Health Consultation

Evaluation of Shellfish and Sediment from Chambers Creek -
Sequalitchew Creek Study Area
Pierce County, Washington

September 26, 2012

Prepared by

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

Washington State Department of Health

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Foreword

The Washington State Department of Health (DOH) has prepared this health consultation with funds from 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 and is the principal federal public health agency responsible for health issues related to hazardous substances. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances.

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

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

For additional information, please visit our website or call us toll free at 1-877-485-7316: http://www.doh.wa.gov/consults

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

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Summary

Introduction:

The Washington State Department of Health (DOH) has prepared this health consultation at the request of the DOH Office of Shellfish and Water Protection (OSWP). The purpose of this health consultation is to evaluate the potential human health hazard posed by contaminants in shellfish and sediments in the study area stretching north from Sequalitchew Creek to just past Chambers Creek (Chambers Creek Study area), Pierce County, Washington. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

DOH reached three important conclusions about sediment and shellfish from the Chambers Creek Study area, Pierce County, Washington.

Conclusion 1:
DOH concludes that touching, breathing, or accidentally eating sediment from Chambers Creek Study area is not expected to harm people's health.

Basis for decision:
Maximum levels of contaminants in sediments are below level of contaminants of concern.

Conclusion 2:
DOH concludes that the general population and high-end (subsistence) consumers of shellfish (geoduck and horse clams) from Chambers Creek Study area are not likely to experience non-cancer health effects.

Basis for decision:
Exposure scenarios were evaluated using the maximum level of contaminants of concern. The results were below levels known to cause harmful non-cancer health effects.

Conclusion 3:
DOH concludes that the general population and high-end (subsistence) consumers of shellfish (geoduck and horse clams) from Chambers Creek Study area are not likely to experience cancer health effects.

Basis for decision:
At maximum concentrations (arsenic, dioxin or alpha-BHC) in shellfish, the 90th percentile (based on Suquamish consumers only) would result in a lifetime cancer risk within the range of cancer risks considered acceptable by the Environmental Protection Agency (EPA) (1 excess cancer risk per 10,000 people exposed to 1 excess cancer risk per 1,000,000 people exposed ($1x10^{-4}$ to $1x10^{-6}$)).

Next steps:
DOH will provide copies of this health consultation to OSWP, EPA, Ecology, the Nisqually Indian Tribe (NIT), the Squaxin Island Tribe, and Northwest Indian Fisheries Commission.

For More Information:

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

Purpose and Statement of Issues

The Washington State Department of Health (DOH) has prepared this health consultation at the request of the DOH Office of Shellfish and Water Protection (OSWP). The purpose of this health consultation is to evaluate the potential human health hazard posed by contaminants in shellfish and sediments in the study area stretching north from Sequalitchew Creek to just past Chambers Creek, Pierce County, Washington. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Site Background

The study area is located in Pierce County, Washington (see Figure 1). The area between Chambers Creek and Sequalitchew Creek has historically been closed to shellfish harvesting due to numerous municipal and industrial pollution sources along its shores. Therefore, only limited assessment of shellfish resources or the status of pollution has occurred in the area.

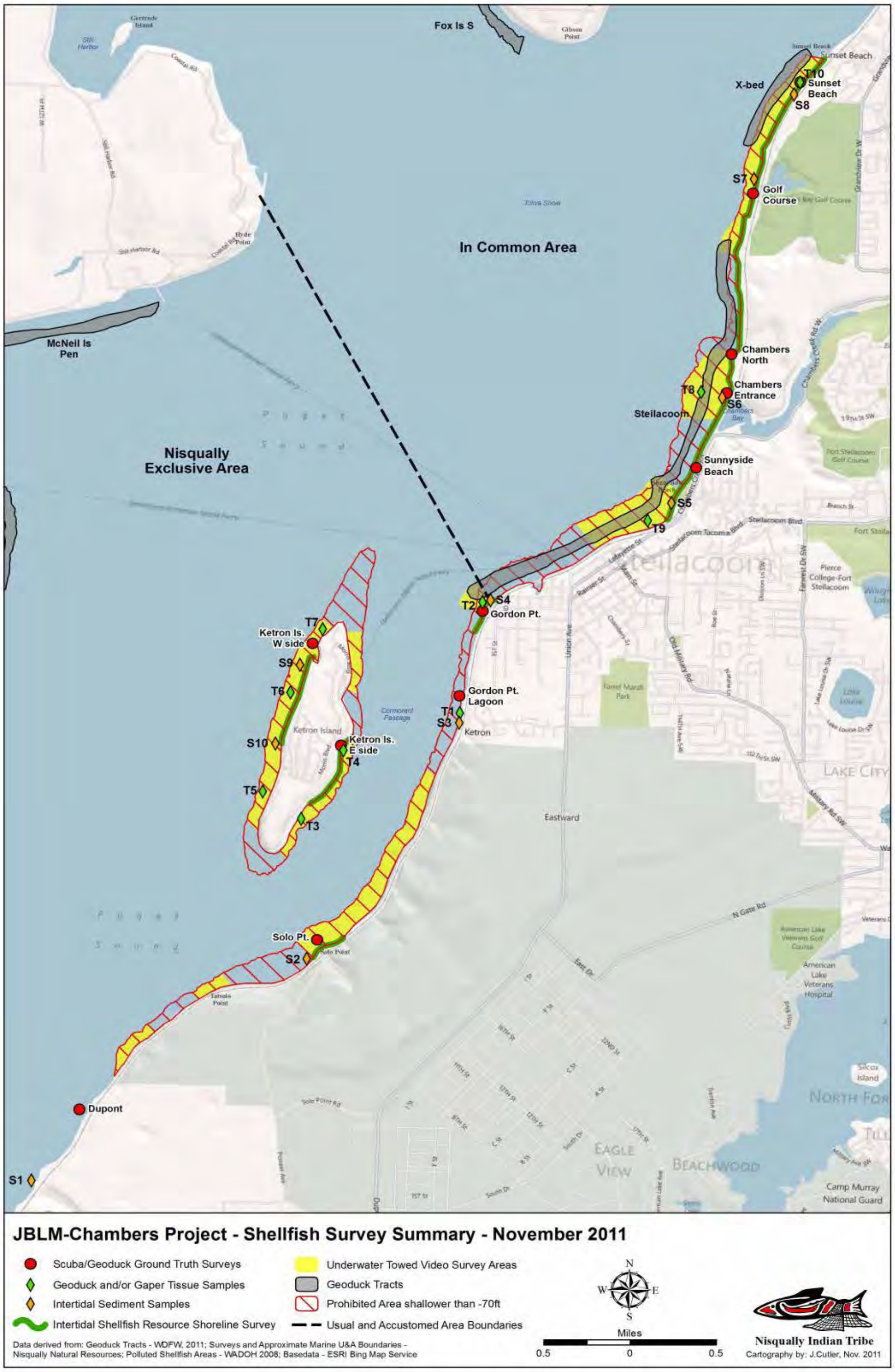
A literature review was conducted to identify potential current and legacy pollution sources in the study area. Part of the literature review was an internet search of many databases on the Washington State Department of Ecology's (Ecology) website, including the Environmental Information Management (EIM) database, National Pollutant Discharge Elimination System (NPDES) permits and fact sheets, and the Publications database. Subsequent inquiries with Ecology, Pierce County Public Works, and other facility staff were also conducted, as well as internet searches of specific industries and pollution sites. Potential current and legacy pollution sources were identified and are categorized below:

- **Wastewater outfalls -** Active facilities include the Chambers Creek and Joint Base Lewis McChord wastewater treatment plants. Legacy pollution may also be detected at former wastewater plant outfalls at Steilacoom, Dupont, and Ketron Island.

- **Chambers Creek Watershed -** Past monitoring of ambient water, sediment, and shellfish tissue have detected chlorinated pesticides, herbicides, polychlorinated biphenyls (PCBs), and metals [1,2,3,4,5]. Industries that have historically discharged into Chambers Creek and the adjacent shoreline include the former Abitibi/Boise Cascade pulp mill, Pacific Bridge and Lone Star Northwest gravel mines, Chambers Bay marina, and many smaller businesses upstream.

- **Sequalitchew Creek Watershed -** The former Dupont Works explosives manufacturing facility was active for more than 75 years on either side of Sequalitchew Creek [6]. Deposits of arsenic, mercury, cadmium, and lead have historically been documented [6,7]. The City of Dupont's monitoring of this site includes detection of pesticides, herbicides, PCBs, metals, and semi-volatile organics [8]. Nearby Fort Lewis contamination sites (metals, pesticides, PCBs) may have legacy impacts downstream [9]. Current activities in the watershed include the CalPortland gravel mine.

Figure 1. Sequalitchew Creek to Chambers Creek study area, sample collection map, Pierce County, Washington State.



Other shoreline impacts include deposition from the former Asarco Smelter plume, boat maintenance activities at the Steilacoom Marina at Gordon Point, and incidental spills along the Northern Pacific/Burlington Northern Santa Fe (BNSF) railroad tracks that hug the east shore of the study area.

Currently, the Chambers Creek to Sequalitchew Creek study area is classified as closed for shellfish harvesting due to pollution and areas along the beaches are within the closure area for sewage treatment plants outfalls. OSWP is responsible for classifying recreational shellfish growing areas.

Sample Collection, preparation, and analysis

SCUBA divers from the Nisqually Indian Tribe (NIT) collected 5 geoduck samples at 10 different locations for a total of 50 geoducks on September 26 – 29, 2011. Also 5 horse clam samples were collected at 2 locations for a total of 10 horse clams on September 29, 2011. Samples were individually placed in zipper-locked plastic bags, given a unique identifier, placed on ice, and hand delivered to Ecology's laboratory in Lacey, Washington. DOH and NIT staff dissected each geoduck in a manner similar to the way they would be cleaned prior to consumption. As described in the Chambers Creek to Sequalitchew Creek study area shellfish and sediment sample plan [10]. Sample dissection and homogenization followed the DOH standard operating procedure (SOP) for geoduck tissue liquid nitrogen grinding [11]. Edible portions of geoduck tissue (neck and mantle) were separated from the shell and gutball, and the outer skin of the neck and mantle was removed and discarded. Similarly, horse clam tissue (neck and mantle) were separated from the shell and gutball. However, the gutball and the outer skin of the neck and mantle was removed and discarded. Samples were homogenized in liquid nitrogen and composited to make a single sample for each location. Each composite consisted of the edible portion of 5 individual geoducks, geoduck gutballs or edible portions of horse clams from each sampling site. Test America Laboratories, Inc., analyzed homogenized tissues. Tissues were analyzed for metals, herbicides, PCBs and other semi-volatile organics, and dioxins and furans.

Sediment samples were collected at 10 locations on October 10, 2011 and delivered to Test America Laboratories, Inc. Sediment samples were collected as described in the Chambers Creek to Sequalitchew Creek study area shellfish and sediment sample plan [10]. Tissues were analyzed for metals, herbicides, PCBs and other semi-volatile organics, and dioxins and furans.

Results

The maximum contaminant concentrations for tissue samples are presented in Tables 1, 2, and 3. The non-edible portions of the geoducks (gutball) had slightly higher levels of contaminants than the edible portions (mantle and neck strap). The horse clams had slightly lower levels of contaminants than edible portions of the geoducks (mantle and neck strap).

Table 4, shows the maximum detected contaminants in sediments. None of the detected contaminants in the sediment samples exceeded their screening values and are below the state residential soil standards for everyday exposure.

Table 1. Maximum concentration of contaminants detected in geoduck (mantle and neck strap) collected within Chambers Creek study area in Pierce County, Washington by the Nisqually Indian Tribe in 2011 from Washington.

Chemicals	Maximum Concentration (ppm)	Screening Values (ppm)		EPA Cancer Class	(MRL or RfD) (mg/kg/day)	Contaminant of Concern
		General Population	Subsistence consumer			
Arsenic total	3.4	n/a	n/a	A	0.0003	n/a
Arsenic, inorganic	0.034	1.2	0.147			No
Cadmium	0.13 J	4	0.49	B1	0.001	No
Chromium	0.12 J	12	1.47	D	0.003	No
Copper	11	160	19.7	D	0.04	No
Lead	0.022 J	n/a	n/a	B2	n/a	Yes
Mercury	0.012 J	0.4	0.049	D	0.0001*	No
Selenium	1.2	20	2.46	D	0.005	No
Silver	0.166	20	2.46	D	0.005	No
Zinc	35	1200	147.5	D	0.3	No
Anthracene	0.0016 J	1200	147.5	D	0.3	No
alpha-BHC	0.00082 J	32	3.9	B2	0.008	No
beta-BHC	0.00056 J	2.4	0.3	C	0.0006**	No
Total Dioxin TEQ	3.2E-7	4.0E-6	4.9E-7		1.00E-9***	No

A - EPA: Human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
C - EPA: Possible human carcinogen (no human, limited animal studies)
D - EPA: Not classifiable as to health carcinogenicity
J - data qualifier: The associated numerical result is an estimate
RfD - EPA oral reference dose
MRL - ATSDR's Minimal Risk Level
* Minimal Risk Level (MRL) for methlymercury
** ATSDR Intermediate Minimal Risk Level (MRL)
*** ATSDR Minimal Risk Level (MRL) for Dioxin TEQ
n/a - not available
ppm -parts per million
mg/kg/day - milligrams per kilogram body-weight per day
TEQ - Toxic Equivalent

Table 2. Maximum concentration of contaminants detected in geoduck gutball collected within Chambers Creek study area in Pierce County, Washington by Nisqually Indian Tribe in 2011 from Washington.

Chemicals	Maximum Concentration (ppm)	Screening Values (ppm)		EPA Cancer Class	(MRL or RfD) (mg/kg/day)	Contaminant of Concern
		General Population	Subsistence consumer			
Arsenic total	5.9	n/a	n/a	A	0.0003	n/a
Arsenic, inorganic	0.059	1.2	0.147			No
Cadmium	0.82	4	0.49	B1	0.001	Yes
Chromium	0.43	12	1.47	D	0.003	No
Copper	16	160	19.7	D	0.04	No
Lead	0.35	n/a	n/a	B2	n/a	Yes
Mercury	0.016	0.4	0.049	D	0.0001*	No
Nickel	0.39	80	9.8		0.02	No
Selenium	2.4	20	2.46	D	0.005	No
Silver	2.6	20	2.46	D	0.005	No
Zinc	44	1200	147.5	D	0.3	No
Acenaphthene	0.0041 J	240	29.5		0.06	No
Anthracene	0.0033 J	1200	147.5	D	0.3	No
Fluorene	0.0028 J	160	19.7	D	0.04	No
Phenanthrene	0.0020 J	160	19.7	D	0.04**	No
Benzoic acid	3.2	16,000	1,966	D	4	No
Total Dioxin TEQ	3.4E-7	4.0E-6	4.9E-7		1.00E-9***	No

A - EPA: Human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
D - EPA: Not classifiable as to health carcinogenicity
J - data qualifier: The associated numerical result is an estimate
RfD - EPA oral reference dose
MRL - ATSDR's Minimal Risk Level
* Minimal Risk Level (MRL) for methlymercury
** Fluoranthene RfD value was used as a surrogate
*** ATSDR Minimal Risk Level (MRL) for Dioxin TEQ
n/a - not available
ppm -parts per million
mg/kg/day - milligrams per kilogram body-weight per day
TEQ - Toxic Equivalent

Table 3. Maximum concentration of contaminants detected in horse clams collected within Chambers Creek study area in Pierce County, Washington by Nisqually Indian Tribe in 2011 from Washington.

Chemicals	Maximum Concentration (ppm)	Screening Values (ppm)		EPA Cancer Class	(MRL or RfD) (mg/kg/day)	Contaminant of Concern
		General Population	Subsistence consumer			
Arsenic total	1.2	n/a	n/a	A	0.0003	n/a
Arsenic total	0.012	1.2	0.147			No
Cadmium	0.035 J	4	0.49	B1	0.001	No
Chromium	0.15	12	1.47	D	0.003	No
Copper	0.011 J	160	19.7	D	0.04	No
Lead	0.33 J	n/a	n/a	B2	n/a	Yes
Nickel	0.17	80	9.8		0.02	No
Selenium	0.26 J	20	2.46	D	0.005	No
Silver	0.076 J	20	2.46	D	0.005	No
Zinc	8.4	1200	147.5	D	0.3	No
Pyrene	0.0016 J	120	14.7	D	0.03	No
Total Dioxin TEQ	2.4E-7	4.0E-6	4.9E-7		1.00E-9**	No

A - EPA: Human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
D - EPA: Not classifiable as to health carcinogenicity
J - data qualifier: The associated numerical result is an estimate
RfD - EPA oral reference dose
MRL - ATSDR's Minimal Risk Level
* Minimal Risk Level (MRL) for methlymercury
** ATSDR Minimal Risk Level (MRL) for Dioxin TEQ
n/a - not available
ppm - parts per million
mg/kg/day - milligrams per kilogram body-weight per day
PCBs - polychlorinated biphenyls
TEQ - Toxic Equivalent

Table 4. Maximum concentrations of contaminants detected in sediment within Chambers Creek study area in Pierce County, Washington collected by Nisqually Indian Tribe and Washington State Department of Health in 2011.

Compounds	Maximum Concentration (ppm)	Comparison Value (ppm)	EPA Cancer Class	Comparison Value Reference	Contaminant of Concern (COC)
Antimony	0.37	20	D	RMEG	No
Arsenic	4.7	20	A	EMEG	No
Beryllium	0.17 J	100		EMEG	No
Cadmium	0.28	10	B1	EMEG	No
Chromium	22	200 [a]	A	RMEG	No
Copper	13	2,000	D	IM EMEG	No
Lead	7.5	250	B2	MTCA	No
Mercury	0.043	1	D	MTCA	No
Nickel	26	1,000		RMEG	No
Selenium	0.59 J	300	D	EMEG	No
Silver	0.057 J	300	D	RMEG	No
Zinc	32	20,000	D	EMEG	No
2-Methylnaphthalene	0.0066	200		RMEG	No
1-Methylnaphthalene	0.0067	4,000		EMEG	No
Acenaphthene	0.0056	3,000		RMEG	No
Acenaphthylene	0.0016	2,000*	D		No
Anthracene	0.011 J	20,000	D	RMEG	No
Benzo(a)anthracene	0.027	0.15	B2	RSL	No
Benzo(a)pyrene	0.03	0.1	B2	CREG	No
Benzo(b)fluoranthene	0.034	0.15	B2	RSL	No
Benzo(k)fluoranthene	0.015	1.5	B2	RSL	No
Benzo(ghi)perylene	0.02 J	2,000*	D		No
Chrysene	0.033	15	B2	RSL	No
Dibenz(a,h)anthracene	0.0061	0.1**		CREG	No
Dibenzofuran	0.00093 J	78	D	RSL	No
Fluorene	0.0068	2,000	D	RMEG	No
Indeno(1,2,3-cd)pyrene	0.021	0.15	B2	RSL	No
Naphthalene	0.0067	30,000	C	IM EMEG	No
Phenanthrene	0.04	2,000*	D		No
Pyrene	0.051	2,000	D	RMEG	No
3 & 4-Methylphenol	0.026 J	6,100		RSL	No
Bis(2-ethylhexyl)phthalate	0.032 J	3,000	B2	EMEG	No
Di-n-butyl phthalate	0.012 J	5,000	D	RMEG	No

Phenol	0.63	20,000	D	RMEG	No
Total Dioxin TEQ	0.00000043	0.00005	B2	EMEG	No

CREG - ATSDR's Cancer Risk Evaluation Guide (child)
RMEG - ATSDR's Reference Dose Media Evaluation Guide (child)
EMEG - ATSDR's Environmental Media Evaluation Guide (child)
IM EMEG - ATSDR's Intermediate Environmental Media Evaluation Guide (child)
J - data qualifier: The associated numerical result is an estimate
A - EPA: Human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
C - EPA: Possible human carcinogen (no human, limited animal studies)
D - EPA: Not classifiable as to health carcinogenicity
RSL - EPA: Regional Screening Level
* Fluoranthene RMEG value was used as a surrogate
** Benzo(a)pyrene CREG value was used as a surrogate
Total Dioxin TEQ - sum of dioxin/furans toxic equivalent (TEQ)
MTCA - Washington State Model Toxics Control Act

Discussion

The main goal of sampling from the Chambers Creek Study area was to determine if geoduck and horse clams are suitable for commercial harvest based on human health criteria. With the exception of mercury, PCBs, and some pesticides, there are no existing regulatory criteria established with regard to chemical contaminant levels in shellfish. The following discussion presents how geoduck and horse clam tissue contaminant data were evaluated with regard to human health.

Shellfish Contaminants of Concern Screening

Contaminants of concern (COC) were determined by employing a screening process. Screening values (SVs) were developed according to EPA guidance and are used to narrow the focus of evaluation to contaminants that are present at potential levels of public health concern (Appendix B) [12]. Maximum shellfish contamination levels for each contaminant were screened against values for non-cancer health effects (see Tables 1, 2, and 3).

With the exception of lead, SVs for chemicals that do not cause cancer represent levels that are not expected to cause any health problems. For lead, SVs are usually based on the goal of keeping children's blood lead levels below 5 micrograms per deciliter (µg/dl). These types of SVs often form the basis for cleanup goals. In general, if a contaminant's maximum concentration is greater than its SV, then the contaminant is evaluated further. For chemicals that cause cancer, SVs represent levels that are calculated to increase the risk of cancer by about 1 in 100,000. However, for this health consultation all contaminants that are possible carcinogens were automatically evaluated further, except cadmium. Cadmium was not considered because it is only known to cause cancer through inhalation and not ingestion.

Sediment Contaminants of Concern

COCs in sediments were determined by employing a screening process. Maximum sediment contaminant levels were screened against health-based soil comparison values. Several types of health-based comparison or SVs were used during this process [see the glossary (Appendix A) for descriptions of "comparison value," "cancer risk evaluation guide (CREG)," "environmental media evaluation guide (EMEG)," and "reference dose media evaluation guide (RMEG)"]. Comparison values such as the CREG and EMEG offer a high degree of protection and assurance that people are unlikely to be harmed by contaminants in the environment. For chemicals that cause cancer, the comparison values represent levels that are calculated to increase the estimated risk of cancer by about 1 in 1,000,000. These types of comparison values often form the basis for cleanup. In general, if a contaminant's maximum concentration is greater than its comparison value, then the contaminant is evaluated further.

Comparisons may also be made with legal standards such as the cleanup levels specified in the Washington State toxic waste cleanup regulation, the Model Toxics Control Act (MTCA). Legal standards may be strictly health-based or they may incorporate non-health considerations such as the cost, the practicality of attainment, or natural background levels.

However, none of the detected contaminants in the sediment samples exceeded their screening values and are below the state residential soil standards for everyday exposure. Therefore, sediment will not be evaluated any further.

Exposure Pathways

In order for any contaminant to be a health concern, the contaminant must be present at a high enough concentration to cause potential harm, and there must be a completed route of exposure [a] to people.

In general, people can be exposed through incidental ingestion of soils or sediments that are contaminated, eating foods and drinking water containing contaminants, inhaling airborne contaminants, and skin contact with contaminated media. Human use patterns and site-specific conditions were considered in the evaluation of exposure to the contaminants of concern identified in Tables 1 - 4. Exposure to contaminants in surface sediment can occur through the following completed pathways and routes:

Ingestion Exposure (swallowing)

Most people inadvertently swallow small amounts of sediment, soil, and dust (and any contaminants they might contain). Young children often put hands, toys, pacifiers, and other things in their mouths, and these items may have dirt or dust on them that may be swallowed. Adults may ingest sediments, soil, and dust through activities such as gardening, mowing, construction work, dusting, and recreational activities. For chemicals (like dioxins) that are persistent and build up over time, contaminants in food are the primary source of exposure. Meat, dairy products, and fish contribute more than 90% of the dioxin intake for the public. Therefore, everyone has some dioxin in their body. Yet for most, it is not a health threat; the

[a] Route of exposure means the way people come into contact with a hazardous substance. There are three routes of exposure, breathing (inhalation), eating or drinking (ingestion), or contact with the skin (dermal contact). A completed exposure pathway exists when there is direct evidence of a strong likelihood that people have in the past or are presently coming in contact with site-related contaminants.

health threat depends on how much meat or seafood a person eats, over what period of time and the level of contamination found. Exposure to contaminants in clams at the Chambers Creek site for the general population and a subsistence fish/shellfish consumer occurs mainly through ingestion.

The following discussion addresses human use patterns and site-specific conditions that are considered in the evaluation of exposure to contaminants in clams, and contaminants in surface sediment at the Chambers Creek study area. Exposure to contaminants in surface sediments can occur through the following pathways and routes:

- Inadvertent sediment ingestion, dust particle inhalation, and dermal absorption of contaminants in sediment during beach play.

Inhalation Exposure (breathing)

Although people can inhale suspended sediment, soil, or dust, airborne sediment usually consists of relatively large particles that are trapped in the nose, mouth, and throat and are then swallowed, rather than breathed into the lungs.

Skin Exposure (dermal)

Dirt particles that can adhere to the skin may cause additional exposure to contaminants through dermal absorption. Although human skin is an effective barrier for many environmental contaminants, some chemicals can move easily through the skin.

Evaluating Exposure to Contaminants in Geoduck and Horse Clams

As mentioned above, there are no established regulatory levels with regard to chemical contaminants in seafood and shellfish (excluding mercury) [13, 14]. The U.S. Food and Drug Administration (FDA) had previously derived action levels, tolerances, and guidance levels for poisonous deleterious substances in seafood, but these levels were not intended for enforcement purposes [13, 14]. More recently, these levels were removed from FDA guidance documents to eliminate confusion.

In absence of existing regulatory levels, DOH will assess human health risk using the methodology described below:

- Estimate how much geoduck meat is consumed by potentially exposed consumers, tribal members, and additional high-end geoduck consuming populations. Because it appears that horse clam consumption rates are lower than geoduck rates, therefore DOH will be using geoduck consumption rates in this report.

- Obtain data from analyze geoduck and horse clam samples for contaminant concentrations in order to estimate levels in tissue (in this case, samples taken from the Chambers Creek study area by the NIT).

- Using this information, DOH can establish what people are potentially exposed to (i.e., DOH can calculate the dose of a contaminant that a person would receive from consuming geoduck or horse clams). For the purpose of this health consultation, it will be assumed that all geoduck or horse clams consumed are harvested from Chambers Creek study area.

- Finally, determine if the calculated exposure dose is considered safe. This is done by comparing the calculated exposure dose to ATSDR's minimal risk level (MRL) or EPA's oral reference dose (RfD) specific to each chemical of concern, modeling blood lead levels in children and fetuses, and estimating a consumer's lifetime increased estimated cancer risk.

Geoduck Consumption Rates

The majority of geoduck harvested in Puget Sound is exported to markets in Asia. The amount of geoduck typically consumed per person in the Asian markets is not known, but geoduck are costly (~ $20.00 per pound), so frequent consumption is not likely and are probably eaten only on special occasions. Nevertheless, it is important to estimate a reasonable geoduck consumption rate in order to estimate exposure to chemical contaminants.

Table 5 shows shellfish and geoduck consumption rates for the U.S. population, Puget Sound Native American Tribes, and Asian and Pacific Islanders (API) from King County [15, 16, 17]. Suquamish geoduck consumption rates range from 1 three-ounce (oz.) meal per month (75^{th} percentile Suquamish children) to 2.7 eight-oz. meals per week (95^{th} percentile Suquamish adults).

The consumption rate used in this evaluation is based on the 90^{th} percentile Suquamish (consumers only) rate for geoduck (i.e., 0.44 g/kg/day which corresponds to ~ 1.0 eight-oz. meals per week). This rate represents geoduck as a portion of the total shellfish eaten. The 2000 Suquamish survey presents a range of total seafood ingestion rates that include many species of shellfish, as well as fin fish. Geoduck is a subgroup of all shellfish. The geoduck only rate used in this evaluation is not meant to represent a tribal subsistence consumption rate. Appendix C, Table C1 shows the exposure assumptions.

Table 5. Shellfish or geoduck consumption rates for adults and children, General Population, Asian Pacific Islander, and Tribal.

Consumption Rate **(meals per month)**	**Daily rate-** **(g/day)** [a]		**Grams shellfish consumed per kilogram body weight per day** **(g/kg/day)** [b]		**Comparable ingestion rates**
	Adults	Children	Adults	Children	
0.25 3 meals per year	1.9	0.7	0.03	0.05	Average U.S. general population marine shellfish consumption rate (1.7 g/day)
					Suquamish Tribal children median (consumers only) geoduck consumption rate (0.053 g/kg/day)
0.5 6 meals per year	3.7	1.4	0.05	0.09	Squaxin Island Tribal adult median shellfish consumption rate (0.065 g/kg/day)
					Suquamish Tribal adult median (consumers only) geoduck consumption rate (0.052 g/kg/day)
1	7.5	2.8	0.11	0.19	Tulalip Tribal adult median shellfish consumption rate (0.153 g/kg/day) Suquamish Tribal children 75th percentile (consumers only) geoduck consumption rate (0.23 g/kg/day)
2	15	5.6	0.22	0.37	Suquamish Tribal adults 80th percentile (consumers only) geoduck consumption rate (0.25 g/kg/day)
4	30	11	0.43	0.73	Suquamish Tribal adults 90th percentile (including non-consumers) geoduck consumption rate (0.39 g/kg/day)
					Suquamish Tribal adults 90th percentile (consumers only) geoduck consumption rate (0.44 g/kg/day)
					King County Asian and Pacific Islander median all shellfish consumption rate (0.50 g/kg/day)
					Suquamish Tribal children 95th percentile (including non-consumers) geoduck consumption rate (0.84 g/kg/day)
10	76	28	1.08	1.9	Suquamish Tribal adult 95th percentile geoduck consumption rate consumers only (1.117 g/kg/day)

[a]- assumes eight-ounce meal (227 g) for adults and three-ounce meal (85 g) for children
[b]- assumes a bodyweight of 70 kg for adults and 15 kg for children

Chemical Specific Toxicity

Arsenic

The majority of information concerning the health effects of arsenic exposure in humans comes from studies of populations that were chronically exposed to arsenic in their drinking water and occupational studies in which workers were exposed to arsenic trioxide dust in the workplace. Several studies have indicated that workers exposed to arsenic trioxide (As2O3) dust in air at smelters have an increased risk of lung cancer [18]. Furthermore, a positive dose response between cumulative exposure to arsenic and lung cancer risk was observed. In other words, the more arsenic workers were exposed to, the more likely they were to develop lung cancer. Chronic exposure to arsenic in drinking water has occurred in large populations in Taiwan, Chile, Mexico, Argentina, and Bangladesh [18]. In Bangladesh, where the water concentrations were frequently greater than 0.5 mg/L and as high as 3.8 mg/L, symptoms included dermatological effects (hyperpigmentation, hypopigmentation, keratosis, cracking skin, lesions, and skin cancers), bladder cancer, and black foot disease that ultimately leads to gangrene. Studies in U.S. populations exposed to arsenic in drinking water have not shown increased cancer incidences, but arsenic concentrations in water were generally less than those reported in Taiwan and Bangladesh.

The effects of chronic exposure to arsenic in shellfish have not been studied. Seafood is recognized as one of the main dietary sources of arsenic [19]. However, arsenic in shellfish is considered nontoxic because it is present mainly in its organic form; only the inorganic forms, arsenite and arsenate, are considered toxic [20]. Arsenic ingested with shellfish is usually in the relatively nontoxic form of arsenobetaine [21].

Speciation of the various forms of arsenic has been conducted in shellfish [20, 21, 22, 23] Inorganic and organic species present in some shellfish (pacific oysters) include arsenite, arsenate, methylarsonic acid (MA), dimethylarsinic acid (DMA), and the nontoxic arsenobetaine (AB). Shellfish contains a relatively small amount of inorganic arsenic compared to the total arsenic concentration. The ratio of mean concentration of inorganic As species to total concentration of As in oysters ranges approximately from 1% to 2% [21, 22, 23].

On the other hand, other studies revealed that shellfish may contain a relatively large amount of inorganic arsenic (up to 19% of the total arsenic in one homogenate) [20]. The levels of inorganic arsenic compared to total arsenic concentration in most shellfish vary from species to species; therefore, the amount of toxic arsenic species in shellfish (geoduck) is uncertain. Recent data obtained from the Suquamish Tribe and EPA’s Manchester Laboratory revealed that inorganic arsenic levels in edible tissue is less than 1% of the total arsenic. For this assessment, DOH assumes that inorganic arsenic represents 1% of the total arsenic detected in edible tissue.

Cadmium

Cadmium is a naturally-occurring element in the earth's crust. Cadmium is used mainly in batteries, pigments, metal coatings, and metal alloys. Cadmium is found in most foods at low levels, with the lowest levels found in fruits and the highest levels found in leafy vegetables and potatoes. Shellfish have higher cadmium levels (up to 1 ppm) than other types of fish or meat.

Cadmium is stored in the liver and kidneys and slowly leaves the body in the urine and feces [24]. However, high levels of cadmium will cause kidney damage and cause bones to become fragile and break easily. Occupational exposure to inhaled cadmium is suspected to be a cause of lung cancer in workers while animal studies have confirmed the ability of cadmium to cause lung tumors via the inhalation route. Studies of workers exposed to airborne cadmium also suggest a link with prostate cancer. The ability of cadmium to cause cancer via the oral route is disputed. The RfD for cadmium ingested with food is 0.001 mg/kg/day.

Dioxins and Furans

Dioxins, Furans TEQ Concentrations

Although several dioxin and furan congeners were analyzed in tissue, only a single value called a dioxin toxic equivalent (TEQ) is presented in this health consultation. Each dioxin/furan or dioxin-like PCB congener is multiplied by a Toxic Equivalency Factor (TEF) to produce the dioxin TEQ. The TEQs for each chemical are then summed to give the overall 2,3,7,8-tetrachlorodibenzo-p-dioxin TEQ. The TEQ approach is based on the premise that many dioxins/furans and dioxin-like PCB congeners are structurally and toxicologically similar to 2,3,7,8-tetrachlorodibenzo-p-dioxin. TEFs are used to account for the different potency of dioxins and furans relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin, and are available for ten chlorinated dibenzofurans and seven chlorinated dibenzodioxins using the World Health Organization (WHO) methodology [25].

Dioxins and furans (dioxins) consist of about 210 structural variations of dioxin congeners, which differ by the number and location of chlorine atoms on the chemical structure. The primary sources of dioxin releases to the environment are the combustion of fossil fuels and wood; the incineration of municipal, medical, and hazardous waste; and certain pulp and paper processes. Dioxins also occur at very low levels from naturally occurring sources and can be found in food, water, air, and cigarette smoke.

The most toxic of the dioxin congeners, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) can cause chloracne (a condition of acne like lesions on the face and neck). Exposure to high levels of dioxins can cause liver damage, developmental effects, and impaired immune function [26]. Long-term exposure to dioxins could increase the likelihood of developing cancer. Studies in rats and mice exposed to TCDD resulted in thyroid and liver cancer [27]. EPA considers TCDD to be a probable human carcinogen and developed a cancer slope factor of $1.5\text{x } 10^5$ mg/kg/day [28, 29].

Lead – Occurrence, Health Concerns, and Risks

Lead is a naturally occurring chemical that is normally found in soil. In Washington, normal background concentrations rarely exceed 20 ppm [30]. However, widespread use of certain products (such as leaded gasoline, lead-containing pesticides, and lead-based paint) and emissions from certain industrial operations (such as smelters) have resulted in significantly higher levels of lead in many areas of the state.

Elimination of lead in gasoline and solder used in food and beverage cans has greatly reduced exposure to lead. Currently, the main pathways of lead exposure in children are ingestion of paint chips, contaminated soil and house dust, and drinking water in homes with old plumbing.

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

Health Effects

Exposure to lead can be monitored by measuring the level of lead in the blood. In general, blood lead rises 1-5 μg/dl for every 1,000 ppm increase in soil or dust concentration [31]. For children, the Centers for Disease Control and Prevention (CDC) has defined an elevated blood lead level (BLL) as greater than, or equal to, 10 micrograms of lead per deciliter of blood (μg/dl). However, there is growing evidence that damage to the central nervous system resulting in learning problems can occur at blood lead levels less than 10 μg/dl. The CDC has recently updated its definition for elevated BLL to greater than, or equal to, 5 μg/dl [32]. U.S. state childhood lead program's 2006 data showed 1.21% of children tested in the U.S. had blood lead levels greater than 10 μg/dl [33].

Lead poisoning can affect almost every system of the body and often occurs with no obvious or distinctive symptoms. Depending on the amount of exposure a child has, lead can cause behavior and learning problems, central nervous system damage, kidney damage, reduced growth, hearing impairment, and anemia [34].

In adults, lead can cause health problems such as high blood pressure, kidney damage, nerve disorders, memory and concentration problems, difficulties during pregnancy, digestive problems, and pain in the muscles and joints [34]. These health effects have usually been associated with blood lead levels greater than 30 μg/dl.

Because of chemical similarities to calcium, lead can be stored in bone for many years. Even after exposure to environmental lead has been reduced, lead stored in bone can be released back into the blood where it can have harmful effects. Normally this release occurs relatively slowly. However, certain conditions such as pregnancy, lactation, menopause, and hyperthyroidism can cause more rapid release of the lead, which could lead to a significant rise in blood lead levels [35].

Evaluating Non-cancer Hazards

Estimated doses for average U.S. and Suquamish Tribe shellfish or geoduck consumption were calculated and shown in Appendix C, Tables C1 – C7. These were intended to represent a reasonable range for exposure to contaminants from geoduck consumption for children and adults. In order to evaluate the potential for *non-cancer* adverse health effects in children and adults that might result from exposure to contaminants in geoduck harvested from the study area, a dose is estimated for each COC. These estimated doses were then compared to either the MRL. MRLs are an estimate of the daily human exposure to a substance that is likely to be without appreciable risk of adverse health effects during a specified duration of exposure. In the absence of MRLs, DOH uses the EPA's RfD. RfDs are doses below which non-cancer adverse health effects are not expected to occur. MRLs and/or RfDs are derived from observed effect levels obtained from human population and laboratory animal studies. These observed effect levels can be either the lowest-observed adverse effect level (LOAEL) or a no-observed adverse effect level (NOAEL). In human or animal studies, the LOAEL is the lowest dose at which an adverse health effect is seen, while the NOAEL is the highest dose that does not result in any adverse health effects.

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

Estimated exposure doses, exposure assumptions, and hazard quotients are presented in Appendix C for COCs found in shellfish. Based on exposure estimates quantified in Appendix C Table C1, people eating shellfish from the study area are not likely to experience adverse non-cancer health effects from exposure to COCs in shellfish at this site since the exposure dose did not exceed the MRL or RfD.

Evaluating Exposure to Lead

The biokinetics of lead are different from most toxicants because it is stored in bones and remains in the body long after it is ingested. Children's exposure to lead is evaluated through the use of the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) developed by the EPA. The IEUBK predicts blood lead levels in a distribution of exposed children based on the amount of lead that is in environmental media (e.g., shellfish) [36]. It is important to note that the IEUBK model is not expected to accurately predict the blood lead level of a child (or a small group of children) at a specific point in time. In part, this is because a child (or group of children) may behave differently and therefore have different amounts of exposure to contaminated soil and dust than the average group of children used by the model to calculate blood lead levels. For example, the model does not take into account reductions in exposure that could result from community education programs. Despite this limitation, the IEUBK model is a useful tool to help prevent lead poisoning because of the information it can provide about the hazards of environmental lead exposure. For children who are regularly exposed to lead contaminated fish, the IEUBK model can estimate the percentage of young children who are likely to have blood lead concentrations that exceed a level that may be associated with health problems (usually 10 μg/dl).

Average Shellfish Lead Concentrations and Estimated Blood Lead Levels

The IEUBK model was used to estimate the percentage of children that could have elevated blood lead levels if they frequently eat lead contaminated shellfish. Default parameters are used for all model inputs unless stated [36]. Exposure was based on a tribal scenario for children eating shellfish containing an average concentration of lead (see Appendix D, Tables D1 – D3).

The adult lead model was used to estimate the 95th percentile Fetal Blood Lead and the average blood lead levels of women who consume lead contaminated seafood. Exposure was based on a general population and tribal scenario for adults eating shellfish containing an average concentration of lead (see Appendix D, Tables D4 – D6).

EPA's target cleanup goal is no more than 5% of the community with BLLs above 10 µg/dL. Consuming shellfish from the Chambers Creek study area would result in children BLL ranging from 0.3% to 0.4% above the EPA 10 µg/dL target level (see Appendix D, Tables D1 – D3).

Similarly, consuming shellfish from the Chambers Creek study area would result in less than 5% estimated BLL above 10 µg/dL for an adult (see Appendix D, Tables D4 – D6). A pregnant mother consuming shellfish from the Chambers Creek study area would result in the fetus' BLL ranging from 0.3% to 0.7% above 10 µg/dL and the mother's average BLL ranging from 1.5 µg/dL to 1.8 µg/dL.

Evaluating Cancer Risk

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

Current regulatory practice assumes there is no "safe dose" of a carcinogen. Any dose of a carcinogen will result in some additional cancer risk. Cancer risk estimates are, therefore, not yes/no answers but measures of chance (probability). Such measures, however uncertain, are useful in determining the magnitude of a cancer threat because any level of a carcinogenic contaminant carries an associated risk. The validity of the "no safe dose" assumption for all cancer-causing chemicals is not clear. Some evidence suggests that certain chemicals considered to be carcinogenic must exceed a threshold of tolerance before initiating cancer. For such chemicals, risk estimates are not appropriate. Recent guidelines on cancer risk from EPA reflect the potential that thresholds for some carcinogenesis exist. However, EPA still assumes no threshold unless sufficient data indicate otherwise [37].

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

Estimated Cancer Risk

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

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

Cancer is a common illness and its occurrence in a population increases with the age of the population. There are many different forms of cancer resulting from a variety of causes; not all are fatal. Approximately 1 in 3 to 1 in 2 people living in the United States will develop cancer at some point in their lives [38].

Total estimated cancer risk from exposure to maximum contaminants in geoduck (neck and strap) range from low (5 estimated excess cancers per 100,000 people exposed) to slight (1 estimated excess cancer per 1,000,000 people exposed) (see Appendix C, Table C3). This estimate is within EPA's acceptable risk for fish consumption. The range of cancer risks considered acceptable by EPA is 1 excess cancer risk per 10,000 people exposed to 1 excess cancer risk per 1,000,000 people exposed ($1x10^{-4}$ to $1x10^{-6}$). Similarly, total estimated cancer risk from exposure to maximum contaminants in geoduck (gut ball) range from low (7 estimated excess cancers per 100,000 people exposed) to slight (2 estimated excess cancers per 1,000,000 people exposed) (see Appendix C, Table C4).

Total estimated cancer risk from exposure to maximum contaminants in horse clams range from very low (2 estimated excess cancers per 100,000 people exposed) to insignificant (4 estimated excess cancers per 10,000,000 people exposed) (see Appendix C, Table C5). This estimate is within EPA's acceptable risk for fish consumption. The range of cancer risks considered acceptable by EPA is 1 excess cancer risk per 10,000 people exposed to 1 excess cancer risk per 1,000,000 people exposed ($1x10^{-4}$ to $1x10^{-6}$).

Uncertainty

Carcinogenic Potential of Arsenic

Although there is some uncertainty surrounding the magnitude of the carcinogenic potential of arsenic, there is a strong scientific basis for choosing a slope factor that is different from the value (1.5 per mg/kg-day) currently listed in the EPA integrated risk information system (IRIS) database [39]. Several recent reviews of the literature have evaluated bladder and lung cancer endpoints instead of skin cancer (which is the endpoint used for the current IRIS value):

- National Research Council (2001) [40]
- EPA Office of Drinking Water (2001) [41]
- Consumer Product Safety Commission (2003) [42]
- EPA Office of Pesticide Programs (2003) [43]
- California Office of Environmental Health Hazard Assessment (2004) [44]
- EPA IRIS Review Draft for the SAB (2005) [39]

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

Child Health Considerations

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

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

These unique vulnerabilities of infants and children demand special attention in communities that have contaminated water, food, soil, or air. Children's health was considered in the writing of this health consultation and the exposure scenarios treated children as the most sensitive population being exposed. The doses calculated for the COCs are not expected to result in adverse health effects for children.

Conclusions

1. DOH concludes that touching, breathing, or accidentally eating sediment from Chambers Creek Study area is not expected to harm people's health. Maximum levels of contaminants in sediments are below level of contaminants of concern.

2. DOH concludes that the general population and high-end (subsistence) consumers of shellfish (geoduck and horse clams) from Chambers Creek Study area are not likely to experience non-cancer health effects. Exposure scenarios were evaluated using the maximum level of contaminants of concern. The results were below levels known to cause harmful non-cancer health effects.

3. DOH concludes that the general population and high-end (subsistence) consumers of shellfish (geoduck and horse clams) from Chambers Creek Study area are not likely to experience cancer health effects. At maximum concentrations (arsenic, dioxin or alpha-BHC) in shellfish, the 90^{th} percentile (based on Suquamish consumers only) would result in a lifetime cancer risk within the range of cancer risks considered acceptable by EPA (1 excess cancer risk per 10,000 people exposed to 1 excess cancer risk per 1,000,000 people exposed ($1x10^{-4}$ to $1x10^{-6}$)).

Public Health Action Plan

Actions Planned

DOH will provide copies of this health consultation to OSWP, EPA, Ecology, the Nisqually Indian Tribe (NIT), the Squaxin Island Tribe, and Northwest Indian Fisheries Commission.

Report Preparation

This health consultation for the Chambers Creek was prepared by the Washington State Department of Health under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. This report was (supported/supported in part) by funds from a cooperative agreement with the Agency for Toxics Substances and Disease Registry, U.S. Department of Health and Human Services. This document has not been reviewed and cleared by ATSDR.

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Appendix A 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 [acute exposure], of intermediate duration, or long-term [chronic exposure].
Groundwater	Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].
Hazardous Substance	Any material that poses a threat to public health and/or the environment. Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive.
Indeterminate Public Health Hazard	The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.
Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].
Ingestion Rate (IR)	The amount of an environmental medium that could be ingested typically on a daily basis. Units for IR are usually liter/day for water, and mg/day for soil.

Inhalation	The act of breathing. A hazardous substance can enter the body this way [see **route of exposure**].
Inorganic	Compounds composed of mineral materials, including elemental salts and metals such as iron, aluminum, mercury, and zinc.
Lowest Observed Adverse Effect Level (LOAEL)	The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.
Maximum Contaminant Level (MCL)	A drinking water regulation established by the federal Safe Drinking Water Act. It is the maximum permissible concentration of a contaminant in water that is delivered to the free flowing outlet of the ultimate user of a public water system. MCLs are enforceable standards.
Media	Soil, water, air, plants, animals, or any other part of the environment that can contain contaminants.
Minimal Risk Level (MRL)	An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see **reference dose**].
Model Toxics Control Act (MTCA)	The hazardous waste cleanup law for Washington State.
Monitoring Wells	Special wells drilled at locations on or off a hazardous waste site so water can be sampled at selected depths and studied to determine the movement of groundwater and the amount, distribution, and type of contaminant.
No Apparent Public Health Hazard	A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.
No Observed Adverse Effect Level (NOAEL)	The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No Public Health Hazard	A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.
Oral Reference Dose (RfD)	An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by EPA.
Organic	Compounds composed of carbon, including materials such as solvents, oils, and pesticides that are not easily dissolved in water.
Parts per billion (ppb)/Parts per million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
Plume	A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.
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).
Remedial Investigation (RI)	The CERCLA process of determining the type and extent of hazardous material contamination at a site.
Route of Exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].
Surface Water	Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with **groundwater**].
Volatile Organic Compound (VOC)	Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Appendix B Screening Value Calculations

For Non-cancer Health Effects

SV = [(MRL or RfD)*BW]/CR [45]

SV = Screening value (mg/kg or ppm)
MRL = Minimal risk level (mg/kg/day)
RfD = Reference dose (mg/kg/day)
BW = Mean body weight (kg)
CR = Mean daily consumption rate (kg/day)

BW (adult) = 70 kg
General population CR = 17.5 g/day = 0.0175 kg/day
Subsistence Consumer CR = 142.4 g/day = 0.1424 kg/day

If maximum concentration is greater than screening value, further evaluation is required.

For Cancer Health Effects

SV_{cancer} = [(RL / CSF) * BW]/ CR [45]

SV_{cancer} = Cancer screening value (mg/kg or ppm)
RL = Risk level (life time cancer risk)
BW = Mean body weight (kg)
CR = Mean daily consumption rate (kg/day)
CSF = Oral cancer slope factor (mg/kg/day)

BW (adult) = 70 kg
General population CR = 17.5 g/day = 0.0175 kg/day
Subsistence Consumer CR = 142.4 g/day = 0.1424 kg/day
RL = $1x10^{-5}$
CSF = contaminants specific

If maximum concentration is greater than screening value, further evaluation is required.

Appendix C Exposure Assumptions

General population and Tribal exposure scenarios were evaluated for consumption of shellfish from Chambers Creek. Exposure assumptions given in Table C1 below were used with the following equations to estimate contaminant doses associated with shellfish consumption.

$$\text{Dose}_{(\text{non-cancer (mg/kg-day)})} = \frac{C \times CF_1 \times IR \times CF_2 \times EF \times ED}{AT_{\text{non-cancer}}}$$

$$\text{Cancer Risk} = \frac{C \times CF_1 \times IR \times CF_2 \times EF \times ED \times CPF}{AT_{\text{cancer}}}$$

Table C1. Exposure Assumptions

Parameter	Value	Unit	Comments
Concentration (C) – High-end	Variable	ug/kg	Average value.
Conversion Factor$_1$ (CF_1)	0.001	mg/ug	Converts contaminant concentration from micrograms (ug) to milligrams (mg)
Ingestion Rate (IR) – median Suquamish children - geoduck [43]	0.05	g/kg/day	~ 3 three-oz. meals per year
Ingestion Rate (IR) – 75th percentile Suquamish children – geoduck [43]	0.23	g/kg/day	~ 1 three-oz. meal per month
Ingestion Rate (IR) – 95th percentile Suquamish children (includes non-consumers) – geoduck [43]	0.84	g/kg/day	~ 1 three-oz. meal per week
Ingestion Rate (IR) – U.S. average adults - all shellfish	0.03	g/kg/day	~ 3 eight-oz. meals per year
Ingestion Rate (IR) – median Tulalip adults - all shellfish [44]	0.11	g/kg/day	~ 1 eight-oz. meal per month
Ingestion Rate (IR) – 90th percentile adults Suquamish – geoduck (consumers only) [43]	0.44	g/kg/day	~ 1 eight-oz. meal per week
Conversion Factor$_2$ (CF_2)	0.001	kg/g	Converts mass of fish from grams (g) to kilograms (kg)
Exposure Frequency (EF)	365	days/year	Assumes daily exposure consistent with units of ingestion rate given in g/day
Exposure Duration (ED)	70	years	Number of years eating shellfish (adults)
Averaging Time$_{\text{non-cancer}}$ (AT)	25550	days	70 years
Averaging Time$_{\text{cancer}}$ (AT)	25550	days	70 years
Minimal Risk Level (MRL) or Oral Reference Dose (RfD)	Contaminant-specific	mg/kg/day	Source: ATSDR, EPA
Cancer Slope Factor (CSF)	Contaminant-specific	$mg/kg\text{-}day^{-1}$	Source: EPA

Table C2. Non-cancer hazards associated with exposure to contaminants of concern in geoduck gutball sampled from Chamber Creek study area, Pierce County, Washington.

Chemical	Maximum Concentration	RfD (mg/kg/day)	Child Dose			Adult Dose		
			Median Suquamish	75th Suquamish	95th Suquamish (includes non-consumers)	Average U.S	Median Tulalip (All Shellfish)	90th Suquamish*
Cadmium	0.82	0.001	4.1E-5	1.9E-4	6.9E-4	2.5E-5	9.0E-5	3.6E-4
Hazard Quotient			0.04	0.19	0.69	0.025	0.09	0.36

* 90th Suquamish (consumers only).

Hazard Quotient (HQ) formula:

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

RfD - EPA's Oral Reference Dose
mg/kg/day - milligrams per kilogram body-weight per day

Table C3. Estimated cancer risk associated with exposure to maximum contaminants of concern in geoduck (neck and strap) sampled from Chamber Creek study area, Pierce County, Washington.

Chemical	Maximum Concentration (ppm)	CSF (mg/kg/day)	Child Cancer Risk [a]			Adult Cancer Risk [a]		
			Median Suquamish	75th Suquamish	95th Suquamish (includes non-consumers)	Average U.S	Median Tulalip (All Shellfish)	90th Suquamish*
Arsenic (inorganic) (ppm)	0.034	5.7 [b]	8.3E-7	3.8E-6	1.4E-5	2.5E-6	9.1E-6	3.7E-5
alpha-BHC	0.00082 J	6.3	2.2E-8	1.0E-7	3.7E-7	6.6E-8	2.4E-7	9.7E-7
Total Dioxin TEQ	3.2E-7	150000**	2.1E-7	9.5E-7	3.5E-6	6.2E-7	2.3E-6	9.1E-6
Total Estimated Cancer Risk			1.1E-6	4.8E-6	1.8E-5	3.2E-6	1.2E-5	4.7E-5

[a]- Cancer risks do not represent cumulative lifetime exposure from childhood to adulthood due to lack of consumption data from 7 to 15 year old children.
[b]- See uncertainty section on page 22-23 for the rationale of using this value.
* 90th Suquamish includes consumers only.
**HEAST = EPA's Health Effects Assessment Summary Tables [46]
EPA's Oral Reference Dose
ATSDR Intermediate Minimal Risk Level
ppb - parts per billion
mg/kg/day - milligrams per kilogram body-weight per day

Table C4. Estimated cancer risk associated with exposure to maximum contaminants of concern in geoduck gutball sampled from Chamber Creek study area, Pierce County, Washington.

Chemical	Maximum Concentration (ppm)	CSF (mg/kg/day)	Child Cancer Risk [a]			Adult Cancer Risk [a]		
			Median Suquamish	75th Suquamish	95th Suquamish (includes non-consumers)	Average U.S	Median Tulalip (All Shellfish)	90th Suquamish*
Arsenic (inorganic) (ppm)	0.059	5.7 [b]	1.4E-6	6.6E-6	2.4E-5	4.3E-6	1.6E-5	6.3E-5
Total Dioxin TEQ	3.4E-7	150000**	2.2E-7	1.0E-6	3.7E-6	6.6E-7	2.4E-6	9.6E-6
Total Estimated Cancer Risk			1.6E-6	7.6E-6	2.8E-5	5.0E-6	1.8E-5	7.3E-5

[a]- Cancer risks do not represent cumulative lifetime exposure from childhood to adulthood due to lack of consumption data from 7 to 15 year old children.
[b]- See uncertainty section on page 22-23 for the rationale of using this value.
* 90th Suquamish includes consumers only.
**HEAST = EPA's Health Effects Assessment Summary Tables [46]
EPA's Oral Reference Dose
ATSDR Intermediate Minimal Risk Level
ppb - parts per billion
mg/kg/day - milligrams per kilogram body-weight per day

Table C5. Estimated cancer risk associated with exposure to maximum contaminants of concern in horse clams sampled from Chamber Creek study area, Pierce County, Washington.

Chemical	**Maximum Concentration** (ppm)	**CSF** (mg/kg/day)	**Child Cancer Risk** [a]			**Adult Cancer Risk** [a]		
			Median Suquamish	75th Suquamish	95th Suquamish (includes non-consumers)	Average U.S	Median Tulalip (All Shellfish)	90th Suquamish*
Arsenic (inorganic) (ppm)	0.012	5.7 [b]	2.9E-7	1.4E-6	4.9E-6	8.8E-7	3.2E-6	1.3E-5
Total Dioxin TEQ	2.4E-7	150000**	1.5E-7	7.1E-7	2.6E-6	4.6E-7	1.7E-6	6.8E-6
Total Estimated Cancer Risk			4.4E-7	2.1E-6	7.5E-6	1.3E-6	4.9E-6	2.0E-5

[a]- Cancer risks do not represent cumulative lifetime exposure from childhood to adulthood due to lack of consumption data from 7 to 15 year old children.
[b]- See uncertainty section on page 22-23 for the rationale of using this value.
* 90th Suquamish includes consumers only.
**HEAST = EPA's Health Effects Assessment Summary Tables [46]
EPA's Oral Reference Dose
ATSDR Intermediate Minimal Risk Level
ppb - parts per billion
mg/kg/day - milligrams per kilogram body-weight per day

Appendix D
Lead Exposure Shellfish Ingestion Scenario Used in the IEUBK Model

This section provides inputs for the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK). The following inputs to the model were used to account for the average shellfish ingestion lead exposure from Chambers Creek site, Washington.

Shellfish (geoduck) consumption rates: median Suquamish children – 0.7 g/day; 75th percentile Suquamish children – 2.8 g/day; 95th percentile Suquamish children (includes non-consumers) – 11.0 g/day. The IEUBK model assumes that a child's total meat intake is 93.5 g/day. EPA's target cleanup goal is no more than 5% of the community with BLLs above 10 µg/dL. Default assumptions were used unless noted.

Table D1. Blood lead values determined using the IEUBK model and median Suquamish children geoduck consumption rate for lead in seafood from Chambers Creek site, Pierce County, Washington.

Seafood	Average Concentration (ppm)	Percent Meat Intake as Shellfish (%)	Blood Lead Level in Percent Above 10 ug/dl Age Range 0 - 84 Months
Geoduck (neck and strap)	0.015	0.8	0.29
Geoduck Gut Ball	0.19		0.29
Horse Clams	0.0029		0.29

ppm - parts per million
EPA's target cleanup goal of having no more than 5% of the community (0-84 months) with BLLs above 10 µg/dL.

Table D2 Blood lead values determined using the IEUBK model and 75th percentile Suquamish children geoduck consumption rate for lead in seafood from Chambers Creek site, Pierce County, Washington.

Seafood	Average Concentration (ppm)	Percent Meat Intake as Shellfish (%)	Blood Lead Level in Percent Above 10 ug/dl Age Range 0 - 84 Months
Geoduck (neck and strap)	0.015	3.0	0.29
Geoduck Gut Ball	0.19		0.31
Horse Clams	0.0029		0.29

ppm - parts per million
EPA's target cleanup goal of having no more than 5 % of the community (0-84 months) with BLLs above 10 µg/dL.

Table D3. Blood lead values determined using the IEUBK model and 95th percentile Suquamish children (includes non-consumers) geoduck consumption rate for lead in seafood from Chambers Creek site, Pierce County, Washington.

Seafood	Average Concentration (ppm)	Percent Meat Intake as Shellfish (%)	Blood Lead Level in Percent Above 10 ug/dl Age Range 0 - 84 Months
Geoduck (neck and strap)	0.015	11.8	0.29
Geoduck Gut Ball	0.19		0.38
Horse Clams	0.0029		0.29

ppm - parts per million
EPA's target cleanup goal of having no more than 5 % of the community (0-84 months) with BLLs above 10 µg/dL.

Lead Exposure Shellfish Ingestion Scenario Used in the Adult Lead Model

This section provides inputs for the Adult lead model. Consumption rates: U.S. average adults - all shellfish 1.9 g/day: median Tulalip adults - all shellfish 7.7 g/day: 90th percentile adults Suquamish – geoduck (consumers only) 30.8 g/day. EPA's target cleanup goal is no more than 5% of the community with BLLs above 10 µg/dL. Shellfish only, soil fraction was not calculated in the model. Default assumptions were used unless noted.

Table D4. Blood lead values determined using the adult lead model and U.S. average adult consumption rate - all shellfish consumption rate for lead in seafood from Chambers Creek site, Pierce County, Washington.

Seafood	Average Concentration (ppm)	Average Mother Blood Lead Concentration in ug/dl Fetus Blood Lead in Percent Above 10 ug/dl	
Geoduck (neck and strap)	0.015	mother	1.5
		fetus	0.3
Geoduck Gut Ball	0.19	mother	1.5
		fetus	0.4
Horse Clams	0.0029	mother	1.5
		fetus	0.3

ppm – parts per million

Table D5. Blood lead values determined using the adult lead model and median Tulalip adult consumption rate - all shellfish consumption rate for lead in seafood from Chambers Creek site, Pierce County, Washington.

Seafood	Average Concentration (ppm)	Average Mother Blood Lead Concentration in ug/dl Fetus Blood Lead in Percent Above 10 ug/dl	
Geoduck (neck and strap)	0.015	mother	1.5
		fetus	0.4
Geoduck Gut Ball	0.19	mother	1.6
		fetus	0.4
Horse Clams	0.0029	mother	1.5
		fetus	0.3

ppm – parts per million

Table D6. Blood lead values determined using the adult lead model and 90th percentile adult Suquamish consumption rate – geoduck (consumers only) consumption rate for lead in seafood from Chambers Creek site, Pierce County, Washington.

Seafood	Average Concentration (ppm)	Average Mother Blood Lead Concentration in ug/dl Fetus Blood Lead in Percent Above 10 ug/dl	
Geoduck (neck and strap)	0.015	mother	1.5
		fetus	0.4
Geoduck Gut Ball	0.19	mother	1.8
		fetus	0.7
Horse Clams	0.0029	mother	1.5
		fetus	0.4

ppm – parts per million