2011, and 2012 events had concentrations of manganese, iron, cadmium, and cobalt in exceedance of CVs. Estimated treated water exposure doses for manganese, cadmium, and cobalt were greater than the health guideline value for each metal (Table 12), with the highest doses received by bottle-fed infants. Maximum estimated doses of manganese received from untreated and treated water exceed levels doses shown to have negative neurological effects in children (Table 23). The two most recent treated water samples at this location, sampled in April and November 2012, had undetectable levels of manganese, iron, cadmium, and cobalt; copper concentrations were below the CV. Residents ingesting treated water from this source on a daily basis between 2010 and 2012 may be at risk of adverse health effects associated with these metals, especially manganese and cobalt, where maximum exposure doses from treated water were up to 63 and 52 times greater than the health guideline values, respectively. Ingestion of treated water at this site after April 2012 is unlikely to pose a risk to public health if the treatment system is well maintained with frequent sampling (every six months) to ensure that the treatment system is functioning properly.

OK737

The water source at OK737 had elevated concentrations of zinc in untreated water collected in 2010, as well as in treated water collected in 2010 and 2012 (the most recent sample at this site). Maximum estimated exposure doses were greater than health guidelines for infants and young children aged ten and under (Table 13). Additionally, the estimated zinc dose for infants exposed to treated water collected during the most recent event was greater than the no observed adverse effects level (NOAEL) for intermediate oral exposure in humans (Table 23), indicating the potential for adverse health effects in children consuming treated or untreated water at this source.

OK739

Untreated water collected at OK739 in 2010 exceeded CVs for manganese, cobalt, and arsenic. Estimated exposure doses exceeded the health guideline values for manganese and cobalt, but not for the non-cancer health guideline value for arsenic (Table 15). Maximum estimated doses of manganese received from untreated water exceed levels doses shown to have negative neurological effects in children (Table 23). The theoretical cancer risk for daily exposure to the maximum measured arsenic concentrations in untreated water at this site is low (4 in 100,000;

see Appendix C). However, treated water from OK 739 collected during the same sampling event and subsequent events (2011 and 2012) had no detectable levels of cobalt or arsenic, and concentrations of manganese were below the CV, indicating that the treated water at this site does not pose a public health risk.

OK750

Sampling station OK750 had concentrations of manganese, iron, and cobalt in exceedance of the respective CVs in untreated water collected in 2010. Maximum estimated exposure doses for all three metals were greater than the health guideline values in the untreated samples (Table 16). Treated water samples collected in 2010 and 2011 had metal concentrations below CVs for all metals. In 2012, treated water samples from OK750 had concentrations of manganese and iron greater than the CVs. Estimated exposure doses exceeded health guideline for manganese only (Table 16), and only for the bottle-fed infant age group, but the estimated dose was greater than the dose associated with mild neurological effects over a lifetime of exposure. In this same sample (treated water 2012), cobalt concentrations resulted in estimated exposure doses greater than the health guideline for infants and toddlers up to age 2, but remained 100 times lower than the dose associated with adverse health effects in humans (Table 23). Treated water from this source may pose a small health risk to infants consuming the water, especially if the treatment system is not maintained.

OK755

Untreated water collected from OK755 in 2010 had iron levels greater than the CV, but maximum estimated doses for all age groups remained below health guideline values (Table 17). Copper concentrations in untreated water at this site were below CVs, but the maximum estimated exposure dose for bottle-fed infants is 0.0103 mg/kg/day, slightly higher than the health guideline for intermediate (15-364 days) exposure of 0.01 mg/kg/day. Estimated doses for all other age groups remained below the health guideline. Infants exposed to untreated water at OK755 may have a small risk of adverse health effects associated with elevated copper ingestion.

OK756

Manganese, iron, and cobalt health guideline values were exceeded for all age groups exposed to untreated water collected from OK762 in 2011 (Table 19). Maximum estimated doses of manganese received from untreated water exceed levels doses shown to have negative neurological effects in children (Table 23). Additionally, health guideline values for cadmium and copper were exceeded by estimated exposure doses for bottle-fed infants exposed to this same sample. However, treated water tested during this event and 2 subsequent events (2011 and 2012) had undetectable concentrations of cadmium and cobalt, and concentrations of manganese, iron and copper were below CVs. Ingestion of treated water at this site is not expected to pose a risk of adverse health effects to exposed populations.

OK773

Untreated water collected at OK773 had concentrations of manganese, iron, and cobalt greater than CVs. Estimated exposure doses did not exceed the iron health guideline for any age group Estimated exposure doses for manganese and cobalt exceeded health guidelines for all age groups exposed to untreated water from this site (Table 20). Maximum estimated doses of manganese received from untreated water exceed levels doses shown to have negative neurological effects in children (Table 23). Subsequent sampling events collected treated water at this site, and no manganese, iron, or cobalt was detected, indicating no adverse effects expected from exposure to treated water at OK773.

OK774

Comparison values for manganese, iron, and cobalt were exceeded in untreated and treated water samples from OK774 collected in 2011. The iron health guideline value was exceeded for infants and children aged five years and under exposed to treated water collected in 2011, and for all age groups exposed to untreated water (Table 21). Manganese and cobalt health guideline values were exceeded by estimated exposure doses for all age groups exposed to untreated or treated water, and estimated doses of manganese were greater than doses shown to have adverse health effects in infants exposed for one year or longer (Table 23). Subsequent sampling events (January and November 2012) resulted in undetectable levels of cobalt and iron in treated water at this source, and concentrations of manganese remained below the comparison value. Ingestion of treated water since 2012 at this site is unlikely to pose a risk to public health if the treatment system is well maintained, and samples should be collected frequently (every six months) to ensure proper functionality.

Sulfates

Forty-one samples from 10 sampling stations exceeded the N.C. 2L groundwater standard[6] of 250 mg/L[7] for sulfate (range of exceedances: 260-520 mg/L). There is no ATSDR health guideline value for sulfate exposure, but the EPA has published a drinking water advisory for sulfate consumption (EPA 2003a). The most common adverse health effect from sulfate consumption is osmotic diarrhea (increased stool volume and water content). Laxative effects (loose stools) have been associated with sulfate concentrations greater than 500 mg/L, which was only observed in one sample near the Ore Knob Mine site, treated drinking water collected from OK762 in 2011. Subsequent sampling at this location measured lower sulfate concentrations (330 and 300 mg/L). Additionally, it is thought that humans can acclimate to elevated sulfate concentrations within 1-2 weeks, so long term effects are not anticipated from exposure to sulfate concentrations observed near Ore Knob Mine.

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[6] N.C. 2L groundwater quality standards are the maximum allowable concentrations of contaminants in groundwater which may be tolerated without creating a threat to human health or which would otherwise render the groundwater unsuitable for use as a drinking water source

[7] mg/L = milligrams of compound per liter of water

Organic substances

Only one sample exceeded ATSDR screening levels for organic substances. Beta-hexachlorocyclohexane (beta-BHC) was detected in untreated water from OK739 collected in 2010. It was not detected in treated water collected during the same event. Beta-BHC is a component of the insecticide Lindane. The single detection may indicate that beta-BHC was a contaminant of the sample collection or handling process and not a groundwater contaminant. The maximum estimated exposure dose to beta-BHC was nearly 100 times lower than the non-cancer ATSDR health guideline. Beta-BHC is classified by the EPA as a possible human carcinogen (ATSDR 2005 BHC), but the theoretical cancer risk from consuming untreated water from this source is very low (2 in 1,000,000; See Appendix C). Additionally, treated water at this source had no detectable beta-BHC, indicating that ingestion of treated water from this source does not pose a public health hazard.

Health effects of selected substances

Cadmium - Long-term exposure to low levels of cadmium in air, food, or water leads to a buildup of cadmium in the kidneys and possible kidney disease. Fragile bones may result from long-term exposures. Eating food or drinking water with very high levels severely irritates the stomach, leading to vomiting and diarrhea. The health effects in children are expected to be similar to the effects seen in adults (kidney, lung, and bone damage depending on the route of exposure). A few studies in animals indicate that younger animals absorb more cadmium than adults. Animal studies indicate that the young are more susceptible than adults to a loss of bone and decreased bone strength from exposure to cadmium. It is not known if cadmium causes birth defects in people. The babies of animals exposed to high levels of cadmium during pregnancy had changes in behavior and learning ability. There is also some information from animal studies that high enough exposures to cadmium before birth can reduce body weights and affect the skeleton in the developing young. The U.S. DHHS identifies cadmium as a known human carcinogen and the EPA as a probable human carcinogen (ATSDR 2012 Cd). Reports of the ability of cadmium to cause cancer in animals following oral exposure are conflicting; with a lack of cancer response reported in multiple studies in rats and mice (IRIS 2009), while a demonstration of cancer response has been reported for animals in other references (TOX 2008). EPA states there are no studies that show cadmium causing cancer after oral exposure (IRIS 2009). Humans absorb 5 to 10% of ingested cadmium. Animal studies show that cadmium accumulates in the liver and kidney. Plants readily accumulate cadmium from the soil (TOX 2008). Neither EPA nor ATSDR provide values to estimate cancer risk for oral exposures.

Cobalt – Cobalt is an essential nutrient that humans need in small amounts for maintenance of vitamin B_{12} (TOX 2008). However, when consumed in high amounts, cobalt can adversely affect the blood, liver, kidneys, and heart. Studies in animals suggest that exposure to high amounts of cobalt during pregnancy can affect the health of the developing fetus, but doses used in these studies were much higher than the amounts to which humans are usually exposed (ATSDR 2004

Co). Birth defects have not been found in human children born to mothers who were treated with cobalt during pregnancy. Cardiomyopathy (heart muscle disease) has been reported in humans exposed to cobalt, but these effects may have been confounded by the alcoholism of the patients. Much larger doses of cobalt were required to induce the same effects in animal studies (ATSDR 2004 Co). The International Agency for Research on Cancer (IARC) determined that certain forms of cobalt have been classified as possibly carcinogenic to humans (IARC 2006), but cobalt has not been found to cause cancer in humans or animals following exposure in food or water. Most studies that indicate cobalt as a carcinogen concern the inhalation route of exposure. Animal studies suggest that children may absorb more cobalt than adults from food and liquids. It is estimated that humans absorb 5 to 45% of ingested cobalt (TOX 2008).

Copper - Copper is an essential nutrient. People need small amounts of copper in their diets to maintain their health, but high levels can harm health. Ingesting high levels of copper can cause nausea, vomiting, and diarrhea. Very high doses of copper can cause damage to the liver and kidneys, and can even cause death. Children exposed to high levels of copper experience the same types of effects as adults. It is not known if children are more sensitive to the adverse effects of copper at lower doses. Although not confirmed in human studies, animal studies suggest that young children may have more severe effects than adults to copper. There are a very small percentage of infants and children who are unusually sensitive to copper. Persons with Wilson's disease[8] or other genetic defects that impair copper homeostatic mechanisms[9] are also unusually susceptible to the toxic effects of copper. It is not known if copper causes birth defects or other developmental effects in humans at high levels. Studies in animals suggest that high levels of copper may cause a decrease in fetal growth. It is not known if exposure to copper causes cancer in humans and the carcinogenicity of copper to humans has not been classified (ATSDR 2004 FAQ Cu). Humans absorb 55 to 75% of ingested copper (TOX 2008).

Iron - Iron is an essential nutrient. Our bodies need some iron for proper bodily functions and to maintain our health. But taking in too much iron, either through eating, drinking or breathing the dust or fumes can cause harm. Eating large amounts of iron in a short period, or lower amounts over long periods, may result in gastrointestinal symptoms including abdominal pain, diarrhea and vomiting and ultimately damage to the heart, pancreas, liver and kidneys. The immune system may also be damaged with long-term ingestion of a large excess of iron, reducing the body's ability to fight off infections. The build-up of excess iron in the body may lead to atherosclerosis (plaque buildup in arteries), although this association is still being studied. Some studies also suggest the brain may be affected by too much iron, resulting in neurodegenerative disorders (damage to the nervous system). Individuals with the liver disease hemochromatosis,

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[8] Wilson's disease - genetic disease that prevents the body from removing excess copper, resulting in copper accumulation in the organs

[9] Homeostatic mechanisms include cellular functions responsible for maintaining a healthy, stable balance of essential nutrients

which is characterized by excessive retention of iron in the liver, are at increased risk of adverse health effects from iron ingestion (TOX 2008, Hayes 2008).

Manganese - Manganese is an essential nutrient required for many metabolic and cellular functions (TOX 2008). Eating a small amount of it each day is important to stay healthy. The most common health problems in workers who inhaled high levels of manganese involve the nervous system. These health effects include behavioral changes and other nervous system effects, which include movements that may become slow and clumsy. This combination of symptoms when sufficiently severe is referred to as “manganism”. Other less severe nervous system effects such as slowed hand movements have been observed in some workers exposed to lower concentrations in the work place. Nervous system and reproductive effects have been observed in animals after high oral doses of manganese (ATSDR 2012 FAQ Mn). Nervous system damage has been reported following ingestion of water contaminated with manganese from 1,800 to 14,000 µg/L (TOX 2008). These effects have been most prominently observed in children and are similar to those observed from inhalation exposure. There is also an accumulating body of evidence suggesting that exposure to excess levels of manganese in drinking water (≥200 µg/L) may lead to neurological deficits in children, including poor school performance, impaired cognitive function, abnormal performance on neurobehavioral tests, and increased oppositional behavior and hyperactivity (ATSDR 2012 Mn). It is not known if these changes were due to manganese alone, or if they were temporary or permanent. Children are also potentially more sensitive to manganese toxicity than adults (ATSDR 2012 Mn). Studies of manganese workers have not found increases in birth defects or low birth weight in their offspring. No birth defects were observed in animals exposed to manganese. It is not known if exposure to manganese causes cancer in humans and the carcinogenicity of manganese to humans has not been classified (ATSDR 2012 FAQ Mn). Humans absorb 3 to 5% of ingested manganese, with dissolved manganese in water absorbed to a greater extent that manganese from food (ATSDR 2012 Mn).

Sodium – Sodium is an essential nutrient required to maintain multiple cellular functions within the body. Excessive intake of very high doses of sodium (accidental poisoning) may cause acute effects such as nausea, vomiting, inflammatory reaction in the gastrointestinal tract, thirst, muscular twitching, convulsions, and possibly death. For long-term lower level exposures, the health effect of primary concern is essential hypertension (i.e. high blood pressure). Numerous studies conducted in humans suggest that excessive sodium intake contributes to age-related increases in blood pressure, leading to hypertension in sensitive individuals (EPA 2003b). Populations more susceptible to induced adverse health effects caused by increased sodium intake include African-Americans, individuals with decreased renal function, and infants and children whose immature kidneys are not as effective in controlling sodium levels as the kidneys of adults (EPA 2003b).

Zinc - Zinc is an essential element in our diet required for many metabolic processes. Too little zinc can cause health problems, but too much zinc is also harmful. Harmful effects generally begin at levels 10-15 times higher than the amount needed for good health. Large doses taken by mouth even for a short time can cause stomach cramps, nausea, and vomiting. Taken longer, it can cause anemia and decrease the levels of good cholesterol. It is not known if high levels of zinc affect reproduction in humans. In animal studies, rats that were fed large amounts of zinc became infertile. It is not known if exposure to zinc causes cancer in humans and the carcinogenicity of zinc to humans has not been classified (ATSDR 2005 FAQ Zn). There are indications that ingesting too little zinc may be associated with an increased risk of developing some types of cancer in humans (TOX 2008). Twenty to 30% of ingested zinc is absorbed (TOX 2008).

Child Health Considerations

The ATSDR recognizes there are unique exposure risks concerning children that do not apply to adults. Children are at a greater risk than are adults to certain kinds of exposures to hazardous substances. Because they play outdoors and because they often carry food into contaminated areas, children are more likely to be exposed to contaminants in the environment. Children are shorter than adults and as a result, they are more likely to breathe more dust, soil, and heavy vapors that accumulate near the ground. They are also smaller, resulting in higher doses of chemical exposure per body weight compared to adults. If toxic exposures occur during critical growth stages, the developing body systems of children can sustain permanent damage. Probably most important, however, is that children depend on adults for risk identification and risk management, housing, and access to medical care. Thus, adults should be aware of public health risks in their community, so they can guide their children accordingly. Child-specific exposure situations and health effects are taken into account in N.C. DPH health effect evaluations (Appendix C).

Conclusions

N.C. DPH evaluated untreated and treated drinking water samples collected at private residences at or near the Ore Knob Mine NPL site. N.C. DPH concluded:

> **Conclusion 1: Drinking water from groundwater sources near the Ore Knob Mine NPL site can harm the health of residents drinking the water daily over many years.** Concentrations of manganese, iron, cadmium, cobalt, and copper were elevated in several untreated water samples. All five metals were also detected at elevated concentrations in treated samples (i.e. samples taken after the water went through a whole-house treatment system) from multiple drinking water source wells, posing a possible health risk for residents in the area consuming the water on a daily basis over many years.

> **Conclusion 2: Drinking water treated by a well maintained treatment system can harm the health of individuals on a sodium restricted diet, but is not expected to**

harm the general population's health. Treatment systems were largely effective at reducing or eliminating exposure to toxic metals in the groundwater. However, treatment systems at several locations failed to eliminate risk of adverse health effects for one or more metals on a long-term or permanent basis. Additionally, the use of ion exchange water systems resulted in high concentration of sodium in treated drinking water. Treatment systems require regular maintenance and testing to ensure they function properly.

Recommendations

The N.C. DPH recommends:

- EPA continues to monitor levels of metal contamination in private residential wells on an annual basis at minimum. More frequent testing would be recommended if measured concentrations of metals approach or exceed health-based screening levels.
- Drinking water sources identified in this assessment as having metal concentrations greater than health-based screening levels continue to use whole-house treatment systems and monitor the effectiveness of the systems to remove metals before consumption until they are able to connect to the municipal system.
- EPA more frequently monitors the functional capacity of treatment systems at OK702, OK706, OK711, OK727, OK737, OK750, and OK774, as each of these locations had concentrations of at least one metal in treated water elevated at a level that may pose a health risk for residents consuming the water over many years.
- EPA resamples the water source at residential well OK755 and considers installing a whole-house water treatment system because the water has not been tested since 2010, and the copper health guideline value was exceeded for bottle-fed infants. If impacted, a whole-house water treatment system should be installed.
- Residents are connected to water lines from a nearby municipality to eliminate the risk of private residence treatment system failures or improper maintenance and to protect individuals on a sodium restricted diet, who may be adversely impacted by the ion exchange water systems installed at affected residences near the site. The EPA has proposed this solution, but action has not yet been taken as of the date of publication of this report.

Public Health Action Plan

- The HACE unit in DPH will contact individual well owners to review their specific well water results. Discussions will include their exposures, the status of their wells and filter systems, and recommendations for long-term reduction of exposure, such as connecting to a municipal water system.

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REPORT PREPARATION

This Public Health Assessment/Health Consultation for the Ore Knob Mine NPL site was prepared by the North Carolina Division of Public Health (N.C. DHHS) under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented.

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Appendix A: Figures

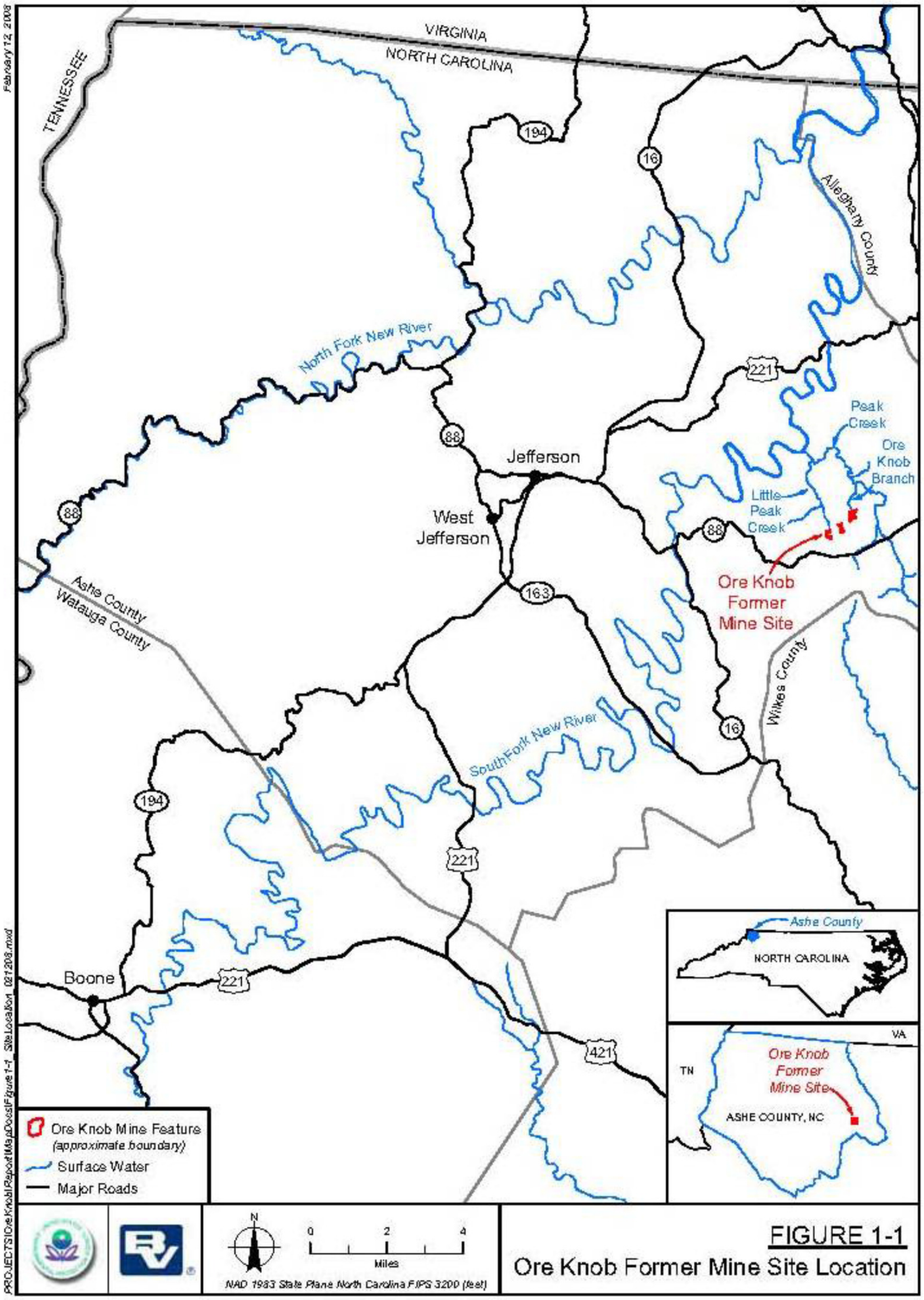

Figure 1. Location of the Ore Knob Mine NPL site, Ashe County, NC, and regional downstream surface waters (ATSDR 2011 PHA). Surface waters depicted here generally flow in a northeastward direction.

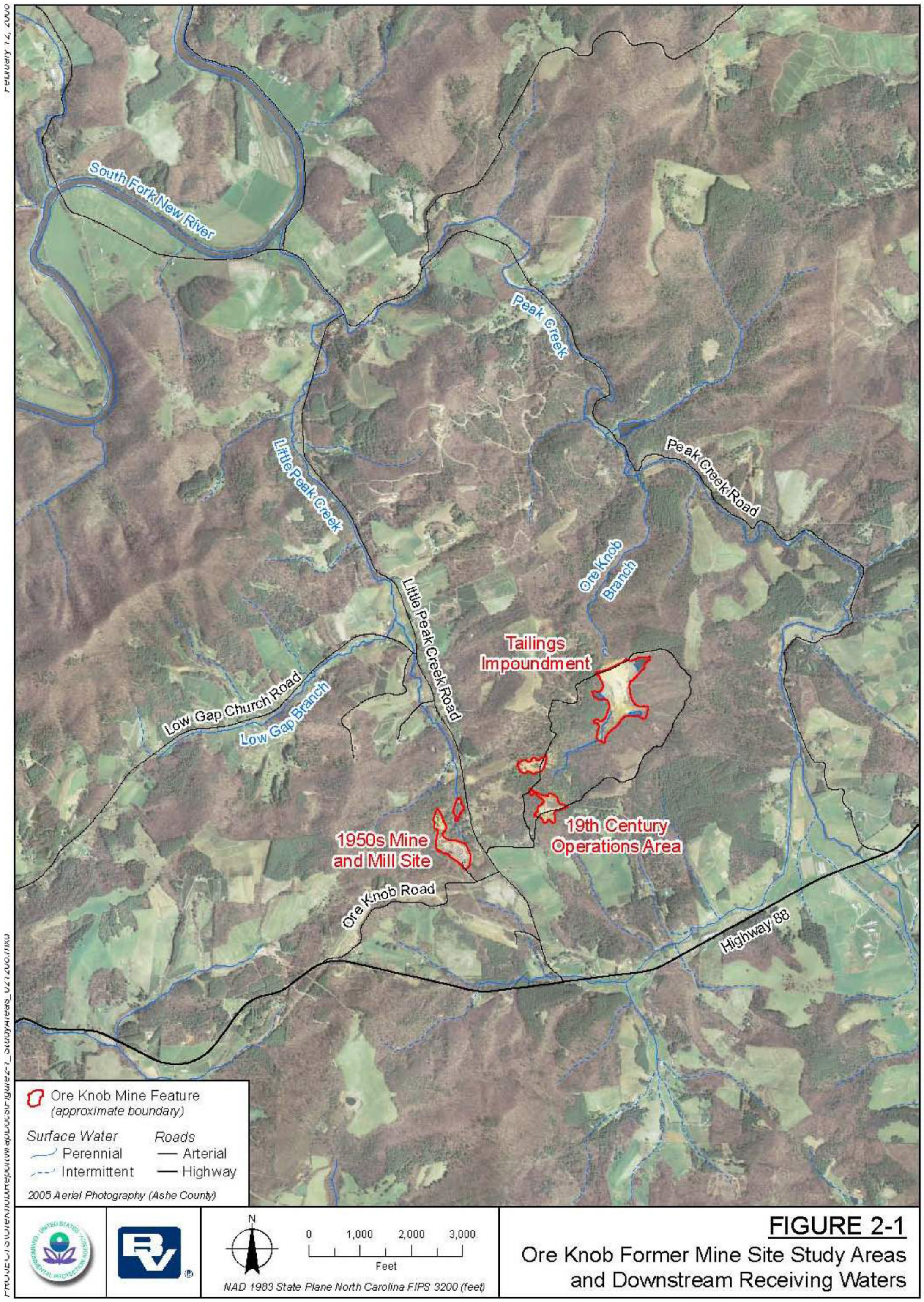

Figure 2. Location of the source areas making up the Ore Knob Mine NPL site and local downstream water surface areas.

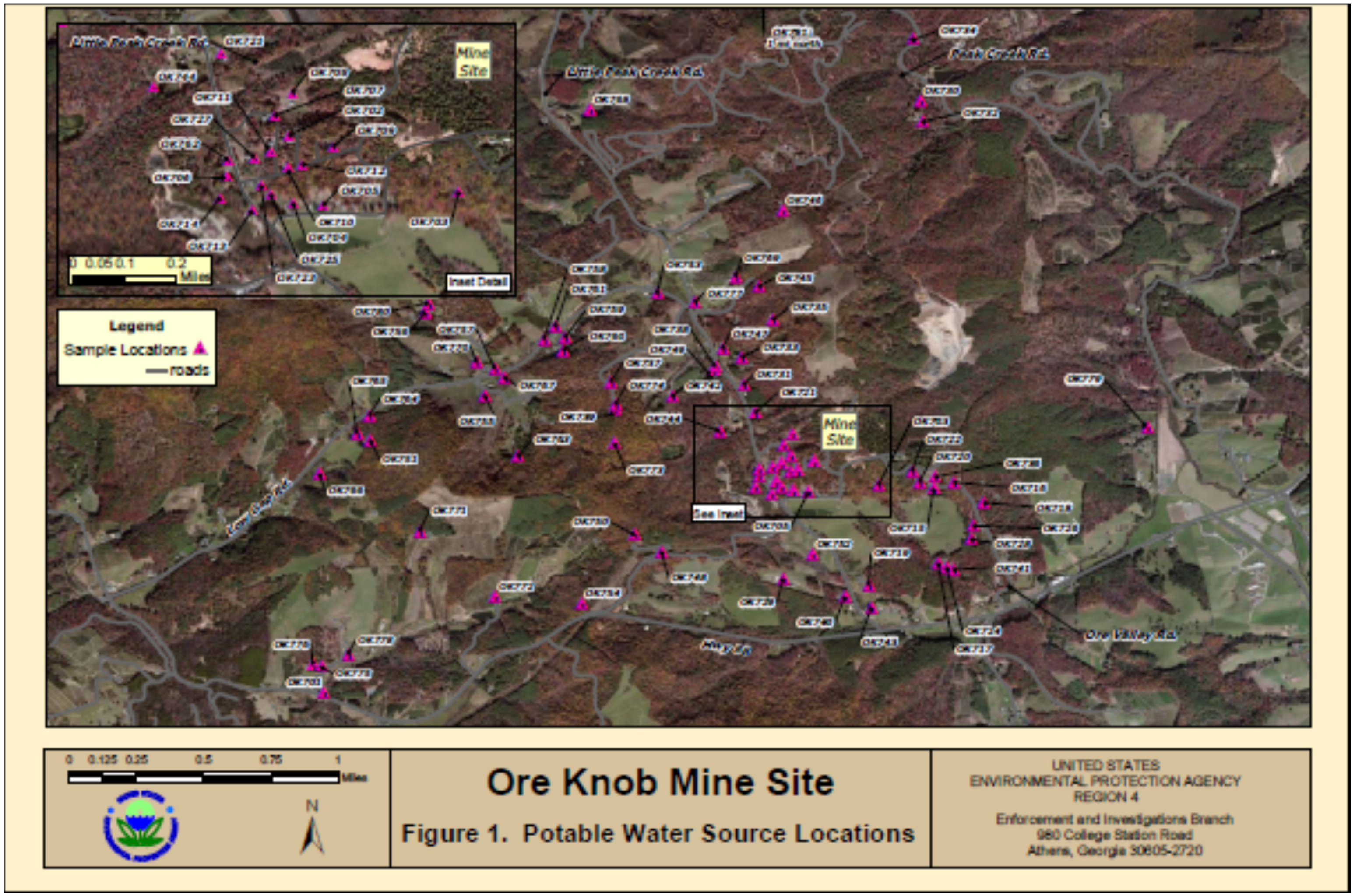

Figure 3. Aerial view of Ore Knob Mine site with locations of sampling stations (EPA 2013a).

Appendix B: Tables -

Table 1. Untreated drinking water sources - data summary and screening value analysis for metals detected in samples collected near the Ore Knob Mine NPL site between 2010 and 2013.

Contaminant	Number of Samples	Number of Detections	No. of Detections Greater than CV	Range of detections (µg/L)	Comparison Values (CV) (µg/L)	Type of CV	Wells in exceedance of CV
Aluminum	112	15	1	42-12000	10000 (child) 35000 (adult)	Chronic EMEG	OK709
Arsenic	112	1	1	1.5	0.023	CREG	OK739
Barium	112	94	0	4.5-130	2000 (child) 7000 (adult)	Chronic EMEG	--
Beryllium	112	3	0	3.6-6.4	20 (child) 70 (adult)	Chronic EMEG	--
Cadmium	112	12	9	0.53-5.1	1 (child) 3.5 (adult)	Chronic EMEG	OK702, OK706, OK709, OK711, OK723, OK727, OK762
Cobalt	112	17	17	9-160	6	EPA RSL	OK702, OK706, OK707, OK709, OK710, OK711, OK723, OK727, OK739, OK750, OK762, OK773, OK774
Copper	112	29	8	11-3800	100 (child) 350 (adult)	Intermediate EMEG	OK706, OK709, OK711, OK723, OK727, OK762
Iron	112	38	21	110-42000	2500	NC DWM / DPH HRE	OK702, OK706, OK708, OK710, OK711, OK712, OK723, OK727, OK738, OK750, OK755, OK761, OK762, OK773, OK774, OK779
Manganese	112	82	19	1.6-18000	500 (child) 1800 (adult)	RMEG	OK702, OK706, OK707, OK709, OK710, OK711, OK712, OK723, OK727, OK739, OK750, OK762, OK773, OK774
Nickel	112	9	0	14-100	200 (child) 700 (adult)	RMEG	--
Selenium	112	6	0	0.32-5.5	50 (child) 180 (adult)	Chronic EMEG	--
Sodium	105	99	2	720-400000	20000	EPA Drinking Water Advisory	OK707, OK748
Strontium	96	87	0	0.6-460	6000 (child) 21000 (adult)	RMEG	--
Zinc	112	77	1	5.8-4900	3000 (child) 11000 (adult)	Chronic EMEG	OK737

Notes: CV = Comparison Value (ATSDR established screening value – March 2015)
CREG = Cancer Risk Evaluation Guide, ATSDR referenced value
EMEG = Environmental Media Evaluation Guide, ATSDR referenced value
RMEG = Reference Dose Media Evaluation Guide, ATSDR referenced value

EPA RSL = U.S. Environmental Protection Agency Regional Screening Levels (January 2015)
NC DWM/DPH HRE = North Carolina Division of Waste Management/Division of Public Health - Health Risk Evaluation (January 2015)
µg/L = micrograms per liter, or "parts per billion" (ppb)

Table 2. Treated drinking water sources - data summary and screening value analysis for metals detected in samples collected near the Ore Knob Mine NPL site between 2010 and 2013.

Contaminant	Number of Samples	Number of Detections	No. of Detections Greater than CV	Range of detections (µg/L)	Comparison Values (CV) (µg/L)	Type of CV	Wells in exceedance of CV
Aluminum	66	6	0	110-1400	10000 (child) 35000 (adult)	Chronic EMEG	--
Arsenic	66	0	0	--	0.023	CREG	--
Barium	66	13	0	0.16-27	2000 (child) 7000 (adult)	Chronic EMEG	--
Beryllium	66	0	0	--	20 (child) 70 (adult)	Chronic EMEG	--
Cadmium	66	6	4	0.56-1.7	1 (child) 3.5 (adult)	Chronic EMEG	OK706, OK727
Cobalt	66	11	10	5-110	6	EPA RSL	OK706, OK711, OK727, OK750, OK774
Copper	66	22	4	11-180	100 (child) 350 (adult)	Intermediate EMEG	OK702, OK706
Iron	66	19	8	100-23000	2500	NC DWM/DPH HRE	OK706, OK711, OK727, OK774
Manganese	66	34	11	1.1-22000	500 (child) 1800 (adult)	RMEG	OK706, OK711, OK727, OK750, OK774
Nickel	66	5	0	14-44	200 (child) 700 (adult)	RMEG	--
Selenium	66	0	0	--	50 (child) 180 (adult)	Chronic EMEG	--
Sodium	68	66	52	3900-250000	20000	EPA Drinking Water Advisory	OK702, OK706, OK707, OK708, OK709, OK710, OK711, OK712, OK719, OK723, OK727, OK739, OK750, OK762, OK774, OK779
Strontium	65	18	0	6.9-340	6000 (child) 21000 (adult)	RMEG	--
Zinc	66	44	2	4.9-7300	3000 (child) 11000 (adult)	Chronic EMEG	OK737

Notes: CV = Comparison Value (ATSDR established screening value – March 2015)
CREG = Cancer Risk Evaluation Guide, ATSDR referenced value
EMEG = Environmental Media Evaluation Guide, ATSDR referenced value
RMEG = Reference Dose Media Evaluation Guide, ATSDR referenced value
EPA RSL = U.S. Environmental Protection Agency Regional Screening Levels (January 2015)

NC DWM/DPH HRE = North Carolina Division of Waste Management/Division of Public Health - Health Risk Evaluation (January 2015)
µg/L = micrograms per liter, or "parts per billion" (ppb)

Table 3. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK702. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Manganese	2.5685 (infant)	0.0171 (infant)	0.050 EPA RfD	Infant YES	Infant NO
	0.6957 (adult)	0.0046 (adult)		Adult YES	Adult NO
Iron	0.7563 (infant)	--	0.70 EPA RfD	Infant YES	Infant NO
	0.2048 (adult)	--		Adult NO	Adult NO
Cadmium	0.0003 (infant)	--	0.0001 ATSDR Chronic Oral MRL	Infant YES	Infant NO
	0.00007 (adult)	--		Adult NO	Adult NO
Cobalt	0.0228 (infant)	--	0.0003 EPA RfD	Infant YES	Infant NO
	0.0062 (adult)	--		Adult YES	Adult NO
Copper	0.0043 (infant)	0.0243 (infant)	0.01 ATSDR Intermediate Oral MRL	Infant NO	Infant YES
	0.0012 (adult)	0.0066 (adult)		Adult NO	Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 4. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK706. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Manganese	1.427 (infant)	1.427 (infant)	0.050 EPA RfD	Infant YES	Infant YES
	0.387 (adult)	0.387 (adult)		Adult YES	Adult YES
Iron	3.425 (infant)	3.282 (infant)	0.70 EPA RfD	Infant YES	Infant YES
	0.928 (adult)	0.889 (adult)		Adult YES	Adult YES
Cadmium	0.0002 (infant)	0.0002 (infant)	0.0001 ATSDR Chronic Oral MRL	Infant YES	Infant YES
	0.00005 (adult)	0.00005 (adult)		Adult NO	Adult NO
Cobalt	0.0137 (infant)	0.0136 (infant)	0.0003 EPA RfD	Infant YES	Infant YES
	0.0037 (adult)	0.0037 (adult)		Adult YES	Adult YES
Copper	0.0257 (infant)	0.0257 (infant)	0.01 ATSDR Intermediate Oral MRL	Infant YES	Infant YES
	0.007 (adult)	0.007 (adult)		Adult NO	Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 5. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK707. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Manganese	0.228 (infant)	--	0.050 EPA RfD	Infant YES	Infant NO
	0.0618 (adult)	--		Adult YES	Adult NO
Cobalt	0.0041 (infant)	--	0.0003 EPA RfD	Infant YES	Infant NO
	0.0011 (adult)	--		Adult YES	Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 6. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK708. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Manganese	0.0728 (infant)	--	0.05 EPA RfD	Infant YES	Infant NO
	0.0197 (adult)	--		Adult NO	Adult NO
Iron	2.14 (infant)	--	0.7 EPA RfD	Infant YES	Infant NO
	0.58 (adult)	--		Adult NO	Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 7. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK709. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Manganese	0.528 (infant)	--	0.05 EPA RfD	Infant YES	Infant NO
	0.143 (adult)	--		Adult YES	Adult NO
Cadmium	0.0007 (infant)	--	0.0001 ATSDR Chronic Oral MRL	Infant YES	Infant NO
	0.0002 (adult)	--		Adult YES	Adult NO
Cobalt	0.0171 (infant)	--	0.0003 EPA RfD	Infant YES	Infant NO
	0.0046 (adult)	--		Adult YES	Adult NO
Copper	0.5422 (infant)	0.0027 (infant)	0.01 ATSDR Intermediate Oral MRL	Infant YES	Infant NO
	0.147 (adult)	0.0007 (adult)		Adult YES	Adult NO
Aluminum	1.7123 (infant)	--	1.0 ATSDR Chronic Oral MRL	Infant YES	Infant NO
	0.464 (adult)	--		Adult NO	Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 8. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK710. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Manganese	0.357 (infant) 0.0966 (adult)	-- --	0.05 EPA RfD	Infant YES Adult YES	Infant NO Adult NO
Iron	1.57 (infant) 0.425 (adult)	-- --	0.7 EPA RfD	Infant YES Adult NO	Infant NO Adult NO
Cobalt	0.002 (infant) 0.0005 (adult)	-- --	0.0003 EPA RfD	Infant YES Adult YES	Infant NO Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 9. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK711. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Manganese	1.299 (infant) 0.352 (adult)	0.228 (infant) 0.0618 (adult)	0.050 EPA RfD	Infant YES Adult YES	Infant YES Adult YES
Iron	5.137 (infant) 1.391 (adult)	0.885 (infant) 0.240 (adult)	0.70 EPA RfD	Infant YES Adult YES	Infant YES Adult NO
Cadmium	0.0003 (infant) 0.00008 (adult)	0.00009 (infant) 0.00002 (adult)	0.0001 ATSDR Chronic Oral MRL	Infant YES Adult NO	Infant NO Adult NO
Cobalt	0.0171 (infant) 0.0046 (adult)	0.0036 (infant) 0.001 (adult)	0.0003 EPA RfD	Infant YES Adult YES	Infant YES Adult YES
Copper	0.0314 (infant) 0.0085 (adult)	0.0087 (infant) 0.0024 (adult)	0.01 ATSDR Intermediate Oral MRL	Infant YES Adult NO	Infant NO Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 10. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK712. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Manganese	0.0999 (infant)	--	0.05 EPA RfD	Infant YES	Infant NO
	0.0271 (adult)	--		Adult NO	Adult NO
Iron	0.9418 (infant)	--	0.70 EPA RfD	Infant YES	Infant NO
	0.255 (adult)	--		Adult NO	Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 11. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK723. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Manganese	1.570 (infant)	--	0.050 EPA RfD	Infant YES	Infant NO
	0.425 (adult)	--		Adult YES	Adult NO
Iron	3.282 (infant)	--	0.70 EPA RfD	Infant YES	Infant NO
	0.889 (adult)	--		Adult YES	Adult NO
Cadmium	0.0002 (infant)	--	0.0001 ATSDR Chronic Oral MRL	Infant YES	Infant NO
	0.00006 (adult)	--		Adult NO	Adult NO
Cobalt	0.0143 (infant)	--	0.0003 EPA RfD	Infant YES	Infant NO
	0.0039 (adult)	--		Adult YES	Adult NO
Copper	0.0499 (infant)	--	0.01 ATSDR Intermediate Oral MRL	Infant YES	Infant NO
	0.0135 (adult)	--		Adult YES	Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 12. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK727. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Manganese	1.370 (infant) 0.371 (adult)	3.139 (infant) 0.850 (adult)	0.050 EPA RfD	Infant YES Adult YES	Infant YES Adult YES
Iron	5.993 (infant) 1.623 (adult)	1.0845 (infant) 0.294 (adult)	0.70 EPA RfD	Infant YES Adult YES	Infant YES Adult NO
Cadmium	0.0005 (infant) 0.0001 (adult)	0.0002 (infant) 0.00007 (adult)	0.0001 ATSDR Chronic Oral MRL	Infant YES Adult YES	Infant YES Adult NO
Cobalt	0.0214 (infant) 0.0058 (adult)	0.0157 (infant) 0.0043 (adult)	0.0003 EPA RfD	Infant YES Adult YES	Infant YES Adult YES
Copper	0.0243 (infant) 0.0066 (adult)	0.0017 (infant) 0.0005 (adult)	0.01 ATSDR Intermediate Oral MRL	Infant YES Adult NO	Infant NO Adult NO
Zinc [a]	0.328 (infant) 0.0889 (adult)	0.285 (infant) 0.0773 (adult)	0.30 ATSDR Chronic Oral MRL	Infant YES Adult NO	Infant NO Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

a. The comparison value was not exceeded for this metal at this site, but the maximum estimated exposure dose exceeds the health guideline

Table 13. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK737. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Zinc	0.699 (infant) 0.189 (adult)	1.042 (infant) 0.282 (adult)	0.30 ATSDR Chronic Oral MRL	Infant YES Adult NO	Infant YES Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 14. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK738. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Iron	0.485 (infant)	--	0.7 EPA RfD	Infant NO	Infant NO
	0.131 (adult)	--		Adult NO	Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 15. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK739. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Manganese	0.557 (infant)	0.0214 (infant)	0.05 EPA RfD	Infant YES	Infant NO
	0.152 (adult)	0.0058 (adult)		Adult YES	Adult NO
Cobalt	0.0013 (infant)	--	0.0003 EPA RfD	Infant YES	Infant NO
	0.0003 (adult)	--		Adult YES	Adult NO
Arsenic	0.0002 (infant)	--	0.0003 ATSDR Chronic Oral MRL	Infant NO	Infant NO
	0.00006 (adult)	--		Adult NO	Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 16. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK750. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Manganese	1.127 (infant)	0.0813 (infant)	0.05 EPA RfD	Infant YES	Infant YES
	0.305 (adult)	0.022 (adult)		Adult YES	Adult NO
Iron	5.850 (infant)	0.457 (infant)	0.70 EPA RfD	Infant YES	Infant NO
	1.585 (adult)	0.124 (adult)		Adult YES	Adult NO
Cobalt	0.0081 (infant)	0.0007 (infant)	0.0003 EPA RfD	Infant YES	Infant YES
	0.0022 (adult)	0.0002 (adult)		Adult YES	Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 17. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK755. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Iron	0.499 (infant)	--	0.70 EPA RfD	Infant NO	Infant NO
	0.135 (adult)	--		Adult NO	Adult NO
Copper [a]	0.0103 (infant)	--	0.01 ATSDR Intermediate Oral MRL	Infant YES	Infant NO
	0.0028 (adult)	--		Adult NO	Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

a. The comparison value was not exceeded for this metal at this site, but the maximum estimated exposure dose exceeds the health guideline

Table 18. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK761. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Iron	0.528 (infant)	--	0.70 EPA RfD	Infant NO	Infant NO
	0.143 (adult)	--		Adult NO	Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 19. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK762. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Manganese	1.313 (infant)	0.0107 (infant)	0.050 EPA RfD	Infant YES	Infant NO
	0.356 (adult)	0.0029 (adult)		Adult YES	Adult NO
Iron	4.709 (infant)	0.0428 (infant)	0.70 EPA RfD	Infant YES	Infant NO
	1.276 (adult)	0.0116 (adult)		Adult YES	Adult NO
Cadmium	0.0001 (infant)	--	0.0001 ATSDR Chronic Oral MRL	Infant YES	Infant NO
	0.00004 (adult)	--		Adult NO	Adult NO
Cobalt	0.0171 (infant)	--	0.0003 EPA RfD	Infant YES	Infant NO
	0.0046 (adult)	--		Adult YES	Adult NO
Copper	0.0143 (infant)	0.0044 (infant)	0.01 ATSDR Intermediate Oral MRL	Infant YES	Infant NO
	0.0039 (adult)	0.0012 (adult)		Adult NO	Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 20. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK773. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	Treated		Untreated	Treated
Manganese	0.7135 (infant)	-	0.05 EPA RfD	Infant YES	Infant NO
	0.193 (adult)	-		Adult YES	Adult NO
Iron	0.585 (infant)	-	0.70 EPA RfD	Infant NO	Infant NO
	0.159 (adult)	-		Adult NO	Adult NO
Cobalt	0.0039 (infant)	-	0.0003 EPA RfD	Infant YES	Infant NO
	0.001 (adult)	-		Adult YES	Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 21. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK774. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Untreated	Treated		Untreated	Treated
Manganese	1.085 (infant)	1.998 (infant)	0.05 EPA RfD	Infant YES	Infant YES
	0.294 (adult)	0.541 (adult)		Adult YES	Adult YES
Iron	3.995 (infant)	1.998 (infant)	0.70 EPA RfD	Infant YES	Infant YES
	1.082 (adult)	0.541 (adult)		Adult YES	Adult NO
Cobalt	0.0043 (infant)	0.0059 (infant)	0.0003 EPA RfD	Infant YES	Infant YES
	0.0012 (adult)	0.0016 (adult)		Adult YES	Adult YES

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value); HG = health guideline

Table 22. Maximum calculated exposure doses relative to health guideline values for metals with concentrations greater than comparison values at OK779. Infant doses were calculated for bottle-fed babies aged birth to < 1 year. Adults were defined as persons ≥ 21 years old.

Contaminant	Calculated max exposure dose (mg/kg/day)		Health guideline / Type (non-cancer) (mg/kg/day)	Does calculated maximum exposure dose exceed HG?	
	Untreated	**Treated**		**Untreated**	**Treated**
Iron	0.385 (infant) 0.104 (adult)	0.0371 (infant) 0.01 (adult)	0.70 EPA RfD	Infant NO Adult NO	Infant NO Adult NO

Note: Untreated refers to source water without filtration or treatment; Treated denotes drinking water after filter or treatment system; mg/kg/day = milligrams of compound per kilogram of body weight per day; EPA = U.S. Environmental Protection Agency; ATSDR = Agency for Toxic Substances and Disease Registry; RfD = reference dose; MRL = minimal risk level; -- = Not detected (Detection limits below comparison value): HG = health guideline

Table 23. ATSDR health effects study data values used for evaluation of site-specific exposure dose estimates for determination of the potential for adverse health effects. Note: No ATSDR Toxicological Profile exists for iron.

Contaminant of Concern	Health Effect Dose (mg/kg/day)	Notes	Reference
Cadmium (Cd)	Chronic Oral Exposures - Human		ATSDR 2012 Cd
	0.0003	NOAEL - female renal effects	
	0.0021	NOAEL - female renal effects - lifetime exposure	
	0.0078	NOAEL - hematological/musculoskeletal/renal effects - >25 years lifetime exposure	
Cobalt (Co)	Intermediate Oral Exposures - Human		ATSDR 2004 Co
	0.07	LOAEL - cardiomyopathy	
	0.04	LOAEL - cardiomyopathy/edema/vomiting/liver necrosis	
Copper (Cu)	Intermediate Oral Exposures - Human		ATSDR 2004 Cu
	0.042	NOAEL - gastrointestinal effects - daily for 2 months	
	0.091	LOAEL - gastrointestinal effects - daily for 2 months	
	0.14	NOAEL - gastrointestinal effects - 12 weeks	
Manganese (Mn)	Chronic Oral Exposures - Human		ATSDR 2012 Mn
	0.0048	NOAEL - neurological effects - 50 year exposure	
	0.059	LOAEL - mild neurological effects - 50 year exposure	
	0.04	NOAEL - reduced performance on IQ, performance and verbal tests in children - 10 year exposure	
	0.07	LOAEL - reduced performance on IQ, performance and verbal tests in children - 10 year exposure	
	0.26	LOAEL - increased infant fatality - ≤1 year exposure	
Zinc (Zn)	Chronic Oral Exposures - Human		ATSDR 2005 Zn
	1.43	LOAEL - male increased probability of prostate cancer - 1+ years exposure	
	Intermediate Oral Exposures - Human		
	0.68	NOAEL - female hematological effects - 90 day exposure	
	0.71	NOAEL - cardiovascular effects - 24 week exposure	
	0.83	NOAEL - female hematological effects - 10 week exposure	
	2	LOAEL - abdominal cramps, vomiting, nausea - 6 week exposure	
Beta-Hexachlorocyclohexane (Beta-BHC)	Chronic Oral Exposures - No Human Data		ATSDR 2005 BHC
	0.8	NOAEL - female rat body weight - 107 week exposure	
	8	LOAEL - female rat decreased body weight - 107 week exposure	

	0.8	LOAEL - female rat hepatic effects - 107 week exposure	
	34	LOAEL - mouse hepatocellular carcinoma - 104 week exposure	

Notes: NOAEL = No Observed Adverse Effects Level
LOAEL = Lowest Observed Adverse Effects Level

Appendix C: Equations and exposure parameters

All equations used to estimate exposure dose for exposure to contaminants associated with the Ore Knob Mine NPL are shown below. These equations can be found in the ATSDR Public Health Assessment Guidance Manual (ATSDR 2005). Population-specific values used (ingestion rate and body weight) are consistent with ATSDR guidance (ATSDR 2014a, ATSDR 2014b).

Ingestion of contaminants present in drinking water

Exposure doses for ingestion of contaminants present in drinking water are calculated using the measured concentrations of contaminants in milligrams per liter (mg/L). The following equation is used to estimate the exposure doses resulting from ingestion of contaminated drinking water:

$$ED_w = \frac{C \times IR \times EF}{BW}$$

Where:

ED_w = exposure dose water (mg/kg/day)
C = contaminant concentration (mg/L)
IR = intake rate of contaminated medium (liters/day)
EF = exposure factor (unitless) = 1 for drinking water consumed daily
BW = body weight (kilograms)

Note: For this assessment, the following values were used:

Age group	Water Ingestion Rate (L/day)[a]	Body weight (kg)
Birth to <1 year	1.113	7.8
1 to <2 year	0.893	11.4
2 to <6 year	0.977	17.4
6 to <11 year	1.404	31.8
11 to <16 year	1.976	56.8
16 to <21 year	2.444	71.6
≥21 year	3.092	80

Note: L/day = liters of water per day; kg = kilograms

a. 95^{th} percentile used for age range per ATSDR guidance document (ATSDR 2014a)

Cancer Health Effect Evaluations

Theoretical increased numbers of cancers are calculated for known or suspected cancer-causing contaminants using the estimated site-specific exposure dose and cancer slope factor (CSF) provided in ATSDR health guideline documents. N.C. DPH evaluates cancer health effects in terms of possible increased cancer risk over background levels. In North Carolina, approximately 30% of women and 50% of men (about 40% combined), will be diagnosed with cancer in their life-time from a variety of causes. This is referred to as the "background cancer risk". The term "excess cancer risk" represents the risk on top of the background cancer risk. A "one-in-a-million" excess cancer risk (1/1,000,000 or 10^{-6} cancer risk) means that if 1,000,000 people are exposed to the cancer-causing substance at a certain level every day of their life-time (considered 78 years), then one cancer above the background number of cancers may develop in those 1 million people. In numerical terms, the background number of cancers expected in 1 million people over their life-time is 40% or 400,000. If they are all exposed to the cancer-causing substance daily throughout their life-time, then 400,001 people may get cancer, instead of the expected 400,000. The expression of the estimated cancer risk is not a prediction that cancer will occur, it represents the upper bound estimate of the probability of additional cancers, and merely suggests that there is a possibility. The actual risk may be much lower, or even no risk.

The estimated cancer risk calculation is:

Estimated Cancer Risk = Dose x CSF

Where:

Estimated Cancer Risk = Expression of the cancer risk (unitless)
Dose = Site-specific dose of carcinogen (mg/kg/day)
CSF = Cancer Slope Factor ($[mg/kg/day]^{-1}$), a measure of cancer potency

This calculation is based on the assumption that there is no safe level of exposure to a chemical that causes cancer. However, the calculated risk estimate is not exact and tends to overestimate the actual risk associated with exposures that may have occurred. This increased cancer risk estimate does not equal the increased number of cancer cases that will actually occur in the exposed population, but estimates an excess cancer risk expressed as the proportion of a population that may be affected by a carcinogen during a lifetime or other selected period of exposure. Qualitative assessment of the predicted increased numbers of cancers is also used and represents terminology suggested by ATSDR and N.C. DPH.

For specific exposure situations N.C. DPH may use exposure periods of less than a life-time to provide a more realistic estimation of the risks that are known or predicted to have occurred for a particular area. If information on the specifics of the exposure situations at a particular site is not known, then N.C. DPH will always use health protective values to estimate the maximum level of risk that we believe to be realistic. For this HC, residency was assumed to start at birth to estimate maximum exposure doses and last for 33 years (95^{th} percentile residential occupancy period) out of a lifetime of 78 years (ATSDR exposure dose guidance life expectancy). Exposure was assumed to occur daily for the length of the residency.

Appendix D – Glossary of Terms and Abbreviations

Acute
Occurring over a short time [compare with chronic].

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems

Cancer risk
A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Cancer Risk Evaluation Guide (CREG)
Media-specific comparison values that are used to identify concentration of cancer-causing substances that are unlikely to result in an increase of cancer rates in an exposed population.

Cancer Slope Factor (CSF)
An upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime exposure to an agent. This estimate, usually expressed in units of proportion (of a population) affected per mg/kg/day, is generally reserved for use in the low-dose region of the dose-response relation, that is, for exposures corresponding to risks less than 1 in 100.

Carcinogen
A substance that causes cancer.

Chronic
Occurring over a long time [compare with acute].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Comparison Value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause 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.

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.

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 and transport mechanism
Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

Environmental Media Evaluation Guide (EMEG)
Concentrations of substance in water, soil, and air to which humans may be exposed during a specified period of time without experiencing adverse health effects. Developed using ATSDR MRL values and may therefore refer to acute, intermediate, or chronic exposure, depending on the MRL used.

EPA
United States Environmental Protection Agency.

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 assessment
The process of finding out how people come into contact with a hazardous substance, how often and

for how long they are in contact with the substance, and how much of the substance they are in contact with.

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: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Health Guidelines
Substance-specific doses or concentrations derived using toxicological information. (ex: minimal risk levels (MRLs) or reference doses (RfDs)).

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].

Intermediate duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

L/day
Liter per day. Unit used to express drinking water ingestion.

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.

mg/kg/day
Milligram of substance per kilogram of body weight per day. Unit used to express exposure dose.

mg/L
Milligram (substance) per liter (water). Unit used to express contaminant concentration in water. 1 mg/L = 1000 µg/L.

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 [see reference dose].

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).

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Reference Dose Media Evaluation Guide (RMEG)
Concentrations of substances in water, soil, and air to which humans may be exposed without experiencing adverse health effects. Developed using EPA reference dose or reference concentration values, and therefore apply to chronic exposures.

Regional Screening Level (RSL)
Chemical-specific concentrations for individual contaminants in air, drinking water, and soil that may warrant further investigation or site cleanup. The SLs may be site-specific concentrations for individual chemicals in soil, air, water and fish. It should be emphasized that SLs are not cleanup standards.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

µg/L
Microgram (substance) per liter (water). Unit used to express contaminant concentration in water. 1000 µg/L = 1 mg/L.

Greetings,

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Completing the survey should take less than 5 minutes of your time. If possible, please provide your responses within the next two weeks. All information that you provide will remain confidential.

The responses to the survey will help ATSDR determine if we are providing useful and meaningful information to you. ATSDR greatly appreciates your assistance as it is vital to our ability to provide optimal public health information.

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