Health Consultation

SR530 Landslide
Evaluation of Private Drinking Water Wells and Surface Water
Oso, Snohomish County, Washington State

September 9, 2014

Prepared by

The Washington State Department of Health
Under a Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

Washington State Department of Health

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Foreword

The Washington State Department of Health (DOH) prepared this health consultation under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the U.S. Department of Health and Human Services. ATSDR is responsible for health issues related to hazardous substances.

The purpose of a health consultation is to assess the health threat posed by hazardous substances in the environment. If needed, a health consultation will also recommend steps or actions to protect public health. Health consultations are initiated in response to health concerns raised by residents or agencies about exposure to hazardous substances.

This health consultation was prepared in accordance with ATSDR methodologies and guidelines. However, the report has not been reviewed and cleared by ATSDR. The findings in this report are relevant to conditions at the site during the time the report was written. It should not be relied upon if site conditions or land use changes in the future.

Use of trade names is for identification only and does not imply endorsement by state or federal health agencies.

For additional information, please contact us at 1-877-485-7316 or visit our web site at www.doh.wa.gov/consults.

For persons with disabilities this document is available on request in other formats. To submit a request, please call 1-800-525-0127 (TDD/TTY call 711).

For more information about ATSDR, contact the CDC Information Center at 1-800-CDC-INFO (1-800-232-4636) or visit the agency's web site at www.atsdr.cdc.gov.

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Summary

Introduction:

The Washington State Department of Health (DOH) has prepared this health consultation at the request of the Snohomish Health District (SHD). The purpose of this health consultation is to evaluate the potential human health hazard posed by contaminants in drinking water for 22 private well owners and surface water near the State Route (SR) 530 landslide in Snohomish County, Washington. The results of this assessment are only a snapshot in time of the current conditions. There is a possibility that groundwater conditions can change in the area. We recommend repeating the sampling of the 22 private wells for the same contaminants within the next year to confirm the groundwater status. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

DOH determined the following regarding drinking water from the 22 private domestic wells and surface water:

Conclusion 1:

Water from the four private wells with arsenic above the federal and state drinking water standard could harm people's health if used for drinking or food preparation. Food preparation includes washing foods, cooking, or using well water as an ingredient.

Basis for Decision

The level of arsenic found in these wells could result in a moderate to high lifetime risk of developing cancer if used for drinking or food preparation.

Conclusion 2:

After the five wells that tested positive for total coliform bacteria have been properly disinfected, water from all 22 private wells will not pose a health threat if used for bathing and cleaning.

Basis for Decision

Maximum levels of contaminants in well water are below levels of concern for bathing and cleaning.

Conclusion 3:

Using private well water with lead, copper, and iron is not expected to harm people's health.

Basis for Decision

Maximum levels of lead, copper, and iron in the private wells is not from the groundwater. It is due to corrosion and water standing in the pipes. Sudden changes to water quality and seismic activity from the landslide can also cause a release of lead and copper from pipes. These levels should go down after properly flushing the pipes.

Conclusion 4:

DOH concludes that swimming in the river is not expected to harm people's health.

Basis for Decision

The maximum level of chemical contaminants found in surface water is below levels of concern.

Next Steps

Recommendations

- The owners of the four private wells with arsenic above the Maximum Contaminant Level (MCL) should consider the following options for reducing exposure to arsenic: use bottled water or an alternate water supply. To determine if arsenic levels in your well are consistently above the MCL and whether an arsenic treatment system needs to be installed, sample your well quarterly or seasonally for one year.

- The owners of the five wells that tested positive for total coliform bacteria should follow the procedures provided by Snohomish Health District for disinfecting their private wells. Please refer to the recommended procedures (Appendix F).

- Repeat sampling of the 22 private wells for the same list of contaminants within the next year to confirm the groundwater status.

- Private well owners should test their water periodically[a] to evaluate the safety of the water supply. Because contaminant levels can vary seasonally, DOH recommends testing for arsenic and other contaminants in late summer and in the early spring to see if there are differences.

- Private well owners should not use water for drinking or food preparation if it contains more than 10 microgram per liter (µg/l) of arsenic.

- Private well owners should not use water containing between 10 µg/l and 50 µg/l of arsenic for drinking or food preparation over the long term.

- Stop using well water immediately for drinking and food preparation if it contains more than 50 µg/l of arsenic.

- Stop using well water for bathing and cleaning if it contains more than 500 µg/l of arsenic.

- Contact the local health department or DOH for advice if arsenic levels in well water are greater than 500µg/l.

- DOH strongly advises against the use of untreated surface water as a drinking water source anywhere in the state.

[a] The Washington State Department of Health recommends that private well users test their well water every year for coliform bacteria and nitrate [1].

Public Health Action Plan

- DOH will provide copies of this health consultation to SHD, private well owners, and Washington State Department of Ecology (Ecology).

- DOH will evaluate future data if or when the data becomes available.

For More Information

If you have any questions about this health consultation contact Lenford O'Garro 360-236-3376 or 1-877-485-7316 at Washington State Department of Health. For more information about ATSDR, contact the Center for Disease Control and Prevention (CDC) Information Center at 1-800-CDC-INFO (1-800-232-4636) or visit the agency's web site at www.atsdr.cdc.gov.

Purpose and Statement of Issues

The Washington State Department of Health (DOH) has prepared this health consultation at the request of the Snohomish Health District (SHD). The purpose of this health consultation is to evaluate the potential human health hazard posed by contaminants in private well drinking water and surface water near the State Route (SR) 530 landslide in Snohomish County, Washington. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Site Background

The SR530 landslide occurred on March 22, 2014, between the towns of Oso and Darrington in Snohomish County, Washington. The landslide covered about one square mile and resulted in the loss of lives, injuries, destruction of homes and property, and road closures. Also, the landslide blocked the North Fork of the Stillaguamish River causing local area flooding and threatened potential downstream flooding.

The U.S. Environmental Protection Agency (EPA), in coordination with the Washington State Department of Ecology (Ecology), sampled surface water in the North Fork of the Stillaguamish River and inundated areas of the slide. This was to address the immediate concerns of exposure to first responders working at the slide area. However, no groundwater sampling occurred at or near the slide area.

In order to protect human health, DOH recommended testing private wells in the area. The target areas for sampling were east, west, and south of the landslide. These sampling areas were selected to help identify if groundwater in the immediate area had been impacted by the landslide. It also allows for comparison with the surface water sampling results. Additionally, local residents remaining in the area expressed concerns about unknown chemicals potentially entering the groundwater from the recent landslide and affecting their well water.

SHD, with support from DOH, offered residents near the SR530 landslide an opportunity to have their private well water tested. Twenty-two private well samples were collected during the week of June 2, 2014. Surface water samples near the SR530 landslide were collected the week of May 25, 2014. Surface water sample locations were expected to be at the same locations as previous surface water samples collected by the EPA. However, some of the locations previously inundated with water from the Stillaguamish River after the SR530 landslide no longer contained surface water. The purpose of collecting surface water samples was as a supplemental monitoring event to evaluate potential water quality impacts from the landslide. All samples were collected by PIONEER Technologies Corporation (PIONEER) and sent to Washington State accredited laboratories for analysis. Surface water samples were analyzed for a full suite of priority pollutants and total coliform bacteria, including: Semi-volatile organic compound (SVOC), inorganic compounds (IOC), volatile organic compound (VOC) testing (See Appendix D, Table D1).

Private well sample results were compared to drinking water regulatory standards. Analysis included;

- SVOC, IOC, and VOC testing (See appendix D, Table D2).

In addition, all samples were tested for the presence of total coliform bacteria.

Community Health Concerns

Drinking water sources for homes in the area are private wells. Several community members near the landslide were concerned that they could potentially be exposed to toxic chemicals associated with household products and metals. Also because the destroyed homes were on septic systems for the disposal of domestic wastewater, fecal coliforms were of concern. However, no groundwater sampling and testing had occurred at or near the site.

Consent/Assent Form

SHD initially contacted the residents about testing their private wells. Sampling times were set up for the first week of June. A well questionnaire and consent letter was mailed or hand delivered to the homes for signature prior to sampling (See Appendix A and B). The letter outlined the need for private well sampling. It also noted that sample collection was voluntary and specific results would only be shared with the home owner and/or resident. A toll-free number was provided if further information was desired.

Results

Chemical Analysis

The results of the sampling are evaluated in this health consultation to determine whether a public health hazard exists for the residents. A total of five compounds were detected in surface water sampled in the area (see Table 1). A total of 16 compounds were detected in private wells sampled in the area (see Table 2). Each resident received a letter with the results for their private well and an explanation. A toll-free number was also provided and DOH staff were available for further discussion with each household.

Table 1. Concentration of compounds detected in Surface Water in North Fork of the Stillaguamish River and inundated areas of the SR530 landslide in Snohomish County, Washington.

Compounds	Concentration Range (ppb)	Comparison Value (ppb)	EPA Cancer Class	Comparison Value Reference	Contaminant of Concern (COC)
Arsenic	1.0 U – 1.4	3	A	EMEG	No
Chromium	1.0 U – 5.3	50*		MTCA	No
Copper	1.0 U – 5.1	100	D	Int EMEG	No
Nickel	1.0 U – 7.3	200		RMEG	No
Zinc	1.0 U – 7.5	3,000	IN	EMEG	No

ppb - parts per billion
RMEG - ATSDR's Reference Dose Media Evaluation Guide (child)
EMEG - ATSDR's Environmental Media Evaluation Guide (child)
Int EMEG - ATSDR's Intermediate Environmental Media Evaluation Guide (child)
A - EPA: Human carcinogen
D - EPA: Not classifiable as to health carcinogenicity
IN – Inadequate information to assess carcinogenic potential
U – Non-detect
MTCA - Washington State Model Toxics Control Act
* - Total chromium

Table 2. Concentration of compounds detected in Drinking/ Groundwater at Private Wells around the SR530 landslide in Snohomish County, Washington.

Compounds	Concentration Range (ppb)	Comparison Value (ppb)	EPA Cancer Class	Comparison Value Reference	Contaminant of Concern (COC)
Arsenic	ND – **28.1**	0.023	A	CREG	Yes
Barium	4.16 – 97.7	2,000	CN	EMEG	No
Chromium	ND – 36.7	50*		MTCA	No
Nickel	ND – 190	200		RMEG	No
Fluoride	ND – 120	800		RSL	No
Nitrate	109 – 814	16,000		RMEG	No
Iron	24.1 – **106,000**	14,000		RSL	Yes
Manganese	22.9 – 467	500	D	RMEG	No
Chloride	855 – 65,800				No†
Sulfate	ND – 6,810				No†
Zinc	ND – **4,190**	3,000	IN	EMEG	Yes
Sodium	1,540 – 39,800				No†
Lead	ND – **65.9**	15	B2	MCL	Yes
Copper	ND – **7,800**	100	D	Int EMEG	Yes
Di(ethylhexyl)adipate	ND – 0.288	29	C	CREG	No
2,4-D	ND – 0.681	100		RMEG	No

ppb - parts per billion
CREG - ATSDR's Cancer Risk Evaluation Guide (child)
RMEG - ATSDR's Reference Dose Media Evaluation Guide (child)
EMEG - ATSDR's Environmental Media Evaluation Guide (child)
Int EMEG - ATSDR's Intermediate Environmental Media Evaluation Guide (child)
A - EPA: Human carcinogen
C - EPA: Possible human carcinogen (no human, limited animal studies)
D - EPA: Not classifiable as to health carcinogenicity
IN – Inadequate information to assess carcinogenic potential
CN - Carcinogenic potential cannot be determined
ND – Non-detect
RSL - EPA Regional Screening Levels
MCL - Maximum contaminant level - Federal and state drinking water standard
MTCA - Washington State Model Toxics Control Act
* - Total chromium
† - See Public Health Implications section
Bold – chemical is a contaminant of concern

Bacteriology Analysis

Bacterial testing for total coliform and fecal coliform was conducted on surface water and drinking water. Total coliform bacteria were present in surface water and some private wells. This is a presence/absent test only. No concentration is identified. In addition, fecal coliform bacteria were present in surface water.

Discussion

Contaminants of Concern

DOH determined contaminants of concern (COC) in water by employing a screening process. Maximum drinking water contaminant levels were screened against health-based drinking water comparison values. Several types of health-based comparison or screening values were used during this process [see the glossary for a description of “comparison value”] including the ATSDR reference dose media evaluation guide (RMEG), environmental media evaluation guide (EMEG), and cancer risk evaluation guide (CREG). Other screening values included the EPA regional screening level (RSL), maximum contaminant goals (MCLGs), primary and secondary maximum contaminant levels (MCLs and SMCLs, respectively), and lifetime health advisories for drinking water (LTHA).

Comparison values (CVs) offer a high degree of protection and assurance that people are unlikely to be harmed by contaminants in the environment. For chemicals that cause cancer, the comparison values represent levels that are calculated to increase the estimated risk of cancer by about one additional cancer in one million people exposed. These types of comparison values often form the basis for cleanup. In general, if a contaminant’s maximum concentration is greater than its CV, it does not mean someone will get sick, it means it has to be evaluated further.

Surface Water Contaminants of Concern

PIONEER collected six surface water samples near the locations where EPA had collected previous surface water samples. Four of the sample locations were within 0.1 miles of the EPA sample locations. However, two of the previous EPA locations within the inundated area no longer contained surface water. Two replacement sample locations were determined by DOH. The replacement sample areas were immediately downriver and upriver (typically has standing surface water) from the SR530 landslide.

Surface water samples were analyzed for total coliform bacteria and priority pollutants. Five compounds (arsenic, copper, chromium, nickel, and zinc) were the only priority pollutant compounds detected in surface water (see Table 1). Since surface water chemical contaminant levels are all below the CVs, these chemicals do not pose a health concern. As a result, no further assessment of chemical exposure to surface water is needed.

Total coliform and fecal coliform were detected at similar concentrations both upriver and downriver of the landslide, indicating that the SR530 landslide likely did not influence the presence of coliform bacteria within the Stillaguamish River.

DOH strongly advises against the use of untreated surface water as a drinking water source, whether the sources are streams, lakes, or rivers. Water that is open to the atmosphere and vulnerable to surface water runoff is not safe to drink without complete treatment. Surface water sources are open to contamination from human and animal waste and other pollution. Consequently, they are particularly susceptible to contamination by organisms such as bacteria, viruses, and parasites that can cause serious illness and disease. Without extensive treatment, water from the Stillaguamish River should not be used for a drinking water source.

Drinking Water Contaminants of Concern
Private well samples were analyzed for total coliform bacteria, SVOCs, IOCs, and VOCs. Five compounds (arsenic, copper, iron, lead, and zinc) in well water exceeded the comparison values (see Tables 2) used in this health consultation. For this evaluation, they are considered to be COCs and will be further evaluated. However, zinc did not exceed the SMCL for drinking water.

Arsenic was detected in four private wells above the drinking water standard (10 parts per billion (ppb)). Lead was detected only in 5 of the 22 private wells. Four of the private wells had lead levels above the EPA recommended action level for water samples of 15 ppb. Copper exceeded the SMCL (1,000 ppb) for drinking water in one private well. Similarly, iron exceeds the SMCL (300 ppb) for drinking water in one private well.

Chloride, sulfate, and sodium are discussed in the Public Health Implications section. Chloride and sulfate did not exceed the SMCL for drinking water. None of them are carcinogens; therefore, only non-cancer hazards will be evaluated. In addition, 5 of the 22 private wells tested positive for total coliform bacteria. The five well owners were informed to disinfect their wells immediately and retest for coliform bacteria (Appendix F). Fecal coliform were absent in all 22 private wells.

Exposure Pathways
In order for any contaminant to be a human health concern, the contaminant must be present at a high enough concentration to cause potential harm, and there must be a completed route of exposure to people. That is, exposure to contaminants in the drinking water where someone is or has swallowed (ingestion exposure), breathed (inhalation exposure), or had contact with their skin (dermal exposure) would be a completed route of exposure. Arsenic, copper, iron, lead, and zinc are COC's, and are inorganic compounds that are soluble in water. The most obvious route of exposure is ingestion of drinking water by residents. IOCs are not readily absorbed through the skin, so dermal contact is not an important route of exposure. Inhalation from water or indoor air during bathing, showering, or cooking was unlikely because arsenic, copper, iron, lead, and zinc are not volatile. Exposure to IOC of concern through ingestion route is evaluated below.

Public Health Implications
The following information describes health effects that have been observed or are thought to be associated with elevated ingestion exposures to the specified chemicals. This information is not intended to be a list of health effects that are expected to occur for all persons consuming contaminated well water.

Chloride, Sulfate, Sodium
Chloride, sulfate, and sodium are essential nutrients and are typically not harmful under most environmental exposure scenarios [2]. The EPA has developed MCLs for chloride and sulfate in drinking water. The EPA has also established a drinking water equivalency level or guidance level for sodium of 20 milligrams per liter (mg/L). However, EPA believes the guidance level for sodium needs updating and is probably low [2]. The Institute of Medicine has established Dietary Reference Intakes for elements [3]. DOH calculated an average daily intake for chloride, sulfate, and sodium by multiplying the maximum level of the element in water by the amount of water ingested per day (1.4 liters). This was then compared to the Dietary Reference Intakes for that element.

Chloride
The maximum level of chloride detected in private drinking water wells was 65,800 ppb or 65.8 mg/L. In a worst-case scenario, a person exposed to the maximum level of chloride in the water, while drinking 1.4 liters of water a day, would obtain 92.1 mg/day of chloride. The Adequate Intakes for chloride from the Dietary Reference Intakes table range from 180 -2,300 mg/day, depending on age and gender [3].

Sodium
The maximum level of sodium detected in private drinking water wells was 39,800 ppb or 39.8 mg/L. In a worst-case scenario, a person exposed to the maximum level of sodium in the water, while drinking 1.4 liters of water a day, would obtain 55.7 mg/day of sodium. The Adequate Intakes for sodium from the Dietary Reference Intakes table range from 120 – 1,500 mg/day, depending on age and gender [3].

Sulfate
The maximum level of sulfate detected in private drinking water wells was 6,810 ppb or 6.81 mg/L. In a worst-case scenario, a person exposed to the maximum level of sulfate in the water, while drinking 1.4 liters of water a day, would obtain 9.5 mg/day of sulfate. The Estimated Total Daily Intakes of sulfate in drinking water and beverages range from 260 – 1,300 mg/day, with an average of 780 mg/day [3].

Chloride, sulfate, and sodium are essential nutrients. The concentrations found are well below levels expected to cause health effects and will not be evaluated further.

Chemical-Specific Toxicity
Below are general summaries of health effects of the COCs. The public health implications of exposure to these COCs are discussed later.

Arsenic
Arsenic is a naturally occurring element in the earth's soil. Background concentrations of arsenic in soil in Eastern Washington range from about 0.5 to 10.3 ppm [4]. However, the widespread use of arsenic-containing pesticides and the emissions from certain smelters has resulted in significantly higher levels of arsenic on many properties in the state. Drinking water in Washington State typically contains about 3 µg/l arsenic. However, higher levels of arsenic have been found in drinking water in some areas in the state [5]. There are two forms of arsenic: organic and inorganic. The EPA established reference dose (RfD) for arsenic is 0.0003 milligram per kilogram per day (mg/kg/day) based on skin color changes and excessive growth of tissue (human data) [6]. EPA classifies the inorganic form of arsenic as a human carcinogen. DOH is not using the slope factor of 1.5 per mg/kg/day due to the arsenic weight of evidence approach. The EPA Integrated Risk Information System (IRIS) review draft for the Science Advisory Board presented a slope factor for combined lung and bladder cancer of 5.7 per mg/kg/day [7]. The slope factor calculated from the work by the National Research Council is about 21 per mg/kg/day [8].

These slope factors could be higher if the combined risk for all arsenic-associated cancers (bladder, lung, skin, kidney, liver, etc.) were evaluated. For this or any other health consultation, DOH uses a slope factor of 5.7 per mg/kg/day, which appears to reflect EPA's most recent assessment.

Copper

Copper is a naturally occurring element in the earth's soil. Background concentrations of copper in soil in Eastern Washington range from about 4 to 53 ppm [4]. Copper is an essential element for good health. Copper rapidly enters the bloodstream and is distributed throughout the body after ingestion. Copper combines with protein and iron to make hemoglobin, which transports oxygen in the blood from the lungs to other parts of the body. Copper usually takes several days to leave the body in feces and urine. However, exposure to very high doses of copper can cause liver and kidney damage and even death [9]. Water containing high levels of copper may cause nausea, vomiting, stomach cramps, or diarrhea when ingested. In addition, long-term exposure to copper dust can irritate the nose, mouth, and eyes and also cause headaches, dizziness, nausea, and diarrhea. The Health Effects Assessment Summary Tables (HEAST) established RfD for copper is 0.04 mg/kg/day.

Iron

Iron is a naturally occurring element in the earth's soil. Background concentrations of iron in soil in Eastern Washington range from about 9,670 to 30,000 ppm [4]. In drinking water, iron is a secondary contaminant. Secondary maximum contaminant levels (SMCL) are established by EPA as guidelines to assist public water systems in managing drinking water for taste, color, and odor and are not considered a threat to human health. One private well sample exceeded the iron SMCL. Iron is essential in the maintenance and production of hemoglobin and myoglobin without which the body cannot sustain basic life functions. Iron combines with protein and copper to make hemoglobin, which transports oxygen in the blood from the lungs to other parts of the body. Generally, acute iron poisoning is the result of children accidentally overdosing on iron-containing supplements for adults and not from incidentally ingesting iron in water. The EPA provisional RfD for iron has been revised to 0.7 mg/kg/day [10].

Zinc

Zinc is a naturally occurring element in the earth's soil. Background concentrations of zinc in soil in Eastern Washington range from about 26 to 82 ppm [4]. Zinc compounds are used as ingredients in many common products, such as vitamin supplements, sun blocks, diaper rash ointments, deodorants, athlete's foot preparations, acne and poison ivy preparations, and antidandruff shampoos [11]. Ingesting high levels of zinc for short periods may cause stomach cramps, nausea, and vomiting may occur. Ingesting high levels of zinc for long periods may cause anemia, damage the pancreas, and decrease levels of high-density lipoprotein (HDL) cholesterol [11]. The EPA established RfD for zinc is 0.3 mg/kg/day.

Lead – Occurrence, Health Concerns, and Risks

Lead is a naturally occurring chemical that is normally found in the earth’s soil. In Washington, normal background concentrations rarely exceed 20 ppm [4]. However, widespread use of certain products (such as leaded gasoline, lead-containing pesticides, and lead-based paint) and emissions from certain industrial operations (such as smelters) have resulted in significantly higher levels of lead in many areas of the state.

Elimination of lead in gasoline and solder used in food and beverage cans has greatly reduced exposure to lead. Currently, the main pathways of lead exposure in children are ingestion of paint chips, contaminated soil and house dust, and drinking water in homes with old plumbing. The EPA has established an action level of 15µg/L for lead in drinking water. The action level is intended to evaluate public water supply systems. If 10% of homes on a public water system have lead levels above the action level, a preventative action such as decreasing the corrosivity of the water is required by the public water system.

Children less than seven years old are particularly vulnerable to the effects of lead. Compared to older children and adults, younger children tend to ingest more dust and soil, absorb significantly more of the lead that they swallow, and more of the lead that they absorb can enter their developing brains. Pregnant women and women of childbearing age should also be aware of lead in their environment because lead ingested by a mother can affect the unborn fetus.

Exposure to lead can be monitored by measuring the level of lead in the blood. In general, blood lead raises 1-5 µg/dl for every 1,000 ppm increase of lead in soil or dust concentration [12]. For children, the CDC defined an elevated blood lead level (BLL) as greater than, or equal to, 10 micrograms of lead per deciliter of blood (µg/dl) [13]. However, there is growing evidence that damage to the central nervous system resulting in learning problems can occur at blood lead levels less than 10µg/dl. U.S. state childhood lead program's 2006 data showed 1.21% of children tested in the U.S. had blood lead levels greater than 10µg/dl [14]. Therefore, CDC has recently updated its definition for elevated BLL to greater than, or equal to, 5µg/dl [15].

Lead poisoning can affect almost every system of the body and often occurs with no obvious or distinctive symptoms. Depending on the amount of exposure a child has, lead can cause behavior and learning problems, central nervous system damage, kidney damage, reduced growth, hearing impairment, and anemia [16].

In adults, high exposure to lead can cause health problems such as high blood pressure, kidney damage, nerve disorders, memory and concentration problems, difficulties during pregnancy, digestive problems, and pain in the muscles and joints [16]. These health effects have usually been associated with blood lead levels greater than 30µg/dl.

Because of chemical similarities to calcium, lead can be stored in bone for many years. Even after exposure to environmental lead has been reduced, lead stored in bone can be released back into the blood where it can have harmful effects. Normally this release occurs relatively slowly. However, certain conditions such as pregnancy, lactation, menopause, and hyperthyroidism can cause more rapid release of the lead, which could lead to a significant rise in blood lead levels [17].

Evaluating Exposure to Lead

The biokinetics of lead are different from most toxicants because it is stored in bones and remains in the body long after it is ingested. Children's exposure to lead is evaluated through the use of the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) developed by the EPA. The IEUBK predicts blood lead levels in a distribution of exposed children based on the amount of lead that is in environmental media (e.g., water) [18]. It is important to note that the IEUBK model is not expected to accurately predict the blood lead level of a child (or a small group of children) at a specific point in time. In part, this is because a child (or group of children) may behave differently and therefore have different amounts of exposure to contaminated soil and dust than the average group of children used by the model to calculate blood lead levels. For example, the model does not take into account reductions in exposure that could result from community education programs. Despite this limitation, the IEUBK model is a useful tool to help prevent lead poisoning because of the information it can provide about the hazards of environmental lead exposure. For children who are regularly exposed to lead contaminated water, the IEUBK model can estimate the percentage of young children who are likely to have blood lead concentrations that exceed a level that may be associated with health problems (usually 10µg/dl). However, CDC has updated its definition for elevated BLL to greater than, or equal to, 5µg/dl [15].

Lead concentrations and estimated blood lead levels
The IEUBK model was used to estimate the percentage of children that could have elevated blood lead levels if they frequently drink lead contaminated water. Default parameters are used for all model inputs unless stated (soil default value removed when evaluating water) [18]. Exposure was based on children drinking water containing the lead concentrations above the CVs (see Appendix E, Table E). Based on the estimated increase in blood lead levels, the lead in water from private wells above the EPA action level of 15µg/L would result in elevated BLL for children.

Lead is rarely found in natural water sources. After the landslide occurred, many people in the area were not using their wells for extended periods. Therefore, the lead detected in a few of these private wells is likely due to homes with old plumbing, brass faucets, or lead solder on copper pipes. Sudden changes to water quality and seismic activity from the landslide can cause a release of lead from the pipes. Corrosion and standing water may also be contributing factors to the increase levels of lead in the water and not the groundwater. Flushing the pipes by letting water run for a few minutes before using water from them for drinking or cooking should reduce the lead levels. Well owners should also clean the aerators on faucets for a few months and consider changing water filters on sink mounted units and/or refrigerators as a precautionary measure. Well owners with elevated levels received education materials about lead in drinking water (http://www.doh.wa.gov/portals/1/Documents/pubs/331-177.pdf).

Evaluating Non-cancer Hazards

Exposure assumptions for estimating arsenic, copper, iron and zinc exposures for private wells are found in Appendix D, Table D1. In order to evaluate the potential for non-cancer adverse health effects that may result from exposure to contaminated media (i.e., soil, air, and water), a dose is estimated for each COC. These doses are calculated for situations (scenarios) in which a person might be exposed to the contaminated media. The estimated dose for each contaminant under each scenario is then compared to the MRL. MRLs are an estimate of the daily human exposure to a substance that is likely to be without appreciable risk of adverse health effects during a specified duration of exposure. In the absence of MRLs, DOH uses EPA's RfD. RfDs are doses below which non-cancer adverse health effects are not expected to occur. MRLs and/or RfDs are derived from toxic effect levels obtained from human population and laboratory animal studies. These toxic effect levels can be either the lowest-observed adverse effect level (LOAEL) or the no-observed adverse effect level (NOAEL). In human or animal studies, the LOAEL is the lowest dose at which an adverse health effect is seen, while the NOAEL is the highest dose that does not result in any adverse health effects.

Because of uncertainty in these data, the toxic effect level is divided by "uncertainty factors" to produce the lower and more protective MRL or RfD. If a dose exceeds the MRL or RfD, it does not mean that adverse health effects will occur. When the MRL or RfD is exceeded, further toxicological evaluation is needed. The further evaluation includes comparing the site-specific estimated dose to doses from animal and human studies that showed either an effect level or a no effect level. This comparison, combined with other toxicological information, such as sensitive groups and chemical metabolism, is used to determine the risk of specific harmful effects. A MRL or RfD is exceeded whenever the hazard quotient (HQ) is greater than one (see Appendix D for the hazard quotient equation).

Estimated exposure doses, exposure assumptions, and hazard quotients are presented in Appendix C for arsenic, copper, iron, and zinc found in private wells water. Based on exposure estimates quantified in Appendix D, residents with levels exceeding CVs are likely to experience adverse non-cancer health effects from exposure to arsenic, copper, and iron.

Arsenic

Arsenic was detected in 16 of the 22 private wells. However, only four samples had arsenic levels above the federal and state drinking water standard MCL of 10 ppb. A maximum concentration of 28.1 ppb was in one private well. The MCL is not based on human health but are set as close to the non-enforceable MCLG (zero) as possible, based on cost and best available treatment technologies for removing arsenic. The ATSDR chronic CREG for arsenic is 0.023 ppb. ATSDR has derived a chronic MRL of 0.0003 mg/kg/day for arsenic.

Estimated exposure doses for children and adults were calculated with resulting doses ranging from 0.00162 to 0.0000186 mg/kg/day (see Appendix D, Table D3). These exposure doses exceed the MRL. Three of the four samples above the MCL child dose range exceed the arsenic NOAEL of 0.0008 mg/kg/day. However, they did not exceed the LOAEL of 0.05 mg/kg/day for chronic exposure to arsenic. Additionally, previous sampling data from one of the private wells indicates higher levels of arsenic in that well. Since arsenic in groundwater can have seasonal variations, DOH expects exposures to arsenic will cause harmful non-cancer health effects in this private well.

Copper

Copper was detected at a maximum concentration of 7,800 ppb in one private well. This maximum level of copper in the drinking water exceeds the ATSDR intermediate EMEG (100 ppb) for children. ATSDR has not derived an MRL for copper. The EPA HEAST has established an RfD for copper of 0.04 mg/kg/day.

Estimated exposure doses for children and adults were calculated with resulting doses ranging from 0.145 to 0.449 mg/kg/day (see Appendix D, Table D2). These exposure doses are exceeds the RfD and the NOAEL (0.0272 mg/kg/day) for acute (short term) exposure, and the NOAEL (0.042 mg/kg/day) for intermediate exposure to copper. Based on the results, DOH expects exposures to copper will cause harmful non-cancer health effects. However, field sampling notes indicate that the home has copper pipes. Therefore, the high level of copper detected in this private well is likely due to copper plumbing. Sudden changes to water quality and seismic activity from the landslide can cause a release of copper from the pipes. Corrosion and standing water may also be contributing factors. Flushing the pipes by letting water run for a few minutes before using water from them for drinking or cooking should reduce the copper levels. Well owners should also clean the aerators on faucets for a few months and consider changing water filters on sink mounted units and/or refrigerators as a precautionary measure. Well owners with elevated levels received education materials about copper in drinking water (http://www.doh.wa.gov/portals/1/Documents/pubs/331-178.pdf).

Iron

Iron was detected at a maximum concentration of 106,000 ppb in one private well. This maximum level of iron in the drinking water exceeds the RSL (14,000 ppb) for children. ATSDR has not derived an MRL for iron. The EPA has established a provisional RfD for iron of 0.7mg/kg/day [9].

Estimated exposure doses for children and adults were calculated with resulting doses ranging from 1.98 to 6.1 mg/kg/day (see Appendix D, Table D2). These exposure doses exceed the provisional RfD for iron.

According to the National Academy of Sciences, the median daily intake of dietary iron is about 11–13 mg/day for children ages 1 to 8 years old [19]. The median daily intake equates to a dose of about 0.73 – 0.87 mg/kg/day for a child. According to the FDA, doses 200 mg or greater per event could poison or kill a child [20]. This equates to a dose of about 13.3 mg/kg/day for a child. An exposure dose for a child at the maximum level in the one private well is about 6.1 mg/kg/day. Field sampling notes indicate that the water sample was extremely turbid and the well was turned on once since the landslide. Therefore, the high level of iron likely occurred from corrosion of iron pipes. Flushing the pipes by letting water run for a few minutes before using water from them for drinking or cooking should reduce the iron levels. Non-cancer adverse health effects are not likely to result from exposure to iron in the private well, and it will not be evaluated any further.

Zinc

Zinc was detected at a maximum concentration of 4,190 ppb in one private well. This maximum level of zinc in the drinking water exceeds the EMEG (3,000 ppb) for children. ATSDR has derived an MRL and EPA has established an RfD for zinc of 0.3 mg/kg/day.

Estimated exposure doses for children and adults were calculated with resulting doses ranging from 0.098 to 0.241 mg/kg/day (see Appendix D, Table D2). These exposure doses are less than the MRL and RfD. Therefore, DOH does not expect that exposures to zinc will cause harmful non-cancer health effects.

Evaluating Cancer Hazards

Some chemicals have the ability to cause cancer. Cancer risk is estimated by calculating a dose similar to those used for evaluating non-cancer hazards and multiplying it by a cancer potency factor, also known as the cancer slope factor. Some cancer potency factors are derived from human population data. Others are derived from laboratory animal studies involving doses much higher than are encountered in the environment. Use of animal data requires extrapolation of the cancer potency obtained from these high dose studies down to real-world exposures. This process involves much uncertainty.

Current regulatory practice assumes there is no “safe dose” of a carcinogen and that any dose of a carcinogen will result in some additional cancer risk. Therefore, estimated cancer risk estimates are not yes/no answers, but measures of chance (probability). Such measures, however uncertain, are useful in determining the magnitude of a cancer threat because any level of a carcinogenic contaminant carries an associated risk. The validity of the “no safe dose” assumption for all cancer-causing chemicals is not clear. Some evidence suggests that certain chemicals considered to be carcinogenic must exceed a threshold of tolerance before initiating cancer. For such chemicals, risk estimates are not appropriate. Recent guidelines on cancer risk from EPA reflect the potential that thresholds for some carcinogenesis exist. However, EPA still assumes no threshold unless sufficient data indicate otherwise [21].

This document describes estimated cancer risk that is attributable to site-related contaminants in qualitative terms like low, very low, slight, and no significant increase in estimated cancer risk. These terms can be better understood by considering the population size required for such an estimate to result in a single cancer case. For example, a low increase in cancer risk indicates an estimate in the range of one cancer case per ten thousand persons exposed over a lifetime. A very low estimate might result in one cancer case per several tens of thousands exposed over a lifetime, and a slight estimate would require an exposed population of several hundreds of thousands to result in a single case. DOH considers estimated cancer risk insignificant when the estimate results in less than one cancer per one million exposed over a lifetime. The reader should note that these estimates are for excess cancers that might result in addition to those normally expected in an unexposed population.

Estimated Cancer Risk

Estimated cancer risk does not reach zero no matter how low the level of exposure to a carcinogen. Terms used to describe this risk are defined below as the number of excess cancers expected in a lifetime:

Term		# of Excess Cancers
moderate	is approximately equal to	1 in 1,000
low	is approximately equal to	1 in 10,000
very low	is approximately equal to	1 in 100,000
slight	is approximately equal to	1 in 1,000,000
insignificant	is less than	1 in 1,000,000

Cancer is a common illness and its occurrence in a population increases with the age of the population. There are many different forms of cancer resulting from a variety of causes; not all are fatal. Approximately 1 in 3 to 1 in 2 people living in the United States will develop cancer at some point in their lives [22].

DOH calculated estimated cancer risk based on exposure doses (Appendix D). Exposure to arsenic in drinking water below the MCL would increase a person's estimated cancer risk by about 6 excess cancers in a population of 100,000 to 6 excess cancers in a population of 10,000 similarly exposed people. Similarly, the range of exposure to arsenic in drinking water above the MCL would increase a person's estimated cancer risk by about 8 excess cancers in a population of 10,000 to 2 excess cancers in a population of 1,000 similarly exposed people (See Appendix D - Table D4).

Uncertainty

Carcinogenic Potential of Arsenic

Although there is some uncertainty surrounding the magnitude of the carcinogenic potential of arsenic, there is a strong scientific basis for choosing a slope factor that is different from the value (1.5 per mg/kg-day) currently listed in the EPA integrated risk information system (IRIS) database [23]. Several recent reviews of the literature have evaluated bladder and lung cancer endpoints instead of skin cancer (which is the endpoint used for the current IRIS value):

- National Research Council (2001) [24]
- EPA Office of Drinking Water (2001) [25]
- Consumer Product Safety Commission (2003) [26]
- EPA Office of Pesticide Programs (2003) [27]
- California Office of Environmental Health Hazard Assessment (2004) [28]
- EPA IRIS Review Draft for the SAB (2005) [23]

Information provided in these reviews allows the calculation of slope factors for arsenic, which range from 0.4 to 23 per mg/kg-day (but mostly greater than 3.7 mg/kg-day). A previous EPA IRIS review draft presented a slope factor for combined lung and bladder cancer of 5.7 per mg/kg-day. The slope factor calculated by the National Research Council is about 21 per mg/kg-day. These slope factors could be higher if the combined risk for all arsenic-associated cancers (bladder, lung, skin, kidney, liver, etc.) were evaluated. For this health consultation, DOH used a slope factor of 5.7 per mg/kg-day.

Children's Health Considerations

The potential for exposure and subsequent adverse health effects often increases for younger children compared with older children or adults. ATSDR and DOH recognize that 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, resulting in hand-to-mouth activities.
- Children are smaller and receive higher doses of contaminant exposures 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 contaminants can cause permanent damage during critical growth stages.

These unique vulnerabilities of infants and children demand special attention in communities that have contaminated water, food, soil, or air. Children's health was considered in the writing of this health consultation and the exposure scenarios treated children as the most sensitive population being exposed. The doses calculated for the copper, iron, lead, and zinc are not expected to result in adverse health effects for children because while detected they are not the true status of the groundwater but rather due to water standing in the pipes. However, arsenic levels can cause adverse health effects for children.

Conclusions

- Four private wells contain arsenic above the MCL. These levels could harm people's health if used for drinking or food preparation. Food preparation includes washing foods, cooking, or using well water as an ingredient. Maximum levels of arsenic in these private wells are above levels of concern, including the federal and state drinking water standard.

- Five wells tested positive for total coliform bacteria. Once these five wells have been disinfected, water from all 22 private wells does not pose a health threat if used for bathing and cleaning.

- DOH concludes that lead, copper, and iron in private wells water are not expected to harm people's health. Maximum levels of lead, copper, and iron in the private wells are due to corrosion and water standing in the pipes and not levels in groundwater. Levels should be reduced after flushing the pipes.

- Swimming in the river is not expected to harm people's health. The maximum level of chemical contaminants found in surface water is not expected to cause non-cancer health effects. The maximum level of chemical contaminants found in surface water is below level of contaminants of concern.

Recommendations

- The owners of the four private wells with arsenic above the MCL should consider the following options for reducing exposure to arsenic: use bottled water or an alternate water supply. To determine if arsenic levels in your well are consistently above the MCL and whether an arsenic treatment system needs to be installed, sample your well quarterly or seasonally for one year.

- The owners of the five private wells that tested positive for total coliform bacteria should follow the procedures provided by Snohomish Health District for disinfecting their private wells. Please refer to the recommended procedures (Appendix F).

- Repeat sampling of the 22 private wells for the same list of contaminants within the next year to confirm the groundwater status.

- Private well owners should test their water periodically[b] to evaluate the safety of the water supply. Because contaminant levels can vary seasonally, DOH recommends testing for arsenic and other contaminants in late summer and in the early spring to see if there are differences.

- Private well owners should not use water for drinking or food preparation if it contains more than 10µg/l of arsenic.

- Private well owners should not use water containing between 10µg/l and 50µg/l arsenic for drinking or food preparation over the long term.

- Immediately stop using well water for drinking and food preparation if it contains more than 50µg/l arsenic.

- Stop using well water for bathing and cleaning if the water contains more than 500µg/l of arsenic.

- Contact the local health department or DOH for advice, if arsenic levels in well water are greater than 500µg/l.

- DOH strongly advises against the use of untreated surface water as a drinking water source anywhere in the state.

---

[b] The Washington State Department of Health recommends that private well users test their well water every year for coliform bacteria and nitrate [1].

Public Health Action Plan

Action Completed:

1. SHD informed the five well owners with positive coliform bacteria to disinfect and retest their wells immediately.

2. In July 2014, DOH sent a letter to each residents/owner of private well tested informing of their well water status, summarizing their results, and the process needed to make their water acceptable for drinking.

Actions Planned:

1. DOH will provide copies of this health consultation to SHD, private well owners, and Washington State Department of Ecology.

2. DOH will evaluate future data if or when the data becomes available.

Report Preparation

This health consultation for the SR 530 landslide Site was prepared by the Washington State Department of Health (DOH) 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, and procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. This report was supported by funds from a cooperative agreement with the Agency for Toxics Substances and Disease Registry, U.S. Department of Health and Human Services. This document has not been reviewed and cleared by ATSDR.

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Appendix A

Consent Form for Residential, Private Well Sampling
Post SR530 Landslide

We would like to invite you to participate in an investigation to determine if your private drinking water well has contaminants that may have been introduced from the recent catastrophic landslide. Washington State Department of Health (DOH) is offering free, voluntary drinking water testing for residents living in the area adjacent to the State Route (SR) 530 landslide. Participation in this investigation will enable you to know the level of contaminants in your water and will enable the DOH to recommend public health actions that may be needed to reduce exposure these contaminants. DOH has contracted with PIONEER Technologies Corporation (PIONEER) to come to your home and collect drinking water samples from your tap or wellhead. Upon your consent, PIONEER will contact you to set up a time that is convenient to come to your home and collect a water sample.

Benefits
I understand that I will benefit from participating by learning whether there is chemical or bacterial contamination in my private well. If elevated levels of contaminants are found in my homes' water that present concerns to human health, I will receive information on how to reduce exposures to the elevated contaminants.

Risks
There are no foreseeable risks in participating in the drinking water sampling.

Procedure/Tests:
A representative from PIONEER will bring sample containers and collect water from your wellhead or tap. The preference is from the wellhead, prior to any treatment, but this is not possible on wells that do not have a tap near the wellhead. Tap water from the kitchen sink is the next best choice. However, tap water can also identify contaminants that may be coming from your water delivery system (e.g., the water pipes). Sampling is only scheduled and funded to include a 1-time sampling from each home that provides consent. Consent must be confirmed by no later than **May 30, 2014.**

Participation
I understand that my participation is **voluntary**. Furnishing any information is voluntary and even if I agree to participate and sign this form, I can stop my participation at any time without penalty. I understand that I must sign this form to participate.

Results
I understand every effort will be made to provide the results of my tests in writing to me within approximately one month. Results that are of immediate health concern will be reported to me as soon as they are known.

Confidentiality
Confidentiality will be protected to the fullest extent possible by law. Any reports produced from this information will give only group information and not identify specific individuals or locations.

I understand that if I participate, any forms containing my name or address will be kept in locked cabinets at DOH. Test results may be released only to other federal, state, and local public health and environmental agencies. These agencies must also protect this confidential information.

Contact
If I have any additional questions or if I feel I have been harmed by this information or the sampling, I may contact: Lenford O'Garro or Joanne Snarski of DOH at 1 (877) 485-7316.

Consent
The risks and benefits of this sampling have been explained to me. All of my questions have been satisfactorily answered. I hereby freely and voluntarily give my signed consent for participating in the testing described above.

I, (print) ____, agree to have my private well water sampled for contaminants that may be present due to the SR530 landslide.

Signature: ____

Date: ____________

Address: ____
Street

____
City State Zip code

____
Mailing

Phone #: ______________________________

Witness: _______________________________ _______________________________
(Print name) (Signature)

Appendix B

Residential Well Questionnaire for Post SR530 Landslide Private Well Sampling

1. Is your water system in working condition? ☐Yes ☐No
2. Can water samples be collected at the wellhead, before any treatment? ☐Yes ☐No
   If yes, the sample will be collected from the wellhead. If no, the sample will be collected from the kitchen sink tap.
3. Has your well been tested before for contaminants? ☐Yes ☐No
   If yes, please provide a copy to DOH or PIONEER.
4. Do you have a well log? A well log is an "as built" diagram of your well.
   If yes, please provide a copy to DOH or PIONEER.
   If no, do you know how deep your well is and/or the depth of the well screen?

   ____
5. Do you treat your water regularly? ☐Yes ☐No
   If yes, please describe the specific treatment you use:

   ____

   ____
6. Have you done any additional treatment (e.g., chlorine) since the landslide? ☐Yes ☐No
   If yes, please describe the treatment and date performed:

   ____

   ____
7. Can you describe the type and condition of pipes in your water distribution system? ☐Yes ☐No
   If yes, please describe below:

   ____

   ____

______________________ ______________________

Signature Print Name

______________________ ______________________

Address Date

Appendix C

Table D1: List of analyte tested for in surface water samples

Category	Parameter	Analytical Method
Bacteriological	Coliform Presence/Absence	SM9223B
	Fecal coliform	SM9221E
	E. Coli	SM9223B
Category	**Parameter**	**Analytical Method**
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	USEPA 624
	1,1,2,2-Tetrachloroethane	USEPA 624
	1,1,2-Trichloroethane	USEPA 624
	1,1-Dichloroethane	USEPA 624
	1,1-Dichloroethene	USEPA 624
	1,2-Dichloroethane	USEPA 624
	1,2-Dichloropropane	USEPA 624
	2-Chloroethyl vinyl ether	USEPA 624
	Acrolein	USEPA 624
	Acrylonitrile	USEPA 624
	Benzene	USEPA 624
	Bromodichloromethane	USEPA 624
	Bromoform	USEPA 624
	Bromomethane	USEPA 624
	Carbon Tetrachloride	USEPA 624
	Chlorobenzene	USEPA 624
	Chloroethane	USEPA 624
	Chloroform	USEPA 624
	Chloromethane	USEPA 624
	cis-1,3-Dichloropropene	USEPA 624
	Dibromochloromethane	USEPA 624
	Ethylbenzene	USEPA 624
	Methylene chloride	USEPA 624
	Tetrachloroethene	USEPA 624
	Toluene	USEPA 624
	trans-1,2-Dichloroethene	USEPA 624
	trans-1,3-Dichloropropene	USEPA 624
	Trichloroethene	USEPA 624
	Vinyl Chloride	USEPA 624
Category	**Parameter**	**Analytical Method**
Semi-volatile Organic Compounds (SVOCs)	1,2,4-Trichlorobenzene	USEPA 625
	1,2-Dichlorobenzene	USEPA 625
	1,2-Diphenyl hydrazine	USEPA 625
	1,3-Dichlorobenzene	USEPA 625
	1,4-Dichlorobenzene	USEPA 625
	2,4,6-Trichlorophenol	USEPA 625
	2,4-Dichlorophenol	USEPA 625
	2,4-Dimethylphenol	USEPA 625
	2,4-Dinitrophenol	USEPA 625
	2,4-Dinitrotoluene	USEPA 625

	2,6-Dinitrotoluene	USEPA 625
	2-Chloronaphthalene	USEPA 625
	2-Chlorophenol	USEPA 625
	2-Nitrophenol	USEPA 625
	3,3'-Dichlorobenzidine	USEPA 625
	4,6-Dinitro-2-methylphenol	USEPA 625
	4-Bromophenyl-phenylether	USEPA 625
	4-Chloro-3-methylphenol	USEPA 625
	4-Chlorophenyl-phenylether	USEPA 625
	4-Nitrophenol	USEPA 625
	Acenaphthene	USEPA 625
	Acenaphthylene	USEPA 625
	Anthracene	USEPA 625
	Benzidine	USEPA 625
	Benzo(ghi)perylene	USEPA 625
	Benzo[a]anthracene	USEPA 625
	Benzo[a]pyrene	USEPA 625
	Benzo[b]fluoranthene	USEPA 625
	Benzo[k]fluoranthene	USEPA 625
	bis(2-Chloroethoxy)methane	USEPA 625
	bis(2-Chloroethyl)ether	USEPA 625
	bis(2-chloroisopropyl)ether	USEPA 625
	bis(2-Ethylhexyl)phthalate	USEPA 625
	Butylbenzylphthalate	USEPA 625
	Chrysene	USEPA 625
	Di-n-butylphthalate	USEPA 625
	Di-n-octylphthalate	USEPA 625
	Dibenz[a,h]anthracene	USEPA 625
	Diethylphthalate	USEPA 625
	Dimethylphthalate	USEPA 625
	Fluoranthene	USEPA 625
	Fluorene	USEPA 625
	Hexachlorobenzene	USEPA 625
	Hexachlorobutadiene	USEPA 625
	Hexachlorocyclopentadiene	USEPA 625
	Hexachloroethane	USEPA 625
	Indeno[1,2,3-cd]pyrene	USEPA 625
	Isophorone	USEPA 625
	n-Nitroso-di-n-propylamine	USEPA 625
	n-Nitrosodiphenylamine	USEPA 625
	Naphthalene	USEPA 625
	Nitrobenzene	USEPA 625
	Pentachlorophenol	USEPA 625
	Phenanthrene	USEPA 625
	Phenol	USEPA 625
	Pyrene	USEPA 625

Category	Parameter	Analytical Method
Pesticides/ Polychlorinated Biphenyls (PCBs)	alpha-BHC	USEPA 608
	gamma-BHC (Lindane)	USEPA 608
	beta-BHC	USEPA 608

	delta-BHC	USEPA 608
	Heptachlor	USEPA 608
	Aldrin	USEPA 608
	Heptachlor epoxide	USEPA 608
	4,4-DDE	USEPA 608
	Endosulfan I	USEPA 608
	Dieldrin	USEPA 608
	Endrin	USEPA 608
	4,4-DDD	USEPA 608
	Endosulfan II	USEPA 608
	4,4-DDT	USEPA 608
	Endrin aldehyde	USEPA 608
	Endosulfan sulfate	USEPA 608
	Aroclor 1016 (PCB-1016)	USEPA 608
	Aroclor 1221 (PCB-1221)	USEPA 608
	Aroclor 1232 (PCB-1232)	USEPA 608
	Aroclor 1242 (PCB-1242)	USEPA 608
	Aroclor 1248 (PCB-1248)	USEPA 608
	Aroclor 1254 (PCB-1254)	USEPA 608
	Aroclor 1260 (PCB-1260)	USEPA 608
	Chlordane	USEPA 608
	Toxaphene	USEPA 608

Category	Parameter	Analytical Method
Total and Dissolved Metals Other constituents	Antimony	USEPA 200.8
	Arsenic	USEPA 200.8
	Beryllium	USEPA 200.8
	Cadmium	USEPA 200.8
	Chromium	USEPA 200.8
	Copper	USEPA 200.8
	Lead	USEPA 200.8
	Mercury	USEPA 245.7
	Nickel	USEPA 200.8
	Selenium	USEPA 200.8
	Silver	USEPA 200.8
	Thallium	USEPA 200.8
	Zinc	USEPA 200.8
	Total Cyanide	EPA 335.4

Table D2: List of analyte tested for in surface water samples

Category	Parameter	Analytical Method
Bacteriological	Coliform Presence/Absence	SM9223B
Category	**Parameter**	**Analytical Method**
Inorganic Compounds (IOCs) and Physical Parameters	Antimony	USEPA 200.8
	Arsenic	USEPA 200.8
	Barium	USEPA 200.8
	Beryllium	USEPA 200.8
	Cadmium	USEPA 200.8
	Chloride	USEPA 300.0
	Chromium	USEPA 200.8
	Copper	USEPA 200.8
	Cyanide	USEPA 335.4
	Fluoride	USEPA 300.0
	Iron	USEPA 200.7
	Lead	USEPA 200.8
	Manganese	USEPA 200.8
	Mercury	USEPA 200.8
	Nickel	USEPA 200.8
	Nitrate	USEPA 300.0
	Nitrite	USEPA 300.0
	Selenium	USEPA 200.8
	Silver	USEPA 200.8
	Sodium	USEPA 200.7
	Sulfate	USEPA 300.0
	Thallium	USEPA 200.8
	Zinc	USEPA 200.8
	Color	USEPA 110.2
	Conductivity	USEPA 120.1
	Total Dissolved Solids (TDS)	USEPA 160.1
Category	**Parameter**	**Analytical Method**
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	USEPA 524.2
	1,1,2-Trichloroethane	USEPA 524.2
	1,1-Dichloroethene	USEPA 524.2
	1,2,4-Trichlorobenzene	USEPA 524.2
	1,2-Dichlorobenzene	USEPA 524.2
	1,2-Dichloroethane	USEPA 524.2
	1,2-Dichloropropane	USEPA 524.2
	1,4-Dichlorobenzene	USEPA 524.2
	Benzene	USEPA 524.2
	Carbon Tetrachloride	USEPA 524.2
	Chlorobenzene	USEPA 524.2
	cis-1,2-dichloroethene	USEPA 524.2
	Ethylbenzene	USEPA 524.2
	m+p-Xylene	USEPA 524.2
	Methylene chloride	USEPA 524.2
	o-Xylene	USEPA 524.2
	Styrene	USEPA 524.2
	Tetrachloroethene	USEPA 524.2

	Toluene	USEPA 524.2
	trans-1,2-Dichloroethene	USEPA 524.2
	Trichloroethene	USEPA 524.2
	Vinyl Chloride	USEPA 524.2
Category	**Parameter**	**Analytical Method**
Synthetic Organic Compounds (SOCs)	Chlordane	USEPA 505
	Endrin	USEPA 505
	Heptachlor	USEPA 505
	Heptachlor epoxide	USEPA 505
	Lindane	USEPA 505
	Methoxychlor	USEPA 505
	PCBs (as total aroclors)	USEPA 505
	Toxaphene	USEPA 505
	2,4,5-TP (Silvex)	USEPA 515.3
	2,4-D	USEPA 515.3
	Dalapon	USEPA 515.3
	Dinoseb	USEPA 515.3
	Pentachlorophenol	USEPA 515.3
	Picloram	USEPA 515.3
	Alachlor	USEPA 525.2
	Atrazine	USEPA 525.2
	Benzo(a)pyrene	USEPA 525.2
	Di(2-ethylhexyl)adipate	USEPA 525.2
	Di(2-ethylhexyl)phthalate	USEPA 525.2
	Hexachlorobenzene	USEPA 525.2
	Hexachlorocyclopentadiene	USEPA 525.2
	Simazine	USEPA 525.2
	Carbofuran	USEPA 531.2
	Oxamyl	USEPA 531.2
	1,2-Dibromo-3-chloropropane (DBCP)	USEPA 504.1
	1,2-Dibromoethane (EDB)	USEPA 504.1
	Glyphosate	USEPA 547
	Endothall	USEPA 548.1
	Diquat	USEPA 549.2

Appendix D

This section provides calculated exposure doses and assumptions used for exposure to chemicals in drinking water near the SR530 Landslide. Three different exposure scenarios were developed to model exposures that might occur. These scenarios were devised to represent exposures to a child (0-5 years), an older child, and an adult. The following exposure parameters and dose equations were used to estimate exposure doses from direct contact with chemicals in water.

Exposure to inorganic contaminants in water via ingestion

Ingestion Route

$$\text{Dose}_{(\text{non-cancer (mg/kg-day)})} = \frac{Cw \times CF \times IR \times EF \times ED}{BW \times AT_{\text{non-cancer}}}$$

$$\text{Dose}_{(\text{cancer (mg/kg-day)})} = \frac{Cw \times CF \times IR \times EF \times ED}{BW \times AT_{\text{cancer}}}$$

$$\text{Cancer Risk} = \frac{Cw \times IR \times EF \times ED \times CPF}{BW \times AT_{\text{cancer}}}$$

Table D1. Exposure assumptions used to estimate private well drinking water dose exposure from near SR530 Landslide, Snohomish County, Washington.

Parameter	Value	Unit	Comments
Concentration (Cw)	Variable	µg/L	Maximum detected value
Conversion Factor (CF)	0.001	µg/mg	Converts contaminant concentration from micrograms(µg) to milligrams (mg)
Ingestion Rate (IR) - adult	1.4	L/day	Exposure Factors Handbook [29]
Ingestion Rate (IR) - older child	1.0		
Ingestion Rate (IR) - child	0.9		
Exposure Frequency (EF)	350	days/year	Two week vacation
Exposure Duration (ED)	30 (5, 10, 15)	years	Number of years at one residence (child, older child, adult years)
Body Weight (BW) - adult	72	kg	Adult mean body weight
Body Weight (BW) - older child	41		Older child mean body weight
Body Weight (BW) - child	15		0-5 year-old child average body weight
Averaging Time$_{\text{non-cancer}}$ (AT)	Variable	days	Equal to Exposure Duration
Averaging Time$_{\text{cancer}}$ (AT)	27375	days	75 years
Cancer Potency Factor (CPF)	5.7	mg/kg-day^{-1}	Souce: EPA

kg - kilogram
µg/L - microgram per liter
µg/mg - microgram per milligram
L/day - liter per day
mg/kg/day - milligrams per kilogram body-weight per day
EPA - Environmental Protection Agency

Private Well Drinking Water Exposure Route –Non-cancer

Table D2. Non-cancer hazard calculations resulting from exposure to copper, iron, and zinc in private well drinking water near SR530 Landslide, Snohomish County, Washington

Contaminant	Maximum Concentration (ppb)	Scenarios	Estimated Dose (mg/kg/day) Ingestion	MRL (mg/kg/day)	Estimated Dose/ MRL
Copper	7,800	Child	4.49E-1	4.0E-2*	11.23
		Older Child	1.82E-1		4.55
		Adult	1.45E-1		3.63
Iron	106,000	Child	6.10	7.0E-1**	8.71
		Older Child	2.48		3.54
		Adult	1.98		2.83
Zinc	4,190	Child	2.41E-1	3.0E-1	0.80
		Older Child	9.80E-2		0.33
		Adult	7.81E-2		0.26

ppb -parts per billion
MRL- ATSDR Minimal Risk Level
*RfD - EPA oral reference dose (Heath Effects Assessment Summary Tables)
**RfD - EPA oral reference dose (Provisional Peer Reviewed Toxicity Values)
mg/kg/day - milligrams per kilogram body-weight per day

Table D3. Non-cancer hazard calculations resulting from exposure to arsenic in private well drinking water near SR530 Landslide, Snohomish County, Washington

Contaminant	Concentration Range (ppb)	Scenarios	Estimated Dose (mg/kg/day) Ingestion	MRL (mg/kg/day)	Estimated Dose/ MRL	Doses Exceed NOAEL? (0.0008 mg/kg/day)	Doses Exceed LOAEL? (0.05 mg/kg/day)
Arsenic	1.0 – 10.0*	Child	5.75E-5 – 5.75E-4	3.0E-4	0.19 – 1.92	No – No	No
		Older Child	2.34E-5 – 2.34E-4		0.08– 0.78	No – No	No
		Adult	1.86E-5 – 1.86E-4		0.06 – 0.62	No – No	No
	12.4 – 28.1	Child	7.13E-4 – 1.62E-3		2.38 – 5.40	No – Yes	No
		Older Child	2.90E-4 – 6.57E-4		0.97 – 2.19	No – No	No
		Adult	2.31E-4 – 5.24E-4		0.77 – 1.75	No – No	No

ppb -parts per billion
MRL- ATSDR Minimal Risk Level
mg/kg/day - milligrams per kilogram body-weight per day
* Range below the MCL

Hazard Quotient formula:

$$HQ = \frac{\text{Estimated Dose (mg/kg-day)}}{\text{MRL (mg/kg-day)}}$$

Private Wells Drinking Water Exposure Route – Cancer

Table D4. Cancer hazard calculations resulting from exposure to arsenic in private well drinking water near SR530 Landslide, Snohomish County, Washington.

Contaminant	Concentration Range (ppb)	EPA Cancer Group	Scenarios	Cancer Potency Factor $(mg/kg\text{-}day)^{-1}$	Increased Cancer Risk Range
					Ingestion
Arsenic	1.0 – 10.0*	A	Child	5.7	2.19E-5 – 2.19E-4
			Older Child		1.78E-5 – 1.78E-4
			Adult		2.13E-5 – 2.13E-4
	12.4 – 28.1		Child		2.71E-4 – 6.14E-4
			Older Child		2.20E-4 – 4.99E-4
			Adult		2.64E-4 – 5.97E-4
Range of the Sum of Cancer Risks below MCL					6.10E-5– 6.10E-4
Range of the Sum of Cancer Risks above MCL					7.55E-4– 1.71E-3

ppb – parts per billion
mg/kg/day - milligrams per kilogram body-weight per day
* Range below the MCL

Appendix E

Lead Exposure scenario used in the IEUBK model

This section provides inputs for the IEUBK model. The following inputs to the model were used to account for lead exposures in private drinking water wells, at SR530 near the landslide area, Oso, Washington.

Changes to the model:
Lead concentration in private wells at an exposure unit on the site. (**Range of Maximum lead concentration in water above comparison value** (20 ppb – 66 ppb). The EPA's target cleanup goal of is no more than 5% of the community (0-84 months) with BLLs above 10µg/dL. CDC has updated its definition for elevated BLL to greater than, or equal to, **5µg/dl**. Therefore, the target blood lead reference value (cutoff) was adjusted to 5µg/dL in the model.

Table E1. Blood lead concentration values at different age ranges for children under the age of seven exposed to the maximum lead concentration in well water near Oso, Washington.

IEUBK Output		
Water concentration Range (20 ppb – 66 ppb)		
Age range (months)	**GM PbB range**	**Percent > 5 µg/dL range**
0-84	2.1 – 5.4	3.4 – 57.2
0-12	1.7 – 3.6	1.0 – 24.2
12-24	2.4 – 6.1	5.8 – 66.0
24-36	2.3 – 6.0	5.2 – 65.6
36-48	2.2 – 5.9	4.3 – 63.1
48-60	2.1 – 5.7	3.6 – 61.4
60-72	2.1 – 5.6	3.1 – 59.9
72-84	2.0 – 5.4	2.5 – 55.9

GM PbB: Blood lead geometric mean
EPA's target cleanup goal is no more than 5 % of the community (0-84 months) with BLLs above 5µg/dL.

Appendix F - RECOMMENDED PROCEDURE FOR DISINFECTION OF WELLS

Prior to Disinfection: Inspect the well for structural integrity. The well should have a tight-fitting concrete or steel cover. The casing usually should extend to the bottom of the well. All cracks and openings which might allow contamination to enter the well should be sealed.

Disinfection of a Well: The disinfectant used in this procedure is produced by adding liquid chlorine bleach to your well water. Typically, liquid chlorine bleach is available in 5 1/4% to 6 1/2% strengths. Do not use bleach with "additives" such as "fresh scent".

1. Roughly calculate the volume of water in the well. (7.5 gallons per cubic foot)
   6 inch diameter wells = 1.5 gallons per foot of water in the well
   36 inch diameter wells = 53 gallons per foot of water in the well
2. Add 1 gallon of liquid bleach to each 1000 gallons of water in the well or use the following table. (Adding a bit too much bleach is not a problem.)

6 Inch Wells		**36 Inch Wells**	
Depth of water / Ounces of Bleach		***Depth of water / Ounces of Bleach***	
10 ft. / 2 oz. 25 ft. / 5 oz. 50 ft. / 10 oz. 75 ft ./ 14 oz.	100 ft / 19 oz. 150 ft / 28 oz. 200 ft. / 38 oz.	1 ft. / 7 oz. 2 ft. / 13 oz. 3 ft / 20 oz. 4 ft. / 27 oz.	5 ft. / 33 oz. 10 ft. / 66 oz. 15 ft. / 100 oz.

Note: Should your water system have a large amount of storage (more than one or two pressure tanks) additional chlorine must be added to the system at a rate of 1 gallon of bleach for every 1000 gallons of storage.

3. Pour the required quantity of bleach into the well. This may be simplified and more effective by mixing the bleach in a clean container with approximately 2 parts water for each 1 part of bleach.
4. Mix the bleach and well water thoroughly. One way to do this is to run water from a nearby faucet and hose directly back down into the well. Circulate this water until you smell the chlorine running from the hose and make certain to wash down the inside surfaces of the well with the chlorinated well water.
5. Draw water out of every faucet in the system until you can smell a strong chlorine odor in the water.
6. Allow chlorinated water to stand in the well and all the pipes in the system for not less than 12 hours.
7. Clear the well of the chlorine by running the water though an outside faucet. Do not do this flushing procedure into plumbing connected to your septic tank.

After following this procedure and allowing the water to become completely free of chlorine, a coliform bacteria sample should be taken. Generally the chlorine will disappear in 7 days for a drilled well and 14 days for a dug well. If this additional testing still indicates the presence of coliform bacteria, the above disinfection procedure may need to be repeated.

Bacteriological Quality Monitoring: The best way to insure continued presence of satisfactory water is to regularly sample and test the water for the coliform bacteria. The following is a recommended schedule for sampling:
• Drilled wells - One sample per twelve months
• Dug wells - One sample per three months

If testing indicates that an intermittent or ongoing contamination problem exists, you should attempt to identify the source of the problem and take corrective action. Contact this office if you have any questions.

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Glossary

Acute	Occurring over a short time [compare with **chronic**].
Agency for Toxic Substances and Disease Registry (ATSDR)	The principal federal public health agency involved with hazardous waste issues, responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services.
Aquifer	An underground formation composed of materials such as sand, soil, or gravel that can store and/or supply groundwater to wells and springs.
Cancer Risk Evaluation Guide (CREG)	The concentration of a chemical in air, soil, or water that is expected to cause no more than one excess cancer in a million persons exposed over a lifetime. The CREG is a *comparison value* used to select contaminants of potential health concern and is based on the *cancer slope factor* (CSF).
Cancer Slope Factor (CSF)	A number assigned to a cancer causing chemical that is used to estimate its ability to cause cancer in humans.
Carcinogen	Any substance that causes cancer.
Chronic	Occurring over a long time (more than 1 year) [compare with **acute**].
CERCLA	Comprehensive Environmental Response Compensation and Liability Act.
Comparison Value (CV)	Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Contaminant	A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.
Dermal Contact	Contact with (touching) the skin [see **route of exposure**].
Dose (for chemicals that are not radioactive)	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 Evaluation Guide (EMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The EMEG is a comparison value used to select contaminants of potential health concern and is based on ATSDR's minimal risk level (MRL).
Environmental Protection Agency (EPA)	United States Environmental Protection Agency.
Epidemiology	The study of the occurrence and causes of health effects in human populations. An epidemiological study often compares two groups of people who are alike except for one factor, such as exposure to a chemical or the presence of a health effect. The investigators try to determine if any factor (i.e., age, sex, occupation, economic status) is associated with the health effect.
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [see **acute exposure**], of intermediate duration, or long-term [see **chronic exposure**].
Groundwater	Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with **surface water**].

Hazardous Substance	Any material that poses a threat to public health and/or the environment. Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive.
Indeterminate Public Health Hazard	The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.
Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see **route of exposure**].
Ingestion Rate (IR)	The amount of an environmental medium that could be ingested typically on a daily basis. Units for IR are usually liter per day (1/day) for water and milligrams per day (mg/day) for soil.
Inhalation	The act of breathing. A hazardous substance can enter the body this way [see **route of exposure**].
Inorganic	Compounds composed of mineral materials, including elemental salts and metals such as iron, aluminum, mercury, and zinc.
Lowest Observed Adverse Effect Level (LOAEL)	The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.
Maximum Contaminant Level (MCL)	A drinking water regulation established by the federal Safe Drinking Water Act. It is the maximum permissible concentration of a contaminant in water that is delivered to the free flowing outlet of the ultimate user of a public water system. MCLs are enforceable standards.
Media	Soil, water, air, plants, animals, or any other part of the environment that can contain contaminants.

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**].
Model Toxics Control Act (MTCA)	The hazardous waste cleanup law for Washington State.
Monitoring Wells	Special wells drilled at locations on or off a hazardous waste site so water can be sampled at selected depths and studied to determine the movement of groundwater and the amount, distribution, and type of contaminant.
No Apparent Public Health Hazard	A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.
No Observed Adverse Effect Level (NOAEL)	The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.
No Public Health Hazard	A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.
Oral Reference Dose (RfD)	An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by EPA.
Organic	Compounds composed of carbon, including materials such as solvents, oils, and pesticides that are not easily dissolved in water.

Parts Per Billion (ppb)/Parts Per Million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
Reference Dose Media Evaluation Guide (RMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The EMEG is a *comparison value* used to select contaminants of potential health concern and is based on EPA's oral reference dose (RfD).
Route of Exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [see **inhalation**], eating or drinking [see **ingestion**], or contact with the skin [see **dermal contact**].
Surface Water	Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with **groundwater**].
Volatile Organic Compound (VOC)	Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

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