Health Consultation

Evaluation of Contaminants in Sediments from the Oakland Bay Site
Shelton, Mason County, Washington

June 24, 2010

Prepared by

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

DOH 334-251 June 2010

Health Consultation: A Note of Explanation

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

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

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HEALTH CONSULTATION

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SHELTON, MASON COUNTY, WASHINGTON

Prepared By:

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Under Cooperative Agreement with the
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Foreword

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

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

For additional information or questions regarding DOH or the contents of this health consultation, please call the health advisor who prepared this document:

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

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

Glossary

Agency for Toxic Substances and Disease Registry (ATSDR)	The principal federal public health agency involved with hazardous waste issues, responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services.
Cancer Risk	A theoretical risk for developing cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.
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	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.
Comparison value	Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.
Contaminant	A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.
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.
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [**acute exposure**], of intermediate duration, or long-term [**chronic exposure**].
Hazardous substance	Any material that poses a threat to public health and/or the environment. Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive.
Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].
Ingestion rate	The amount of an environmental medium that could be ingested typically on a daily basis. Units for IR are usually liter/day for water, and mg/day for soil.
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.
Media	Soil, water, air, plants, animals, or any other part of the environment that can contain contaminants.
Minimal Risk Level (MRL)	An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see **reference dose**].

No Observed Adverse Effect Level (NOAEL)	The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.
Oral Reference Dose (RfD)	An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by EPA.
Organic	Compounds composed of carbon, including materials such as solvents, oils, and pesticides that are not easily dissolved in water.
Parts per billion (ppb)/Parts per million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
Reference Dose Media Evaluation Guide (RMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The RMEG is a *comparison value* used to select contaminants of potential health concern and is based on EPA's oral reference dose (RfD).
Route of exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].
Toxic Equivalent (TEQ)	Is defined as the sum of the products of the concentration of each compound (e.g., dioxin and furan compound) multiplied by its Toxic Equivalent Factor (TEF) value.
Toxic Equivalency Factors (TEFs)	It is an estimate of the toxicity of the compound relative to 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD). Each dioxin/furan is multiplied by a TEF to produce the dioxin TEQ. The TEQs for each chemical are then summed to give the overall 2,3,7,8-tetrachlorodibenzo-*p*-dioxin TEQ.
Volatile organic compound (VOC)	Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Summary

Introduction:

The Department of Health's (DOH) top priority for Oakland Bay residents and others who work or recreate on Oakland Bay (tribal members and the general population) is to ensure that the community has the best information possible to safeguard its health. The Department of Ecology (Ecology) asked DOH to conduct this investigation. The purpose of this health consultation is to evaluate contaminant data for surface sediment from the Oakland Bay site in Shelton, Washington and to make recommendations for actions that ensure the public's health is protected. DOH reached two important conclusions in this health consultation:

Conclusion 1:
DOH concludes that touching, breathing, or accidentally eating surface sediment containing contaminants from the Oakland Bay site for approximately 250 days per year over 30 years and/or 52 days per year over 15 years is not expected to harm health or produce harmful non-cancer health effects in an adult or child, respectively.

Basis for Decision:
The contaminant levels are below those where we would expect to see such effects. Adult exposure to surface sediments might occur while harvesting shellfish or conducting other activities at the Oakland Bay site. Child exposures might occur while playing or digging in the surface sediment at public access areas.

Conclusion 2:
DOH concludes that touching, breathing, or accidentally eating sediment containing contaminants from the Oakland Bay site is not expected to harm health or produce harmful cancer health effects. Theoretical cancer risk for dioxin ranged from one excess cancer risk in 100,000 people exposed to four excess cancer risks in 1,000,000 people exposed, which is considered very low. These levels do not exceed the U.S. EPA acceptable range of between 10^{-4} and 10^{-6}, meaning that regular exposure to a substance would lead to one additional case of cancer per 10,000 to one additional case of cancer per 1,000,000 people exposed. Similarly, theoretical cancer risks for carcinogenic polycyclic aromatic hydrocarbons (cPAHs) are within the EPA's acceptable range of cancer risk of $1x10^{-4}$ to $1x10^{-6}$.

Basis for Decision:
Based on exposure calculations, theoretical cancer risks are not likely for people exposed from childhood into adulthood (average exposure time of 70 years). Similarly, a child that plays and/or digs in the sediment is not likely to be at risk of developing cancer if he or she is exposed 52 days per year during childhood.

Note: *The state of Washington regulation, the Model Toxics Control Act or "MTCA", establishes cleanup levels for contaminated sites. These cleanup levels are based on (1) standard risk-based equations (i.e., an acceptable cancer risk level of one excess cancer risk per one million people exposed (1 x 10^{-6}), which is exceeded in some exposure scenarios (Appendix B, Table B3)*[a]*;(2) federal and state regulatory policies and procedures; and (3) consideration of cross media contamination.*

Next Steps:

1) DOH will provide copies of this health consultation to Ecology, the Squaxin Island Tribe, the Oakland Bay Shellfish Growers Association, and other concerned parties.

2) DOH is in the process of evaluating dioxins in shellfish from the Oakland Bay site. A health consultation is in process, and results will be released in the spring.

For More Information:

Please feel free to contact Elmer Diaz at (360) 236-3357 or toll free at 1-877-485-7316 if you have any questions about this health consultation.

[a] DOH used health protective screening levels and a quantitative risk assessment using site-specific exposure assumptions, to evaluate the health threat posed by the contaminated surface sediment at the Oakland Bay site. Some of those exposure assumptions may be different from those used by Ecology when conducting site cleanups under the Model Toxics Control Act (MTCA) cleanup regulation. Ecology risk levels may differ from those calculated by DOH.

Summary and Statement of Issues

The Washington State Department of Health (DOH) has prepared this health consultation at the request of the Washington State Department of Ecology (Ecology). The purpose of this health consultation is to evaluate the potential human health hazards posed by contaminants in sediments from the Oakland Bay site[b] in Shelton, Mason County, Washington. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Background

The Oakland Bay site is located in South Puget Sound. The site includes Shelton Harbor, Oakland Bay and Hammersley Inlet. Oakland Bay is a small, relatively broad and shallow estuary approximately 4 miles long and 0.75 miles wide with water depths averaging 10 to 35 feet. Shallow and broad intertidal zones are exposed during low tides at the north end of the bay and in Shelton Harbor at the south end (Figure 1). The City of Shelton and its industrial waterfront and harbor are located in the southwest portion of the bay. Due to the restrictive nature of Hammersley Inlet, a long narrow waterway linking the bay to the Puget Sound Basin, the water in Oakland Bay has high refluxing, low flushing, and high retention rates.

Eight major freshwater creeks discharge into the bay: Deer, Cranberry, Malaney, Uncle John, Campbell, Johns, Shelton, and Goldsborough. The waters of Shelton Harbor and the northern portions of Oakland Bay are currently listed as impaired, by the state of Washington under Section 303(d) of the Clean Water Act, because of fecal coliform bacteria levels.[1]

Currently, Oakland Bay is one of the most productive commercial shellfish growing areas in the country. Historical and current industrial uses of Oakland Bay have resulted in sediment contamination in Shelton Harbor and other areas of the bay. For information about potential site contaminant sources at Oakland Bay, please refer to the Summary of Existing Information and Identification of Data Gaps Technical Memorandum for Oakland Bay.[2] Cleanup at the Oakland Bay site has not been conducted and contaminants remain in the sediment.

Sample Collection and Analysis

In September of 2008, Ecology conducted a sediment investigation of the Oakland Bay site. Ecology collected surface sediment (grab) samples[c] at fifty locations from depths of 0 to 10 cm in Shelton Harbor, Oakland Bay, and Hammersley Inlet. Ecology also collected subsurface (0-1

[b] The Oakland Bay site refers to Oakland Bay, Shelton Harbor and Hammersley Inlet (Figure 1).

[c] Ecology collected subtidal and intertidal surface and subsurface samples.

feet and 1-2 feet) [d] samples. Sediment samples were analyzed for semivolatile organic compounds (SVOCs), wood resin,[e] tributyltins, metals, organochlorine pesticides, polychlorinated biphenyls (PCBs) and petroleum hydrocarbons, and dioxin/furans (Appendix A, Table A1 shows a summary of all contaminants sampled). Ecology also performed bioassays tests to evaluate sediment toxicity.

For more information about sample collection and processing methods, please refer to the sediment sampling and analysis plan, Oakland Bay Sediment Characterization Study- Mason County, Washington.[3,3]

Methods, results, and data validation are summarized in the draft data report - Sediment Investigation Report – Oakland Bay Sediment Characterization Study, Mason County, Washington.[4] In general, chemistry data met project criteria and are considered acceptable for use.

Discussion

Contaminants of Concern

DOH used a conservative approach to evaluate whether contaminated sediments at the Oakland Bay site pose a possible health concern (Appendix A). Contaminants of concern (COC) in sediment were determined by employing a screening process. Maximum sediment contaminant levels were first compared to health-based soil comparison values. In general, if a contaminant's maximum concentration is greater than its comparison value, then the contaminant is evaluated further.

Several types of health-based comparison or screening values were used during this process: cancer risk evaluation guide (CREG), environmental media evaluation guide (EMEG), and reference dose media evaluation guide (RMEG) [see the glossary for descriptions]. Comparison values such as the CREG and EMEG offer a high degree of protection and assurance that people are unlikely to be harmed by contaminants in the environment. For chemicals that cause cancer, the comparison values represent levels that are calculated to increase the risk of cancer by about one excess cancer in a million people exposed.

Comparison or screening values may also include legal standards such as the cleanup levels specified in the Washington State MTCA, and EPA's Preliminary Remediation Goals (PRGs) regional screening levels.[5] Agencies, such as Ecology and EPA, use these types of comparison values (which gives a quantitative risk assessment and provides a numeric estimate of theoretical risk or hazard) when evaluating a site. It focuses on current and potential future exposures and

[d] This evaluation will not consider subsurface samples. People are unlikely to be exposed to contaminants in the deeper sediment. Digging at this depth (i.e., 1-2 feet) in these sediments is unlikely at the Oakland Bay site. In this commercial shellfish growing area, people harvest clams that are laying in the surface.

[e] Compounds associated with wood waste include resin acids, guaiacols, ammonia, and hydrogen sulfide (Appendix A, Table A1 presents a summary of these compounds).

considers all contaminated media regardless of whether exposures are occurring, or are likely to occur. These types of values are used for regulatory purposes and often form the basis for site cleanup actions; risk estimates in the context of community health concerns may differ.

Appendix A, Table A1 summarizes the screening results, and Tables A2–A10 list surface sediment (0 to 10 cm) results for dioxin/furan congeners in Shelton Harbor, Oakland Bay, and Hammersley Inlet. Of all contaminants evaluated in sediments, only total dioxins and total cPAHs exceeded health comparison values (Table 1). Thus, only these contaminants will be evaluated further. In general, if a contaminant's maximum concentration is greater than its comparison value, it does not mean that people will get sick but that the contaminants need to be evaluated further.

Table 1. Chemicals of concern detected in surface sediment (0 to 10 cm) from Shelton Harbor, Oakland Bay, and Hammersley Inlet in Mason County, Washington.

Location	Contaminant	Maximum Concentration (ppt)	Range of Concentration (ppt)	EPA Cancer Class	ATSDR comparison value (ppt)	Contaminant of Concern
Shelton Harbor	Total Dioxin TEQ	**175**	1.0 – 175	B2	**50** [a]	**Yes**
Oakland Bay		**54.4**	4.4 – 54.4			
Hammersley Inlet		13.0	1.77 – 13.0			
Shelton Harbor	Total cPAH TEQ [b]	**0.297 (ppm)**	0.02 – 0.297 (ppm)	B2	**0.1 (ppm)** [c]	**Yes**

BOLD – Values exceed comparison value
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
Total Dioxin TEQ – sum of dioxin/furans toxic equivalent (TEQ)
[a] EMEG – Corresponds to ATSDR's chronic Environmental Media Evaluation Guide (child) for 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin [6]
[b] Units are in parts per million
[c] – Corresponds to ATSDR Cancer Risk Evaluation Guide (CREG) for benzo(a)pyrene
ppt – parts per trillion

Exposure Pathways

During shellfish harvesting and/or recreational activities at Oakland Bay beaches, people are likely to be exposed to contaminants in sediments. However, in order for any contaminant to be a health concern, the contaminant must be present at a high enough concentration to cause potential harm, and there must be a completed route of exposure to people[f]. Human use patterns and site-specific conditions were considered in the evaluation of exposure to contaminated sediments at the Oakland Bay site. Exposure to contaminants in sediment can occur through the following completed pathways and routes:

Ingestion exposure (swallowing)

Most people inadvertently swallow small amounts of sediments, soil, and dust (and any contaminants they contain). Young children often put hands, toys, pacifiers, and other things in their mouths, and these items may have dirt or dust on them that can be swallowed. Adults may ingest sediments, soil, and dust through activities such as gardening, mowing, construction work, dusting, and in this case, shellfish related work or recreational activities.

Pica behavior is a persistent eating of non-food substances (such as dirt or paper). In a small percentage of children, pica behavior has been found to result in the ingestion of relatively large amounts of soil (one or more grams per day). Compared to typical children, those who swallow large amounts of contaminated soil may have added risks from short-term exposure. Some adults may also exhibit pica behavior.

Inhalation exposure (breathing)

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

Skin exposure (dermal)

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

The following discussion addresses human use patterns and site-specific conditions that were considered in the evaluation of exposure to dioxins and furans (dioxins), and total cPAHs as contaminants of concern in site sediments through the following pathways and routes of exposure:

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

- Inadvertent sediment ingestion, dust particle inhalation, and dermal absorption of contaminants in sediment during work and/or shoreline user activities for children, general residents and shellfish workers.

Exposure Scenarios

Appendix B provides exposure doses and assumptions used for calculating hazard quotients and cancer risk for the COCs at the Oakland Bay site. An exposure scenario was developed to model exposures that might occur. These scenarios were devised to represent exposures for an adult (250 days per year)[g] and a child (52 days per year). Subsistence users, shoreline property owners, children, and shellfish workers are considered as possible receptors. Adult exposure represents the number of days per year either working and or digging in the sediment, and child exposure represents the number of days per year playing or digging in the sediment. Contact with the sediment can be frequent (i.e., 5 days per week for 50 weeks per year). However, this is likely to be conservative since it is more likely that seasonal exposures are occurring.

Chemical Specific Toxicity

Below are general summaries of dioxin health effects. The public health implications of exposure to dioxins and cPAHs from sediments are discussed in the next section.

Dioxins – General Occurrence and Toxicity

Dioxins and furans

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

The most toxic of the dioxin congeners, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) can cause chloracne (a condition of acne like lesions on the face and neck). Exposure to high levels of dioxins can cause liver damage, developmental effects, and impaired immune function.[9]

[g] This scenario assumes potential worker and/or recreational exposure (i.e., shellfish harvesting, and/or recreational harvesting) of five days per week for 50 weeks per year, which corresponds to 250 days. This scenario also assumes 52 days/year of exposure for a child playing and/or digging in the sediment. EPA recommends the central tendency and Reasonable Maximum Exposure (RME) values for exposure duration for residential and industrial scenarios – soil contact of 350 days/year, and 250 days/year for workers, respectively. EPA suggests that exposure duration may be adjusted to reflect site-specific conditions. Thus, current exposure assumptions should represent conservative actual occurrences as accurately as possible.[7,8]

Long-term exposure to dioxins could increase the likelihood of developing cancer. Studies in rats and mice exposed to TCDD resulted in thyroid and liver cancer.[10] EPA considers TCDD to be a probable human carcinogen and developed a cancer slope factor of 1.5×10^{5} mg/kg/day.[11,12]

Dioxins and Furans, and cPAHs TEQ concentrations

Dioxins are a class of chemicals, and the most toxic of these compounds is 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (commonly referred to as TCDD or dioxin). There are many forms of dioxins and "dioxin-like compounds" (DLCs) that share most, if not all, of the toxic potential of TCDD, although nearly all are considerably less potent. Included in the list of DLCs are chlorinated forms of dibenzofurans and certain polychlorinated biphenyls (PCBs). Although several dioxin and furan congeners were analyzed in the sediment, only a single value, called a dioxin toxic equivalent (TEQ), was used to determine non-cancer health threat and cancer risks. Each dioxin/furan is multiplied by a Toxic Equivalency Factor (TEF) to produce the dioxin TEQ. The TEQs for each chemical are then summed to give the overall 2,3,7,8-tetrachlorodibenzo-p-dioxin TEQ. The TEQ approach is based on the premise that many dioxins/furans and in general dioxin-like PCB congeners are structurally and toxicologically similar to 2,3,7,8-tetrachlorodibenzo-p-dioxin. TEFs are used to account for the different potencies of dioxins and furans relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin, and are available for ten chlorinated dibenzofurans and seven chlorinated dibenzodioxins using the World Health Organization (WHO) methodology.[13] A similar TEQ approach is developed for each cPAH based on the relative potency to benzo(a)pyrene.

Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (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. Based on structural similarities, metabolism, and toxicity, PAHs are often grouped together when one is evaluating their potential for adverse health effects. EPA has classified some PAHs – called cPAHs – as probable human carcinogens (B2) as a result of *sufficient* evidence of carcinogenicity in animals and *inadequate* evidence in humans.[14]

Benzo(a)pyrene is the only cPAH for which EPA has derived a cancer slope factor. The benzo(a)pyrene cancer slope factor was used as a surrogate to estimate the total cancer risk of cPAHs in sediment. It should be noted, benzo(a)pyrene is considered the most carcinogenic of the cPAHs. The use of its cancer slope factor as a surrogate for total cPAH carcinogenicity may overestimate risk. To address this issue, DOH made an adjustment for each cPAH based on the relative potency to benzo(a)pyrene or TEQ.[14]

Dietary sources make up a large percentage of PAH exposure in the U.S. population, and smoked or barbecued meats 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).[14]

Evaluating Non-Cancer Hazards

Appendix B, Table B1 shows exposure assumptions for estimating contaminant doses from surface sediment exposure. In order to evaluate the potential for non-cancer adverse health effects that may result from exposure to contaminated media (i.e., air, water, soil, and sediment), a dose is estimated for each COC; in this case, the maximum dioxins and total cPAHs concentration. These doses are calculated for situations (scenarios) in which a person might be exposed to the contaminated media. The estimated dose for each contaminant under each scenario is then compared to EPA's oral reference dose (RfD). RfDs are doses below which non-cancer adverse health effects are not expected to occur (considered "safe" doses). They are derived from toxic effect levels obtained from human population and laboratory animal studies. These toxic effect levels can be either the lowest-observed adverse effect level (LOAEL) or a no-observed adverse effect level (NOAEL). In human and 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 data uncertainty, the toxic effect level is divided by "safety factors" to produce the lower and more protective RfD. If a dose exceeds the RfD, this indicates only the potential for adverse health effects. The magnitude of this potential can be inferred from the degree to which this value is exceeded. If the estimated exposure dose is only slightly above the RfD, then that dose will fall well below the observed toxic effect level. The higher the estimated dose is above the RfD, the closer it will be to the actual observed toxic effect level. This comparison is called a hazard quotient (HQ) and is given by the equation below:

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

Based on exposure estimates quantified in Appendix B (Table B2), the general population is not likely to experience adverse non-cancer health effects from exposure to the highest TEQ dioxin levels in the sediment at the Shelton Harbor and Oakland Bay since the exposure dose did not exceed the RfD. Similarly, children and adults are not likely to experience adverse non-cancer health effects from exposures to total cPAHs in Shelton Harbor.

Evaluating Cancer Risk

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

Current regulatory practice assumes there is no "safe dose" of a carcinogen. Any dose of a carcinogen will result in some additional cancer risk. Theoretical cancer risk estimates are, therefore, not yes/no answers but measures of chance (probability). Such measures, however uncertain, are useful in determining the magnitude of a cancer threat because any level of a carcinogenic contaminant carries an associated risk. The validity of the "no safe dose" assumption for all cancer-causing chemicals is not clear. Some evidence suggests that certain chemicals considered to be carcinogenic must exceed a threshold of tolerance before initiating cancer. For such chemicals, risk estimates are not appropriate. Recent guidelines on cancer risk from the U.S. EPA reflect the potential that thresholds for some carcinogenesis exist. However, EPA still assumes no threshold unless sufficient data indicate otherwise.[15]

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

Theoretical Cancer Risk

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

Cancer is a common illness and its occurrence in a population increases with the age of the population. There are many different forms of cancer resulting from a variety of causes; not all are fatal. Approximately one quarter to one third of people living in the United States will develop cancer at some point in their lives.[16]

Theoretical cancer risk estimates for exposure to sediments at the Oakland Bay site due to frequent contact with the sediment (i.e., 250 days per year for an adult worker, and/or a recreational fisher), and 52 days per year for a child and or a seasonal exposure and/or shellfish harvesting by the general population are very low. For total dioxins at Shelton Harbor, these estimates are 1 excess cancer estimated per 100,000 people exposed (adult), and 5 excess cancers estimated per 1,000,000 people exposed (child). Similarly, theoretical cancer risks for an adult and child at Oakland Bay were low (4 excess cancers estimated per 1,000,000 people exposed, and 2 excess cancers estimated per 1,000,000 people exposed, respectively).

Theoretical cancer risks for cPAHs at Shelton Harbor for an adult are 1 excess cancer risk estimated per 1,000,000 people exposed, and a child is 6 excess cancer risks estimated per 10,000,000 people exposed (Appendix B, Table B3). These estimates are within EPA's acceptable range. The U.S. EPA generally considers an excess upper-bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6} as an acceptable range, meaning that regular exposure to a substance would lead to 1 additional case of cancer per 10,000 to 1 additional case of cancer per 1,000,000 people exposed. However, these theoretical cancer risk estimates exceed the Washington State MTCA cleanup levels based on an acceptable cancer risk level of 1 excess cancer risk per 1,000,000 people exposed ($1x10^{-6}$).[h]

Uncertainty of actual risks posed by dioxins in the environment

There is uncertainty as to the actual risk posed by low levels of dioxin in the environment. Decisions by environmental and public health agencies as to the lowest allowable levels of dioxin in soil are not purely scientific, but involve policy decisions that take this uncertainty into account. Different agencies make different policy choices (e.g. whether to regulate dioxin on the basis of dioxin's non-cancer or cancer effects, the maximum allowable cancer risk posed by dioxin, etc.) that lead to differences in allowable dioxin soil levels. EPA and Ecology regulate dioxin based on cancer risk. The Ecology state soil cleanup standard for unrestricted land use is 11 parts per trillion based on a human health risk level of 1 additional case of cancer per 1,000,000 individuals over the course of a lifetime (though this risk level could be slightly higher than or as low as zero additional cases of cancer also). The federal (EPA) cleanup level for dioxin was set at 1000 parts per trillion in residential soils based on a human health risk level of 100 additional cases of cancer per 1,000,000 individuals over the course of a lifetime. EPA is proposing revised dioxin preliminary remediation goals (PRGs) of 72 ppt for residential soil and 950 ppt for industrial soil. EPA's revised PRGs are based on a human health risk level of 1 additional case of cancer for 100,000 individuals over the course of a lifetime.

DOH and ATSDR evaluates the non-cancer health effects as well as cancer endpoints of dioxin to estimate the potential hazards of exposure. DOH assesses the likelihood of outcomes on a population and site-specific basis by evaluating variables such as route, duration and frequency of exposure. ATSDR does not establish clean-up goals or preliminary remediation goals, but ATSDR believes that health risks associated with levels of dioxins in soil below one part per billion (ppb) (i.e., 1000 ppt) would be low under most scenarios where the primary exposure pathway is incidental ingestion through direct exposure to soil.[17]

[h] DOH used health protective screening levels and a quantitative risk assessment, using site-specific exposure assumptions, to evaluate the health threat posed by the contaminated surface sediment at the Oakland Bay site. Some of those exposure assumptions may be different from those used by Ecology when conducting site cleanups under the Model Toxics Control Act (MTCA) cleanup regulation. Ecology risk levels may differ from those calculated by DOH.

Children's Health Concerns

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

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

These unique vulnerabilities of infants and children demand special attention in communities that have contamination of their water, food, soil, or air. Although Oakland Bay is a commercial shellfish growing area, it is likely that children will play and/or dig in the sediment at the Oakland Bay site's public access areas. It is also possible that many shoreline residents could be in contact with the sediment regularly in the summer time. Children's health was considered in the writing of this health consultation and the exposure scenarios treated children as the most sensitive population being exposed.

Conclusions

In general, there are uncertainties in evaluating low-level environmental exposures to all contaminants of concern in surface sediment. Thus, the true risk to the public is difficult to assess accurately and depends on a number of factors such as the chemical sensitivity, concentration of chemicals, ingestion, dermal and inhalation rates, frequency and duration of exposure, and the genetic susceptibility of an individual.

- DOH concludes that touching, breathing, or accidentally eating sediment containing dioxins and total cPAHs from the Oakland Bay site for approximately 250 days per year over 30 years and/or 52 days per year over 15 years is not expected to harm health or produce harmful non-cancer health effects in an adult or child, respectively. The levels are below those where we would expect to see such effects. Adult exposure to surface sediments might occur while harvesting shellfish or conducting other activities at the Oakland Bay site. Child exposures might occur while playing or digging in the surface sediment at public access areas.

- DOH concludes that touching, breathing, or accidentally eating sediment containing dioxins and total cPAHs from the Oakland Bay site is not expected to harm health or produce harmful cancer health effects. An adult person that harvests shellfish and/or works at

Oakland Bay is not likely to be at risk of developing cancer if that person is exposed to dioxins and cPAHs in the sediment assuming he or she is exposed from childhood into adulthood (average time cancer exposure of 70 years). Similarly, a child that plays and/or digs in the sediment is not likely to be at risk of developing cancer if he or she is exposed 52 days per year during childhood. Theoretical cancer risks for dioxins for an adult at Shelton Harbor are 1 excess cancer risk in 100,000 people exposed, and for a child are 5 excess cancer risks in 1,000,000 people exposed. Theoretical cancer risks for dioxin at Oakland Bay are 4 excess cancer risks in 1,000,000 people exposed (adult), and 2 excess cancer risks in a million people exposed (child). Theoretical cancer risks for cPAHs at Shelton Harbor for an adult are 1 excess cancer risk estimated per 1,000,000 people exposed, and a child is 6 excess cancer risks estimated per 10,000,000 people exposed (Appendix B, Table B3). These estimates are within the EPA's acceptable range of cancer risk of $1x10^{-4}$ to $1x10^{-6}$.

Note: *These theoretical cancer risk estimates exceed the state of Washington MTCA cleanup levels of contaminated sites based on an acceptable cancer risk level of one excess cancer risk per 1,000,000 people exposed (1×10^{-6}).* [i]

Recommendations

DOH recommends as a prudent public health practice to follow general advice on ways people can minimize exposure to contaminants in sediment at the Oakland Bay site.

General Advice

Ways to Minimize Exposure to Sediments at Oakland Bay

Exposure to contaminants present in Oakland Bay sediments can be reduced if children and adults follow the soil safety guidelines below.

- Wash clams thoroughly before eating them
- Wash your hands and face after playing or working in the sediments, especially before eating
- Use a scrub brush to clean dirt from under your nails
- Use plenty of soap and water
- Wash heavily soiled clothing separately
- Wash children's toys, bedding, and pacifiers frequently

[i] DOH used health protective screening levels and a quantitative risk assessment, using site-specific exposure assumptions, to evaluate the health threat posed by the contaminated surface sediment at the Oakland Bay site. Some of those exposure assumptions may be different from those used by Ecology when conducting site cleanups under the Model Toxics Control Act (MTCA) cleanup regulation. Ecology risk levels may differ from those calculated by DOH.

Mop, dust, and vacuum

- Wash anything that has come in contact with soils before entering your home
- Implement regular damp mopping to avoid breathing indoor house dust
- Vacuum carpets and rugs frequently, plus dust all other surfaces in your home with a wet rag
- Remove shoes before entering your home to avoid tracking soil into your house

Keep pets clean

- Wipe down pets before you let them inside
- Keep your pets clean. Brush and bathe them regularly
- Restrict your pets to areas of your home that are free from carpeting and upholstery. Give pets their own sleeping spots

Eat a healthy diet

- Eat healthy. Foods that contain the daily recommended amounts of nutrients (e.g., calcium, iron, non-fat protein, etc.) can help you to protect against disease.
- Prevent children from eating dirt

Public Health Action Plan

Actions Completed

1. In February 2009, DOH staff developed a shellfish-sampling plan to collect bivalves in Oakland Bay.

2. In March 2009, staff from the Squaxin Island Tribe, Shellfish Growers Association, Taylor Shellfish, Ecology, and DOH collected shellfish samples from Oakland Bay.

3. Shellfish samples were submitted to the Columbia Analytical Services, Inc. laboratory for analysis of dioxins. In April 2009, Washington DOH received shellfish sampling results.

Actions Planned

1. DOH will provide copies of this health consultation to Ecology, the Squaxin Island Tribe, the Oakland Bay Shellfish Growers Association, and concerned parties.

2. DOH is in the process of evaluating dioxins in shellfish from Oakland Bay. A health consultation is in process, and results will be released this Spring.

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Figure 1: Oakland Bay Site Overview, Oakland Bay, Mason County, Washington.

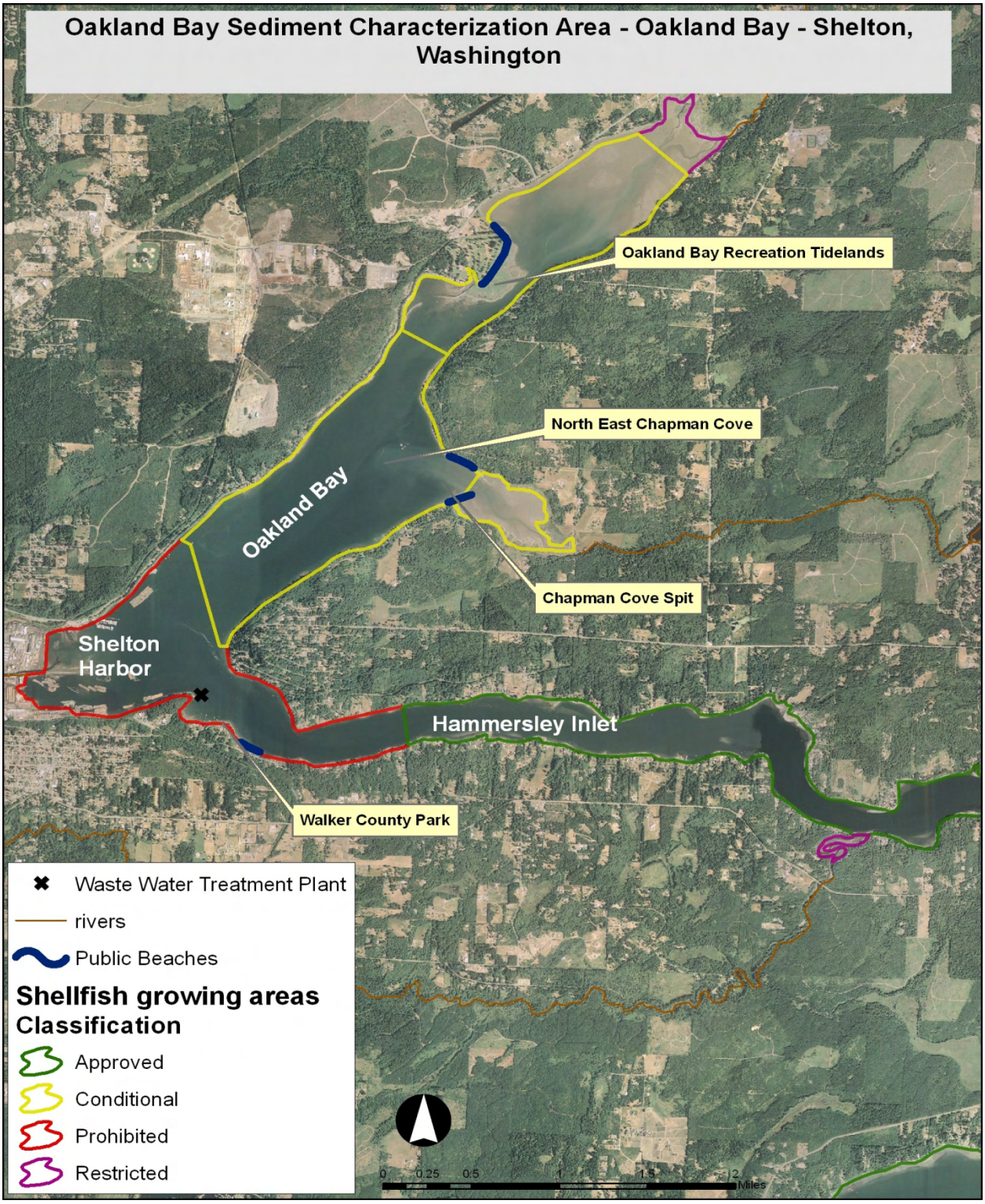
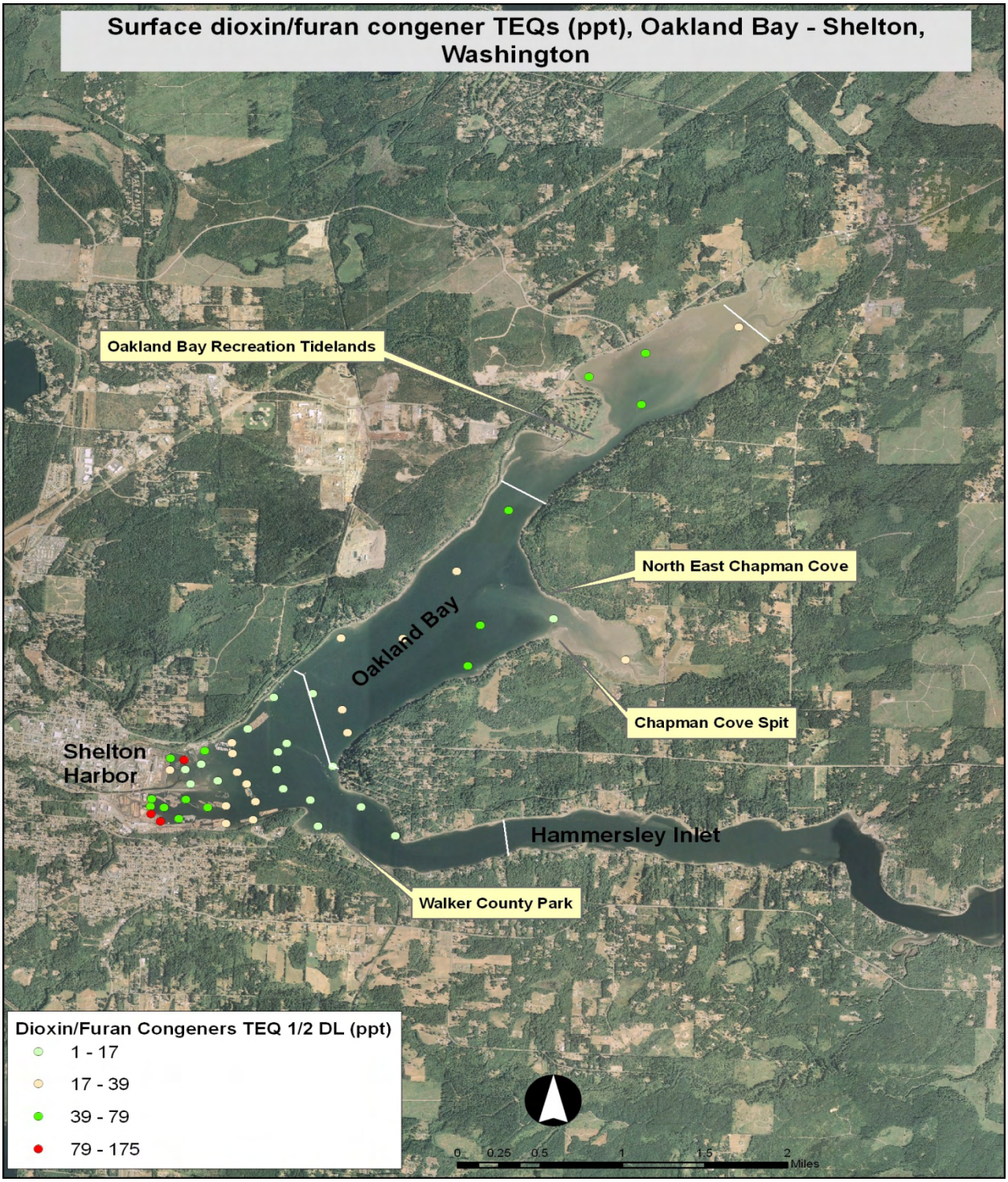


Figure 2: Dioxin results from Oakland Bay and Shelton Harbor Surface Samples, Oakland Bay, Mason County, Washington.



Appendix A

Table A1. Comparison of contaminants detected in sediment within the Oakland Bay site with health based screening levels, Oakland Bay – Shelton, Mason County, Washington.

Compounds	Range Concentration (ppm)	Comparison Value (ppm)	EPA Cancer Class	Comparison Value Reference [A]	Contaminant of Concern (COC)
Antimony	0.065 J - 0.83	20	D	RMEG	No
Arsenic	1.3 - 9.1	20	A	EMEG	No
Cadmium	0.098 J– 1.8	5	B1	EMEG	No
Chromium	12 – 65	230 [a]	A	EPA's PRGs	No
Copper	4.3 – 120	500	D	IM EMEG	No
Lead	2.0 - 47	250	B2	MTCA	No
Mercury	0.0 U – 0.29	1	D	MTCA	No
Nickel	11 – 46	1,000		RMEG	No
Silver	0.017 J – 0.55 J	300	D	RMEG	No
Zinc	14 – 130	20,000	D	EMEG	No
2-Methylnaphthalene	0.0078U – 0.0082U	2,000		EMEG	No
Acenaphthene	0.0079U – 0.0082U	3000		RMEG	No
Acenaphthylene	0.0083U – 0.0086U	2000*	D	RMEG	No
Anthracene	0.0074U – 0.0077U	20000	D	RMEG	No
Benzo(ghi)perylene	0.0065 – 0.082	2000*	D	RMEG	No
Dibenzofuran	0.0072U – 0.0075U	290	D	Region 9 †	No
Fluoranthene	0.0076U – 2.0	2000	D	RMEG	No
Fluorene	0.0086U – 0.0089U	2000	D	RMEG	No
Naphthalene	0.0083U – 0.0087U	1000	C	RMEG	No
Phenanthrene	0.0081U – 0.0084U	2000*	D	RMEG	No
Pyrene	0.0075U- 1.0	2000	D	RMEG	No
Hexachlorobenzene	0.0077U- 0.008U	0.4	B2	CREG	No
Hexachlorobutadiene	0.0078U – 0.0081U	9	C	CREG	No

Compounds	Range Concentration (ppm)	Comparison Value (ppm)	EPA Cancer Class	Comparison Value Reference [A]	Contaminant of Concern (COC)
1,2,4-Trichlorobenzene	0.0087U – 0.0091U	500	D	RMEG	No
1,2-Dichlorobenzene	0.0075U – 0.0079U	5000	D	RMEG	No
1,4-Dichlorobenzene	0.007U – 0.007U	4000	C	IM EMEG	No
2,4-Dimethylphenol	0.014U – 0.015U	1000		RMEG	No
Benzoic acid	0.11U – 0.11U	200000		RMEG	No
Benzyl alcohol	0.014U – 0.014U	18000		Region 9 †	No
Bis(2-ethylhexyl)phthalate	0.011U – 0.068	3000	B2	EMEG	No
Butyl benzyl phthalate	0.011U- 0.038	10000	C	RMEG	No
Di-n-butyl phthalate	0.012U – 0.012U	5000	D	RMEG	No
Di-n-octylphthalate	0.0083U- 0.008U	20000		IM EMEG	No
Diethyl phthalate	0.016 U – 0.016U	300000	D	IM EMEG	No
Dimethyl phthalate	0.007U – 0.007U	100000	D	Region 9 †	No
N-Nitrosodiphenylamine	0.0083U – 0.0087U	9.9	B2	Region 9 †	No
Pentachlorophenol	0.046U – 0.047U	6	B2	CREG	No
Phenol	0.013U – 0.29	20000	D	RMEG	No
Total Aroclors Shelton Harbor	0.0099 JG	1***		EMEG	No
Total Aroclors Oakland Bay	0.0046 UJ				
Total Aroclors Hammersley Inlet	0.06 J				
p-Cresol	0.012 U – 0.41	3,000 [i]	C	RMEG	No
o-Cresol	0.014 U	3,000	C	RMEG	No
Benzo(a)anthracene	0.0057U – 0.29	0.62	B2	Region 9 †	cPAH
Benzo(a)pyrene	0.0078U – 0.2	0.1	B2	CREG	cPAH
Benzo(b)fluoranthene	0.0091 U – 0.38	0.62	B2	Region 9 †	cPAH
Benzo(k)fluoranthene	0.0089U – 0.37	6.2	B2	Region 9 †	cPAH
Chrysene	0.0063U – 0.8	62	B2	Region 9 †	cPAH
Dibenzo(a,h)anthracene	0.0082U – 0.018 J	0.1**		CREG	cPAH

Compounds	Range Concentration (ppm)	Comparison Value (ppm)	EPA Cancer Class	Comparison Value Reference [A]	Contaminant of Concern (COC)
Indeno(1,2,3-cd)pyrene	0.0082U – 0.078	0.62	B2	Region 9 †	cPAH
Sulfide	0.01 U– 1,530	NA [b]	IN	NA	NA
Ammonia	0.03 U – 75.5	NA [c]	D	NA	NA
Butyltin Dibutyltin Tributyltin	0.0034 – 0.008 0.0026 – 0.03 0.0015 – 0.013	20 [d]	D	EMEG	No
3,4,5-Trichloroguaicol 3,4,6-Trichloroguaicol 3,4-Dichloroguaicol 4,5,6-Trichloroguiacol 4,5-Dichloroguaiacol 4,6-Dichloroguaiacol 4-Chlroguaiacol Guaiacol Tetrachloroguaiacol	0.019 U – 0.02 U 0.019U – 0.02 U 0.019U – 0.02 U 0.019U – 0.02 U 0.019U – 0.02 U 0.019U – 0.02 U 0.019U – 0.02 U 0.019 U – 0.02 U 0.019 U – 0.02 U	20000 [e]	D	RMEG	No
9,10-Dichloroestearic acidAbietic acid Dehydroabietic acid Dichlorodehydroabietic acid 12-Chlorodehydroabietic acid 14-Chlorodehydroabietic acid	0.97 U – 0.3 U 0.45 – 0.92 0.29 J – 0.71 0.097 U -0.3 U 0.097 U– 0.3 U 0.097 U– 0.3 U	NA	NA	NA	NA
Isopimaric acid Linolenic acid Neoabietic acid Oleic acid Palustric acid Pimaric acid Sandaracopimaric acid	0.17 – 0.3 U 0.97 U – 0.3 U 0.97 UJ – 0.3 UJ 0.97 U – 0.61 0.97 U – 0.3 U 0.99 – 0.3 U 0.97 U – 0.3 U	NA	NA	NA	NA
Retene	0.019 U – 0.02 U	NA	NA	NA	NA

Compounds	Range Concentration (ppm)	Comparison Value (ppm)	EPA Cancer Class	Comparison Value Reference	Contaminant of Concern (COC)
Total cPAH TEQ [h]	**0.02 - 0.297**	**0.1[f]**	**B2**	**CREG**	**Yes**
Total Dioxin TEQ	**0.000001 – 0.000175**	**0.00005 [g]**	**B2**	**EMEG**	**Yes**

BOLD – Values exceed comparison values
[A] – Please refer to the Public Health Assessment Guidance Manual (2005 update) for more information on derivation of comparison values [18]
CREG - ATSDR's Cancer Risk Evaluation Guide (child)
RMEG - ATSDR's Reference Dose Media Evaluation Guide (child)
EMEG - ATSDR's Environmental Media Evaluation Guide (child)
IM EMEG - ATSDR's Intermediate Environmental Media Evaluation Guide (child)
J, E - data qualifier: The associated numerical result is an estimate
JG - Analyte was positively identified. Value may be greater than the reported estimate.
U- Data qualifier: The analyte was not detected at this level
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
C - EPA: Possible human carcinogen (no human, limited animal studies)
D - EPA: Not classifiable as to health carcinogenicity
IN – Inadequate information to assess carcinogenic potential
† Region 9 – EPA's regional screening levels for chemical contaminants at Superfund sites, July 7, 2008: Preliminary Remediation Goals
MTCA – Model Toxics Control Act
[a] – EPA's Preliminary Remediation Goals (PRGs) based on chromium VI particulates for residential soil
[b]- NA – Not available comparison values for sulfides. Based on hydrogen sulfide
[c] – NA – Not available comparison values for ammonia
[d] – It corresponds to ATSDR chronic EMEG (child) for Tributyltin oxide
[e] – Use phenol as a surrogate
[f] – Corresponds to CREG for benzo(a)pyrene
[g] – Corresponds to ATSDR chronic EMEG (child) for 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin
[h] – These values correspond to the maximum total cPAHs TEQ surface sediment sampled in Shelton Harbor. Values for total cPAHs TEQ in Oakland Bay are below levels of health concern
[i] – Used surrogate meta-cresol ATSDR RMEG (child)
* Fluoranthene RMEG value was used as a surrogate
* * Benzo(a)pyrene CREG value was used as a surrogate
* * * Aroclor 1254 EMEG value was used as a surrogate
Total Dioxin TEQ – sum of dioxin/furans toxic equivalent (TEQ)
Total cPAH TEQ – sum of all carcinogenic polycyclic aromatic hydrocarbons (cPAH) toxic equivalent (TEQ), all cPAH in COC are added using the TEQ approach to obtain Total cPAH TEQ
NA – There are not available comparison values for these compounds. These are natural wood compounds, classified as wood resin acid, and resin fatty acid compounds.

Abbreviations for dioxins

Table A2. Abbreviations for dioxin and furans

1,2,3,4,6,7,8-HPCDD	Heptachlorodibenzo-*p*-dioxin
1,2,3,4,6,7,8-HPCDF	Heptachlorodibenzofuran
1,2,3,4,7,8,9-HPCDF	Heptachlorodibenzofuran
1,2,3,4,7,8-HXCDD	Hexachlorodibenzo-*p*-dioxin
1,2,3,4,7,8-HXCDF	Hexachlorodibenzofuran
1,2,3,6,7,8-HXCDD	Hexachlorodibenzo-*p*-dioxin
1,2,3,6,7,8-HXCDF	Hexachlorodibenzofuran
1,2,3,7,8,9-HXCDD	Hexachlorodibenzo-*p*-dioxin
1,2,3,7,8,9-HXCDF	Hexachlorodibenzofuran
1,2,3,7,8-PECDD	Pentachlorodibenzo-*p*-dioxin
1,2,3,7,8-PECDF	Pentachlorodibenzofuran
2,3,4,6,7,8-HXCDF	Hexachlorodibenzofuran
2,3,4,7,8-PECDF	Pentachlorodibenzofuran
2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
2,3,7,8-TCDF	2,3,7,8-tetrachlorodibenzo-*p*-furan
OCDD	Octachlorodibenzo-*p*-dioxin
OCDF	Octachlorodibenzofuran

Table A3. Surface sediment (0 to 10 cm) dioxin/furan congeners (dry weight (dw) basis) in Shelton Harbor (SH) at the Oakland Bay Site, Oakland Bay – Shelton, Mason County, Washington.

Congener	SH 01 (dw ppt)	SH 02 (dw ppt)	SH 03 (dw ppt)	SH 04 (dw ppt)	SH 05 (dw ppt)	SH 07 (dw ppt)
1,2,3,4,6,7,8-HPCDD	468	1,040	5,590 B	1,550	712	152 B
1,2,3,4,6,7,8-HPCDF	176	290	1,700 B	368	179	42.8 B
1,2,3,4,7,8,9-HPCDF	10	16.2	98.8	24.1	11.5	2.91
1,2,3,4,7,8-HXCDD	4.74	21	29.3	15.9	6.73	1.97
1,2,3,4,7,8-HXCDF	15.7	27.2	126	31.2	16.1	3.46
1,2,3,6,7,8-HXCDD	30.3	76.8	220	75.2	31.7	8
1,2,3,6,7,8-HXCDF	5.15	10.5	37.4	11.9	5.8	1.33
1,2,3,7,8,9-HXCDD	16.7	50.6	85.9	44	19.2	5.09
1,2,3,7,8,9-HXCDF	0.482 J	0.98	4.04	1.15	0.556	0.132 J
1,2,3,7,8-PECDD	3.88	11.6	15.4	7.91	3.44	1.17
1,2,3,7,8-PECDF	2.85	5.5	12.6	4.76	2.31	0.592
2,3,4,6,7,8-HXCDF	4.52	9.37	29.9	10.7	4.71	1.2
2,3,4,7,8-PECDF	4.91	8.17	20.4 B	6.84	3.22	0.801 B
2,3,7,8-TCDD	0.978	2.45	2.88	1.33	0.621	0.295
2,3,7,8-TCDF	3.78	5.21	7.47	3.89	1.66 J	0.581
OCDD	4,850 B	8,030 B	67,600 B	24,200 B	12,500	1,810
OCDF	652	947	7,660 B	1,210	607	157
Total TEQ ND ½ DL	**22.7**	**53**	**175**	**57.9**	**26.5**	**6.47**

J – The associated numerical value is considered an estimate concentration
B – Specified compound was detected in the associated blank
DL – Detection limit

Table A4. Surface sediment (0 to 10 cm) dioxin/furan congeners (dry weight (dw) basis) in Shelton Harbor (SH) at the Oakland Bay Site, Oakland Bay – Shelton, Mason County, Washington.

Congener	SH 09 (dw ppt)	SH 10 (dw ppt)	SH 11 (dw ppt)	SH 12 (dw ppt)	SH 13 (dw ppt)	SH 14 (dw ppt)
1,2,3,4,6,7,8-HPCDD	247	754	498 B	1,980 B	2,870 B	815
1,2,3,4,6,7,8-HPCDF	87.4	336	180 B	605 B	652 B	300
1,2,3,4,7,8,9-HPCDF	5.4	31.7	10.7	33.6	38.9	15.2
1,2,3,4,7,8-HXCDD	2.95	3.41	16.8	32	28.8	8.38
1,2,3,4,7,8-HXCDF	7.27	73.1	24.4	64.3	72.4	24.6
1,2,3,6,7,8-HXCDD	14	48.3	40.1	122	121	44.5
1,2,3,6,7,8-HXCDF	2.63	12.5	10.4	22	20.9	8.38
1,2,3,7,8,9-HXCDD	8.67	11.2	32.7	71.3	79.8	24.1
1,2,3,7,8,9-HXCDF	0.225 J	1.21	1.04	1.94	2.48	0.669
1,2,3,7,8-PECDD	1.72	2.1	14.6	20.1	15.6	5.67
1,2,3,7,8-PECDF	1.01	4.01	10.8	15.5	12.7	3.73
2,3,4,6,7,8-HXCDF	2.25	7.06	8.71	18	18.3	7.49
2,3,4,7,8-PECDF	1.47	14.3	14.2	21.2	17	6.44
2,3,7,8-TCDD	0.351	0.477	5.72	5.67	4.09	1.23
2,3,7,8-TCDF	0.341 J	1.75	20.5	22.1	13.4	3.68
OCDD	2,470	3,500 B	3,900 B	18,600 B	28,900 B	7,300 B
OCDF	292	1,230	562 B	1,970 B	1,880 B	1,160
Total TEQ ND ½ DL	**10.6**	**35.5**	**48.6**	**100**	**106**	**35**

J – The associated numerical value is considered an estimate concentration
B – Specified compound was detected in the associated blank
DL – Detection limit

Table A5. Surface sediment (0 to 10 cm) dioxin/furan congeners (dry weight (dw) basis) in Shelton Harbor (SH) at the Oakland Bay Site, Oakland Bay – Shelton, Mason County, Washington.

Congener	SH 15 (dw ppt)	SH 16 (dw ppt)	SH 18 (dw ppt)	SH 19 (dw ppt)	SH 20 (dw ppt)	SH 21 (dw ppt)
1,2,3,4,6,7,8-HPCDD	41.6	22.2	1,610 B	1,660	1,230	1,420
1,2,3,4,6,7,8-HPCDF	18.2	10.2	558 B	688	447	393
1,2,3,4,7,8,9-HPCDF	1.13	0.579	29.1	36.3	24.8	22.2
1,2,3,4,7,8-HXCDD	0.525 J	0.288 J	18.2	17.6	13.4	15.7
1,2,3,4,7,8-HXCDF	1.43	0.786	51.6	61.4	39.4	33.4
1,2,3,6,7,8-HXCDD	2.34	1.28	85.4	99.8	62.8	70.8
1,2,3,6,7,8-HXCDF	0.521	0.296 J	16.5	19.1	12.9	11.4
1,2,3,7,8,9-HXCDD	1.59	0.811	48.8	45.1	35.9	43.2
1,2,3,7,8,9-HXCDF	0.047 J	0.026 J	1.26	1.51	1.1	1.02
1,2,3,7,8-PECDD	0.297 J	0.162 J	11.2	13	7.26	8.34
1,2,3,7,8-PECDF	0.177 J	0.077 J	8.43	10.9	5.29	5.62
2,3,4,6,7,8-HXCDF	0.505 J	0.284 J	13.6	16.7	10.6	11
2,3,4,7,8-PECDF	0.271 J	0.157 J	12.5	16.6	7.88	7.56
2,3,7,8-TCDD	0.061 J	0.043 J	0.0976 U	3.69	1.62	1.72
2,3,7,8-TCDF	0.138	0.079 J	11.5	16.3	5.35	5.08 J
OCDD	373 B	203 B	14,600 B	14,500 B	12,400 B	12,900 B
OCDF	45	22.4	1,820 B	2,260	1,750	1,230
Total TEQ ND ½ DL	**1.89**	**1.0**	**69.0**	**78.6**	**50.8**	**53.7**

J – The associated numerical value is considered an estimate concentration
B – Specified compound was detected in the associated blank
DL – Detection limit

Table A6. Surface sediment (0 to 10 cm) dioxin/furan congeners (dry weight (dw) basis) in Shelton Harbor (SH) at the Oakland Bay Site, Oakland Bay – Shelton, Mason County, Washington.

Congener	SH 22 (dw ppt)	SH 23 (dw ppt)	SH 24 (dw ppt)	SH 25 (dw ppt)	SH 26 (dw ppt)	SH 27 (dw ppt)
1,2,3,4,6,7,8-HPCDD	197	712	717	820 B	113	83.7
1,2,3,4,6,7,8-HPCDF	11	217	298	330 B	37.5	29.2
1,2,3,4,7,8,9-HPCDF	9.27	13.5	16.1	16.7	2.42	1.53
1,2,3,4,7,8-HXCDD	22.5	7.04	8.19	9.34	1.88	1.34
1,2,3,4,7,8-HXCDF	61.6	22	26.5	26.2	3.16	2.32
1,2,3,6,7,8-HXCDD	7.18	36.1	42.3	48.5	6.56	5.48
1,2,3,6,7,8-HXCDF	39.5	7.13	8.21	9.18	1.29	0.878
1,2,3,7,8,9-HXCDD	0.792	28.6	22.1	26.9	5.34	3.48
1,2,3,7,8,9-HXCDF	4.23	0.611 J	0.666	0.715	0.111 J	0.075 J
1,2,3,7,8-PECDD	4.18	3.93 J	5.01	6.82	0.951	0.657
1,2,3,7,8-PECDF	7.41	2.65 J	3.25	4.12	0.433 J	0.373 J
2,3,4,6,7,8-HXCDF	5.81	6.2	7.51	8.07	1.02	0.896
2,3,4,7,8-PECDF	0.885	4.27 J	5.22	6.23	0.602	0.488
2,3,7,8-TCDD	4.59	1.19	1.05	1.59	0.211	0.143
2,3,7,8-TCDF	197	2.3 J	2.92 J	4.01	0.325 J	0.284 J
OCDD	16,100 B	6,340 B	6,430 B	7,400 B	1,030 B	756 B
OCDF	490	634	1,030	1,020 B	105	80.2
Total TEQ ND ½ DL	**47.4**	**28.8**	**31.8**	**37.9**	**5.16**	**3.8**

J – The associated numerical value is considered an estimate concentration
B – Specified compound was detected in the associated blank
DL – Detection limit

Table A7. Surface sediment (0 to 10 cm) dioxin/furan congeners (dry weight (dw) basis) at Shelton Harbor (SH), and Oakland Bay (OB) Site, Oakland Bay – Shelton, Mason County, Washington.

Congener	SH 28 (dw ppt)	SH 29 (dw ppt)	SH 30 (dw ppt)	OB 01 (dw ppt)	OB 02 (dw ppt)	OB 03 (dw ppt)
1,2,3,4,6,7,8-HPCDD	654	45.4	649 B	97.4 B	345 B	664 B
1,2,3,4,6,7,8-HPCDF	262	18.7	204 B	36.8 B	133 B	256 B
1,2,3,4,7,8,9-HPCDF	15.3	1.07	12.4	2.21	7.99	13.9
1,2,3,4,7,8-HXCDD	6.82	0.606	9.84	1.37	5.09	8.23
1,2,3,4,7,8-HXCDF	27.1	1.56	25.5	3.54	14.7	22.9
1,2,3,6,7,8-HXCDD	40.3	2.6	48.4	5.67	20.3	37.3
1,2,3,6,7,8-HXCDF	7.86	0.595	8.77	1.17	4.59	8.04
1,2,3,7,8,9-HXCDD	21.8	1.85	31.1	3.92	14.6	24.6
1,2,3,7,8,9-HXCDF	0.66	0.052 J	0.785	0.12 J	0.408 J	0.689
1,2,3,7,8-PECDD	4.39	0.339 J	7.39	0.749	2.8	4.41
1,2,3,7,8-PECDF	3.14	0.179 J	4.56	0.445 J	2.16	2.88
2,3,4,6,7,8-HXCDF	6.41	0.5 J	7.39	1.14	4.29	7.56
2,3,4,7,8-PECDF	5.74	0.279 J	8.02	0.566	2.84	3.95
2,3,7,8-TCDD	0.813	0.073 J	1.84	0.125	0.567	0.828
2,3,7,8-TCDF	3.89	0.163	5.51	0.387	2.19	2.41
OCDD	5,860 B	394 B	5,720 B	833 B	2,570 B	5,830 B
OCDF	735	50	586 B	112 B	350 B	783 B
Total TEQ ND ½ DL	**29.8**	**2.08**	**36.0**	**4.4**	**16.6**	**29.0**

J – The associated numerical value is considered an estimate concentration
B – Specified compound was detected in the associated blank
DL – Detection limit

Table A8. Surface sediment (0 to 10 cm) dioxin/furan congeners (dry weight (dw) basis) at Oakland Bay (OB) Site, Oakland Bay – Shelton, Mason County, Washington.

Congener	OB 04 (dw ppt)	OB 05 (dw ppt)	OB 06 (dw ppt)	OB 07 (dw ppt)	OB 08 (dw ppt)	OB 09 (dw ppt)
1,2,3,4,6,7,8-HPCDD	467 B	634 B	965 B	181 B	856 B	849
1,2,3,4,6,7,8-HPCDF	186 B	246 B	405 B	68.6 B	269 B	333
1,2,3,4,7,8,9-HPCDF	10.1	12.9	21.3	3.94	16.5	18.3
1,2,3,4,7,8-HXCDD	7.09	8.06	13.4	2.91	14	12.5
1,2,3,4,7,8-HXCDF	22.8	24.1	34.2	6.31	25.8	32
1,2,3,6,7,8-HXCDD	38.8	34	55.4	12.1	45.3	48.2
1,2,3,6,7,8-HXCDF	7.07	7.95	12	2.36	10.5	10.9
1,2,3,7,8,9-HXCDD	21.5	22.7	38.6	8.69	40	35.3
1,2,3,7,8,9-HXCDF	0.514	0.596	0.964	0.229 J	0.763	0.925
1,2,3,7,8-PECDD	5.44	4.26	6.83	1.58	6.84	6.2
1,2,3,7,8-PECDF	3.37	2.58	4.23	0.914	3.5	3.55
2,3,4,6,7,8-HXCDF	7.06	7.27	11.3	2.2	9.71	10.4
2,3,4,7,8-PECDF	5.99	3.76	5.62	1.15 B	4.5 B	4.83
2,3,7,8-TCDD	1.19	0.734	1.1	0.233	0.756	0.982
2,3,7,8-TCDF	3.87	2.25	3.06	0.692	2.8	2.85
OCDD	3,480 B	5,240 B	8,080 B	1,410 B	4,860 B	7,230 B
OCDF	488 B	759 B	1,230 B	171 B	529 B	938 B
Total TEQ ND ½ DL	**27.2**	**27.6**	**43.3**	**8.72**	**37**	**38.5**

J – The associated numerical value is considered an estimate concentration
B – Specified compound was detected in the associated blank
DL – Detection limit

Table A9. Surface sediment (0 to 10 cm) dioxin/furan congeners (dry weight (dw) basis) at Oakland Bay (OB) Site, Oakland Bay – Shelton, Mason County, Washington.

Congener	OB 10 (dw ppt)	OB 11 (dw ppt)	OB 12 (dw ppt)	OB 13 (dw ppt)	OB 14 (dw ppt)	OB 17 (dw ppt)
1,2,3,4,6,7,8-HPCDD	1,250 B	982	1,210 B	1,070	478	280 B
1,2,3,4,6,7,8-HPCDF	455 B	397	502 B	427	182	95.6 B
1,2,3,4,7,8,9-HPCDF	26.3	21.9	28.2	28.1	11	5.36
1,2,3,4,7,8-HXCDD	17	13.8	18.1	15.5	6.69	3.96
1,2,3,4,7,8-HXCDF	43.5	35.9	41.9	41.6	18.1	10.9
1,2,3,6,7,8-HXCDD	64	55.8	68	57.3	27.5	17.5
1,2,3,6,7,8-HXCDF	15.3	13.7	16.8	14.6	6.7	3.48
1,2,3,7,8,9-HXCDD	47.5	40.5	53.8	48.8	19.8	11.8
1,2,3,7,8,9-HXCDF	1.28	1.07	1.47	1.06	0.645	0.34 J
1,2,3,7,8-PECDD	8.66	7.03	8.44	8.01	3.75	2.48
1,2,3,7,8-PECDF	5.23	4.22	5.24	4.58	2.07	1.61
2,3,4,6,7,8-HXCDF	13.5	11.9	15.2	13.9	5.93	3.15
2,3,4,7,8-PECDF	6.75 B	5.27	6.81 B	5.47	2.95	2.37
2,3,7,8-TCDD	1.07	0.84	1.21	1.16	0.473	0.519
2,3,7,8-TCDF	3.6	2.64	3.68	3.18	1.59	1.57
OCDD	11,600 B	7,890 B	9,710 B	7,220 B	4,060	1,580
OCDF	1,180 B	1,060 B	1,180 B	1,220 B	412	268
Total TEQ ND ½ DL	**53.6**	**43.8**	**54.4**	**48.3**	**21.9**	**13.4**

J – The associated numerical value is considered an estimate concentration
B – Specified compound was detected in the associated blank
DL – Detection limit

Table A10. Surface sediment (0 to 10 cm) dioxin/furan congeners (dry weight (dw) basis) at Oakland Bay (OB) and Hammersley Inlet (HI), Oakland Bay – Shelton, Mason County, Washington.

Congener	OB 18 (dw ppt)	OB 19 (dw ppt)	HI 02 (dw ppt)	HI 03 (dw ppt)	HI 04 (dw ppt)	HI 05 (dw ppt)
1,2,3,4,6,7,8-HPCDD	768 B	1,040 B	72.1 B	224 B	40 B	48.8 B
1,2,3,4,6,7,8-HPCDF	290 B	379 B	24.2 B	71.7 B	14.2 B	18.3 B
1,2,3,4,7,8,9-HPCDF	15.7	21.6	1.53	4.96	0.911	1.15
1,2,3,4,7,8-HXCDD	9.86	13.6	0.954	3.51	0.538	0.684
1,2,3,4,7,8-HXCDF	24.8	34.4	2.39	9.8	1.37	1.64
1,2,3,6,7,8-HXCDD	42.9	60.7	4.29	18.5	2.41	2.63
1,2,3,6,7,8-HXCDF	8.82	12.4	0.789	3.27	0.457	0.523
1,2,3,7,8,9-HXCDD	28.7	40.6	2.87	12.4	1.59	1.8
1,2,3,7,8,9-HXCDF	0.72	1.09	0.079 J	0.318 J	0.048 J	0.048 J
1,2,3,7,8-PECDD	5.21	7.3	0.574	2.65	0.305 J	0.34 J
1,2,3,7,8-PECDF	3.12	4.22	0.304 J	1.79	0.183 J	0.213 J
2,3,4,6,7,8-HXCDF	8.46	10.8	0.728	2.9	0.442 J	0.55
2,3,4,7,8-PECDF	4.16	5.78 B	0.477 B	3.22 B	0.279 BJ	0.358 J
2,3,7,8-TCDD	0.793	0.984	0.085 J	0.515	0.068 J	0.068 J
2,3,7,8-TCDF	2.68	3.49	0.301 J	1.86	40	0.199
OCDD	6,490 B	9,640 B	629 B	1,790 B	330 B	420 B
OCDF	867 B	1,130 B	66.9 B	193 B	41.4 B	53.1 B
Total TEQ ND ½ DL	**33.0**	**45.5**	**3.19**	**13.0**	**1.77**	**2.09**

J – The associated numerical value is considered an estimate concentration
B – Specified compound was detected in the associated blank
DL – Detection limit

Table A11. Surface sediment (0 to 10 cm) dioxin/furan congeners (dry weight (dw) basis) in Hammersley Inlet (HI) at the Oakland Bay Site, Oakland Bay – Shelton, Mason County, Washington.

Congener	HI 06 (dw ppt)	HI 07 (dw ppt)
1,2,3,4,6,7,8-HPCDD	184 B	64.2 B
1,2,3,4,6,7,8-HPCDF	64.1 B	24.7 B
1,2,3,4,7,8,9-HPCDF	3.98	1.59
1,2,3,4,7,8-HXCDD	2.85	0.708
1,2,3,4,7,8-HXCDF	7.96	2.31
1,2,3,6,7,8-HXCDD	13.4	3.44
1,2,3,6,7,8-HXCDF	2.59	0.717
1,2,3,7,8,9-HXCDD	9.59	2.22
1,2,3,7,8,9-HXCDF	0.229 J	0.078 J
1,2,3,7,8-PECDD	1.86	0.377 J
1,2,3,7,8-PECDF	1.12	0.23 J
2,3,4,6,7,8-HXCDF	2.24	0.684
2,3,4,7,8-PECDF	1.96	0.369 J
2,3,7,8-TCDD	0.277	0.082 J
2,3,7,8-TCDF	1.2	0.197
OCDD	1,370 B	577 B
OCDF	152 B	73.8 B
Total TEQ ND ½ DL	**9.74**	**2.71**

J – The associated numerical value is considered an estimate concentration
B – Specified compound was detected in the associated blank
DL – Detection limit

Appendix B

This section provides calculated exposure doses and assumptions used for exposure to chemicals currently present in surface sediments from the Oakland Bay and Shelton Harbor site. An exposure scenario was developed to model exposures that might occur. These scenarios were devised to represent exposures for an adult (worker exposure scenario harvesting shellfish 5 days per week, 52 weeks per year, and/or a recreational exposure scenario), and a child playing and/or digging in the beaches 52 days per year. The following exposure parameters and dose equations were used to estimate exposure doses from direct contact with chemicals in the sediment.

Exposure to chemicals in sediment via ingestion, inhalation, and dermal absorption.

Total dose $_{\text{(non-cancer)}}$ = Ingested dose + inhaled dose + dermally absorbed dose

Ingestion Route

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

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

Dermal Route

$$\text{Dermal Transfer (DT)} = \frac{C \times AF \times ABS \times AD \times CF}{ORAF}$$

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

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

Inhalation of Particulate from Sediment Route

$$\text{Dose}_{\text{non-cancer (mg/kg-day)}} = \frac{C \times SMF \times IHR \times EF \times ED \times 1/PEF}{BW \times AT_{\text{non-cancer}}}$$

$$\text{Cancer Risk} = \frac{C \times SMF \times IHR \times EF \times ED \times CPF \times 1/PEF}{BW \times AT_{\text{cancer}}}$$

Table B1. Exposure assumptions used for exposure to dioxins in surface sediments from Oakland Bay, Shelton, Mason County, Washington.

Parameter	Value	Unit	Comments
Concentration (C)	Variable	mg/kg	Maximum detected value
Conversion Factor (CF)	0.000001	kg/mg	Converts contaminant concentration from milligrams (mg) to kilograms (kg)
Ingestion Rate (IR) – adult	100	mg/day	Exposure Factors Handbook [19]
Ingestion Rate (IR) – older child	100		
Ingestion Rate (IR) - child	200		
Exposure Frequency (EF)	250	days/year	About 52 weeks per year (adult worker)
	52		One day/ per week/ per year (number of years playing or digging in sediment (child))
Exposure Duration (Ed) [j]	30 (5, 10,15)	years	Number of years spent at the beach (child, older child, adult years).
Body Weight (BW) - adult	72	kg	Adult mean body weight
Body Weight (BW) – older child	41		Older child mean body weight
Body Weight (BW) - child	15		0-5 year-old child average body weight
Surface area (SA) - adult	5700	cm^2	Exposure Factors Handbook [19]
Surface area (SA) – older child	2900		
Surface area (SA) - child	2900		
Averaging $Time_{non\text{-}cancer}$ (AT)	1825	days	5 years (child)
	3650		10 years (older child)
Averaging $Time_{cancer}$ (AT)	27375	days	75 years
Cancer Potency Factor (CPF)	1.5E+5	$mg/kg\text{-}day^{-1}$	Source: EPA (dioxins and cPAHs)
	7.3		
24 hr. absorption factor (ABS)	PAH = 0.13 Dioxin= 0.03	unitless	Source: EPA (Chemical Specific) polycyclic aromatic hydrocarbon (PAH) & dioxins
Oral route adjustment factor (ORAF)	1	unitless	Non-cancer (nc) / cancer (c) - default
Adherence duration (AD)	1	days	Source: EPA
Adherence factor (AF)	0.2	mg/cm^2	Child, older child
	0.07		Adult
Inhalation rate (IHR) - adult	15.2	m^3/day	Exposure Factors Handbook [19]
Inhalation rate (IHR) – older child	14		
Inhalation rate (IHR) - child	8.3		
Soil matrix factor (SMF)	1	unitless	Non-cancer (nc) / cancer (c) - default
Particulate emission factor (PEF)	1.20E+9	m^3/kg	Model Parameters

[j] Exposure duration is the length of time exposure occurs at the concentration

Oakland Bay surface sediment Exposure Route –Non-cancer

Table B2. Non-cancer hazard calculations resulting from exposure to dioxins in surface sediments from Oakland Bay, Mason County, Washington.

Contaminant	TEQ Concentration (ppm) (mg/kg)	Scenarios	Estimated Dose (mg/kg/day)			Total Dose	RfD/ MRL/ LOAEL (mg/kg/day)	Total Dose/ (RfD/ MRL/ LOAEL)
			Incidental Ingestion of Soil	Dermal Contact with Soil	Inhalation of Particulates			
Total Dioxin TEQ Shelton Harbor	0.000175	Child	3.3E-10	2.9E-11	1.2E-14	3.6E-10	1.0E-9	0.36
		Older Child	6.1E-11	1.1E-11	7.1E-15	7.2E-11		0.072
		Adult	1.7E-10	2.0E-11	4.2E-14	1.9E-10		0.19
Total cPAH TEQ Shelton Harbor	0.3	Child	5.7E-07	2.1E-07	1.9E-11	7.8E-07	1.0E+1	<0.00000001
		Older Child	1.0E-07	7.9E-08	1.2E-11	1.8E-07		<0.00000001
		Adult	2.9E-07	1.5E-07	7.2E-11	4.4E-07		<0.00000001
Total Dioxin TEQ Oakland Bay	0.000054	Child	1.0E-10	8.9E-12	3.6E-15	1.1E-10	1.0E-9	0.109
		Older Child	1.9E-11	3.3E-12	2.2E-15	2.2E-11		0.02
		Adult	5.1E-11	6.2E-12	1.3E-14	5.7E-11		0.06

Children exposure frequency assumes that they are exposed by digging and/or playing in the sediment for 52 days/year at the Oakland Bay site's public access areas
Adult – refers to the30 year life time exposure

Oakland Bay surface sediment Exposure Route – Cancer

Table B3. Cancer hazard calculations resulting from exposure to dioxins in surface sediments from Oakland Bay, Mason County, Washington.

Contaminant	Concentration (ppm)	EPA Cancer Class	Cancer Potency Factor ($mg/kg\text{-}day^{-1}$)	Scenarios	Increased Cancer Risk			Total Cancer Risk
					Incidental Ingestion of Soil	Dermal Contact with Soil	Inhalation of Particulates	
Total Dioxin TEQ Shelton Harbor	0.000175	B2	1.5E+5	Child	3.3E-6	2.9E-7	1.2E-10	3.6E-06
				Older Child	1.2E-6	2.1E-7	1.4E-10	1.4E-06
				Adult	9.9E-6	1.2E-6	1.3E-09	1.1E-05
Total cPAH TEQ Shelton Harbor	0.3	B2	7.3	Child	2.8E-7	1.0E-7	9.6E-12	3.8E-07
				Older Child	1.0E-7	7.7E-8	1.2E-11	1.8E-07
				Adult	8.3E-7	4.3E-7	1.1E-10	1.3E-06
Total Dioxin TEQ Oakland Bay	0.000054	B2	1.5E+5	Child	1.0E-6	8.9E-8	3.6E-11	1.1E-06
				Older Child	3.8E-7	6.5E-8	4.4E-11	4.5E-07
				Adult	3.1E-6	3.7E-7	3.9E-10	3.5E-06

Children exposure frequency assumes that they are exposed by digging and/or playing in the sediment for 52 days/year at the Oakland Bay site's public access areas
Adult – refers to the30 year life time exposure

Certification

The Washington State Department of Health prepared this Health Consultation under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It was completed in accordance with approved methodology and procedures existing at the time the health consultation was initiated. Editorial review was completed by the Cooperative Agreement partner.

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The Division of Health Assessment and Consultation, ATSDR, has reviewed this public health consultation and concurs with the findings.

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