Public Health Assessment

Initial/Public Comment Release

Evaluation of Chemical Exposures from Shellfish and Sediments
Port Gamble Bay, Kitsap County, Washington

Prepared by
The Washington State Department of Health

FEBRUARY 5, 2014

COMMENT PERIOD ENDS: MARCH 7, 2014

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

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment-Public Comment Release was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR's Cooperative Agreement Partner has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate. This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. In addition, ATSDR's Cooperative Agreement Partner will utilize this document to determine if follow-up health actions are appropriate at this time.

This document has now been released for a 30-day public comment period. Subsequent to the public comment period, ATSDR's Cooperative Agreement Partner will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This will conclude the public health assessment process for this site, unless additional information is obtained by ATSDR's Cooperative Agreement Partner which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

Use of trade names is for identification only and does not constitute endorsement by the U.S. Department of Health and Human Services.

Please address comments regarding this report to:

Agency for Toxic Substances and Disease Registry
Attn: Records Center
1600 Clifton Road, N.E., MS F-09
Atlanta, Georgia 30333

You May Contact ATSDR Toll Free at
1-800-CDC-INFO or
Visit our Home Page at: http://www.atsdr.cdc.gov

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Public Comment

This report is being released for public comment. The information is distributed solely for the purpose of pre-dissemination public comment process. This is according to applicable information quality guidelines. It has not been formally disseminated by the Agency of Toxic Substances and Disease Registry (ATSDR) or the Department of Health (DOH). It should not be construed to represent any agency determination or policy.

This is an opportunity for anyone to review and comment on this document. Comments submitted by the date indicated on the front cover will be addressed in the final version. To submit public comments, address them to DOH via e-mail (Lenford.O'Garro@doh.wa.gov) or via postal mail addressed to:

Site Assessments and Toxicology
Washington State Department of Health
P.O. Box 47846
Olympia, WA 98504-7846

Foreword

The Washington State Department of Health (DOH) has prepared this public health assessment 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 public health assessment is to assess the health threat posed by hazardous substances in the environment. If needed, DOH will recommend steps or actions to protect public health. Public health assessments are initiated in response to health concerns raised by residents, tribes, or agencies about exposure to hazardous substances.

This public health assessment was prepared in accordance with ATSDR methodologies and guidelines. ATSDR has reviewed this document and concurs with its findings based on the information presented. The findings in this report are relevant to conditions at the site during the time of this report. These should not be relied upon if site conditions or land use changes in the future. The glossary in Appendix A defines technical terms.

Use of trade names is for identification only and does not imply endorsement by DOH, the Centers for Disease Control and Prevention (CDC), ATSDR, the Public Health Service, or the U.S. Department of Health and Human Services.

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

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

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

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Summary

Introduction

The Washington State Department of Health (DOH) conducted this public health assessment in response to a petition by the Port Gamble S'Klallam Tribe. Past releases of metals, polycyclic aromatic hydrocarbons (PAHs), and dioxin/furan compounds resulted in contamination of bay sediments. Some contamination occurred as a result of the former Pope and Talbot mill activities. The saw mill operated at the mouth of the bay from 1853 to 1995. For the purposes of this assessment, the term "site" refers to the upper portion of Port Gamble Bay. This includes the former mill area, the western shore including the former landfills and log rafting areas, and the reservation on eastern shore including Point Julia.

Overview

The tribe is concerned about exposures to chemicals from eating shellfish and touching shoreline sediments of the bay. The term chemical used throughout this document includes metals. Sediment and tissue samples were only available from the upper portion of the bay. Tribal subsistence consumers of shellfish rely on non-commercially caught shellfish as a major source of protein. This assessment used local consumption rate data including

- High tribe-estimated subsistence consumption rate (499 g/day for adults, 95^{th} percentile of Suquamish survey, Puget Sound only).
- Low tribe-estimated subsistence consumption rate (252 g/day for adults, upper confidence limit of the average of Suquamish survey).
- General population consumption rates (60 g/day, high-end King County recreational harvesters).

This assessment focused on health risks from chemical contaminants in shellfish. Tribe members should balance these risks with the positive health benefits provided from harvesting and eating shellfish. Compared to other common sources of protein, shellfish have approximately a third of the calories and a tenth of the fats. Harvesting shellfish also provides physical activity contributing to good health.

DOH reached six conclusions in this public health assessment:

Conclusion 1. Eating shellfish meat at the ***high tribe-estimated subsistence consumption rate*** every day for a lifetime could be harmful to the health of an adult or child tribe member.

Basis for Decision. Tribe members were assumed to harvest 100% of their shellfish from the upper portion of Port Gamble Bay. At the high-tribe estimated subsistence consumption rate tribal members eat 1.1 pounds of shellfish meat per day. Eating shellfish every day at this rate would results in a moderate increase in cancer risk. This risk is estimated to be an increase of two additional cases of cancer in 1,000 people exposed at this rate. This cancer risk exceeds the Environmental Protection Agency (EPA) target risk range.[1] Inorganic arsenic is the largest

[1] The EPA target risk range is one additional case of cancer per 10,000 people exposed to one additional case per 1,000,000 people exposed. http://www.epa.gov/oswer/riskassessment/pdf/baseline.pdf

contributor to this risk. Arsenic occurs naturally in the sediments. Arsenic levels in tissues have likely been the same in shellfish since before the mill existed. At the high tribe-estimate subsistence consumption rate, ingestion of cadmium may lead to health effects of the kidney. Ingestion of dioxin and dioxin-like compounds may lead to an increased risk of reproductive and developmental effects.

Next Steps.

DOH recommends that:

Consumers, who eat more than 1–2 meals of shellfish per week, can reduce exposure by:

- Collecting and eating shellfish from a variety of locations away from the former mill area.
- Eating a variety of shellfish.
- Eating an average serving size (meal size - 8 oz. of uncooked meat per meal); young children should eat proportionally smaller meal sizes.
- Eating larger clams without the skin and gut ball.
- Soaking shellfish in saltwater about 20–60 minutes to expel sand stored inside their shells and digestive system.

Washington State Department of Ecology (Ecology):

- Ecology proceeds cleaning up sediments at the former mill area. This will contribute to a long-term reduction in exposures to tribal members.
- Ecology coordinates with Washington Department of Natural Resources (DNR), Washington Department of Fish and Wildlife (DFW), DOH, and the tribe to determine which parcels should be closed prior to remediation.
- Ecology post signs discouraging subsistence shellfish harvest on parcels affected by remedial action. DOH evaluates chemical concentrations in shellfish after remediation. This will determine if signs restricting harvest are removed.

DOH:

- DOH reviews additional tissue sampling and analysis plans and chemical data as they become available. DOH will adjust recommendations as appropriate.
- DOH coordinates with Ecology, tribes, and local health to provide tribal members with educational materials and a fact sheet.

Conclusion 2. Eating shellfish at the ***low tribe-estimated subsistence consumption rate*** every day for a lifetime could be harmful to the health of adult or child tribe members.

Basis for Decision. Tribe members were assumed to harvest 100% of their shellfish from the upper portion of Port Gamble Bay. At the low tribe-estimated subsistence consumption rate, tribe members eat about a half pound of shellfish meat every day. Ingestion of arsenic in shellfish at this rate slightly increases cancer risk by an estimated three additional cases of cancer in 10,000 people exposed. Arsenic occurs naturally in the sediments. Arsenic has likely contributed to tissue concentrations in shellfish since before the mill existed. One hundred Port Gamble S'Klallam Tribe members participated in an exposure investigation in 2001 that measured arsenic metabolites in urine. Results indicated that urinary levels were within normal ranges present in the U.S. population.

Next Steps. DOH recommends that

- Frequent consumers, who eat more than 1–2 meals of shellfish per week, can reduce exposure by following the list in Conclusion 1 above.
- Ecology post signs discouraging subsistence shellfish harvest on parcels affected by remedial action. DOH will evaluate chemical concentrations in shellfish after remediation. This will determine if signs restricting harvest can be removed.

Conclusion 3. Eating residentially, recreationally, or commercially harvested shellfish at a ***consumption rate of 1-2 meals per week or less*** is not expected to harm the health of an adult or child.

Basis for Decision. Local residents and recreational harvesters eat shellfish at a lower consumption rate. Consumers eating commercially harvested shellfish are not expected to eat shellfish exclusively from Port Gamble Bay. Estimated exposures from eating 1–2 meals per week should not result in health effects. Cancer risk from these exposures is at a level below the EPA 1 in 10,000 risk criteria.

Next Steps. DOH recommends that

- The former mill area and western shoreline be opened by DOH for commercial shellfish harvesting.
- DOH close approved commercial harvest sites on a parcel-by-parcel basis prior to remediation. DOH will evaluate confirmation data which will determine if a parcel may be reopened for commercial shellfish harvest.
- Ecology post signs discouraging tribal, residential, and recreational shellfish harvest on parcels affected by remedial action. DOH will evaluate chemical concentrations in shellfish after remediation. This will determine if signs restricting harvest are removed.

Conclusion 4. Touching and/or accidentally eating intertidal sediment during recreational or harvesting activities are not expected to harm the health of an adult or child of the Port Gamble S'Klallam Tribe or the general population.

Basis for Decision. Tribal children playing at Point Julia and tribal members harvesting shellfish may come in contact with contaminants in sediments. The amount of chemicals that could get into the body by these pathways is below a level that could harm health.

Next Steps. No further action is necessary.

Conclusion 5. DOH cannot conclude if there is a health threat to tribal members from eating geoduck or crab harvested from Port Gamble Bay.

Basis for Decision. Geoduck data were limited by poor sample location, low sample numbers, and high analytical detection levels in some samples. Likewise, there were low sample numbers and lower quality data for crab. These data do not allow for a confident estimation of exposure from eating geoduck or crab from the bay.

Next Steps. DOH recommends that

- More geoduck samples be collected from each of the existing harvest tracts, especially from the contaminated areas. Samples should be analyzed for metals, dioxin and dioxin-like compounds (congeners), and PAHs.
- More crab samples be collected and analyzed for metals, dioxin-like compounds, and PAHs.

Conclusion 6 – DOH cannot conclude if there is a health threat to tribal members from eating resident finfish in the bay.

Basis for Decision. Fish tissue data were not available at the time of this assessment. The tribe estimates that shellfish consumption represents only 65% of the subsistence diet. Exposure from eating fish, which represents 35% of the subsistence diet, has not been evaluated. The primary data gap is there hasn't been any sampling of fish regularly consumed by tribal members from Port Gamble Bay.

Next Steps. DOH recommends that edible tissues of fish samples of non-migratory species be analyzed for metals, dioxin-like compounds, and PAHs.

For More Information

If you have any questions about this public health assessment contact the Washington State Department of Health at 1-877-485-7316. A copy of this public health assessment will be provided to the public library in Poulsbo, Washington. You can also find it on the DOH site assessment website: www.doh.wa.gov/consults.

For more information regarding current fish advisories, visit the DOH webpage[2] or by call toll-free 877-485-7316.

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

[2] http://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories.aspx

Purpose and Statement of Issues

DOH conducted this public health assessment in response to a petition the Port Gamble S'Klallam Tribe submitted to ATSDR. The Port Gamble S'Klallam Tribe contacted ATSDR Region 10 Office in Seattle with health concerns regarding exposures to chemicals from eating shellfish and touching shoreline sediments of Port Gamble Bay. For the purposes of this document, the site refers to the upland area of the former mill as well as the affected sediments of the upper half of the bay. Port Gamble Bay is one of seven original sites identified for focused sediment investigation, cleanup, and source control under the Washington State Puget Sound Initiative. At the request of the Department of Ecology (Ecology), DOH has assessed health hazards and completed health consultations at all of these sites, including Port Gamble Bay. This report addresses health concerns brought forward by the Port Gamble S'Klallam Tribe, which also encompasses the work requested by Ecology. DOH prepares public health assessments and health consultations under a cooperative agreement with ATSDR. This document has been reviewed and certified by ATSDR.

This report specifically addresses current and future exposures: 1) from eating intertidal and subtidal shellfish; and 2) touching or incidentally ingesting intertidal sediment (not subtidal sediment). It does not address exposures that may occur or have occurred on the upland areas of the former mill or the upland areas of the associated landfills on the nearby shoreline.

Background

Site Description

Port Gamble Bay is located just south of the Strait Juan de Fuca at the north end of the Kitsap Peninsula (Figure 1) and covers more than two square miles of intertidal and subtidal habitat.[3] The bay is bounded by Admiralty Bay and Hood Canal to the north and by the Kitsap Peninsula to the east, south, and west. Port Gamble Bay is generally shallow with depths up to 60 feet.

Native Americans around Puget Sound inhabited this area long before the arrival of Euro-Americans. The S'Klallam, Chimakum, Skokomish (formerly the Twana), Suquamish, and other tribes on Puget Sound have traditionally used the bay for commercial, ceremonial, and subsistence harvesting as part of their "usual and accustomed" fishing and shellfish grounds. The Port Gamble S'Klallam Tribe lived in a village on the west side of Port Gamble Bay at Teekalet Point until 1853, when the Puget Sound Mill Company, later known as the Pope and Talbot Saw Mill, was established. At that time the Port Gamble S'Klallam Tribe was relocated to Point Julia on the eastern shore of the bay. As part of an informal agreement among the tribes, the bay itself is primarily used by the Port Gamble S'Klallam Tribe who live on the reservation on the eastern shore. The Pope and Talbot sawmill operated until 1995 and was dismantled in 1997. In 2007, Pope and Talbot declared bankruptcy and assets were transferred to Pope Resources and the Olympic Property Group.

[3] The intertidal zone is generally the area above water at low tide and underwater at high tide. The subtidal zone starts immediately below the intertidal zone and is mostly covered with seawater.

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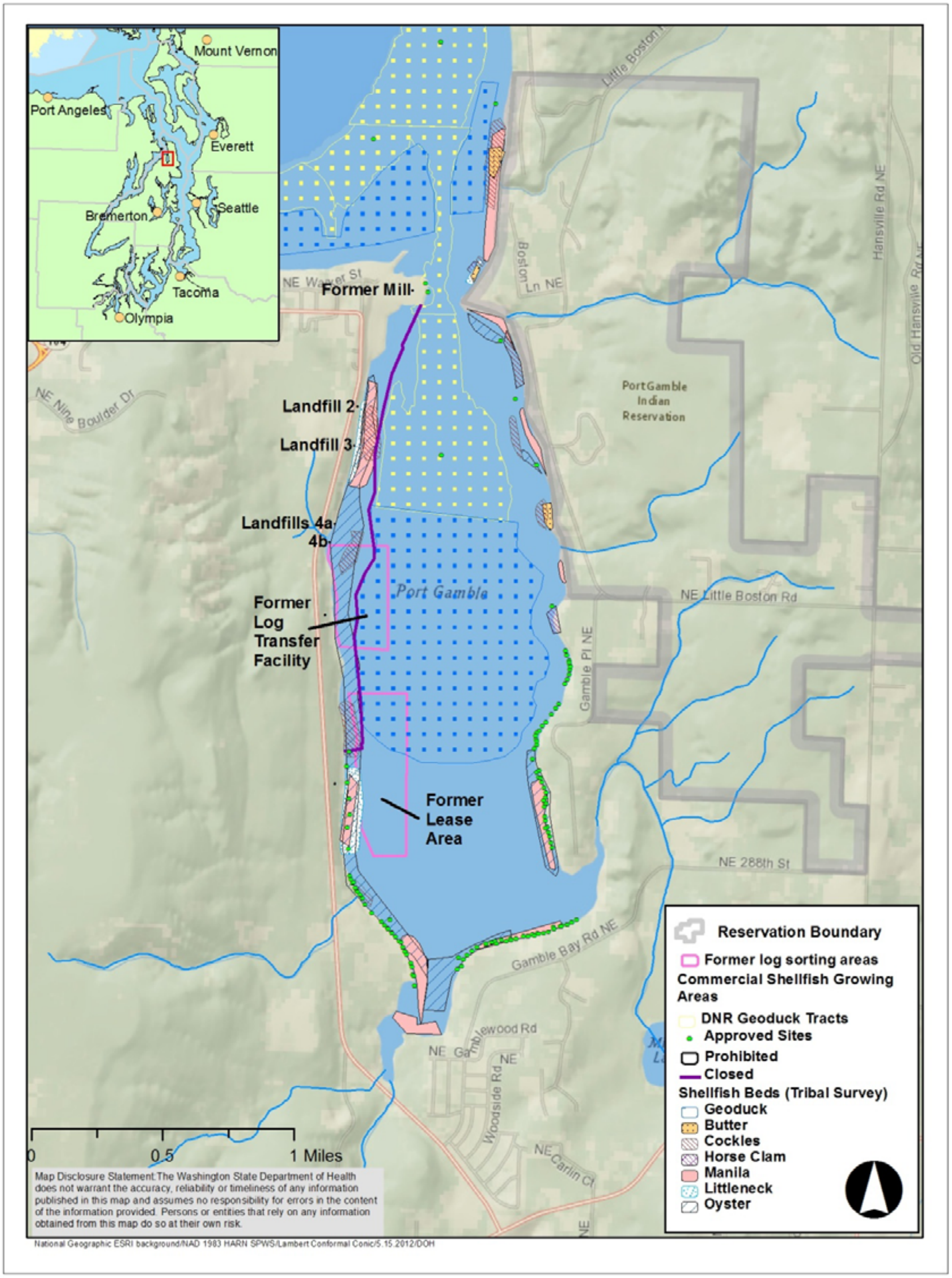
Past releases of metals, polycyclic aromatic hydrocarbons (PAHs), and dioxin-like compounds occurred during activities conducted by Pope and Talbot from 1853 to 1995. Activities included milling, chipping, log rafting, log sorting, log transfer, debris and industrial waste dumping, and other activities associated with mill operations.

Historically, the tribe coexisted with the Pope and Talbot mill since it began and provided part of the work force at the mill. Overall, tribal members are generally aware of contamination issues in the bay; however, individual members may not realize the potential hazards and depth of the issue.

Figure 1. Former mill, landfill, and log rafting areas with commercial and tribal shellfish beds, Port Gamble Bay, Kitsap County



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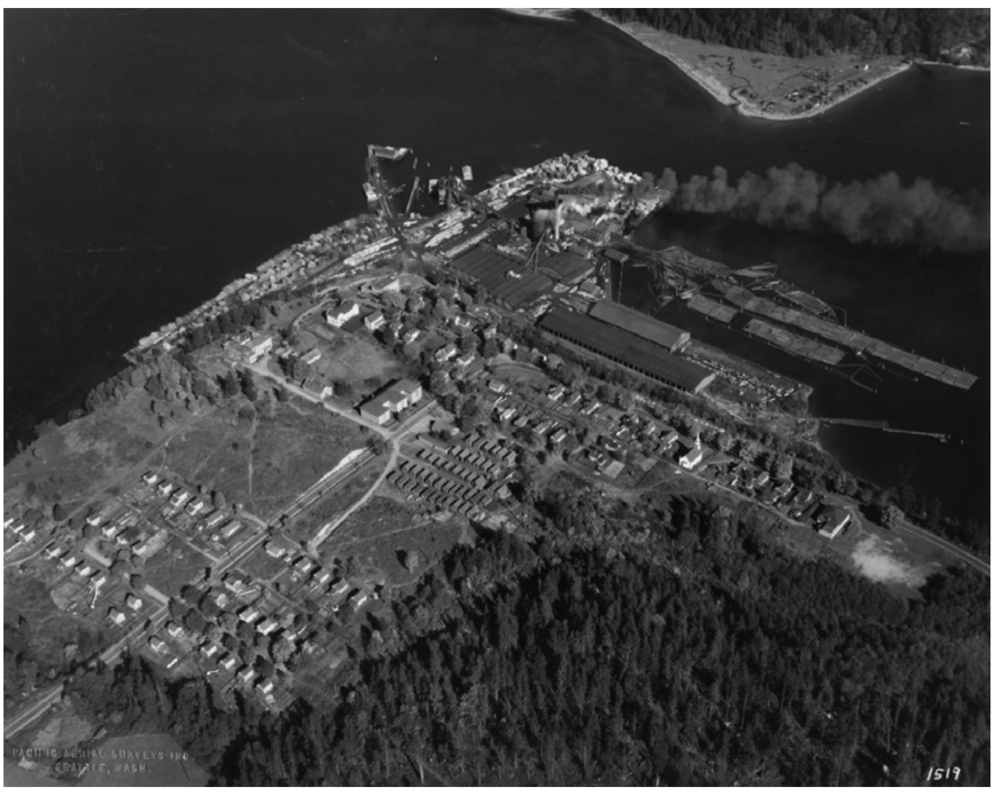
Site History and Previous Remedial Activities

Pope and Talbot operated the mill from 1853 to 1995. Two chip mills operated at the mill on the northern and southern edge of the point from 1928 to 1995 and 1974 to 1995, respectively. Log rafting activities were documented in the 1920s and may even have occurred earlier (1). The former log transfer facility (FLTF) sort yard operated from 1970 to 1995 and consisted of a ramp, pilings, and access road (2). In addition to using the FLTF, Pope and Talbot leased an additional 72 acres of the bay from Washington Department of Natural Resources (DNR) from 1970 to 2001 for additional log transfer and sorting. The FLTF and former leased area (FLA) are located off the western shore of the bay (Figure 1). From the 1940s to the 1980s, Pope and Talbot used three landfills on the western shore (Landfills 2, 3, and 4) for municipal, industrial building, and mill waste (Figure 1). Landfill 1, lies up gradient over half a mile away from Port Gamble Bay and that watershed does not drains into Port Gamble Bay. Numerous creosote-treated pilings were used throughout the bay to support these activities. Historical photos show activities leading to fate and transport of chemicals into the bay and surrounding land (Figure 2).

Figure 2. Historical aerial view of Port Gamble in approximately 1950; photo taken for the Washington State Advertising Commission (obtained from the Washington State Archives).



Characterization and remediation activities associated with intertidal sediments are summarized below and described in more detail in Appendix B. In brief, soil, groundwater, and sediment investigations have occurred near the site as follows:

- In the past, dredging of the narrow channel into the bay has occurred to allow boats easy access the bay (3;4).
- From 2002 to 2005 Pope and Talbot Inc., removed approximately 26,000 tons of upland soil from the former mill (3).
- In 2003 and 2007 Pope and Talbot Inc., collectively dredged about 21,000 cubic yards of sediment and wood waste near the southern chip loading facility (3;4).
- In December 2003, Ecology determined that the release of metals from the intertidal sediments below historical Landfills 2 and 3 did not pose a threat to human health. As a result, no sediment remedial activity took place (5). Debris was still visible in the intertidal zone at these landfills, especially Landfills 2 and 3, during site visits in 2011. Debris consisted of brick, firebrick, asphalt, concrete, and metal pieces.
- In September and October 2004, Pope and Talbot, Inc., removed approximately 1,300 cubic yards of intertidal sediment, brick, metal, and glass debris from approximately 15,500 square feet of intertidal area below historical Landfill 4 (6;7).
- In 1996, Pope and Talbot removed pilings from the FLA and part of the FLTF after milling and log rafting ceased in 1995. Pilings have creosote-related contamination issues, mostly PAHs (4).
- Log rafting occurred south of the mill from the early days of mill operations according to aerial photos. Former log rafting, transfer, and sorting resulted in substantial amounts of wood debris and waste on and in sediments. No remediation has been performed to date.

Natural Resources

Port Gamble Bay has steep banks, emergent marshes, eelgrass beds in the intertidal (*Zostera japonica)* and intertidal/subtidal (*Zostera marina*) zones, and hardened reef structures. There are a number of marine species that occur throughout the area, including commercially important finfish and shellfish species. The term "shellfish" is used in a general sense throughout this document and is meant to include both molluscan bivalves and crustaceans.

Several tributaries enter into Port Gamble Bay, some of which support migratory fish populations. Starting at the eastern shore of the bay, these include Little Boston Creek just below Point Julia on the Port Gamble S'Klallam reservation; Middle Creek; Martha John Creek at Cedar Cove; Gamble Creek (the largest freshwater system entering at the bottom of the bay); several unnamed minor tributaries entering on the western shore; and Ladine DeCouteau Creek located less than a mile south of Teekalet Point adjacent to Landfill 4 (8) (Figure 1).

Between 1996 and 1998, the Kitsap Public Health District facilitated a sanitary survey project within Port Gamble Bay to improve livestock and septic management and reduce bacterial contamination of surface waters (8). This effort resulted in reopening Cedar Cove for shellfish harvesting in 1999. By permit, the Port Gamble Waste Water Treatment Plant emits secondary treated effluent into Hood Canal, north of Teekalet Point. DOH prohibits commercial and recreational harvest of shellfish in the area around the outfall (Figure 1). Future plans include plant decommissioning and removal of the effluent pipe. Thus, the prohibited status of the geoduck tract and intertidal area north of Teekalet Point may be lifted in the future. Effluent from the wastewater treatment plant on the Port Gamble S'Klallam tribal land is released upland on the reservation.

Fish

This public health assessment does not address potential chemical exposures through fish consumption because chemical concentrations in fish and the water column of Port Gamble Bay were not available. However, according to the EPA Region 10 framework document for selecting and using tribal consumption rates for seafood in Puget Sound (9), fish make up 35% of the subsistence diet, Therefore, fish should be recognized as a potential source of chemical exposure that may or may not be associated with mill activities.

According to Port Gamble S'Klallam tribe's fishery biologist, tribal members harvest and consume salmonids present in Port Gamble Bay including chum salmon (*Oncorhynchus keta*), coho salmon (*Oncorhynchus kisutch*), Chinook and blackmouth (immature Chinook) salmon (*Oncorhynchus tshawytscha*), pink salmon (*Oncorhynchus gorbuscha*), coastal cutthroat trout (*Oncorhynchus clarki clarki*) and steelhead (*Oncorhynchus mykiss*). Washington State Department of Fish and Wildlife (WDFW) confirmed migrations of these species into one or more tributaries on Port Gamble Bay.[4] Chemical concentrations in these migratory fish could reflect region- and site-related contamination. Immature Chinook, known as "blackmouth" salmon, are resident to Puget Sound and can stay in Port Gamble Bay for some amount of time. If enough food is available, coastal cutthroat and steelhead can live their entire lives in the bay and its tributary streams.

The tribe operates a hatchery for fall chum salmon located at the mouth of Little Boston Creek. Chum fry are released into Port Gamble Bay in April and May and reside in the bay for several months before migrating to the open ocean. In cooperation with WDFW, the tribe also operates coho salmon net pens about a half mile south into the bay as part of long-term fishery augmentation of Puget Sound coho salmon. These salmon are raised for several months in the bay then released in late May.

Forage fish such as herring (*Clupea pallasii*), surf smelt (*Hypomesus pretiosus*), and sand lance (*Ammodytes hexapterus*) spawn in parts of Port Gamble Bay. The bay hosts the second largest herring spawning area in the state. Herring and herring roe have traditionally been harvested for consumption by tribes; therefore, the potential exists to harvest this species in the future. Surf smelt are currently harvested by the tribe for consumption. The tribe's fisheries biologist reported that members eat other finfish harvested from Port Gamble Bay including Pacific cod (*Gadus macrocephalus*), and pollock (walleye pollock, *Theragra chalcogramma*) that reside in the bay.

DOH Advisory—DOH has set several fish consumption advisories in Puget Sound and in particular for the Port Gamble area (Marine Area 9 including Admiralty Inlet and north end of Hood Canal). Advisories are based on an adult meal size of eight ounces (227 grams) of uncooked fish.

- Chinook salmon – no more than one meal per week (all of Puget Sound)
- Blackmouth salmon (immature resident Chinook salmon) – no more than one meal per month (all of Puget Sound)

[4] http://wdfw.wa.gov/mapping/salmonscape/

- Puget Sound rockfish – no more than one meal per week; do not eat yelloweye and canary rockfish (due to they are protected species)

No meal limits have been set for bottom flatfish (sole, sand dab, and flounder) or other species of salmon (coho, chum, pink, or sockeye) in the Port Gamble Area.

Oysters and Clams

Shellfish bivalve species known to Port Gamble Bay include geoduck (*Panope generosa*), Pacific oyster (*Crassostrea gigas*), butter clam (*Saxidomus gigantea*), native littleneck clam (*Leukoma staminea*), manila littleneck clam (*Venerupis philippinarium*), horse clam (*Tresus capax*, and *T. nuttallii*), cockle (*Clinocardium nuttallii*), eastern soft shell clam (*Mya arenaria*), and the invasive purple varnish clam (*Nuttalia obscurata*).

Subsistence, residential, and recreational harvesting of intertidal shellfish occurs at low tide on the shores of Port Gamble Bay. In Puget Sound, the tide rises and falls twice a day, with one tide being lower than the other. Lower tides usually occur once a day during daylight hours, twice on rare occasions during the summer. Tribal data indicates that geoduck, oysters, cockles, littleneck, manila, horse, and butter clams are harvested from the intertidal portions of the bay. See Figure 1 for tribal harvesting areas.

Licensed commercial shellfish companies harvest intertidal clams and oysters on the southern shores of the bay and wild geoduck from subtidal tracts at the top of the bay. [5] DFW and DNR co-manage the commercial geoduck tracts with the tribes. Tract 20100 is active and located within the northern half of the bay. Tract 20000 is active and located just north of the mouth of the bay and along the eastern shore of Hood Canal along the reservation. Tract 20050, north of Teekalet Point in Hood Canal, is prohibited because of the proximity to the Port Gamble Waste Water Treatment Plant outfall. Tribal survey data indicate that the range of geoduck extends into the bay and into intertidal areas beyond tract areas indicated by DNR (Figure 1).

DOH and Kitsap Public Health District routinely test for bacteria and biotoxins in shellfish and water in both recreational and commercial harvest areas of Puget Sound, including Port Gamble Bay. In the past, DOH has temporarily issued advisories in Port Gamble Bay as a result of biotoxin levels.[6] When concentrations drop to safe levels, DOH reopens the area to harvest. In the mid 1990s, DOH prohibited harvest of shellfish from Cedar Cove as a result of consistent high coliform levels. In 1999, DOH approved harvest from this area after mitigation of poor septic systems and water waste sources.

DOH Shellfish Shoreline Closure—In 2002, the Port Gamble S'Klallam Tribe requested that the western shoreline be certified for commercial harvest. Since no tissue data were available at that time, DOH closed a portion of the western shoreline as a result of chemical contamination observed in sediments sampled in 2000 near the landfills and former mill. DOH recommended

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[5] http://wdfw.wa.gov/fishing/commercial/geoduck/

[6] http://www.doh.wa.gov/CommunityandEnvironment/Shellfish/BeachClosures.aspx; For more information regarding these hazards and current advisories, visit the DOH webpage or call the toll free 24-hour Shellfish Safety Hotline 800-562-5632.

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tissue sampling and analysis for confirmation before opening the shoreline. On behalf of Pope and Talbot, Inc., Parametrix took two clam samples and one oyster sample in 2003 near the former mill. In 2006, DOH recommended a minimum of five composite tissue samples be collected for oyster, littleneck clams, manila clams, and cockles at each source of contamination (former mill, Landfill 2, Landfill 3, and Landfill 4) to determine if the shoreline could be reopened for commercial harvest (10). The closure runs along the western shoreline from south of the former mill to the northern border of the former leased area and includes shellfish from intertidal sediments to a depth of minus 18 feet (Figure 1). As described in the Exposure Evaluation section of this document, data from samples collected by the tribe from 2008 to 2011 and by Ecology in 2011 will be used to assess contamination and determine need for ongoing closure of the western shoreline.

Crab and Shrimp

Dungeness crab (*Cancer magister*) and red rock crab (*Cancer productus*) live on subtidal sediments of Puget Sound and Port Gamble Bay. State recreational crab fishing within Marine Area 9 (Admiralty Inlet and north end of Hood Canal including Port Gamble Bay) has a limited season from July 1 through Labor Day. State commercial harvest of crabs in Hood Canal and Port Gamble Bay is prohibited by DFW. Tribal commercial, recreational, ceremonial, and subsistence crabbing activities occur within Port Gamble Bay.

Spot prawn (*Pandalus playceros*), coonstripe shrimp (*P. danae and P. hypsinotus*) and pink shrimp (*P. eous and P. jordani*) are known to be present in Puget Sound and Hood Canal and may be present in Port Gamble Bay. State recreational shrimp season occurs on specific days, usually in May as quotas last. In addition, coonstripe and pink shrimp (not Spot prawn) may be harvested June through mid-October. State recreational and tribal shrimp activities within Port Gamble Bay were not identified at the time of this evaluation.

DOH Crab Advisory—In October 2006, DOH issued a Puget Sound recreational crab consumption advisory that it currently maintains. The advisory recommends not eating crab "butter" or viscera. Viscera are the internal organs under the shell. Advisories are based on an adult meal size equaling 8 ounces (227 grams) of uncooked crab.

Demographics

The land around Port Gamble Bay is used predominately for rural residential, forest, and agricultural purposes. The small unincorporated community of Port Gamble is located adjacent to the former mill. In 2009, the zip code area of Port Gamble included 153 residents.[7] Private forest land, owned by Olympic Property Group, lines the western shore of the bay south of Port Gamble. Rural residences surround the southeastern and southern half of the bay. Gamblewood is a small community located around at the southern tip of the bay, near the delta of Gamble Creek.

Puget Sound tribes inhabited this area long before the arrival of Euro-Americans. Several Native American tribes on Puget Sound have traditionally used the bay for commercial, ceremonial, and

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[7] http://www.city-data.com/

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subsistence harvesting as part of their "usual and accustomed" fishing and shellfish grounds. As part of an informal agreement among the tribes, the bay itself is now used primarily by the Port Gamble S'Klallam Tribe who live on the eastern shore. However, the tribes represented at the Point No Point treaty of 1855, the S'Klallam, Chimakum, and the Skokomish, include the bay as part of their "usual and accustomed" harvest grounds. The Suquamish also consider Port Gamble part of their "usual and accustomed" harvest grounds, as stipulated in the Treaty of Point Elliott[8].

The Port Gamble S'Klallam Tribal Reservation lies along the northeastern shore of the bay (Figure 1). The reservation consists of 1,340 acres of land and shoreline held in trust by the U.S. Government plus three pieces of land adjacent to the reservation. Historically, the spit at Point Julia, opposite of Teekalet Point, housed the tribe in a settlement called Little Boston. In 1939, Little Boston burned down and the tribal village relocated to the bluff above. The Bureau of Indian Affairs and Kitsap County Board of Health agreed that destroying what remained of Little Boston was the best option at the time as a result of its location in a flood plain and for health reasons.

According to the U.S. Census Bureau[9] in 2000, the S'Klallam Reservation census counted 699 persons living on the reservation. In 2009, the tribe[10] reported approximately 1,156 enrolled members with over 788 people living on the reservation and adjacent lands.

Community Health Concerns

The goal of this section is to document and respond to specific community health concerns. In November 2011, DOH met with tribal council members, Port Gamble S'Klallam Tribe, and the Suquamish Tribe.

The following is a list of specific tribal concerns shared in our meetings and phone conversations. Responses to these questions can be found in Appendix C.

1. How does the risk from eating clams and oysters from the reservation shoreline differ from eating shellfish from the mill or western shore shoreline?
2. How does the risk from eating shellfish from Port Gamble Bay differ from eating shellfish from the Puget Sound Region? How do risks differ from eating shellfish in the pre-mill era?
3. Which shellfish are least contaminated? Which are the safest to eat?
4. Should we be concerned if people give shellfish to the tribal food bank? Or is there a concern about sharing harvests among tribal members?
5. Is there a higher health concern for elders who have harvested from the bay their whole lives?
6. Poverty rate is significant on the reservation. Some tribal members depend on fish and shellfish as their main source of food. How will these people be affected by eating shellfish from Port Gamble Bay?

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[8] http://www.goia.wa.gov/treaties/treaties/pointelliot.htm

[9] http://www.census.gov/

[10] http://www.pgst.nsn.us/

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7. What is the comparative risk of eating clams from Point Julia versus fast food hamburgers or store bought foods?
8. Growing up, we were taught that shellfish are a healthy food. If shellfish have been affected by contamination, what does this mean?
9. What does the contamination mean for people who make a living from harvesting shellfish from the bay?
10. What is the additive risk of multiple chemicals that people may be exposed to?
11. What is the risk to children playing on the intertidal sediments of Point Julia during the summertime?

One ongoing concern to the Port Gamble S'Klallam Tribe is exposure to arsenic from consumption of seafood.

Discussion

Environmental Data

To address health concerns regarding exposures to chemicals from eating shellfish and touching intertidal sediments from Port Gamble Bay, this consultation considered exposures from shellfish tissue and intertidal sediment data collected from Port Gamble Bay. Points of exposure were determined using analytical data from sediment and shellfish tissue samples (summarized in Appendices E and F). These data sets and their limitations are briefly described here.

Intertidal Sediments–Several sampling events yielded intertidal sediment samples from Port Gamble Bay's shoreline (1;5;6;12-16). These samples were taken from the intertidal zone of the shoreline at various locations throughout the bay (Figure 3). Appendix D, Table D1 summarizes maximum concentrations of contaminants measured in sediment samples from different locations throughout Port Gamble Bay. Per ATSDR methodology, non-detected chemicals were assumed to be present at the detection limit. Appendix E summarizes sediment sampling results, sample locations, and chemical analysis performed (Table E1).

Shellfish Tissue–Several sampling events yielded74 samples from oyster, intertidal clam, geoduck, and crab present in the northern portion of Port Gamble Bay. Sample locations are shown in Figure 4. Appendix D, Table D3 summarizes the maximum concentrations of chemicals found in species throughout the bay. Intertidal clams sampled in Port Gamble Bay were comprised mostly of littleneck clams; however, samples of manila, cockle, butter, and horse clams have also been collected. Per ATSDR methodology, non-detected analytes were assumed to be present at their respective detection limits. Appendix F summarizes the tissue sampling results, location, species, and chemical analyses of data (Table F1).

Specific Areas of Concern–The Port Gamble S'Klallam Tribe is interested in understanding subsistence exposures from eating shellfish collected on the reservation located on the eastern shoreline of the bay versus those collected at the former mill area versus those collected on the western shore near the former landfills and log sorting and transfer areas. In addition, the western shoreline is again being considered for commercial harvesting sites. DOH closed the western shoreline for commercial harvesting in 2002 based on a need for more data.

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Exposures from these areas are specific to oyster and clam harvesting in the intertidal zone. To address these concerns, the following summarizes composited clam and oyster samples taken from specific areas of Port Gamble Bay:

1. Former Mill Area
    - 15 clam samples, littleneck (n=12) and cockle (n=3)
    - 4 oyster samples
2. Western Shoreline
    - From the log sort and transfer areas,
        - 3 clam samples: littleneck (n=1), manila (n=1), cockle (n=1)
        - 1 oyster sample
    - From Landfill 2
        - 4 clam samples: littleneck (n=2), manila (n=1), cockle (n=1)
        - 1 oyster sample
    - From Landfill 3
        - 4 clam samples: littleneck (n=2), manila (n=1), cockle (n=1)
    - From Landfill 4
        - 4 clam samples: littleneck (n=2), manila (n=1), cockle (n=1)
        - 1 oyster sample
3. Eastern Shoreline (Port Gamble S'Klallam Tribe Reservation)
    - 23 clam samples: littleneck (n=8), manila (n=3), cockle (n=5), butter (n=3), and horse (n=4)
    - 7 oyster samples

Data Gaps and Limitations

DOH has used several data sets to assess exposures. In some cases no data have been collected and it was not possible to assess certain exposures. The following discussion describes biases in sampling strategies and analytical deficiencies, as well as data gaps that still need to be filled to fully assess exposures.

Data Limitations. The amount and type of chemical in contaminated media is another source of uncertainty. Environmental samples are very costly so as a result it is not practical or efficient to analyze an adequate number of samples for every existing chemical. Instead, sampling usually focuses on contaminants that are thought to be present based on historic land use or knowledge of specific chemical spills. In addition, as instrumental quality improves, detection limits become lower over time. However, even using the best available analytical methods, detection limits are often still not low enough to adequately detect and characterize risk for some compounds (e.g., dioxin/furan compounds). For these chemicals, much of the estimated risk is based on detection limits for chemicals that may or may not be present, or may be present at levels substantially lower than that assumed.

The level of detection for total PCB Aroclors ranged from 0.01–0.091 mg/kg. This concentration range is three orders of magnitude higher than the screening value (0.00002 mg/kg), thus detection limit is not sensitive enough to determine if a health threat does exist. Furthermore, at these detection levels only 8 of the 62 (13%) samples analyzed for Aroclors had one of the

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Aroclors mixtures detected, indicating that these samples may not be well characterized. Six of the samples with Aroclors detected were at the former mill area, which has been more recently characterized by PCB congener analyses (see discussion below).

Sediment Sample Biases–Each sampling effort had a purpose that may not have been ideal for characterizing sediment sample exposures from the shorelines of Port Gamble Bay. Overall, there are enough intertidal sediment samples to estimate exposures at the former mill, Landfill 2 and Landfill 3.

On the eastern shoreline, the tribe collected limited sediment data from Point Julia; however, not many locations have been sampled and thus concentrations may not represent where children play. Landfill 4 had its own sediment investigation and cleanup; however, these data were not available for this report. There is some question as to how low into the intertidal area of shellfish harvesting these samples were taken. The FLTF and the FLA are represented by one sample each, limiting characterization of this part of the shoreline. These latter samples were taken to represent a potential exposure to a person who would walk along the western shoreline (4;13).

Shellfish Tissue Sample Biases or Deficiencies–Overall the species and distribution of samples collected represent areas where the tribe harvests shellfish, or would harvest shellfish if they knew it was safe to do so. Not all samples have been analyzed for all four groups of contaminants: metals, PAHs, dioxin/furan compounds, and PCBs.

Like the sediment data from sampling locations in 2011, tissue PCB congener data do have detection limits that allow for a better comparison to the screening levels; however, only a few littleneck samples have been taken thus far, six from the former mill area, two from the eastern shoreline and three from the western shoreline (13).

Data Gaps–DOH identified the following data gaps when trying to assess exposures to sediments and shellfish:

- No shellfish tissue samples have been collected from the southern portion of the bay, which supports the commercial intertidal clam and oyster shellfish industry.
- There are limited data for geoduck (n=3) and crab (n=3), which make up a little over a third of the tribe-estimated subsistence consumption .
- There are limited PCB congener data for oysters (n=2), crab (n=2), and geoduck (n=2). Littleneck /manila, cockle, butter, horse clams (n=0); however, there is only one sample at each landfill.
- No fish samples were available to assess exposures from finfish consumption.
- Butter clams and horse clams have not been analyzed for metals; however, these species are most likely represented by data from other species.

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Figure 3. Sediment sampling locations at Port Gamble Bay, Kitsap County, Washington.

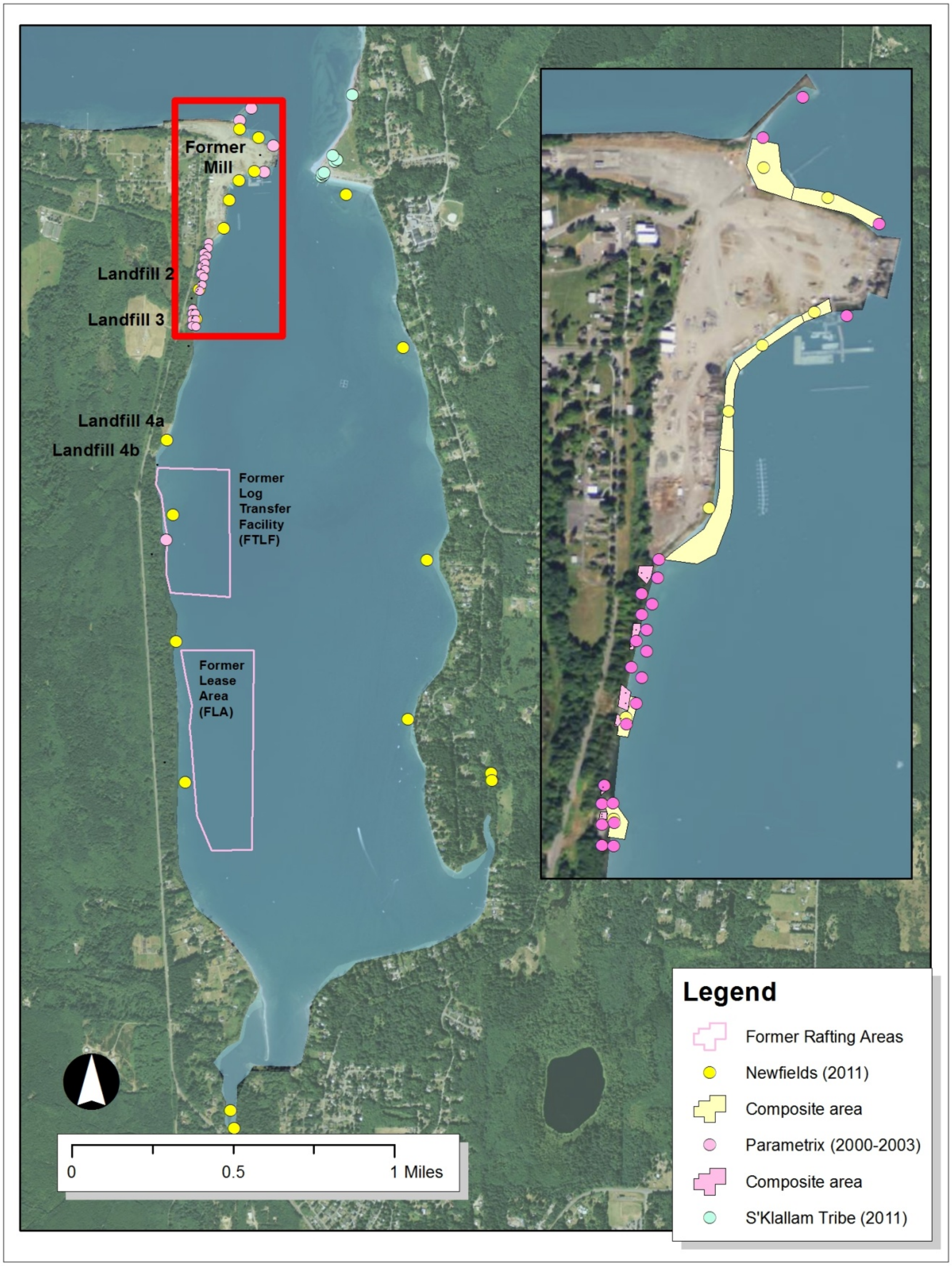

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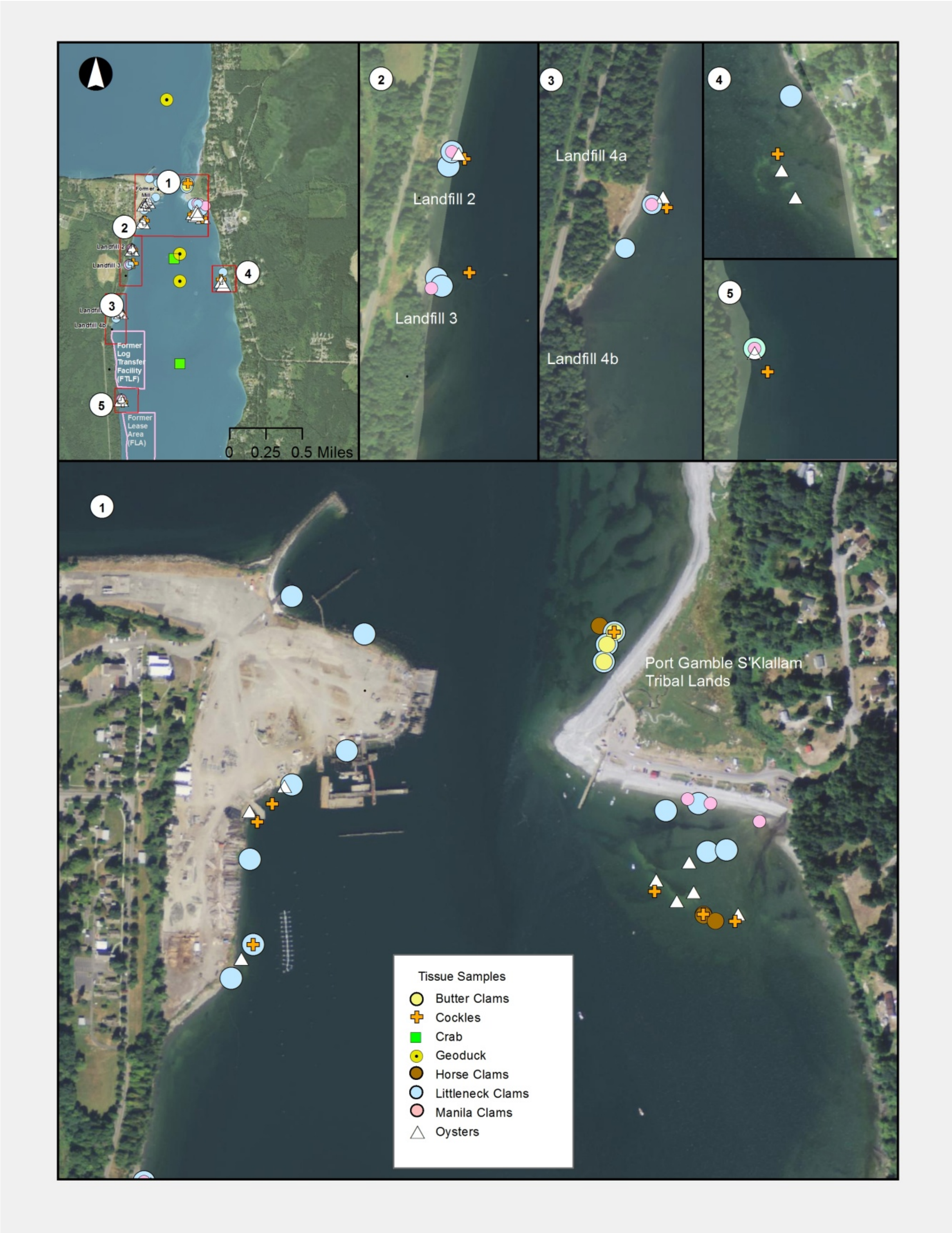
Figure 4. Tissue sampling locations at Port Gamble Bay, Kitsap County, Washington.



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Exposure Pathway

The exposure pathway focuses on the nature and extent of contamination and how people may be exposed. In order to cause potential harm, an exposure pathway must be complete and contaminant(s) must be present at high enough concentrations. This exposure pathway analysis consists of five elements: 1) source, 2) fate and transport, 3) points of exposure, 4) exposure routes, and 5) potential populations. Depending on these elements, exposure to a contaminant may have occurred in the past, may be occurring, or may occur in the future. The first three elements (source, fate and transport, and points of exposure) have been covered in the first sections of this document.

Exposure Routes

This evaluation considered three routes of exposure: swallowing (ingestion), skin contact (dermal), and breathing in (inhalation) dust generated at the site.

- *Swallowing (Ingestion)*–Shellfish that continually live in or on contaminated sediments of the bay may take in chemicals while they filter feed. Not all chemicals accumulate in the tissues of animals but some do, increasing in concentration. Preparation methods and cooking may affect chemical concentrations in shellfish. Eating contaminated shellfish may increase exposure.

  People can inadvertently swallow small amounts of sediment. Young children less than six years old may swallow even more particles as they often put fingers, toys, pacifiers, and other objects in their mouths. In extreme cases, a small percentage of children and some adults exhibit pica behavior, which is a persistent eating of non-food substances (such as dirt or paper). People may get sediment on their hands during activities on the shoreline such as collecting shellfish or playing on the intertidal sediment. During windy conditions, windblown sand may also enter the mouth and be swallowed.

- *Skin Contact (Dermal)*–The skin provides an effective barrier for most environmental contaminants, but some do cross the skin and enter the body. Intertidal sediment can adhere to the skin and may result in prolonged exposure to contaminants. Some chemicals can move through the skin depending on the size of the chemical and whether it can dissolve or mix in water. The transfer of chemicals through the skin will depend on the chemical and be limited by duration of contact. Dermal contact will be considered as a route of exposure.

- *Breathing (Inhalation)*–At low tide, dry intertidal sediments may be moved into the air during windy days; this mostly consists of relatively large particles that would be trapped in the nose, mouth, and throat. Because of their size, these particles would be swallowed rather than inhaled into the lungs, leading to incidental ingestion (see first exposure route above). Gaseous or volatile chemicals in the air have not been reported or sampled at this site. Thus, the transfer of chemicals through the lungs is not considered as a route of exposure at this site.

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Potentially Exposed Populations

This section identifies people and sensitive populations that may come in contact with contamination that may be present in Port Gamble Bay. For clarification, the intertidal sediment and shell harvesting areas are classified as being part of the former mill area, the western shoreline (below the former mill from Landfill 2 to the bottom of the FLA), the eastern shoreline on the reservation (the north and south beach of Point Julia to the southern portion of the reservation near the gravel spit). The following populations may come in contact with contaminants at Port Gamble Bay:

Figure 5. View of low tide at Point Julia looking south along the shellfish harvest areas on the eastern shoreline of Port Gamble Bay, Kitsap County, Washington.

Sensitive Populations– Of particular emphasis at this site is the subsistence use of resources by the Port Gamble S'Klallam tribal community who live on the reservation located on the bay. Along with fish, tribal adults and children depend on shellfish collected from the bay as a primary source of protein. Subsistence exposures include ingestion of shellfish and contact with sediment while harvesting shellfish and recreating on the shore. The tribe mostly harvests from the eastern shoreline, but also may harvest from the former mill area or western shoreline. The following factors affect the exposures to subsistence shellfish consumers:

Figure 6. View of low tide at Point Julia looking at the western shoreline across Port Gamble Bay, Kitsap County, Washington.

- Tribe-estimated consumption rates for shellfish are higher compared to the general population; these consumption rates are similar to those of the Suquamish Tribe (9;12;20). This assessment considers a high and low tribe-estimated subsistence consumption rate.
- During harvest, contact with intertidal sediments occurs while using a rake or shovel and harvesters' hands to collect oysters and clams from the intertidal zone of the bay.
- Incidental ingestion of sediments may also occur if seafood is not properly cleaned and sediment remains on and/or in the edible portion of shellfish.
- At extreme low tides (more than two feet below sea level), geoduck can be harvested by hand digging in intertidal sediment; however, these low tides are infrequent with fewer than 20 extreme tides a year.[11] Digging for geoduck may result in high skin surface area contact with sediments for a short amount of time with possible incidental ingestion.
- Crabs are usually harvested by crab trap/pot; though sediment from the trap/pot may reach the boat it is washed off. Very little sediment contact is expected.

[11] http://wdfw.wa.gov/fishing/shellfish/geoduck/

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High Risk Populations–The tribal community has expressed health concerns for children eating shellfish and playing on the shoreline sediments at Point Julia, especially during summer when school is out. Children spend more time outdoors and, because of normal hand-to-mouth behavior, they tend to ingest more sediment than adult populations. Furthermore, some children may periodically exhibit soil pica behavior which can result in ingestion of higher amounts of sediment. The screening analysis described in Appendix D for sediment contact and exposure calculations in Appendices E and F use child exposure assumptions to be protective of this population. In addition, exposure assumptions for elderly lifetime residents are considered. The tribe brought up concerns regarding cumulative effects from exposure to elderly tribe members who have depended on resources from Port Gamble Bay their entire lives.

Residential Populations–Three distinct residential populations reside near or on Port Gamble Bay:

- Tribal residents who depend on shellfish (and fish) as the major source of protein in their diet. As described above, these members eat shellfish at the high tribe-estimated subsistence consumption rate.
- Tribal residents who frequently eat shellfish but not as much as the high-end subsistence tribal members. These members eat shellfish at a low tribe-estimated subsistence consumption rate. Tribal customs include shellfish gathering, preparation, ceremonies, and preservation techniques which result in more shellfish consumption by tribe members. Lower subsistence populations are estimated to eat approximately four times more shellfish than the general population. The integration of shellfish harvest in tribal culture also leads to more contact with bay sediments.
- Non-tribal shoreline property owners and their children on the eastern and southern half of the bay who may come in contact with the sand and sediments at the shoreline at low tide, during recreation or shellfish harvesting. Eating shellfish harvested from the bay may lead to exposure, though consumption rates may not be as high as tribal consumption rates. In this assessment, these residents are considered general population exposures. Exposures will be estimated based on intertidal clam and oyster ingestion only (not geoduck or crab). Geoduck may only be harvested in the intertidal zone intermittently during extreme low tides, and therefore are not considered readily available or a consistent part of the diet.

Figure 7. View of low tide in Port Gamble Bay to the north from Gamblewood Community Club Park, Kitsap County, Washington.

Detailed description of exposure factors used in the exposure dose calculations can be found in Appendices E and F. Tribal and general population consumption rates are listed in Table 1. Specific species consumption rates are listed in Appendix F, Table F2.

Recreational Populations–Currently the only non-resident access point to the bay occurs at the private Gamblewood Community Club Park at the southern end of the bay for Gamblewood

Community Club Members only. Future land use of the western shore and former mill area has not yet been determined and could likely result in public access points. As access increases, visitors may play on the shoreline, or occasionally harvest shellfish. Exposure may occur by eating shellfish or incidental ingestion and contact with sediments on the bay. Residential and tribal exposures to sediments represent higher rates of contact and, thus are used as a worst-case scenario protective of recreational populations.

Table 1. Daily shellfish ingestion rates for consumption scenarios, Port Gamble Bay, Kitsap County, Washington. [a, b]

Shellfish Consumer	Adult	Source	Child	Source
High tribe-estimated subsistence consumption rate	499 g/day 1.1 lb/day	95th percentile Suquamish Consumption Survey (EPA Tribal Framework, Puget Sound shellfish only)	83 g/day 0.18 lb/day	95th percentile (< 6 years) Suquamish consumption survey (EPA EFH Table 10-107)
Low tribe-estimated subsistence consumption rate	217 g/day 0.47 lb/day)	95% UCL of mean Suquamish Consumption Survey (EPA EFH Table 10-103, adjusted for Puget Sound shellfish only) [c]	23 g/day 0.05 lb/day	95% UCL of the mean (< 6 yrs) Suquamish consumption survey (EPA EFH 10-107)
General Population	60 g/day 0.13 lb/day	90th percentile Survey from King County locations (EPA EFH Table 10-67); 95% UCL of mean U.S. general population (13-49 years) (EPA EFH Table 10-10)	16 g/day 0.04 lb/day	Mean (ages 3-5 years) U.S. general population (EPA EFH Table 10-10)

Notes: Source: EPA Tribal Framework 2007(9;13) , Suquamish Tribe 2000 (20), EPA Exposure Factor Handbook 2011 (21)
[a] Tribal consumption rates provided in the Suquamish Survey were adjusted by the survey mean body weights, 79 kg for adults and 16.8 kg for children
[b] Individual species contribute to the tribal shellfish diet; Consumption is comprised of clams (51%), oysters (13%), geoduck (19%), and crab (17% separated into crab meat and crab butter, 13% and 4% respectively).
[c] The 95% UCL of the mean, 266 g/day listed in Table 10-103 was adjusted 81% based on the fraction of Puget Sound shellfish to total shellfish consumed in the tribal framework (499 g/day: 613 g/day) assuming a 79 kg adult body weight.
UCL – Upper 95th percentile confidence limit of the mean
g/day – grams of shellfish tissue prepared to eat per day (does not include shell weight)
lb/day – pounds (or fraction of a pound) of shellfish eaten per day (does not include shell weight)
EFH – Exposure Factors Handbook (U.S. Environmental Protection Agency 2011)
EPA – Environmental Protection Agency

Consumers of Commercial Harvest–No information on tissue concentrations is available for intertidal clams or oysters harvested commercially from Port Gamble Bay. Tissue data are available only for the northern portion of the bay. Because consumers of commercially harvested shellfish will eat shellfish from many different sources, it is assumed that estimated exposures for recreational populations will conservatively protect populations that would eat commercial shellfish.

Worker Populations–Commercial harvest of both intertidal shellfish and sub-tidal geoduck occurs in Port Gamble Bay. Workers may touch sediments while harvesting intertidal shellfish. Geoduck clams at sub-tidal depths are harvested underwater with a surface supplied air hose (Hookah diving) and drysuit gear that prevents exposures to sediment. Thus, exposure to sediments by workers during geoduck harvest is not considered a complete route of exposure and not evaluated further in this assessment. Residential and tribal exposures to sediments represent higher rates of contact and thus could be used as a worst-case scenario protective of occupational populations.

Screening Analysis

In order for any contaminant to be a health concern, the contaminant must be present at a high enough concentration to cause potential harm. DOH compiled results from sediment and tissue samples taken from Port Gamble Bay during various investigations. Maximum contaminant levels in sediment were screened against health-based residential soil comparison values (CV). Several types of CVs 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)”]. CVs 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 CVs represent levels that are calculated to increase the estimated risk of cancer by about 1 in a 1,000,000. These types of CVs often form the basis for cleanup.

Comparisons may also be made with legal standards such as the cleanup levels specified in the Washington State Model Toxics Control Act (MTCA) and EPA Regional Screening Levels (RSL) for residential soils. 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.

For shellfish, DOH screened the maximum concentration data for each species with CVs calculated with the high tribe-estimated subsistence intake rate for tissue to determine if levels pose a potential health threat. If concentrations are above the health-based CVs, it does not mean that adverse health effects will occur, but tells us that additional evaluation is necessary (22). Tissue or sediment concentrations below a CV do not pose a health threat and further evaluation is not needed.

Sediment–DOH screened sediment data by comparing sediment concentrations with ATSDR soil CVs, MTCA and EPA’s RSL (See Appendix D, Table D1). This screening is considered to be a conservative approach to determine chemicals of potential concern. The following chemicals of potential concern in sediment were identified for further evaluation (see bold text in Table D1):

- Arsenic
- PAHs with carcinogenic effects

Chromium will not be evaluated further for sediment exposures. Chromium concentration was elevated (211.6 mg/kg) above the CV of (50 mg/kg)[12] in one sample near Landfill 2 but nowhere else in Port Gamble Bay. Clearly there was a source for this sample when measured in 2003 as it exceeded background chromium levels. This sample is an outlier in the data set. Number of

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[12] CV calculated by multiplying the MRL by adult body weight (79 kg) then dividing by the tribe-estimated subsistence consumption rate (499 g/day) and adjusting with a conversion factor (see full equation and parameter description in Appendix D) as based on the EPA guidance for assessing exposures to subsistence fishers (19).

total samples tested was 17 (n is the number of samples thus n=17). The average concentration of total chromium for all sediment samples taken from Landfill 2 is approximately 37.3 mg/kg, well below the CV. Furthermore, the screening process compared total chromium with the health-based CV for hexavalent chromium, Cr(VI), which is a conservative value. Without speciation of the chromium in the sample, it is unknown what portion of the chromium consists of Cr(VI), but it is less than 100%.

Likewise, lead will not be evaluated further for sediment exposures. The lead concentration in one sample at Landfill 3 exceeded the Washington State cleanup level of 250 mg/kg. Again, this is an outlier in the data set and average concentration at this landfill is 37.5 mg/kg (n=10). Thus, lead will not be evaluated further for sediment exposures.

Shellfish–DOH screened maximum tissue chemical concentrations for each species using CVs derived from ATSDR and EPA guidance documents (9;22). As agreed upon with the tribe, high tribe-estimated subsistence consumption rates for shellfish ingestion were based on the Suquamish 95^{th} percentile consumption for adults (499 g/day) adjusted for consumption of shellfish from Puget Sound only (9;20). Derivation of CVs for exposure to chemicals from shellfish consumption is described in detail in Appendix D. CVs for shellfish tissues are listed in Table D3. This screening is considered to be a conservative approach to determine chemicals of potential concern.

The following chemicals of potential concern in shellfish tissue were identified for further evaluation (see bold text in Table D3):

- Arsenic
- Cadmium
- Chromium
- Copper
- Dioxin/Furan compounds
- PCBs
- PAHs with carcinogenic effects

Silver will not be evaluated further for tissue exposures. The subsistence CV for silver was exceeded only in the geoduck samples using the high tribe-estimated subsistence consumption rate (499 g/day). Using the Port Gamble S'Klallam tribe-estimated geoduck consumption rate (96.8 g/day), the revised CV (4.1 g/day) was not exceeded by the maximum geoduck silver concentration (1.47 mg/kg). Furthermore, silver has not been detected in any of the intertidal or subtidal sediment samples from the bay. This exceedance is likely a result of the inclusion of the gut ball in geoduck analyses. DOH has found previously that metals, including silver, are higher in the gut ball than in siphon and body (23;24); presumably this is due to the contents found within the gut of the clam.

Zinc will not be evaluated further for tissue exposures. Zinc is an essential element needed in the diet. Based on shellfish consumption of 499 g/day, the CV for zinc (47 mg/kg)[13] was consistently exceeded approximately 2–3 fold in oysters, averaging 159 mg/kg. Using the Port Gamble S'Klallam tribe-estimated oyster consumption rate of 62.4 g/day, the revised CV (380 mg/kg) was not exceeded by the maximum value (263 mg/kg). Oysters contain more zinc per serving than any other food (25). According to the national nutrient database maintained by the U.S. Department of Agriculture (USDA), the zinc nutrient value for raw Pacific oysters is 166 mg/kg (26) similar to that found at the site.

Health Effects Evaluation

The health effects evaluation consists of a more in depth analysis to determine possible public health implications of chemical-specific toxicity and site-specific exposures. Exposure assumptions and calculations for estimating contaminant exposure doses from contacting sediment and eating shellfish are in Appendices E and F.

Non-Carcinogenic Effects

In order to evaluate the potential for non-carcinogenic adverse health effects, a dose is estimated for each chemical of potential concern. In this case, either the average concentration or the 95th upper confidence limit on the mean was used. These doses are calculated for the four scenarios described above in which a person might be exposed.

These doses are calculated for the four scenarios described above in which a person might be exposed. These estimated doses were then compared to either ATSDR's minimal risk level (MRL) or EPAs oral reference dose (RfD). 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 also 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. An MRL or RfD is exceeded whenever the Hazard Quotient (HQ) is greater than one.

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[13] CV calculated by multiplying the MRL by adult body weight (79 kg) then dividing by the tribe-estimated subsistence consumption rate (499 g/day) and adjusting with a conversion factor (see full equation and parameter description in Appendix D) as based on the EPA guidance for assessing exposures to subsistence fishers (19).

Based on exposure estimates quantified in Appendices E and F, the general population and average tribal members eating at the low tribe-estimated subsistence consumer rate are not likely to experience adverse non-carcinogenic health effects from exposures to the chemical levels in Port Gamble Bay. High tribe-estimated subsistence consumption rates do lead to some risk of developing non-carcinogenic health effects from arsenic, cadmium, and dioxin-like compounds eaten in shellfish. Appendix G contains detailed discussions of chemical-specific exposures and adverse effects.

Carcinogenic Effects

Cancer is a term used for diseases where abnormal cells divide without control then invade other tissues. According to the National Cancer Institute, 41% of men and women born today (approximately 2 in 5 adults) will be diagnosed with cancer at some time during their lifetime. This estimate is based on 2007–2009 incidence rates (27).

Some chemicals have the ability to cause cancer. Cancer risk is estimated by calculating a dose for a chemical and multiplying it by a cancer potency factor. Some cancer potency factors are derived from human population data. Others are derived from laboratory animal studies involving doses much higher than encountered in the environment. Use of animal data requires extrapolation of the cancer potency from high dose studies down to low-level exposures. This process involves much uncertainty.

Current regulatory practice assumes there is no “safe dose” of a carcinogen. In other words, any dose of a carcinogen will result in some additional cancer risk. Cancer risk estimates are not yes/no answers but measures of chance (probability). The validity of “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. Unless a chemical has been shown to have a threshold, DOH assumes that no threshold exists.

This document estimates cancer risk that is attributable to site-related contaminants in qualitative terms like moderate, 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 additional cancer case per ten thousand persons exposed over a lifetime (1×10^{-4}). A very low estimate might result in one cancer case per several tens of thousands exposed over a lifetime (1×10^{-5}). DOH considers estimated cancer risk as insignificant when the estimate results in less than one additional cancer per one million exposed over a lifetime.

Estimated Cancer Risk

Cancer risk estimates do 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		Number of Excess Cancers
Moderate	approximately equal to	1 in 1,000
Low	approximately equal to	1 in 10,000
Very Low	approximately equal to	1 in 100,000
Slight	approximately equal to	1 in 1,000,000
Insignificant	is less than	1 in 1,000,000

It should be noted that EPA generally considers an excess upper-bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6} as their target risk range. That means regular exposure to a substance would lead to one additional case of cancer per ten thousand to one additional case of cancer per one million people exposed.

For those chemical concentrations that exceed comparison values, a more in-depth analysis of exposure and levels causing adverse effects is warranted. Estimating exposure requires identifying how much, how often and how long a person may come in contact with a concentration of a substance in sediment or in shellfish. The mathematical equations used to estimate how much of a substance a person may contact based on their actions or habits is described in Appendices E and F. Potential health risks were evaluated for: 1) high tribe-estimated subsistence harvest and consumption, 2) low tribe-estimated subsistence harvest and consumption, 3) general population resident collection and consumption, and 4) sediment exposures to a child playing on the reservation shoreline.

Subsistence shellfish consumption was found to be the major route of exposure and represents more than 95% of the carcinogenic risk. Arsenic was the major contributor to carcinogenic risk estimates for high tribe-estimated subsistence intake rates (61%), followed by dioxin/furan (22%), and PAH compounds (16%). Chemical-specific evaluations can be found in Appendix G.

Multiple Chemical Exposures

A person can be exposed to more than one chemical through more than one pathway. Exposure to a chemical through multiple pathways occurs if a contaminant is present in more than one medium (i.e., air, soil, surface water, groundwater, tissue, and sediment). For example, the dose of a contaminant received from drinking water might be combined with the dose received from contact with the same contaminant in shellfish.

For many chemicals, much information is available on how the individual chemical produces effects. However, it is much more difficult to assess exposure to multiple chemicals. Due to the large number of chemicals in the environment, it is impossible to measure all of the possible interactions between these chemicals. The potential exists for these chemicals to interact in the body and increase or decrease the potential for adverse health effects. Individual cancer risk estimates can be added since they are measures of probability. However, when estimating non-cancer risk, similarities must exist between the chemicals if the doses are to be added. Groups of chemicals that have similar toxic effects can be added, such as volatile organic compounds (VOCs) which cause liver toxicity. PAHs are another group of compounds that can be assessed as one combined dose based on similarities in chemical structure and metabolites.

After adding the lifetime cancer risk estimates for multiple chemicals from sediment and shellfish exposures, the total estimated cancer risk for a tribal member consuming shellfish at the tribe-estimated subsistence consumption rate is approximately 1.6 additional cancers in 1,000 people exposed. The total cancer risk for the average tribal member is approximately 2.8 additional cancers in 10,000 people exposed.

Uncertainties

Assessment of risks attributable to environmental exposures is filled with many uncertainties. Uncertainty with regard to the health assessment process refers to the lack of knowledge about factors such as chemical toxicity, human variability, human behavior patterns, and chemical concentrations in the environment. Uncertainty can be reduced through further study.

Data Limitations–This assessment has used data from several different sampling efforts. Data sampling biases and analytical deficiencies were described in detail above.

Chemical Toxicity–The majority of uncertainty comes from our knowledge of chemical toxicity. For most chemicals, there is little knowledge of the actual health impacts that can occur in humans from environmental exposures unless epidemiological or clinical evidence exists. As a result, toxicological experiments are performed on animals. These animals are exposed to chemicals at much higher levels than found in the environment. The critical doses in animal studies are often extrapolated to "real world" exposures for use in human health risk assessments. In order to be protective of human health, uncertainty factors are used to lower that dose in consideration of variability in sensitivity between animals and humans and the variability within humans. These uncertainty factors can account for a difference of two to three orders of magnitude when calculating risk. Furthermore, there are hundreds of chemicals for which little toxicological information is known in animals or humans. These chemicals may in fact be toxic at some level, but risks to humans cannot be quantified due to uncertainty.

Tissue Inorganic Arsenic–Inorganic arsenic in tissues was not measured during evaluations of shellfish used in this study. The majority of arsenic found in seafood is organic arsenic. DOH assumed that inorganic arsenic represented 1% of the total arsenic in these species based on the 95^{th} percentile upper confidence limit (UCL) of the mean in shellfish (0.819%) presented in a 2002 Ecology Puget Sound study (9;20;28). Inorganic arsenic in the five samples analyzed for the Port Gamble S'Klallam Tribe ranged from less than 0.002 mg/kg (detection limit) in cooked cockles and raw geoduck (in and out of raw batter) to 0.105 mg/kg in cooked geoduck and 0.239 mg/kg in clams. The latter two represented 3.5% and 4.5% of the total arsenic measured. The average inorganic arsenic of these five samples is approximately 1.7% of total arsenic. There was no information on where these samples were harvested, how they were prepared then processed, or analytical detection limit or quality control information available at the time of this evaluation. In addition, sample size is not large enough to represent the variety of species represented in tissue samples. It is possible that inorganic arsenic may be more than 1% in any one sample, thus underestimation of potential hazard might occur. However, based on the 95^{th} percentile upper confidence level of the Ecology 2002 study, DOH believes 1% is appropriate estimation based on site-specific data throughout Puget Sound.

Consumption Rates–The amount of contaminated media (fish, water, air, or soil) that people eat, drink, inhale, or absorb through their skin is another source of uncertainty. Although recent work has improved our understanding of these exposure factors, they are still a source of uncertainty. In the case of Port Gamble Bay, uncertainty exists with respect to how much shellfish people eat from Port Gamble Bay, how often they are eating it, what species they are eating, how often children use public access areas, and how much sediment or soil children may inadvertently eat. Estimates are based on best available information or worst-case scenarios. This evaluation is based on the assumption that 100% of the shellfish harvested and consumed was from Port

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Gamble Bay. There is more uncertainty in estimating exposures to children as they are not as well characterized and consumption rates and patterns were extrapolated from adult consumption. From lack of data, exposure estimates for children less than two years old were made using consumption rates for children two years old to less than six years old. Exposure estimates for children 11 years old and older were made using adult consumption rates. These assumptions overestimate consumption in these age groups.

Resource Limits–Port Gamble Bay alone may not be large enough to support high or low tribe-estimated subsistence shellfish harvest in many members. For example, a subsistence shellfish consumer eating clams (i.e., littleneck, manila, cockle, butter, and horse clams) at the 95^{th} percentile consumption rate, 256 grams of clam meat per day needs to collects on average approximately 40 clams per day based on the average weight of a manila clam (6.35 g) (29). Thus, the calculations in this public health assessment represent a subsistence shellfish harvester collecting approximately 10,300 clams per year, every year during their lifetime (ages 11 and higher). More information on population numbers of clams, oysters, and crabs in Port Gamble Bay is needed to determine the limits of Port Gamble Bay in supporting this kind of harvest.

Preparation and Cooking Methods–Another source of uncertainty is how seafood is actually prepared for consumption and laboratory testing (i.e., whole fish with guts versus gutless or fillets, large clams with skin, and gut ball). Horse clams are a large clam and may show similar heavy metal patterns to geoduck clams where the skin and gut ball contain the major portion of heavy metals. Large clams should be analyzed without skin and without the gut since these are not usually retained during preparation.

Sampling Season– The amount and type of chemicals in shellfish may vary as they are affected by the season in which they were sampled. Sampling efforts occurred at different times of the year: March – September, November, and December. Different species exhibit elevated concentrations at different times of the year, especially for the "fat-loving" organic compounds that can concentrate in reproductive tissues.

Evaluation of Health Outcome Data

Evaluations of health outcome (*i.e.*, mortality and morbidity) data (HOD) in public health assessments are done using specific guidance in ATSDR's *Public Health Assessment Guidance Manual* (22). The main requirements for evaluating HOD are: the presence of a completed human exposure pathway; high enough contaminant levels to result in measurable health effects; sufficient number of people in the completed pathway for health effects to be measured; and a health outcome database in which disease rates for the population of concern can be identified (22).

This site does not meet the requirements for including an evaluation of HOD in this public health assessment. Although completed human exposure pathways exist at this site, the exposed population is not sufficiently defined, nor has a health outcome database been established to permit meaningful measurements of possible site-related health effects.

EPA studied two specific issues of concern regarding arsenic intake among tribe members: 1) an exposure investigation led by EPA to determine levels of arsenic in urine and blood in tribal

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members, and 2) quantification of species of arsenic in consumed seafood (fish and shellfish) (11). Concentrations of inorganic arsenic in these samples were not statistically different from other food samples analyzed by EPA (11).

Child Health Considerations

The potential for exposure and subsequent adverse health effects may be different for children than for adults. Fetuses and children are susceptible to developmental toxicity that can occur at levels much lower than those causing other types of toxicity. Children are more likely:

- To play outdoors in contaminated areas by disregarding signs and wandering into restricted locations.
- To bring food into contaminated areas resulting in more hand-to-mouth exposures.
- To receive higher doses of a contaminant because they are smaller.
- To breathe dust and soil because they are shorter and therefore, closer to the ground.
- To have underdeveloped functional capacity of various organ systems and/or metabolic pathways resulting in different rates of detoxification.

The unique vulnerabilities of infants and children require special attention in communities that have contamination of their water, food, soil, or air. It is likely that children will play and/or dig in the sediment along public access points or shoreline residences. Thus, exposure scenarios in this public health assessment treated children as the most sensitive population being exposed.

Exposure doses were specifically estimated for tribal children playing on the intertidal sediments of the reservation shoreline. Children from 2 years old to less than 6 years old are the children with behaviors most likely to result in highest exposures. Using average sediment concentrations and child exposure parameters, non-carcinogenic health effects are not expected to occur. The risk for this age group to develop cancer is approximately 4 additional cases in 1,000,000 children exposed and is considered very slight to insignificant.

Conclusions

DOH reached six conclusions in this public health assessment:

Eating shellfish meat from the upper portion of Port Gamble Bay at the **high tribe-estimated subsistence consumption rates** every day for a lifetime could be harmful to the health of an adult or child tribe member.

Eating shellfish from the upper portion of Port Gamble Bay at the **low tribe-estimated subsistence consumption rate** every day for a lifetime could be harmful to the health of adult or child tribe members.

Eating residentially, recreationally, or commercially harvested shellfish from the upper portion of Port Gamble Bay at a **consumption rate of 1-2 meals per week or less** is not expected to harm the health of an adult or child.

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A determination cannot be made as to whether there is a health risk to tribal members from eating geoduck or crab Harvested from Port Gamble Bay.

A determination cannot be made as to whether there is a health risk to tribal members from eating resident finfish in the bay.

Touching and accidentally eating intertidal sediment during recreational or harvesting activities are not expected to harm the health of an adult or child of the Port Gamble S'Klallam Tribe or the general population.

Recommendations

To protect **tribal members eating at the high tribe-estimated subsistence consumption rate**, DOH recommends the following:

- Ecology work toward completion of the Cleanup Action Plan for Port Gamble Bay. Proceeding with cleanup, especially at the former mill area, will contribute to a reduction in exposures to tribal members eating at the tribe-estimated subsistence consumption rate.
- Tribal members eating at the tribe-estimated subsistence consumption rate not harvest shellfish from the former mill area or the western shoreline.

DOH recommends the following to Ecology and the Port Gamble S'Klallam Tribe:

- More geoduck samples from each of the existing harvest tracts within contaminated areas should be collected and analyzed for metals, dioxin-like compounds, and PAHs.
- More crab samples should be collected and analyzed for metals, dioxin-like compounds, and PAHs.
- Fish samples of non-migratory species should be collected and edible tissues analyzed for metals, dioxin-like compounds, and PAHs.
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To protect **tribal members, local residents, and future recreational harvesters** of shellfish from the upper portion of the bay, DOH recommends the following:

- DOH suggests that frequent consumers of Port Gamble Bay shellfish, especially those who eat shellfish more than 1–2 times per week, follow these steps to reduce exposure to chemical contaminants:

  a. Collect and eat shellfish from a variety of locations away from the former mill area.
  b. Consider eating an average serving size (8 oz meal uncooked meat).
  c. Eat a variety of shellfish.
  d. Young children should eat proportionally smaller meal sizes.
  e. Eat larger clams without the skin and gut ball.
  f. Soak shellfish in seawater for a couple hours or overnight to expel sand stored inside their shells and digestive system, before cooking.

- Ecology post signs on a parcel-by-parcel basis discouraging shellfish harvesters from eating shellfish from an area during and after a remedial action (removal of sediment,

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pilings, or wood waste/debris). Suspended contaminants may result in increased tissue chemical concentrations.

- After a remedial action is complete, shellfish tissue samples should be collected to further evaluate contaminant concentrations prior to removing any signs restricting harvest.
- Ecology require monitoring of shellfish from Port Gamble Bay. DOH would need to review monitoring plans prior to implementation.

DOH recommends that:

- The former mill area and western shoreline be opened by DOH for commercial shellfish harvesting.
- Approved commercial harvest sites should be closed on a parcel-by-parcel basis by DOH (if necessary) during and after a remedial action. DOH may reopen a commercial harvest site based on confirmation tissue data that demonstrate shellfish can be eaten without undue health risk.

Public Health Action Plan

The following actions are planned at Port Gamble Bay

- DOH will coordinate with Ecology, tribes, and local health agencies to provide educational materials and a fact sheet.
- DOH will review additional tissue sampling and analysis plans and contaminant data as they become available and adjust recommendations as appropriate.
- Ecology will post signs discouraging tribal, recreational, and residential harvest on a parcel-by-parcel basis during and after a remedial action (removal of sediment, pilings, or wood waste/debris). Ecology will provide confirmation tissue data to DOH which will determine if the signs may be removed.
- Ecology will inform DOH when and where a remedial action will take place. DOH will close approved commercial harvest sites on a parcel-by-parcel basis during and after a remedial action. Ecology will provide confirmation tissue data to DOH which will determine if a site may be reopened for commercial shellfish harvest.
- DOH will review the long-term monitoring plan for shellfish.
- A copy of this public health assessment will be provided to the Tribes, Ecology, local health agencies, Pope Resources, Olympic Property Group, Washington State Departments of Natural Resources, Washington State Department of Fish and Wildlife, and the public library in Poulsbo, Washington.
- A copy of this public health assessment will be placed on the DOH site assessment website: www.doh.wa.gov/consults.

Report Preparation

This Public Health Assessment for Port Gamble Bay in Kitsap County, Washington, was prepared by the Washington Department of Health (DOH) under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, and procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented.

Authors
Lenford O'Garro, Toxicologist/Health Assessor
Rhonda S. Kaetzel, PhD, DABT, Toxicologist/Health Assessor

State Reviewers
Joanne Snarski, Principal Investigator
Erin Kochaniewicz, Public Health Educator
Marilyn Hanna, Administrative Personnel

ATSDR Reviewers

Division of Community Health Investigations (DCHI)

Audra Henry, Technical Project Officer
Sven Rodenbeck, Acting Western Branch Chief
Kai Elgethun, Western Branch Associate Director for Science
Lynn Wilder, Division Associate Director for Science
Tina Forrester, Acting Division Director

.

Appendix A–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 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].
Hazardous Substance	Any material that poses a threat to public health and/or the environment. Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive.
Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].
Ingestion Rate (IR)	The amount of an environmental medium that could be ingested typically on a daily basis. Units for IR are usually liter/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 **oral reference dose**].
Model Toxics Control Act (MTCA)	The hazardous waste cleanup law for Washington State.
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.

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Oral Reference Dose (RfD)	An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by EPA.
Organic	Compounds composed of carbon, including materials such as solvents, oils, and pesticides that are not easily dissolved in water.
Parts per billion (ppb)/Parts per million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
Reference Dose Media Evaluation Guide (RMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The EMEG is a *comparison value* used to select contaminants of potential health concern and is based on EPA's oral reference dose (RfD).
Subsistence Consumption	Consumers who rely on non-commercially caught shellfish as a major source of protein in their diet (EPA Region 10 [14]Framework definition). Consumption rates are population-specific and described as grams shellfish eaten per day (g/day).
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].

[14] Subsistence definition from EPA Region 10 Framework for selecting and using tribal fish and shellfish consumption rates for risk-based decision making at CERCLA and RCRA cleanup sites in Puget Sound and the Strait of Georgia.

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Appendix B–Summary of Previous Remedial Activities

Upland Remedial Activities

This public health assessment does not address risks to public health from past, current, or future exposures on the upland mill area itself. Pope Resources has not yet determined future land use and the cleanup action plan has not yet been finalized. A full description of upland remedial activities can be found in the upland remedial investigation report (3). Information from upland remedial activities is summarized here to provide context of potential sources that may have contributed to sediment and tissue chemical concentrations.

After an initial investigation by Ecology in January 1997, environmental investigations have been conducted by Pope and Talbot, Pope Resources, Olympic Property Group, Ecology, and the Port Gamble S'Klallam Tribe to characterize soil, groundwater, surface water, sediment, and shellfish tissue quality. The following upland remedial activities have occurred:

- In April 1997, Pope and Talbot removed accumulated materials from 12 catch basins, four valve vaults, and four sumps.
- From 1999 to 2001, Pope and Talbot completed soil, groundwater and surface water sampling and identified eleven source areas. These areas are listed in Table B1, along with chemicals of concern.
- From 2002 to 2005, Pope and Talbot excavated approximately 20,460 tons of contaminated soil from the upland portion of the site (Table B1).
- In 2004 and 2005, Pope and Talbot removed an additional 5,850 tons of soil near Source Area 4 as a result of consistent mercury impacts in groundwater. Further well investigations in 2009 did not detect total or dissolved mercury or cadmium in the quarterly well monitoring.
- In 2006, Pope and Talbot further characterized arsenic in soil and migration to groundwater near Source Area 8 (Table B1) and concluded that arsenic was naturally occurring. No further remediation was performed at that time. In 2009, further investigation of total and dissolved arsenic in groundwater confirmed the sporadic presence of elevated arsenic in groundwater and deeper soils. Use of arsenic by Pope and Talbot operations has not been documented, and thus has not been associated with the concentration measured.
- In 2007, groundwater sampling by Pope and Talbot found chromium, mercury, and nickel detected in localized areas.
- In 2009, five discrete soil samples near the former refuse burner (also known as the former hog fuel burner) were analyzed for dioxin/furan compounds to fill a data gap. Wood wastes (hog fuel) contained salts, which in some circumstances can lead to the formation of dioxin/furan compounds when burned. Dioxin/furan levels did not exceed state standards. Air transport offsite has not been assessed.
- In 2009, fifteen discrete soil samples did not detect organochlorine pesticides.

In regard to upland sources, the 2011 Remedial Investigation and Feasibility Study (RI/FS) report prepared by Anchor, on behalf of Pope Resources and Olympic Property Group, recommended that institutional controls prevent the future use of groundwater as a drinking water supply, as well as ensure adequate soil cover to minimize future wildlife impacts. Sediment remedial and bay-wide cleanup activities are addressed in Ecology's feasibility study and Cleanup Action Plan for the bay.

Table B1. Upland source areas, activities (date of operation), and chemicals of potential concern at the former Pope and Talbot sawmill mill, Port Gamble, Kitsap County, Washington.

Source Area	Tons Soil Removed	Chemicals of Potential Concern
Diesel Storage (~1930) and Train House (~1965)	500	cPAH, Arsenic
Fuel Area (~1995)		Metals, cPAH
Wood Treatment 1 (~1965)	1,900	Lead, cPAH
End Paint 1/Near the Sawmill (~1950)	5,500*	Mercury
Maintenance Area/ Boiler/ Sawmill (~1900-1995)	13,420	TPH (diesel and oil), cPAH, Chromium, Lead, Mercury
Bull Chain Area (~1929-1995)	2,300	TPH (diesel and oil)
Wood Treatment 2 (~1950-1992)	1,000	Mercury, cPAH
Wood Treatment 3 (~1995)	340*	TPH, arsenic
End Paint 2 (~1995)	300	Mercury
Locomotive Shed (~1970)	320	Mercury, chromium
Fuel Oil Storage (~1990-1995)	570	TPH, cPAH
Other Areas		
Additional Fuel and Oil Storage Area	150	cPAH
Hog-fuel Burner		Dioxin/Furan

Source: Data collected in 1999-2001 and remediated in 2002 as summarized and reported in the 2011 remedial investigation report for the upland former sawmill (3). *Areas remediated in 2004 and 2005

cPAH–Polycyclic aromatic hydrocarbons associated with carcinogenic health effects
SVOC–Semi-volatile organic compounds (many in this case associated with petroleum
TPH–Total petroleum hydrocarbons (diesel range or motor oil range)

Dredging and Sediment Removal Activities

The purpose of this public health assessment is directly related to chemical concentrations on the intertidal (shoreline) sediments. In the past, Pope and Talbot likely dredged the narrow channel into the bay near the former mill area to allow boats easy access the bay; however, specific dates and depths of dredging are not available. Prior to 1998, limited information was available on sediment chemistry in Port Gamble Bay. Pope and Talbot, Pope Resources, and the Olympic Property Group have facilitated the following remedial activities:

- In 2003, Pope and Talbot dredged approximately 13,500 cubic yards of sediment and wood waste from 1.8 acres of a mostly subtidal area to the west of the southern chip loading facility.
- In 2007, Ecology, working with DNR and Pope Resources, dredged approximately 17,500 cubic yards of sediment and wood waste in the 1-acre area adjacent to the 2003 dredging area and placed a clean layer of sand over the newly dredged area.

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Characterization of subtidal sediments in the bay has been done by Pope Resources and Olympic Property Group as well as more recent efforts by Ecology. Intertidal and subtidal sediments have also been characterized by Ecology as part of Port Gamble Bay's listing on the Puget Sound Initiative[15]; however, subtidal sediment data are not reviewed in this report.

In 2012, Ecology's Remedial Investigation (RI) cleanup report recommended that five sediment management areas be considered in the feasibility study for clean up (4). These areas were created based on ecological toxicity and/or human health threats from wood waste breakdown products, cPAHs, and dioxin/furan compounds. The areas include: 1) the embayment to the northeast of the former mill between the jetty and the point, 2) the embayment and area that extends south of the former mill, 3) the central bay, 4) the former lease area (FLA, see description below), and 5) a larger area that encompasses all four of the other areas in the west-central portion of Port Gamble Bay.

Former Landfills

As part of Ecology's Voluntary Cleanup Program, Parametrix, on behalf of Pope and Talbot, conducted several investigations in the early 2000s to characterize soils and sediments at Landfills 2, 3, and 4. These landfills are located south of the former mill on the western shore of the bay between State Road 104 and the bay (Figure 1) (5;6;30). Ecology determined in December 2003 that the release of metals from the intertidal sediments of Landfills 2 and 3 did not pose a threat to human health. As a result, no sediment remedial activity took place. Sediment at Landfill 4 was remediated in 2004. Debris was still visible in the intertidal zone at all these landfills, especially Landfills 2 and 3, during site visits in 2011 and consists of brick, fire brick, asphalt, concrete, and metal pieces.

Landfill 2

This landfill is about an acre in size and located one-third mile south of the town on the western shore of the bay. The landfill was reportedly used for disposal of building demolition debris until 1950 (5). Because of upland slope erosion, deposited debris has moved down the slope into the upper intertidal zone (approximately between +12 and -5 feet mean sea level, (MSL)). After preliminary sediment sampling showed that cadmium, copper, and zinc exceeded Ecology's Sediment Quality Standards (SQS) (31), Parametrix conducted a debris survey and more sediment sampling in 2001 (5). The debris survey found approximately 1,000 cubic yards of debris present on the shoreline up to two and a half feet in depth. Sediment sampling consisted of 12 discrete surfaces (top 10 cm) grab samples outside of the debris zone and four composite samples from within the debris zone. These samples were analyzed for metals, total petroleum hydrocarbons (TPH), and volatile organic compounds (VOCs), including PAHs and PCBs. These data are included in this assessment and are summarized in Appendix D, Table D1, and Appendix E, Table E3.

[15] http://www.ecy.wa.gov/puget_sound/2007actionagenda.htm

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Landfill 3

This landfill is located about 700 feet south of Landfill 2 and is less than one-half acre in size. This site was used as a refuse and debris dump prior to the 1950s (5). In parallel with the Landfill 2 study, Parametrix also performed a debris survey and collected seven surface grab samples and two composite samples. The debris survey indicated that there was approximately 300 cubic yards of debris, which has greater than 40% of surface coverage at the Landfill. These sediment data are included in this assessment and summarized in Appendix D, Table D1 in the main text and Appendix E, Table E3.

Landfill 4

This former landfill served as a disposal site for the town of Port Gamble for a limited period around 1940; however, the specific period of operation and nature of material disposed is not known(6;7). This landfill consists of two areas, designated as Landfills 4A and 4B. Landfill 4A, the northern most area, covered approximately one acre and consisted of 7,000 cubic yards of debris consisting of decomposed solid wastes, such as domestic trash and debris, industrial demolition material, and ash. Landfill 4B, approximately 200 feet south of Landfill 4A, covered approximately one-half acre of the intertidal zone and consisted of 3,000 cubic yards of primarily industrial debris and ash. Pope and Talbot completed debris and sediment removal in September and October 2004. A total of 1,300 tons of sediment was excavated as deep as three feet. After confirmation sampling, the excavation area was backfilled with a shoreline mix material in late October 2004. Confirmation sampling data are not used in this evaluation since the area sampled was subsequently covered.

Log Rafting, Sorting, and Transfer Activities

Log rafting has occurred in the bay south of the mill from the early days of the mill according to aerial photos. Two areas specific to log rafting have been identified south of the mill (4;12). Considerable wood debris and wood waste has been identified in and on the sediments near the mill and in the bay. This wood debris has not been associated with specific chemical contamination other than those associated with decaying wood processes. When milling and log rafting ceased in 1995, Pope and Talbot removed pilings from the former leased area in 1996. Pilings have creosote-related contamination issues, mostly PAHs.

Former Log Transfer Facility (FLTF)

The location of the FLTF haul out road is approximately half a mile south of the former mill. Pope and Talbot used this area to transfer logs into the bay from 1970 to 1995. It consisted of a dock, pilings, and an access road. Parametrix indicated that results of the 1999 survey identified a small area of wood debris covered by 0.5–1 foot of sediment near the FLTF.

Former Leased Area (FLA)

Pope and Talbot leased a 72-acre area from Department of Natural Resources (DNR Lease No. 20-012795) for in-water storage from 1970 to 2001 for temporary log storage and transfer purposes. Log rafting ceased in 1995 when the mill closed. Parametrix reported that based on site operations, there were no sources of contaminants within the lease area and that the only potential sources included contaminants from residential, commercial, and agricultural upland activities

(32). In 2012, Ecology's cleanup report identified a relatively small sediment management area in the FLA for further consideration in the feasibility study based on ecological toxicity threats (4). However, both of these rafting areas are included in the site boundary defined by elevated cPAHs in subtidal sediments.

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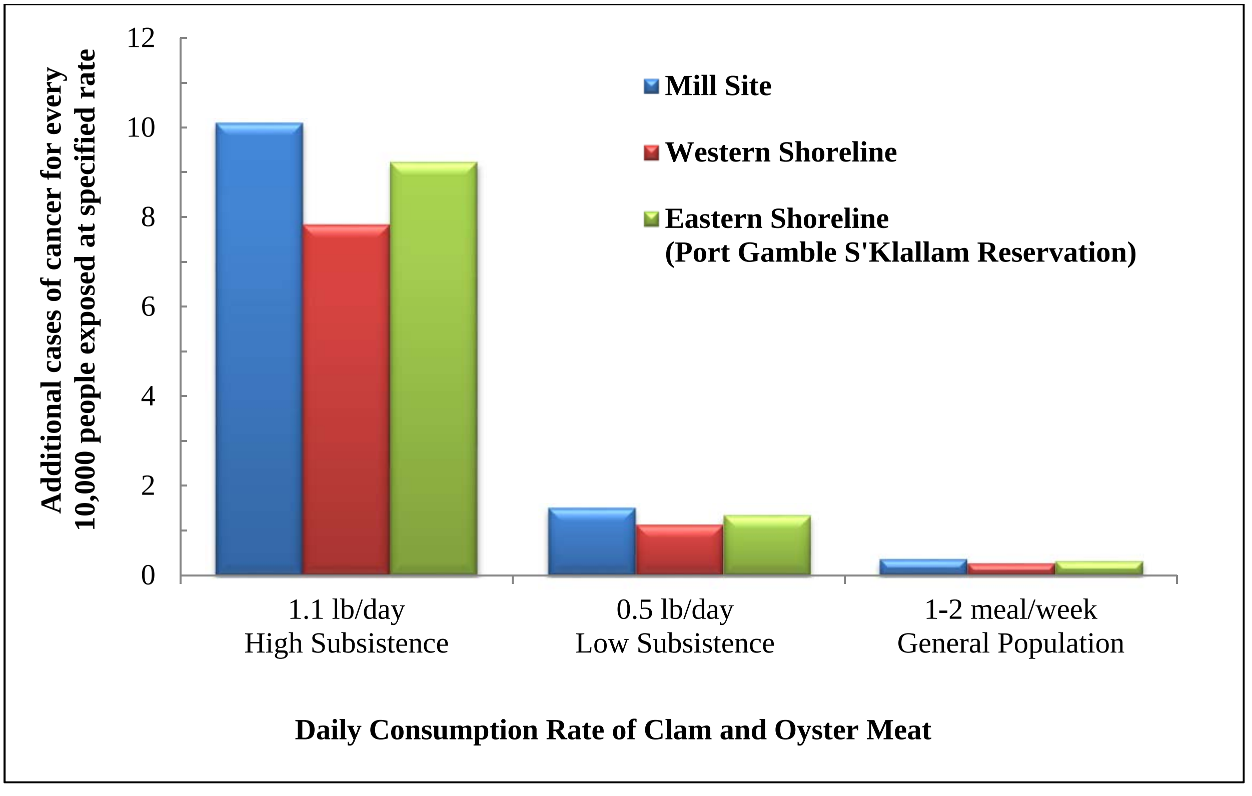
Appendix C–Response to Community Concerns

A number of community health concerns related to Port Gamble Bay were expressed during tribal meetings/interviews and outreach activities. Specific individual health concerns identified during discussions are addressed below.

1. **How does the risk from eating clams and oysters from the reservation shoreline differ from eating clams and oysters from the former mill area or western shoreline?**

DOH Response: Based on current sampling results and the number of clams and oysters tribal members or the general population may eat, the estimated cancer risk from eating clams and oysters harvested on the reservation is lower than at the former mill area (Figure C1). However, the cancer risk for each of these areas is influenced by different chemicals found in the shellfish.

Figure C1. Comparison of lifetime cancer risk from exposure to contaminants by eating clams and oysters from different shorelines in the upper portion of Port Gamble Bay at tribe-estimated and general population consumption rates.



Estimated cancer risks from eating clams and oysters from the former mill area are driven by arsenic and carcinogenic PAHs, whereas, the risks from eating clams and oysters from the reservation shoreline are driven by arsenic, dioxin and dioxin-like compounds. However, some of the samples taken from the reservation that were analyzed for dioxin-like compounds had analytical issues, making these results somewhat questionable.

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2. **How does the risk of eating shellfish from Port Gamble Bay differ from eating shellfish from other areas of Puget Sound? How do current risks differ from eating shellfish in the pre-mill era?**

DOH Response: It is not possible to determine the risks from eating shellfish before the mill was established or even before to 1992, when the first shellfish sample from the bay was reported. Arsenic concentrations in Port Gamble Bay are similar to concentrations throughout Puget Sound and appear to be from natural deposits. Therefore, we assume that risks attributable to arsenic were the same in the pre-mill era. The levels of PAHs and dioxin-like compounds can either relate to past releases or activities from the former Pope and Talbot mill or be influenced by human activity both locally and globally over time (background).

Ecology compared sediment concentrations in Port Gamble Bay with background levels of chemicals in sediments from Holmes Harbor, Dabob Bay, and Carr Inlet (4). In addition, Ecology compared chemical concentrations in shellfish tissue from Port Gamble Bay tissue to sites in Puget Sound used as background comparisons for clams, geoduck and crab (4). Background sites included Dungeness Bay, Freshwater Bay, Skagit Bay, Padilla/Fidalgo Bay, Pedder Bay, Salsbury Point, Bainbridge Island, Vashon Island, Dungeness National Wildlife Refuge, Seahurst Park, Blake Island, East Passage (near Carr Inlet), Port Washington Narrows, Keyport, and Samish Island near Hat Island. Ecology did not have background oyster samples identified for use in the analysis.

A summary of Ecology's conclusions are listed in Table C1. Ecology concluded that arsenic, which contributes almost half of the cancer risk for high tribe-estimated subsistence consumers, is similar to levels found at background sites in Puget Sound and does not appear to be related to activities at the former mill. However, concentrations of cadmium, dioxin/furan compounds (crab butter only), and carcinogenic PAHs in tissues from Port Gamble Bay may be higher than some tissue concentrations from background areas in the Puget Sound.

Table C1. Summary of chemical concentrations in sediments and clam, geoduck, and crab tissue from Port Gamble compared to background concentration found throughout Puget Sound (oyster data not available).

Sediments	Shellfish	Contaminants
Below background (intertidal and subtidal)	Clams and crab (muscle and butter) below background; geoduck unknown (no background data)	Arsenic, Mercury
Intertidal below background **Subtidal above background**	**Clam above background**; geoduck, crab (muscle and butter) below background	Cadmium
Similar to background (intertidal and subtidal)	**Crab muscle above background**; crab butter below background; clam unknown (no background data)	Copper
Above background (Intertidal and subtidal)	**Crab butter above background**; clam, crab muscle, and geoduck below background	Dioxin
Similar to background (intertidal and subtidal)	Clam similar to background; crab and geoduck unknown (inadequate background data)	PCB
Above background (intertidal and subtidal)	**Clam, crab (muscle and butter), and geoduck above background**	PAH

PAH polycyclic aromatic hydrocarbons
PCB – Polychlorinated biphenyls

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As part of a U.S. Department of Agriculture (USDA) Food Safety Initiative, cadmium levels in oysters have been studied throughout Puget Sound (33). Concentrations from Puget Sound range between 0.44 to 2.5 mg/kg, with higher levels from locations within central Hood Canal. Average cadmium levels from oysters of Port Gamble Bay (1.23 mg//kg, 95%UCL) were similar to the average cadmium levels from locations throughout Puget Sound (1.24 mg/kg). Concentrations from Puget Sound ranged from 0.44 to 2.5 mg/kg, with higher levels from locations within central areas of Hood Canal.

3. Which shellfish are least contaminated? Which shellfish are the safest to eat?

DOH Response: This is a difficult question to answer because shellfish species do not accumulate contaminants in a similar manner. In our assessment, we considered how much and how often a tribal member eats a specific species and the specific chemical concentration in that species. Species considered included four groups: 1) clams (littleneck, manila, cockle, butter, and horse); 2) oysters; 3) geoduck clams; and 4) crab meat/crab butter.

Overall, clams are the highest group of shellfish consumed per day by tribal members and therefore have the highest impact on potential chemical exposures. Each of the species of shellfish measured different concentrations of each contaminant. Some species had undetected levels of contaminants.

The following summary characterizes exposure from each group of shellfish:

Clams– As estimated by the tribe, clams make up 51% to the subsistence shellfish diet, more than any other group of shellfish. Thus intake of chemicals is primarily from clam consumption. Concentrations of chemicals in native littleneck clams are well characterized and are representative of other clams (manila, cockle, butter, and horse clams). Arsenic was not detected in any of the cockles taken from the bay and levels of metals and dioxin-like compounds have not been measured in butter and horse clams.

Oysters– As estimated by the tribe, oysters make up 13% of the subsistence shellfish diet. Oysters are considered a nutritional source of zinc and copper because of their ability to accumulate these metals in their tissues. Zinc and copper are elevated in samples from Port Gamble Bay but are not considered to be a health threat. Individuals with known genetic sensitivity to copper metabolism may be at risk, but this is a rare disease (Wilson’s Disease). Cadmium is elevated in oysters from the bay and may contribute to kidney problems if clams and oysters are consumed at the tribe-estimated subsistence rate. Oysters from Port Gamble Bay have lower cadmium concentrations than oysters from Hood Canal.

Geoduck– As estimated by the tribe, Geoduck clams make up 19% of the subsistence shellfish diet. There are not enough good data to accurately estimate risks from eating geoduck from Port Gamble Bay at the tribe-estimated subsistence rates. There were only three composite samples taken at the time of this report. Not all contaminants were measured in all three samples. Some of the dioxin-like compound data and carcinogenic PAHs have detection limits too high to adequately estimate exposures. For some compounds the best available technology cannot measure low enough to determine if a health threat exists. Because there is some evidence that concentration of contaminants in subtidal sediments are elevated we believe that more geoduck sampling is needed to more accurately determine chemical exposures and health risks from eating geoduck collected in the bay.

Crab– As estimated by the tribe, crab makes up 17% of the subsistence diet, 13% of which is crab meat and 4% of which is crab butter. We cannot accurately determine the health threat posed by crab consumption. There are not enough good data to support a robust evaluation. However, based on limited samples, it appears that crab meat is the second largest contributor to arsenic intake in the subsistence diet. PCB concentrations were highest in crab butter. In Puget Sound, crab butter tends to accumulate PAHs and dioxin-like compounds at higher levels than other shellfish and crab muscle. Therefore, it is best to avoid eating this part of the crab.

4. Should we be concerned if people give fish or shellfish to the tribal food bank?

DOH Response: DOH does not have data for fish from Port Gamble Bay and therefore is not able to provide information about health threats from fish harvested from the bay.

In response to this concern, DOH contacted the Tribal food bank to see whether people were providing donations of shellfish from Port Gamble Bay and how often this activity occurs. The food bank did not have any record of receiving these types of donations. Therefore, this is not an issue of concern. However, tribal members have indicated that harvest of seafood is often shared among tribal members. As discussed below (question 7), shellfish are low in calories and fat and offer a good source of protein.

Whether you get seafood from a store, market, or some other source, it is always good to know where it comes from. This will allow you to make informed choices about the food brought home.

5. Is there a concern for elders who have harvested from the bay their whole lives?

DOH Response–We assessed lifetime cancer risks for individuals eating shellfish every day of the year from 0.5 years old to those who live to 78 years of age. According to the tribe, high-end consumers eat approximately 1.1 pounds of shellfish meat (uncooked) every day. This consists of clam (51%), oyster (13%), geoduck (19%), and crab (17%). For these consumers, the overall long term cancer risk from exposure to multiple chemicals is estimated to be 1.6 additional cancers for every 1,000 people exposed at the subsistence rate of consumption.

In addition, there is some scientific evidence indicating that non-carcinogenic effects could occur during the lifetime of a consumer eating at the tribe-estimated consumption rate. These high consumption rates may lead to kidney effects or developmental and reproductive health effects. It is important to understand the level of risk posed by this level of exposure from shellfish compared to other sources protein (see response to #7 and #8 below).

6. Poverty rate is significant on the reservation. Some tribal members depend on fish and shellfish as their main source of food. How will these people be affected?

DOH Response: According to the 2010 Census, 20% of the Port Gamble Tribal Community population is below poverty level. Along with fish, harvesting shellfish from Port Gamble Bay may be a main source of protein for these people and their families. DOH's assessment concluded that contaminant levels in shellfish from the bay are low and not a risk to people who eat them at a lower tribe-estimated subsistence rate (0.5 pounds per day for 78 years or less). However, there may be a higher risk to those who eat at the high tribe-estimated subsistence rate (1.1 pounds shellfish meat per day for 78 years). Depending on the nutrition level and contaminant level of alternative foods, this risk may not be significantly higher (see questions #7 and #8).

7. What is the comparative risk of eating clams from Point Julia versus fast food hamburgers or store bought foods?

DOH Response: Everyone is exposed to dioxin-like compounds, metals, and cPAHs because these chemicals are present at low levels in many foods available from the marketplace and present throughout our environment. For nonsmokers, about 90% to 95% of exposure to these chemicals usually comes from food[16].

The U.S. Food and Drug Administration (FDA) monitors potential dietary sources of dioxin/furan compounds in food and then works to eliminate sources before they enter the food supply[17]. For example, an adult tribe member eating 1.1 pounds of shellfish meat a day has an estimated intake of dioxin-like compounds higher than the U.S. population intake from protein sources other than shellfish (Table C2). However, a similar level of risk for both cancer and non-cancer effects is expected to occur based on the intake of the U.S. population. Thus, it is difficult to tell how these low levels of exposure will impact an individual's health differently from that of the larger population.

Table C2. Comparison of age-specific dioxin/furan intake (pg/kg-day) estimated by U.S. FDA with Port Gamble Bay tribal intakes.

Age Groups	Infants (6 to < 12 mo.)	Children (6 yrs)	Children (10 yrs)	Children (14-16 yrs)	Adults (25-30 yrs)	Adults (60-70 yrs)
Intake based on U.S. FDA total diet study foods collected in 2001-2004						
Total (fats, oils, fruits, vegetables, proteins, other)	1.7	1.5	1.1	0.8-1.0	0.7-0.8	0.6
Total (protein only: dairy, eggs, fish, meat, poultry)	1.1	0.8	0.5	0.06	0.01	0.03
Port Gamble Total Intake from age-specific shellfish consumption						
Shellfish (high tribe-estimated subsistence consumer rate)	3.4	1.8	1.0	3.3	2.3	2.5
Shellfish (low tribe-estimated subsistence consumer rate)	0.4	0.19	0.10	0.55	0.39	0.4

Notes: Source U.S. FDA dioxin furan exposure estimates assuming non-detects at the level of detection

[16] https://fortress.wa.gov/ecy/publications/publications/1109219.pdf

[17] http://www.fda.gov/Food/FoodSafety/FoodContaminantsAdulteration/ChemicalContaminants/DioxinsPCBs/ucm077498.htm

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The main source of exposure to PAHs for adults is food.[18] PAHs are found in grains (cereal) and fats (oils). Cereals have been found to be the main dietary source of PAHs contributing 27% to 35% of total dietary exposure. For smokers, a significant contribution of PAH exposures comes from cigarette smoke. Additionally, cooking steps such as roasting, grilling, barbecuing, and smoking generate PAHs and increase the level of PAHs in the food being cooked. Charred food of any kind contains PAHs but they vary in concentration and type. Levels of PAHs in these foods are similar to those found in shellfish at Port Gamble Bay.

When comparing risk and benefits from different foods to determine what food choice may be better for you, it is important to understand the dietary guidelines established for a healthy diet. Knowing the number of calories your body needs, the kinds of fats you should include or limit in your diet, and the recommended food groups will help determine what choices are better for you.

Though the bodies of Native Americans may have adapted differently than average Americans, the 2010 Dietary Guidelines for Americans provides a foundation for people to follow. Some of the main things to keep in mind include:

- *Calorie Intake*–Recommended calorie intakes are: 1,600– 2,400 kilocalories (kcal) per day for women; 2,000–3,000 kcal per day for men; 1,000–2,000 kcal per day for young children; and 1,400–3,200 kcal per day for older children (usually boys will have higher calorie needs than girls). Calorie intake should vary depending on a person's level of physical activity.
- *Foods to Reduce*–It is recommended that people lower their intake of sodium, solid fats (saturated- and trans-fatty acids), sugars, cholesterol, and refined grains. Eating too much of these increases a person's risk of some chronic diseases, such as diabetes and heart disease.
- *Foods to Increase*–It is recommended that people increase their intake of nutrient-rich foods, which provide vitamins, minerals, and relatively few calories.

We can compare the nutritional content of clams with other sources of protein people may commonly eat (e.g., hamburger, chicken, pork, and salmon) to weigh the benefit and potential risks of each food (Table C3). When comparing tribal intakes of seafood to equivalent amounts of other sources of protein, you can see that the shellfish have approximately a third of the calories and a tenth of the fats while still providing a good amount of protein. Thus, shellfish are a highly recommended addition to the diet.

[18] http://fsrio.nal.usda.gov/pathogens-and-contaminants/chemical-and-physical-contaminants/polycyclic-aromatic-hydrocarbons

Table C3. Nutritional content of clams, oysters, and crabs at high and low tribe-estimated subsistence intake rates compared to other sources of protein commonly eaten at the same rates.

Food	Calories (kcal)	Fats (g)	Saturated Fats (g)	Choles-terol (mg)	Protein (g)	Sodium (mg)
Low tribe estimated subsistence consumer rate (geoduck and crab butter not available)						
Clams, mixed species, raw (111.3g)	96	1.1	0.21	33	16.3	669
Oysters, Pacific, raw (27.1 g)	22	0.6	0.14	14	2.6	29
Crab, Dungeness, raw (27.4 g)	24	0.3	0.04	16	4.8	81
Total (165.8 g)	142	2.0	0.39	63	23.7	779
Other Sources of protein (165.8 g) equivalent amount						
Hamburger, large, fast food, plain	516	27.7	10.2	86	27.4	574
Chicken, roasted meat and skin	370	22.2	6.2	126	39.7	153
Pork chops, braised, bone in	423	26.1	7.4	143	44.0	114
Salmon, sockeye, cooked dry heat	280	11.1	1.5	104	42.1	222
Salmon, Chinook, smoked	194	7.2	1.5	38	30.3	1300
High tribe-estimated subsistence consumer rate (geoduck and crab butter not available)						
Clams, mixed species, raw (255 g)	219	2.5	0.5	76	37.4	1533
Oysters, Pacific, raw (62.4)	51	1.4	0.3	31	5.9	66
Crab, Dungeness, raw (62.9)	54	0.6	0.1	37	11.0	186
Total (380.3 g)	324	4.5	0.9	144	54.3	1785
Other sources of protein (380.3 g) equivalent amount						
Hamburger, large, fast food, plain	1182	65.4	23.3	198	62.4	1315
Chicken, roasted meat and skin	847	50.9	14.2	289	91.9	153
Pork chops (blade), braised, bone in	970	59.8	17.1	327	100.9	262
Salmon, sockeye, cooked dry heat	643	25.4	3.5	240	96.6	510
Salmon, Chinook, smoked	445	16.4	3.5	87	69.5	2982

Source: U.S. Department of Agriculture National Nutrient Database (26) adapted to intake rates provided by Port Gamble S'Klallam Tribe
Abbreviations: grams (g), milligrams (mg), kcal (kilocalories, equal to Calories)
Note: Raw seafood values differ from cooked seafood values.

8. Growing up, we were taught that shellfish are a healthy food. If affected by contamination, what does this mean for this good food source?

DOH Response: It is important to consider both the benefits gained from eating shellfish and potential negative health effects from shellfish if they contain any amount of contaminants. See the nutritional value of shellfish compared to other sources of protein above (Table C3)

Shellfish are a nutritious source of protein. They are low in calories and saturated fats and are a healthy contribution to a low fat diet. Shellfish are also a good source of omega-3 fatty acids and essential nutrients like iron, zinc, copper, and vitamin B-12. DOH recommends everyone incorporate shellfish into their diet. In addition, subsistence harvest provides daily physical activity that counters other risk factors (e.g., being overweight) for health effects such as diabetes and cancer).

Often, doctors cannot explain why one person develops cancer and another does not. Research shows that risk factors increase the chance that a person will develop cancer. The most common risk factors for cancer include growing older, tobacco, sunlight, ionizing radiation, viruses, bacteria, hormones, family history of cancer, alcohol, poor diet, lack of physical activity, being overweight, and some environmental chemicals. According to the National Cancer Institute (NCI), 41.24% of men and women born today (approximately 1 in 2 adults) will be diagnosed with cancer at some time during their lifetime (based on 2007–2009 incidence rates) (27). The contribution of risks from eating contaminated shellfish at the high tribe-estimated subsistence rate are 1,000 to 10,000 times lower than the overall risk of developing cancer in your lifetime. Eating other meats will have a larger impact on caloric intake and decrease the amount of physical activity, both of which are associated with overweight conditions which can lead to increased cancer risk.

This assessment concludes that eating shellfish from the upper portion of Port Gamble Bay at the high and low tribe-estimated subsistence consumption rate every day for a lifetime could be harmful to the health of adult or child tribe members. While some exposure does occur, only tribal members who eat shellfish every day at the high tribe-estimated subsistence rate (1.1 pound of shellfish meat per day for a lifetime) have some estimated risk of developing cancer, kidney effects, or showing developmental and reproductive effects. However, while calculated cancer risks for the low tribe-estimated consumption rate (half a pound of shellfish meat per day for a lifetime) falls just outside the EPA's cancer risk range, they are still within what is considered background risk levels in the Puget Sound.

Many factors must be considered when one is recommending limits or rates on the consumption of shellfish. They include the positive health benefits of eating shellfish, the quality and comprehensiveness of environmental data, and the availability of alternate sources of nutrition. In addition, these limits or rates do not take into account that multiple shellfish species are consumed. This would require weighting the percent of each species eaten. Also, the major risk is coming from the level of arsenic, which would still occur no matter where the shellfish were collected in Puget Sound. While there are contaminants in shellfish, there is less concern about eating shellfish from the bay daily at the low tribe-estimated subsistence consumption rate.

9. What does the contamination mean for people who make a living from fish and shellfish of the bay?

DOH Response: DOH does not have fish tissue data for Port Gamble Bay and therefore does not address fish consumption in this public health assessment. DOH does have statewide and Puget Sound fish advisories that people can check before fishing. For more information, about possible advisories for the water bodies where you fish, check DOH's fish website (www.doh.wa.gov/fish).

For shellfish the southern shoreline is currently open for commercial shellfish harvesting. Impacts to these commercial areas could happen during and after the remedial action. DOH will close approved commercial harvest sites on a parcel-by-parcel basis depending on where remedial action is taking place. Information about shellfish locations can be found the Department of Health website.[19]

DOH's evaluation looked at sediments and shellfish from the upper portion of Port Gamble Bay. The western shoreline and mill area are closed for shellfish harvesting. Based on the evaluation, sediment exposure is not expected to increase people's risk. The western shoreline will be opened for commercial harvest after cleanup and shellfish data confirm the area is okay.

10. What is the additive risk of multiple chemicals that people may be exposed to?

DOH Response: There are two kinds of risks: risk of developing cancer and risk of health effects not related to cancer.

Cancer Risks– Based on U.S. cancer rates from 2007–2009, 41.24% of men and women (1 in 2 people) born today will be diagnosed with cancer at some time during their lifetime. The risk of developing cancer from different chemicals can be determined by adding the risks from each chemical together. For people eating at the high tribe-estimated subsistence consumption rate, the risk from exposure to multiple chemicals is *two additional cancers for every 1,000* people (eating 1.1 pounds of shellfish meat per day for 78 years). For those who eat at the low tribe-estimated subsistence consumption rate of one-half pound of shellfish meat a day the risk is less, approximately *three additional cancers for every 10,000 people* (eating one-half pound of shellfish meat per day).

Non-Cancer Risks–For non-cancer risks, it is difficult to add up effects caused by different chemicals because they target different areas of the body. For example cadmium intake by high tribe-estimated subsistence consumer rate may result in health effects for the kidney. Exposure to dioxin-like compounds at the high tribe-estimated subsistence rate may result in reproductive or developmental effects. Since these effects are different they are not additive. Eating shellfish at the low tribe-estimated consumption rate (one-half pound a day) is not expected to result in these effects.

11. What is the risk to children playing on the shoreline of Point Julia during the summertime?

DOH Response–There is very little risk to children playing on the shoreline of the reservation during the summertime. Although some exposure to contaminants does occur, levels that can get into a child's body will not result in harmful health effects. You can reduce exposures by washing hands before eating, reducing the amount of hand-to-mouth behavior, and bathing after trips to the shoreline.

[19] www.doh.wa.gov/CommunityandEnvironment/Shellfish.aspx

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Appendix D–Screening Evaluation Methodology

Sediment Comparison Values (CVs) for Screening

ATSDR developed environmental guidelines for substances in soil that will be used as surrogates for exposures to sediments on the shoreline. These guidelines are derived in a uniform way using health guidelines and standard default exposure assumptions. The default exposure assumptions generally represent high estimates of exposure (greater than the mean, approaching the 90^{th} percentile) based on observed ranges of child activity patterns (e.g., ingestion rates, residence times, etc.).

- **Environmental Media Evaluation Guides (EMEGs):** EMEGs are estimated contaminant concentrations that are not expected to result in adverse non-carcinogenic health effects based on ATSDR evaluation. EMEGs are based on ATSDR minimal risk levels (MRL, see description below) and conservative child assumptions about exposure, such as intake rate, exposure frequency and duration, and body weight.
- **Cancer Risk Guides (CREGs):** CREGs are estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10^{-6}) persons exposed during their lifetime (70 years). ATSDR's CREGs are calculated from EPA's cancer slope factors (CSFs) for oral exposures or unit risk values for inhalation exposures. These values are based on EPA evaluations and assumptions about hypothetical cancer risks at low levels of exposure.
- **Reference Dose Media Evaluation Guides (RMEGs):** ATSDR derives RMEGs from EPA's oral reference doses (RfD, see description below), which are developed based on EPA evaluations. RMEGs represent the concentration in water or soil at which daily human exposure is unlikely to result in adverse non-carcinogenic effects.

If a chemical is known to have carcinogenic effects, it is automatically identified as a Chemical of Potential Concern (COPC) and considered further, unless the exposure concentration is several orders of magnitude below the CV or not detected consistently. Cadmium is an exception as its carcinogenic effects only occur after inhalation exposure, not ingestion, thus carcinogenic effects were not evaluated further in this assessment.

Typically, ATSDR methodology selects the lowest comparison value to be consistent with the conditions of exposure at or near the site for screening purposes. In this case, chronic exposures for children most closely represent those that would occur at the site. CVs used to screen sediment concentrations can be found in Table D1.

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Table D1. Maximum concentration [a] of chemicals in intertidal sediments compared to health-based comparison values for residential soil [b] exposures at Port Gamble Bay, Kitsap County, Washington.

Chemical	Maximum Sediment Concentrations (mg/kg) around the Bay [a,b] (Number Detected / Number of Samples)								Health-Based Soil CV (mg/kg) [b]	Type of CV [c]
	Mill	Landfill 2	Landfill 3	Log Sort Areas	Creeks to South	Eastern Shore	Reser-vation	Reser-vation Creek		
Total Metals [d]										
Arsenic	**4.1** (10/10)	**10 J** (3/17)	**20.9 J** (2/10)	**3.5** (4/4)	**6.1** (4/4)	**2.5** (2/2)	**6.0** (2/8)	**8 U** (0/4)	**0.47** 15	**CREG** cEMEG
Cadmium [e]	1.1 (5/10)	1.5 (6/17)	0.70 (2/10)	0.74 (4/4)	0.3 (1/4)	0.2 (1/2)	0.2 U (0/8)	0.3 U (0/4)	5 2	cEMEG MTCA
Chromium	31.4 (10/10)	**211.6** (17/17)	32.9 (10/10)	20.5 (4/4)	40 (4/4)	25.6 (2/2)	23.1 (8/8)	32.4 (4/4)	50	cEMEG Cr(VI)
Copper	41.6 (10/10)	217 (17/17)	56.6 (10/10)	10 (4/4)	20.4 (4/4)	12.2 (2/2)	19.5 (8/8)	68.4 (4/4)	500	iEMEG
Lead	24 (10/10)	216 (17/17)	**252** (10/10)	3 (1/4)	9 (4/4)	3.0 U (0/2)	13 (6/8)	49 (4/4)	400 250	RSL MTCA
Mercury	0.03 (2/10)	0.044 (14/17)	0.106 (9/10)	0.03 (4/4)	0.08 (4/4)	0.03 U (0/2)	0.03 U (0/8)	0.25 (2/4)	5 1	RMEG Methyl mercury MTCA
Silver	0.9 U (0/10)	2.5 U (0/17)	2.5U (0/10)	0.4U (0/4)	0.8 U (0/4)	0.4 U (0/2)	0.4 U (0/8)	0.5 U (0/4)	250	RMEG
Zinc	175 (10/10)	513 (17/17)	78.3 (10/10)	29 (4/4)	50 (4/4)	40 (2/2)	31 (8/8)	58 (4/4)	15,000	cEMEG
Polychlorinated Aromatic Compounds										
Dioxin/Furan TCDD-EQ [e]	1.83E-5 (6/6)	7.49E-7 (1/1)	4.17E-7 (1/1)	1.46E-6 (3/3)	2.2E-6 (4/4)	6.34E-7 (2/2)	1.88E-7 (2/2)	-	3.5E-5	RMEG
PCB Congener TCDD-EQ [e]	1.03E-7 (6/6)	1.22E-7 (1/1)	4.11E-8 (1/1)	2.67E-7 (3/3)	1.4E-7 (4/4)	2.11E-8 (2/2)	2.16E-8 (2/2)	-	3.5E-5	RMEG
PCB Aroclor	-	0.016 (5/16)	0.075 (6/9)	-	-	-	-	-	1	cEMEG

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Table D1. (Continued).

Chemical	Maximum Sediment Concentrations (mg/kg) around the Bay [a,b] (Number Detected / Number of Samples)								Health-Based Soil CV (mg/kg) [b]	Type of CV [c]
	Mill	Landfill 2	Landfill 3	Log Sort Areas	Creeks to South	Eastern Shore	Reser-vation	Reser-vation Creek		
Polycyclic Aromatic Hydrocarbons (PAHs) with Carcinogenic Effects [g]										
~Benz(a)anthracene	0.018 U (5/10)	0.017 (3/17)	0.004 U (0/10)	0.016 (1/4)	0.016 (2/4)	0.0028 (1/2)	0.0048 (1/6)	0.060 U (0/4)		cPAH [g]
~Benzo(a)pyrene	0.018U (3/10)	0.031 (10/17)	0.003 (2/10)	0.016 (1/4)	0.054 (3/4)	0.0074 (1/2)	0.0048 U (0/6)	0.060 U (0/4)	0.096	CREG
~Benzo(b)fluoranthene	0.25 (7/10)	0.034 (8/17)	0.006 (3/10)	0.016 (1/4)	0.026 (2/4)	0.0075 (2/2)	0.0048 U (0/6)	0.060 U (0/4)		cPAH [g]
~Benzo(k)fluoranthene	0.092 (7/10)	0.078 (14/17)	0.12 (6/10)	0.016 (1/4)	0.022 (3/4)	0.0068 (2/2)	0.0048 (1/6)	0.059 (1/4)		cPAH [g]
~Chrysene	0.76 (9/10)	0.15 (16/17)	0.035 (7/10)	0.074 (1/4)	0.1 (4/4)	0.050 (2/2)	0.015 (3/6)	0.120 (2/4)		cPAH [g]
~Dibenz (a,h) anthracene	0.054 (6/10)	0.010 (5/17)	0.004 (1/10)	0.018 (1/4)	0.015 (2/4)	0.0028 (1/2)	0.0048 U (0/6)	0.060 U (0/4)		cPAH [g]
~Indeno(1,2,3-c,d)pyrene	0.018U (4/10)	0.0042 (1/17)	0.002 U (0/1)	0.016 (1/4)	0.013 (3/4)	0.0027 (1/2)	0.0048 U (0/6)	0.060 U (0/4)		cPAH [g]
~Total cPAH BaP-EQ[g]	**0.347** (9/10)	**0.123** (17/17)	0.033 (5/10)	0.035 (1/4)	0.028 (4/4)	0.022 (2/2)	0.0098 (2/6)	**0.133** (2/4)	**0.096**	**CREG (BaP)**
PAHs with non-carcinogenic effects (ncPAH)										
Acenaphthene	0.018 U (5/10)	0.017 (3/17)	0.004 U (0/10)	0.016 (1/4)	0.016 (2/4)	0.0028 (1/2)	0.0048 (1/6)	0.060 U (0/4)	3,000	RMEG
Acenaphthylene	0.018U (3/10)	0.031 (10/17)	0.003 (2/10)	0.016 (1/4)	0.054 (3/4)	0.0074 (1/2)	0.0048 U (0/6)	0.060 U (0/4)	3,000	RMEG (acenaphthene)
Anthracene	0.25 (7/10)	0.034 (8/17)	0.006 (3/10)	0.016 (1/4)	0.026 (2/4)	0.0075 (2/2)	0.0048 U (0/6)	0.060 U (0/4)	15,000	RMEG
Benzo(g,h,i) perylene	0.092 (7/10)	0.078 (14/17)	0.12 (6/10)	0.016 (1/4)	0.022 (3/4)	0.0068 (2/2)	0.0048 (1/6)	0.059 (1/4)	1,500	RMEG (pyrene)
Fluoranthene	0.76 (9/10)	0.15 (16/17)	0.035 (7/10)	0.074 (1/4)	0.1 (4/4)	0.050 (2/2)	0.015 (3/6)	0.120 (2/4)	2,000	RMEG
Fluorene	0.054 (6/10)	0.010 (5/17)	0.004 (1/10)	0.018 (1/4)	0.015 (2/4)	0.0028 (1/2)	0.0048 U (0/6)	0.060 U (0/4)	2,000	RMEG

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Table D1. (Continued).

Chemical	Maximum Sediment Concentrations (mg/kg) around the Bay [a,b] (Number Detected / Number of Samples)								Health-Based Soil CV (mg/kg) [b]	Type of CV [c]
	Mill	Landfill 2	Landfill 3	Log Sort Areas	Creeks to South	Eastern Shore	Reser-vation	Reser-vation Creek		
1-Methylnapthalalene	0.018U (4/10)	0.0042 (1/1)	0.002 U (0/1)	0.016 (1/4)	0.013 (3/4)	0.0027 (1/2)	0.0048 U (0/6)	0.060 U (0/4)	3,500	cEMEG
2-Methylnaphthalene	0.0088 (4/6)	0.0050 (3/17)	0.005 U (0/10)	0.006 (1/4)	0.018 (2/4)	0.0032 (1/2)	0.0048 U (0/6)	0.060 U (0/4)	200	RMEG
Naphthalene	0.063 (2/10)	0.044 (12/17)	0.01 (7/10)	0.058 (1/4)	0.3 (2/4)	0.030 (2/2)	0.066 (2/6)	0.059 (1/4)	1,000	RMEG
Phenanthrene	0.20 (8/10)	0.11 (15/17)	0.015 (4/10)	0.046 (1/4)	0.016 (4/4)	0.024 (2/2)	0.010 (2/6)	0.071 (2/4)	1,500	RMEG (Pyrene)
Pyrene	0.430 (9/10)	0.14 (16/17)	0.034 (6/10)	0.075 (1/4)	0.016 (4/4)	0.042 (2/2)	0.016 (3/6)	0.096 (2/4)	1,500	RMEG
Semi-Volatile Organic Compounds										
1,2,4-Trichlorobenzene	-	0.0070 U (0/17)	0.004 U (0/10)	0.0034 U (0/3)	0.034 U (0/4)	0.0033 U (0/2)	0.0033 U (0/2)	0.06 U (0/4)	500	RMEG
1,2-Dichlorobenzene	-	0.004 (0/17)	0.004 U (0/10)	0.0024 U (0/3)	0.0024 U (0/4)	0.0024 U (0/2)	0.0024 U (0/2)	0.06 U (0/4)	4,500	RMEG
1,3-Dichlorobenzene	-	0.0024 U (0/1)	0.0025 (1/1)	0.0025 U (0/3)	0.0026 U (0/4)	0.0025 U (0/2)	0.0025 U (0/2)	0.06 U (0/4)	1,000	iEMEG
1,4-Dichlorobenzene	-	0.0030 U (0/17)	0.004 U (0/10)	0.0028 U (0/3)	0.0028 U (0/4)	0.0027 U (0/2)	0.0027 U (0/2)	0.06 U (0/4)	3,500	cEMEG
2,4-Dimethylphenol	-	0.030 (8/17)	0.003 (3/10)	0.0033 U (0/3)	0.0034 U (0/4)	0.0033 U (0/2)	0.0033 (0/2)	0.06 U (0/4)	1,000	RMEG
2-Methylphenol (o-cresol)	-	0.0060 (1/17)	0.005 U (0/10)	0.0051 U (0/3)	0.011 (1/4)	0.005 U (0/2)	0.0049 U (0/2)	0.06 U (0/4)	2,500	RMEG
4-Methylphenol (p-cresol)	-	0.16 (6/17)	0.0014 (2/10)	0.0064 U (0/3)	0.0064 U (0/4)	0.0063 U (0/2)	0.0062 U (0/2)	0.06 U (0/4)	2,500	RMEG (o-cresol)
Benzoic acid	-	8 (16/17)	0.097 (9/10)	0.098 U (0/3)	0.075 U (0/4)	0.095 U (0/2)	0.0095 U (0/2)	0.06 U (0/4)	200,000	RMEG
Benzyl alcohol	-	0.027 (8/17)	0.037 (3/10)	0.0059 U (0/3)	3.3 U (0/4)	0.0057 U (0/2)	0.0057 U (0/2)	0.3 U (0/4)	6,100	RSL
Bis(2-Ethylhexyl) phthalate	-	0.33 (1/17)	0.2 U (0/10)	0.014 U (0/3)	0.014 U (0/4)	0.014 U (0/2)	0.014 U (0/2)	0.06 U (0/4)	50	CREG

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Table D1. (Continued).

Chemical	Maximum Sediment Concentrations (mg/kg) around the Bay [a,b] (Number Detected / Number of Samples)								Health-Based Soil CV (mg/kg) [b]	Type of CV [c]
	Mill	Landfill 2	Landfill 3	Log Sort Areas	Creeks to South	Eastern Shore	Reser-vation	Reser-vation Creek		
Butylbenzyl phthalate	-	0.006 U (0/17)	0.0059 U (0/10)	0.0059 U (0/3)	0.006 U (0/4)	0.0058 U (0/2)	0.0058 U (0/2)	0.06 U (0/4)	10,000	RMEG
Dibenzofuran	0.018 5/6	0.0056 (2/5)	0.0040 U (0/10)	0.011 U (0/3)	0.026 (3/4)	0.0038 (1/2)	0.0048 U (0/2)	0.06 U (0/4)	78	RSL
Diethyl phthalate	-	0.033 U (0/17)	0.035 (1/10)	0.0059 (1/3)	0.036 (1/4)	0.0035 U (0/2)	0.034 U (0/2)	0.06 U (0/4)	40,000	RMEG
Dimethyl phthalate	-	0.0040 U (0/17)	0.004 U (0/10)	0.035 U (0/3)	0.0028 U (0/4)	0.0027 U (0/2)	0.0027 U (0/2)	0.06 U (1/4)	5,000	RMEG
Di-n-butyl phthalate	-	0.026 (3/17)	0.0078 U (0/10)	0.0028 U (0/3)	0.0079 U (0/4)	0.0077 U (0/2)	0.0077 U (0/2)	0.06 U (0/4)	5,000	RMEG
Di-n-octyl phthalate	-	0.005 U (0/17)	0.0056 U (0/10)	0.0079 U (0/3)	0.0057 (0/4)	0.0055 U (0/2)	0.0055 U (0/2)	0.06 U (0/4)	20,000	iEMEG
Hexachlorobenzene	-	0.004 (8/17)	0.0041 (2/10)	0.0042 U (0/3)	0.0042 U (0/4)	0.004 U (0/2)	0.004 U (0/2)	0.06 U (0/4)	0.44	CREG
Hexachlorobutadiene	-	0.0042 U (0/17)	0.0044 U (0/10)	0.0044 U (0/3)	0.0044 U (0/4)	0.0043 U (0/2)	0.0043 U (0/2)	0.06 U (0/4)	9	CREG
Hexachloroethane	-	0.0027 U (0/1)	0.0028 U (0/1)	0.0028 U (0/3)	0.0029 U (0/4)	0.0028 U (0/2)	0.0028 U (0/2)	0.06 U (0/4)	18	CREG
N-Nitroso diphenylamine	-	0.0049 U (0/17)	5.2 U (0/10)	0.0052 U (0/3)	0.0052 U (0/4)	0.0051 U (0/2)	0.0051 U (0/2)	0.06 U (0/4)	140	CREG
Pentachlorophenol	-	0.044 (8/17)	**46 U** (1/10)	0.047 (0/3)	0.047 (0/4)	0.046 (0/2)	0.046 (0/2)	0.30 U (0/4)	1.8	CREG
Phenol	-	11 U (0/17)	55 (9/10)	0.015 (1/3)	0.092 (3/4)	0.044 U (0/2)	0.020 U (0/2)	0.06 U (0/4)	15,000	RMEG
Total Petroleum Hydrocarbons (TPH)										
TPH-Gasoline fraction	-	3.6 U (0/4)	3.7 U (0/2)	-	-	-	-	-	2,000	MTCA
TPH-Diesel fraction	-	13 (3/4)	6.8 (2/2)	-	-	-	5.1 (0/2)	38 (2/4)	2,000	MTCA
TPH-heavy oil fraction	-	150 (3/4)	32 (2/2)	-	-	-	10 U (0/2)	150 (2/4)	2,000	MTCA

Notes: Source of data – Newfields 2011 (13), Ridolfi 2011 (16); Parametrix 2000, 2003, 2004 (5;6;17);

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[a] Maximum intertidal sediment concentrations may not be representative for any given area. These values are used for screening only. **Bold** type indicates that the concentration value exceeded comparison value.
[b] Using CVs based on residential soil exposures for exposures to sediments is a conservative approach to screening and sediment screening values are scarce.
[c] For contaminants with multiple health-based CVs, the lowest CV was selected. For chemicals with no CV, a CV from a surrogate chemical (in parentheses) with similar physiochemical and structure properties was used.
[d] Total metal values (speciated analyses not available)
[e] Carcinogenic effects of cadmium documented after inhalation exposures; thus, cadmium will only be considered for further evaluation if the non-carcinogenic CV is exceeded.
[f] Individual dioxin, furan, and PCB congeners were multiplied by their TEF and then summed to get the TCDD-EQ
[g] Individual cPAHs with carcinogenic effects were multiplied by their RPF and then summed together to get the BaP-EQ

Abbreviations (see definitions in glossary):

ATSDR	Agency for Toxic Substances and Disease Registry, U.S. Department of Human Health Services
BaP-EQ	Benzo(a)pyrene Equivalents: sum of individual cPAHs multiplied by the relative potency factor (RPF) describing the carcinogenic potential relative to BaP.
CREG	Cancer Risk Evaluation Guide (ATSDR)
CV	Health-based comparison value
EMEG	Environmental Media Evaluation Guide for chronic (cEMEG) or intermediate (iEMEG) exposures to children (ATSDR)
EPA	U.S. Environmental Protection Agency
J	Estimated value between the reporting limit and the detection limit
mg/kg	milligrams chemical per kilogram sediment, same as parts per million (ppm)
MRL	Minimal Risk Levels for Hazardous Substances for non-carcinogenic effects (ATSDR)
MTCA	Model Toxic Control Act; cleanup levels for Washington State
PGST	Port Gamble S'Klallam Tribe
PAH	Polynuclear aromatic hydrocarbons with carcinogenic (cPAH) and noncarcinogenic effects (ncPAH); cPAHs include benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3-c,d)pyrene and are indicated with a tilde (~)
RfD	Reference Dose developed by EPA for non-carcinogenic effects
RMEG	Reference Dose Media Evaluation Guide for exposures to children (ATSDR)
RSL	Regional Screening Levels for chemicals with non carcinogenic effects (EPA)
TCDD	2, 3,7,8-Tetrachlorodibenzodioxin
TEQ	TCDD equivalent; individual dioxins, furans or PCB congeners multiplied by a toxic equivalency factor (TEF) then added together to equal the TEQ.
TPH	Total Petroleum Hydrocarbons
U	data qualifier: The analyte was not detected at this level.

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Shellfish Tissue Comparison Values

Maximum shellfish tissue concentrations were screened using values considered to be protective of tribal members eating shellfish exclusively from Port Gamble Bay at the high tribe-estimated subsistence consumption rate. This conservative approach identified contaminants of most concern. Average tissue concentrations are used in further evaluations to determine what an individual is more likely to be exposed to over a long period of time. These CVs were calculated using chemical/metal-specific ATSDR Minimal Risk Levels (MRLs) or EPA's chronic oral reference doses (RfDs). These are defined as follows:

> **Minimal Risk Level (MRL)**: An MRL is an estimate of daily human exposure to a substance (in milligrams per kilogram per day [mg/kg-day] for oral exposures) that is likely to be without non-carcinogenic health effects during a specified duration of exposure based on ATSDR evaluations.
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> **Reference Dose (RfD)**: An RfD is an estimate in mg/kg-day with uncertainty spanning an order of magnitude of a daily oral exposure to the human population including sensitive subgroups that is likely to be without an appreciable risk of harmful effects during a lifetime. These can be found on EPA's Integrated Risk Information System (IRIS) or in EPA Regional Screening Level Tables[20].

The following equation demonstrates how shellfish comparisons values ($CV_{shellfish}$) were calculated for non-carcinogenic endpoints.

Equation C1: Calculation of tissue comparison value (CV) for non-carcinogenic effects

$$CV_{shellfish} = \frac{MRL\ (or\ RfD) \times BW}{IR \times CF}$$

Equation C2: Calculation of tissue comparison value (CV) for carcinogenic effects

$$CV_{shellfish} = \frac{(Target\ Risk\ 1 \times 10^{-6}) \times BW}{CSF \times IR \times CF}$$

If a chemical was found to have carcinogenic effects, it was automatically identified as a COPC and considered further. Cadmium is an exception as its carcinogenic effects only occur after inhalation exposure, not ingestion, thus carcinogenic effects were not considered in this assessment. Calculated CVs for comparison with shellfish tissue can be found in Table D3.

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[20] http://www.epa.gov/region9/superfund/prg/

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Table D2. Definition of parameters used to calculate comparison values in the shellfish tissue chemical screening process, Port Gamble Bay, Kitsap County, Washington.

Parameter and Abbreviation		Value	Unit	Source
Shellfish Comparison Value	$CV_{shellfish}$	Calc.	mg chemical /kg tissue	Chemical-specific calculated for non-carcinogenic effects (adults)
Body Weight	BW	79	kg	Tribal member body weight – Adult per Suquamish (2000)
Conversion Factor	CF	0.001	kg/g	Converts from grams of tissue to kilogram of tissue
Ingestion Rate of Shellfish	IR	499	g/day	Suquamish 95th percentile shellfish consumption rate for adults per EPA Framework (2007)
Minimal Risk Level	MRL	Chemical-specific	mg/kg-day	Published by ATSDR
Cancer Slope Factor	CSF	Chemical-specific	mg/kg-day	Published by EPA
Reference Dose	RfD	Chemical-specific	mg/kg-day	Published by EPA (IRIS or RSL)

Source: ATSDR 2005 (22), Suquamish 2000 (20), EPA Tribal Framework 2007 (9)
Abbreviations not defined in table:
ATSDR – Agency for Toxic Substances and Disease Registry
EPA – U.S. Environmental Protection Agency
IRIS – EPA's Integrated Risk Information System
RSL – EPA's Regional Screening Levels
mg/kg - milligrams per kilogram
kg - kilogram
kg/g - milligrams per gram
g/day - grams per day
mg/kg-day - milligrams per kilogram body-weight per day

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Table D3. Maximum concentration of chemicals/metals analyzed in shellfish tissues from the northern portion of the bay compared to health-based comparison values calculated with an adult tribe-estimated subsistence consumption rate, Port Gamble Bay, Kitsap County, Washington.

Chemical [a]	Maximum Concentration (mg/kg) for Species Collected from Port Gamble Bay [a] (Number Detected / Number of Samples)									MRL or RfD[b] (mg/kg-day)	Subsistence Comparison Value [b,c] (mg/kg)
	Oyster	Littleneck	Manila	Cockle	Geoduck	Butter	Horse	Crab Meat	Crab Butter		
Total Metals [d]											
Arsenic [e]	**2** (10/11)	**5** (20/20)	**3** (5/5)	**1 U** (0/7)	**2** (3/3)	-	-	**7** (3/3)	**8** (3/3)	0.0003 (iAs)	0.05
Cadmium [f]	**1.49** (11/11)	**0.71** (21/21)	**0.35** (5/5)	**0.05** (5/7)	**0.26** (3/3)	-	-	**0.34** (1/3)	**1.34** (3/3)	0.0001	0.02
Chromium [g]	**0.2** (11/11)	**1.9** (18/18)	**0.3** (5/5)	**0.4** (7/7)	**0.2** (3/3)	-	-	0.1 (2/3)	0.1 (3/3)	0.001 Cr(VI) 1.5 RfD CrIII	0.2
Copper	**33.5** (11/11)	**25.6** (19/19)	**9.70** (5/5)	**5.82** (7/7)	**6.29** (3/3)	-	-	**8.65** (3/3)	**19.2** (3/3)	0.01	1.6
Lead	0.147 (1/11)	2.0 (12/19)	0.5 (4/5)	0.5 (1/7)	0.4 U (0/3)	-	-	0.4 U (0/3)	0.4 U (0/3)	-	-
Mercury	0.012 (11/11)	0.016 (16/19)	0.01 (5/5)	0.006 (4/7)	0.02 (3/3)	-	-	0.047 (3/3)	0.03 (3/3)	0.0003 Methyl mercury	0.05
Silver	0.16 (11/11)	0.3 (16/16)	0.10 (5/5)	0.06 (6/6)	**1.47** (3/3)	-	-	0.19 (3/3)	0.5 (3/3)	0.005	0.8
Zinc	**263** (11/11)	26.9 (21/21)	16 (5/5)	15.6 (7/7)	30.8 (3/3)	-	-	**50.2** (3/3)	17.6 (3/3)	0.3	47
Polychlorinated Aromatic Compounds [h]											
Dioxin/Furan TEQ [h]	**7.34E-7** (3/4)	**7.36E-7** (11/13)	-	**1.67E-7** (1/1)	**6.97E-7** (2/2)	-	-	**7.18E-7** (3/3)	**2.04E-6** (3/3)	1E-09 7E-10 RfD (TCDD)	1.6E-07
PCB Congener TEQ [h]	**1.34E-7** (2/2)	**5.00E-8** (11/11)	-	-	**1.31E-7** 3/3	-	-	**1.23E-7** (3/3)	**1.67E-7** (2/2)	1E-09 7E-10 RfD (TCDD)	1.6E-07
PCB Total Aroclor	**0.057** (5/14)	**0.076 U** (10/24)	**0.028 U** (0/8)	**0.031 U** (1/12)	**0.040 U** (0/3)	**0.028U** (0/3)	**0.028 U** (0/4)	**0.072 U** (0/1)	**0.091 U** (0/1)	2E-05 (Aroclor 1254)	0.003

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Chemical [a]	Maximum Concentration (mg/kg) for Species Collected from Port Gamble Bay [a] (Number Detected / Number of Samples)									MRL or RfD[b] (mg/kg-day)	Subsistence Comparison Value [b,c] (mg/kg)
	Oyster	Littleneck	Manila	Cockle	Geoduck	Butter	Horse	Crab Meat	Crab Butter		
Polycyclic Aromatic Hydrocarbons with Carcinogenic Effects (cPAHs) [i]											
~Benz(a)anthracene	**0.043** (13/14)	0.017 (14/24)	0.0028 (6/7)	0.0042 (7/12)	**0.5 (0/3)**						
~Benzo(a)pyrene	0.0077 (9/14)	0.0033 (5/24)	0.0020 (1/7)	0.0010 (2/12)	0.005U (0/2)	0.0005U (0/3)	0.0005U (0/4)	0.005U (0/3)	0.0048U (0/3)		0.000022
~Benzo(b) fluoranthene	0.028 (10/11)	0.0048 (3/8)	0.0012 (1/4)	0.0016 (2/7)	0.005U (0/2)	0.0005U (0/3)	0.0005U (0/4)	0.005U (0/3)	0.0048U (0/3)		
~Benzo(k) fluoranthene	0.028 (10/11)	0.0055 (5/8)	0.0012 (1/4)	0.0016 (2/7)	0.005U (0/2)	0.0005U (0/3)	0.0005U (0/4)	0.005U (0/3)	0.0048U (0/3)		
~Total Benzo-fluoranthenes	0.056 (13/14)	0.012 (11/24)	0.0024 (1/7)	0.0032 (2/7)	0.005U (0/2)	0.0005U (0/3)	0.0005U (0/4)	0.005U (0/3)	0.0048U (0/3)		
~Chrysene	0.062 (13/14)	0.010 (14/24)	0.0032 (7/7)	0.005 (10/12)	0.005U (0/2)	0.0006 (2/3)	0.0005U (0/4)	0.005U (0/3)	0.0048U (0/3)		
~Dibenz (a,h) anthracene	0.0011 (3/14)	0.0006 (3/24)	0.0005U (0/7)	0.0005U (0/12)	0.005U (0/2)	0.0005U (0/3)	0.0005U (0/4)	0.005U (0/3)	0.0048U (0/3)		
~Indeno(1,2,3-c,d)pyrene[e]	0.0013 (3/13)	0.0013 (2/24)	0.0008 (1/7)	0.0005U (0/12)	0.005U (0/2)	0.0005U (0/3)	0.0005U (0/4)	0.005U (0/3)	0.0048U (0/3)		
~cPAH BaP-EQ [i]	**0.0169** (13/14)	**0.0134** (12/24)	**0.003** (7/7)	**0.002** (10/12)	**0.0012U** (0/3)	**0.0012** (2/3)	**0.0012U** (0/4)	**0.016 U** (0/3)	**0.016 U** (0/3)	0.096	**0.000022** (Cancer class B1)
Polycyclic Aromatic Hydrocarbons with Non-carcinogenic Effects (ncPAH)											
Acenaphthene	0.008 (4/4)	0.004 (5/17)	0.0005U (0/3)	0.0005U (0/4)	-	0.0005U (0/3)	0.0005U (0/4)	0.0005U (0/2)	0.0008 (3/3)	0.06 RfD	9
Acenaphthylene	0.0014 (1/4)	0.0001 (4/17)	0.0005U (0/3)	0.0005U (0/4)	-	0.0005U (0/3)	0.0005U (0/4)	0.0005U (0/2)	0.0005U (0/2)	0.06 (acenaphthene)	9
Anthracene	0.0075 (1/4)	0.0067 (7/17)	0.0005U (0/3)	0.0005U (0/4)	-	0.0005U (0/3)	0.0005U (0/4)	0.0005U (0/2)	0.0005U (0/2)	0.3 RfD	50
Benzo(g,h,i) perylene	0.0005U (0/4)	0.0005 (1/17)	0.0005U (0/3)	0.0005U (0/4)	-	0.0005U (0/3)	0.0005U (0/4)	0.0005U (0/2)	0.0005U (0/2)	0.03 (pyrene)	5
Fluoranthene	180 (4/4)	0.150 (19/19)	0.0012 (3/3)	0.0022 (4/4	-	0.0030 (3/3)	0.0013 (0/4	0.0005U (0/2)	0.0006 (1/2)	0.04	6
Fluorene	0.0095 (4/4)	0.0063 (10/17)	0.0005U (0/3)	0.0005U (0/4)	-	0.0005U (0/3)	0.0005U (0/4)	0.0005U (0/2)	0.0005U (0/2)	0.04	6

.

Chemical [a]	Maximum Concentration (mg/kg) for Species Collected from Port Gamble Bay [a] (Number Detected / Number of Samples)									MRL or RfD[b] (mg/kg-day)	Subsistence Comparison Value [b,c] (mg/kg)
	Oyster	Littleneck	Manila	Cockle	Geoduck	Butter	Horse	Crab Meat	Crab Butter		
1-Methylnapthalalene	0.0005U (0/3)	0.0005U (0/13)	0.0005U (0/3)	0.0005U (0/4)	-	0.0005U (0/3)	0.0005U (0/4)	0.0005U (0/2)	0.0005U (0/2)	0.07	10
2-Methylnaphthalene	0.0009 (4/4)	0.0045 (8/17)	0.0005U (0/3)	0.0005U (0/4)	-	0.0005U (0/3)	0.0005U (0/4)	0.0005U (0/2)	0.0006 (1/2)	0.004 RfD	1
Naphthalene	0.002 (1/4)	0.0032 (4/17)	0.0005U (0/3)	0.0005U (0/4)	-	0.0005U (0/3)	0.0005U (0/4)	0.0005U (0/2)	0.0005U (0/2)	0.02 RfD	3
Phenanthrene	0.041 (4/4)	0.056 (19/19)	0.0012 (3/3)	0.0033 (3/3)	-	0.0020 (3/3)	0.0011 (4/4)	0.0005U (0/2)	0.0005U (0/2)	0.03 (pyrene)	5
Pyrene	0.110 (14/14	0.085 (19/19)	0.0007 (2/3)	0.0010 (3/4)	-	0.0015 (3/3)	0.0010 (4/4)	0.0005U (0/2)	0.0005U (0/2)	0.03	5

Source of data – Newfields 2011 (13), Ridolfi 2011 (16); Hart Crowser 2008 (12); Parametrix 2003; DOH 1996 (18)

Notes: [a] Tissue concentrations listed as milligrams per kilogram (mg/kg) or parts per million (ppm) wet weight. **Bold** values exceed comparison values and will be considered for further evaluation.

[b] For contaminants with multiple health-based CVs, the lowest CV was selected. For chemicals with no CV, a CV from a surrogate chemical with similar physiochemical and structure properties was used and listed in parentheses.

[c] Conservative subsistence health-based CV calculated by multiplying the MRL by adult body weight (79 kg) then dividing by the tribe-estimated subsistence consumption rate (499 g/day) and adjusting with a conversion factor (see full equation and parameter description in Appendix D) as based on the EPA guidance for assessing exposures to subsistence fishers (19). Compounds that have carcinogenic health effects are automatically evaluated further

[d] Total metals listed (speciated analyses not available).

[e] Health effects of arsenic are based on the toxicity of inorganic arsenic As(III) and As(V). In Puget Sound shellfish, inorganic arsenic accounts for approximately 1% of the total arsenic (Ecology 2002) listed in this table, see text for further discussion.

[f] Carcinogenic effects of cadmium only documented after inhalation exposures; thus, cadmium will only be considered for further evaluation if the non-carcinogenic CV is exceeded.

[g] Chromium is also a polyvalent metal which exists mainly as either Cr(III) or Cr(VI) state. The CV for chromium is based on Cr(VI) which is more toxic than Cr(III); however, Cr(III) is the common form found in shellfish.

[h] Individual dioxin, furan, and PCB congeners were multiplied by their TEF and then summed to get the TCDD-EQ

[i] PAHs associated with carcinogenic health effects (cPAHs) are designated with a ~; Individual cPAHs with carcinogenic effects were multiplied by their RPF and then summed together to get the BaP-EQ.

Abbreviations (see definitions in glossary):

ATSDR – Agency for Toxic Substances and Disease Registry, U.S. Department of Human Health Services
BaP-EQ – Benzo(a)Pyrene-Equivalents
CV – Health-based comparison value
EPA – U.S. Environmental Protection Agency
mg/kg – mg chemical per kilogram tissue, this is equivalent to parts per million (ppm)
MRL – Minimal Risk Levels for Hazardous Substances developed by ATSDR for non-carcinogenic effects
PAH – Polycyclic (or polynuclear) aromatic hydrocarbons; PAHs associated with carcinogenic effects are designated as cPAHs.
PCB – Polychlorinated biphenyls
PGST – Port Gamble S'Klallam Tribe
RfD – Reference Dose developed by EPA for non-carcinogenic effects (from Integrated Risk Information System or most recent Regional Screening Levels may 2012)
RPF – Relative potency factors used to weigh PAHs with carcinogenic effects relative to BaP
TEQ – Tetrachlorodibenzodioxin Equivalents TEF – TCDD Equivalent Factor; these are relative toxicity factors used to weight dioxin, furan and PCB congeners relative to TCDD
U-data qualifier: The analyte was not detected at this level.

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Appendix E–Sediment Exposure Assumptions, Calculations, and Risk Evaluation

This Appendix of the Port Gamble Bay Public Health Assessment provides the concentrations at points of exposure (Table E1) and the methodology and assumptions used to calculate exposure doses for people coming into contact with the shoreline sediments from the bay (Table E2). A summary of exposure doses and health risk calculations are summarized for non-carcinogenic risks (Table E3) and carcinogenic risks (Table E4).

The following activity scenarios have been defined for this site:

- Shellfish harvest by tribe members at the high tribe-estimated subsistence consumption rate (adult and child)
- Shellfish harvest by tribe members at the low tribe-estimated subsistence consumption rate (adult and child)
- General northwest population non-specific activity (adult and child), bay resident
- Tribe member child playing at the shoreline during the summer months

Sediment Points of Exposure

DOH compiled results from the following sediment sample studies done at Port Gamble Bay on behalf of Pope and Talbot, Ecology, and the Port Gamble S'Klallam Tribe over the past decade:

- Parametrix, on behalf of Pope and Talbot, sampled sediment from the former mill (34) Landfills 2 and 3 (5;35) and Landfill 4 (6). Data used in this report represents discrete samples and composite samples taken from the top 10 centimeters of sediments below the ordinary high water mark. Sediment data taken from Landfill 4 represent pre-remediation concentrations which were replaced with clean sand, thus these data were not used in this report.
- Newfields, on behalf of Ecology collected six samples along the western shore, three of which were composites co-located with tissue samples, four samples along the eastern shore, and two samples each from Martha John Creek basin and Port Gamble Creek basin (6;13).
- Ridolfi, on behalf of the Port Gamble S'Klallam Tribe collected sediment samples from areas of concern on Point Julia (16). Data used in this report represent sediment samples (0–4 inches deep) near pilings under the pier and near the barge north of the point. There is some uncertainty as to how these samples represent exposure points for children playing on the shoreline or people collecting shellfish throughout intertidal shorelines on the reservation. Thus, concentrations from these samples represent worst-case exposures, not typical exposures.

After data compilation, estimated values (designated by J flag) were used for chemicals with samples detected below the reporting limit but above the detection limit. Compounds that were not detected (designated with a U flag) were assumed to be present at the detection limit. When possible, exposure point concentrations for sediments were derived using a conservative estimate of the mean concentration. This conservative estimate is typically the upper limit of a one-sided

95% confidence interval for the concentration mean (95% UCL) calculated by ProUCL 4.1.00[21] (36). The method of calculation was based on sample size, coefficient of variation, and the underlying distribution of the data. If the sample size was too small (less than 10 samples), or had an inadequate number of detected values, the average value was used. The sediment sampling source, location, number, and analyses performed are listed in Table E1.

Table E1. Summary of sediment samples from Port Gamble Bay, Kitsap County, Washington

		Composite and Discrete Samples								
Investigation	**Collection Date**	**Mill**	**Landfill 2**	**Landfill 3**	**Landfill 4**	**FLTF/FLA**	**East shore**	**Creeks**	**Reservation**	**Analyses**
Ecology (Newfields)	7/28/11	6	1	1	1	3	2	4	2	Metals, PAH, PCB Congeners, Dioxin/Furan
PGST (Ridolfi) [a]	11/19/2010							4	6	Metals, PAH, PCB Aroclor, Dioxin/Furan
Pope and Talbot (Parametrix)	5/15/00		16	9						Metals, PAH, PCB Aroclor, Dioxins/Furans
Pope and Talbot (Parametrix)	3/1/92	4				1				Metals, PAH, PCB Aroclor, Dioxin/Furan, SVOC

Sources: (4-6;12;13;16)
Notes:
a. PGST sampled the upper portion of the intertidal zone on Point Julia near a derelict boat and beneath the pier. These locations do not represent average shoreline concentrations but potential contaminated areas.
FLA – Former leased area
FLTF – Former log transfer facility
PAH – Polycyclic aromatic hydrocarbons
PGST – Port Gamble S'Klallam Tribe
PCB – Polychlorinated biphenyls
SVOC – Semi-volatile organic chemicals

All intertidal sediment samples taken from the upper portion of Port Gamble Bay were used to calculate the exposure point concentration (C_s) for incidental ingestion and dermal contact at the shoreline. Calculated means or 95% UCL of the means are listed in Tables E3 to E5.

Sediment Exposure Dose Calculations

This section provides the assumptions and calculations used to estimate daily intakes for exposure to chemicals in sediments from Port Gamble Bay. Exposure doses were calculated for incidental ingestion of sediment and dermal absorption of sediment adhered to skin. Inhalation of sediment particles was not considered as a route of exposure since inhalation of dust particles from wet sediments are not expected to occur. Volatile and semi-volatile organic chemicals in sediments have not been identified as contaminants of concern.

[21] http://www.epa.gov/osp/hstl/tsc/software.htm

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The following equations were used to calculate exposures and risks:

Equation E1: Incidental Ingestion Route

$Dose_{ing} = \frac{C_S \times IR_S \times EF \times CF}{BW}$ Where, $EF = \frac{ET \times F \times ED}{AT}$

The exposure factor (EF) will vary depending on the scenario (see scenario-specific calculations for EF in Table E2).

Equation E2: Skin Contact Route

$Dose_{der} = \frac{C_S \times AF \times ABS \times AD \times CF \times SA \times EF}{BW}$ Where, $EF = \frac{ET \times F \times ED}{AT}$

Again, the exposure factor (EF) will vary depending on the scenario (see scenario-specific calculations for EF in Table E2).

Equation E3: Total Exposure Dose for non-carcinogenic risks

$$Total\ Exposure\ Dose = Dose_{ingestion} + Dose_{dermal}$$

Equation E4: Hazard Quotient for non-carcinogenic risks

$$HQ = \frac{Total\ Dose}{MRL\ (or\ RfD)}$$

If the hazard quotient is greater than 1.0, comparison to the most sensitive study is warranted.

Equation E5: Carcinogenic risks

$$Estimated\ Cancer\ Risk = \frac{Dose\ \times CSF\ \times ED_{as}}{BW\ \times 78\ years\ (Averaging\ time)}$$

If the carcinogenic risks are greater than an increased incidence of 1 cancer per 10,000 people (1×10^{-4}), the exposure dose will be discussed further in the text.

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Table E2. Assumptions used to estimate exposures and health risks for people contacting sediments, Port Gamble Bay, Kitsap County, Washington.

Parameter and Abbreviation		Value	Units	Source
Exposure Dose - Ingestion	D(ing)	Calc.	mg/kg-day	D(ing) = C*IR*CF*EF/BW milligrams chemical per kilogram bodyweight per day
Exposure Dose - Dermal	D(der)	Calc.	mg/kg-day	D(der) = (C*AF*ABS*AD*CF*EF*SA)/BW milligrams chemical per kilogram bodyweight per day
Concentration in Sediment	Cs	Calc.	mg/kg	Mean chemical-specific concentration for sediment (95% UCL of the mean if adequate data available); milligram chemical per kilogram sediment
Conversion Factor	CF	0.000001	kg/mg	Converts from kilograms soil to milligrams soil
Minimal Risk Level	MRL	Chemical-specific	mg/kg-day	Milligram chemical per kilogram bodyweight per day; Published by ATSDR
Reference Dose	RfD	Chemical-specific	mg/kg-day	Milligram chemical per kilogram bodyweight per day; Published by EPA
Cancer Slope Factor	CSF	Chemical specific	unitless	Published by EPA
Body Weight	BW	16.8	kg	Tribal body weight, Child < 6 years old (Suquamish study, Table T-2)
		9.2		Body weight, Child 0.5 to < 1 year (EFH)
		11.4		Body weight, Child 1 to < 2 years (EFH)
		17.4		Body weight, Child 2 to < 6 years (EFH)
		31.8		Body weight, Child 6 to < 11 years (EFH)
		56.8		Body weight, Child 11 to < 16 years (EFH)
		71.6		Body weight, Child 16 to < 21 years (EFH)
		64.8		Body weight, Child 11 to < 21 years (EFH)
		79		Tribal body weight, Adult (Suquamish study, Table T-2)
		80		Body weight, Adult 21 to < 65 years (EFH)
		76		Body weight, Adult 65+ years (EFH)
Exposure Factor (EF=F*ED/AT)	EF	1	unitless	Harvest at the high tribe-estimated subsistence consumption rate
		0.38		Harvest at the low tribe-estimated subsistence consumption rate
		0.19		General population resident
		0.33		Tribal child playing on shoreline

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Table E2 (continued).

Parameter and Abbreviation		Value	Units	Source
Frequency	F	365	days/year	Harvest at the high tribe-estimated subsistence consumption rate; number of days per year in sediments based on harvesting
		140		Harvest at the low tribe-estimated subsistence consumption rate, number of days per year in sediments based on harvesting
		70		General population resident, number of days per year based on harvesting and recreation
		120		Tribal child playing on shoreline, based on number of days during summer (4 months year)
Exposure Duration	ED	78	year	Tribal exposure duration, number of years on reservation
		33		General population exposure duration, number of years at one residence for non-carcinogenic effects
		16		Child playing on shoreline exposure duration, up to 16 years old
Age-specific Exposure Duration (used for age-specific calculations)	ED	0.5	year	Child 0.5 to < 1 years old
		1		Child 1 to < 2 years old
		4		Child 2 to < 6 years old
		5		Child 6 to < 11 years old
		5		Child 11 to < 16 years old
		5		Child 16 to < 21 years old
		10		Child 11 to < 21 years old
		44		Adult 21 to < 65 years old
		13		Adult 65+ years old
Averaging Time	AT	28470	day	Tribal averaging time, number of days in lifetime at one residence (ED*365 days per year)
		12045		General population averaging time, number of days in lifetime at one residence (ED*365 days per year)
Hazard Quotient	HQ	Calc.	unitless	Ratio of exposure dose to MRL or RfD (HQ=D/MRL)
Cancer Risk	CR	Calc.	$(mg/kg\text{-}day)^{-1}$	Increased risk of getting cancer (CR=D*CSF*EDas/78)

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Table E2 (continued).

Parameter and Abbreviation		Value	Units	Source
Ingestion Parameters				
Incidental Ingestion Rate	IR	100	mg/day	Milligrams sediment eaten per day; adult and child 0.5 years to < 1 year (EFH Table 5-1)
		200		Milligrams sediment eaten per day; Child 1 to < 21 years old (EFH Table 5-1)
Dermal Parameters				
Absorption Duration	AD	1	day	Fraction of day sediment is in contact with the skin (worst-case) RAGS E
Skin-sediment Adherence Factor	AF	0.2	mg/cm^2	Amount of sediment that adheres to skin, child 1-6 years (RAGS E); milligrams sediment per area of skin (centimeters squared)
		0.07		Amount of sediment that adheres to skin, child and adult (7-31 years) (RAGS E)
Dermal Absorption Factor	ABS	As 0.20	unitless	Chemical-specific, fraction of chemical that absorbs through the skin in 24-hours (EPA RSL; EPA RAGS E)
		PAH 0.13		
Surface Area	SA	2900	cm^2	Surface area exposed, child 1-6 years (RAGS E)
		5700		Surface area exposed, child and adult 7-31 years (RAGS E)

Sources: EPA EFH 2011 (21), Suquamish Tribe 2000 (20), ATSDR 2005 (22), EPA Tribal Framework 2007 (9), EPA Supplemental Guidance for developing soil screening levels for Superfund sites 2002 (37)

Abbreviations not defined in the Table:

<	less than
As	Arsenic
ATSDR	Agency for Toxic Substances and Disease Registry
Calc.	Calculated
cm	centimeters
EFH	EPA Exposure Factors Handbook 2011
EPA	U.S. Environmental Protection Agency
mg	milligram
kg	kilogram
PAH	polycyclic aromatic hydrocarbons
RAGS E	EPA Risk Assessment Guidance for Superfund Part E, Volume 1: Human Health Evaluation Manual (Part E - Supplemental Guidance for Dermal Risk Assessment)
RSL	EPA Regional Screening Levels
UCL	upper confidence limit of the mean

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Table E3a. Location-specific dose and non-carcinogenic hazard estimates from exposure to average **arsenic** concentrations in sediment from Port Gamble Bay, Kitsap County, Washington: high and low tribe-estimated subsistence consumer rates.

Location	Average Concen-tration (mg/kg)	Age	High Tribe-estimated Subsistence Consumer Harvest Exposure Dose (mg/kg-day)			Low Tribe-estimated Subsistence Consumer Harvest Exposure Dose (mg/kg-day)			Minimal Risk Level	Hazard Quotient	
			Ingestion	Dermal Contact	Total	Ingestion	Dermal Contact	Total		High-end Subsistence	Low-end Subsistence
All Shorelines	3.2	Child < 2 yr	8.78E-05	7.04E-05	1.58E-04	3.5E-05	2.8E-05	6.3E-05	0.0003	0.53	0.20
		Child 2 to < 6 yr	3.55E-05	2.06E-05	5.61E-05	1.4E-05	8.2E-06	2.2E-05		0.19	0.07
		Child 6 to < 11 yr	1.94E-05	2.21E-05	4.16E-05	7.8E-06	8.9E-06	1.7E-05		0.14	0.05
		Child 11 to < 21 yr	9.62E-06	3.84E-06	1.35E-05	3.8E-06	1.5E-06	5.4E-06		0.045	0.017
		Adult 21+ yr	7.93E-06	6.32E-06	1.43E-05	3.2E-06	2.5E-06	5.7E-06		0.05	0.02
		Lifetime	1.60E-04	1.23E-04	2.84E-04	6.4E-05	4.9E-05	1.1E-04		0.95	0.36
Mill	3.1	Child < 2 yr	8.8E-05	7.0E-05	1.6E-04	3.4E-05	2.7E-05	6.1E-05		0.53	0.20
		Child 2 to < 6 yr	3.6E-05	2.1E-05	5.6E-05	1.4E-05	7.9E-06	2.2E-05		0.19	0.072
		Child 6 to < 11 yr	1.9E-05	2.2E-05	4.2E-05	7.5E-06	8.5E-06	1.6E-05		0.14	0.053
		Child 11 to < 21 yr	9.6E-06	3.8E-06	1.3E-05	3.7E-06	1.5E-06	5.2E-06		0.045	0.017
		Adult 21+ yr	7.9E-06	6.3E-06	1.4E-05	3.0E-06	2.4E-06	5.5E-06		0.05	0.018
		Lifetime	1.6E-04	1.2E-04	2.8E-04	6.1E-05	4.7E-05	1.1E-04		0.95	0.36
Eastern Shoreline	2.4	Child < 2 yr	6.9E-05	5.5E-05	1.2E-04	2.6E-05	2.1E-05	4.8E-05		0.41	0.16
		Child 2 to < 6 yr	2.8E-05	1.6E-05	4.4E-05	1.1E-05	6.2E-06	1.7E-05		0.15	0.06
		Child 6 to < 11 yr	1.5E-05	1.7E-05	3.3E-05	5.8E-06	6.7E-06	1.2E-05		0.11	0.04
		Child 11 to < 21 yr	7.5E-06	3.0E-06	1.1E-05	2.9E-06	1.2E-06	4.0E-06		0.035	0.013
		Adult 21+ yr	6.2E-06	5.0E-06	1.1E-05	2.4E-06	1.9E-06	4.3E-06		0.037	0.014
		Lifetime	1.3E-04	9.7E-05	2.2E-04	4.8E-05	3.7E-05	8.5E-05		0.74	0.28
Western Shoreline	3.9	Child < 2 yr	1.1E-04	8.9E-05	2.0E-04	4.3E-05	3.4E-05	7.7E-05		0.67	0.50
		Child 2 to < 6 yr	4.5E-05	2.6E-05	7.1E-05	1.7E-05	1.0E-05	2.7E-05		0.24	0.16
		Child 6 to < 11 yr	2.5E-05	2.8E-05	5.3E-05	9.4E-06	1.1E-05	2.0E-05		0.18	0.13
		Child 11 to < 21 yr	1.2E-05	4.9E-06	1.7E-05	4.7E-06	1.9E-06	6.5E-06		0.057	0.036
		Adult 21+ yr	1.0E-05	8.0E-06	1.8E-05	3.8E-06	3.1E-06	6.9E-06		0.06	0.04
		Lifetime	2.0E-04	1.6E-04	3.6E-04	7.8E-05	6.0E-05	1.4E-04		**1.2**	0.87

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Table E3b. Location-specific dose and non-carcinogenic hazard estimates from exposure to average **arsenic** concentrations in sediment from Port Gamble Bay, Kitsap County, Washington: general population and tribal child on reservation shoreline.

Location	Average Concen-tration (mg/kg)	Age	General Population Resident Exposure Dose (mg/kg-day)			Tribal Child on Reservation Exposure Dose (mg/kg-day)			Minimal Risk Level	Hazard Quotient	
			Ingestion	Dermal Contact	Total	Ingestion	Dermal Contact	Total		General Population	Tribal Child
All Shorelines	3.2	Child < 2 yr	1.8E-05	1.4E-05	3.16E-05				0.0003	0.11	
		Child 2 to < 6 yr	7.1E-06	4.1E-06	1.12E-05					0.037	
		Child 6 to < 11 yr	3.9E-06	4.4E-06	8.31E-06					0.028	
		Child 11 to < 21 yr	1.9E-06	7.7E-07	2.69E-06					0.0090	
		Adult 21+ yr	1.6E-06	1.3E-06	2.85E-06					0.0095	
		Lifetime	3.2E-05	2.5E-05	5.67E-05					0.19	
Mill	3.1	Child < 2 yr	1.7E-05	1.3E-05	3.0E-05					0.10	
		Child 2 to < 6 yr	6.8E-06	3.9E-06	1.1E-05					0.036	
		Child 6 to < 11 yr	3.7E-06	4.2E-06	8.0E-06					0.027	
		Child 11 to < 21 yr	1.8E-06	7.4E-07	2.6E-06					0.0086	
		Adult 21+ yr	1.5E-06	1.2E-06	2.7E-06					0.009	
		Lifetime	3.1E-05	2.4E-05	5.4E-05					0.18	
Eastern Shoreline	2.4	Child < 2 yr	1.3E-05	1.1E-05	2.4E-05	2.3E-05	1.8E-05	4.1E-05		0.079	0.14
		Child 2 to < 6 yr	5.3E-06	3.1E-06	8.4E-06	9.1E-06	5.3E-06	1.4E-05		0.028	0.048
		Child 6 to < 11 yr	2.9E-06	3.3E-06	6.2E-06	5.0E-06	5.7E-06	1.1E-05		0.021	0.036
		Child 11 to < 21 yr	1.4E-06	5.8E-07	2.0E-06	2.5E-06	9.9E-07	3.5E-06		0.0067	0.012
		Adult 21+ yr	1.2E-06	9.5E-07	2.1E-06					0.0071	
		Lifetime	2.4E-05	1.9E-05	4.3E-05					0.14	
Western Shoreline	3.9	Child < 2 yr	2.1E-05	1.7E-05	3.8E-05					0.13	
		Child 2 to < 6 yr	8.6E-06	5.0E-06	1.4E-05					0.045	
		Child 6 to < 11 yr	4.7E-06	5.4E-06	1.0E-05					0.034	
		Child 11 to < 21 yr	2.3E-06	9.3E-07	3.3E-06					0.0109	
		Adult 21+ yr	1.9E-06	1.5E-06	3.5E-06					0.012	
		Lifetime	3.9E-05	3.0E-05	6.9E-05					0.23	

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Table E4a. Location-specific carcinogenic risk estimates from exposure to average **arsenic** concentrations in sediment from Port Gamble Bay, Kitsap County, Washington: high and low tribe-estimated subsistence consumer rates.

Location	Average Concen-tration (mg/kg)	Age	Cancer Slope Factor	High Tribe-estimated Subsistence Consumer Harvest Increased Cancer Risk			Low Tribe-estimated Subsistence Consumer Harvest Increased Cancer Risk		
				Ingestion	Dermal Contact	Total	Ingestion	Dermal Contact	Total
All Shorelines	3.2	Child < 2 yr	5.7	5.37E-06	3.72E-06	9.09E-06	2.06E-06	1.43E-06	3.49E-06
		Child 2 to < 6 yr		1.08E-05	6.02E-06	1.68E-05	4.12E-06	2.31E-06	6.43E-06
		Child 6 to < 11 yr		7.35E-06	8.38E-06	1.57E-05	2.82E-06	3.22E-06	6.04E-06
		Child 11 to < 21 yr		7.28E-06	2.91E-06	1.02E-05	2.79E-06	1.11E-06	3.91E-06
		Adult 21+ yr		1.75E-05	1.39E-05	3.14E-05	6.70E-06	5.35E-06	1.21E-05
		Lifetime		4.82E-05	3.50E-05	8.32E-05	1.85E-05	1.34E-05	3.19E-05
Mill	3.1	Child < 2 yr		5.19E-06	3.59E-06	8.78E-06	1.99E-06	1.38E-06	3.37E-06
		Child 2 to < 6 yr		1.04E-05	5.81E-06	1.62E-05	3.98E-06	2.23E-06	6.21E-06
		Child 6 to < 11 yr		7.10E-06	8.09E-06	1.52E-05	2.72E-06	3.10E-06	5.83E-06
		Child 11 to < 21 yr		7.03E-06	2.81E-06	9.84E-06	2.70E-06	1.08E-06	3.77E-06
		Adult 21+ yr		1.69E-05	1.35E-05	3.03E-05	6.47E-06	5.16E-06	1.16E-05
		Lifetime		4.66E-05	3.38E-05	8.03E-05	1.79E-05	1.30E-05	3.08E-05
Eastern Shoreline	2.4	Child < 2 yr		4.07E-06	2.82E-06	6.88E-06	1.56E-06	1.08E-06	2.64E-06
		Child 2 to < 6 yr		8.13E-06	4.56E-06	1.27E-05	3.12E-06	1.75E-06	4.87E-06
		Child 6 to < 11 yr		5.56E-06	6.34E-06	1.19E-05	2.13E-06	2.43E-06	4.57E-06
		Child 11 to < 21 yr		5.51E-06	2.20E-06	7.71E-06	2.11E-06	8.43E-07	2.96E-06
		Adult 21+ yr		1.32E-05	1.06E-05	2.38E-05	5.07E-06	4.05E-06	9.12E-06
		Lifetime		3.65E-05	2.65E-05	6.30E-05	1.40E-05	1.02E-05	2.41E-05
Western Shoreline	3.9	Child < 2 yr		6.55E-06	4.54E-06	1.11E-05	2.51E-06	1.74E-06	4.25E-06
		Child 2 to < 6 yr		1.31E-05	7.34E-06	2.05E-05	5.03E-06	2.82E-06	7.85E-06
		Child 6 to < 11 yr		8.97E-06	1.02E-05	1.92E-05	3.44E-06	3.92E-06	7.36E-06
		Child 11 to < 21 yr		8.89E-06	3.55E-06	1.24E-05	3.41E-06	1.36E-06	4.77E-06
		Adult 21+ yr		2.13E-05	1.70E-05	3.83E-05	8.18E-06	6.52E-06	1.47E-05
		Lifetime		6.54E-05	4.72E-05	1.13E-04	2.51E-05	1.81E-05	4.32E-05

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Table E4b. Location-specific carcinogenic risk estimates from exposure to average **arsenic** concentrations in sediment from Port Gamble Bay, Kitsap County, Washington: general population and tribal child on reservation shoreline.

Location	Average Concen-tration (mg/kg)	Age	Cancer Slope Factor	General Population Resident Increased Cancer Risk			Tribal child on reservation shoreline Increased Cancer Risk		
				Ingestion	Dermal Contact	Total	Ingestion	Dermal Contact	Total
All Shorelines	3.2	Child < 2 yr	5.7	1.0E-06	7.4E-07	1.8E-06			
		Child 2 to < 6 yr		2.1E-06	1.2E-06	3.3E-06			
		Child 6 to < 11 yr		1.4E-06	1.6E-06	3.0E-06			
		Child 11 to < 21 yr		1.4E-06	5.6E-07	2.0E-06			
		Adult 21+ yr		3.4E-06	2.7E-06	6.1E-06			
		Lifetime		9.3E-06	6.8E-06	1.6E-05			
Mill	3.1	Child < 2 yr		9.9E-07	7.1E-07	1.7E-06			
		Child 2 to < 6 yr		2.0E-06	1.2E-06	3.1E-06			
		Child 6 to < 11 yr		1.4E-06	1.6E-06	2.9E-06			
		Child 11 to < 21 yr		1.3E-06	5.4E-07	1.9E-06			
		Adult 21+ yr		3.2E-06	2.6E-06	5.8E-06			
		Lifetime		8.9E-06	6.5E-06	1.5E-05			
Eastern Shoreline	2.4	Child < 2 yr		7.8E-07	5.6E-07	1.3E-06	1.3E-06	9.6E-07	2.3E-06
		Child 2 to < 6 yr		1.6E-06	9.0E-07	2.5E-06	2.7E-06	1.6E-06	4.2E-06
		Child 6 to < 11 yr		1.1E-06	1.2E-06	2.3E-06	1.8E-06	2.1E-06	3.9E-06
		Child 11 to < 21 yr		1.1E-06	4.2E-07	1.5E-06	1.8E-06	7.2E-07	2.5E-06
		Adult 21+ yr		2.5E-06	2.0E-06	4.6E-06			
		Lifetime		7.0E-06	5.1E-06	1.2E-05	7.7E-06	5.3E-06	1.3E-05
Western Shoreline	3.9	Child < 2 yr		1.3E-06	9.0E-07	2.2E-06			
		Child 2 to < 6 yr		2.5E-06	1.5E-06	4.0E-06			
		Child 6 to < 11 yr		1.7E-06	2.0E-06	3.7E-06			
		Child 11 to < 21 yr		1.7E-06	6.8E-07	2.4E-06			
		Adult 21+ yr		4.1E-06	3.3E-06	7.4E-06			
		Lifetime		1.1E-05	8.3E-06	2.0E-05			

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Table E5a. Location-specific dose and carcinogenic risk estimates from exposures to average polycyclic aromatic hydrocarbons concentration **(cPAH BaP-EQ)** in sediment from Port Gamble Bay, Kitsap County, Washington: high tribe-estimated subsistence consumer rate.

Location	Average Concen-tration (mg/kg)	Age	Exposure Dose (mg/kg-day)			Cancer Slope Factor	High-end Subsistence Tribal Member Increased Cancer Risk		
			Ingestion	Dermal Contact	Total		Ingestion	Dermal Contact	Total
All Shorelines	0.063	Child < 2 yr	1.80E-06	9.05E-07	2.70E-06	7.3	1.36E-07	6.13E-08	1.97E-07
		Child 2 to < 6 yr	7.28E-07	2.65E-07	9.92E-07		2.72E-07	9.91E-08	3.72E-07
		Child 6 to < 11 yr	3.98E-07	2.95E-07	6.93E-07		1.86E-07	1.38E-07	3.24E-07
		Child 11 to < 21 yr	1.97E-07	5.11E-08	2.48E-07		1.85E-07	4.79E-08	2.32E-07
		Adult 21+ yr	1.62E-07	8.42E-08	2.47E-07		4.43E-07	2.30E-07	6.72E-07
		Lifetime	3.28E-06	1.60E-06	4.88E-06		1.22E-06	5.76E-07	1.80E-06
Mill	0.22	Child < 2 yr	6.34E-06	3.19E-06	9.52E-06		4.80E-07	2.16E-07	6.95E-07
		Child 2 to < 6 yr	2.56E-06	9.33E-07	3.50E-06		9.60E-07	3.49E-07	1.31E-06
		Child 6 to < 11 yr	1.40E-06	1.04E-06	2.44E-06		6.56E-07	4.86E-07	1.14E-06
		Child 11 to < 21 yr	6.95E-07	1.80E-07	8.75E-07		6.50E-07	1.69E-07	8.19E-07
		Adult 21+ yr	5.72E-07	2.97E-07	8.69E-07		1.56E-06	8.09E-07	2.37E-06
		Lifetime	1.16E-05	6.80E-06	1.99E-05		5.04E-06	2.57E-06	7.61E-06
Eastern Shoreline	0.014	Child < 2 yr	3.20E-07	1.61E-07	4.81E-07		2.42E-08	1.09E-08	3.51E-08
		Child 2 to < 6 yr	1.30E-07	4.71E-08	1.77E-07		4.85E-08	1.76E-08	6.61E-08
		Child 6 to < 11 yr	7.09E-08	5.25E-08	1.23E-07		3.32E-08	2.46E-08	5.77E-08
		Child 11 to < 21 yr	3.51E-08	9.10E-09	4.42E-08		3.29E-08	8.52E-09	4.14E-08
		Adult 21+ yr	2.89E-08	1.50E-08	4.39E-08		7.88E-08	4.09E-08	1.20E-07
		Lifetime	5.85E-07	2.85E-07	8.69E-07		2.18E-07	1.03E-07	3.20E-07
Western Shoreline	0.049	Child < 2 yr	1.40E-06	7.05E-07	2.11E-06		1.06E-07	4.77E-08	1.54E-07
		Child 2 to < 6 yr	5.67E-07	2.06E-07	7.73E-07		2.12E-07	7.72E-08	2.89E-07
		Child 6 to < 11 yr	3.10E-07	2.30E-07	5.40E-07		1.45E-07	1.08E-07	2.53E-07
		Child 11 to < 21 yr	1.54E-07	3.98E-08	1.93E-07		1.44E-07	3.73E-08	1.81E-07
		Adult 21+ yr	1.26E-07	6.56E-08	1.92E-07		3.45E-07	1.79E-07	5.24E-07
		Lifetime	2.56E-06	1.25E-06	3.80E-06		9.52E-07	4.49E-07	1.40E-06

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Table E5b. Location-specific dose and carcinogenic risk estimates from exposures to average polycyclic aromatic hydrocarbons concentration (**cPAH BaP-**EQ) in sediment from Port Gamble Bay, Kitsap County, Washington: average tribal member.

Location	Average Concen-tration (mg/kg)	Age	Average Tribal Member Exposure Dose (mg/kg-day)			Cancer Slope Factor	Average Tribal Member Increased Cancer Risk		
			Ingestion	Dermal Contact	Total		Ingestion	Dermal Contact	Total
All Shorelines	0.063	Child < 2 yr	6.90E-07	3.47E-07	1.04E-06	7.3	5.22E-08	2.35E-08	7.57E-08
		Child 2 to < 6 yr	2.79E-07	1.02E-07	3.81E-07		1.04E-07	3.80E-08	1.43E-07
		Child 6 to < 11 yr	1.53E-07	1.13E-07	2.66E-07		7.15E-08	5.29E-08	1.24E-07
		Child 11 to < 21 yr	7.56E-08	1.96E-08	9.53E-08		7.08E-08	1.84E-08	8.91E-08
		Adult 21+ yr	6.23E-08	3.23E-08	9.46E-08		1.70E-07	8.81E-08	2.58E-07
		Lifetime	1.26E-06	6.14E-07	1.87E-06		4.69E-07	2.21E-07	6.90E-07
Mill	0.22	Child < 2 yr	2.43E-06	1.22E-06	3.65E-06		1.84E-07	8.28E-08	2.67E-07
		Child 2 to < 6 yr	9.83E-07	3.58E-07	1.34E-06		3.68E-07	1.34E-07	5.02E-07
		Child 6 to < 11 yr	5.38E-07	3.99E-07	9.37E-07		2.52E-07	1.87E-07	4.38E-07
		Child 11 to < 21 yr	2.66E-07	6.91E-08	3.36E-07		2.49E-07	6.47E-08	3.14E-07
		Adult 21+ yr	2.19E-07	1.14E-07	3.33E-07		5.98E-07	3.10E-07	9.09E-07
		Lifetime	5.04E-06	2.61E-06	7.65E-06		1.93E-06	9.87E-07	2.92E-06
Eastern Shoreline	0.014	Child < 2 yr	1.23E-07	6.18E-08	1.85E-07		9.29E-09	4.18E-09	1.35E-08
		Child 2 to < 6 yr	4.97E-08	1.81E-08	6.78E-08		1.86E-08	6.77E-09	2.54E-08
		Child 6 to < 11 yr	2.72E-08	2.01E-08	4.73E-08		1.27E-08	9.42E-09	2.21E-08
		Child 11 to < 21 yr	1.35E-08	3.49E-09	1.70E-08		1.26E-08	3.27E-09	1.59E-08
		Adult 21+ yr	1.11E-08	5.75E-09	1.68E-08		3.02E-08	1.57E-08	4.59E-08
		Lifetime	2.24E-07	1.09E-07	3.33E-07		8.34E-08	3.93E-08	1.23E-07
Western Shoreline	0.049	Child < 2 yr	5.37E-07	2.70E-07	8.08E-07		4.07E-08	1.83E-08	5.90E-08
		Child 2 to < 6 yr	2.17E-07	7.91E-08	2.96E-07		8.14E-08	2.96E-08	1.11E-07
		Child 6 to < 11 yr	1.19E-07	8.81E-08	2.07E-07		5.57E-08	4.12E-08	9.69E-08
		Child 11 to < 21 yr	5.89E-08	1.53E-08	7.42E-08		5.51E-08	1.43E-08	6.94E-08
		Adult 21+ yr	4.85E-08	2.52E-08	7.37E-08		1.32E-07	6.86E-08	2.01E-07
		Lifetime	9.81E-07	4.78E-07	1.46E-06		3.65E-07	1.72E-07	5.37E-07

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Table E5c. Location-specific dose and carcinogenic risk estimates from exposures to average polycyclic aromatic hydrocarbons concentration **(cPAH BaP-EQ)** in sediment from Port Gamble Bay, Kitsap County, Washington: general population resident.

Location	Average Concen-tration (mg/kg)	Age	General Population Resident Exposure Dose (mg/kg-day)			Cancer Slope Factor	General Population Resident Increased Cancer Risk		
			Ingestion	Dermal Contact	Total		Ingestion	Dermal Contact	Total
All Shorelines	0.063	Child < 2 yr	3.45E-07	1.74E-07	5.19E-07	7.3	2.61E-08	1.18E-08	3.79E-08
		Child 2 to < 6 yr	1.40E-07	5.08E-08	1.90E-07		5.22E-08	1.90E-08	7.13E-08
		Child 6 to < 11 yr	7.64E-08	5.66E-08	1.33E-07		3.57E-08	2.65E-08	6.22E-08
		Child 11 to < 21 yr	3.78E-08	9.81E-09	4.76E-08		3.54E-08	9.18E-09	4.46E-08
		Adult 21+ yr	3.11E-08	1.62E-08	4.73E-08		8.49E-08	4.40E-08	1.29E-07
		Lifetime	6.30E-07	3.07E-07	9.37E-07		2.34E-07	1.10E-07	3.45E-07
Mill	0.22	Child < 2 yr	1.22E-06	6.12E-07	1.83E-06		9.20E-08	4.14E-08	1.33E-07
		Child 2 to < 6 yr	4.92E-07	1.79E-07	6.71E-07		1.84E-07	6.70E-08	2.51E-07
		Child 6 to < 11 yr	2.69E-07	1.99E-07	4.68E-07		1.26E-07	9.33E-08	2.19E-07
		Child 11 to < 21 yr	1.33E-07	3.46E-08	1.68E-07		1.25E-07	3.23E-08	1.57E-07
		Adult 21+ yr	1.10E-07	5.69E-08	1.67E-07		2.99E-07	1.55E-07	4.54E-07
		Lifetime	2.52E-06	1.30E-06	3.82E-06		9.67E-07	4.94E-07	1.46E-06
Eastern Shoreline	0.014	Child < 2 yr	6.14E-08	3.09E-08	9.23E-08		4.65E-09	2.09E-09	6.74E-09
		Child 2 to < 6 yr	2.48E-08	9.04E-09	3.39E-08		9.30E-09	3.38E-09	1.27E-08
		Child 6 to < 11 yr	1.36E-08	1.01E-08	2.37E-08		6.36E-09	4.71E-09	1.11E-08
		Child 11 to < 21 yr	6.73E-09	1.75E-09	8.48E-09		6.30E-09	1.63E-09	7.93E-09
		Adult 21+ yr	5.54E-09	2.88E-09	8.42E-09		1.51E-08	7.84E-09	2.30E-08
		Lifetime	1.12E-07	5.46E-08	1.67E-07		4.17E-08	1.97E-08	6.14E-08
Western Shoreline	0.049	Child < 2 yr	2.69E-07	1.35E-07	4.04E-07		2.03E-08	9.15E-09	2.95E-08
		Child 2 to < 6 yr	1.09E-07	3.96E-08	1.48E-07		4.07E-08	1.48E-08	5.55E-08
		Child 6 to < 11 yr	5.95E-08	4.41E-08	1.04E-07		2.78E-08	2.06E-08	4.84E-08
		Child 11 to < 21 yr	2.95E-08	7.64E-09	3.71E-08		2.76E-08	7.15E-09	3.47E-08
		Adult 21+ yr	2.43E-08	1.26E-08	3.68E-08		6.61E-08	3.43E-08	1.00E-07
		Lifetime	4.90E-07	2.39E-07	7.30E-07		1.83E-07	8.60E-08	2.69E-07

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Table E5d. Location-specific dose and carcinogenic risk estimates from exposures to average polycyclic aromatic hydrocarbons concentration (**cPAH BaP-EQ**) in sediment from Port Gamble Bay, Kitsap County, Washington: general population resident.

Location	Average Concen-tration (mg/kg)	Age	Tribal Child Play Exposure Dose (mg/kg-day)			Cancer Slope Factor	Tribal Child on Reservation Shoreline Increased Cancer Risk		
			Ingestion	Dermal Contact	Total		Ingestion	Dermal Contact	Total
All Shoreline	0.063	Child < 2 yr	5.91E-07	2.98E-07	8.89E-07	7.3	4.48E-08	2.01E-08	6.49E-08
		Child 2 to < 6 yr	2.39E-07	8.71E-08	3.26E-07		8.95E-08	3.26E-08	1.22E-07
		Child 6 to < 11 yr	1.31E-07	9.70E-08	2.28E-07		6.12E-08	4.54E-08	1.07E-07
		Child 11 to < 21 yr	6.48E-08	1.68E-08	8.16E-08		6.07E-08	1.57E-08	7.64E-08
		Adult 21+ yr							
		Lifetime	1.03E-06	4.98E-07	1.52E-06		2.56E-07	1.14E-07	3.70E-07
Eastern Shoreline	0.014	Child < 2 yr	1.05E-07	5.30E-08	1.58E-07		7.97E-09	3.59E-09	1.16E-08
		Child 2 to < 6 yr	4.26E-08	1.55E-08	5.81E-08		1.59E-08	5.80E-09	2.17E-08
		Child 6 to < 11 yr	2.33E-08	1.73E-08	4.06E-08		1.09E-08	8.08E-09	1.90E-08
		Child 11 to < 21 yr	1.15E-08	2.99E-09	1.45E-08		1.08E-08	2.80E-09	1.36E-08
		Adult 21+ yr							
		Lifetime	1.83E-07	8.87E-08	2.71E-07		4.56E-08	2.03E-08	6.59E-08

Notes for Tables E3-E5

Abbreviations

<	less than
ATSDR	Agency for Toxic Substances and Disease Registry, U.S. Department of Human Health Services
CSF	Cancer slope factor
EPA	U.S. Environmental Protection Agency
mg/kg	milligrams chemical per kilogram dry weight (same as parts per million, ppm)
mg/kg-day	Daily dose in milligrams chemical per kilograms bodyweight per day
MRL	Minimal Risk Level established by ATSDR
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
RfD	Oral Reference Dose established by EPA
TEQ	Toxic Equivalency Quotient
yr	year

Blank cells in tables Per the tribal request, tribal exposure scenario developed for tribal children is for Point Julia (eastern shoreline) only, which is part of the reservation.

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Appendix F–Shellfish Assumptions, Calculations, and Risk Evaluation

This Appendix of the Port Gamble Bay Public Health Assessment provides a summary of tissue data (Table F1), and methodology and assumptions (Table F2) used to calculate exposure doses for people eating shellfish from the bay. A summary of tribal exposure doses and health risk calculations are summarized for non-carcinogenic risks (Table F4 and F5) and carcinogenic risks (Table F6). Location-specific exposure dose, and risk results are summarized in Tables F7–F9. The following consumption scenarios have been defined for this site: 1) High tribe-estimated subsistence shellfish consumer (adult and child), 2) Low tribe-estimated subsistence shellfish consumer (adult and child), and 3) General northwest resident (adult and child) for clams and oysters only.

Shellfish Points of Exposure

DOH compiled results from the following tissue sample studies done at Port Gamble Bay on behalf of Pope and Talbot, Ecology, the Port Gamble S'Klallam tribe, and DOH:

- Ecology's contractor (Newfields) collected composite littleneck tissue samples in September 2011 at the former mill area and intertidal locations along Port Gamble Bay, including 1–4 littleneck clams from 7–10 subsample locations. In addition they collected two composite samples of Dungeness crab (six individuals each). For sample details see Ecology's cleanup report (4;13).
- Port Gamble S'Klallam Tribe collected samples in 2008, 2010, and 2011. Details of the 2008 and 2010 sampling can be found in Ecology's cleanup reports (4). In 2011 the Tribe collected an additional 25 littleneck, manila, horse, cockle, and butter clam samples on the south and north shorelines of Point Julia (16).
- In 2003, Parametrix collected three tissue samples at the former mill area (two composite samples of littleneck and one oyster composite) (2).
- As part of DOH's Puget Sound Ambient Monitoring Program, chemicals were measured in three littleneck clam composite samples from Port Gamble Bay (18) in 1992 and 1993.

Oyster composite samples consisted of approximately 15 individuals. Littleneck, manila, cockle, butter, and horse composite samples consisted of approximately 30 individuals. Crab composite samples consisted of 5 to 8 individuals and were collected overnight with a crab pot; edible tissue (muscle) and crab butter (hepatopancreas) were composited and analyzed separately. Geoduck composite samples consisted of 3 individuals; skins of the neck were removed and the gut ball was included in the tissue composite. One sample was taken from the tract just north of Port Gamble Bay, outside of the study area.

Table F1. Summary of composited shellfish tissue samples from Port Gamble Bay, Kitsap County, Washington.

Location and Study	Collection Date	Oyster	Littleneck	Manila	Cockle	Crab	Geoduck	Butter	Horse	Analyses
Mill										
Ecology (Newfields)	7/28/11		6							Metals, PAH, PCB Congeners, Dioxin/Furan
PGST	4/29/10	3	1		3					Metals, PAH, PCB , Dioxin/Furan (2 samples)
Pope and Talbot (Parametrix)	5/15/03	1	2							Metals, PAH, PCB Aroclor, Dioxin/Furan
Washington State Department of Health	3/1/92		3							Metals, PAH, PCB Aroclor, Dioxin/Furan, SVOC
Landfills 2, 3, and 4										
Ecology (Newfields)	7/28/11		3							Metals, PAH, PCB Congeners, Dioxin/Furan
PGST	4/29/10	2	3	3	3					Metals, PAH, PCB Aroclor
Rafting Areas (FLTF and FLA)										
PGST	4/29/10	1	1	1	1					Metals, PAH, PCB Aroclor
Central subtidal portion of bay										
Ecology (Newfields)	7/28/11					2				Metals, PAH, PCB Congeners, Dioxin/Furan
PGST	12/15/08					1				Metals, PCB Aroclor, Dioxin/Furan
PGST	4/29/10						3			Metals, PAH, PCB Aroclor
PGST Reservation										
PGST	9/22/11	3	6	3	4			3	4	PAH, PCB Aroclor
PGST	4/29/10	2			1					Metals, PAH, PCB Aroclor
PGST	12/15/08	2	2							Metals, PCB Aroclor, Dioxin/Furan
Reference Sites										
PGST	4/29/10	1		1	1					Metals, PAH, PCB Aroclor
Pope and Talbot (Parametrix)	5/15/03		2							Metals, PAH, PCB Aroclor, Dioxin/Furan
Total Samples from the Bay		14	27	7	13	3	3	3	4	

Notes: Source: Newfields 2011 (13), Ridolfi 2011 (16), Hart Crowser 2008 (12), Parametrix 2000, 2003 (2;12;38), Ecology 2011 (4;13), and WDOH 1996 (18). Abbreviations used:

FLA – Former leased area
FLTF – Former log transfer facility
PAH – Polycyclic aromatic hydrocarbons
PGST – Port Gamble S'Klallam Tribe
PCB – Polychlorinated biphenyls
SVOC – Semi-volatile organic chemicals

For chemicals detected below the reporting limit but above the detection limit, the estimated values (designated by J flag) were used. Compounds that were not detected (designated with a U flag) were assumed to be present at the detection limit. As described for sediments, the upper limit of a one-sided 95% confidence interval for the concentration mean (95% UCL) was calculated by ProUCL 4.1.00[22]. The method of calculation was based on sample size, coefficient of variation, and the underlying distribution of the data.

Shellfish Tissue Exposure Dose Calculations

This section provides the assumptions and calculations used to estimate daily intakes for exposure to chemicals in shellfish from Port Gamble Bay. Exposure doses were calculated for 1) high tribe-estimated subsistence rates based on concentrations from clams, oysters, geoduck, and crab samples collected from the bay; 2) high tribe-estimated subsistence rates based on based on concentrations from clams, oysters, geoduck, and crab samples; and 3) general northwest resident based on concentration of clams and oysters only. Tribal scenarios were based on specific intake rates of different shellfish species by tribal members provided by the tribe.

Table F2. Shellfish intake rates by species (g/day) for potentially exposed populations at Port Gamble Bay, Kitsap County, Washington.

Consumption Scenarios	Fraction of Diet [a]	Intake rate of shellfish (g/day)					
		High Tribe-estimated Subsistence Rates		Low Tribe-estimated Subsistence Rates		General Population Resident	
		Adult	Child	Adult	Child	Adult	Child
Scenario 1 - Tribal consumption of all species							
Total	1	499	83	217	23	-	-
Clams [b]	0.51	255.9	42.6	111.3	11.8	-	-
Oyster	0.13	62.4	10.4	27.1	2.9	-	-
Geoduck	0.19	96.8	16.1	42.1	4.5	-	-
Crab meat	0.13	62.925	10.5	27.4	2.9	-	-
Crab butter	0.04	20.975	3.5	9.1	1.0	-	-
Scenario 2 - Consumption of clams and oysters for comparison of different areas							
Total	1	318.3	52.9	138.4	14.7	60	16
Clams [b]	0.80	255.9	42.5	111.3	11.8	48.2	12.9
Oyster	0.20	62.4	10.4	27.1	2.9	11.8	3.1

Note: g/day – grams shellfish eaten per day
a. Fraction of diet determined based on the subsistence tribal member's ratio of species-specific intake rate to the total intake rate. Total intake rate determined by EPAs tribal framework 2007 (9) based on the Suquamish Survey 2000 (20); species intake rates adapted by the Port Gamble Tribe (4;12).
b. Clam species include littleneck, manila, cockle, butter, and horse clams.

Estimated exposure from consumption of clams and oysters only was done to compare shoreline areas. This included the non-tribal resident of the bay as a representative of general population (adult and child) and both high and low tribe estimated subsistence consumption rates (adult and child). Exposures to chemicals from tissues of the bay were examined for 1) former mill area;

[22] http://www.epa.gov/osp/hstl/tsc/software.htm

2) western shore, which includes the former landfills and log rafting areas; 3) and the eastern shore, which includes areas on and near the reservation. The following consumption rates were applied to these populations:

Mean chemical concentration was determined for each species. The 95th upper confidence limit of the mean was used if enough data (n=10) of sufficient quality were available. The detection limit was used for compounds that were not detected. The exposure point concentration for shellfish was calculated by multiplying the chemical concentration for each category of shellfish: clams (i.e., littleneck, manila, cockles) oysters, geoduck, or crab, by their respective fraction of the diet. The fraction of the diet consumed by the Port Gamble S'Klallam Tribe at subsistence rates was discussed and agreed upon by Ecology and the tribe and reported in the draft remedial investigation report (4;12) (Table F1).

Equation F1: Shellfish Ingestion Exposure Dose

$Exposure\ Dose = \frac{EPC \times IR_{shellfish} \times CF \times EF}{BW}$ Where, $EF = \frac{F \times ED}{AT}$

The exposure factor (EF) will vary depending on the scenario. The EF determines the time, frequency and duration of exposure.

Equation F2: Hazard quotient for non-carcinogenic risks

$$Hazard\ Quotient\ (HQ) = \frac{Exposure\ Dose}{MRL\ (or\ RfD)}$$

If the hazard quotient is greater than 1.0, comparison to the most sensitive study is warranted and will be discussed in the text.

Equation F3: Carcinogenic Risks

$$Estimated\ Risk = \frac{Exposure\ Dose \times CSF \times ED_{as}}{BW \times 78\ years\ (lifetime)}$$

If the carcinogenic risks are greater than an increased incidence of one cancer per one million people (1×10^{-6}), the exposure dose will be discussed further in the text.

Table F3. Assumptions used to estimate exposure and health risks for people eating shellfish from Port Gamble Bay, Kitsap County, Washington.

Parameter and Abbreviation		Value	Unit	Source
Exposure Dose	D	Calc.	mg/kg-day	=Σ(C*IR*CF)*EF/BW; milligrams chemical per kilogram body weight per day
Concentration in Shellfish Tissue	Ct	Calc.	mg/kg	Average chemical-specific value for each category (clams, oysters, geoduck and crab) (95% UCL if adequate data available); milligrams chemical per kilogram tissue
Conversion Factor	CF	0.001	kg/g	Converts mass of shellfish from grams to kilograms
Hazard Quotient	HQ	Calc.	unitless	Ratio of exposure dose to MRL or RfD (HQ=Dose/MRL)
Cancer Risk	CR	Calc.	$(mg/kg\text{-}day)^{-1}$	CR=D*CSF*ED/78
Minimal Risk Level	MRL	Chemical -specific	mg/kg-day	Published by ATSDR
Reference Dose	RfD	Chemical -specific	mg/kg-day	Published by EPA
Cancer Slope Factor	CSF	Chemical specific	unitless	Published by EPA
Averaging Time	AT	28470	days	Tribal averaging time, number of days in lifetime at one residence (ED*365 days per year)
		12045		Tribal averaging time, number of days in lifetime at one residence (ED*365 days per year)
Body Weight	BW	16.8	kg	Tribal body weight, Child < 6 years old (Suquamish study, Table T-2)
		9.2		Body weight, Child 0.5 to < 1 year (EFH)
		11.4		Body weight, Child 1 to < 2 years (EFH)
		17.4		Body weight, Child 2 to < 6 years (EFH)
		31.8		Body weight, Child 6 to < 11 years (EFH)
		56.8		Body weight, Child 11 to < 16 years (EFH)
		71.6		Body weight, Child 16 to < 21 years (EFH)
		64.8		Body weight, Child 11 to < 21 years (EFH)
		79		Tribal body weight, Adult (Suquamish study, Table T-2)
		80		Body weight, Adult 21 to < 65 years (EFH)
		76		Body weight, Adult 65+ years (EFH)

Table F3 (continued).

Parameter and Abbreviation		Value	Unit	Source
Consumption Rate – Higher Tribe-estimated subsistence Consumer	IR	499	g/day (grams tissue eaten per day)	Higher adult tribe-estimated subsistence consumption rate based on 95% consumption rate from Suquamish 2000, EPA Tribal Framework
		83		Higher child tribe-estimated subsistence consumption rate based on 95% consumption rate from Suquamish 2000; EFH Table 10-107 [95% for all shellfish × BW]
Consumption Rate - Lower Tribe-estimated subsistence Consumer		217		Lower adult tribe-estimated subsistence consumption rate based on mean UCL consumption rate; Suquamish 2000, EFH Table 10-103 (95% UCL of mean for Group E × BW × fraction from Puget Sound only)
		23		Lower adult tribe-estimated subsistence intake rate based on mean UCL consumption rate; Suquamish 2000, EFH Table 10-107 (95% UCL of mean for all shellfish × BW)
Consumption Rate - General Population		60		General population adult shellfish intake rate King County/Puget Sound (EFH, Table 10-67, 90th percentile × BW)
		16		Mean (ages 3-5 years), U.S. general population (EPA EFH Table 10-10 × BW)
Fraction of Tribal Diet (species specific)	FD	0.51	unitless	Clam (littleneck, manila, cockle, butter, horse)
		0.13		Oyster
		0.19		Geoduck
		0.17		Crab (0.13 for crab meat and 0.04 for crab butter)
Fraction of General Population Diet (clams and oysters only)		0.8		Clam
		0.2		Oyster
Exposure Factor (EF=F*ED/AT)	EF	1	unitless	Higher tribe-estimated subsistence consumer
		0.38		Lower tribe-estimated subsistence consumer
		0.19		General population shellfish consumer
Age-dependent adjustment factor	ADAF	10	unitless	Child < 2years old
		3		Child < 16 years old
		1		16+ years old

Table F3 (continued).

Parameter and Abbreviation		Value	Unit	Source
Frequency	F	365	days/year	Higher tribe estimated subsistence consumer - Number of days per year eating shellfish
		140		Lower tribe- estimated subsistence consumer, number of days per year eating shellfish (Mean meals per year, Suquamish Study, Table T-9)
		70		General population shellfish consumer, number of days per year eating shellfish (Median meals per year, Suquamish Table T-9)
Exposure Duration	ED	78	years	Tribal exposure duration, number of years eating shellfish
		33		General population exposure duration, number of years eating shellfish for non-carcinogenic effects
		78		General population exposure duration, number of years eating shellfish for carcinogenic effects
Age-specific Exposure Duration (used for age-specific cancer calculations)	ED	0.5	years	Child 0.5 to < 1 year
		1		Child 1 to < 2 years
		4		Child 2 to < 6 years
		5		Child 6 to < 11 years
		5		Child 11 to <16 years
		5		Child 16 to < 21 years
		10		Child 11 to < 21 years
		44		Adults 21 to < 65 years
		13		Adults 65+ years

Sources: EPA EFH 2011 (21), The Suquamish Tribe 2000 (20), ATSDR 2005 (22), EPA Tribal Framework 2007 (9)

Abbreviations not defined in Table: < less than

ATSDR Agency for toxic substances and disease registry, U.S. Department of Human Health Services.
Calc. calculated
EPA U.S. Environmental Protection Agency
EFH Exposure Factors Handbook released 2011 by EPA
g grams
kg kilograms
mg milligrams
UCL upper confidence limit of the mean

Table F4. Annual exposure dose estimates for tribal populations eating all species based on samples taken from the upper portion of Port Gamble Bay, Kitsap County, Washington

Chemical:	Arsenic [a]	Cadmium	Chromium	Copper	Dioxin/ Furan (TEQ) [b]	PCB Congeners (TEQ) [b]	PCB Aroclor	cPAH (BaP-EQ) [c]
Species [d]	**Average Concentration from Upper Portion of Bay (mg/kg) [e]**							
Clam	*0.022	*0.35	*0.61	*7.0	*2.35E-07	*4.46E-08	*2.01E-02	*2.01E-02
Oyster	*0.020	*1.26	*0.24	*22.3	5.69E-07	1.32E-07	*3.75E-02	*3.75E-02
Geoduck	0.017	0.21	0.13	4.1	6.82E-07	1.31E-07	3.60E-02	3.60E-02
Crab Muscle	0.057	0.04	0.10	6.1	3.51E-07	1.23E-07	7.20E-02	7.20E-02
Crab Butter	0.067	0.87	0.10	9.1	1.70E-07	1.67E-06	9.10E-02	9.10E-02
Scenario and Age Group	**Annual Dose (mg/kg-day)**							
High tribe-estimated subsistence rate								
Child 0.5 to < 1 years old	2.4E-04	3.8E-03	3.5E-03	7.5E-02	3.4E-09	1.4E-09	3.1E-04	5.1E-05
Child 1 to < 2 years old	2.0E-04	3.0E-03	2.8E-03	6.0E-02	2.7E-09	1.1E-09	2.5E-04	4.1E-05
Child 2 to < 6 years old	1.3E-04	2.0E-03	1.8E-03	4.0E-02	1.8E-09	7.2E-10	1.7E-04	2.7E-05
Child 6 to < 11 years old	7.1E-05	1.1E-03	1.0E-03	2.2E-02	9.8E-10	3.9E-10	9.1E-05	1.5E-05
Child 11 to < 16 years old	2.4E-04	3.7E-03	3.4E-03	7.3E-02	3.3E-09	1.3E-09	3.1E-04	4.9E-05
Child 16 to < 21 years old	1.9E-04	2.9E-03	2.7E-03	5.8E-02	2.6E-09	1.0E-09	2.4E-04	3.9E-05
Adults 21 to < 65 years old	1.7E-04	2.6E-03	2.4E-03	5.2E-02	2.3E-09	9.4E-10	2.2E-04	3.5E-05
Adults 65+ years old	9.0E-05	2.7E-03	2.5E-03	5.4E-02	2.5E-09	9.9E-10	2.3E-04	3.7E-05
Low tribe estimated subsistence rate								
Child 0.5 to < 1 years old	2.6E-05	4.0E-04	3.7E-04	8.0E-03	3.6E-10	1.4E-10	3.3E-05	5.4E-06
Child 1 to < 2 years old	2.1E-05	3.2E-04	3.0E-04	6.4E-03	2.9E-10	1.2E-10	2.7E-05	4.3E-06
Child 2 to < 6 years old	1.4E-05	2.1E-04	2.0E-04	4.2E-03	1.9E-10	7.6E-11	1.8E-05	2.8E-06
Child 6 to < 11 years old	7.5E-06	1.2E-04	1.1E-04	2.3E-03	1.0E-10	4.2E-11	9.7E-06	1.6E-06
Child 11 to < 16 years old	4.0E-05	6.1E-04	5.0E-04	1.2E-02	5.5E-10	2.2E-10	5.1E-05	8.2E-06
Child 16 to < 21 years old r	3.1E-05	4.9E-04	4.0E-04	9.6E-03	4.4E-10	1.7E-10	4.1E-05	6.5E-06
Adults 21 to < 65 years old	2.8E-05	4.3E-04	3.6E-04	8.6E-03	3.9E-10	1.6E-10	3.6E-05	5.8E-06
Adults 65+ years old	3.0E-05	4.6E-04	3.8E-04	9.1E-03	4.1E-10	1.6E-10	3.8E-05	6.2E-06

Notes:

a. Based on 1% inorganic arsenic of total arsenic in shellfish.
b. Dioxin/furan and PCB congeners summed using TEQ method.
c. cPAHs summed using BaP-EQ method.
d. Tribe-estimated subsistence diet assumed to be comprised of 51% clams, 19% geoduck,, 17% Crab (13% muscle, 4% butter), and 13% oyster based on 95[th] Suquamish consumption rates.
e. Average concentrations with *asterisk were calculated using the 95[th] upper confidence limit.

Abbreviations: < less than; * 95% UCL of the mean
BaP-Eq – benzo(a)pyrene equivalents
cPAH – carcinogenic polycyclic aromatic hydrocarbons
mg/kg – milligrams chemical per kilogram shellfish tissue
mg/kg-day – milligrams chemical per kilogram bodyweight per day
PCB – polychlorinated biphenyls
TEQ – 2,3,7,8-tetrachlorodibenzodioxin equivalents

Table F5. Non cancer risk estimates (hazard quotient) for tribal populations eating all species based on samples taken from the upper portion of Port Gamble Bay, Kitsap County, Washington

Chemical:	**Arsenic [a]**	**Cadmium**	**Chromium**	**Copper**	**Dioxin/ Furan (TEQ) [b]**	**PCB Congeners (TEQ) [b]**	**PCB Aroclor**
MRL or RfD:	0.0003 (MRL)	0.001 (RfD Food)	0.001 (MRL CrVI)	0.01 (int. MRL)	1E-09 (MRL)	1E-09 (MRL)	2E-05 (MRL)
Scenario and Age Group	**Hazard Quotient [c]**						
High tribe-estimated subsistence rate							
Child 0.5 to < 1 years old	0.81	**3.8**	**3.5**	**7.5**	**3.4**	**1.4**	**16**
Child 1 to < 2 years old	0.66	**3.0**	**2.8**	**6.0**	**2.7**	**1.1**	**13**
Child 2 to < 6 years old	0.43	**2.0**	**1.8**	**4.0**	**1.8**	0.72	**8.3**
Child 6 to < 11 years old	0.24	**1.1**	**1.0**	**2.2**	**1.0**	0.39	**4.6**
Child 11 to < 16 years old	0.79	**3.7**	**3.4**	**7.3**	**3.3**	**1.3**	**15**
Child 16 to < 21 years old	0.63	**2.9**	**2.7**	**5.8**	**2.6**	**1.0**	**12**
Adults 21 to < 65 years old	0.56	**2.6**	**2.4**	**5.2**	**2.3**	0.94	**11**
Adults 65+ years old	0.59	**2.7**	**2.5**	**5.4**	**2.5**	0.99	**11**
Low tribe estimated subsistence rate							
Child 0.5 to < 1 years old	0.086	0.40	0.37	0.80	0.36	0.14	**1.7**
Child 1 to < 2 years old	0.070	0.32	0.30	0.64	0.29	0.12	**1.3**
Child 2 to < 6 years old	0.046	0.21	0.20	0.42	0.19	0.08	0.9
Child 6 to < 11 years old	0.025	0.12	0.11	0.23	0.10	0.042	0.5
Child 11 to < 16 years old	0.13	0.61	0.50	**1.2**	0.55	0.22	**2.6**
Child 16 to < 21 years old	0.10	0.49	0.40	0.96	0.44	0.17	**2.0**
Adults 21 to < 65 years old	0.094	0.43	0.36	0.86	0.39	0.16	**1.8**
Adults 65+ years old	0.10	0.46	0.38	0.91	0.41	0.16	**1.9**

Notes:
a. Based on 1% inorganic arsenic of total arsenic in shellfish.
b. Dioxin/furan and PCB congeners summed using TEQ method.
c. Tribe-estimated subsistence diet assumed to be comprised of 51% clams, 19% geoduck,, 17% Crab (13% muscle, 4% butter), and 13% oyster based on 95[th] Suquamish consumption rates; used average concentrations of chemicals listed in Table F4.

Abbreviations: < less than
CrVI – hexavalent chromium (represents only a portion of total chromium measured)
mg/kg-day – milligrams chemical per kilogram bodyweight per day
MRL – minimal risk level developed by Agency of Toxic Substances and Disease Registry (chronic duration, except for copper which is for intermediate duration exposures)
PCB – polychlorinated biphenyls
RfD – oral reference dose developed by the Environmental Protection Agency
TEQ – 2,3,7,8-tetrachlorodibenzodioxin equivalents

Table F6. Carcinogenic risk estimates for tribal populations eating all species based on samples taken from the upper portion of Port Gamble Bay, Kitsap County, Washington

Chemical:	**Arsenic [a]**	**Dioxin/ Furan (TEQ) [b]**	**PCB Congeners (TEQ) [b]**	**PCB Aroclor**	**cPAH (BaP-EQ) [c]**	**Total Lifetime Cancer Risk [d]**
Cancer Slope Factor:	5.7	150000	150000	2	7.3	NA
Scenario and Age Group	**Cancer Risk Estimates (mg/kg/day)$^{-1}$ [e]**					
High tribe-estimated subsistence rate – upper portion of bay (all samples)						
Child 0.5 to < 1 yr	8.9E-06	3.3E-06	1.3E-06	4.0E-06	2.4E-05	3.7E-05
Child 1 to < 2 yr	1.4E-05	5.3E-06	2.1E-06	6.5E-06	3.8E-05	6.0E-05
Child 2 to < 6 yr	3.8E-05	1.4E-05	5.5E-06	1.7E-05	3.0E-05	8.7E-05
Child 6 to < 11 yr	2.6E-05	9.4E-06	3.8E-06	1.2E-05	2.1E-05	6.0E-05
Child 11 to < 16 yr	8.7E-05	3.2E-05	1.3E-05	3.9E-05	6.9E-05	**2.0E-04**
Child 16 to < 21 yr	6.9E-05	2.5E-05	1.0E-05	3.1E-05	1.8E-05	**1.2E-04**
Adults 21 to < 65 yr	**5.4E-04**	**2.0E-04**	7.9E-05	**2.5E-04**	**1.4E-04**	**9.6E-04**
Adults 65+ years old	1.7E-04	6.2E-05	2.5E-05	7.6E-05	4.5E-05	**3.0E-04**
Lifetime sum	**9.5E-04**	**3.5E-04**	**1.4E-04**	**4.3E-04**	**3.4E-04**	**1.8E-03**
Low tribe estimated subsistence rate– upper portion of bay (all samples)						
Child 0.5 to < 1 yr	9.5E-07	3.5E-07	1.4E-07	4.3E-07	2.5E-06	4.0E-06
Child 1 to < 2 yr	1.5E-06	5.6E-07	2.2E-07	6.9E-07	4.1E-06	6.4E-06
Child 2 to < 6 yr	4.0E-06	1.5E-06	5.9E-07	1.8E-06	3.2E-06	9.3E-06
Child 6 to < 11 yr	2.7E-06	1.0E-06	4.0E-07	1.2E-06	2.2E-06	6.3E-06
Child 11 to < 16 yr	1.1E-05	4.2E-06	1.7E-06	5.2E-06	9.2E-06	2.7E-05
Child 16 to < 21 yr	2.6E-05	9.4E-06	3.7E-06	1.2E-05	6.8E-06	4.6E-05
Adults 21 to < 65 yr	9.0E-05	3.3E-05	1.3E-05	4.1E-05	2.4E-05	**1.6E-04**
Adults 65+ years old	2.8E-05	1.0E-05	4.1E-06	1.3E-05	7.5E-06	5.0E-05
Lifetime sum	**1.5E-04**	5.6E-05	2.2E-05	6.9E-05	5.0E-05	**2.8E-04**

Notes:
a. Based on 1% inorganic arsenic of total arsenic in shellfish
b. Dioxin/furan and PCB congeners summed using TEQ method.
c. Individual cPAHs summed using BaP-EQ method.
d. Total lifetime cancer risks summed from risk of arsenic, dioxin/furan, PCB congeners and cPAHs; arsenic and PCBs appear to be from background sources.
e. Tribe-estimated subsistence diet comprised of 51% clams, 19% geoduck,, 17% Crab (13% muscle, 4% butter), and 13% oyster with 95th and mean (95th UCL) Suquamish consumption rates; average concentrations of chemicals listed in Table F4.

Abbreviations: < less than
BaP – benzo(a)pyrene equivalents
cPAH – polycyclic aromatic hydrocarbons (7) associated with carcinogenic effects
CrVI – hexavalent chromium (represents only a portion of total chromium measured)
mg/kg-day – milligrams chemical per kilogram bodyweight per day
PCB – polychlorinated biphenyls
TEQ – 2,3,7,8-tetrachlorodibenzodioxin equivalents

Table F7. Location-specific annual exposure dose estimates for tribal populations and the general population eating clams and oysters based on samples taken from the upper portion of Port Gamble Bay, Kitsap County, Washington.

Chemical:	**Arsenic [a]**	**Cadmium**	**Chromium**	**Copper**	**Dioxin/ Furan (TEQ) [b]**	**PCB Congeners (TEQ) [b]**	**PCB Aroclor**	**cPAH (BaP-EQ) [c]**
Species [d]	**Average Concentration from Upper Portion of Bay (mg/kg) [e]**							
Clam	*0.022	*0.35	*0.61	*6.96	*2.4E-07	*4.5E-08	*2.0E-02	*2.7E-03
Oyster	*0.020	*1.26	*0.24	*22.26	5.7E-07	1.3E-07	*3.8E-02	*1.0E-02
Scenario and Age Group	**Annual Dose (mg/kg-day)**							
High tribe-estimated subsistence rate – upper portion of bay (all samples)								
Child 0.5 to < 1 year old	1.2E-04	3.0E-03	3.1E-03	5.7E-02	1.7E-09	3.5E-10	1.4E-04	2.4E-05
Child 1 to < 2 years old	1.0E-04	2.4E-03	2.5E-03	4.6E-02	1.4E-09	2.9E-10	1.1E-04	1.9E-05
Child 2 to < 6 years old	6.6E-05	1.6E-03	1.6E-03	3.0E-02	9.1E-10	1.9E-10	7.2E-05	1.3E-05
Child 6 to < 11 years old	3.6E-05	8.8E-04	9.0E-04	1.7E-02	5.0E-10	1.0E-10	3.9E-05	6.9E-06
Child 11 to < 16 years old	1.2E-04	2.9E-03	3.0E-03	5.6E-02	1.7E-09	3.5E-10	1.3E-04	2.3E-05
Child 16 to < 21 years old	9.6E-05	2.3E-03	2.4E-03	4.4E-02	1.3E-09	2.7E-10	1.0E-04	1.9E-05
Adults 21 to < 65 years old	8.6E-05	2.2E-03	2.1E-03	4.0E-02	1.2E-09	2.5E-10	9.4E-05	3.5E-05
Adults 65+ years old	9.0E-05	2.2E-03	2.3E-03	4.2E-02	1.3E-09	2.6E-10	9.8E-05	3.7E-05
Low tribe estimated subsistence rate – upper portion of bay (all samples)								
Child 0.5 to < 1 years old	1.3E-05	3.2E-04	3.3E-04	6.1E-03	1.8E-10	3.8E-11	1.4E-05	2.5E-06
Child 1 to < 2 years old	1.1E-05	2.6E-04	2.7E-04	4.9E-03	1.5E-10	3.0E-11	1.2E-05	2.1E-06
Child 2 to < 6 years old	7.0E-06	1.7E-04	1.7E-04	3.2E-03	9.7E-11	2.0E-11	7.6E-06	1.3E-06
Child 6 to < 11 years old	3.8E-06	9.3E-05	9.6E-05	1.8E-03	5.3E-11	1.1E-11	4.2E-06	7.4E-07
Child 11 to < 16 years old	2.0E-05	4.9E-04	5.0E-04	9.3E-03	2.8E-10	5.8E-11	2.2E-05	3.9E-06
Child 16 to < 21 years old	1.6E-05	3.9E-04	4.0E-04	7.4E-03	2.2E-10	4.6E-11	1.7E-05	3.1E-06
Adults 21 to < 65 years old	1.4E-05	3.5E-04	3.6E-04	6.6E-03	2.0E-10	4.1E-11	1.6E-05	2.8E-06
Adults 65+ years old	1.5E-05	3.7E-04	3.8E-04	7.0E-03	2.1E-10	4.3E-11	1.6E-05	2.9E-06

Table F7 (continued).

Chemical:	Arsenic [a]	Cadmium	Chromium	Copper	Dioxin/ Furan (TEQ) [b]	PCB Congeners (TEQ) [b]	PCB Aroclor	cPAH (BaP-EQ) [c]
Low tribe estimated subsistence rate – mill								
Child 0.5 to < 1 years old	1.3E-05	3.2E-04	6.0E-04	8.3E-03	1.5E-10	4.1E-11	2.4E-05	5.8E-06
Child 1 to < 2 years old	1.0E-05	2.6E-04	4.9E-04	6.7E-03	1.2E-10	3.3E-11	1.9E-05	4.7E-06
Child 2 to < 6 years old	6.7E-06	1.7E-04	3.2E-04	4.4E-03	7.7E-11	2.1E-11	1.3E-05	3.1E-06
Child 6 to < 11 years old	3.7E-06	9.4E-05	1.7E-04	2.4E-03	4.2E-11	1.2E-11	6.8E-06	1.7E-06
Child 11 to < 16 years old	1.9E-05	5.0E-04	9.2E-04	1.3E-02	2.2E-10	1.4E-10	3.6E-05	8.8E-06
Child 16 to < 21 years old	1.5E-05	3.9E-04	7.3E-04	1.0E-02	1.8E-10	1.1E-10	2.9E-05	7.0E-06
Adults 21 to < 65 years old	1.4E-05	3.5E-04	6.6E-04	9.0E-03	1.6E-10	1.0E-10	2.6E-05	6.3E-06
Adults 65+ years old	1.4E-05	3.7E-04	6.9E-04	9.5E-03	1.7E-10	1.1E-10	2.7E-05	6.6E-06
General Population – mill								
Child 0.5 to < 1 years old	6.9E-06	1.8E-04	3.3E-04	4.5E-03	7.9E-11	2.2E-11	1.3E-05	3.2E-06
Child 1 to < 2 years old	5.6E-06	1.4E-04	2.7E-04	3.7E-03	6.4E-11	1.8E-11	1.0E-05	2.5E-06
Child 2 to < 6 years old	3.6E-06	9.4E-05	1.7E-04	2.4E-03	4.2E-11	1.2E-11	6.8E-06	1.7E-06
Child 6 to < 11 years old	2.0E-06	5.1E-05	9.5E-05	1.3E-03	2.3E-11	6.4E-12	3.7E-06	9.1E-07
Child 11 to < 16 years old	4.2E-06	1.1E-04	2.0E-04	2.8E-03	4.8E-11	1.3E-11	7.8E-06	1.9E-06
Child 16 to < 21 years old	3.3E-06	8.5E-05	1.6E-04	2.2E-03	3.8E-11	1.1E-11	6.2E-06	1.5E-06
Adults 21 to < 65 years old	3.0E-06	7.6E-05	1.4E-04	2.0E-03	3.4E-11	9.6E-12	5.6E-06	1.4E-06
Adults 65+ years old	3.1E-06	8.0E-05	1.5E-04	2.1E-03	3.6E-11	1.0E-11	5.9E-06	1.4E-06
Species [d]	**Average Concentration from Western Shoreline (mg/kg)**							
Clam	*0.025	*0.39	*0.34	*3.87	1.6E-07	8.5E-08	2.8E-02	*2.0E-03
Oyster	0.010	1.22	0.200	8.90	7.3E-07	1.3E-07	3.3E-02	1.5E-03

Table F7 (continued).

Chemical:	**Arsenic [a]**	**Cadmium**	**Chromium**	**Copper**	**Dioxin/ Furan (TEQ) [b]**	**PCB Congeners (TEQ) [b]**	**PCB Aroclor**	**cPAH (BaP-EQ) [c]**
Scenario and Age Group	**Annual Dose (mg/kg-day)**							
High tribe-estimated subsistence rate – western shoreline								
Child 0.5 to < 1 years old	1.3E-04	3.2E-03	1.8E-03	2.8E-02	1.6E-09	5.4E-10	1.6E-04	1.1E-05
Child 1 to < 2 years old	1.0E-04	2.6E-03	1.4E-03	2.3E-02	1.3E-09	4.4E-10	1.3E-04	8.8E-06
Child 2 to < 6 years old	6.7E-05	1.7E-03	9.5E-04	1.5E-02	8.2E-10	2.9E-10	8.7E-05	5.8E-06
Child 6 to < 11 years old	3.7E-05	9.2E-04	5.2E-04	8.1E-03	4.5E-10	1.6E-10	4.8E-05	3.2E-06
Child 11 to < 16 years old	1.2E-04	3.1E-03	1.7E-03	2.7E-02	1.5E-09	5.3E-10	1.6E-04	1.1E-05
Child 16 to < 21 years old	9.8E-05	2.5E-03	1.4E-03	2.2E-02	1.2E-09	4.2E-10	1.3E-04	8.5E-06
Adults 21 to < 65 years old	8.8E-05	2.2E-03	1.2E-03	1.9E-02	1.1E-09	3.8E-10	1.1E-04	7.6E-06
Adults 65+ years old	9.2E-05	2.3E-03	1.3E-03	2.0E-02	1.1E-09	4.0E-10	1.2E-04	8.0E-06
Low tribe estimated subsistence rate – western shoreline								
Child 0.5 to < 1 years old	1.3E-05	3.4E-04	1.9E-04	3.0E-03	1.7E-10	5.8E-11	9.6E-06	1.2E-06
Child 1 to < 2 years old	1.1E-05	2.7E-04	1.5E-04	2.4E-03	1.3E-10	4.7E-11	7.7E-06	9.4E-07
Child 2 to < 6 years old	7.1E-06	1.8E-04	1.0E-04	1.6E-03	8.7E-11	3.1E-11	5.1E-06	6.1E-07
Child 6 to < 11 years old	3.9E-06	9.8E-05	5.5E-05	8.6E-04	4.8E-11	1.7E-11	2.8E-06	3.4E-07
Child 11 to < 16 years old	2.1E-05	5.2E-04	2.9E-04	4.5E-03	2.5E-10	8.8E-11	5.8E-06	1.8E-06
Child 16 to < 21 years old	1.6E-05	4.1E-04	2.3E-04	3.6E-03	2.0E-10	7.0E-11	4.6E-06	1.4E-06
Adults 21 to < 65 years old	1.5E-05	3.7E-04	2.1E-04	3.2E-03	1.8E-10	6.3E-11	1.9E-05	1.3E-06
Adults 65+ years old	1.5E-05	3.9E-04	2.2E-04	3.4E-03	1.9E-10	6.6E-11	2.0E-05	1.3E-06
General Population – western shoreline								
Child 0.5 to < 1 years old	7.4E-06	1.9E-04	1.0E-04	3.0E-03	9.0E-11	3.2E-11	9.6E-06	6.3E-07
Child 1 to < 2 years old	5.9E-06	1.5E-04	8.4E-05	2.4E-03	7.3E-11	2.5E-11	7.7E-06	5.1E-07
Child 2 to < 6 years old	3.9E-06	9.8E-05	5.5E-05	1.6E-03	4.8E-11	1.7E-11	5.1E-06	3.4E-07
Child 6 to < 11 years old	2.1E-06	5.4E-05	3.0E-05	8.6E-04	2.6E-11	9.1E-12	2.8E-06	1.8E-07
Child 11 to < 16 years old	4.5E-06	1.1E-04	6.3E-05	4.5E-03	5.5E-11	1.9E-11	5.8E-06	3.9E-07
Child 16 to < 21 years old	3.5E-06	8.9E-05	5.0E-05	3.6E-03	4.3E-11	1.5E-11	4.6E-06	3.1E-07
Adults 21 to < 65 years old	3.2E-06	8.0E-05	4.5E-05	3.2E-03	3.9E-11	1.4E-11	4.1E-06	2.7E-07
Adults 65+ years old	3.3E-06	8.4E-05	4.7E-05	3.4E-03	4.1E-11	1.4E-11	4.3E-06	2.9E-07

Table F7 (continued).

Chemical:	Arsenic [a]	Cadmium	Chromium	Copper	Dioxin/ Furan (TEQ) [b]	PCB Congeners (TEQ) [b]	PCB Aroclor	cPAH (BaP-EQ) [c]
Species [d]	**Average Concentration from Eastern Shoreline (mg/kg)**							
Clam	0.017	0.21	0.27	1.28	7.2E-07	9.1E-08	3.1E-02	*1.2E-03
Oyster	0.015	1.14	0.20	6.21	7.2E-07	1.3E-07	4.0E-02	4.3E-03
Scenario and Age Group	**Annual Dose (mg/kg-day) Eastern Shoreline (reservation)**							
High tribe-estimated subsistence rate – eastern shoreline (reservation)								
Child 0.5 to < 1 years old	9.6E-05	2.3E-03	1.5E-03	1.3E-02	4.1E-09	5.6E-10	1.9E-04	1.0E-05
Child 1 to < 2 years old	7.7E-05	1.8E-03	1.2E-03	1.0E-02	3.3E-09	4.6E-10	1.5E-04	8.2E-06
Child 2 to < 6 years old	5.1E-05	1.2E-03	7.8E-04	6.8E-03	2.2E-09	3.0E-10	1.0E-04	5.4E-06
Child 6 to < 11 years old	2.8E-05	6.5E-04	4.3E-04	3.7E-03	1.2E-09	1.6E-10	5.5E-05	2.9E-06
Child 11 to < 16 years old	9.3E-05	2.2E-03	1.4E-03	1.3E-02	4.0E-09	5.5E-10	1.9E-04	9.9E-06
Child 16 to < 21 years old	7.4E-05	1.7E-03	1.1E-03	1.0E-02	3.2E-09	4.4E-10	1.5E-04	7.9E-06
Adults 21 to < 65 years old	6.6E-05	1.6E-03	1.0E-03	8.9E-03	2.9E-09	3.9E-10	1.3E-04	7.0E-06
Adults 65+ years old	7.0E-05	1.6E-03	1.1E-03	9.4E-03	3.0E-09	4.1E-10	1.4E-04	7.4E-06
Low tribe estimated subsistence rate – eastern shoreline (reservation)								
Child 0.5 to < 1 years old	1.0E-05	2.4E-04	1.6E-04	1.4E-03	4.4E-10	6.0E-11	2.0E-05	1.1E-06
Child 1 to < 2 years old	8.2E-06	1.9E-04	1.3E-04	1.1E-03	3.5E-10	4.8E-11	1.6E-05	8.7E-07
Child 2 to < 6 years old	5.4E-06	1.3E-04	8.3E-05	7.3E-04	2.3E-10	3.2E-11	1.1E-05	5.7E-07
Child 6 to < 11 years old	2.9E-06	6.9E-05	4.5E-05	4.0E-04	1.3E-10	1.7E-11	5.9E-06	3.1E-07
Child 11 to < 16 years old	1.6E-05	3.7E-04	2.4E-04	2.1E-03	6.7E-10	9.2E-11	3.1E-05	1.7E-06
Child 16 to < 21 years old	1.2E-05	2.9E-04	1.9E-04	1.7E-03	5.3E-10	7.3E-11	2.5E-05	1.3E-06
Adults 21 to < 65 years old	1.1E-05	2.6E-04	1.7E-04	1.5E-03	4.8E-10	6.5E-11	2.2E-05	1.2E-06
Adults 65+ years old	1.2E-05	2.7E-04	1.8E-04	1.6E-03	5.0E-10	6.9E-11	2.3E-05	1.2E-06

Table F7 (continued).

Chemical:	Arsenic [a]	Cadmium	Chromium	Copper	Dioxin/ Furan (TEQ) [b]	PCB Congeners (TEQ) [b]	PCB Aroclor	cPAH (BaP-EQ) [c]
General Population – eastern shoreline (reservation)								
Child 0.5 to < 1 years old	5.5E-06	1.3E-04	8.5E-05	7.5E-04	2.4E-10	3.3E-11	1.1E-05	5.9E-07
Child 1 to < 2 years old	4.5E-06	1.1E-04	6.9E-05	6.0E-04	1.9E-10	2.6E-11	8.9E-06	4.8E-07
Child 2 to < 6 years old	2.9E-06	6.9E-05	4.5E-05	4.0E-04	1.3E-10	1.7E-11	5.8E-06	3.1E-07
Child 6 to < 11 years old	1.6E-06	3.8E-05	2.5E-05	2.2E-04	6.9E-11	9.5E-12	3.2E-06	1.7E-07
Child 11 to < 16 years old	3.4E-06	7.9E-05	5.2E-05	4.6E-04	1.5E-10	2.0E-11	6.7E-06	3.6E-07
Child 16 to < 21 years old	2.7E-06	6.3E-05	4.1E-05	3.6E-04	1.2E-10	1.6E-11	5.3E-06	2.8E-07
Adults 21 to < 65 years old	2.4E-06	5.6E-05	3.7E-05	3.2E-04	1.0E-10	1.4E-11	4.8E-06	2.5E-07
Adults 65+ years old	2.5E-06	5.9E-05	3.9E-05	3.4E-04	1.1E-10	1.5E-11	5.0E-06	2.7E-07

Table F7 Notes:
a. Based on 1% inorganic arsenic of total arsenic in shellfish.
b. Dioxin/furan and PCB congeners summed using TEQ method.
c. cPAHs summed using BaP-EQ method.
d. Diet assumed to be comprised of 80% clams, 20% oyster based on tribal consumption of these species and their availability in Port Gamble Bay.
e. Average concentrations with asterisk were calculated using the 95[th] upper confidence limit.
Abbreviations: < less than
BaP-Eq – benzo(a)pyrene equivalents
cPAH – carcinogenic polycyclic aromatic hydrocarbons
mg/kg – milligrams chemical per kilogram shellfish tissue
mg/kg-day – milligrams chemical per kilogram bodyweight per day
PCB – polychlorinated biphenyls
TEQ – 2,3,7,8-tetrachlorodibenzodioxin equivalents

Table F8. Location-specific non-cancer risk estimates (hazard quotients) for tribal populations and the general population eating clams and oysters based on samples taken from the upper portion of Port Gamble Bay, Kitsap County, Washington.

Chemical:	Arsenic [a]	Cadmium	Chromium	Copper	Dioxin/ Furan (TEQ) [b]	PCB Congeners (TEQ) [b]	PCB Aroclor
MRL or RfD:	0.0003 (MRL)	0.001 (RfD Food)	0.001 (MRL CrVI)	0.01 (int. MRL)	1E-09 (MRL)	1E-09 (MRL)	2E-05 (MRL)
Scenario and Age Group	**Hazard Quotient - Upper Portion of Bay [c]**						
High tribe-estimated subsistence rate – upper portion of bay							
Child 0.5 to < 1 years old	0.41	**3.0**	**3.1**	**5.7**	**1.7**	0.35	**6.8**
Child 1 to < 2 years old	0.33	**2.4**	**2.5**	**4.6**	**1.4**	0.29	**5.5**
Child 2 to < 6 years old	0.22	**1.6**	**1.6**	**3.0**	0.91	0.19	**3.6**
Child 6 to < 11 years old	0.12	0.88	0.90	**1.7**	0.50	0.10	**2.0**
Child 11 to <16 years old	0.40	**2.9**	**3.0**	**5.6**	**1.7**	0.35	**6.6**
Child 16 to <21 years old	0.32	**2.3**	**2.4**	**4.4**	**1.3**	0.27	**5.2**
Adults 21 to < 65 years old	0.29	**2.6**	**2.1**	**4.0**	**1.2**	0.25	**4.7**
Adults 65+ years old	0.30	**2.7**	**2.3**	**4.2**	**1.3**	0.26	**4.9**
Low tribe estimated subsistence rate – upper portion of bay							
Child 0.5 to < 1 years old	0.044	0.32	0.33	0.61	0.18	0.038	0.72
Child 1 to < 2 years old	0.035	0.26	0.27	0.49	0.15	0.030	0.58
Child 2 to < 6 years old	0.023	0.17	0.17	0.32	0.10	0.020	0.38
Child 6 to < 11 years old	0.013	0.09	0.10	0.18	0.05	0.011	0.21
Child 11 to <16 years old	0.067	0.49	0.50	0.93	0.28	0.058	**1.1**
Child 16 to <21 years old	0.053	0.39	0.40	0.74	0.22	0.046	0.87
Adults 21 to < 65 years old	0.048	0.35	0.36	0.66	0.20	0.041	0.78
Adults 65+ years old	0.050	0.37	0.38	0.70	0.21	0.043	0.82
General Population (around bay) – upper portion of bay							
Child 0.5 to < 1 years old	0.024	0.18	0.18	0.33	0.10	0.021	0.39
Child 1 to < 2 years old	0.019	0.14	0.15	0.27	0.081	0.017	0.32
Child 2 to < 6 years old	0.013	0.093	0.10	0.18	0.053	0.011	0.21
Child 6 to < 11 years old	0.0069	0.051	0.052	0.10	0.029	0.0059	0.11
Child 11 to <16 years old	0.015	0.11	0.11	0.20	0.061	0.012	0.24
Child 16 to <21 years old	0.012	0.084	0.087	0.16	0.048	0.010	0.19
Adults 21 to < 65 years old	0.010	0.076	0.078	0.14	0.043	0.0089	0.17
Adults 65+ years old	0.011	0.080	0.082	0.15	0.046	0.0093	0.18

Table F8 (continued).

Chemical:	**Arsenic [a]**	**Cadmium**	**Chromium**	**Copper**	**Dioxin/ Furan (TEQ) [b]**	**PCB Congeners (TEQ) [b]**	**PCB Aroclor**
Scenario and Age Group	**Hazard Quotient – Mill**						
High tribe-estimated subsistence rate – Mill							
Child 0.5 to < 1 years old	0.40	**3.1**	**5.7**	**7.8**	**1.4**	0.38	**11**
Child 1 to < 2 years old	0.32	**2.5**	**4.6**	**6.3**	**1.1**	0.31	**9.0**
Child 2 to < 6 years old	0.21	**1.6**	**3.0**	**4.1**	0.72	0.20	**5.9**
Child 6 to < 11 years old	0.11	0.88	**1.6**	**2.3**	0.40	0.11	**3.2**
Child 11 to <16 years old	0.39	**3.0**	**5.5**	**7.6**	**1.3**	0.37	**11**
Child 16 to <21 years old	0.31	**2.4**	**4.4**	**6.0**	**1.1**	0.30	**8.6**
Adults 21 to < 65 years old	0.27	**2.1**	**3.9**	**5.4**	0.95	0.26	**7.7**
Adults 65+ years old	0.29	**2.2**	**4.1**	**5.7**	**1.0**	0.28	**8.1**
Low tribe estimated subsistence rate – Mill							
Child 0.5 to < 1 years old	0.042	0.32	0.60	0.83	0.15	0.041	**1.2**
Child 1 to < 2 years old	0.034	0.26	0.49	0.67	0.12	0.033	**1.0**
Child 2 to < 6 years old	0.022	0.17	0.32	0.44	0.077	0.021	0.63
Child 6 to < 11 years old	0.012	0.09	0.17	0.24	0.042	0.012	0.34
Child 11 to <16 years old	0.064	0.50	0.92	1.3	0.22	0.14	**1.8**
Child 16 to <21 years old	0.051	0.39	0.73	**1.0**	0.18	0.11	**1.4**
Adults 21 to < 65 years old	0.046	0.35	0.66	0.90	0.16	0.10	**1.3**
Adults 65+ years old	0.048	0.37	0.69	0.90	0.17	0.11	**1.4**
General Population – Mill							
Child 0.5 to < 1 years old	0.023	0.18	0.33	0.45	0.079	0.022	0.64
Child 1 to < 2 years old	0.019	0.14	0.27	0.37	0.064	0.018	0.52
Child 2 to < 6 years old	0.012	0.094	0.17	0.24	0.042	0.012	0.34
Child 6 to < 11 years old	0.007	0.051	0.10	0.13	0.023	0.006	0.19
Child 11 to <16 years old	0.014	0.11	0.20	0.28	0.048	0.013	0.39
Child 16 to <21 years old	0.011	0.085	0.16	0.22	0.038	0.011	0.31
Adults 21 to < 65 years old	0.010	0.076	0.14	0.45	0.034	0.010	0.28
Adults 65+ years old	0.010	0.080	0.15	0.37	0.036	0.010	0.29

Table F8 (continued).

Chemical:	Arsenic [a]	Cadmium	Chromium	Copper	Dioxin/ Furan (TEQ) [b]	PCB Congeners (TEQ) [b]	PCB Aroclor
Scenario and Age Group	**Hazard Quotient – Western Shoreline**						
High tribe-estimated subsistence rate – western shoreline							
Child 0.5 to < 1 years old	0.42	**3.2**	**1.8**	**2.8**	**1.6**	0.54	**8.2**
Child 1 to < 2 years old	0.34	**2.6**	**1.4**	**2.3**	**1.3**	0.44	**6.7**
Child 2 to < 6 years old	0.22	**1.7**	**0.9**	**1.5**	0.82	0.29	**4.4**
Child 6 to < 11 years old	0.12	0.9	**0.5**	0.81	0.45	0.16	**2.4**
Child 11 to <16 years old	0.41	**3.1**	**1.7**	**2.7**	**1.5**	0.53	**8.0**
Child 16 to <21 years old	0.33	**2.5**	**1.4**	**2.2**	**1.2**	0.42	**6.4**
Adults 21 to < 65 years old	0.29	**2.2**	**1.2**	**1.9**	**1.1**	0.38	**5.7**
Adults 65+ years old	0.31	**2.3**	**1.3**	**2.0**	**1.1**	0.40	**6.0**
Low tribe estimated subsistence rate – western shoreline							
Child 0.5 to < 1 years old	0.045	0.34	0.19	0.30	0.17	0.058	0.88
Child 1 to < 2 years old	0.036	0.27	0.15	0.24	0.13	0.047	0.71
Child 2 to < 6 years old	0.024	0.18	0.10	0.16	0.09	0.031	0.46
Child 6 to < 11 years old	0.013	0.10	0.06	0.09	0.05	0.017	0.25
Child 11 to <16 years old	0.069	0.52	0.29	0.45	0.25	0.088	**1.3**
Child 16 to <21 years old	0.055	0.41	0.23	0.36	0.20	0.070	**1.1**
Adults 21 to < 65 years old	0.049	0.37	0.21	0.32	0.18	0.063	0.95
Adults 65+ years old	0.051	0.39	0.22	0.34	0.19	0.066	**1.0**
General Population – western shoreline							
Child 0.5 to < 1 years old	0.025	0.19	0.10	0.16	0.090	0.032	0.48
Child 1 to < 2 years old	0.020	0.15	0.084	0.13	0.073	0.025	0.39
Child 2 to < 6 years old	0.013	0.10	0.055	0.086	0.048	0.017	0.25
Child 6 to < 11 years old	0.0071	0.054	0.030	0.047	0.026	0.009	0.14
Child 11 to <16 years old	0.015	0.11	0.063	0.10	0.055	0.019	0.29
Child 16 to <21 years old	0.012	0.089	0.050	0.078	0.043	0.015	0.23
Adults 21 to < 65 years old	0.011	0.080	0.045	0.070	0.039	0.014	0.21
Adults 65+ years old	0.011	0.084	0.047	0.073	0.041	0.014	0.22

Table F8 (continued).

Chemical:	Arsenic [a]	Cadmium	Chromium	Copper	Dioxin/ Furan (TEQ) [b]	PCB Congeners (TEQ) [b]	PCB Aroclor
Scenario and Age Group	**Hazard Quotient – Eastern Shoreline (Reservation)**						
High tribe-estimated subsistence rate – eastern shoreline (reservation)							
Child 0.5 to < 1 years old	0.32	**2.3**	**1.5**	**1.3**	**4.1**	0.56	**9.5**
Child 1 to < 2 years old	0.26	**1.8**	**1.2**	**1.0**	**3.3**	0.46	**7.7**
Child 2 to < 6 years old	0.17	**1.2**	**0.8**	0.68	**2.2**	0.30	**5.0**
Child 6 to < 11 years old	0.09	0.65	**0.4**	0.37	**1.2**	0.16	**2.8**
Child 11 to < 16 years old	0.31	**2.2**	**1.4**	**1.3**	**4.0**	0.55	**9.3**
Child 16 to < 21 years old	0.25	**1.7**	**1.1**	**1.0**	**3.2**	0.44	**7.4**
Adults 21 to < 65 years old	0.22	**1.6**	**1.0**	0.89	**2.9**	0.07	**6.6**
Adults 65+ years old	0.23	**1.6**	**1.1**	0.94	**3.0**	0.07	**6.9**
Low tribe estimated subsistence rate – eastern shoreline (reservation)							
Child 0.5 to < 1 years old	0.034	0.24	0.16	0.14	0.44	0.060	**1.0**
Child 1 to < 2 years old	0.027	0.19	0.13	0.11	0.35	0.048	0.82
Child 2 to < 6 years old	0.018	0.13	0.08	0.07	0.23	0.032	0.54
Child 6 to < 11 years old	0.010	0.07	0.05	0.04	0.13	0.017	0.29
Child 11 to <16 years old	0.052	0.37	0.24	0.21	0.67	0.092	**1.5**
Child 16 to <21 years old	0.041	0.29	0.19	0.17	0.53	0.073	**1.2**
Adults 21 to < 65 years old	0.037	0.26	0.17	0.15	0.48	0.065	**1.1**
Adults 65+ years old	0.039	0.27	0.18	0.16	0.50	0.069	**1.2**
General Population – eastern shoreline (reservation)							
Child 0.5 to < 1 years old	0.018	0.13	0.085	0.075	0.24	0.033	0.55
Child 1 to < 2 years old	0.015	0.11	0.069	0.060	0.19	0.026	0.45
Child 2 to < 6 years old	0.010	0.069	0.045	0.040	0.13	0.017	0.29
Child 6 to < 11 years old	0.0053	0.038	0.025	0.022	0.069	0.009	0.16
Child 11 to <16 years old	0.011	0.079	0.052	0.046	0.15	0.020	0.34
Child 16 to <21 years old	0.0089	0.063	0.041	0.036	0.12	0.016	0.27
Adults 21 to < 65 years old	0.0080	0.056	0.037	0.032	0.10	0.014	0.24
Adults 65+ years old	0.0084	0.059	0.039	0.034	0.11	0.015	0.25

Notes:
a. Based on 1% inorganic arsenic of total arsenic in shellfish.
b. Dioxin/furan and PCB congeners summed using TEQ method.
c. Diet assumed to be comprised of 80% clams, 20% oyster based on tribal consumption of these species and availability in the bay; used average concentrations (in Table F7)
Abbreviations: < less than

CrVI hexavalent chromium (represents only a portion of the total chromium measured)
mg/kg milligrams chemical per kilogram shellfish tissue
mg/kg-day – milligrams chemical per kilogram bodyweight per day
MRL Minimal risk level (based on chronic duration, except for copper which is based on intermediate duration)
PCB polychlorinated biphenyls
RfD oral Reference dose developed by environmental Protection Agency
TEQ – 2,3,7,8-tetrachlorodibenzodioxin equivalents

Table F9. Location-specific cancer risk estimates for tribal populations and the general population eating clams and oysters based on samples taken from the upper portion of Port Gamble Bay, Kitsap County, Washington.

Chemical:	**Arsenic**	**Dioxin/ Furan (TEQ)**	**PCB Congeners (TEQ)**	**PCB Aroclor**	**cPAH (BaP-EQ)**	**Total Lifetime Risk**
Cancer Slope Factor:	5.7	150000	150000	2	7.3	
Scenario and Age Group	**Cancer Risk Estimates – Upper Portion of Bay**					
High tribe-estimated subsistence rate – Upper portion of bay						
Child 0.5 to < 1 years old	4.5E-06	1.7E-06	3.4E-07	1.7E-06	1.1E-05	1.8E-05
Child 1 to < 2 years old	7.3E-06	2.7E-06	5.5E-07	2.8E-06	1.8E-05	2.9E-05
Child 2 to < 6 years old	1.9E-05	7.0E-06	1.4E-06	7.3E-06	1.4E-05	4.2E-05
Child 6 to < 11 years old	1.3E-05	4.8E-06	9.9E-07	5.0E-06	9.7E-06	2.9E-05
Child 11 to <16 years old	4.4E-05	1.6E-05	3.3E-06	1.7E-05	3.3E-05	9.6E-05
Child 16 to <21 years old	3.5E-05	1.3E-05	2.6E-06	1.3E-05	8.7E-06	5.9E-05
Adults 21 to < 65 years old	2.8E-04	1.0E-04	2.1E-05	1.1E-04	6.8E-05	4.7E-04
Adults 65+	8.6E-05	3.1E-05	6.5E-06	3.3E-05	2.1E-05	1.4E-04
Lifetime sum	**4.8E-04**	**1.8E-04**	**3.6E-05**	**1.9E-04**	**1.6E-04**	**8.6E-04**
Low tribe estimated subsistence rate – Upper portion of bay						
Child 0.5 to < 1 years old	4.8E-07	1.8E-07	3.6E-08	1.8E-07	1.2E-06	1.9E-06
Child 1 to < 2 years old	7.8E-07	2.9E-07	5.9E-08	3.0E-07	1.9E-06	3.0E-06
Child 2 to < 6 years old	2.0E-06	7.5E-07	1.5E-07	7.8E-07	1.5E-06	4.5E-06
Child 6 to < 11 years old	1.4E-06	5.1E-07	1.0E-07	5.3E-07	1.0E-06	3.0E-06
Child 11 to <16 years old	7.4E-06	2.7E-06	5.5E-07	2.8E-06	5.5E-06	1.6E-05
Child 16 to <21 years old	5.8E-06	2.1E-06	4.4E-07	2.2E-06	1.4E-06	9.9E-06
Adults 21 to < 65 years old	4.6E-05	1.7E-05	3.5E-06	1.8E-05	1.1E-05	7.8E-05
Adults 65+	1.4E-05	5.3E-06	1.1E-06	5.5E-06	3.5E-06	2.4E-05
Lifetime sum	**7.1E-05**	**2.6E-05**	**5.3E-06**	**2.7E-05**	**2.2E-05**	**1.2E-04**

Table F9 (continued).

Chemical:	Arsenic	Dioxin/ Furan (TEQ)	PCB Congeners (TEQ)	PCB Aroclor	cPAH (BaP-EQ)	Total Lifetime Risk
General Population (around bay) – Upper portion of bay						
Child 0.5 to < 1 years old	2.6E-07	9.6E-08	2.0E-08	1.0E-07	6.5E-07	1.0E-06
Child 1 to < 2 years old	4.2E-07	1.6E-07	3.2E-08	1.6E-07	1.0E-06	1.7E-06
Child 2 to < 6 years old	1.1E-06	4.1E-07	8.4E-08	4.3E-07	8.3E-07	2.4E-06
Child 6 to < 11 years old	7.6E-07	2.8E-07	5.7E-08	2.9E-07	5.6E-07	1.7E-06
Child 11 to <16 years old	1.6E-06	5.9E-07	1.2E-07	6.1E-07	1.2E-06	3.5E-06
Child 16 to <21 years old	1.3E-06	4.6E-07	9.5E-08	4.8E-07	3.1E-07	2.1E-06
Adults 21 to < 65 years old	1.0E-05	3.7E-06	7.5E-07	3.8E-06	2.5E-06	1.7E-05
Adults 65+	3.1E-06	1.1E-06	2.3E-07	1.2E-06	7.7E-07	5.2E-06
Lifetime sum	**1.7E-05**	**6.2E-06**	**1.3E-06**	**6.5E-06**	**6.6E-06**	**3.1E-05**
Scenario and Age Group	**Cancer Risk Estimates - Mill**					
High tribe-estimated subsistence rate – Mill						
Child 0.5 to < 1 years old	4.3E-06	1.3E-06	3.7E-07	2.9E-06	2.5E-05	3.1E-05
Child 1 to < 2 years old	7.0E-06	2.1E-06	5.9E-07	4.6E-06	4.1E-05	5.1E-05
Child 2 to < 6 years old	1.8E-05	5.6E-06	1.6E-06	1.2E-05	3.2E-05	5.8E-05
Child 6 to < 11 years old	1.3E-05	3.8E-06	1.1E-06	8.3E-06	2.2E-05	4.0E-05
Child 11 to <16 years old	4.2E-05	1.3E-05	3.6E-06	2.8E-05	7.4E-05	1.3E-04
Child 16 to <21 years old	3.4E-05	1.0E-05	2.8E-06	2.2E-05	2.0E-05	6.6E-05
Adults 21 to < 65 years old	2.6E-04	8.0E-05	2.2E-05	1.7E-04	1.5E-04	5.2E-04
Adults 65+	8.2E-05	2.5E-05	7.0E-06	5.4E-05	4.8E-05	1.6E-04
Lifetime sum	**4.6E-04**	**1.4E-04**	**3.9E-05**	**3.0E-04**	**3.7E-04**	**1.0E-03**

Table F9 (continued).

Chemical:	Arsenic	Dioxin/ Furan (TEQ)	PCB Congeners (TEQ)	PCB Aroclor	cPAH (BaP-EQ)	Total Lifetime Risk
Low tribe estimated subsistence rate – Mill						
Child 0.5 to < 1 years old	4.6E-07	1.4E-07	3.9E-08	3.0E-07	2.7E-06	3.3E-06
Child 1 to < 2 years old	7.5E-07	2.3E-07	6.3E-08	4.9E-07	4.4E-06	5.4E-06
Child 2 to < 6 years old	2.0E-06	5.9E-07	1.7E-07	1.3E-06	3.4E-06	6.1E-06
Child 6 to < 11 years old	1.3E-06	4.0E-07	1.1E-07	8.8E-07	2.3E-06	4.2E-06
Child 11 to <16 years old	7.1E-06	2.1E-06	1.4E-06	4.6E-06	1.2E-05	2.3E-05
Child 16 to <21 years old	5.6E-06	1.7E-06	1.1E-06	3.7E-06	3.3E-06	1.2E-05
Adults 21 to < 65 years old	4.4E-05	1.3E-05	8.6E-06	2.9E-05	2.6E-05	9.2E-05
Adults 65+	1.4E-05	4.2E-06	2.7E-06	9.0E-06	8.0E-06	2.9E-05
Lifetime sum	**6.8E-05**	**2.1E-05**	**1.3E-05**	**4.5E-05**	**5.0E-05**	**1.5E-04**
General Population – Mill						
Child 0.5 to < 1 years old	2.5E-07	7.6E-08	2.1E-08	1.7E-07	1.5E-06	1.8E-06
Child 1 to < 2 years old	4.1E-07	1.2E-07	3.4E-08	2.7E-07	2.4E-06	2.9E-06
Child 2 to < 6 years old	1.1E-06	3.2E-07	9.0E-08	7.0E-07	1.9E-06	3.3E-06
Child 6 to < 11 years old	7.3E-07	2.2E-07	6.2E-08	4.8E-07	1.3E-06	2.3E-06
Child 11 to <16 years old	1.5E-06	4.6E-07	1.3E-07	1.0E-06	2.7E-06	4.8E-06
Child 16 to <21 years old	1.2E-06	3.7E-07	1.0E-07	8.0E-07	7.1E-07	2.4E-06
Adults 21 to < 65 years old	9.6E-06	2.9E-06	8.1E-07	6.3E-06	5.6E-06	1.9E-05
Adults 65+	3.0E-06	9.0E-07	2.5E-07	2.0E-06	1.7E-06	5.9E-06
Lifetime sum	**1.6E-05**	**4.9E-06**	**1.4E-06**	**1.1E-05**	**1.5E-05**	**3.8E-05**

Table F9 (continued).

Chemical:	Arsenic	Dioxin/ Furan (TEQ)	PCB Congeners (TEQ)	PCB Aroclor	cPAH (BaP-EQ)	Total Lifetime Risk
Scenario and Age Group	**Cancer Risk Estimates Western Shoreline**					
High tribe-estimated subsistence rate – Western shoreline						
Child 0.5 to < 1 years old	4.6E-06	1.5E-06	5.2E-07	2.1E-06	5.1E-06	1.2E-05
Child 1 to < 2 years old	7.5E-06	2.4E-06	8.4E-07	3.4E-06	8.3E-06	1.9E-05
Child 2 to < 6 years old	2.0E-05	6.3E-06	2.2E-06	8.9E-06	6.5E-06	3.5E-05
Child 6 to < 11 years old	1.3E-05	4.3E-06	1.5E-06	6.1E-06	4.4E-06	2.4E-05
Child 11 to <16 years old	4.5E-05	1.5E-05	5.1E-06	2.1E-05	1.5E-05	8.0E-05
Child 16 to <21 years old	3.6E-05	1.2E-05	4.0E-06	1.6E-05	4.0E-06	5.5E-05
Adults 21 to < 65 years old	2.8E-04	9.1E-05	3.2E-05	1.3E-04	3.1E-05	4.4E-04
Adults 65+	8.8E-05	2.8E-05	9.9E-06	4.0E-05	9.7E-06	1.4E-04
Lifetime sum	**5.0E-04**	**1.6E-04**	**5.6E-05**	**2.3E-04**	**7.4E-05**	**7.8E-04**
Low tribe estimated subsistence rate – Western shoreline						
Child 0.5 to < 1 years old	4.9E-07	1.6E-07	5.6E-08	2.2E-07	5.4E-07	1.3E-06
Child 1 to < 2 years old	8.0E-07	2.6E-07	9.0E-08	3.6E-07	8.8E-07	2.0E-06
Child 2 to < 6 years old	2.1E-06	6.7E-07	2.4E-07	9.5E-07	6.9E-07	3.7E-06
Child 6 to < 11 years old	1.4E-06	4.6E-07	1.6E-07	6.5E-07	4.7E-07	2.5E-06
Child 11 to <16 years old	7.5E-06	2.4E-06	8.5E-07	3.4E-06	2.5E-06	1.3E-05
Child 16 to <21 years old	6.0E-06	1.9E-06	6.7E-07	2.7E-06	6.6E-07	9.2E-06
Adults 21 to < 65 years old	4.7E-05	1.5E-05	5.3E-06	2.1E-05	5.2E-06	7.3E-05
Adults 65+	1.5E-05	4.7E-06	1.6E-06	6.7E-06	1.6E-06	2.3E-05
Lifetime sum	**7.2E-05**	**2.3E-05**	**8.2E-06**	**3.3E-05**	**1.0E-05**	**1.1E-04**

Table F9 (continued).

Chemical:	Arsenic	Dioxin/ Furan (TEQ)	PCB Congeners (TEQ)	PCB Aroclor	cPAH (BaP-EQ)	Total Lifetime Risk
General Population – Western shoreline						
Child 0.5 to < 1 years old	2.7E-07	8.7E-08	3.0E-08	1.2E-07	3.0E-07	6.8E-07
Child 1 to < 2 years old	4.3E-07	1.4E-07	4.9E-08	2.0E-07	4.8E-07	1.1E-06
Child 2 to < 6 years old	1.1E-06	3.7E-07	1.3E-07	5.2E-07	3.8E-07	2.0E-06
Child 6 to < 11 years old	7.8E-07	2.5E-07	8.8E-08	3.5E-07	2.6E-07	1.4E-06
Child 11 to <16 years old	1.6E-06	5.3E-07	1.8E-07	7.4E-07	5.4E-07	2.9E-06
Child 16 to <21 years old	1.3E-06	4.2E-07	1.5E-07	5.9E-07	1.4E-07	2.0E-06
Adults 21 to < 65 years old	1.0E-05	3.3E-06	1.1E-06	4.7E-06	1.1E-06	1.6E-05
Adults 65+	3.2E-06	1.0E-06	3.6E-07	1.4E-06	3.5E-07	4.9E-06
Lifetime sum	**1.7E-05**	**5.6E-06**	**1.9E-06**	**7.9E-06**	**3.0E-06**	**2.8E-05**
Scenario and Age Group	**Cancer Risk Estimates – Eastern Shoreline (Reservation)**					
High tribe-estimated subsistence rate – Eastern shoreline (reservation)						
Child 0.5 to < 1 years old	3.5E-06	4.0E-06	5.4E-07	2.4E-06	4.8E-06	1.3E-05
Child 1 to < 2 years old	5.6E-06	6.4E-06	8.8E-07	3.9E-06	7.7E-06	2.1E-05
Child 2 to < 6 years old	1.5E-05	1.7E-05	2.3E-06	1.0E-05	6.0E-06	4.0E-05
Child 6 to < 11 years old	1.0E-05	1.2E-05	1.6E-06	7.1E-06	4.1E-06	2.7E-05
Child 11 to <16 years old	3.4E-05	3.9E-05	5.3E-06	2.4E-05	1.4E-05	9.2E-05
Child 16 to <21 years old	2.7E-05	3.1E-05	4.2E-06	1.9E-05	3.7E-06	6.6E-05
Adults 21 to < 65 years old	2.1E-04	2.4E-04	3.3E-05	1.5E-04	2.9E-05	5.2E-04
Adults 65+	6.6E-05	7.5E-05	1.0E-05	4.6E-05	9.0E-06	1.6E-04
Lifetime sum	**3.7E-04**	**4.2E-04**	**5.8E-05**	**2.6E-04**	**6.9E-05**	**9.2E-04**

Table F9 (continued).

Chemical:	Arsenic	Dioxin/ Furan (TEQ)	PCB Congeners (TEQ)	PCB Aroclor	cPAH (BaP-EQ)	Total Lifetime Risk
Low tribe estimated subsistence rate – Eastern shoreline (reservation)						
Child 0.5 to < 1 years old	3.7E-07	4.2E-07	5.8E-08	2.6E-07	5.1E-07	1.4E-06
Child 1 to < 2 years old	6.0E-07	6.8E-07	9.3E-08	4.2E-07	8.2E-07	2.2E-06
Child 2 to < 6 years old	1.6E-06	1.8E-06	2.4E-07	1.1E-06	6.4E-07	4.2E-06
Child 6 to < 11 years old	1.1E-06	1.2E-06	1.7E-07	7.5E-07	4.4E-07	2.9E-06
Child 11 to <16 years old	5.7E-06	6.5E-06	8.8E-07	4.0E-06	2.3E-06	1.5E-05
Child 16 to <21 years old	4.5E-06	5.1E-06	7.0E-07	3.1E-06	6.1E-07	1.1E-05
Adults 21 to < 65 years old	3.5E-05	4.0E-05	5.5E-06	2.5E-05	4.8E-06	8.6E-05
Adults 65+	1.1E-05	1.3E-05	1.7E-06	7.7E-06	1.5E-06	2.7E-05
Lifetime sum	**5.5E-05**	**6.2E-05**	**8.5E-06**	**3.8E-05**	**9.3E-06**	**1.3E-04**
General Population – Eastern shoreline (reservation)						
Child 0.5 to < 1 years old	2.0E-07	2.3E-07	3.1E-08	1.4E-07	2.8E-07	7.4E-07
Child 1 to < 2 years old	3.3E-07	3.7E-07	5.1E-08	2.3E-07	4.4E-07	1.2E-06
Child 2 to < 6 years old	8.6E-07	9.8E-07	1.3E-07	6.0E-07	3.5E-07	2.3E-06
Child 6 to < 11 years old	5.9E-07	6.7E-07	9.1E-08	4.1E-07	2.4E-07	1.6E-06
Child 11 to <16 years old	1.2E-06	1.4E-06	1.9E-07	8.6E-07	5.0E-07	3.3E-06
Child 16 to <21 years old	9.8E-07	1.1E-06	1.5E-07	6.8E-07	1.3E-07	2.4E-06
Adults 21 to < 65 years old	7.7E-06	8.7E-06	1.2E-06	5.4E-06	1.0E-06	1.9E-05
Adults 65+	2.4E-06	2.7E-06	3.7E-07	1.7E-06	3.3E-07	5.8E-06
Lifetime sum	**1.3E-05**	**1.5E-05**	**2.0E-06**	**9.1E-06**	**2.8E-06**	**3.3E-05**

Notes for Table F9:
a. Based on 1% inorganic arsenic of total arsenic in shellfish.
b. Dioxin/furan and PCB congeners summed using TEQ method.
c. cPAHs summed using BaP-EQ method.
d. Diet assumed to be comprised of 80% clams, 20% oyster based on tribal consumption of these species and their availability in Port Gamble Bay using average concentrations (see Table F7).
Abbreviations: < less than
BaP-Eq – benzo(a)pyrene equivalents
cPAH – carcinogenic polycyclic aromatic hydrocarbons
mg/kg – milligrams chemical per kilogram shellfish tissue
mg/kg-day – milligrams chemical per kilogram bodyweight per day
PCB – polychlorinated biphenyls
TEQ – 2,3,7,8-tetrachlorodibenzodioxin equivalents

Multiple Chemicals and Routes

Chemical is a term that includes metals, metalloids, and the substances they form with other constituents. This calculation estimates an excess cancer risk expressed as the proportion of a population that may be affected by a carcinogen during a lifetime of exposure. Total lifetime cancer risk is the sum of increased cancer risk from ingesting shellfish and/or contact with shoreline sediments (through incidental ingestion of sediment and dermal contact) for all chemicals identified as chemicals of potential concern.

For a chemical with a hazard quotient (HQ) greater than 1.0, the exposure dose of the chemical was compared to the No-Observed-Adverse-Effect-Level (NOAEL), or other comparable value of the most sensitive study to determine the margin of exposure.

To assess the potential for toxic effects from exposure to chemical mixtures associated with non-carcinogenic effects at the site, a Hazard Index (HI) for the mixture of chemicals is defined as a sum of the HQ. If the HI is less than 1.0 it is highly unlikely that significant or additive toxic interactions would occur, as a result no further evaluation is necessary. For chemical mixtures with an HI greater than 1.0, estimated doses of the individual chemicals were compared to their NOAELs (or comparable values). If the dose of one or more of the individual chemicals is within one order of magnitude of its respective NOAEL (0.1 × NOAEL), then there is potential for additive or interactive effects.

Appendix G–Chemical-Specific Toxicity Evaluation

For those chemical concentrations that exceed comparison values, a more in-depth analysis of exposure and levels causing adverse effects is warranted. The mathematical equations used to estimate how much of a substance a person may contact based on their actions or habits is described in Appendices E and F. Potential health risks were evaluated for 1) subsistence shellfish harvest and consumption, 2) average tribal member shellfish harvest and consumption, 3) general population resident harvest and consumption, and 4) sediment exposures to a child playing on the reservation shoreline (for arsenic and cPAHs only). For chemicals of potential concern, non-carcinogenic and/or carcinogenic effects may be evaluated depending on screening results. Carcinogenicity for specific chemicals was determined by EPA and is defined in Table G1.

Table G1. EPA classification of chemicals based on existing scientific evidence for carcinogenicity:

<table>
<tr><th>Group</th><th>Classification</th><th>Definition for Chemicals</th></tr>
<tr><td>Group A</td><td>“Human Carcinogen”</td><td>Enough evidence that chemicals can cause cancer in humans.</td></tr>
<tr><td>Group B</td><td>“Probable Human Carcinogen”</td><td>Limited evidence that chemicals can cause cancer in humans but at present it is not conclusive. Sufficient evidence exists for carcinogenicity in animals.
Group B1 chemicals have limited evidence with human data.
Group B2 chemicals have inadequate evidence with human data.</td></tr>
<tr><td>Group C</td><td>“Possible Human Carcinogen”</td><td>Inadequate evidence that chemicals can cause cancer in humans but at present it is far from conclusive. Limited evidence exists in animals in the absence of human data.</td></tr>
<tr><td>Group D</td><td>“Not Classifiable as to human carcinogenicity”</td><td>Inadequate evidence that chemicals can cause cancer in humans or animals or no data are available.</td></tr>
<tr><td>Group E</td><td>“Evidence of non-carcinogenicity for humans”</td><td>Chemicals show no evidence for carcinogenicity in multiple animal and or human studies.</td></tr>
</table>

Table G2. Summary of exposure doses, levels at which health effects occur, and lifetime cancer risks for each chemical.

Chemical	Scenario	Estimated Exposure Dose (mg/kg-day) [a]				MRL or RfD (mg/kg-day)	NOAEL	LOAEL	Tolerable Daily Intakes	Cancer Slope Factor	Lifetime Cancer Risk	
		Sediment		Shellfish								
		Adult	Child	Adult	Child						Sediment	Shellfish
Arsenic	Higher Tribe-estimated Subsistence consumption rate	7.20E-06	8.90E-05	1.7E-04	1.3E-04	0.0003 (human)	0.008	0.014	0.002 [b]	5.7	8.4E-05	**9.5E-04**
	Lower Tribe-estimated Subsistence consumption rate	2.80E-06	3.40E-05	2.8E-05	1.4E-05						3.2E-05	**1.5E-04**
	General Population	1.40E-06	1.70E-05	3.1E-06	3.8E-06						1.6E-05	1.7E-05
	Tribal child at shoreline		2.90E-05								1.3E-05	-
Cadmium	Higher Tribe-estimated Subsistence consumption rate			**2.6E-03**	**2.0E-03**	0.001 RfD for food (human)	0.01	NA	0.001 [c]	NA	-	-
	Lower Tribe-estimated Subsistence consumption rate			4.3E-04	2.1E-04							
	General Population			7.6E-05	7.8E-05							
	Tribal child at shoreline											
Chromium	Higher Tribe-estimated Subsistence consumption rate			2.4E-03	1.8E-03	1.5 Cr(III) 0.001 Cr(VI);	1,468 Cr(III) 2.5 Cr(VI)	NA	NA	NA	-	-
	Lower Tribe-estimated Subsistence consumption rate			3.6E-04	2.0E-04							
	General Population			7.8E-05	9.5E-05							
	Tribal child at shoreline											

Table G2 (continued).

Chemical	Scenario	Estimated Exposure Dose (mg/kg-day) [a]				MRL or RfD (mg/kg-day)	NOAEL	LOAEL	Tolerable Daily Intakes	Cancer Slope Factor	Lifetime Cancer Risk	
		Sediment		Shellfish								
		Adult	Child	Adult	Child						Sediment	Shellfish
Copper	Higher Tribe-estimated Subsistence consumption rate			**0.052**	**0.04**	0.01 intermediate MRL (human)	0.042	0.091	~0.13 to 0.17 [c]	NA	-	-
	Lower Tribe-estimated Subsistence consumption rate			0.0086	0.0042							
	General Population			0.0014	0.0018							
	Tribal child at shoreline											
Dioxin/ Furan TEQ	Higher Tribe-estimated Subsistence consumption rate			**2.3E-09**	**1.8E-09**	1E-09 (MRL monkey) 7E-10 (RfD (human)	NA	1.2E-07 2.0E-08	1E-09 to 4E-09 [b]	150000	**-**	**3.5E-04**
	Lower Tribe-estimated Subsistence consumption rate			3.9E-10	1.9E-10						-	5.6E-05
	General Population			4.3E-11	5.3E-11						-	6.2E-6
	Tribal child at shoreline										-	-
PCB Congener TEQ	Higher Tribe-estimated Subsistence consumption rate			**9.4E-10**	**7.2E-10**	1E-09 (MRL monkey) 7E-10 (RfD (human	NA	5.0E-03	NA	150000	**-**	**1.4E-04**
	Lower Tribe-estimated Subsistence consumption rate			1.6-E-10	7.6E-11						-	2.2E-05
	General Population			8.9E-12	1.1E-11						-	1.3E-06
	Tribal child at shoreline										-	-

Table G2 (continued).

Chemical	Scenario	Estimated Exposure Dose (mg/kg-day) [a]				MRL or RfD (mg/kg-day)	NOAEL	LOAEL	Tolerable Daily Intakes	Cancer Slope Factor	Lifetime Cancer Risk	
		Sediment		Shellfish								
		Adult	Child	Adult	Child						Sediment	Shellfish
cPAH BaP-EQ	Higher Tribe-estimated Subsistence consumption rate	1.20E-07	1.53E-06	3.5E-5	2.7E-5	NA	NA	NA	NA	7.3	1.8E-06	**3.4E-04**
	Lower Tribe-estimated Subsistence consumption rate	4.61E-08	5.87E-07	5.8E-6	2.8E-6						6.9E-07	5.0E-05
	General Population	2.30E-08	2.93E-07	6.0E-7	7.3E-7						3.5E-07	6.6E-6
	Tribal child at shoreline	-	5.03E-07								6.6E-08	-
Cancer Risks for Multiple Chemical	Higher Tribe-estimated Subsistence consumption rate										8.6E-05	**1.8E-03**
	Lower Tribe-estimated Subsistence consumption rate										3.3E-05	**2.8E-04**
	General Population										1.6E-05	3.1E-5
	Tribal child at shoreline										1.3E-05	-

Notes:
a Exposure doses for children represent ages 2 to < 6 years old and for adults represent ages 21 to < 65 years old; tribal doses estimated for all species, general population for clam and oyster only
b World Health Organization total daily intakes adjusted for adults
c Tolerable daily intakes set by the Food and Nutrition Board of the Institute of Medicine adjusted for adults
ATSDR Agency for Toxic Substances and Disease Registry
BaP-EQ Benzo(a)pyrene equivalents
cPAH Polycyclic aromatic hydrocarbons with carcinogenic effects
EPA Environmental Protection Agency
LOAEL Lowest observed adverse effect level
mg/kg-day milligram chemical per kilogram bodyweight per day (exposure dose)
MRL Minimal risk level (ATSDR)
NA Not available
Bold - Exceeds MRL, RfD or cancer risk of 1.0E-4
NOAEL No observed adverse effect level
PCB polychlorinated biphenyls
RfD Oral reference dose (EPA)
TEQ 2,3,7,8-tetrachlorodibenzodioxin equivalents
Blank cells in tables Per the tribal request, tribal exposure scenario developed for tribal children is for Point Julia (eastern shoreline) only, which is part of the reservation.

Arsenic

Arsenic is a naturally-occurring element in the earth's soil and is present naturally in Puget Sound. Normal Puget Sound soil background concentrations rarely exceed 7.3 mg/kg (90^{th} percentile) and average 2.86 mg/kg (39). Arsenic consists of two forms, organic arsenic and inorganic arsenic. Inorganic arsenic is much more harmful than organic arsenic. Inorganic arsenic is mostly likely the dominant form in the sediments of the Port Gamble Bay. Emissions from smelters and use of arsenical pesticides have resulted in significantly higher levels of arsenic in many parts of the state. Contamination from the use of arsenic by Pope and Talbot has only been identified in specific upland areas; remediation of the uplands is not addressed in his report. The fate and transport of arsenic from the upland to specific sediment areas has not been identified. With the exception of three samples at the landfills, arsenic sediment concentrations are similar to the median concentration (2.86 mg/kg) found throughout the Puget Sound.

Crabs have the highest arsenic levels (4–8 mg/kg) among the species sampled from Port Gamble Bay, which is typical throughout Puget Sound. Of the clam and oyster species, the highest tissue concentration was found in littleneck clams (4 mg/kg). In studies of shellfish, inorganic arsenic ranges from 1% to 20% of the total arsenic in shellfish (18;28;40-44). In a study specific to Puget Sound, Ecology evaluated speciated arsenic data from shellfish tissues near cleanup sites including clam (n=15 composite samples), oyster (n=1 composite sample), cockle (n=1 composite sample), and crab (n=6 composite samples) (28). Percent inorganic arsenic in these samples was analyzed results showed a mean of 0.665% with an upper confidence limit 0.819%; therefore, 1% the total arsenic appears to be a conservative estimate of inorganic arsenic in shellfish tissues in the area and was used to estimate exposures. For this evaluation, DOH assumed that 1% of arsenic in shellfish was inorganic arsenic.

Non-carcinogenic Effects

The ATSDR MRL and EPA-established reference dose (RfD) for arsenic is 0.0003 mg/kg-day based on skin color changes and excessive growth of tissue (human data) after drinking water exposures. The dose at the high tribe-estimated subsistence rate is 5–6 times lower than the no-observed-adverse-effect level (NOAEL, 0.0008 mg/kg-day) and 80-102 times below the lowest-observed-adverse effect level (LOAEL, 0.014 mg/kg-day) from the most sensitive human study. Non-carcinogenic effects have not been found in some studies where people are exposed to arsenic in drinking water at chronic doses of 0.0004 to 0.01 mg/kg-day. Other studies found effects as low as 0.0043 mg/kg-day. It is not clear how food exposures compare to drinking water exposures in terms of absorption efficiency. Slower absorption with food may lead to the body having more time to detoxify inorganic arsenic thus avoiding high internal doses that can lead to harm. Exposures to high concentrations from long-term use of contaminated drinking water may cause dermal effects (e.g., hyperpigmentation, hyperkeratosis, corns, and warts) and peripheral neuropathy characterized by numbness in the hands and feet.

Estimated exposures to arsenic from sediments and shellfish consumption occurring for a long time (more than one year) in children and adults eating shellfish at the high tribe-estimated subsistence consumption rate are below levels where observable non-cancerous effects have been reported in human studies. Sediment contact and consumption of shellfish from Port Gamble Bay could result in an estimated arsenic exposure dose of 0.00018 mg/kg-day and

0.00022 mg/kg-day for an adult and child high-end subsistence tribal member respectively (Appendix E, Table E4 and Appendix F, Table F4).

Carcinogenic Effects

EPA classifies inorganic arsenic as a ‘Class A’ human carcinogen. Long-term oral exposure to arsenic in drinking water resulted in increased risk of skin, bladder, and lung cancer; however, much uncertainty exists about what levels of intake might lead to increased cancer risk. 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 EPA IRIS value) (45-53). Information provided in these reviews allows the calculation of slope factors for arsenic which range from 0.4 to 27 per mg/kg-day (but mostly greater than 3.7 mg/kg-day). 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 1.5 per mg/kg-day currently listed in the EPA Integrated Risk Information System (IRIS) database (54). The EPA IRIS review draft for the Science Advisory Board presented a slope factor for combined lung and bladder cancer of 5.7 per mg/kg-day (55). The slope factor calculated from the work by the National Research Council is about 21 per mg/kg-day (56). The revised external review draft of the EPA IRIS toxicological review presented revised cancer slope factors for these cancers as 16.9 and 25.7 per mg/kg-day for men and women respectively (57). Until EPA officially implements these values in IRIS and ATSDR recommends using these values, DOH will apply the interim slope factor of 5.7 per mg/kg-day.

Exposures to arsenic from eating shellfish from Port Gamble Bay at the high and low tribe-estimated subsistence consumption rate could result in a lifetime excess risk of developing 9.5 or 1.5 additional cancers in every 10,000 people exposed, respectively (see Appendix F, Table F6).

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 found in leafy vegetables and potatoes. Shellfish generally have higher cadmium levels (up to 1 mg/kg) than other types of fish or meat. In Port Gamble Bay, cadmium levels are highest in oysters but these levels are not as high as those found in oysters of the nearby Hood Canal (58). Cadmium is stored in the liver and kidneys and slowly leaves the body in the urine and feces in humans and animals (59).

Non-carcinogenic Effects

The RfD for cadmium exposure from food is 0.001 mg/kg-day, based on adverse effects in the kidney at higher doses. A NOAEL of 0.001 mg/kg-day was established based on human studies involving chronic exposures to cadmium in food. The EPA RfD for food is less conservative than both the MRL and the RfD for water, 0.0001 and 0.0005 mg/kg-day respectively. The latter two are based on environmental exposures, whereas the EPA RfD for food accounts for lower absorption that occurs when eating food. Cadmium absorption varies depending on the type of food and may be lower with shellfish (Ref). The World Health Organization’s Provisional Tolerable Weekly Intake (PTWI) for cadmium (0.007 mg/kg bodyweight) corresponds to a daily intake of 0.001 mg/kg-day (60).

Summary–Estimated exposures to cadmium occurring for a long time (more than one year) in children and adults eating shellfish at the high tribe-estimated subsistence consumption rate are slightly higher than levels where no effects have been reported in human studies. This consumption rate leads to a dose slightly above the NOAEL and it is unknown what dose above the NOAEL will result in effects in the kidney. Eating shellfish at the low tribe-estimated subsistence consumption rate may result in an estimated exposure lower than levels where effects are expected to occur. Consumption of cadmium from shellfish collected from Port Gamble Bay could result in an exposure dose of 0.0026 mg/kg-day for adult high tribe-estimated subsistence consumers and up to 0.002 mg/kg-day for a child, respectively (see Appendix F, Table F5). Low tribe-estimated subsistence consumption rates and the general population consumption rates have exposures lower than the RfD (for food or water) and the MRL.

Carcinogenic Effects

EPA classified cadmium as a Group B1, "probable human carcinogen," based on limited evidence in workplace settings and inhalation exposure which are not relevant to these exposures. Several studies have failed to show cadmium to be carcinogenic by the oral route and carcinogenicity by this route has been disputed by many studies.

Chromium

Chromium is a naturally-occurring element in the air, water, soil, and earth's crust. Chromium is found in three main forms: chromium metal, trivalent chromium or Cr(III), and hexavalent chromium or Cr(VI). Chromium is used in metallurgy, dye and pigments, wood preservatives, tanning, refractory material, and as reagents for processing hydrocarbons. Of these, Cr(VI) is most easily absorbed and harmful. Cr(III) is the most stable state of chromium. Cr(III) is an essential nutrient required for maintenance of normal fat and cholesterol metabolism and insulin and glucose metabolism. It is the biologically active form, found in virtually all foods and used as a supplement. With low doses, some ingested Cr(VI) is converted to Cr(III) and most will exit the body in the feces within a few days and never enter the blood stream. Only about 1% –2% of ingested chromium passes through the walls of the intestine enter the bloodstream.

Chromium levels in sediments and shellfish tissues near the site have not been characterized into the individual forms of chromium. Total chromium concentrations in sediments around Port Gamble Bay were not high enough to trigger further evaluation for health effects for this pathway. According to the U.S. Food and Drug Administration (FDA), Cr(III) is most likely the form present in shellfish (61). Surveys of contaminants in shellfish conducted by FDA and the National Fisheries Service found average chromium levels to range from 0.1 mg/kg to 0.9 mg/kg. Levels in shellfish from Port Gamble Bay fall within this range, ranging from 0.1 to 0.7 mg/kg minus one outlier at 1.9 mg/kg near the former mill area.

Non-carcinogenic Effects

EPA established an oral RfD for trivalent Cr(III) at 1.5 mg/kg-day (62). A NOAEL of 1,468 mg/kg-day was established based on animal study involving chronic exposures to chromium in which no effects were observed. ATSDR established a chronic MRL of 0.001 mg/kg-day for Cr(VI) based on effects in the small intestine (i.e., hyperplasia of the duodenum) (63) and EPA established an RfD for Cr(VI) at 0.003 mg/kg-day based on a NOAEL of 2.5 mg/kg-day at which no effects were observed in animal studies (64). Table G2 compares tribal intake values to reference daily intake values of Cr(III) (65;66).

Summary– Estimated exposures to total chromium from ingesting shellfish over a long time (more than one year) in children and adults consuming shellfish at the higher tribe-estimated subsistence consumption rate are not expected to result in harmful health effects. Consuming shellfish at the lower tribe-estimated subsistence consumption rate and at the general population rate have lower estimated exposures. High tribe-estimated subsistence consumption of shellfish from Port Gamble Bay could result in estimated exposure doses of 0.0024 and 0.0018 mg/kg-day (total chromium) for adults and children, respectively (Appendix F, Table F5). The high subsistence dose is more than two orders of magnitude lower than the RfD for Cr(III) and is near the ATSDR MRL and EPA RfD for Cr(VI). The shellfish intake of total chromium by these consumers is most likely to be in the Cr(III) form and is higher than levels healthy people usually consume; however, there is no indication that these levels would lead to harm. A tolerable uptake level has not been established because few serious health effects have been linked to higher intakes of Cr(III) (65;66).

Carcinogenic Effects

There is no evidence of carcinogenicity of Cr(III) by repeated ingestion in humans or animals. Under EPA classification, Cr(VI) is classified as a Group A "Human Carcinogen" by the inhalation route of exposure, not a route of concern for this assessment. Carcinogenicity of Cr(VI) by the oral route of exposure cannot be determined and is labeled as Group D (not classifiable as to human carcinogenicity).

Copper

Copper is a metal that occurs naturally throughout the environment in rocks, soil, water, and air. Copper is used in alloys to make different kinds of metal products. It is also used in agriculture to treat diseases and as a wood preservative. Copper is an essential element and intake is necessary for humans to live. It is one of eight essential metals that humans store in large (milligram) amounts (100-150 mg) (67). Copper rapidly enters the bloodstream and is distributed throughout the body after eating or drinking it. The average daily intake of copper in the U.S. is about 1 mg/day. The body is very good at blocking high levels of copper from entering the bloodstream. Copper leaves the body mostly in feces and urine. People with Wilson's disease (a genetic disorder that allows copper to build up in the body) are sensitive to large intakes of copper.

Non-carcinogenic Effects

Neither a chronic MRL nor an oral RfD for copper has been established. An intermediate MRL of 0.01 mg/kg-day has been established for gastrointestinal effects after oral ingestion for less than two months (65;68;69). The National Research Council (NRC) concluded that the main concern regarding chronic (long-term) exposure to excess copper is liver toxicity in sensitive populations such as people with Wilson's disease, who do not metabolize copper normally. However, the majority of the population is nonresponsive (70). Chronic doses given to healthy individuals up to 7–10 milligrams a day (approximately 0.1 mg/kg-day) have not resulted in liver or kidney damage (65;71). Table G3 compares daily recommended intakes for copper developed by the Institute of Medicine (IOM) (65) with intakes of high and low tribe-estimated subsistence consumption of shellfish.

Table G3. Daily recommended intakes for copper compared to tribal intake of copper, Port Gamble Bay, Kitsap County, Washington.

Age	Recommended Daily Allowance (RDA) (mg/day)	Tolerable Upper Intake Level (UL) (mg/day)	High Tribe-Estimated Subsistence Intake (mg/day)	High Tribe-Estimated Subsistence Intake (mg/day)
7–12 months	0.22	NA	-	-
1–8 years	0.34–0.44	1–3	0.7	0.2
9–13 years	0.70	5	-	-
14–18 years	0.89	8	4.1	1.8
19+ years	0.90	10	8.3	3.6

Source: Institute of Medicine, Food, and Nutrition Board, National Institutes of Health 2001 (65)
mg/day milligrams copper per day (intake rate)
RDA – average daily level of intake sufficient to meet the nutrient requirement nearly all (97%–98% health individuals
UL – Maximum daily intake unlikely to cause adverse health effects

Summary–Estimated exposures to copper from shellfish occurring over a long period of time (more than one year) in children and adults living a high-end subsistence lifestyle are not expected to result in harmful health effects. Consumption of shellfish from Port Gamble Bay at the higher tribe-estimated subsistence intake rate could result in the estimated exposure dose of 0.052 and 0.04 mg/kg-day for adults and children, respectively (Appendix F, Table F5). While these values are higher than the MRL for intermediate durations (less than two months) for copper sensitive populations, they do not exceed the daily tolerable upper intake level set by the FDA.

Carcinogenic Effects

EPA has not classified copper as carcinogenic from lack of data (Class D). There are no human data, inadequate animal data, and equivocal mutagenicity data. Thus, carcinogenic effects were not evaluated.

Dioxin and Dioxin-like Compounds

Dioxin and furan compounds consist of about 210 structural variations, which differ by the number and location of chlorine atoms on the chemical structure. The primary sources of dioxin/furan compounds in the environment include the combustion of fossil fuels and wood; the incineration of municipal, medical and hazardous wastes; and certain pulp and paper processes. Because of their stability in the environment, dioxin/furan compounds occur at very low levels from naturally-occurring sources and can be found in food, water, air, and cigarette smoke.

Health effects from exposures to dioxins and dioxin-like compounds have been documented extensively in epidemiological and toxicological studies. 2,3,7,8-Tetrochlorodibenzo-*p*-dioxin (TCDD), one of the most toxic members of this class of compounds, has a robust database and has been selected as the "index chemical" for the dioxin toxicity equivalence factor (TEF) approach. Many dioxin/furan compounds and dioxin-like PCB congeners are structurally and toxicologically similar to TCDD and can be scaled to the toxicity of TCDD. The World Health Organization expert panel assigned TEF values intended to be health-protective, thus any exposure based on TEQ will be an over-estimate because of the conservative nature of the TEF methodology (72;73). The concentration of each dioxin-like congener is multiplied by its TEF and summed to equal the TCDD-Equivalent value (TEQ). This method is used for dioxin, furan, and PCB congeners measured in sediments and tissues of Port Gamble Bay.

Non-carcinogenic Effects

EPA established a chronic RfD of 7×10^{-10} mg/kg-day for TCDD in 2010 based on reproductive and developmental effects observed at TCDD doses in humans at 2×10^{-8} mg/kg-day (74;75). ATSDR established a chronic MRL of 1×10^{-9} mg/kg-day, based on neurobehavioral developmental changes in monkeys prenatally exposed to TCDD (76;77). In 1998, World Health Organization recommended that maximum tolerable daily intake range between 1×10^{-9} to 4×10^{-9} mg/kg-day. In 2001, the Joint Food and Agricultural Organization (FAO)/WHO Expert Committee on Food Additives (JECFA) recommended a maximum tolerable daily intake up to 2.3×10^{-9} mg/kg-day.

Summary–Estimated long-term exposures to dioxin/furan compounds from shellfish in adults and children eating and harvesting shellfish at the tribe-estimated subsistence consumption rate are below levels where reproductive and developmental effects have been reported in human studies. High-end subsistence consumption of shellfish from Port Gamble Bay for a tribal adult and child could result in exposure doses of 2.3×10^{-9} and up to 1.8×10^{-9} mg/kg-day respectively. There are no data available at these exposures to confirm that no health effects could occur. While these exposures are higher than both the MRL and RfD, the dose is within the tolerable intake ranges developed by WHO and JECFA.

Eating and harvesting shellfish at the lower tribe-estimated subsistence consumption rate and the general population rate have estimated exposures below the MRL, RfD, and daily intake ranges set by WHO and JECFA; therefore, no harm is expected to these populations.

Carcinogenic Effects

EPA considers TCDD to be a Class B2 “Probable Human Carcinogen”. The carcinogenic dose response is an ongoing scientific debate and is currently being reassessed by EPA. The cancer slope factor used in this report, 150,000 $(\text{mg/kg-day})^{-1}$, is based on an early evaluation by EPA (1985) listed previously in the Health Effects Assessment Summary Tables (HEAST). Studies in rats and mice exposed to TCDD resulted in thyroid, liver, lung, and nasal turbinate tumors. Several evaluations presented cancer slope factors ranging from 9,700 to 1,000,000 $(\text{mg/kg-day})^{-1}$ using different tumor classification schemes (78;79). Thus, considerable uncertainty exists in the cancer risk estimates developed here.

For the high tribe-estimated subsistence consumption of shellfish, long-term exposure to dioxin/furan compounds could increase the likelihood of developing cancer. Consumption of shellfish at this rate could result in a lifetime excess risk of developing 3.5 additional cancers in every 10,000 people exposed for high-end tribe-estimated subsistence consumption rate and 5.6 additional cancers in every 100,000 people exposed for lower tribe-estimated subsistence consumption rate.

Polychlorinated Biphenyls (PCBs)

PCBs are a group of chlorinated chemicals that were first introduced into commercial use in 1929 as insulating fluids for electric transformers and capacitors. Other applications include use in hydraulic fluids, paint additives, plasticizers, adhesives, and fire retardants. Production of PCBs in the U.S. stopped in 1977 following concerns about toxicity and persistence in the environment. Transformers have been documented at the former mill though sediment samples have not tried to answer the questions of transport from any leakage to the shoreline sediments.

Similar to dioxin/furan compounds, there are 209 congeners that vary by the number and location of chlorine atoms on the base structure. PCBs are often identified by one of their trade names, Aroclor, which were various mixtures of congeners defined by a four-digit number. The last two digits give the percent weight of chlorination for the congeners in that mixture. In general, PCB persistence and toxicity increases with the degree of chlorination in the mixture. The individual PCB congeners are structurally and toxicologically similar to TCDD and their toxicity can be weighted in a manner similar to dioxin/furan compounds. Total PCBs are reported as either the sum of Aroclor mixtures or the TEQ sum of PCB congeners which have been multiplied by their TEF, as with the dioxin/furan compounds. The shellfish samples analyzed for Aroclor had many undetected results. The detection limit for Aroclors is much higher than analysis of individual congeners.

Non-carcinogenic Effects

Since PCB congeners are expressed as dioxin-like TEQs, PCB congeners are compared to the toxicity value for TCDD. As stated above, EPA established a chronic RfD of 7×10^{-10} mg/kg-day for TCDD in 2010 based on reproductive and developmental effects observed at TCDD doses in humans at 2×10^{-8} mg/kg-day (80;81). ATSDR established a chronic MRL of 1×10^{-9} mg/kg-day based on neurobehavioral developmental changes in monkeys prenatally exposed to TCDD (76;77). In 1998, WHO recommended that maximum tolerable daily intake range between 1×10^{-9} to 4×10^{-9} mg/kg-day. In 2001, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) recommended a maximum tolerable daily intake up to 2.3×10^{-9} mg/kg-day.

The MRL and RfD for the PCB Aroclors (0.00002 mg/kg-day) is based on adverse immune system effects (decreased antibody response) observed in Aroclor-exposed monkeys (82). PCB Aroclors have also been shown to cause liver toxicity in animals given higher doses of PCB.

Summary–Estimated long-term exposures to PCB congeners from shellfish in children and adult eating at high tribe-estimated subsistence consumption rates are below levels known to cause harm; however, there is uncertainty as to how low exposures cause effects. Subsistence consumption of shellfish from Port Gamble Bay could result in the PCB exposure doses of 9.4×10^{-10} and 7.2×10^{-10} mg/kg-day for adults and children respectively. These exposures are higher than the RfD for TCDD but lower than the level at which effects are known to occur.

When using the Aroclor detection limit to estimate concentrations of PCBs, the estimated exposure dose is approximately 2.2×10^{-4} and 3.1×10^{-4} mg/kg-day for subsistence adults and children. These estimated doses based on non-detected levels are higher than the MRL. This confirms that Aroclor results at the detection limits used in these sample analyses are not useful in estimating harmful effects of PCBs and not recommended by EPA (83).

Carcinogenic Effects

EPA has designated PCBs as Class B2 probable human carcinogen based on *sufficient* evidence from animal studies but *inadequate* evidence from human studies. The cancer slope factor used to assess cancer risk when using TEF approach for PCB Congener s 150,000 $(mg/kg\text{-}day)^{-1}$. PCB Aroclor mixtures cause liver cancer in animals. EPA suggests using an upper-bound slope factor of 2.0 per mg/kg-day.

Summary–Based on PCB TEQ concentrations in tissues, consumption of shellfish from around the bay could result in a lifetime excess risk of developing 1.4 additional cancer in every 10,000 people exposed for high subsistence tribal members and 2.2 additional cancers in every 100,000 people exposed if consuming shellfish at the low tribe-estimated subsistence consumption rate. This is considered low cancer risk and is barely distinguishable from background cancer rates in the absence of PCBs.

Polycyclic Aromatic Hydrocarbons with Carcinogenic Effects (cPAHs)

PAHs are generated by the incomplete combustion of organic matter, including oil, wood, and coal. They are found in materials such as creosote, coal, coal tar, and used motor oil. Dietary sources make up a large percentage of PAH exposure in the U.S. population (82). Smoked or barbequed meat and fish contain relatively high levels of PAHs. The majority of dietary exposure to PAHs for the average person comes from ingestion of vegetables and grains (cereals). Based on structural similarities, metabolism and toxicity, PAHs are often grouped together when evaluating the potential for adverse health effects.

Non-carcinogenic Effects

Exposures to PAHs from shellfish and sediments at Port Gamble Bay occur at levels much lower than levels where observable non-carcinogenic effects have been reported (Tables D1 and D3 in Appendix D). Many of these compounds were several orders of magnitude below comparison values.

Carcinogenic Effects

EPA classified some PAHs as probable human carcinogens (Class B2) as a result of *sufficient* evidence of carcinogenicity in animals but *inadequate* evidence in humans. These compounds include benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-c,d)pyrene. EPA has established a cancer slope factor only for B(a)P (2.0 per mg/kg-day), which is considered the most carcinogenic, causing stomach cancers in animals drinking water containing BaP in it. In a manner similar to deriving the TEQ for dioxin/furan compounds, each cPAH is multiplied by a Relative Potency Factor (RPF). EPA established RPFs using the weight-of-evidence for carcinogenicity of the cPAHs in 1993 (refs). Products of each congener multiplied by its RPF are summed to equal the BaP-relative potency equivalent (BaP-EQ). EPA is currently reviewing the relative potency factor (RPF) approach for PAHs which may expand the number of PAHs included as potentially carcinogenic (84).

Eating shellfish from around Port Gamble Bay at subsistence consumption rates could result in a lifetime excess risk of developing 3.4 additional cancer cases in every 10,000 people exposed for high-end subsistence tribal members and 5.0 additional cancers in every 100,000 people exposed for low-end subsistence consumers.

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