Health Consultation

Asbestos and Metals in Groundwater and Leachate

Swift Creek, Whatcom County, Washington

Prepared by
The Washington State Department of Health

APRIL 4, 2016

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

Health Consultation: A Note of Explanation

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

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

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Foreword

The 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. ATSDR has reviewed this document and concurs with its findings based on the information presented. 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

Federal, state, and local health agencies have been working together to assess the potential community health threat posed by airborne asbestos associated with the Sumas Mountain Asbestos Site. The site includes Swift Creek and the portion of the Sumas River located north of Swift Creek.

Asbestos and metals in groundwater also pose a potential health threat. At the request of the Whatcom County Health Department (WCHD), the Washington State Department of Health (DOH) completed an evaluation of Swift Creek groundwater and leachate results for samples collected between 2009 and 2012. Leachate is a liquid that is created when water passes through materials, such as the Swift Creek sediments.

The purpose of the evaluation is to determine whether the concentrations of naturally occurring asbestos and metals found in groundwater and metals in the leachate are at levels of health concern. While leachate created during the testing is not used as a water supply, the concentrations may represent groundwater conditions that could result from rain water moving down through stored Swift Creek sediments.

DOH reached the following five conclusions regarding the metals and asbestos found in groundwater and metals found in leachate:

Conclusion 1

DOH concludes that the maximum amount of arsenic found in the leachate could pose a public health hazard if this source is used for drinking or food preparation. It does not pose a public health hazard for bathing or cleaning. DOH cannot currently conclude whether the maximum amount of chromium found in leachate could pose a public health hazard. The other tested metals are not a public health hazard.

Basis for Decision

The maximum amount of arsenic in the leachate exceeds the federal and state drinking water standards used for public water systems. The maximum amount of chromium, however, is below the standards. When quantifying the health threat posed by arsenic and chromium, DOH conservatively assumed that all the chromium found in groundwater from the leachate was from the more toxic chromium (VI), which is considered a mutagen. Using this conservative exposure assumption, DOH determined that arsenic and chromium in the leachate could each pose an increased cancer risk if used for drinking or food preparation. Skin contact with either the arsenic or chromium in the leachate poses a low cancer risk. Arsenic poses a non-cancer health threat for children because the maximum level exceeded the no observed adverse effect level (NOAEL).

Conclusion 2

DOH cannot currently conclude whether the maximum amount of arsenic and chromium found in groundwater from the private wells could pose a public health hazard when used for drinking or food preparation, bathing, or cleaning. The other tested metals are not a public health hazard.

Basis for Decision

The maximum amount of arsenic and chromium found in groundwater from the private wells are below the federal and state drinking water standards used for public water systems. These standards, however, are not strictly health based. DOH had to make some conservative assumptions when evaluating the health threat posed by these two metals because the arsenic detection limit was too high and chromium was not speciated. We conservatively assumed that the maximum amount of chromium found in groundwater from these wells was hexavalent chromium (chromium (VI)), which is considered a mutagen, and used the arsenic analytical reporting limit (10 parts per billion (ppb)). Using these conservative assumptions, we determined that arsenic and chromium could each pose an increased cancer risk when the water is used for drinking or food preparation. Skin contact with either the arsenic or the chromium in the water could pose a low cancer risk. The cancer risks, however, are likely overestimated. Using the same conservative assumptions, DOH determined that the maximum amounts of arsenic and chromium do not pose a non-cancer health threat.

Conclusion 3

DOH cannot currently conclude whether asbestos could harm people's health if groundwater from the private wells tested near Swift Creek is used for drinking, food preparation, bathing, or cleaning.

Basis for Decision

The private wells were not tested for asbestos.

Conclusion 4

DOH cannot currently conclude whether the maximum amount of arsenic and chromium found in groundwater from the monitoring wells could pose a public health hazard if representative of water used for drinking or food preparation, bathing, or cleaning. The other tested metals are not a public health hazard.

Basis for Decision

The maximum amount of arsenic and chromium found in groundwater from the monitoring wells are below the federal and state drinking water standards used for public water systems. These standards, however, are not strictly health based. DOH had to make some conservative assumptions when evaluating the health threat posed by these two metals because the arsenic detection limit was too high and chromium was not speciated. We conservatively assumed that the maximum amount of chromium found in groundwater from these wells was the more toxic chromium (VI), which is considered a mutagen, and used the arsenic analytical reporting limit (10 ppb). Using these conservative assumptions, DOH determined that the maximum amounts of arsenic and chromium do not pose a non-cancer health threat. However, the arsenic and chromium each could pose an increased cancer risk when used for drinking or food preparation.

Skin contact with either the arsenic or chromium in the water could pose a low cancer risk. The cancer risks, however, are likely overestimated.

Conclusion 5

DOH concludes asbestos fibers found in groundwater collected from monitoring wells are not expected to harm people's health if the water from these wells were used for drinking and food preparation (i.e., drinking or cooking) or bathing and cleaning (i.e., touching). Asbestos in water from private wells may or may not have similar water quality. DOH cannot currently conclude whether the asbestos fibers found in the groundwater from the monitoring wells could affect indoor or outdoor air quality.

Basis for Decision

Concentrations of asbestos in the groundwater collected from the monitoring wells are all below the federal and state drinking water standard of 7 million fibers longer than 10 µm per liter. The federal and state drinking water standard is based upon evidence of benign gastrointestinal tumors (adenomatous polyps) observed in rats. However, cancer is expected to be the most sensitive endpoint for asbestos ingestion. Based on potential cancer effects, the California Environmental Protection Agency developed the same asbestos drinking water standard as the federal and state standard. Although asbestos in groundwater from the monitoring wells is not expected to harm people's health if ingested, it could be deposited on surfaces such as walls and floors, vegetation, and other objects. When dry, the fibers could become airborne and contribute to a potential indoor and outdoor air health threat. Asbestos fibers in dredged materials and flood deposits from Swift Creek are already known to be of concern.

Next Steps

1. Consider taking the following steps to better assess the potential health threat posed by contaminated groundwater near Swift Creek:
   - Select an analytical method for arsenic that has a lower reporting limit,
   - Expand the chromium analysis to include hexavalent chromium speciation (chromium (VI)),
   - Test private wells near Swift Creek for asbestos. If found in private wells, consider testing indoor air for asbestos to determine if it might pose a threat to indoor air quality, and
   - Conduct activity-based sampling or other appropriate methods to determine if asbestos-containing groundwater might pose a health threat when used for irrigation or other outdoor uses.

2. Consider additional leachate testing to further assess how the dredged sediments from Swift Creek might impact groundwater if the sediments are managed, stored, or disposed above or below grade.

3. If someone has a well screened in an aquifer containing Swift Creek sediments and it is not properly developed or maintained, it could result in levels of asbestos and some metals posing a health threat. Consider providing information to well owners about proper well maintenance to reduce the potential for exposure to asbestos and metals.

4. DOH will provide copies of this health consultation report to Whatcom County Health Department, Whatcom County Public Works, Environmental Protection Agency (EPA), and the Washington State Department of Ecology, other federal, state, and local agencies. A copy of the report will also be posted on the DOH Site Assessment webpage (http://www.doh.wa.gov/DataandStatisticalReports/EnvironmentalHealth/SiteAssessments).

5. DOH is available to review future monitoring plans and evaluate groundwater results from private and/or monitoring wells to determine if the contaminants pose a potential health threat.

For More Information

If you have any questions about this health consultation contact Barbara Trejo at 360-236-3373 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

Federal, state, and local health agencies have been working together to assess the potential community health threat posed by airborne asbestos associated with the Sumas Mountain Asbestos Site. The site includes Swift Creek and the portion of the Sumas River located north of Swift Creek.

Asbestos and metals in groundwater also pose a potential health threat. At the request of the Whatcom County Health Department (WCHD), the Washington State Department of Health (DOH) completed an evaluation of Swift Creek groundwater and leachability test results for samples collected between 2009 and 2012. The purpose of the evaluation is to determine whether the concentrations of naturally occurring asbestos and metals found in groundwater and metals in the leachate are at levels of health concern. Leachate is a liquid that is created when water passes through materials, such as the Swift Creek sediments. While leachate from the testing is not used as a water supply, the concentrations may represent groundwater conditions that could result from rain water leaching through stored Swift Creek sediments.

DOH conducts health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Site Background

Swift Creek is located in Whatcom County, Washington (Figure 1). The creek originates on the west side of Sumas Mountain and flows into the Sumas River. An active landslide on the mountain annually contributes approximately 120,000 cubic yards of sediment to Swift Creek. These sediments, which have been deposited in and along the creek and downstream in the Sumas River, contain naturally occurring asbestos and metals.

The lateral extent of the sediment deposition is unknown. However, relatively recent flood events indicate that sediments containing asbestos and metals have been deposited beyond the creek and river banks at some locations.

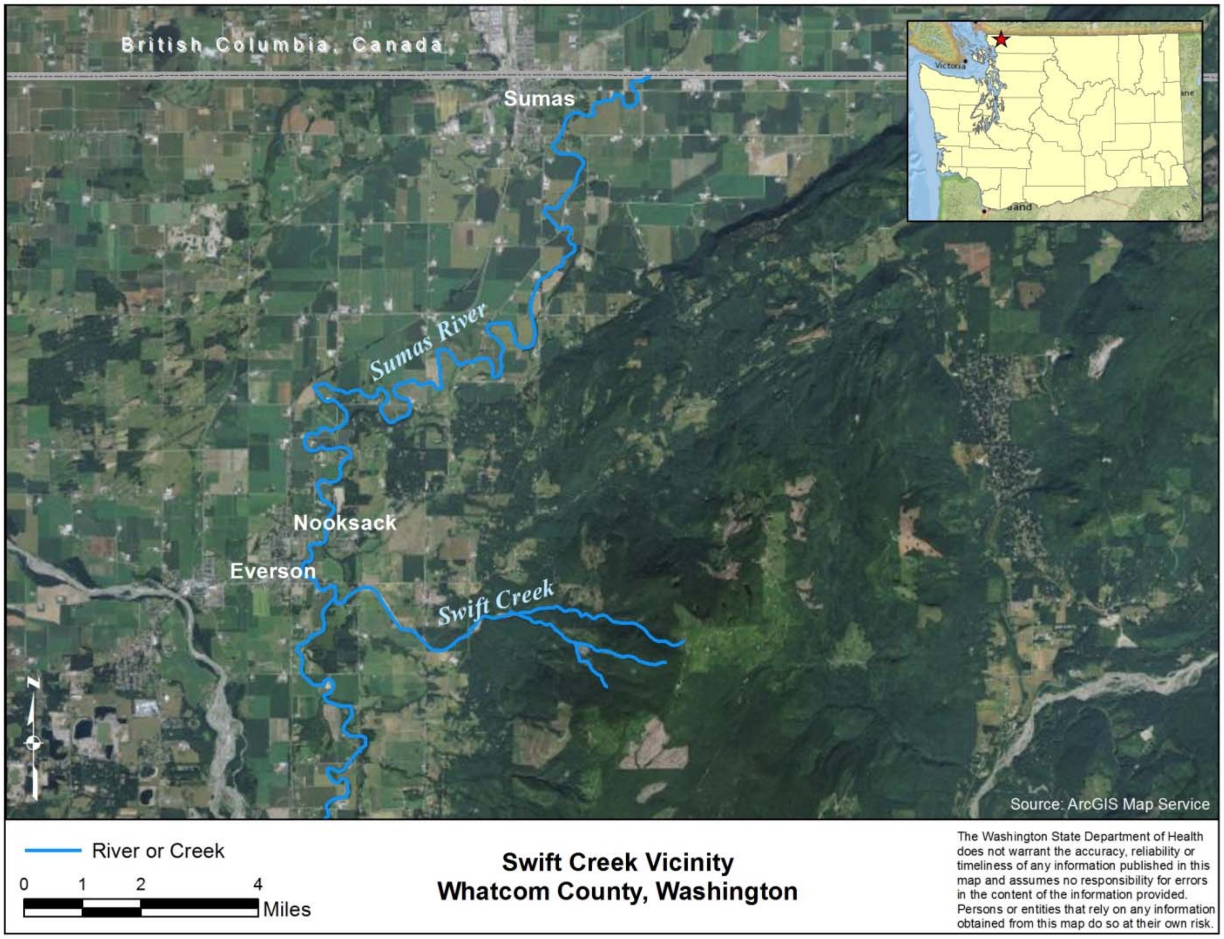
Due to the rapid accumulation of the sediments in Swift Creek, there is a high risk of flooding. To control the flooding, Whatcom County periodically dredges portions of Swift Creek, predominantly between Goodwin and Oat Coles Roads. Whatcom County stores the dredged sediments on the bank along the creek in designated stockpile areas.

DOH completed two health consultations in 2006 and 2008 addressing the potential health threat posed by airborne asbestos fibers. Recently, ATSDR conducted some air testing in the vicinity of Swift Creek and the Sumas River to further evaluate whether asbestos fibers in the sediments are becoming airborne and posing a potential health threat. A health consultation summarizing their findings will be available in the near future.

Land Use and Demographics

Property in the vicinity of Swift Creek and Sumas River is used for agricultural, residential, commercial, and industrial purposes. Well logs on file at the Washington State Department of Ecology (Ecology) indicate that some domestic, industrial, and irrigation wells are located in the vicinity of the creek and river (1).

Figure 1: Swift Creek Vicinity Map, Swift Creek, Whatcom County, Washington



Environmental Investigations

Between 2009 and 2012, WCHD and the U.S. Environmental Protection Agency (EPA) tested groundwater from monitoring wells in the vicinity of Swift Creek for asbestos and metals (2-8). The testing was done to evaluate the possible impact of Swift Creek sediments on groundwater. EPA also tested three private wells for metals in July 2012. Well logs were only available for two of the three private wells. Both of those wells are located at a depth similar to the monitoring wells. Additionally, WCHD and EPA tested dredged sediments stored along Swift Creek for metals and conducted sediment leachability testing. The leachability testing was done to help determine whether metals would leach from the sediments and potentially affect groundwater if these sediments were stored in an unlined disposal area. In 2012, Whatcom County Public Works

(WCPW) conducted some additional asbestos and metals testing at the monitoring wells (9). A summary of all the investigations is included in Table 1. Appendix B contains a more detailed description of the investigations, including figures showing the well locations.

Community Health Concerns

WCHD is concerned that the naturally occurring asbestos found in Swift Creek and Sumas River sediments might be a health concern if it becomes airborne. They also are concerned that the asbestos and naturally occurring metals found in the sediments might pose a potential health threat if the sediments are located in an area where groundwater is used as a drinking water source.

Discussion

Asbestos and metals were found in groundwater in the vicinity of Swift Creek during the 2009 and 2012 investigations. Metals were also found in the leachate. While leachate from the testing is not used as a water supply, the concentrations may represent groundwater conditions that could result from rain water leaching through stored Swift Creek sediments. DOH used the asbestos and total metals[a] results from all the investigations to evaluate the potential health threat.

During the course of our evaluation, we determined that the July 2012 EPA investigation results obtained from the PMW-1 to PMW-4 monitoring wells were not representative because these wells had not been developed prior to the testing.[b] EPA concurred with these findings. While we did not use these monitoring well results as part of this health consultation, we did determine that groundwater from an improperly installed (e.g., undeveloped) or poorly maintained well could result in levels of asbestos and some metals that could pose a health threat.[c]

WCHD and EPA used the Synthetic Precipitation Leaching Procedure (SPLP) in 2009 and 2012 to assess how land applying Swift Creek sediments might affect groundwater quality. How SPLP results are interpreted, however, can vary. Some suggest leachate generated using SPLP represents pore water concentrations while others indicate leachate represents diluted concentrations like what would be found in groundwater in an underlying aquifer (10;11). Pore water is the water occupying the spaces between sediment particles. DOH conservatively

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[a] Total metals were used because they represent what someone might actually be exposed to.

[b] Monitoring wells are developed to ensure removal of fines from the vicinity of the well screen. This allows groundwater to freely flow from the aquifer into the well. Well development also reduces the turbidity of the sample. Turbid samples can result in an overestimation of contaminant concentrations.

[c] We did not include the undeveloped well data in the health consultation report because the samples were improperly collected and are not representative of groundwater in the aquifer. The results are also not likely representative of any other well in the area because the results from each would likely be unique. However, the undeveloped well data do suggest that if someone has a well screened in an aquifer containing Swift Creek sediments and it's not properly developed, it could result in levels of asbestos and some metals posing a health threat.

assumed for this health consultation that the leachate results represent possible groundwater concentrations.

Exposure Pathway Evaluation

To begin assessing the possible health threat posed by the asbestos and metals in groundwater and metals in leachate, an exposure pathway evaluation was conducted. An exposure pathway evaluation helps determine ways in which people might come into contact with the contaminants. An exposure pathway is the route a contaminant takes from where it began (source) to where it ends, and how people can come into contact with it. An exposure pathway has five parts:

- **Source of contamination** (such as the Sumas Mountain landslide material or sediments);
- **Environmental media and transport mechanism** (such as a chemical leaching or eroding from a source material);
- **Point of exposure** (such as tap water);
- **Route of exposure** (such as ingestion, inhalation, or dermal contact); and
- **Receptor population** (people potentially or actually exposed to a chemical).

When all five parts are present, it is considered a complete exposure pathway. A potential exposure pathway exists if one or more parts are missing.

There are many factors that determine if an exposure will cause health effects. These factors include:

- **Dose** (how much),
- **Duration** (how long),
- **Exposure** (how someone comes in contact with the chemicals), and
- **Personal** (a person’s age, sex, diet, family traits, lifestyle (such as smoking tobacco), and state of health).

For asbestos, the fiber type and size are some additional factors.

Properties in the vicinity of Swift Creek and downstream Sumas River have used, and continue to use, groundwater for domestic, commercial, industrial, and agricultural purposes. If drinking water wells associated with these properties draw groundwater from the sediments, a completed past, current, and potential future exposure pathway exists.

Exposures to asbestos and metals in groundwater, if they occurred, would be through ingestion, dermal contact, and/or inhalation. Exposures could occur over a lifetime if groundwater is used daily for drinking, cooking, or showering and bathing. Dermal contact and breathing in contaminants could also occur if the groundwater is used for irrigation or other non-potable uses.

Health Screening Evaluation

To evaluate the potential health threat posed by the contaminants found in groundwater and leachate, DOH compared the level of each contaminant to health comparison values (CVs). This allows for identification of contaminants that might be of health concern. Health comparison values are concentrations of contaminants that are unlikely to cause people to get sick. This is done to be protective of the most sensitive individuals (i.e., children and older adults). It is also done to account for our lack of certainty regarding the adverse health effects of low levels of contaminants. If a chemical was noted as being less than a reporting limit, DOH compared the reporting limit[d] to the health comparison values.

Because groundwater in the vicinity of Swift Creek is a known potable drinking water source, DOH used ATSDR drinking water health comparison values (e.g., cancer risk evaluation guides (CREGs), environmental media evaluation guides (EMEGs), and reference dose media evaluation guides (RMEGs)) (12). The CREG is the concentration of a contaminant in water that is expected to cause no more than one additional cancer in a million persons exposed over a lifetime. An EMEG and RMEG are concentrations in water below which adverse non-cancer health effects are not expected to occur. The EMEG was developed using ATSDR minimal risk levels (MRLs) while the RMEG was developed using EPA's reference doses (RfDs). If no ATSDR health comparison values were available, DOH used EPA's tap water regional screening levels (RSLs) (13). In the absence of the EPA RSLs, DOH used levels set in the Federal Drinking Water Standards and Health Advisories and Washington State Administrative Code 246-290 for Group A Public Water Supplies (14;15).

If a contaminant does not exceed its health comparison value, no further evaluation of that contaminant is necessary. This is because we do not expect those contaminants will pose a health threat. When a contaminant is found to be above a health comparison value, further evaluation is needed. However, just because a contaminant was found above the comparison value does not mean it will cause people to get sick. When a contaminant does not have a health comparison value available, a health comparison value for a contaminant similar in structure may be used as a substitute. If no substitute is available, the contaminant is further evaluated.

Five metals were identified as contaminants of potential concern (COPC) in the private wells and leachate: arsenic, calcium, chromium, magnesium, and potassium (Tables 2 and 3). The monitoring wells had the same COPC along with manganese (Table 4).

The health comparison value for asbestos fibers greater than 10 μm in length in drinking water is the federal and state drinking water standard of 7 million fibers per liter.[e] None of the monitoring wells[f] had asbestos levels exceeding the drinking water standard (Table 5).[g]

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[d] Reporting limits are the lowest concentration at which a chemical can be detected in a sample and its concentration can be reported with a reasonable degree of accuracy and precision.

[e] EPA set the drinking water standard (maximum contaminant level goal (MCLG) and maximum contaminant level (MCL) for asbestos based upon evidence of benign gastrointestinal tumors (adenomatous polyps) occurring in male rats following the oral administration of greater than 10 μm long chrysotile fibers (16). The California Environmental Protection Agency (CalEPA) developed a public health goal (PHG) for asbestos in drinking water of 7 MFL exceeding 10 μm in length, which is the same as the EPA MCL (17). The CalEPA PHG was calculated assuming a theoretical excess individual cancer risk level of one in a million (10^{-6}) from exposure to asbestos.

[f] Only the monitoring wells were tested for asbestos.

[g] The detection limit for one of the developed well samples was slightly above the health comparison value. However, because the asbestos data report indicated that no asbestos fibers were detected in that sample, no further assessment of the asbestos fibers greater than 10 μm in the developed wells was determined to be necessary.

Therefore, asbestos fibers sizes longer than 10 µm were not considered COPC except for the possibility of these fiber sizes affecting air quality. A health comparison value for water was not available for smaller fiber sizes (shorter than 10 µm).[h] As a result, these fiber sizes were identified as COPC.

Health-Effects Evaluation

All six contaminants of potential health concern (asbestos, arsenic, calcium, chromium, magnesium, and potassium) are naturally occurring and may be found in rock, soil, water, air, food, and dust.

Calcium, magnesium, and potassium are essential nutrients. They typically are not harmful in drinking water under most environmental exposure scenarios. As a result, no health based levels have been established for these contaminants in drinking water. However, they could pose a health threat if large amounts are ingested. To determine if they needed to be carried forward for further evaluation, DOH calculated intake levels and compared them to National Academies, Institute of Medicine, Food and Nutrition Board's tolerable upper intake levels (ULs)[i] for calcium and magnesium (Tables 6 and 7). Because a UL was not available for potassium, DOH used the National Academies' adequate intake (AI) level[j] (Table 8).

DOH calculated intake levels by multiplying the mean ingestion rates of 0.9 liters of water per day (l/day) for a child, 1 l/day for an older child, and 1.4 l/day for an adult[k] by the highest levels of calcium, magnesium, and potassium found in the private wells, monitoring wells, or leachate. To estimate whether the intake levels might pose a health threat, they were compared to appropriate gender and age range ULs or AIs. As shown in Table 9, the highest concentrations of these elements are below levels expected to cause health effects and will not be evaluated further.

Asbestos

Asbestos is a fibrous, naturally occurring mineral. There are six forms of asbestos. The concentration of asbestos fibers in water varies widely with the highest concentrations found in areas where asbestos occurs naturally. It also can be found in water when pipes made with asbestos-containing cement corrode.

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[h] Asbestos fiber size results smaller than 10 µm should not be compared to the EPA MCL.

[i] A tolerable upper intake level (UL) is the highest average daily intake that is likely to pose no risk of adverse health effects to almost all individuals in the general population. As intake increases above the UL, the potential risk of adverse effects may increase.

[j] Adequate intakes are recommended intake values based on observed or experimentally determined estimates of nutrient intake by a group of healthy people that are assumed to be adequate. An adequate intake is established when a Recommended Daily Allowance (RDA) cannot be determined.

[k] The 1.4 l/day mean adult ingestion rate used in this health consultation is slightly more conservative than the mean adult ingestion rate provided in ATSDR's new exposure dose guidance (~1.2 L/day).

Drinking water containing asbestos is the most common way for people to be exposed via the oral route. If asbestos fibers are swallowed almost all of the fibers pass through the intestines within a few days and are excreted in the feces (18). A small number of fibers, however, may penetrate into cells that line the stomach or intestines; a few could penetrate all the way through and may get into the blood (18). Some of those become trapped in other tissues, and some are removed in the urine (18).

ATSDR reports in its 2001 toxicological profile for asbestos that the weight of evidence indicates that asbestos ingestion does not cause any significant non-carcinogenic effects in the gastrointestinal tract or other tissues (18). However, they do report there is evidence that asbestos ingestion could result in cancer. Briefly, ATSDR notes that some groups of people who have been exposed to asbestos fibers in their drinking water have higher than average death rates from esophagus, stomach, and intestine cancers. However, it was difficult to tell whether this is caused by asbestos or by something else. There is some evidence that acute oral exposure may induce precursor lesions of colon cancer, and that chronic oral exposure may lead to an increased incidence risk of gastrointestinal tumors. Animals given very high doses of asbestos in food did not get more fatal cancers than usual, although some extra non-fatal tumors did occur in the intestines of rats in one study. ATSDR found no information specifically concerning health effects in children exposed to asbestos by the oral or dermal routes (18). As a result, they indicate that childhood exposures are likely to result in responses similar to those reported in adults.

The length of asbestos fibers appears to be one of the most important determinants of its toxicity via the oral route. Data from the National Toxicology Program (NTP) animal feed studies conducted between the mid-1980s and early 1990s provide some evidence about asbestos carcinogenicity and fiber size (19;20). During those studies, they found evidence regarding carcinogenicity for intermediate-range (65 percent greater than 10 micrometers (µm) and approximately 14 percent greater than 100 µm) chrysotile fibers, but not for short-range (98 percent smaller than 10 µm) fibers. Male rats exposed to the intermediate range chrysotile asbestos were reported to have an increased incidence of adenomatous polyps in the large intestine (19).

EPA set a maximum contaminant level goal (MCLG) and a maximum contaminant level (MCL) in 1999 at 7 million fibers per liter (MFL) for asbestos greater than 10 micrometers (µm) in length (18).[1] These levels were based on tumorigenic effects observed in experimental animals (17). EPA set the MCLG based on the best available science to prevent potential health problems (21). EPA currently considers the asbestos MCLG and MCL protective of human health (21).

The World Health Organization (WHO) in 2003 indicated evidence available at that time did not suggest ingestion of drinking water containing asbestos is hazardous to health and concluded that there was no need to establish a guideline for asbestos in drinking water (22). However, in the same year, the California Environmental Protection Agency (CalEPA) developed a public health goal (PHG) for asbestos in drinking water of 7 MFL exceeding 10 µm in length, which is the

[1] The MCLs is set as close to the MCLG as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies.

same as the EPA MCL (17). The CalEPA PHG was calculated assuming a theoretical excess individual cancer risk level of one in a million (10^{-6}) from exposure to asbestos (17).

DOH found only limited information regarding the possibility of waterborne asbestos becoming airborne. A study conducted by the New York Department of Health in 1988 looked at that possibility (23). Briefly, the study indicated that asbestos contamination in excess of 10 billion fibers per liter was reportedly detected in a New York community's drinking water. Mean waterborne asbestos concentrations were 24 MFL in the impacted houses versus only 1.1 MFL in the control houses. Transmission electron microscopy results indicated that airborne asbestos concentrations were highest in impacted houses, with airborne asbestos concentrations positively correlated with water concentrations.[m] Clusters of chrysotile, often with several hundreds of fibers, were also detected in the air samples from impacted houses. The study findings suggested that the increased concentrations in impacted houses were due primarily to short (less than 1 µm) fibers.

Metals

Arsenic

Arsenic can occur in inorganic or organic forms. It is typically found in soils and many types of rock in the inorganic form. In the past, arsenic was used to treat wood and as a pesticide in orchards. It has also been added in small amounts to other metals to form alloys with improved properties and is used as a semiconductor in electronics (24).

Drinking water in Washington typically contains less than 3 µg/l arsenic (25). However, higher levels of arsenic have been found in some areas in Washington. Those elevated levels are usually associated with water located in rock or soil that has a naturally high amount of arsenic.

EPA has set an MCLG for arsenic at zero and MCL at 10 µg/l (14).

The primary way people are exposed to arsenic is by drinking or preparing food with water containing arsenic (24). Arsenic in water is poorly absorbed through the skin so dermal exposure is not a concern unless levels are very high. Arsenic does not readily evaporate from water so inhalation exposure is also not a concern.

Long-term exposure to small amounts of arsenic can increase the risk of developing cancer of the bladder, lung, skin, liver, kidney, or prostate (25). Other health effects may include high blood pressure, narrowing of the blood vessels, nerve damage, anemia, diabetes, stomach upset, and skin changes (25).

[m] Mean concentrations in impacted houses were reported as 0.12 fibers per cubic centimeter (fibers/cm^3) and 1.7 nanogram per cubic meter (ng/m^3) on Nuclepore filters and 0.053 fibers/cm^3 and 2.3 ng/m^3 on Millipore filters versus only 0.037 fibers/cm^3 and 0.31 ng/m^3 on Nuclepore filters and 0.0077 fibers/cm^3 and 0.14 ng/m^3 on Millipore filters from control houses.

Chromium

In the United States, chromium ranges from about 2 to 10 µg/l in shallow groundwater; however, levels as high as 50 µg/l have been reported in some supplies (26). Chromium can be found in consumer products such as wood treated with copper dichromate, leather tanned with chromic sulfate, and stainless steel cookware (27). Chromium (III) and chromium (VI) are the most common forms.

Chromium (III) is often added to vitamins as a dietary supplement. It has relatively low toxicity and is a concern in drinking water only at very high concentrations. Chromium (VI) is more toxic and poses potential health risks at lower concentrations. Chromium (III) and chromium (VI) can convert back and forth in water depending on environmental conditions (28). As a result, measuring just one form may not capture all of the chromium that is present (28). Chromium (VI) occurs naturally in the environment from the erosion of natural chromium deposits, but it can also be produced by industrial processes (28).

ATSDR reports in its toxicological profile that chromium speciation in groundwater also depends on the oxidation-reduction (redox) potential and pH conditions in the aquifer (2.7). They note that chromium (VI) predominates in groundwater under highly oxidizing conditions; whereas chromium (III) predominates under reducing conditions. Oxidizing conditions are generally found in shallow, oxygenated groundwater, and reducing conditions generally exist in deeper, anaerobic groundwater. Chromium (III) will predominate in more acid groundwater. Chromium (VI) can be reduced to chromium(III) if an appropriate reducing agent is available (27). The most common reducing agents present in aqueous systems include: organic matter, hydrogen sulfide, sulfur, iron sulfide, ammonium, and nitrate (27).

Exposure to chromium (VI) compounds can occur through inhalation of ambient air, ingestion of water, or dermal contact with products that contain chromium (VI) compounds, such as pressure-treated wood (29). Exposure to chromium (VI) can also occur during showering. However, inhalation exposure during showering is much less of a health risk than oral exposures because the chance of inhaling water droplets during showering is very small (30). Most dermal effects reported regarding chromium were either due to intermediate to chronic occupational exposures or acute exposure to high levels of chromium compounds (27). Environmental exposure to chromium compounds is not likely to result in dermal effects (27).

Chromium (VI) has long been known at a potent human carcinogen when inhaled. However, based on animal studies (rats and mice) conducted by the National Toxicology Program, there is sufficient evidence to indicate it is also carcinogenic via oral exposure (29;30). EPA noted in its 2010 draft toxicological review of Chromium (VI) that it is considered carcinogenic by a mutagenic mode of action for all routes of exposure; however, the evidence to support this conclusion regarding mutagenicity is still being weighed (31).

Results of occupational exposure studies and chronic duration animal studies indicate that inhalation and oral exposures to chromium (VI) compounds are associated with respiratory and gastrointestinal system cancers, respectively (27). Worker exposure to chromium may also result in irritation of the lining of the nose, runny nose, and breathing problems (27). The main health problems seen in animals following ingestion of chromium (VI) compounds are to the stomach and small intestine (irritation and ulcer) and the blood (anemia) (27). Chromium (III) compounds are much less toxic and do not appear to cause these problems. Sperm damage and damage to the male reproductive system have also been seen in laboratory animals exposed to chromium (VI) (27).

The current EPA MCLG and MCL for total chromium is 100 µg/l (14). In 2011, CalEPA developed a public health goal for chromium (VI) in drinking water of 0.02 µg/l (30). This level represents a lifetime cancer risk of one in a million. CalEPA determined that the PHG was protective against all identified toxic effects from both oral and inhalation exposure to chromium (VI) that might occur from drinking chromium (VI) contaminated water. California currently has an MCL for total chromium and chromium (VI) of 50 µg/l and 10 µg/l, respectively (32).

In a field study to assess inhalation exposure to chromium during showering, researchers found that exposure to aerosols from water containing up to 10 mg/l chromium(VI) is unlikely to create a health hazard (33).

Manganese

Manganese does not exist in nature as an elemental form, but is found mainly as oxides, carbonates, and silicates. It exists in both inorganic and organic forms. Inorganic forms of manganese are most often found in the environment and the workplace. Manganese is found in foods and water and can be added to certain foods and nutritional supplements (34).

Groundwater in the U.S. contains median manganese levels ranging from 5 µg/l to 150 µg/l (34). The 99th percentile levels for rural and urban areas was reported as 2,900 µg/l and 5,600 µg/l, respectively (34).

There is currently no EPA MCLG or MCL for manganese. However, EPA has established a 300 µg/l lifetime health advisory for manganese (35). The lifetime health advisory is estimated to be an intake level for the general population that is not expected to result in adverse health effects (35).

ATSDR reports in its toxicological profile that exposure to manganese can occur through ingestion, inhalation, and dermal contact (34). They report that the primary source of manganese intake is through eating food or drinking water that contains manganese. Inhaling air with manganese containing particulate matter is the primary source of excess exposure for the general population in the U.S. Only very small amounts of manganese will enter the skin when coming into contact with manganese containing liquids.

ATSDR also reports that there is no evidence that manganese causes cancer in humans or animals (34). However, they do report the following types of non-cancer health effects in humans and animals (34). Inhaling manganese containing dust or particulate mattercan produce significant non-cancer health effects including neurological effects. Fumes from welding activities can also increase the chance of manganese exposure. Increased concentrations of manganese in drinking water also appear to result in adverse neurological effects. The level at which manganese produces neurological effects in humans who ingest water containing manganese, however, has not been establish. Children appear to be potentially more sensitive to manganese toxicity than adults. Animals exposed to very high manganese doses in a laboratory experienced nervous system disturbances, reproductive changes, and illnesses involving the kidneys and urinary tract.

Evaluating Non-Cancer Health Effects

Asbestos

Neither an ATSDR oral MRL nor an EPA oral RfD are available for quantitatively assessing the non-cancer health effects associated with ingesting asbestos.

ATSDR reports that the weight of evidence indicates that asbestos ingestion does not cause any significant non-carcinogenic effects in the gastrointestinal tract or other tissues (18). The CalEPA, however, has calculated a public health-protective concentration for non-carcinogenic effects of asbestos in drinking water of 2,400 MFL[n] (17). Briefly, the authors noted this was done using a lowest observed adverse effect level (LOAEL) of 107 mg/kg-day for nephrotoxicity. Uncertainty factors of 10 each were applied to account for extrapolation of a LOAEL to a NOAEL, interspecies extrapolation, and human variability. Additionally, an uncertainty factor of 3 was applied to account for sub-chronic to chronic study duration extrapolation. CalEPA also assumed a relative source contribution of 20 percent and an adult daily consumption rate of 2 liters per day. The levels of asbestos found in groundwater from the developed and undeveloped wells near Swift Creek are well below the 2,400 MFL level established by CalEPA.

Based on the ATSDR and CalEPA findings, non-cancer health effects associated with ingestion of the asbestos fiber sizes and concentrations found in the monitoring wells are not expected.

Metals - Arsenic, Chromium, and Manganese

To evaluate non-cancer health effects associated with exposure to arsenic, chromium, and manganese, doses were calculated for the ingestion and dermal routes of exposure using the maximum concentration found in the private wells, monitoring wells, and leachate. DOH conservatively assumed that all the chromium detected in the groundwater and leachate was chromium (VI). Because the arsenic reporting limit for many of the samples exceeded the health based screening level, DOH conservatively assumed the maximum arsenic level equivalent to the reporting limit.

The equations and exposure parameters used to calculate doses for a child, older child, and adult are provided in Appendix C. The doses were then compared to chronic MRLs or RfDs to determine if health effects were possible. When a dose exceeded a MRL or RfD, further assessment was conducted by comparing the doses to an oral no observed adverse effects level (NOAEL) or benchmark reference dose.

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[n] CalEPA did not report the asbestos fiber size used during the study.

Tables 10 and 11 summarize the estimated doses and comparisons with the MRLs, RfDs, NOAELs, and benchmark reference dose. As shown in the tables, arsenic was found at the highest level in the leachate and was the only metal that exceeded its NOAEL for a child and older child. This suggests that arsenic in leachate could pose a non-cancer health threat.

As noted earlier, there is uncertainty whether the SPLP results represent pore water concentrations or diluted concentrations like what would be found in an underlying aquifer. When comparing the maximum arsenic level found in the SPLP leachate to the maximum amount found in the groundwater near Swift Creek, it appears that the leachate may be more representative of pore water concentrations and therefore the non-cancer health threat may be overestimated.

Evaluating Cancer Health Effects

Some contaminants have the ability to increase a person's risk of developing cancer. Because current risk assessment practice assumes there is no "safe dose" of a carcinogen, any dose of a carcinogen will result in some additional increased cancer risk. 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.

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 (36).

Cancer risk that is attributable to site-related contaminants can be described in quantitative and qualitative terms by considering the population size required for such an estimate to result in a single cancer case. Contaminants are considered to pose an increased cancer risk when the estimated cancer risk is greater than or equal to one additional cancer case per ten thousand persons exposed over a lifetime (>= 1E-04). One additional cancer cases per million persons exposed over a lifetime to nine additional cancer cases per hundred thousand persons exposed over a lifetime (1E-06 to 9E-05) is considered a low cancer risk. A cancer risk is considered insignificant or indiscernible from background when the cancer risk estimate is less than one additional cancer per one million persons exposed over a lifetime (<1E-06).

For known or suspected carcinogens, EPA generally strives to achieve the lowest risk possible. EPA regulatory actions generally seek to keep exposure levels at concentrations that represent an upper-bound excess lifetime cancer risk to an individual between a target risk range of 1E-04 to 1E-06 using information on the relationship between dose and response (37).

Metals – Arsenic and Chromium

DOH calculated doses for arsenic and chromium using concentrations in groundwater from the private wells and monitoring wells and in leachate. Again, DOH conservatively assumed that all chromium detected in the groundwater and leachate was the more toxic chromium (VI). Because the arsenic reporting limit for many of the samples exceeded the health based screening level, DOH conservatively assumed the maximum arsenic level was equivalent to the reporting limit. The equation for calculating doses along with associated input parameters are provided in Appendix C. The calculated doses were used to estimate cancer risk levels using the appropriate cancer slope factors. We assumed that chromium (VI) is a mutagen and adjusted the risks for the different ages accordingly.

Tables 12 and 13 summarize the estimated doses and cancer risk levels associated with ingesting and dermal exposure to the maximum amounts of arsenic and chromium found in groundwater from private wells, monitoring wells, and leachate. As shown in the tables, most of the risk is associated with ingesting the water. The following bullets summarize the estimated total cancer risk (ingestion and dermal) for arsenic and chromium:

- Private Wells
    - Arsenic: 6 additional cancers in a population of 10,000 people.
    - Chromium: 2 additional cancers in a population of 10,000 people.

- Monitoring Wells
    - Arsenic: 6 additional cancers in a population of 10,000 people.
    - Chromium: 4 additional cancers in a population of 10,000 people.

- Leachate
    - Arsenic: 2 additional cancers in a population of 1,000 people.
    - Chromium: 1 additional cancer in a population of 10,000 people.

These estimated cancer risks for arsenic and chromium are all greater than or equal to one additional cancer case per ten thousand persons exposed over a lifetime (>= 1E-04) and are considered to pose an increased cancer risk. They are also higher than EPA's target risk range. However, it is important to note that because DOH conservatively assumed that the maximum arsenic levels were the elevated reporting limits from the private well and monitoring well testing and that all chromium detected in the wells was chromium (VI) and mutagenic, the cancer risk for each of the contaminants could be overestimated.

Oral exposures to chromium (VI) compounds are associated with gastrointestinal system cancers. While oral exposure to arsenic can increase the risk of developing cancer of the bladder, lung, skin, liver, kidney, or prostate.

Asbestos

As noted earlier, data from the National Toxicology Program (NTP) animal feed studies provided some evidence of asbestos carcinogenicity for intermediate-range (65 percent greater than 10 micrometers (µm) and approximately 14 percent greater than 100 µm) chrysotile fibers, but not for short-range (98 percent smaller than 10 µm) chrysotile fibers (19;20). The monitoring wells were the only wells tested for asbestos. It is unknown whether asbestos might be a concern in private wells.

None of the monitoring wells contained asbestos fibers longer than 10 µm above the EPA MCL, which was the screening level used in this health consultation. As a result, the asbestos found in the groundwater from the monitoring wells is expected to pose an insignificant cancer risk for ingestion. Asbestos in the groundwater, however, could be deposited on surfaces such as walls, vegetation, and other objects. When dry, the fibers could become airborne and pose a potential indoor and outdoor air health threat if inhaled.

Children's Health Considerations

Children can be uniquely vulnerable to the hazardous effects of environmental contaminants like those found in drinking water. This is because children are smaller and receive higher doses of contaminant exposure per body weight. Additionally, the fetus is highly sensitive to many contaminants, particularly with respect to potential impacts on childhood development. For these reasons, DOH considered the specific impacts that contaminated drinking water might have on children.

Conclusions

1. DOH concludes that the maximum amount of arsenic found in the leachate could pose a public health hazard when used for drinking or food preparation but not for bathing or cleaning. DOH cannot currently conclude whether the maximum amount of chromium found in leachate could pose a public health hazard. This is because chromium was not speciated. The other tested metals are not a public health hazard.

2. DOH cannot currently conclude whether the maximum amount of arsenic and chromium found in groundwater from the private wells could pose a public health hazard when used for drinking or food preparation, bathing or cleaning. This is because the arsenic detection limit was too high and chromium was not speciated. The other tested metals are not a public health hazard.

3. DOH cannot currently conclude whether asbestos could harm people's health if groundwater from the private wells tested near Swift Creek is used for drinking, food preparation, bathing, or cleaning. This is because the private wells were not tested for asbestos and the asbestos results from the monitoring wells may differ from conditions in the private wells.

4. DOH cannot currently conclude whether the maximum amount of arsenic and chromium found in groundwater from the monitoring wells could pose a public health hazard if representative of water used for drinking or food preparation, bathing, or cleaning. This is because the arsenic detection limit was too high and chromium was not speciated.

5. DOH concludes asbestos fibers found in groundwater collected from monitoring wells are not expected to harm people's health if the water from these wells were used for drinking and food preparation (i.e., drinking or cooking) or bathing and cleaning (i.e., touching). Asbestos in water from private wells may or may not have similar water quality. DOH cannot currently conclude whether the asbestos fibers found in the groundwater from the monitoring wells could affect indoor or outdoor air quality.

Recommendations

1. Consider taking the following steps to better assess the potential health threat posed by contaminated groundwater near Swift Creek:
   - Select an analytical method that has a lower reporting limit for arsenic,
   - Expand the chromium analysis to include hexavalent chromium speciation (chromium (VI)),
   - Test private wells near Swift Creek for asbestos. If found in private wells, consider testing indoor air for asbestos to determine if it might pose a threat to indoor air quality.
   - Conduct activity-based sampling or other appropriate methods to determine if asbestos containing groundwater might pose a health threat when used for irrigation or other outdoor uses.

2. Consider additional leachate testing to further assess how the dredged sediments from Swift Creek might impact groundwater if the sediments are managed, stored, or disposed above or below grade.

3. If someone has a well screened in an aquifer containing Swift Creek sediments and it is not properly developed or maintained, it could result in levels of asbestos and some metals posing a health threat. Consider providing information to well owners about proper well maintenance to reduce the potential for exposure to asbestos and metals.

Public Health Action Plan

1. DOH will provide copies of this health consultation report to Whatcom County Health Department, Whatcom County Public Works, EPA, Washington State Department of Ecology and other federal, state, and local agencies. A copy of the report will also be posted on the DOH Site Assessment webpage (http://www.doh.wa.gov/DataandStatisticalReports/EnvironmentalHealth/SiteAssessments).

2. DOH is available to review future monitoring plans and evaluate groundwater results from private and/or monitoring wells to determine if the contaminants pose a potential health threat.

Report Preparation

This health consultation for the Swift Creek 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. ATSDR has reviewed this document and concurs with its findings based on the information presented.

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Tables

Table 1: Summary of Groundwater and Leachate Testing, Swift Creek, Whatcom County, Washington

Media	Sampling Location	Date (Agency)	Analysis
Groundwater	Monitoring Wells HMW1 to HMW3	April 2009 (WCHD) June 2009 (WCHD)	Metals (total and dissolved) and asbestos
		July 2012 (EPA)	Metals (total and dissolved)
		October 2012 (EPA and WCPW)	Metals (total and dissolved) and asbestos
	Monitoring Wells PMW1 to PMW4	July 2012 (EPA) October 2012 (EPA and WCPW)	Metals (total and dissolved) and asbestos
	Private Wells	July 2012 (EPA)	Metals (total and dissolved)
Leachate		June 2009 (WCHD) July 2012 (EPA)	Metals (total)

WCHD – Whatcom County Health District; EPA – U.S Environmental Protection Agency;
WCPW – Whatcom County Public Works

Table 2: Total Metals in Private Wells Compared to Drinking Water Health Comparison Values, Swift Creek, Whatcom County, Washington

Metals	Cancer Class	Maximum Concentration (µg/l)	Drinking Water Health Comparison Value		Chemical of Potential Health Concern
			(µg/l)	Reference	
Aluminum	--	10.7	10,000	Child Chronic EMEG	No
Antimony	--	10 U	4	Child RMEG	No*
Arsenic	A	**10 U**	3 0.023	Child Chronic EMEG CREG	**Yes**
Barium	CN	23.2	2,000	Child Chronic EMEG	No
Beryllium	KL	0.4 U	20	Child Chronic EMEG	No
Cadmium	B1	0.5 U	1	Child Chronic EMEG	No
Calcium	--	**42,200**	-	-	**Yes**
Chromium	KL	**7.2**	9 0.031	Child Chronic EMEG[a] EPA Cancer RSL[a]	No **Yes**
Cobalt	2B	1 U	100	Child Intermediate EMEG	No
Copper	D	66.8	100	Child Intermediate EMEG	No
Iron	--	214	11,000	EPA RSL	No
Lead	B2	10 U	15	EPA Action Level	No
Magnesium	--	**52,500**	-	-	**Yes**
Manganese	D	118	300	EPA Lifetime Health Advisory	No
Mercury	D	0.2 U	2	EPA Primary MCL	No
Nickel	2B	6.2	100	EPA Lifetime Health Advisory	No
Potassium	--	**2,010**	-	-	**Yes**
Selenium	D	20 U	50	Child Chronic EMEG	No
Silver	D	2 U	50	Child Chronic RMEG	No
Sodium	--	7,240	20,000	Drinking Water Advisory	No
Thallium	--	10 U	0.16	EPA RSL	No*
Vanadium	--	2.3	63	EPA RSL	No
Zinc	IN	214	3,000	Child Chronic RMEG	No

µg/l – micrograms per liter; < - less than the practical quantitation limit (PQL) or reporting limit, **Bold** – One or more samples exceeded the health comparison value or no health comparison value is available, - not available
NC – Non Cancer, C – Cancer, -- No cancer classification available
EPA Cancer Classes: A - Human carcinogen, CN - Carcinogenic potential cannot be determined, KL – EPA: Known/Likely human carcinogen, B1 - Probable human carcinogen (limited human, sufficient animal studies), D - Not classified as to human carcinogenicity, IN - Likely to be carcinogenic to humans,
IARC Cancer Classes: 2B - possibly carcinogenic to humans (limited human evidence; less than sufficient evidence in animals
[a] – used hexavalent chromium as a surrogate, [b] - target hazard index (HI) = 1.0
EMEG - ATSDR's Environmental Media Evaluation Guide – Non-cancer, RMEG – ATSDR Reference Dose Media Evaluation Guides, CREG – ATSDR's Cancer Risk Evaluation Guides, EPA – U.S. Environmental Protection Agency, EPA RSL – EPA regional screening level
* Not detected in any sample

Table 3: Total Metals Ranges in Leachate Compared to Health Comparison Values, Swift Creek, Whatcom County, Washington

Leachate Metals	Maximum Concentration		Drinking Water Health Comparison Value		Chemical of Potential Health Concern
	SPLP (µg/l)	DI Water (µg/l)	(µg/l)	Reference	
Aluminum	<20	23	10,000	Child Chronic EMEG	No
Antimony	<10	<10	4	Child RMEG	No*
Arsenic	**40**	**<10**	3 0.023	Child Chronic EMEG CREG	**Yes**
Barium	15	7.9	2,000	Child Chronic EMEG	No
Beryllium	<0.4	<0.4	20	Child Chronic EMEG	No
Cadmium	<10	<5	1	Child Chronic EMEG	No*
Calcium	4,320	3,670	--	--	**Yes**
Chromium	**<5**	**<2**	9 0.031	Child Chronic EMEG[a] EPA Cancer RSL[a]	No **Yes**
Cobalt	<10	<1	100	Child Intermediate EMEG	No
Copper	<10	<10	100	Child Intermediate EMEG	No
Iron	<10	20	11,000	EPA Non-Cancer RSL[b]	No
Lead	<10	<10	15	EPA Action Level	No
Magnesium	15,200	17,900	--	--	**Yes**
Manganese	<0.6	<0.6	300	EPA Lifetime Health Advisory	No
Mercury	<1 - <2	<1	2	EPA Primary MCL	No
Nickel	<2	<2	100	EPA Lifetime Health Advisory	No
Potassium	100	100	--	--	**Yes**
Selenium	<20	<20	50	Child Chronic EMEG	No
Silver	<10	<10	50	Child Chronic RMEG	No
Sodium	7,600	8,700	20,000	Drinking Water Advisory	No
Thallium	R	<10	0.16	EPA Non-Cancer RSL[b]	No*
Vanadium	<2	<2	63	EPA Non-Cancer RSL[b]	No
Zinc	23	20	2,000	EPA Lifetime Health Advisory	No

SPLP – synthetic precipitation leaching procedure; DI – deionized; µg/l – micrograms per liter; -- no data; MCL – federal maximum contaminant level, R – data rejected by the lab because of analytical problems
* Not detected in any sample
EMEG - ATSDR's Environmental Media Evaluation Guide – Non-cancer, RMEG – ATSDR Reference Dose Media Evaluation Guides, CREG – ATSDR's Cancer Risk Evaluation Guides, EPA – U.S. Environmental Protection Agency, EPA RSL – EPA regional screening level

Table 4: Total Metals in Monitoring Wells Compared to Drinking Water Health Comparison Values, Swift Creek, Whatcom County, Washington

Metals	Cancer Class	Maximum Concentration (µg/l)	Drinking Water Health Comparison Values		Chemical of Potential Health Concern
			(µg/l)	Reference	
Aluminum	--	784	10,000	Child Chronic EMEG	No
Antimony	--	10 U	4	Child RMEG	No*
Arsenic	A	**20 U**	3 0.023	Child Chronic EMEG CREG	**Yes**
Barium	CN	113	2,000	Child Chronic EMEG	No
Beryllium	KL	ND<1	20	Child Chronic EMEG	No
Cadmium	B1	ND<1	1	Child Chronic EMEG	No
Calcium	--	**17,900**	-	-	**Yes**
Chromium	KL	**17.6**	9 0.031	Child Chronic EMEG[a] EPA Cancer RSL[a]	**Yes**
Cobalt	2B	2	100	Child Intermediate EMEG	No
Copper	D	ND<20	100	Child Intermediate EMEG	No
Iron	--	11,000	11,000	EPA RSL	No
Lead	B2	10 U	15	EPA Action Level	No
Magnesium	--	**70,800**	-	-	**Yes**
Manganese	D	**550**	300	EPA Lifetime Health Advisory	**Yes**
Mercury	D	ND<0.5	2	EPA Primary MCL	No
Nickel	2B	27.5	100	EPA Lifetime Health Advisory	No
Potassium	--	**1,900**	-	-	**Yes**
Selenium	D	20 U	50	Child Chronic EMEG	No
Silver	D	2 U	50	Child Chronic RMEG	No
Sodium	--	12,100	20,000	Drinking Water Advisory	No
Thallium	--	10 U	0.16	EPA RSL	No*
Vanadium	--	5	63	EPA RSL	No
Zinc	IN	ND<20	3,000	Child Chronic RMEG	No

µg/l – micrograms per liter; < - less than the practical quantitation limit (PQL) or reporting limit, **Bold** – One or more samples exceeded the health comparison value or no health comparison value is available, - not available
NC – Non Cancer, C – Cancer, -- No cancer classification available, U-undetected, ND-not detected
EPA Cancer Classes: A - Human carcinogen, CN - Carcinogenic potential cannot be determined, KL – EPA: Known/Likely human carcinogen, B1 - Probable human carcinogen (limited human, sufficient animal studies), D - Not classified as to human carcinogenicity, IN - Likely to be carcinogenic to humans,
IARC Cancer Classes: 2B - possibly carcinogenic to humans (limited human evidence; less than sufficient evidence in animals
[a] – used hexavalent chromium as a surrogate, [b] - target hazard index (HI) = 1.0
EMEG - ATSDR's Environmental Media Evaluation Guide – Non-cancer, RMEG – ATSDR Reference Dose Media Evaluation Guides, CREG – ATSDR's Cancer Risk Evaluation Guides, EPA – U.S. Environmental Protection Agency, EPA RSL – EPA regional screening level
* Not detected in any sample

Table 5: Asbestos Fibers in Monitoring Wells Compared to Drinking Water Health Comparison Values, Swift Creek, Whatcom County, Washington

Asbestos Fiber Size	Cancer Class	Maximum Asbestos Concentration (MFL)	Drinking Water Health Comparison Value		Possible Chemical of Potential Health Concern
			MFL	Reference	
>= 0.5 µm	A	890	NA	NA	Yes
>= 0.5 µm – 10 µm		220	NA	NA	Yes
> 10 µm		ND<1.519 (<9.70)*	7	EPA MCL**	No*

A - Human carcinogen (EPA), < less than, > greater than, > = greater than or equal to, µm - micrometers,
MFL – million fibers per liter, - not tested*While the detection limit for one sample was slightly above the health comparison value, the data report indicated that no asbestos fibers were detected. The remaining monitoring well asbestos results did not contain chrysotile above the health comparison value.
** EPA MCL is for fiber sizes greater than 10 µm and should not be used to compare to concentrations of shorter fiber sizes
NA- not available,

Table 6: National Academies, Institute of Medicine, Food and Nutrition Board Tolerable Upper Intake Levels (ULs) for Calcium(38)

Age	Male (mg/day)	Female (mg/day)	Pregnant (mg/day)	Lactating (mg/day)
0-6 months	1,000	1,000	-	-
7-12 months	1,500	1,500	-	-
1-8 years	2,500	2,500	-	-
9-18 years	3,000	3,000	3,000	3,000
19-50 years	2,500	2,500	2,500	2,500
51+ years	2,000	2,000	-	-

mg/day - milligrams per day

Table 7: National Academies, Institute of Medicine, Food and Nutrition Board Tolerable Upper Intake Levels (ULs) for Supplemental Magnesium(39)

Age	Males (mg/day)	Females (mg/day)	Pregnant (mg/day)	Lactating (mg/day)
Infants	Undetermined	Undetermined	-	-
1-3	65	65	-	-
4-8	110	110	-	-
9-18	350	350	350	350
19+	350	350	350	350

mg/day - milligrams per day

Table 8: National Academies, Institute of Medicine, Food and Nutrition Board Adequate Intake (AI) for Potassium(40)

Life Stage	Age	Males (mg/day)	Females (mg/day)
Infants	0-6 months	400	400
Infants	7-12 months	700	700
Children	1-3 years	3,000	3,000
Children	4-8 years	3,800	3,800
Children	9-13 years	4,500	4,500
Adolescents	14-18 years	4,700	4,700
Adults	19 years and older	4,700	4,700
Pregnancy	14-50 years	-	4,700
Breast-feeding	14-50 years	-	5,100

mg/day – milligrams per day

Table 9: Calcium, Magnesium, and Potassium Intake Compared to UL or AI, Swift Creek, Whatcom County, Washington

Essential Nutrient	Maximum Concentration (mg/l)	Intake Level (mg/day)*			Exceeds UL or AI
		Child	Older Child	Adult	
Calcium	42.2	38.0	42.2	59.1	No
Magnesium	70.8	63.7	70.8	99.1	No
Potassium	2.0	1.8	2.0	2.9	No

mg/l – milligrams per liter, mg/day – milligrams per day, AI – adequate intake, UL – tolerable upper intake level
*Intake level = concentration (milligrams per liter) x liters of water consumed per day.

Table 10: Groundwater Non-Cancer Doses for Domestic Wells and Monitoring Wells Compared to Oral MRLs or RfDs and NOAELs, Swift Creek, Whatcom County, Washington

Well Group	Contaminant	Maximum Concentration (µg/l)	Age Group	Non-Cancer Dose (mg/kg/day)		Estimated Total Non-Cancer Dose (mg/kg/day)	Chronic Oral MRL or RfD (mg/kg/day)	Estimated Dose/ MRL or RfD	NOAEL (mg/kg/day)	Doses Exceed NOAEL
				Ingestion	Dermal					
Private Wells	Arsenic	<10	Child	5.8E-04	2.1E-06	6.0E-04	3.0E-04(41)	**2.0**	8.0E-04(24)	No
			Older Child	2.3E-04	6.9E-07	2.3E-04		0.77		No
			Adult	1.9E-04	4.4E-07	1.9E-04		0.63		No
	Chromium	7.2	Child	4.1E-04	3.0E-06	4.1E-04	9.0E-04(41)	0.46	9.0E-02*(27)	No
			Older Child	1.7E-04	9.9E-07	1.7E-04		0.19		No
			Adult	1.3E-04	6.4E-07	1.3E-04		0.14		No
Monitoring Wells	Arsenic	<10* (20 U)	Child	5.8E-04	2.1E-06	6.0E-04	3.0E-04	**2.0**	8.0E-04	No
			Older Child	2.3E-04	6.9E-07	2.3E-04		0.77		No
			Adult	1.9E-04	4.4E-07	1.9E-04		0.63		No
	Chromium	17.6	Child	1.0E-03	7.5E-06	1.0E-03	9.0E-04	1.1	9.0E-02*	No
			Older Child	4.1E-04	2.4E-06	4.1E-04		0.46		No
			Adult	3.3E-04	1.6E-06	3.3E-04		0.37		No
	Manganese	550	Child	3.2E-02	1.2E-04	3.2E-02	2.4E-02(42)	**1.3**	1.4E-01(43)	No
			Older Child	1.3E-02	3.8E-05	1.3E-02		0.54		No
			Adult	1.0E-02	2.4E-05	1.0E-02		0.42		No

* Benchmark dose for chromium (VI)
** Arsenic detection limits for the October 2012 sampling event were 20 µg/l; however during other sampling events, arsenic detection limits were 10 µg/l or less.
No arsenic was detected above 10 µg/l during any other sampling event. As a result, DOH used 10 µg/l arsenic as the maximum concentration, rather than 20 µg/l.
mg/kg/day – milligrams per kilogram/day
µg/l – microgram per liter
< - less than
U – the analyte was not detected above the reported sample quantitation limit,

Table 11: Leachate –Non-Cancer Doses Compared to Oral MRLs and NOAELs, Swift Creek, Whatcom County, Washington

Well Group	**Contaminant**	**Maximum Concentration (µg/l)**	**Age Group**	**Non-Cancer Dose (mg/kg/day)**		**Estimated Total Non-Cancer Dose (mg/kg/day)**	**Chronic Oral MRL (mg/kg/day)**	**Estimated Dose/ MRL**	**NOAEL (mg/kg/day)**	**Doses Exceed NOAEL**
				Ingestion	**Dermal**					
Leachate	Arsenic	40	Child	2.3E-03	8.5E-06	2.3E-03	3.0E-04(41)	**7.7**	8.0E-04(24)	**Yes**
			Older Child	9.4E-04	2.8E-06	9.4E-04		**3.1**		**Yes**
			Adult	7.4E-04	1.8E-06	7.4E-04		**2.5**		No
	Chromium	<5	Child	2.9E-04	2.1E-06	2.9E-04	9.0E-04(41)	0.32	9.0E-02*(27)	No
			Older Child	1.2E-04	6.9E-07	1.2E-04		0.13		No
			Adult	9.3E-05	4.4E-07	9.3E-05		0.10		No

* Benchmark dose for chromium (VI)
mg/kg/day – milligrams per kilogram/day
µg/l – microgram per liter
< - less than

Table 12: Groundwater Cancer Dose and Risk Estimates for Chemicals of Potential Concern in Private Wells and Monitoring Wells, Swift Creek, Whatcom County

Well Group	Contaminant	Maximum Concentration (µg/l)	Age Group*	Exposure Dose (mg/kg/day)			Cancer Slope Factor (mg/kg/day)	Estimated Cancer Risk			Estimated Mutagenic Cancer Risk**** (Ingestion + Dermal)
				Ingestion	Dermal	Ingestion + Dermal (mg/kg/day)		Ingestion	Dermal	Ingestion + Dermal	
Private Wells	Arsenic	<10	Child	3.8E-05	1.4E-07	3.8E-05	5.7E+00(44)	2.2E-04	8.1E-07	2.2E-04	--
			Older Child	3.1E-05	1.8E-07	3.1E-05		1.8E-04	1.0E-06	1.8E-04	
			Adult	3.7E-05	2.7E-07	3.7E-05		2.1E-04	1.5E-06	2.1E-04	
			Total	1.1E-04	5.9E-07	1.1E-04		6.1E-04	3.3E-06	6.1E-04	
	Chromium**	7.2	Child (0- <2 yrs)	2.1E-05	1.5E-07	2.1E-05	5.0E-01(42)	1.0E-05	7.6E-08	1.0E-05	1.0E-04
			Child (2- <5 yrs)	1.7E-05	1.2E-07	1.7E-05		8.3E-06	6.1E-08	8.3E-06	2.4E-05
			Older Child (5- <16 yrs)	2.5E-05	2.9E-07	2.5E-05		1.2E-05	1.5E-07	1.2E-05	3.6E-05
			Adult (16 - <30)	2.5E-05	3.6E-07	2.5E-05		1.2E-05	1.8E-07	1.2E-05	1.2E-05
			Total	8.8E-05	9.2E-07	8.8E-05		4.2E-05	4.7E-07.	4.2E-05.	1.7E-04
Monitoring Wells	Arsenic	<10*** 20U	Child	3.8E-05	1.4E-07	3.8E-05	5.7E+00(44)	2.2E-04	8.1E-07	2.2E-04	--
			Older Child	3.1E-05	1.8E-07	3.1E-05		1.8E-04	1.0E-06	1.8E-04	
			Adult	3.7E-05	2.7E-07	3.7E-05		2.1E-04	1.5E-06	2.1E-04	
			Total	1.1E-04	5.9E-07	1.1E-04		6.1E-04	3.3E-06	6.1E-04	
	Chromium**	17.6	Child (0- <2 yrs)	5.1E-05	3.7E-07	5.1E-05	5.0E-01(42)	2.5E-05	1.9E-07	2.5E-05	2.5E-04
			Child (2- <5 yrs)	4.0E-05	3.0E-07	4.0E-05		2.0E-05	1.5E-07	2.0E-05	6.0E-05
			Older Child (5- <16 yrs)	6.0E-05	7.1E-07	6.1E-05		3.0E-05	3.6E-07	3.0E-05	9.0E-05
			Adult (16 - <30)	6.1E-05	8.8E-07	6.2E-05		3.1E-05	4.4E-07	3.1E-05	3.1E-05
			Total	2.1E-04	2.3E-06	2.1E-04		1.1E-04	1.1E-06	1.1E-04	4.3E-04

-- not applicable
* Age groups were adjusted slightly for chromium to account for mutagenic risk calculations.(45)
** DOH conservatively assumed that the detected chromium was chromium (VI). Chromium (VI) is considered a contaminant with a mutagenic mode of action for carcinogenesis.
*** Arsenic detection limits for the October 2012 sampling event were 20 µg/l , however during other sampling events arsenic detection limits were 10 µg/l or less. No arsenic was detected above 10 µg/l during any other sampling event. As a result, DOH used 10 µg/l arsenic as the maximum concentration, rather than 20 µg/l.
**** Mutagenic risk was estimated for chromium (VI) by multiplying the ingestion + dermal cancer risk for a child 0- <2 years , child 2- <5 years, older child 5- <16 years, and an adult (16 - <30) by 10, 3, 3, and 1, respectively).(45)

Table 13: Groundwater Cancer Dose and Risk Estimates for Chemicals of Potential Concern in Leachate, Swift Creek, Whatcom County

Well Group	Contaminant	Maximum Concentration (µg/l)	Age Group*	Exposure Dose (mg/kg/day)			Cancer Slope Factor (mg/kg/day)	Cancer Risk			Estimated Mutagenic Cancer Risk*** (Ingestion + Dermal
				Ingestion	Dermal	Ingestion + Dermal (mg/kg/day)		Ingestion	Dermal	Ingestion + Dermal	
Leachate	Arsenic	40	Child	1.5E-04	5.6E-07	1.5E-04	5.7E+00(44)	8.7E-04	3.2E-06	8.7E-04	--
			Older Child	1.2E-04	7.4E-07	1.2E-04		7.1E-04	4.2E-06	7.1E-04	
			Adult	1.5E-04	1.1E-06	1.5E-04		8.5E-04	6.1E-06	8.6E-04	
			Total	4.2E-04	2.4E-06	4.2E-04		2.4E-03	1.4E-05	2.4E-03	
	Chromium**	<5	Child (0- <2 yrs)	1.4E-05	1.1E-07	1.4E-05	5.0E-01(42)	7.2E-06	5.3E-08	7.2E-06	7.2E-05
			Child (2- <5 yrs)	1.2E-05	8.5E-08	1.2E-05		5.8E-06	4.2E-08	5.8E-06	1.7E-05
			Older Child (5- <16 yrs)	1.7E-05	2.0E-07	1.7E-05		8.6E-06	1.0E-07	8.7E-06	2.6E-05
			Adult (16 - <30)	1.7E-05	2.5E-07	1.7E-05		8.7E-06	1.2E-07	8.8E-06	8.8E-06
			Total	6.0E-05	6.5E-07	6.0E-05		3.0E-05	3.2E-07	3.0E-05	1.2E-04

-- not applicable
* Age groups were adjusted slightly for chromium to account for mutagenic risk calculations.(45)
** DOH conservatively assumed that the detected chromium was chromium (VI). Chromium (VI) is considered a contaminant with a mutagenic mode of action for carcinogenesis.
*** Mutagenic risk was estimated for chromium (VI) by multiplying the ingestion + dermal cancer risk for a child 0- <2 years , child 2- <5 years, older child 5- <16 years, and an adult (16 - <30) by 10, 3, 3, and 1, respectively).(45)

Appendices

Appendix A - 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**].
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.

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**].

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 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.
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**].

Appendix B– Environmental Investigations

- In March 2009, the Whatcom County Health Department (WCHD) installed and developed three shallow monitoring wells (HMW-1 through HMW-3) to evaluate whether groundwater in the vicinity of the dredged Swift Creek sediments contained higher levels of naturally occurring asbestos and metals than an upgradient background well. HMW-1 and HMW-2 were installed immediately south of Swift Creek near Goodwin Road bridge and Oat Coles Road bridge crossings, respectively (Figure B-1) (2). HMW-3, the background well, was installed at the southwest corner of Massey Road and Oat Coles Road. The wells were reportedly installed in glacial outwash with 10 foot screens between a depth of approximately 10 to 20 feet below ground surface (bgs). It appears that groundwater at that time flowed to the west-northwest.

  WCHD tested the three wells for asbestos and total and dissolved metal in April and June 2009. Asbestos in groundwater was measured using EPA Method 100.2, which is a method for determining asbestos structures over 10 microns (μm) in length in drinking water (2). Asbestos identification was done by transmission electron microscopy (TEM). The results are reported as million fibers per liter (MFL) >10 μm. Metals were analyzed using EPA test methods 200.7, 200.8, and 245.1.

  Asbestos was not detected above the practical quantitation limit (PQL) in any of the three monitoring wells (2). A few metals were found in HMW-1 including barium, calcium, chromium, and magnesium. Those same metals were found in HMW-2 and HMW-3 along with some other metals including, but not limited to, arsenic, iron, and manganese.

- In June 2009, WCHD collected six samples of the dredged sediments stockpiled along Swift Creek to determine the potential for contaminants to leach from stockpiled Swift Creek dredged sediments and discharge to groundwater (8). The samples (SCS-1 through SCS-6) were collected approximately 2 feet below the surface of the stockpiled sediment (Figure B-2). Leachability testing of the sediment was conducted using EPA Method 1312, Synthetic Precipitation Leaching Procedure (SPLP).[o] The leachate obtained using the SPLP method was tested for total metals using EPA Method7471A for mercury and 6010B/3051 for the remaining metals and pH[p]. Sediment samples were tested for priority pollutant metals[q], cobalt, and magnesium.

  Barium, chromium, copper, lead, mercury, cobalt, and magnesium were found in most of the

[o] The SPLP was developed to determine the mobility of both organic and inorganic contaminants present in liquids, soils, and waste.(46) It has also been suggested the SPLP is designed to simulate waste exposure to acid rain.(47) When conducting the SPLP on soils or sediments collected west of the Mississippi River, a small amount of soil is mixed with an extraction fluid, which is made by adding a mixture of sulfuric and nitric acids to reagent water until the pH is 5.00 + 0.05. The sample is then rotated for 18 +/- 2 hours. After that, the sample is filtered, the extraction fluid pH measured, and appropriate analysis conducted.(46)

[p] The initial pH of the SPLP extraction fluid used for the Swift Creek sediment samples was reported as 4.95. The pH of the extraction fluid after the test ranged from 8.74-9.49.(8)

[q] Priority pollutant metals tested included arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, and silver.

sediment samples (8). Barium and magnesium were detected in all the leachate samples; arsenic was detected in two of the samples.

- In 2010, Whatcom County Public Works (WCPW) conducted a geotechnical investigation east of Goodwin Road to explore subsurface conditions in the vicinity of a proposed sedimentation basin (48). Part of that investigation included installing four monitoring wells (PMW-1 through PMW-4)(Figure B-2). The wells depths range from 40 to 60 feet bgs. PMW-1, PMW-2, and PMW-4 have 10 foot screens while PMW-3 has a 20 foot screen. PMW-3 is also screened at a lower elevation in the aquifer than the other three PMW wells. Like the WCHD wells, it appears that these monitoring wells were installed in glacial outwash.

  No groundwater sampling occurred at PMW-1 to PMW-4 during the geotechnical work (48). However, groundwater levels were measured. Based on those measurements, WCPW determined groundwater flowed to the west. Although no groundwater samples were collected, some soil samples collected during the monitoring well installation, were tested for the presence of identifiable asbestos fibers using polarized light microscopy (PLM) for asbestos (EPA/600/R-93/116) (48). Asbestos was not detected in any of the soil samples.

- In July 2012, EPA tested groundwater from monitoring wellls HMW-1 though HMW-3 and PMW-1 through PMW-4. They also tested three nearby domestic wells. In October 2012, they resampled the seven monitoring wells (3-7). Resampling occurred because it was discovered after the July sampling that monitoring wells PMW-1 through PMW-4 had not been developed after they were installed in 2010. EPA developed the wells prior to resampling in October to ensure that representative groundwater samples were being collected.

  Seven monitoring wells and three domestic wells were tested for total and dissolved metals in July 2010. However, only wells PMW-1 through PMW-4 were tested for asbestos (3-5). In October 2010, seven monitoring wells were tested for asbestos and total and dissolved metals (3;6;7). None of the domestic wells were retested in October.

  Metals were analyzed using EPA Methods 6010 and 7470. Asbestos in groundwater was measured using EPA Method 100.2, which is a method for determining asbestos structures over 10 µm in length in drinking water. EPA also tested for asbestos structures greater than 0.5 µm using modified EPA Method 100.2 (4-7).

  Asbestos fibers greater than 0.5 µm were detected in all four monitoring wells in July while fibers greater than 10 µm were only found in PMW-1, PMW-3, and PMW-4. During the October testing, asbestos fibers greater than 0.5 µm were detected in HMW-2, PMW-1 PMW-2, and PMW-4. The concentration of asbestos fibers greater than 0.5 µm, however, were 1 to 2 orders of magnitude less than those detected in July. Abestos fibers greater than 10 µm were only found in PMW-1 and PMW-4. The concentrations greater than 10 µm were approximately 1 to 3 orders of magnitude less than detected in July (3-7).

A number of metals (total and dissolved) including, but not limited to, aluminum, barium, calcium, iron, and magnesium were found in the monitoring wells and the domestic wells during the July and October sampling events. However, the concentration of detected total metals declined significantly between July and October when the wells were developed.

EPA collected and analyzed sediments at locations (SC-01, SC-02, DM-1, DM-2 (duplicate) of DM-1) (3-5.) The sediment locatons are shown on Figure B-2. EPA conducted SPLP testing on sediments.[r] The sediments were analyzed for metals. Additionally, EPA used deionized water to test for metals leachability from the Swift Creek sediments.[s] Barium, calcium, magnesium, sodium, and zinc were the only metals detected in the SPLP sediment leachate. The same metals detected in the SPLP leachate were found in the leachate generated using deionzied water (3-5). However, aluminum, iron, and potassium were also found in the deionized water leachate.

- Whatcom County Public Works also tested two HMW wells (HMW-1 and HMW-3) and four PMW wells in October 2012 for asbestos and total and dissolved metals. Asbestos structures >= 5 µm or >= 5 – 10 µm and > 10 µm were measured using EPA Method 100.2 (9). Metals were analyzed using EPA Methods 200.7 and 200.8 (9).

  Asbestos structures > 0.5 µm were detected in the six tested monitoring wells (9). Asbestos structures > 10 µm were found in PMW-2, PMW-4, and HMW-1. A number of metals (total and dissolved) including, but not limited to, arsenic, barium, chromium, nickel, and vanadium were found in the monitoring wells.

[r] The pH of the initial SPLP extraction fluid was 5.03; the post extraction fluid pH results ranged from 6.75 to 9.42 (e-mail communication between Barbara Trejo, DOH and Steven Hall, Ecology and Environment, November 27, 2012).

[s] The initial pH of the deionized water was estimated to be about 7; the post test pH of the water ranged from 7.77 to 9.54 (e-mail communication between Barbara Trejo, DOH and Steven Hall, Ecology and Environment, November 27, 2012).

Figure B-1: Swift Creek Groundwater Sampling Locations, Swift Creek, Whatcom County, Washington

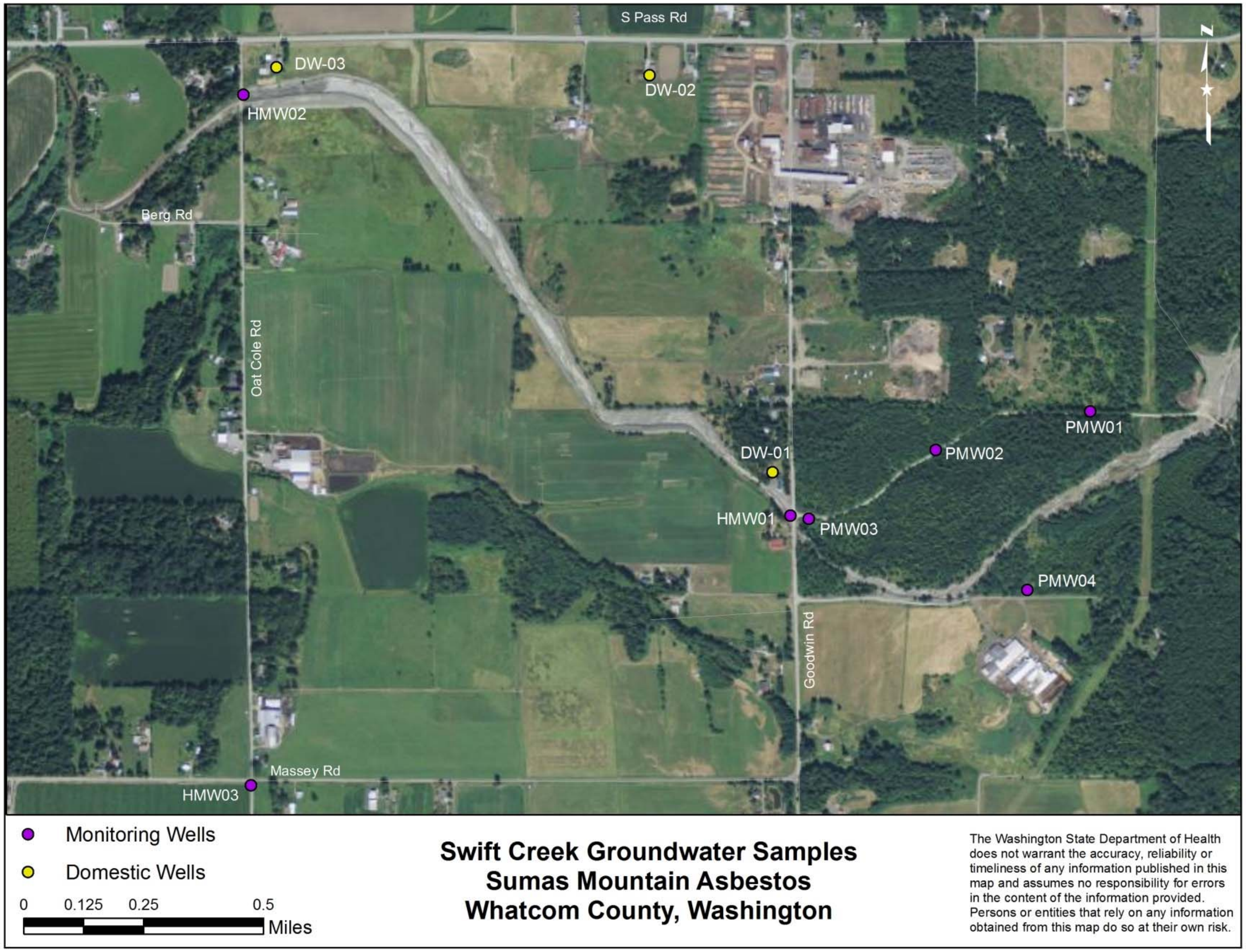
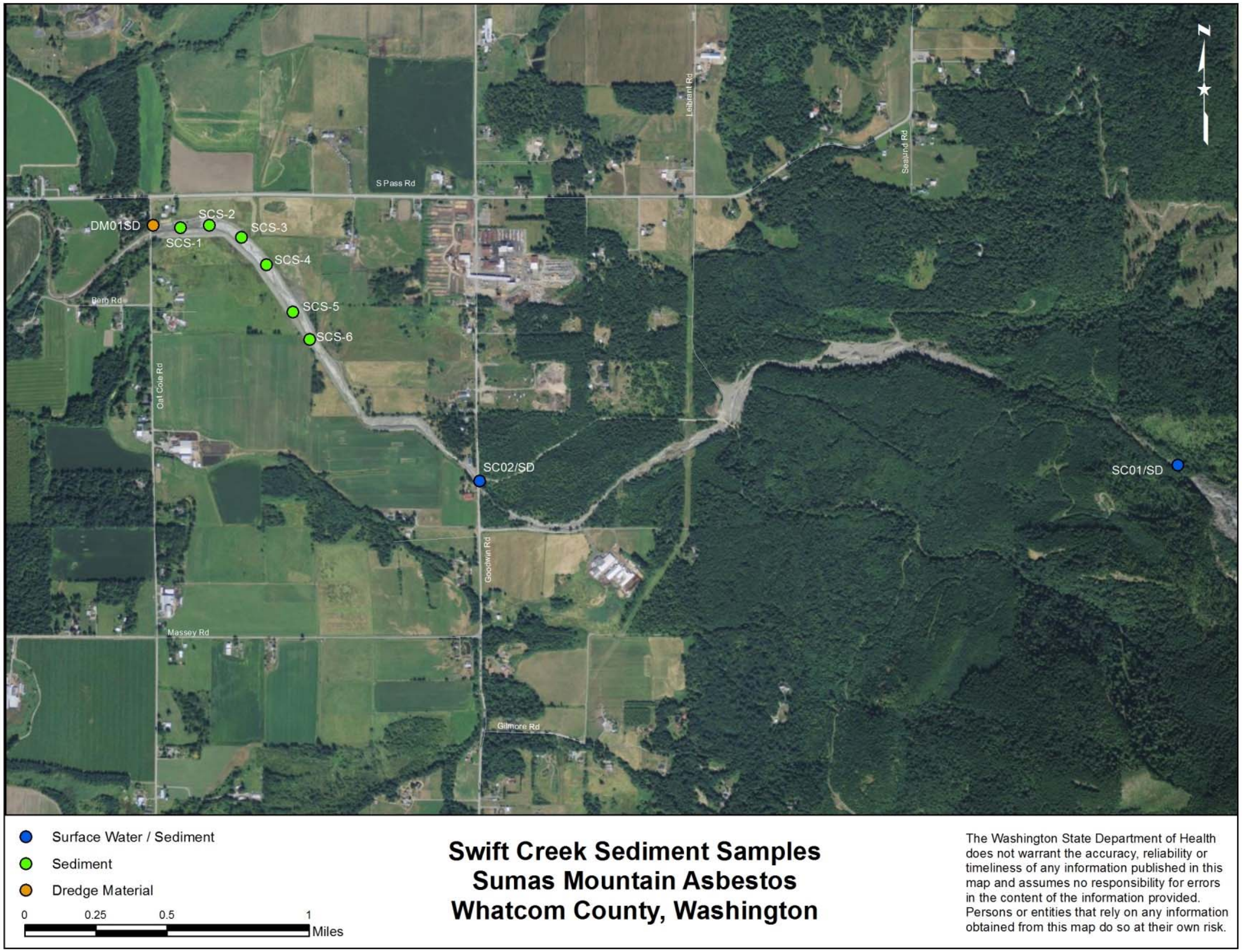


Figure B-2: Swift Creek Sediment Sampling Locations, Swift Creek, Whatcom County, Washington



Appendix C – Equations and Exposure Factors

Ingestion Route

$$ID = \frac{Cw \times IR \times EF \times ED}{BW \times AT}$$

Cw =concentration (mg/l)		
IR = ingestion rate (l/day)	*Child*	0.9
	Older child	1
	Adult	1.4
EF = exposure frequency (days/year)		350
ED = exposure duration (years)*	*Child*	5
	Older child	10
	Adult	15
BW = body weight (kg)	*Child*	15
	Older child	41
	Adult	72
AT = averaging time (days)	*non-carc*	variable**
	carc	27375

* Use Default values for BW and ED except for Chromium (VI), a chemical with a mutagenic mode of action for carcinogenesis, when calculating cancer risk.(45)

	Chromium (VI)	
	BW	ED
Child(0 - <2 yrs)	8	2
Child(2 - <5 yrs)	15	3
Older Child (5 - <16 yrs)	41	11
Adult(16 - <30 years)	72	14

**Non-cancer AT
Child = 1825 days
Older child = 3650 days
Adult = 5475 days

Dermal Route - Inorganics

$$DAD_{event} = \frac{DAev \times EV \times EF \times ED \times SA}{BW \times AT}$$

$$DA_{event} = \frac{Kp \times Cw \times t}{ORAFnc}$$

C_{dw} = concentration in drinking water mg/L		
EV = event frequency (events/day)		1
EF = exposure frequency (days/year)		350
SA = surface area (cm2)		6640
		11800
		20000
ED = exposure duration (years)*	*Child*	5
	Older child	10
	Adult	15
BW = body weight (kg)	*Child*	15
	Older child	41
	Adult	72
AT = averaging time (days)	*non-carc*	variable**
	carc	27375

* Use Default values for ED (above) except for Chromium (VI), a contaminant with a mutagenic mode of action for carcinogenesis, when calculating cancer risk. Instead use an ED of 2, 3, 11, and 14 for a child (0 - <2 yrs), child (2 - <5 yrs), older child (5 - <16 yrs) and adult(16 - <30 years), respectively.(45)

**Non-cancer AT
Child = 1825 days
Older child = 3650 days
Adult = 5475 days

Kp = skin permeability coef. (cm/hr)	*chemical specific****
t = hours/event	*0.5*
ORAFnc = Oral Route Adjustment Factor	1
ORAFc = Oral Route Adjustment Factor	1

*** Kp Values
Arsenic = 0.001
Chromium = 0.002
Manganese = 0.001

Reference List

(1) Well Logs. Washington State Department of Ecology Webpage [2012 [cited 2012 Nov. 13]; Available from: URL:https://fortress.wa.gov/ecy/waterresources/map/WCLSWebMap/default.aspx

(2) Bennett Engineering L. Groundwater Investigation Report, Swift Creek Vicinity Between Goodwin Road and Oat Coles Road, Whatcom County, Washington. 2009. Bellingham, Washington, Bennett Engineering, LLC.

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