Health Consultation

EVALUATION OF SELECTED METALS IN GEODUCK TISSUE FROM TRACTS 09950 AND 10400

DUMAS BAY, PUGET SOUND
KING AND PIERCE COUNTIES, WASHINGTON

April 18, 2007

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

The purpose of this health consultation is to identify and prevent harmful human health effects resulting from exposure to hazardous substances in the environment. Health consultations focus on specific health issues so that DOH can respond to requests from concerned residents or agencies for health information on hazardous substances. DOH evaluates sampling data collected from a hazardous waste site, determines whether exposures have occurred or could occur, reports any potential harmful effects, and recommends actions to protect public health. The findings in this report are relevant to conditions at the site during the time of this health consultation, and should not necessarily be relied upon if site conditions or land use changes in the future.

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For more information about ATSDR, contact the ATSDR Information Center at 1-888-422-8737 or visit the agency's Web site: www.atsdr.cdc.gov/.

Glossary

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.
Cancer Slope Factor	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	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.
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 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**].

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	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.
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.
Media	Soil, water, air, plants, animals, or any other part of the environment that can contain contaminants.
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.
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.

Purpose

The Washington State Department of Health (DOH) prepared this health consultation at the request of the Puyallup Tribe, the Washington State Department of Natural Resources (DNR) and the DOH Office of Shellfish and Water Protection (OSWP). The purpose of this health consultation is to evaluate geoduck contaminant data from two geoduck[a] tracts along the King and Pierce Counties' shoreline and to make recommendations for actions that ensure the public's health is protected. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Background and Statement of Issues

The Puyallup Tribe requested OSWP to certify two geoduck tracts (09950 and 10400) in Puget Sound near the city of Redondo – Poverty (Dumas) Bay – for commercial harvest (Figure 1). The Puget Sound Initiative (PSI) as a pilot demonstration project has identified Poverty (Dumas) Bay as a high priority aquatic land site. This site was selected because of the large wild stock commercial shellfish tracts that have been closed to commercial harvest due to pollution from two permitted municipal outfalls (Lakota and Redondo) and the extensively urbanized area that surround the Bay.

These tracts are not currently classified for commercial harvest due to pollution concerns from marina and municipal sewage outfalls and other sources. Recreational harvest is not advised due in part to wastewater treatment plant (WWTP) outfalls in the area and past and present discharges of non-point urban pollution. Plans to extend the Redondo wastewater treatment plant's existing outfall are under way. Efforts to extend the Lakota WWTP outfall are in the early stages. The extension of these outfalls will eliminate potential impacts on the proposed geoduck harvest areas.[1]

In order to certify the proposed area for commercial harvest, the OSWP must determine that the proposed harvest area is not impacted by point and non-point sources of contamination. DOH identified arsenic, lead, cadmium, and mercury as the contaminants most likely to build up in geoduck at levels of potential health concern based on previous studies conducted on geoduck tissues in Brightwater outfall zones of the Puget Sound. Tissues in the Brightwater study were analyzed for trace metals and organics. The results of the Brightwater study were similar to other studies of geoduck tissue in Puget Sound that have found generally very low concentrations of

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[a] 

a.k.a. Pacific Geoduck, Geoduck, Panopea abrupta
Found in the Pacific from southern Alaska to Baja California, the geoduck is noted for its extra long siphons that can reach up to 4 feet (1.2 meters) and may constitute half the weight of the animal (which can weigh 8 pounds and live up to a century). Most of the geoduck harvested in the United States is exported to Asia where it is considered a delicacy.

organic contaminants and higher concentrations of metals.[2] Appendix A, Table A1 lists previous geoduck sampling analysis in Puget Sound, and Figure 2 lists soil arsenic levels in the vicinity of geoduck tracts of interest resulting from historic deposition by the Tacoma smelter.

The contaminants chosen for the chemical risk assessments associated with consumption of shellfish harvested in this area were selected because: a) they have shown to possibly accumulate at levels relevant to public health from other studies, and b) are associated with a known source (ASARCO smelter).[3] Of particular concern in the area are lead, arsenic, and cadmium, which were emitted from the ASARCO smelter in Ruston, Washington until 1986. Figure 2 lists soil arsenic levels in the vicinity of geoduck tracts of interest resulting from historic deposition by the Tacoma smelter. Most organic contaminants are not a public health issue in geoduck because of low lipid content and low trophic level. Furthermore, sediment samples taken from near the Redondo and Lakota outfalls showed no exceedences of sediment quality standards for organic compounds.[3]

DOH has partnered with DNR and Department of Ecology (DOE) to complete this geoduck sampling effort in Poverty (Dumas) Bay. Department of Natural Resources (DNR) is the project lead for the PSI project. The goal of the PSI pilot is to reopen shellfish beds in an urban environment to determine if it's possible to manage our aquatic resources in a sustainable manner for commercial and recreational harvesting. Analyzing geoduck tissue for chemical contaminants is just one of many steps toward the certification of commercial geoduck tracts.

Sample Collection, preparation, and analysis

Five geoducks were collected at 24 locations (18 locations along tract 10400 and 6 locations along tract 09950) (Figures 3 and 4). Geoducks were homogenized and composited to make a single sample for each location. Composited geoduck samples were collected on June 5-7 and June 12, 2006, by SCUBA divers from the Puyallup Tribe and DNR. Samples were individually placed in zipper-locked plastic bags, given a unique identifier, placed on ice, and hand delivered to the Ecology's laboratory in Lacey. DOH and DNR staff dissected each geoduck in a manner similar to the way they would be cleaned prior to consumption. Edible portions of geoduck muscle tissue (neck and mantle) were separated from the shell and gutball, and the outer skin of the neck and mantle was removed and discarded. Geoducks (edible, non-edible and gutballs) were homogenized in liquid nitrogen creating one composite sample (each composite consisted of five individual geoducks from each sampling site). Columbia Analytical Services analyzed homogenized tissues. Tissues were analyzed for total arsenic, cadmium, lead and mercury.

Results

A complete set of results is presented in Table 1. Figure 4 shows sample locations (sample identifications have been simplified in this report to reflect the geoduck tract name where the sample was taken). The non-edible portions had slightly higher levels of contaminants than edible portions. There are no obvious differences in metal concentrations between locations where sample was taken. Only total arsenic was detected in all samples.

Discussion

The main goal of geoduck sampling from geoduck tracts of interest (tracts 09950 and 10400) was to determine if geoduck is suitable for commercial harvest based on human health criteria. With the exception of mercury, there are no existing regulatory criteria established with regard to chemical contaminant levels in shellfish.[4] The following discussion presents how geoduck tissue contaminant data were evaluated with regard to human health.

Table 1. Metal concentrations (ppm) of geoducks sampled from tracts near Dumas and Lakota Dumas Bay site, Puget Sound King and Pierce Counties, Washington.

Contaminant	Area	N	Edible Range	Edible mean	N	Gutball Range	Gutball mean	N	Gutball and other range	Gutball and other non-edible
Arsenic, total	All	24	2.28-4.96	3.3	12	3.71-5.22	4.3	11	3.14-5.37	4.5
	1	6	3.04 -3.7	3.227	3	3.83-5.17	4.347	3	4.42- 5.37	4.840
	2	6	2.36-3.83	3.320	3	3.94-4.63	4.183	3	3.14-3.93	3.573
	3	6	2.42-4.96	3.595	3	3.71-5.22	4.243	3	4.41-5.33	5.020
	4	6	2.28-3.86	3.0	3	3.87-4.83	4.4	2	3.87-4.97	4.4
Cadmium	All	24	0.075-0.300	0.14	12	0.078-0.211	0.14	11	0.210-0.463	0.307
	1	6	0.075-0.154	0.109	3	0.091-0.161	0.117	3	0.255-0.281	0.270
	2	6	0.082-0.196	0.153	3	0.126-0.191	0.148	3	0.210-0.264	0.241
	3	6	0.093-0.300	0.145	3	0.107-0.211	0.159	3	0.358-0.463	0.398
	4	6	0.088-0.187	0.148	3	0.078-0.196	0.121	2	0.282-0.364	0.323
Lead	All	24	0.007-0.026	0.012	12	0.034-0.140	0.068	11	0.052-0.273	0.12
	1	6	0.007-0.016	0.011	3	0.039-0.100	0.066	3	0.052-0.080	0.067
	2	6	0.008-0.015	0.012	3	0.059-0.092	0.070	3	0.067-0.187	0.117
	3	6	0.008-0.026	0.014	3	0.034-0.072	0.049	3	0.072-0.273	0.150
	4	6	0.009-0.015	0.012	3	0.046-0.140	0.084	2	0.133-0.146	0.140
Mercury	All	24	0.005-0.015	0.007	12	0.004-0.013	0.008	12	0.007-0.033	0.018
	1	6	0.005-0.006	0.006	3	0.005-0.007	0.006	3	0.010-0.018	0.015
	2	6	0.005-0.008	0.006	3	0.005-0.010	0.008	3	0.007-0.017	0.012
	3	6	0.005-0.012	0.007	3	0.004-0.011	0.007	3	0.014-0.028	0.020
	4	6	0.006-0.015	0.010	3	0.006-0.013	0.010	3	0.011-0.033	0.023

Contaminant Screening

Geoduck contaminant data were screened using values derived by DOH considered protective of subsistence geoduck consumers (Table 2). Comparison values were derived using extreme high-end consumption rates (Appendix B). Table 2 shows the maximum concentration of each contaminant measured in geoduck necks (edible) compared to health-based subsistence consumer comparison values. The fact that a contaminant exceeds its health comparison value does not mean that a public health hazard exists but rather signifies the need to consider the chemical further.

When a chemical exceeds a health-based screening value (SV), additional evaluation of that chemical is necessary. Of all contaminants analyzed, only maximum levels of inorganic arsenic and cadmium exceeded health-based comparison values protective of subsistence consumers. Therefore, arsenic and cadmium will be evaluated further as contaminants of concern (COCs).

Table 2. Maximum metal concentrations (mg/kg) in Dumas Bay geoduck compared to subsistence consumption screening values, Dumas Bay site, Puget Sound, King and Pierce Counties, Washington.

Contaminant	Units	Maximum concentration (edible)	Comparison Value [a]
Arsenic total	mg/kg	4.96	NA
Arsenic, inorganic 1 % of total	mg/kg	**0.05**	**0.0004**
Cadmium	mg/kg	**0.30**	**0.22**
Lead *	mg/kg	0.026	0.07 [b]
Mercury	mg/kg	0.015	0.015

NA – Not available
BOLD Values exceed comparison value
[a] Derived assuming high-end consumption rate (Suquamish (consumers only) 90th percentile all shellfish consumption rate)
[b] Value was derived using the IEUBK model and assumes 50% of meat portion of diet is geoduck
* IEUBK - Integrated Exposure Uptake Biokinetic Model for Lead in Children to be used to predict blood lead levels in children (Appendix B, Table B2 shows assumptions used in the IEUBK to determine comparison value for lead in shellfish).

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 (As_2O_3) dust in air at smelters have an increased risk of lung cancer.[5] 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.[5] 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.[6] 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.[7] Arsenic ingested with shellfish is usually in the relatively nontoxic form of arsenobetaine.[8]

Speciation of the various forms of arsenic has been conducted in shellfish.[7,8,9,10] 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%.[8,9,10]

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).[7] 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. All shellfish in Puget Sound have some cadmium in them, but usually at levels that are not a concern for human health. Frequent eating of shellfish contaminated with cadmium over a long period of time can lead to a build-up of cadmium in the kidneys. If the levels reach a high enough level, the cadmium in the kidney will cause kidney damage, and also causes bones to become fragile and break easily. Studies of humans or animals that eat or drink cadmium have not found increases in cancer, although additional research is needed to be more certain that eating or drinking cadmium definitely does or does not cause cancer.[11]

Evaluating exposure to contaminants in geoduck

As mentioned above, there are no established regulatory levels with regard to chemical contaminants in seafood and shellfish (excluding mercury). 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.[12,13] More recently, these levels were removed from FDA guidance documents to eliminate confusion.

In absence of existing regulatory levels, DOH assessed human health risk using the methods described below:

- Estimate how much geoduck meat is consumed by potentially exposed consumers, tribal members, and additional high-end geoduck consuming populations.
- Obtain contaminant data or analyze geoduck samples for contaminant concentrations to estimate levels in geoduck tissue.
- Establish what people are potentially exposed to by calculating the dose of contaminants a person would receive from consuming geoduck.
- Determine if the calculated exposure dose is considered safe. This is done by comparing the calculated exposure dose to an oral reference dose (RfD) specific to each chemical of concern, and estimating a consumer's lifetime increased 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 is not known, but geoducks are costly (~ $20.00 per pound), so frequent consumption is not likely; rather, geoduck are probably eaten only on special occasions. Nevertheless, it is important to attempt to estimate a reasonable geoduck consumption rate in order to estimate exposure to chemical contaminants.

Table 3 shows shellfish or geoduck consumption rates for the U.S. population and Puget Sound Native American Tribes, and Asian and Pacific Islanders (API) from King County[13,14,15,16] High-end consumption of geoduck amounts to roughly four 8-oz meals per month (or one meal per week). Typical geoduck consumers likely eat less than six meals per year (or 0.5 meal per month) as evidenced by the Suquamish Tribe median consumption rate of geoduck at a similar rate (0.052 g/kg/day compared to 0.05 g/kg/day).

Table 3. Adults and children's shellfish or geoduck consumption rates.

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 Tribe 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 Tribe adult median shellfish consumption rate (0.065 g/kg/day) Suquamish Tribe adult median (consumers only) geoduck consumption rate (0.052 g/kg/day)
1	7.5	2.8	0.11	0.19	Tulalip Tribe adult median shellfish consumption rate (0.153 g/kg/day) Suquamish Tribe chidren 75th percentile (consumers only) geoduck consumption rate (0.23 g/kg/day)
2	15	5.6	0.22	0.37	Suquamish adults 80th percentile (consumers only) Geoduck consumption rate (0.25 g/kg/day).
4	30	11	0.43	0.73	Suquamish adults 90th percentile (including non-consumers) Geoduck consumption rate (0.39 g/kg/day). Suquamish adults 90th percentile (consumers only) geoduck consumption rate (0.44 g/kg/day) King County Asian Pacific Islander median all shellfish consumption rate (0.50 g/kg/day) Suquamish children 95th percentile (including non-consumers) geoduck consumption rate (0.84 g/kg/day)
10	76	28	1.08	1.9	Suquamish adult 95th percentile geoduck consumption rate (1.06 g/kg/day)

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

Non-cancer Hazard Evaluation

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, estimated doses for average U.S. shellfish consumers and geoduck from the Suquamish Tribe were calculated as shown in Appendix C. This was intended to represent a reasonable range of children's and adult's exposure to contaminants from geoduck consumption. These estimated doses were compared to EPA's reference dose, or ATSDR's minimal risk level (MRL). These are doses below which non-cancer adverse health effects are not expected to occur (so called "safe" doses). They are derived from toxic effect levels obtained from human population and laboratory animal studies. These toxic effect levels are divided by multiple "safety factors" to give the lower, more protective RfD or MRL. A dose that exceeds the RfD or MRL indicates only the potential for adverse health effects. The magnitude of this potential can be inferred from the degree to which this value is exceeded by the exposure dose. If the estimated exposure dose is only slightly above the RfD or MRL, then that dose will fall well below the toxic effect level. The higher the estimated dose is above the RfD or MRL, the closer it will be to the toxic effect level.

Exposure assumptions and dose calculations are shown in Appendix C. In order to determine if an exposure dose represents a hazard of non-cancer human health effects, exposure doses are compared to the RfD (or MRL) to obtain a hazard quotient (HQ) where:

HQ = Estimated dose/RfD

This provides a convenient method to measure the relative health hazard associated with a dose. As the hazard quotient exceeds one and approaches an actual toxic effect level, the dose becomes more of a health concern.

When this approach is applied to consumption of geoduck from the proposed harvest area near geoduck tracts 10400 and 09950, children from the Suquamish Tribe consuming geoduck at median (~ three 3-oz meals per year), 75^{th} percentile (~ 1 three-oz meals per month), and 95^{th} percentile rates (~ 1 three-oz meal per week) do not exceed a hazard quotient of one for arsenic or cadmium (Appendix C, Table C2). This means that typical children would not likely be exposed to contaminants from consumption of geoduck that would result in adverse non-cancer health effects.

Adults eating one meal per week (high-end consumption equal to Suquamish 90^{th} percentile) do not exceed a hazard quotient of one attributable to exposure to inorganic arsenic or cadmium in geoduck (Appendix C, Table C2).

Cancer Risk

Cancer risk is estimated by calculating a dose similar to that described in the previous section 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 suggests that there is no “safe dose” of a carcinogen and that a very small dose of a carcinogen will give a very small 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 associated risk. 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. More recent guidelines on cancer risk from EPA reflect the existence of thresholds for some carcinogens. However, EPA still assumes no threshold unless sufficient data indicate otherwise. This consultation assumes that there is no threshold for carcinogenicity.

Cancer Risk = Estimated Dose x Cancer Slope Factor

Cancer risk is expressed as a probability. For instance, a cancer risk of 1×10^{-5} can be interpreted to mean that a person’s overall risk of obtaining cancer increases by 0.00001, or if 100,000 people were exposed, there might be one extra cancer in that population above normal cancer rates. The reader should note that these estimates are for theoretical excess cancers that might result in addition to those normally expected in an unexposed population. Cancer risks quantified in this document are an upper-bound theoretical estimate. Actual risks are likely to be much lower.

When the above approach is applied to consumption of geoduck from tracts 09950 and 10400 near Dumas Bay, lifetime increased cancer risks range from 1.02×10^{-7} to 1.71×10^{-6} for children (low-end to high-end estimates) and 8.55×10^{-7} to 1.25×10^{-5} (low-end to high-end estimates) for adults, respectively (Appendix C, Table C3). These risks do not exceed the range of cancer risks considered acceptable by EPA (1×10^{-4} to 1×10^{-6}). Cancer risk would not exceed 1×10^{-4} if cumulative exposure was assumed beginning at childhood into adulthood by using the high-end estimate. Cumulative lifetime exposure from childhood to adulthood is a source of uncertainty due to lack of consumption data from 7 to 15 year old children.

Uncertainty

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 IRIS database. 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) [17]
- EPA Office of Drinking Water (2001) [18]
- Consumer Product Safety Commission (2003) [19]

- EPA Office of Pesticide Programs (2003)[20]
- California Office of Environmental Health Hazard Assessment (2004)[21]
- EPA IRIS Review Draft for the SAB (2005)[22]

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). The recent 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, which appears to reflect EPA's most recent assessment.

Child Health Considerations

ATSDR recognizes that infants and children may be more vulnerable to exposures than adults when faced with contamination of air, water, soil, or food. This vulnerability is a result of the following factors:

- Children are smaller and receive higher doses of chemical exposure per body weight

- Children's developing body systems are more vulnerable to toxic exposures, especially during critical growth stages in which permanent damage may be incurred.

Special consideration was given to children's exposure to contaminants in this health consultation by evaluating children's exposure to lead in geoduck separate from adults acknowledging that children are more susceptible to lead's toxicity than adults.

Conclusions

1. Exposure to arsenic, cadmium, lead, and mercury in Dumas Bay geoduck represents *no apparent public health hazard*

   - Average or high-end (subsistence) consumption of geoduck from Dumas Bay is not likely to result in non-cancer or cancer health effects.

     - Inorganic arsenic levels in edible tissue are less than 1% of the total arsenic. At these levels children are unlikely to be exposed to arsenic from consumption of geoduck that results in adverse non-cancer and cancer health effects.

     - Although cadmium levels slightly exceeded health-based comparison values protective of subsistence consumers. Levels found in Dumas Bay geoduck are not likely to result in adverse non-cancer health effects.

     - Lead was present in geoduck at levels below health concern for children. Children consuming shellfish at high-end rates from Dumas Bay that contain the maximum reported lead concentration (0.026 ppm) would not be expected to have elevated blood lead levels.

- Mercury levels in geoduck were not present at levels of health concern.

2. Geoducks have not been widely sampled in Puget Sound and therefore little is known about species and geographic variability of contaminants in tissue.

3. Future monitoring projects should consider analysis of metals in geoduck over a broader area in order to determine species variability of contaminant levels in geoduck harvested throughout Puget Sound.

Recommendation

- The OSWP should use this health consultation to guide their decision for certifying geoduck tracts 09950 and 10400 in Puget Sound.

Public Health Action Plan

Actions Taken

1. Sampling and analysis of geoduck for As, Hg, Cd and Pb has been conducted to determine whether or not chemical contaminants from tracts near the Dumas Bay site are present at levels of health concern.

2. Geoduck contaminant data for As, Hg, Cd and Pb have been evaluated by DOH and presented within this health consultation.

Action Planned

- The Department of Health's Office of Shellfish and Water Protection will use this health consultation as part of the process used to certify shellfish growing areas.

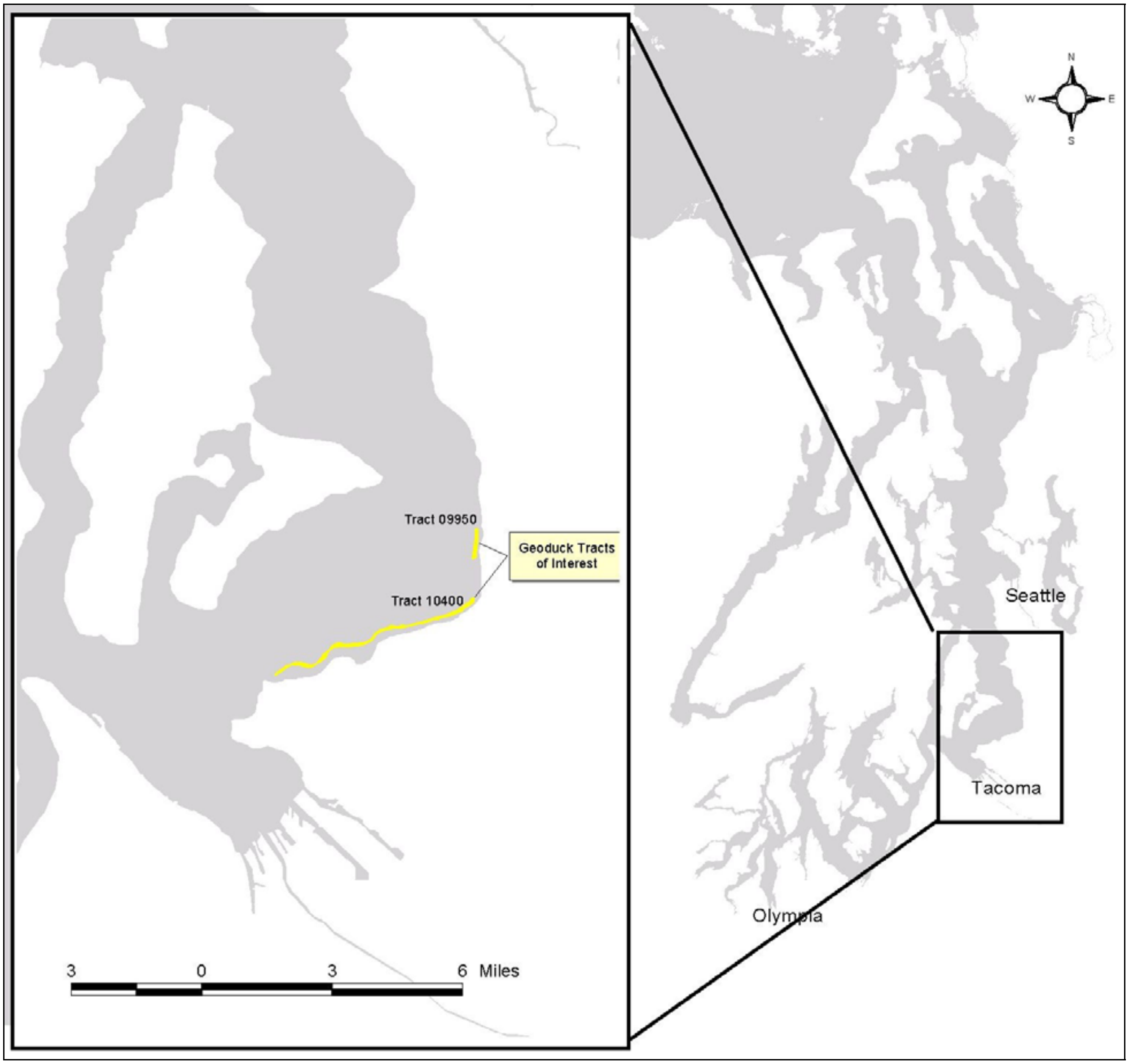

Figure 1. Geoduck tracts requested for commercial harvest classification by the Puyallup Tribe.

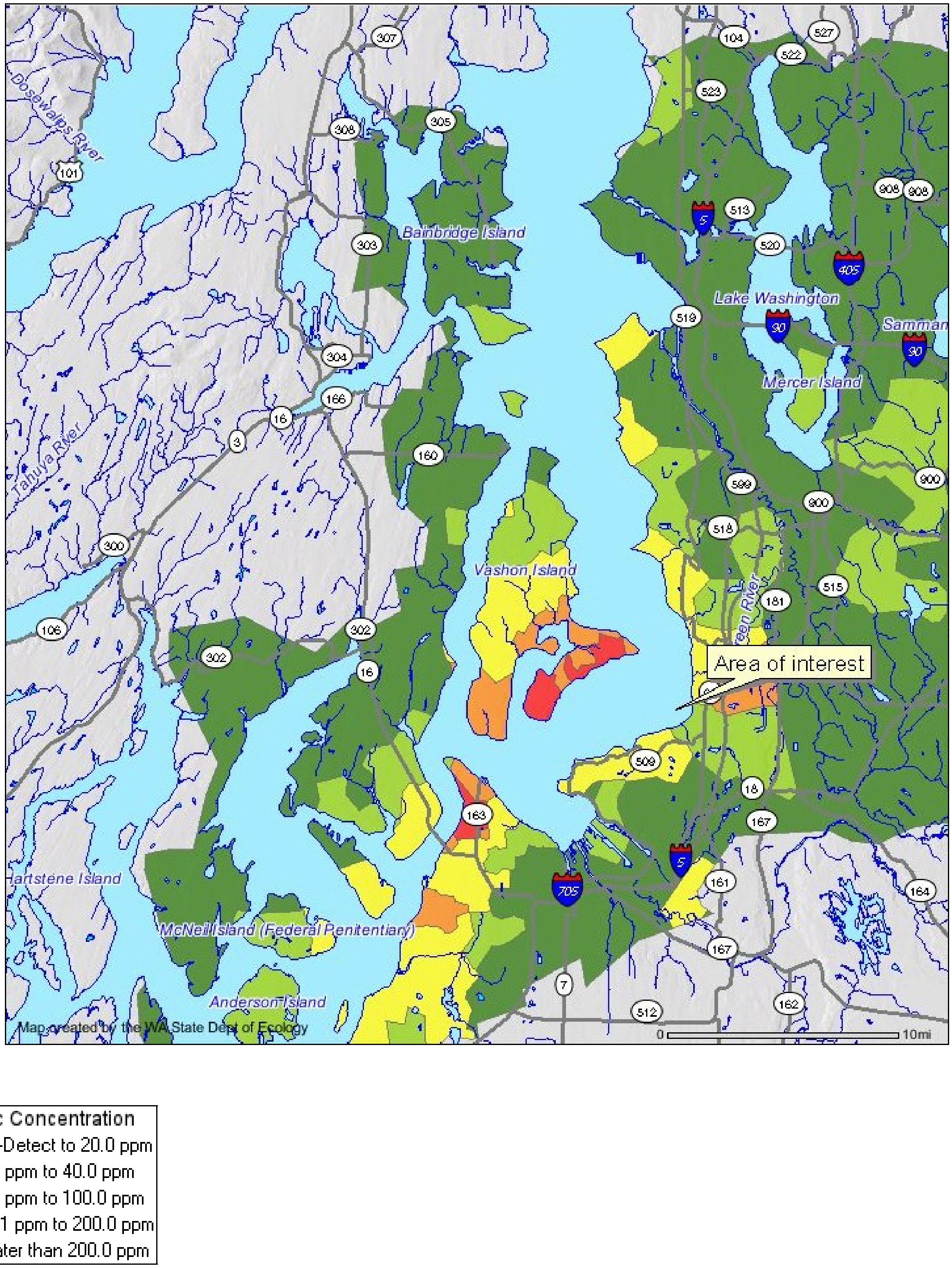

Figure 2. Soil arsenic levels resulting from historic deposition by the Tacoma smelter in the vicinity of geoduck tracts of interest.

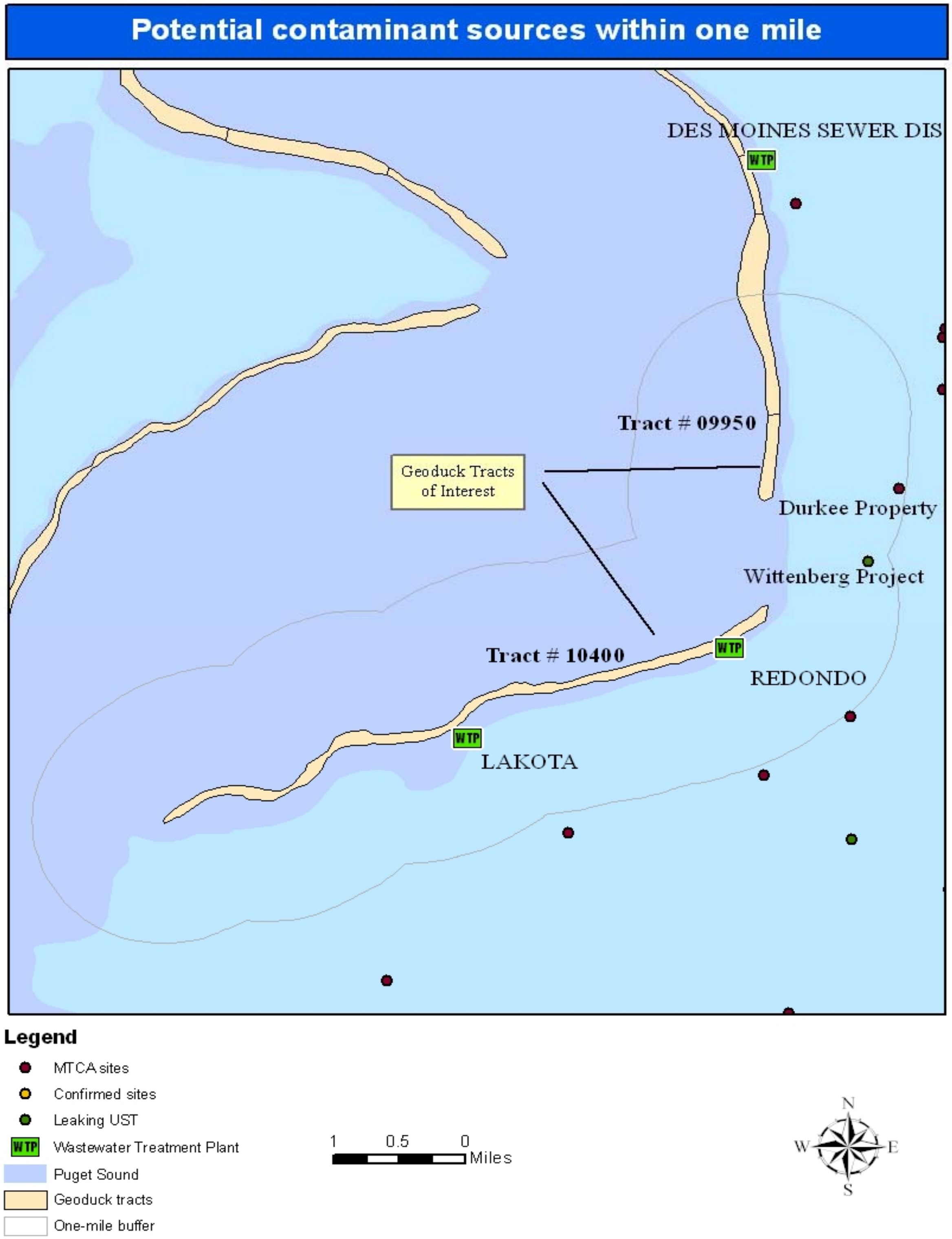

Figure 3. Potential sources of contamination near geoduck tracts of interest. Buffer around geoduck tracts is a one mile radius.

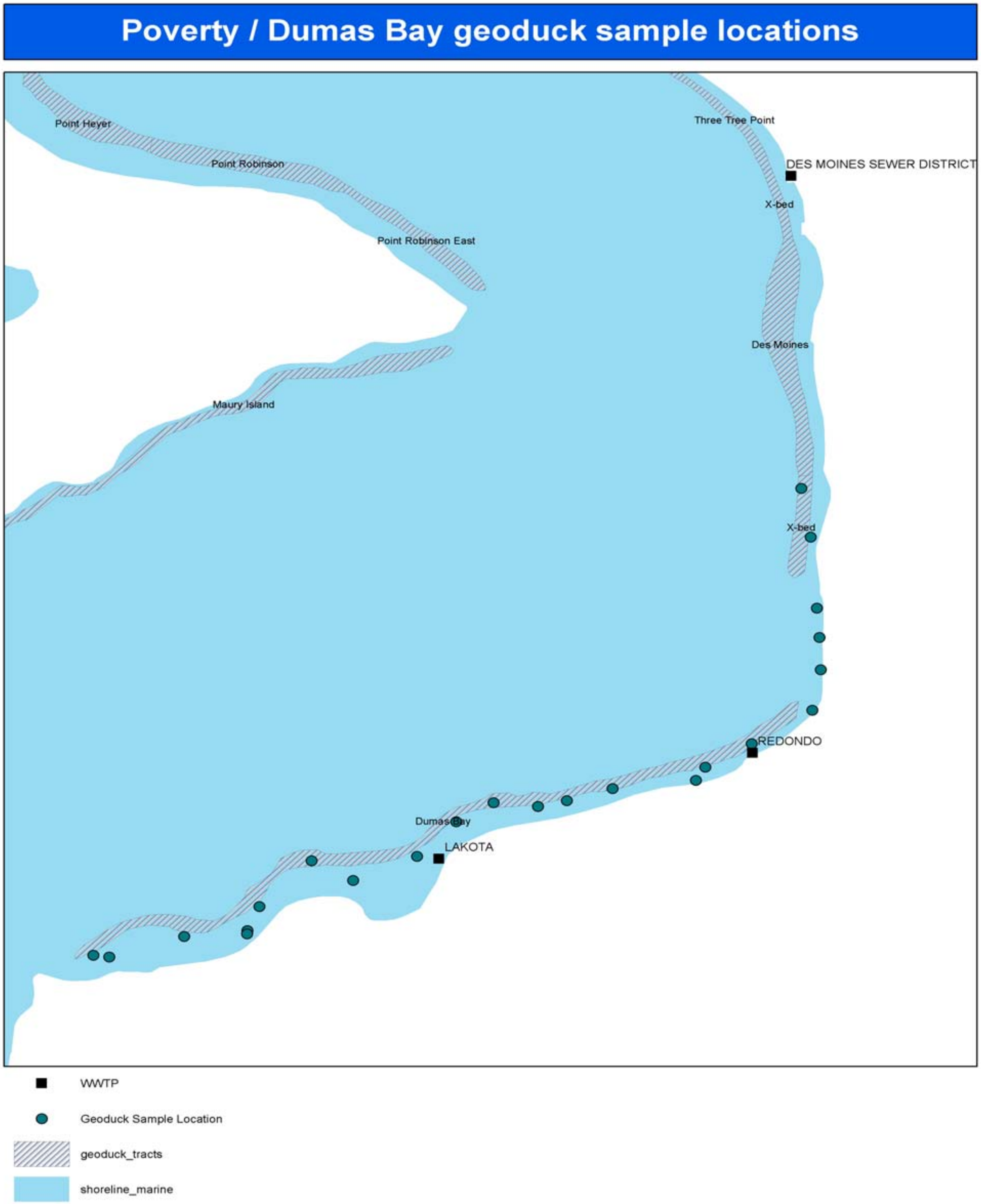

Figure 4. Five geoducks were collected at 24 locations (18 locations along tract 10400 and 6 locations along tract 09950) in Dumas Bay, Washington.

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Appendix A

Table A1. Sources of Puget Sound geoduck contaminant data.

Study Name	Entity	Location	Sample Size	Analytes
Brightwater Marine Outfall Geoduck Tissue Study	King County DNR	King County / Snohomish County	9 whole individuals 9 individuals "edible tissue"	Numerous analytes include inorganic (metals) and organic (PAHs, PCBs, pesticides) chemicals
Rayonier Mill Marine Remedial Investigation	Rayonier Inc.	Port Angeles Harbor Dungeness Bay Freshwater Bay	3 whole individuals from each location	Numerous analytes include inorganic (metals) and organic (PAHs, PCBs, pesticides) chemicals Dioxins/Furans
Rayonier Mill Exposure Investigation	Lower Elwha Klallam Tribe DOH	Strait of Juan de Fuca	5 whole composites	Dioxins/Furans
Point Wells Oil Spill		Indianola, Kitsap County	9	PAHs
Kingston Outfall Study	Kitsap County	Kingston, Kitsap County Skiff Point, Kitsap County Nisqually Reach, Thurston County Data results also reported from the Manchester Remedial Investigation.	4 whole body composites 2 siphon composites	Numerous includes inorganic (metals) and organic (PAHs, PCBs, pesticides) chemicals
Preliminary Data	Suquamish Tribe U.S. EPA Region 10	Near Eagle Harbor, Kitsap County	8 composite "edible tissue" 3 composite "gutballs"	Numerous includes inorganic (metals) and organic (PAHs, PCBs, pesticides) chemicals. Dioxins / Furans
Preliminary Data	Suquamish Tribe U.S. EPA Region 10	North King County shoreline	60 individual "edible" 60 individual "gutballs"	Metals including arsenic species in a subset of samples.

Appendix B

Contaminant Screening Process

The information in this section describes how the contaminants of concern in shellfish were chosen from a set of many contaminants. A contaminant's maximum shellfish concentration was compared to a screening value (comparison value), and if the contaminant's concentration was greater than that value, then it was considered further.

Comparison values were calculated using chronic EPA's reference doses (RfDs) and cancer slope factors (CSFs). RfDs represent an estimate of daily human exposure to a contaminant below which non-cancer adverse health effects are unlikely.

This screening method ensured consideration of contaminants that may be of concern for shellfish consumers. The equations below show how comparison values were calculated for both non-cancer and cancer endpoints associated with consumption of shellfish.

$$CV_{non\text{-}cancer} = \frac{RfD * BW}{SIR * CF}$$

$$CV_{cancer} = \frac{Risk\ Level * BW}{SIR * CF * CPF}$$

Where CV for non-cancer

RfD = oral reference dose (mg/kg-day).
BW = mean body weight of the general population or subpopulation of concern (kg).
SIR = mean daily consumption rate of the species of interest by the general population or subpopulation of concern averaged over a 70-yr lifetime (kg/d).
CF = conversion factor (kg/g)

Where CV for cancer

Risk Level = an assigned level of maximum acceptable individual lifetime risk (e.g., RL = 10^{-5} for a level of risk not to exceed one excess case of cancer per 100,000 individuals exposed over a 70-yr lifetime.
CPF = Cancer Potency Factor

Table B1. Parameters used to calculate comparison values used in the shellfish contaminant screening process. Dumas Bay site, Puget Sound King and Pierce Counties, Washington.

Abbreviation	Parameter	Units	Value	Comments
CV	Comparison Value	mg/kg	Calculated	
RfD	Reference Dose	mg/kg-day	Chemical Specific	EPA
			322	Suquamish 90th percentile all shellfish consumption rate (consumers only)
BW	Bodyweight	kg	70	Adult
CF	Conversion Factor	kg/g	0.001	kilograms per gram
AT	Averaging Time	Days	25550	Days in 70 year lifetime
EF	Exposure Frequency	Days	365	Days per year
ED	Exposure Duration	Years	70 (adult)	Years consuming geoduck
Risk Level	Lifetime cancer risk	Unitless	$1x10^{-5}$	
CPF	Cancer Potency Factor	kg-day/mg	Chemical Specific	EPA

Screening values for arsenic in shellfish

DOH used a high consumption scenario for shellfish harvesters for screening purposes. This scenario represents consumption of harvesters who eat extreme amounts and uses the Suquamish 90th percentile all shellfish consumption (consumers only) which is 322 g/day.

The levels of arsenic at Dumas Bay geoduck exceeded screening values (high-end rates) for subsistence consumers (Table 2). Appendix C, Tables C2 and C3 show non-cancer and cancer risk associated with exposure to inorganic arsenic at Dumas Bay site.

Developing comparison values for lead in shellfish

Since the biokinetics of lead are different from many chemicals, a different approach was used for deriving comparison values. The IEUBK model was used with the following assumptions to determine a level of lead in shellfish that would be protective of child who eats geoduck at a subsistence rate.

Table B2. Assumptions (other than default) used in the IEUBK to determine comparison value for lead in shellfish.

Parameter	Value	Units	Notes
Seafood Concentration	0.026 (the maximum value from edible portion)	ppm	Solve for value that results in > 5% of 12-24 month old children with blood lead levels greater than 10 ug/dl
Percentage meat intake that is fish [a]	50 and 12	percent	Solve for value that results in > 5% of 12-24 month old children with blood lead levels greater than 10 ug/dl
Lower end consumption rate	0.07 [b]	ppm	Solve for value that results in > 5% of 12-24 month old children with blood lead levels greater than 10 ug/dl
Higher end consumption rate	0.27 [c]	ppm	Solve for value that results in > 5% of 12-24 month old children with blood lead levels greater than 10 ug/dl

[a] assumes that a child's total meat intake is 93.5 g/day
[b] assumes that 50% of meat portion of diet is geoduck
[c] assumes that 12 % of meat portion of diet is geoduck

Appendix C

Exposure dose calculations and assumptions

Average and upper-bound general population exposure scenarios were evaluated for consumption of shellfish from Dumas Bay. Exposure assumptions given in Table C1 below were used with the following equations estimate contaminant doses associated with shellfish consumption.

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

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

Table C1. Exposure Assumptions

Parameter	Value	Unit	Comments
Concentration (C) – Average			Average value
Concentration (C) – High-end	Variable	ug/kg	Maximum 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	0.05	g/kg/day	~ 3 three-oz. meals per year
Ingestion Rate (IR) – 75th percentile Suquamish children - geoduck	0.23		~ 1 three-oz. meal per month
Ingestion Rate (IR) – 95th percentile Suquamish children (includes non-consumers) - geoduck	0.84		~ 1 three-oz. meal per week
Ingestion Rate (IR) – U.S. average adults - all shellfish	0.03		~ 3 eight-oz. meals per year
Ingestion Rate (IR) – median Tulalip adults - all shellfish	0.11		~ 1 eight-oz. meal per month
Ingestion Rate (IR) – 90th percentile adults Suquamish - geoduck	0.44		~ 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 (adult) 5 (child)	years	Number of years eating shellfish.
Averaging Time$_{\text{non-cancer}}$ (AT)	10950	days	30 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 Potency Factor (CPF)	Contaminant-specific	mg/kg-day^{-1}	Source: See above uncertainty regarding As

Table C2. Non-cancer hazards associated with exposure to contaminants of concern in geoduck sampled from tracts 09950 and 10400 - Dumas Bay site, Puget Sound King and Pierce Counties, Washington.

Chemical	Maximum Concentration	RfD (mg/kg/day)	Child Hazard Quotient			Adult Hazard Quotient		
			Median Suquamish (0.05 g/kg/day)	75th Suquamish (0.23 g/kg/day)	95th Suquamish (includes non-consumers) (0.84 g/kg/day)	Average U.S (0.03 g/kg/day)	Median Tulalip (All Shellfish) (0.11 g/kg/day)	90th Suquamish (0.44 g/kg/day)
Arsenic (inorganic) (ppm)	0.05	0.0003	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	0.30	0.001	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table C3. Cancer risk associated with exposure to contaminants of concern in geoduck from tracts near Dumas Bay site, Dumas Bay site, Puget Sound King and Pierce Counties, Washington.

Chemical	Maximum Concentration	CSF (mg/kg/day)	Child Cancer Risk [a]			Adult Cancer Risk [a]		
			Median Suquamish (0.05 g/kg/day)	75th Suquamish (0.23 g/kg/day)	95th Suquamish (includes non-consumers) (0.84 g/kg/day)	Average U.S (0.03 g/kg/day)	Median Tulalip (All Shellfish) (0.11 g/kg/day)	90th Suquamish (0.44 g/kg/day)
Arsenic (inorganic) (ppm)	0.05	5.7	1.02E-07	4.68E-07	1.71E-06	8.55E-07	3.14E-06	1.25E-5

[a] Cancer risk presented do not represent cumulative lifetime exposure from childhood to adulthood due to lack of consumption data from 7 to 15-year-old children.

Certification

This Evaluation of Selected Metals in Geoduck Tissue from Tracts 09950 and 10400 Dumas Bay, Puget Sound King and Pierce Counties, Washington Public Health consultation 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 was completed in accordance with approved methodologies and procedures existing at the time the health consultation were initiated. Editorial review was completed by the Cooperative Agreement partner.

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The Division of Health Assessment and Consultation (DHAC), ATSDR, has reviewed this health consultation and concurs with its findings.

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