Health Consultation

Assessment of exposure to heavy metals in sediment at Tibble Fork Reservoir

Tibble Fork Reservoir
Utah County, Utah

Prepared by
Utah Department of Health and Human Services

March 2023

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

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. 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 healthcare 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.

You may contact the Utah Department of Health and Human Service Environmental Epidemiology Program at

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Foreword

The Utah Department of Health and Human Services (DHHS) prepared this health consultation in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the U.S. Department of Health and Human Services and is the principal federal public health agency responsible for health issues related to hazardous waste. This health consultation was prepared in accordance with methodologies and guidelines developed by ATSDR.

The purpose of this health consultation is to identify and prevent harmful human health effects which result from exposure to hazardous substances in the environment. Health consultations focus on specific health issues so DHHS can respond to requests from concerned residents or agencies for health information about hazardous substances. DHHS evaluates sampling data collected from a hazardous site, determines whether exposures have occurred or could occur, reports any potential harmful effects, and recommends actions to protect public health. The findings in this report are relevant to conditions at the site during the time of this health consultation and should not necessarily be relied upon if site conditions or land use changes in the future. For additional information or questions regarding DHHS or the contents of this health consultation, please call the health assessor who prepared this document:

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1. Summary

The Utah Department of Health and Human Services (DHHS) Environmental Epidemiology Program (EEP), as part of a cooperative agreement with the Agency for Toxic Substance and Disease Registry (ATSDR), prepared this health consultation at the request of the Utah Department of Environmental Quality (UDEQ), to evaluate the human health risks due to exposure to sediment contaminated with heavy metals at Tibble Fork Reservoir in Utah County.

On August 20, 2016, an accidental sediment release occurred during rehabilitation work on an earthen dam which released sediment contaminated with heavy metals into the North Fork of the American Fork River. To respond to concerns from UDEQ and the community regarding health effects from exposure to contaminated sediment while recreating, the EEP requested UDEQ conduct investigative sampling of sediments from Tibble Fork Reservoir to fill data gaps identified previously. Samples were collected in October of 2018 and analyzed for 11 heavy metals (antimony, arsenic, cadmium, copper, iron, lead, manganese, mercury, nickel, silver, and zinc).

This public health assessment focuses on recreational users who may come in contact with heavy metals found in beach sediment and/or lake bottom sediment. UDEQ provided DHHS EEP with data collected in 2018 to assess the public health risks associated with the site.

Conclusion 1	EEP concludes that touching or accidentally eating heavy metals in sediment from recreational exposure (i.e., swim, paddle board, kayak, beach comb, etc.) at Tibble Fork Reservoir is not expected to harm people's health because levels in sediment are below levels of health concern.
Basis for Decision	People may come in contact with contaminated sediment while recreating at Tibble Fork Reservoir. Children may be exposed to heavy metals in soil by putting their soiled fingers in their mouths. In addition, adults may be exposed to heavy metals by unintentionally eating or swallowing sediment during reactional activities. Arsenic exceeded screening levels, however, EEP estimated exposure doses and found that they are well below levels known to result in harmful health effects for adults and children who regularly recreate at Tibble Fork Reservoir. Additionally, the highest levels of arsenic where in areas not regularly accessed by the public.
Next Steps	If future environmental data reveal potential health hazards not addressed in this report, EEP will address them in a separate assessment.
For More Information	Call the Utah Department of Health and Human Services at (801) 538-6191 and ask for information about the Tibble Fork Reservoir assessment or email APPLETREE@utah.gov.

2. Background

2.1. Site Description and History

Tibble Fork Reservoir is a 22-acre freshwater lake located in American Fork Canyon approximately 13 miles east of American Fork in Utah County (Figure 1). It is fed by the American Fork River, Deer Creek, and Tibble Fork Creek and is a popular recreation area to hike, fish, boat, and swim. Historic mining activities in the area led to contamination of heavy metals in the streams that feed into Tibble Fork Reservoir. Discharged mine effluent and seepage from tailings and waste rock impoundments are a major source of heavy metal pollution in surface waters. Mine drainage is metal-rich water formed from a chemical reaction between water and rocks containing sulfur-bearing minerals which creates sulfuric acid and iron. The resulting acid mine runoff further dissolves heavy metals such as copper, lead, and mercury into groundwater or surface water. There are approximately 350 mines in Utah County (USGS, 2020). The Yankee and Globe lead and zinc mines are upstream from Tibble Fork Reservoir in addition to several other abandoned gold and silver mines. Elevated levels of heavy metals from historic mining activity have been found in the reservoir sediment, but have not been typically found in the reservoir waters (UT DEQ, 2019).

On August 20, 2016, as part of a dam-rehabilitation project on the Tibble Fork Reservoir, crews began draining the lake which triggered an unexpected large release of sediment into the North Fork of the American Fork River. An estimated 5,100 cubic yards of contaminated sediment was released into the American Fork River. As part of the $7.3 million rehabilitation project a sandy beach was built on the north shore of the lake for visitors. The release of the sediment increased public awareness and concern of heavy metals at Tibble Fork Reservoir. Members of the public have expressed concern that the contaminated sediment poses a health risk to people who use the reservoir for recreation.

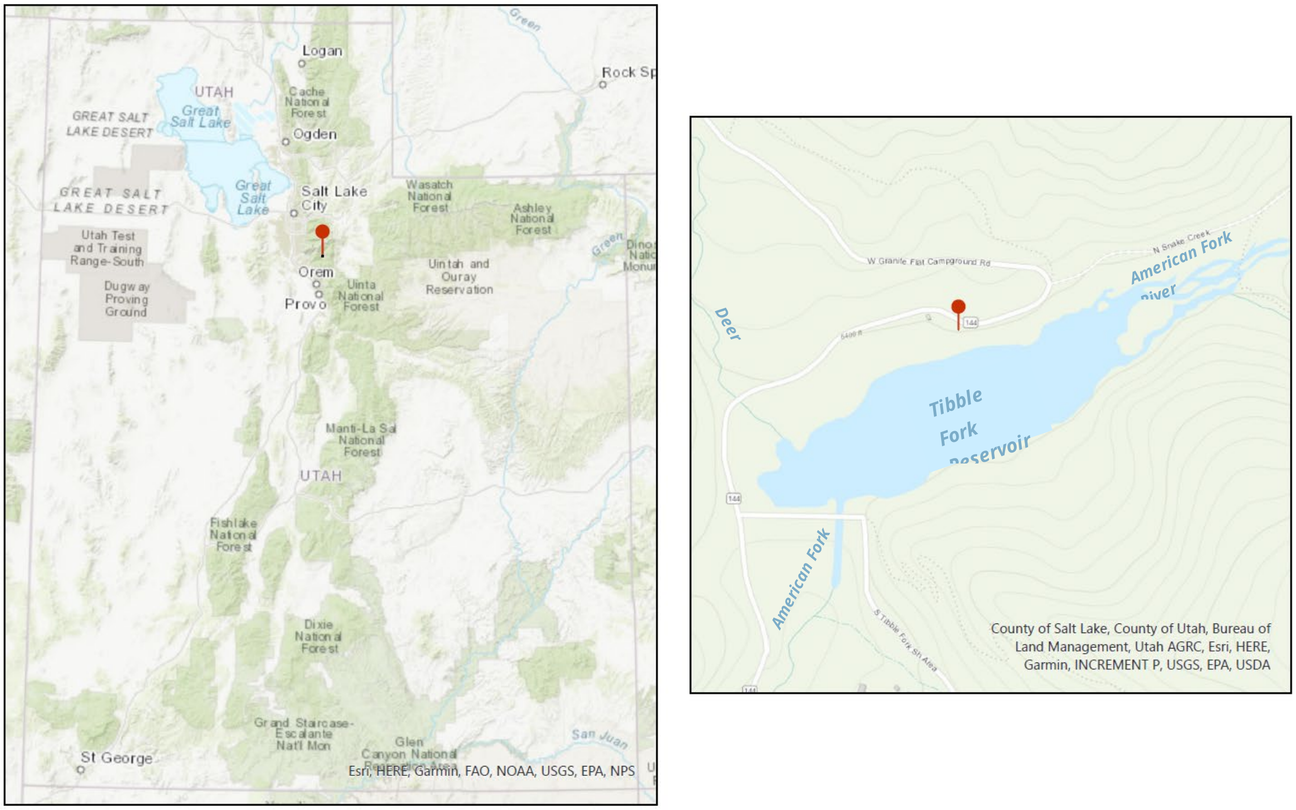

Figure 1. Map of Tibble Fork Reservoir in Utah County, Utah.

2.1.1. Site Visit

On August 25, 2018, Utah APPLETREE visited Tibble Fork Reservoir during a high use time (mid-afternoon on a Saturday) to take photographs and assess the frequency and types of use. Utah APPLETREE staff examined the beach and day use area, observed recreational activities, and hiked around the circumference of the reservoir to identify other areas of frequent use. Several children were observed digging and playing in the sand and sediment on the beach and shallow water. Paddle boards and kayaks were very popular among adults, including in the shallow sections of the water which stirred up significant sediment and required them to exit the watercrafts. While a layer of sand was placed on the more utilized western half of the beach, the sand was already washing away, and underlying sediment was visible in places. The eastern portion of the beach was bare sediment with no added sand.

3. Sampling Data

The data used in this evaluation consists of sediment data collected on October 24, 2016, by the UDEQ Division of Water Quality (DWQ). A total of nine sediment samples from Tibble Fork Reservoir were collected near the sandy beach area, where recreators were most likely to come in contact with contaminated sediment, and near the inlet where the North Fork of the American Fork River enters the reservoir (Figure 2). Beach samples were collected from the midpoint in beach areas, while shoreline samples were collected approximately 5–6 feet from the water's edge in water that was roughly 2–3 feet deep. Samples were analyzed by Environmental Protection Agency (EPA) Method

SW6020B for 11 heavy metals including antimony, arsenic, cadmium, copper, iron, lead, manganese, mercury, nickel, silver, and zinc. Heavy metals were selected based on a 2010 report from UDEQ where elevated concentrations were detected in sediment sample cores. The complete sediment data results are shown in Tables A1—11 in Appendix A.

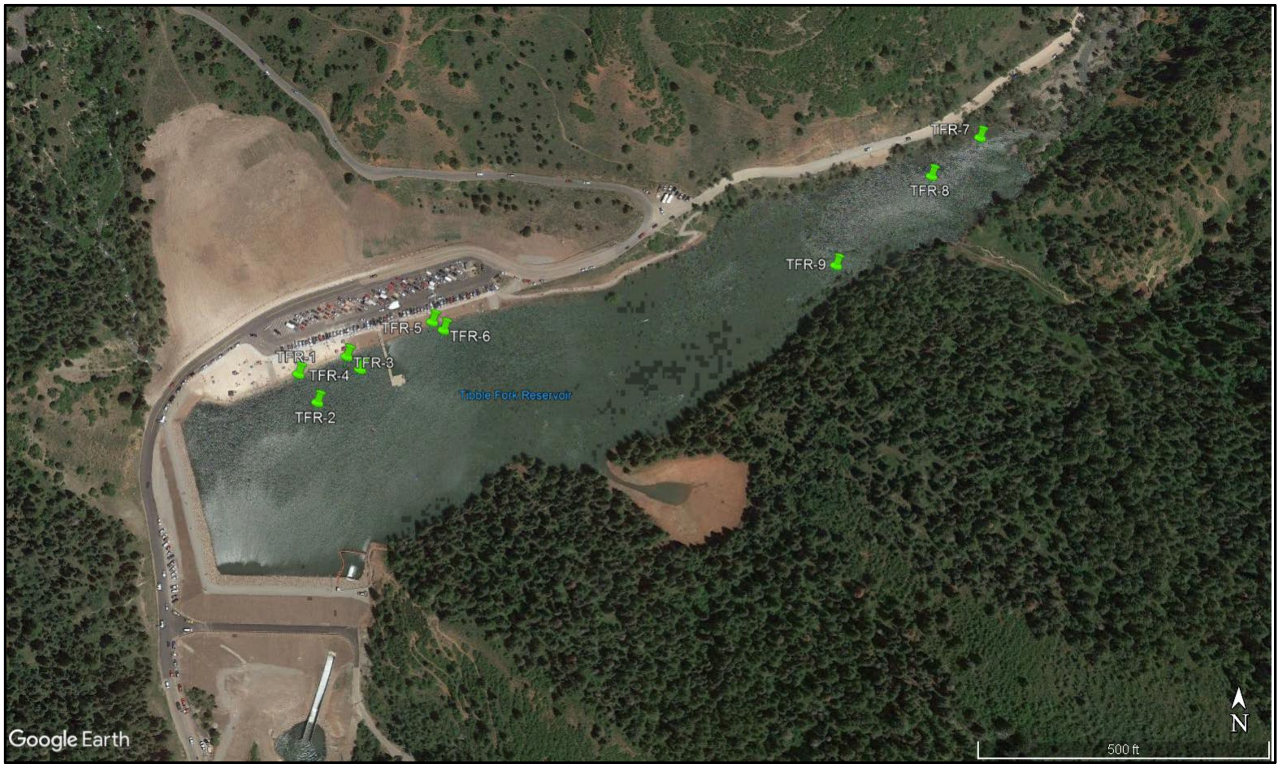

Figure 2. Sediment sampling locations in Tibble Fork Reservoir (DWQ, 2018).

4. Scientific Evaluations

4.1. Exposure Pathways Analysis

A conceptual site model helps visualize how contaminants of potential concern (COCs) move through the environment at the site and how people might come in contact with them by identifying the five components of an exposure pathway. An exposure pathway is the path a contaminant takes from its environmental release or source to the point where people might come in contact with, or be exposed to, the contaminant. EEP evaluates each pathway at a site to determine whether all five components exist, and if people are being exposed, were exposed, or may be exposed in the future (ATSDR, 2005). These five elements must exist for a person to be exposed to a contaminant:

(1) a source of contamination

(2) transport through an environmental medium

(3) a point of exposure

(4) a route of human exposure, and

(5) an exposed population.

Exposure pathways can be classified as either *completed*, *potential*, or *eliminated*. In a *completed* exposure pathway, all five elements exist and indicate that exposure to a contaminant has occurred in the past, is occurring, or will occur in the future. In a *potential* exposure pathway, at least one of the five elements has not been confirmed, but it may exist. Exposure to a contaminant may have occurred in the past, may be occurring, or may occur in the future. An exposure pathway can be eliminated if at least one of the five elements is missing and will never be present (ATSDR, 2005). Recreational users are considered the receptor population for this health consultation. The conceptual site model for exposure to heavy metals at Tibble Fork by recreational users is detailed in Table 1.

Table 1. Conceptual site model of exposure pathways for heavy metals from Tibble Fork Reservoir.

Source	Environmental medium	Exposure point	Exposure route*	Exposed population	Time frame	Status
Contaminated sediment release	Sediment	Tibble Fork Reservoir beach area and shoreline	• Incidental ingestion • Dermal	People recreating near beach including: anglers, swimmers, and beachgoers	Past	Complete
					Current	Complete
					Future	Complete
Contaminated sediment release	Surface water	Tibble Fork Reservoir	• Incidental ingestion • Dermal	People recreating in water including: swimmers, kayakers, and paddle boarders	Past	Complete
					Current	Complete
					Future	Complete

*NOTE: Dermal exposure to most metals in surface water and sediment is considered an insignificant exposure pathway and is not quantitatively evaluated in this health consultation.

4.2. Sediment Evaluation

4.2.1. Screening Analysis

4.2.1.1. Surface Water

Two primary routes of exposure to surface water exist: 1) incidental (accidental) ingestion of surface water during swimming/wading, and 2) dermal (skin) exposure to contaminants while swimming/wading. Water samples were collected from the American Fork River by UDEQ in 2017 following the sediment release (UT DEQ, 2017). Total metal concentrations in all water quality samples were below the recreational screening values for all metals. Additionally, dermal exposure to metal-contaminated surface water is considered a relatively insignificant exposure pathway since metals do not generally penetrate the skin barrier and enter the body, thus, exposure to heavy metals in water was not quantitatively evaluated in this assessment.

4.2.1.2. Sediment

Sediment soil is the environmental medium under consideration in this health consultation through two possible routes of exposure: 1) incidental (accidental) ingestion and 2) dermal (skin) contact with sediment. Incidental ingestion of sediment is the primary route of exposure and can occur along the shoreline or beach area and while swimming/wading. Dermal contact is not considered a relevant exposure pathway for metal-contaminated sediment due to the limited ability of metal contaminants to cross the skin barrier and enter the bloodstream. Therefore, dermal exposure was not quantitatively addressed in this evaluation.

The contaminants of concern for this health consultation were 11 heavy metals including antimony, arsenic, cadmium, copper, iron, lead, manganese, mercury, nickel, silver, and zinc. Maximum concentrations of each heavy metal were screened against health-based comparison values (CVs) to determine which were potential contaminants of concern and required further evaluation. A health-based CV is an estimate of daily human exposure to a chemical that is not likely to result in harmful health effects over a specified exposure duration. These health-based guidelines are conservative levels of protection, however, exceeding a CV does not necessarily mean that harmful effects will occur. Contaminants exceeding CVs require a complete review of the site-specific exposure estimates to better understand if harmful effects could come from exposure at a specific site. Table A-12, in Appendix A, provides a list and description of the health-based CVs used in this assessment. Table 2 shows the results of the environmental screening analysis.

In general, low levels of heavy metals were detected in sediment samples. The highest concentrations were found at sampling sites near the inlet of the American Fork River where it enters the reservoir (sample sites TFR 7–9, see Figure 2). Arsenic was the only contaminant that exceeded ATSDR's screening value and was selected for further evaluation. Current research shows there is no safe level of lead, however, the maximum concentration for lead was below the EPA regional screening level (RSL) for residential soil of 400 parts per million (ppm).

In August 2010, as part of an environmental assessment for the dam rehabilitation, the environmental consulting company, AMEC, performed a bathymetric survey of the bottom of Tibble Fork Reservoir. During this assessment six core samples of sediment were collected and analyzed for heavy metals to determine baseline concentrations of metals expected to be present in the reservoir sediment. Mean concentrations of metals in sediment data collected in 2010 were greater than or comparable to levels in sediments samples from 2018 (see Figure A–1 in Appendix A).

Table 2. Sediment sample results for 11 heavy metals (ppm)[a] from Tibble Fork Reservoir collected in October 2018 compared to soil screening values.

Contaminant	Minimum concentration (ppm)	Maximum concentration (ppm)	Mean concentration (ppm)	Comparison value (ppm)	Source for comparison value (CV)[c]
Antimony	< 0.839 [b]	6.99	2.71	21	ATSDR RMEG child
Arsenic	3.07	36.5	14.9	16	ATSDR Chronic EMEG child
Cadmium	< 0.597 [b]	4.48	1.79	5.2	ATSDR Chronic EMEG child
Copper	< 15.7 [b]	44.8	28.4	520	ATSDR Intermediate EMEG child
Iron	3290	24,400	11,703	55,000	EPA child RSL
Lead[d]	3.2	200	67.1	400	EPA RSL
Manganese	72.8	626	302	1,900	EPA child RSL
Mercury	< 0.0379 [b]	0.219	0.0939	100	ATSDR Intermediate EMEG child
Nickel	< 21[b]	< 40.5[b]	30.0	1,000	RMEG child
Silver	< 0.315[b]	0.908	0.556	260	RMEG child
Zinc	< 19.6[b]	567	186	16,000	Chronic EMEG child

Shaded values: Contaminant level exceeds at least one non-pica child CV.
[a]All results are reported in parts per million sediment (ppm).
[b]Minimum concentrations are below the practical quantitation limit (PQL).
[c]The CV listed is the lowest non-cancer CV; cancer risk for arsenic is assessed in the Public Health Evaluation section.

ATSDR = Agency for Toxic Substances and Disease Registry
EPA = Environmental Protection Agency
EMEG = Environmental Media Evaluation Guide
RMEG = Reference Dose Media Evaluation Guide
RSL = U.S. EPA Regional Screening Level
NA = Not applicable

[d]No ATSDR health-based CV exists for screening lead in soils because there is no clear threshold for health effects associated with lead exposures.

4.2.2. Evaluation of Ingestion

4.2.2.1. Exposure Point Concentrations and Exposure Calculations

<u>Arsenic</u>

Arsenic is a naturally occurring element that is widely distributed in the earth's crust with levels in soil ranging from <0.997 to 97 ppm. Arsenic is usually found in two forms in the environment—inorganic (arsenic combined with oxygen, chlorine, and sulfur) and organic (combined with carbon and hydrogen). Inorganic arsenic is found in soil and many kinds of rocks, especially in minerals and ores that contain copper or lead. Samples collected at Tibble Fork in 2018 contained arsenic levels that ranged between 3.07 and 35.3 ppm, with an average concentration of 14.9 ppm (Table 2). Only three samples were above the recommended CV and were from sampling sites located where the American Fork River enters the reservoir (Figure 2). Arsenic is known to cause both non-cancer and cancer health effects. Long term oral exposure to low levels of inorganic arsenic may cause dermal effects such as hyperpigmentation and hyperkeratosis as well as an increased risk of skin, bladder, and lung cancer (ATSDR, 2007). The International Agency for Research on Cancer (IARC) has determined inorganic arsenic is carcinogenic to humans (IARC, 2012).

Non-cancer evaluation

To evaluate if health effects are likely to occur from exposure to a contaminant, site specific exposure dose estimates are compared to ATSDR's minimum risk levels (MRLs), which are health-based guidelines. An MRL is an estimate of daily human exposure to a substance (in milligrams per kilogram per day [mg/kg/day for oral exposure]) that is likely to be without non-cancer health effects during a specified duration of exposure based on ATSDR evaluations. Exposure dose estimates were calculated using standard ATSDR equations and exposure factors (ATSDR, 2005). Detailed information on calculations and exposure assumptions can be found in Tables C–1 and C–2 in Appendix C. Exposure dose estimates were then used to calculate hazard quotients (HQs), which is the ratio of the potential exposure to a substance and the level at which no adverse effects are expected. If the HQ is less than 1, then no adverse health effects are expected as a result of exposure.

ATSDR has developed a chronic oral MRL for inorganic arsenic of 0.0003 milligrams per kilogram body weight per day (mg/kg/day), based on hyperpigmentation, keratosis, and possible vascular complications in humans (ATSDR, 2007). This MRL is derived from a no observed adverse effect level (NOAEL) of 0.0008 mg/kg/day for dermal effects based on a study in which a large population of farmers in Taiwan were exposed to high levels of arsenic in well water (ATSDR, 2007), with an uncertainty factor (UF) of three to take human variability into account.

The maximum concentration of arsenic detected in sediment samples (35.5 mg/kg) was used to calculate exposure dose estimates for children (birth to those younger than 21 years) and adults; results are presented in Table 3. For children in all age groups and adults, the estimated exposure doses were below the MRL for arsenic of 0.0003 mg/kg/day and HQs were less than 1 (Table 3). Only three out of the nine sediment samples were above the recommended CV for arsenic. These samples were collected where the American Fork River enters Tibble Fork Reservoir where children are less likely to be recreating (See Figure 2). Samples near the beach were all below ATSDR's recommended CV (Table A–2). EEP concludes that accidentally eating arsenic found in sediment at Tibble Fork Reservoir is not expected to harm people's health because arsenic levels in sediment are below levels of health concern.

Table 3. Site-specific ingestion exposure doses for chronic exposure to arsenic in soil at 36.5 mg/kg along with non-cancer hazard quotients (HQ).

PUBLIC HEALTH ASSESSMENT SITE TOOL PHAST Exposure group	CTE dose (mg/kg/day)	CTE non-cancer HQ	RME dose (mg/kg/day)	RME non-cancer HQ	Exposure duration (yrs.)
Birth to < 1 year	2.5×10^{-5}	0.085	6.9×10^{-5}	0.23	1
1 to < 2 years	2.8×10^{-5}	0.095	6.3×10^{-5}	0.21	1
2 to < 6 years	1.2×10^{-5}	0.041	4.1×10^{-5}	0.14	4
6 to < 11 years	6.8×10^{-6}	0.023	2.3×10^{-5}	0.075	5
11 to < 16 years	1.9×10^{-6}	0.0063	6.3×10^{-6}	0.021	5
16 to < 21 years	1.5×10^{-6}	0.0050	5.0×10^{-6}	0.017	5
Total child	-	-	-	-	21
Adult	1.4×10^{-6}	0.0045	4.5×10^{-6}	0.015	33

Source: Utah Department of Environmental Quality sampling data from 2018.
Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram soil; RME = reasonable maximum exposure (higher); yrs. = years.

* The calculations in this table were generated using ATSDR's PHAST v2.1.1.0. The non-cancer hazard quotients were calculated using the EPC: 37 mg/kg and chronic (greater than 1 year) minimal risk level of 0.0003 mg/kg/day.

Cancer evaluation

Theoretical cancer risk is the likelihood, or chance, of getting cancer. The EEP evaluated the excess lifetime cancer risk for recreational arsenic oral exposures using the child and adult doses listed below (Table 4 and Table 5). Theoretical cancer risk is estimated by calculating an exposure dose and multiplying it by the cancer slope factor (see equation 3 in Appendix C). EPA has calculated an oral cancer slope factor of 1.5 mg/kg/day for arsenic. The reader should note these estimates are for excess cancers that might result in addition to those normally expected in an unexposed population. The cumulative cancer risk to children was 3.0×10^{-6} for the central tendency exposure (CTE) and 9.0×10^{-6} for the reasonable maximum exposure (RME), or ~3 and ~9 excess cancer cases per million exposed individuals. For adults, the estimated cancer risk for the RME was 2.9×10^{-6}, or ~3 excess cancer cases per million exposed individuals. We used a worst-case scenario with the highest levels of arsenic (35.5 mg/kg) to estimate the theoretical cancer risk. Actual risks are likely to be much lower.

EEP further evaluated the cancer risks from exposure to arsenic using the 95% upper confidence limit (UCL) of 22.5 mg/kg. The 95% UCL provides a better estimate for the central tendency of the exposure point concentration, compared to the maximum concentration (Table 5). The cumulative cancer risk estimate to children was 1.8 x 10^{-6} (CME) and 5.5 x 10^{-6} (RME), or ~2 and ~6 excess cancer cases per million exposed individuals. Only the RME cancer risk estimate for adults (1.8 x 10^{-6}) exceeded the one in a million extra cancer cases threshold. However the estimate was very low with only ~2 excess cancer cases per million people exposed. The cancer risk from arsenic at Tibble Fork Reservoir is very low (10^{-6} cancer risk). EEP's estimated exposure doses of arsenic in both adults (4.5 X 10^{-6}) and children (4.1 x 10^{-5}) is safer than the lowest dose of arsenic (0.014 mg/kg/day) that has been shown to cause cancer in humans (Tseng et al. 1968). Based on the conservative assumptions used to calculate cancer risk estimates and the low arsenic levels where recreators are most likely to come in contact with contaminated sediment near the beach, EEP concludes there is no concern for increased cancer risk.

Table 4. Site-specific ingestion exposure doses for chronic exposure to arsenic in soil at 36.5 mg/kg along with cancer risk estimates.

PUBLIC HEALTH ASSESSMENT SITE TOOL PHAST Exposure group	CTE dose (mg/kg/day)	CTE cancer risk	RME dose (mg/kg/day)	RME cancer risk	Exposure duration (yrs.)
Birth to < 1 year	2.5 x 10^{-5}	-	6.9 x 10^{-5}	-	1
1 to < 2 years	2.8 x 10^{-5}	-	6.3 x 10^{-5}	-	1
2 to < 6 years	1.2 x 10^{-5}	-	4.1 x 10^{-5}	-	4
6 to < 11 years	6.8 x 10^{-6}	-	2.3 x 10^{-5}	-	5
11 to < 16 years	1.9 x 10^{-6}	-	6.3 x 10^{-6}	-	5
16 to < 21 years	1.5 x 10^{-6}	-	5.0 x 10^{-6}	-	5
Total Child	-	3.0 x $10^{-6‡}$	-	9.0 x $10^{-6‡}$	21
Adult	1.4 x 10^{-6}	8.6 x 10^{-7}	4.5 x 10^{-6}	2.9 x $10^{-6‡}$	33

Source: Utah Department of Environmental Quality sampling data from 2018.
Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram soil; RME = reasonable maximum exposure (higher); yrs = years.
* The calculations in this table were generated using ATSDR's PHAST v2.1.1.0. The cancer risks were calculated using the cancer slope factor of 1.5 $(mg/kg/day)^{-1}$.
‡ A shaded cell indicates the cancer risk exceeds one extra case in a million people similarly exposed.

Table 5. Site-specific ingestion only exposure doses for chronic exposure to arsenic in soil at 22.46 mg/kg along with cancer risk estimates*

PUBLIC HEALTH ASSESSMENT SITE TOOL PHAST Exposure group	CTE dose (mg/kg/day)	CTE cancer risk	RME dose (mg/kg/day)	RME cancer risk	Exposure duration (yrs.)
Birth to < 1 year	1.6×10^{-5}	-	4.3×10^{-5}	-	1
1 to < 2 years	1.7×10^{-5}	-	3.9×10^{-5}	-	1
2 to < 6 years	7.6×10^{-6}	-	2.5×10^{-5}	-	4
6 to < 11 years	4.2×10^{-6}	-	1.4×10^{-5}	-	5
11 to < 16 years	1.2×10^{-6}	-	3.9×10^{-6}	-	5
16 to < 21 years	9.3×10^{-6}	-	3.1×10^{-6}	-	5
Total child	-	1.8×10^{-6} ‡	-	5.5×10^{-6} ‡	21
Adult	8.3E-07	5.3E-7	2.8×10^{-6}	1.8×10^{-6} ‡	33

Source: Utah Department of Environmental Quality sampling data from 2018.
Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram soil; RME = reasonable maximum exposure (higher); yrs. = years.

* The calculations in this table were generated using ATSDR's PHAST v2.1.1.0. The cancer risks were calculated using the cancer slope factor of 1.5 $(mg/kg/day)^{-1}$.
‡ A shaded cell indicates the cancer risk exceeds one extra case in a million people similarly exposed.

Based on the data used in this assessment and conservative exposure assumptions, arsenic levels in the sediment at Tibble Fork Reservoir are not likely to harm people's health.

Evaluation of lead exposure

Lead is a naturally occurring metal found in the earth's crust primarily in ore deposits which are rocks containing several valuable minerals. Widespread use of lead containing products such as lead-based paints, old pipe solder, gasoline additives, and ammunition has led to contamination of lead throughout the environment. Thus, people can be exposed to lead from air, water, soil, and food.

The method to evaluate risks from exposure to lead is different from the assessment method for non-lead COC where exposure doses are calculated and then compared with health-based guidelines. Biokinetic modeling is used to assess health risks associated with lead exposure. The modeling predicts the blood lead concentrations in exposed children and adults since exposure to lead comes from a variety of environmental sources, as mentioned above. Additionally, health effects associated with lead exposure have typically been reported in terms of blood lead concentrations in the scientific literature. For children, exposure to lead is evaluated through the Integrated

Exposure Uptake Biokinetic Model (IEUBK), developed by the EPA, which estimates blood lead concentrations in children younger than age seven who are exposed to environmental lead from many sources including air, diet, water, soil, and dust. The Centers for Disease Control and Prevention (CDC) has established a level of concern for blood lead levels of 5 micrograms of lead per deciliter of blood (μg/dL) or greater based on research that shows measurable adverse neurological, behavioral, immunological, and developmental effects in children (CDC, 2011, 2012a, 2012b). The IEUBK model contains default input parameters for the different environmental media concentrations that represent national averages or plausible central values that were developed based on many years of research (US EPA, 2007). The default value for lead in soil is 200 ppm in the IEUBK model. The range of lead concentrations at Tibble Fork Reservoir was from 3.2 to 200 ppm with an average concentration of 67.1 ppm. Since the maximum concentration of lead in sediment from Tibble Fork was also 200 ppm, a time weighted average (TWA) approach for a recreational exposure and use of the IEUBK model was not appropriate for this assessment. Like arsenic, concentrations of lead were highest where the American Fork River enters the reservoir, where children are unlikely to be exposed (Table A-6). Although there is no safe level of lead, the maximum sediment concentration was below the EPA RSL value of 400 ppm.

Children's health concerns

The potential for exposure and resulting adverse health effects often increases for younger children compared with older children and adults. ATSDR and DHHS recognize children are susceptible to developmental toxicity that can occur at levels much lower than those causing other types of toxicity. The following factors contribute to this vulnerability:

- Children are more likely to play outdoors in contaminated areas by disregarding signs and wandering onto restricted locations.
- Children often bring food into contaminated areas which results in hand-to-mouth activities.
- Children are smaller and receive higher doses of contaminant per body weight.
- Children are shorter than adults; therefore, they have a higher possibility of breathing in dust and soil.
- Fetal and child exposure to toxic chemicals can cause permanent damage during critical growth stages which results in lifelong effects.

These unique vulnerabilities of infants and children require special attention in communities that have contamination of their water, food, soil, or air. Children's health was considered as this health consultation was written and the exposure scenarios treated children as the most sensitive population being exposed and represents the basis for the public health conclusions and recommendations.

5. Conclusions

Exposure to heavy metal contaminants in sediment at Tibble Fork Reservoir is not expected to result in adverse health effects for recreational users, therefore, there is **no apparent public health hazard** (see Table A–13 in Appendix A for ATSDR public health hazard categories).

- For recreational use of the Tibble Fork Reservoir, one contaminant exceeded environmental screening values: arsenic.
- However, estimated recreational exposure doses for arsenic did not exceed health-based guidelines for non-cancer health effects and cancer risk estimates were low.
- Levels of heavy metals in sediment were similar to samples collected in 2010, indicating the sediment release in 2016 did not significantly impact current levels in the reservoir.
- While sediment lead levels were below the EPA RSL of 400 ppm, the best available science indicates there is no safe level of lead exposure, especially in children. Therefore, the EEP recommends recreators take actions to limit their exposure to lead containing materials.

6. Recommendations and Public Health Action Plan

Based upon evaluation of sediment concentrations of heavy metals, the EEP makes the following recommendations:

- People who come in contact with sediment at Tibble Fork Reservoir should rinse off after visiting the reservoir and, as always, wash hands well with soap and water before eating or drinking.
- EEP will provide a copy of health consultation to stakeholders;
- EEP will communicate findings to the public through APPLETREE website; and
- EEP will provide additional health education through distribution of health education materials such as fact sheets and respond to any questions via phone, meetings, or emails, etc. as requested or necessary.

7. Report Preparation

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9. Appendices

Appendix A. Additional Tables and Figures

Table A–1. Antimony (ppm) results for Tibble Fork Reservoir sediment samples taken in October 2018.

Sample ID	Collection date	Matrix	Analyte	DF	Results	PQL	Units
TFR-1	10/24/2018	Soil	Antimony	50	< 0.956	0.956	mg/kg-dry
TFR-2	10/24/2018	Soil	Antimony	50	< 1.15	1.15	mg/kg-dry
TFR-3	10/24/2018	Soil	Antimony	50	< 1.62	1.62	mg/kg-dry
TFR-4	10/24/2018	Soil	Antimony	50	< 1.04	1.04	mg/kg-dry
TFR-5	10/24/2018	Soil	Antimony	50	< 0.839	0.839	mg/kg-dry
TFR-6	10/24/2018	Soil	Antimony	50	< 1.03	1.03	mg/kg-dry
TFR-7	10/24/2018	Soil	Antimony	50	4.90	1.22	mg/kg-dry
TFR-8	10/24/2018	Soil	Antimony	50	5.84	1.49	mg/kg-dry
TFR-9	10/24/2018	Soil	Antimony	50	6.99	1.43	mg/kg-dry

Table A–2. Arsenic (ppm) results for Tibble Fork Reservoir sediment samples taken in October 2018.

Sample ID	Collection date	Matrix	Analyte	DF	Results	PQL	Units
TFR-1	10/24/2018	Soil	Arsenic	50	5.55	0.597	mg/kg-dry
TFR-2	10/24/2018	Soil	Arsenic	40	3.07	0.576	mg/kg-dry
TFR-3	10/24/2018	Soil	Arsenic	50	4.45	1.01	mg/kg-dry
TFR-4	10/24/2018	Soil	Arsenic	50	7.56	0.652	mg/kg-dry
TFR-5	10/24/2018	Soil	Arsenic	50	8.72	0.524	mg/kg-dry
TFR-6	10/24/2018	Soil	Arsenic	50	14.5	0.646	mg/kg-dry
TFR-7	10/24/2018	Soil	Arsenic	50	25.2	0.764	mg/kg-dry
TFR-8	10/24/2018	Soil	Arsenic	50	28.6	0.932	mg/kg-dry
TFR-9	10/24/2018	Soil	Arsenic	50	36.5	0.896	mg/kg-dry

Table A–3. Cadmium (ppm) results for Tibble Fork Reservoir sediment samples taken in October 2018.

Sample ID	Collection date	Matrix	Analyte	Results	PQL*	Units
TFR-1	10/24/2018	Soil	Cadmium	< 0.597	0.597	mg/kg-dry
TFR-2	10/24/2018	Soil	Cadmium	< 0.720	0.720	mg/kg-dry
TFR-3	10/24/2018	Soil	Cadmium	< 1.01	1.01	mg/kg-dry
TFR-4	10/24/2018	Soil	Cadmium	< 0.652	0.652	mg/kg-dry
TFR-5	10/24/2018	Soil	Cadmium	0.675	0.524	mg/kg-dry
TFR-6	10/24/2018	Soil	Cadmium	< 0.646	0.646	mg/kg-dry
TFR-7	10/24/2018	Soil	Cadmium	4.48	0.764	mg/kg-dry
TFR-8	10/24/2018	Soil	Cadmium	3.70	0.932	mg/kg-dry
TFR-9	10/24/2018	Soil	Cadmium	3.61	0.896	mg/kg-dry

*Practical quantitation limit

Table A–4. Copper (ppm) results for Tibble Fork Reservoir sediment samples taken in October 2018.

Sample ID	Collection date	Matrix	Analyte	Results	PQL	Units
TFR-1	10/24/2018	Soil	Copper	< 17.9	17.9	mg/kg-dry
TFR-2	10/24/2018	Soil	Copper	< 21.6	21.6	mg/kg-dry
TFR-3	10/24/2018	Soil	Copper	< 30.4	30.4	mg/kg-dry
TFR-4	10/24/2018	Soil	Copper	< 19.6	19.6	mg/kg-dry
TFR-5	10/24/2018	Soil	Copper	< 15.7	15.7	mg/kg-dry
TFR-6	10/24/2018	Soil	Copper	< 19.4	19.4	mg/kg-dry
TFR-7	10/24/2018	Soil	Copper	44.8	22.9	mg/kg-dry
TFR-8	10/24/2018	Soil	Copper	44.4	28.0	mg/kg-dry
TFR-9	10/24/2018	Soil	Copper	41.7	26.9	mg/kg-dry

*Practical quantitation limit

Table A–5. Iron (ppm) results for Tibble Fork Reservoir sediment samples taken in October 2018.

Sample ID	Collection date	Matrix	Analyte	Results	PQL	Units
TFR-1	10/24/2018	Soil	Iron	8,890	4,780	mg/kg-dry
TFR-2	10/24/2018	Soil	Iron	4,020	2,880	mg/kg-dry
TFR-3	10/24/2018	Soil	Iron	3,430	1,620	mg/kg-dry
TFR-4	10/24/2018	Soil	Iron	3,290	2,610	mg/kg-dry
TFR-5	10/24/2018	Soil	Iron	11,500	8,390	mg/kg-dry
TFR-6	10/24/2018	Soil	Iron	6,800	5,170	mg/kg-dry
TFR-7	10/24/2018	Soil	Iron	21,000	12,200	mg/kg-dry
TFR-8	10/24/2018	Soil	Iron	22,000	14,900	mg/kg-dry
TFR-9	10/24/2018	Soil	Iron	24,400	14,300	mg/kg-dry

*Practical quantitation limit

Table A–6. Lead (ppm) results for Tibble Fork Reservoir sediment samples taken in October 2018.

Sample ID	Collection date	Matrix	Analyte	Results	PQL	Units
TFR-1	10/24/2018	Soil	Lead	7.39	1.19	mg/kg-dry
TFR-2	10/24/2018	Soil	Lead	3.20	1.15	mg/kg-dry
TFR-3	10/24/2018	Soil	Lead	5.38	2.03	mg/kg-dry
TFR-4	10/24/2018	Soil	Lead	4.20	1.30	mg/kg-dry
TFR-5	10/24/2018	Soil	Lead	9.55	1.05	mg/kg-dry
TFR-6	10/24/2018	Soil	Lead	5.74	1.29	mg/kg-dry
TFR-7	10/24/2018	Soil	Lead	193	1.53	mg/kg-dry
TFR-8	10/24/2018	Soil	Lead	175	1.86	mg/kg-dry
TFR-9	10/24/2018	Soil	Lead	200	1.79	mg/kg-dry

*Practical quantitation limit

Table A–7. Manganese (ppm) results for Tibble Fork Reservoir sediment samples taken in October 2018.

Sample ID	Collection date	Matrix	Analyte	Results	PQL	Units
TFR-1	10/24/2018	Soil	Manganese	220	5.97	mg/kg-dry
TFR-2	10/24/2018	Soil	Manganese	81.1	7.20	mg/kg-dry
TFR-3	10/24/2018	Soil	Manganese	72.8	10.1	mg/kg-dry
TFR-4	10/24/2018	Soil	Manganese	85.1	6.52	mg/kg-dry
TFR-5	10/24/2018	Soil	Manganese	626	10.5	mg/kg-dry
TFR-6	10/24/2018	Soil	Manganese	316	6.46	mg/kg-dry
TFR-7	10/24/2018	Soil	Manganese	354	7.64	mg/kg-dry
TFR-8	10/24/2018	Soil	Manganese	464	9.32	mg/kg-dry
TFR-9	10/24/2018	Soil	Manganese	500	8.96	mg/kg-dry

*Practical quantitation limit

Table A–8. Mercury (ppm) results for Tibble Fork Reservoir sediment samples taken in October 2018.

Sample ID	Collection date	Matrix	Analyte	Results	PQL	Units
TFR-1	10/24/2018	Soil	Mercury	< 0.0439	0.0439	mg/kg-dry
TFR-2	10/24/2018	Soil	Mercury	< 0.0514	0.0514	mg/kg-dry
TFR-3	10/24/2018	Soil	Mercury	< 0.0393	0.0393	mg/kg-dry
TFR-4	10/24/2018	Soil	Mercury	< 0.0468	0.0468	mg/kg-dry
TFR-5	10/24/2018	Soil	Mercury	< 0.0379	0.0379	mg/kg-dry
TFR-6	10/24/2018	Soil	Mercury	< 0.0485	0.0485	mg/kg-dry
TFR-7	10/24/2018	Soil	Mercury	0.174	0.0621	mg/kg-dry
TFR-8	10/24/2018	Soil	Mercury	0.219	0.0614	mg/kg-dry
TFR-9	10/24/2018	Soil	Mercury	0.184	0.0674	mg/kg-dry

*Practical quantitation limit

Table A–9. Nickel (ppm) results for Tibble Fork Reservoir sediment samples taken in October 2018.

Sample ID	Collection date	Matrix	Analyte	Results	PQL	Units
TFR-1	10/24/2018	Soil	Nickel	< 23.9	23.9	mg/kg-dry
TFR-2	10/24/2018	Soil	Nickel	< 28.8	28.8	mg/kg-dry
TFR-3	10/24/2018	Soil	Nickel	< 40.5	40.5	mg/kg-dry
TFR-4	10/24/2018	Soil	Nickel	< 26.1	26.1	mg/kg-dry
TFR-5	10/24/2018	Soil	Nickel	< 21.0	21.0	mg/kg-dry
TFR-6	10/24/2018	Soil	Nickel	< 25.9	25.9	mg/kg-dry
TFR-7	10/24/2018	Soil	Nickel	< 30.6	30.6	mg/kg-dry
TFR-8	10/24/2018	Soil	Nickel	< 37.3	37.3	mg/kg-dry
TFR-9	10/24/2018	Soil	Nickel	< 35.9	35.9	mg/kg-dry

*Practical quantitation limit

Table A–10. Silver (ppm) results for Tibble Fork Reservoir sediment samples taken in October 2018.

Sample ID	Collection date	Matrix	Analyte	Result	PQL	Units
TFR-1	10/24/2018	Soil	Silver	< 0.358	0.358	mg/kg-dry
TFR-2	10/24/2018	Soil	Silver	< 0.432	0.432	mg/kg-dry
TFR-3	10/24/2018	Soil	Silver	< 0.608	0.608	mg/kg-dry
TFR-4	10/24/2018	Soil	Silver	< 0.391	0.391	mg/kg-dry
TFR-5	10/24/2018	Soil	Silver	< 0.315	0.315	mg/kg-dry
TFR-6	10/24/2018	Soil	Silver	< 0.388	0.388	mg/kg-dry
TFR-7	10/24/2018	Soil	Silver	0.759	0.459	mg/kg-dry
TFR-8	10/24/2018	Soil	Silver	0.844	0.559	mg/kg-dry
TFR-9	10/24/2018	Soil	Silver	0.908	0.538	mg/kg-dry

*Practical quantitation limit

Table A–11. Zinc (ppm) results for Tibble Fork Reservoir sediment samples taken in October 2018.

Sample ID	Collection date	Matrix	Analyte	Results	PQL	Units
TFR-1	10/24/2018	Soil	Zinc	27.2	17.9	mg/kg-dry
TFR-2	10/24/2018	Soil	Zinc	< 21.6	21.6	mg/kg-dry
TFR-3	10/24/2018	Soil	Zinc	< 30.4	30.4	mg/kg-dry
TFR-4	10/24/2018	Soil	Zinc	< 19.6	19.6	mg/kg-dry
TFR-5	10/24/2018	Soil	Zinc	39.8	15.7	mg/kg-dry
TFR-6	10/24/2018	Soil	Zinc	28.7	19.4	mg/kg-dry
TFR-7	10/24/2018	Soil	Zinc	567	22.9	mg/kg-dry
TFR-8	10/24/2018	Soil	Zinc	472	28.0	mg/kg-dry
TFR-9	10/24/2018	Soil	Zinc	470	26.9	mg/kg-dry

*Practical quantitation limit

Table A–12. List of ATSDR-derived CVs, as well as some common types of non-ATSDR screening levels.

Agency	Screening level	Definition	Basis for level
ATSDR	Environmental media evaluation guides (EMEGs)	Estimated contaminant concentrations that are not expected to result in adverse noncarcinogenic health effects based on ATSDR evaluation.	ATSDR minimal risk levels (MRLs)
	Reference dose media evaluation guides (RMEGs)	Represent the concentration in water or soil at which daily human exposure is unlikely to result in adverse noncarcinogenic effects.	EPA reference doses (RfDs) and reference dose concentrations (RfCs)
	Cancer risk evaluation guides (CREGs)	Estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10^{-6}) persons exposed during their lifetime (70 years).	EPA cancer slope factors (CSFs) or inhalation unit risks (IURs)
EPA	Maximum contaminant levels (MCLs)	Enforceable drinking water regulations that are protective of public health, but also consider economic and technological constraints.	The Safe Drinking Water Act (SDWA) establishes national primary drinking water regulations that are enforceable standards [Note: Not all MCLs are health-based].
	Regional screening levels (RSLs)	Risk-based concentrations derived from standardized equations combining exposure information assumptions with toxicity data.	A variety of EPA (RfDs, RfCs), ATSDR (MRLs), and other values.
Other federal and state agencies, such as the Department of Energy (DOE), Department of Interior (DOI), Federal Drug Administration (FDA), Texas Commission on Environmental Quality (TCEQ), California's Environmental Protection Agency (CalEPA), ect.	Vary by agency		Values will vary depending on source, medium, and contaminant; examine carefully to see if they are health-based and appropriate for use.

Table A–13. ATSDR public health hazard categories.

Category/definition	Data sufficiency	Criteria
A. Urgent public health hazard This category is used for sites where short-term exposures (< 1 yr) to hazardous substances or conditions could result in adverse health effects that require rapid intervention.	This determination represents a professional judgment based on critical data which ATSDR has judged sufficient to support a decision. This does not necessarily imply the available data are complete; in some cases additional data may be required to confirm or further support the decision.	Evaluation of available relevant information* indicates site-specific conditions or likely exposures have had, are having, or are likely to have in the future, an adverse impact on human health that requires immediate action or intervention. Such site-specific conditions or exposures may include the presence of serious physical or safety hazards.
B. Public health hazard This category is used for sites that pose a public health hazard due to the existence of long-term exposures (> 1 yr.) to hazardous substance or conditions that could result in adverse health effects.	This determination represents a professional judgment based on critical data which ATSDR has judged sufficient to support a decision. This does not necessarily imply the available data are complete; in some cases additional data may be required to confirm or further support the decision.	Evaluation of available relevant information* suggests that, under site-specific conditions of exposure, long-term exposures to site-specific contaminants (including radionuclides) have had, are having, or are likely to have in the future, an adverse impact on human health that requires one or more public health interventions. Such site-specific exposures may include the presence of serious physical or safety hazards.
C. Indeterminate public health hazard This category is used for sites in which critical data are insufficient with regard to the extent of exposure and/or toxicologic properties at estimated exposure levels.	This determination represents a professional judgment that critical data are missing and ATSDR has judged the data are insufficient to support a decision. This does not necessarily imply all data are incomplete; but that some additional data are required to support a decision.	The health assessor must determine, using professional judgment, the criticality of such data and the likelihood the data can be obtained and will be obtained in a timely manner. Where some data are available, even limited data, the health assessor is encouraged, to the extent possible, to select other hazard categories and to support their decision with clear narrative that explains the limits of the data and the rationale for the decision.
D. No apparent public health hazard This category is used for sites where human exposure to contaminated media may be occurring, may have occurred in the past, and/or may occur in the future, but the exposure is not expected to cause any adverse health effects.	This determination represents a professional judgment based on critical data which ATSDR considers sufficient to support a decision. This does not necessarily imply the available data are complete; in some cases, additional data may be required to confirm or further support the decision made.	Evaluation of available relevant information* indicates, under site-specific conditions of exposure, exposures to site-specific contaminants in the past, present, or future are not likely to result in any adverse impact on human health.
E: No public health hazard This category is used for sites that, because of the absence of exposure, do NOT pose a public health hazard.	Sufficient evidence indicates no human exposures to contaminated media have occurred, none are now occurring, and none are likely to occur in the future.	

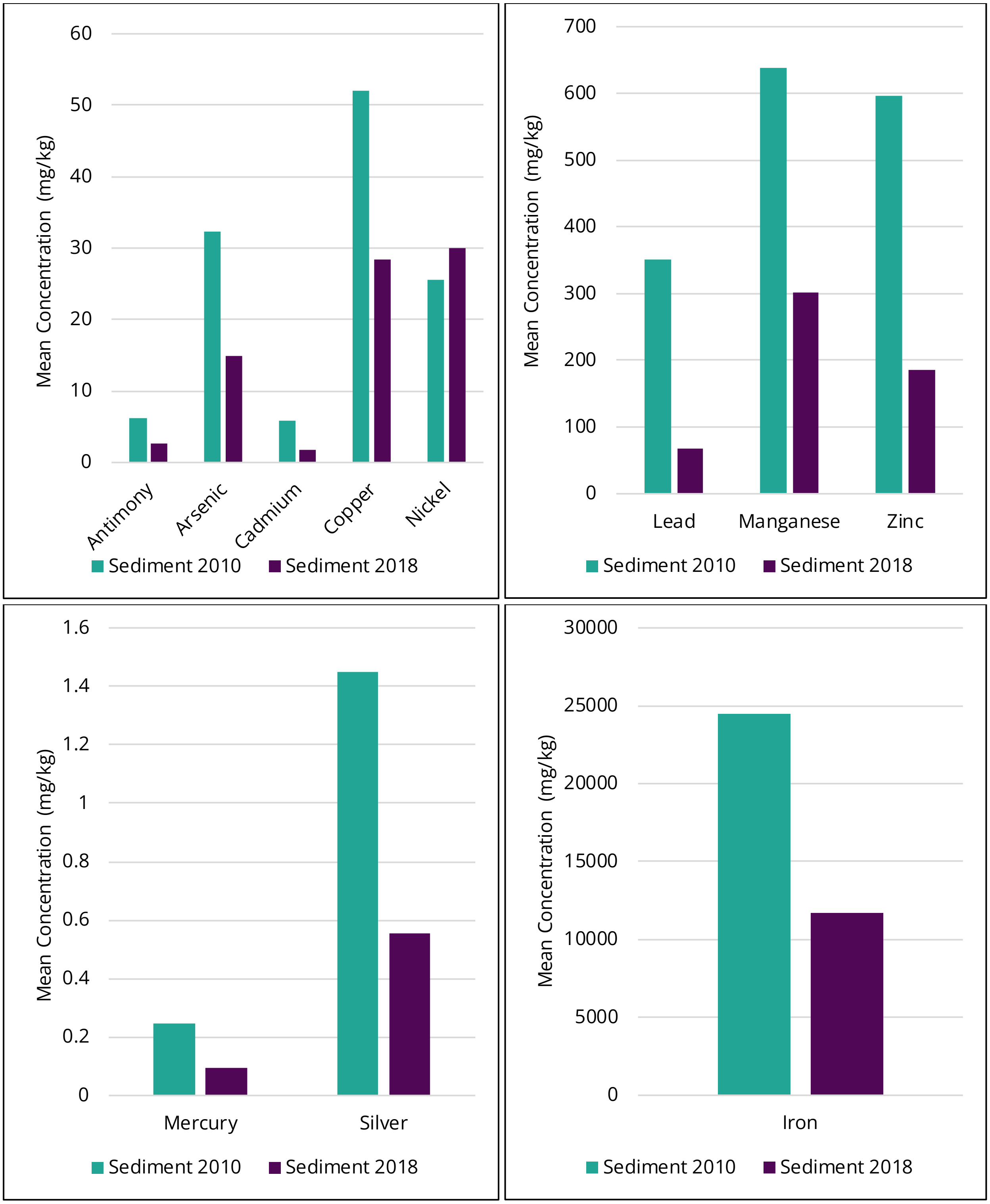

Figure A–1. Comparison of mean concentration of heavy metals in sediment samples collected in 2010 and 2018 at Tibble Fork Reservoir, Utah.

Appendix B. Screening tables

Table B–1. PHAST CV screening results for Tibble Fork Reservoir for sediment

Contaminant name	CASRN	Conc (ppm)	Above or equal to recommended ATSDR CV?	Above or equal to other CV?	CREG	Chronic EMEG child	Chronic EMEG adult	Int EMEG child	Int EMEG adult	RMEG child	RMEG adult	Acute EMEG pica child	Int EMEG pica child
ANTIMONY	7440-36-0	6.99	No	No	NA	NA	NA	31	480	21 [#]	320	5,300	3.2 [3] [b]
ARSENIC [a]	7440-38-2	36.5	Yes [1]	Yes [2]	0.26 [2]	16 [1]	240	NA	NA	16 [1]	240	27 [3] [b]	NA
CADMIUM	7440-43-9	4.48	No	No	NA	5.2 [#]	80	26	400	26	400	NA	2.7 [3] [b]
COPPER	7440-50-8	44.8	No	No	NA	NA	NA	520 [#]	8,000	NA	NA	53	53
IRON	7439-89-6	24,400	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LEAD	7439-92-1	200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MANGANESE	7439-96-5	626	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MERCURY	007487-94-7	0.219	No	No	NA	NA	NA	100	1,600	16 [#]	240	37	11
NICKEL	7440-02-0	40.5	No	No	NA	NA	NA	NA	NA	1,000 [#]	16,000	NA	NA
SILVER	7440-22-4	0.908	No	No	NA	NA	NA	NA	NA	260 [#]	4,000	NA	NA
ZINC	7440-66-6	567	No	No	NA	16,000 [#]	240,000	16,000 [#]	240,000	16,000 [#]	240,000	NA	1,600

[#]	Recommended ATSDR CV.
[1]	Recommended ATSDR CV met or exceeded.
[2]	Additional ATSDR CV met or exceeded.
[3]	Acute/Intermediate pica ATSDR CV met or exceeded.
[4]	Non-ATSDR value met or exceeded.
[a]	The CREG for arsenic is below background levels, so the recommended soil CV is the chronic EMEG/RMEG.
[b]	Consider a pica scenario in your evaluation.

Table B–2. PHAST results for selection of contaminants of concern for heavy metals in Tibble Fork Reservoir.

Contaminant name	Exposure medium	Maximum site concentration (ppm)	Unit	ATSDR recommended CV	ATSDR CV type	Non-ATSDR screening value	Non-ATSDR screening value type	Selected screening value	Contaminant of concern?
ANTIMONY	Soil/sediment	6.99	ppm	21	RMEG child			21	No
ARSENIC	Soil/sediment	36.5	ppm	16	Chronic EMEG child/RMEG child			16	Yes
CADMIUM	Soil/sediment	4.48	ppm	5.2	Chronic EMEG child			5.2	No
COPPER	Soil/sediment	44.8	ppm	520	Intermediate EMEG child			520	No
IRON	Soil/sediment	24,400	ppm	NA	NA	55,000	Child RSL	55,000	No
LEAD	Soil/sediment	200	ppm	NA	NA				Yes
MANGANESE	Soil/sediment	626	ppm	NA	NA	1,900	Child RSL	1,900	No
MERCURY	Soil/sediment	0.219	ppm	16	RMEG child	No	16	RMEG child	No
NICKEL	Soil/sediment	40.5	ppm	1,000	RMEG child			1,000	No
SILVER	Soil/sediment	0.908	ppm	260	RMEG child			260	No
ZINC	Soil/sediment	567	ppm	16,000	Chronic EMEG child/Intermediate EMEG child/RMEG child			16,000	No

Appendix C. Exposure Dose Calculations

Exposure dose (ED) calculation for soil ingestion (ATSDR, 2005):

Non-cancer evaluation:

For non-cancer illnesses, we first estimate the health risk for children. Children ages 2-6 represent a vulnerable, sensitive population. Assessing potential health risks for this age group is assumed to protect the most sensitive adult populations. Because children are smaller and are assumed to swallow more soil than adults do, their exposure dose is higher. In calculating contaminant doses for a recreational scenario, EEP defines a recreational exposure as 60 days per year for 2 hours a day. We assume the recreator is on site 3 days per week, 20 weeks per year, for 4 years. For an assessment of non-cancer health risk, EEP used the ATSDR exposure assessment documents to calculate and exposure dose for children recreating in the Tibble Fork Reservoir. The doses were calculated using the following equation:

Equation 1:

$$\mathbf{D} = \frac{(\mathbf{C_{sed}} * \mathbf{IR} * \mathbf{EF} * \mathbf{AF} * \mathbf{CF})}{\mathbf{BW}}$$

where,

D	=	exposure dose (mg/kg/day)
C	=	contaminant concentration in soil/sediment (mg/kg)
IR	=	intake rate of contaminated soil/sediment (mg/day)
EF	=	exposure factor (unitless)
AF	=	bioavailability factor (unitless)
CF	=	conversion factor (1 x 10^{-6} kg/mg)
BW	=	body weight (kg)

The exposure factor is calculated with the following equation:

Equation 2:

$$\mathbf{EF} = \frac{\mathbf{F} * \mathbf{ED}}{\mathbf{AT}}$$

where,

F: frequency of exposure (days/year)

ED: exposure duration (years)

AT: averaging time (days—ED x 365 days/year for non-carcinogens; 78 years x 365 days/year for carcinogens)

Table C–1. Site-specific exposure parameters

Exposure group	Body weight (kg)	Exposure duration (years)	CTE intake rate (mg/day)	RME intake rate (mg/day)
Birth to < 1 year	7.8	1	55	150
1 to < 2 years	11.4	1	90	200
2 to < 6 years	17.4	4	60	200
6 to < 11 years	31.8	5	60	200
11 to < 16 years	56.8	5	30	100
16 to < 21 years	71.6	5	30	100
Total child (all age groups)	-	21	-	-
Adult	80	33	30	100

Abbreviations: cm^2 = centimeters square skin; CTE = central tendency exposure (typical); kg = kilograms; mg/cm^2/event = milligram chemical per centimeter square of skin per event; mg/day = milligram soil per day; RME = reasonable maximum exposure (higher).

EEP used the following assumptions to calculate child doses of arsenic from ingestion of sediment:

Table C–2. Exposure Assumptions for exposure to arsenic at Tibble Fork Reservoir, Utah County, UT.

Parameter	Value	Unit	Comments
Concentration (C)	36.5	mg/kg	Maximum concentration
Ingestion rate (IR)	—	mg/day	Estimated soil ingestion rate; variable, see Table C–1
Exposure factor (EF)	0.16	unitless	Assume recreator is on site 3 days per week, 20 weeks per year, for 33 years
Conversion factor (CF)	10^{-6}	kg/mg	Converts contaminant concentration from milligrams (mg) to kilograms (kg)
Frequency of exposure (F)	60	days/year	Average days exposed to sediment
Exposure duration (ED)	—	years	Number of years at site; variable, see Table C–1
Body weight (BW)	—	kg	Variable, see Table C–1
Bioavailability factor (AF)	0.6	unitless	Bioavailability factor for arsenic

Cancer evaluation:

For oral exposure, the cancer risk (CR), is calculated by multiplying a cancer slope factor (CSF) by the estimated exposure dose and adjusting for lifetime exposure (ED/LY). EPA's cancer slope factor for arsenic is 1.5 (mg/kg/day).[1] Cancer risk for children was calculated as cumulative cancer risk for the first 19 years of life.

Equation 3:

$$\textbf{Cancer Risk} = (\textbf{D} * \textbf{CSF}) * (\textbf{ED}/\textbf{LY})$$

where,

D	=	exposure dose (mg/kg/day)
CSF	=	cancer slope factor in $(mg/kg/day)^{-1}$
ED	=	exposure duration (years)
LY	=	lifetime (78 years)

Appendix E. Glossary

ATSDR	Agency for Toxic Substances and Disease Registry.
COC	Contaminant of concern
CSF	Cancer slope factor. An upper bound calculated by EPA on the increased cancer risk from a lifetime of oral exposure to a substance. Approximates a 95% confidence limit.
CDC	The Centers for Disease Control and Prevention.
CREG	Cancer risk evaluation guide. An estimate of the concentration of a contaminant that would be expected to cause no more than one excess case of cancer in a million persons exposed every day, 24 hours a day, for their lifetimes.
CTE	Central tendency exposure. CTE refers to persons who have average or typical intake factors.
CV	Comparison value. A concentration calculated by ATSDR or EPA of a substance in air, water, food, or soil unlikely to cause harmful health effects in exposed people.
UDEQ	Utah Department of Environmental Quality.
DHHS	Department of Health and Human Services.
DWQ	Division of Water Quality, within the Utah Department of Environmental Quality.
EEP	Environmental Epidemiology Program, within the Utah Department of Health and Human Services.
EMEG	Environmental media evaluation guide, based on ATSDR's MRL. A concentration of a substance in water, soil, and air to which humans may be exposed during a specified period of time (acute, intermediate, or chronic) without experiencing adverse, non-cancer health effects. Acute is 14 days or less, intermediate is 15 days to one year, and chronic is more than one year.
EPA	United States Environmental Protection Agency.
Exposure dose	The measured or calculated dose to which a population is likely to be exposed considering all sources and routes of exposure.
HQ	Hazard quotient is calculated to evaluate the potential for non-cancer health hazards to occur from exposure to a contaminant.

kg	Kilograms. One kilogram is equal to 2.205 pounds.
mg	Milligrams. One thousandth of a gram.
mg/kg/day	Milligrams per kilograms of body weight per day.
MRL	Minimal risk level. 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, non-cancerous effects. MRLs are calculated for a route of exposure over a specific time period. Acute is 14 days or less, intermediate is 15 days to one year, and chronic is more than one year.
ppm	Parts per million.
PQL	Practical quantitation limit is the minimum concentration of an analyte (substance) that can be measured with a high degree of confidence that the analyte is present at or above that concentration.
RME	Reasonable maximum exposure. RME refers to persons at the upper end of the exposure distribution (approximately 95th percentile). The RME scenario assesses exposures that are higher than average but still within a realistic exposure range.
RfD	Reference dose. An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance unlikely to cause harm in humans, including sensitive subgroups.
RMEG	Reference dose media evaluation guide, based on EPA's RfD. A concentration of a substance in water, soil, or air to which humans may be exposed during a specific period of time (acute, intermediate, or chronic) without experiencing adverse, non-cancer health effects. Acute is 14 days or less, intermediate is 15 days to one year, and chronic is more than one year.
RSL	Regional screening levels are contaminant concentrations in soil, water, or air, below which any negative health effects would be unlikely. RSLs are derived by EPA's Region 3 Office using EPA's reference doses (RfDs) and cancer slope factors (CSFs). This ensures that RSLs consider both non-cancer and cancer risks.
Soil ingestion	The consumption of soil. This may result from a number of behaviors, including mouthing, contacting dirty hands, eating dropped foods, and consuming soil directly.
µg	Micrograms. One millionth of a gram.

UF	Uncertainty factor. UFs are mathematical adjustments for reasons of safety when knowledge is incomplete. For example, UFs are applied to no-observed-adverse-effect-levels to derive minimal risk levels, thus accounting for variations in people's sensitivity to a contaminant and differences between animals and humans.