APPENDIX G

CONSIDERATION OF PUGET SOUND DREDGED MATERIAL MANAGEMENT PROGRAM (DMMP) ACTIONS IN TERMS OF EFFECTS ON BIOMAGNIFICATION OF PERSISTENT ORGANIC POLLUTANTS IN SOUTHERN RESIDENT KILLER WHALES AND STELLER SEA LIONS

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Summary

This appendix updates the 2010 DMMP Programmatic Biological Evaluation (PBE) Appendix B for the 2014 determination. It recounts the evidence for endangerment and food-web relationships from sediment to Southern Resident killer whale (SRKW), Steller sea lion, and harbor seal, and describes how the Dredged Material Management Program's (DMMP's) ongoing evaluation of suitability of dredged material for unconfined, open-water disposal and site management includes elements to protect marine mammals.

Several lines of evidence suggest that persistent bioaccumulative toxicants (PBTs) such as total polychlorinated biphenyls (ΣPCB [1]), total polychlorinated dioxins/furans (ΣPCDD/F), and total polybrominated diphenyl ethers (ΣPBDEs) are present in the food web in the Salish Sea at levels that may have toxic effects on organisms protected by the ESA or the Marine Mammal Protection Act. Model projections indicate that ΣPCBs are slowly declining but killer whales will continue to be exposed for generations. Numerous sources relate rapid increases in ΣPBDE in anadromous fish, marine invertebrates, and marine mammals. Lebeuf et al. (2004) indicated a ΣPBDE doubling time of 2.2-3 years in beluga whales in the St. Lawrence estuary. For killer whales, Mongillo (2009) cites research indicating J pod individuals that use Puget Sound have higher PCB concentrations than the more northerly ranging K or L pods, and the predicted blubber ΣPBDE doubling time for all 3 pods ranges from 3 to 4 years.

SRKW, Steller sea lions, and harbor seals consume prey species that frequent Puget Sound (the purview of the DMMP). Under the ESA, NMFS (2006) has designated SRKW Critical Habitat (CH) that includes seven of the eight DMMP open-water disposal sites. Designated CH includes a Primary Constituent Element that addresses prey suitability: "(2) Prey species of sufficient quantity, *quality*, and availability to support individual growth, reproduction, and development, as well as *overall population growth* " (emphasis added). SRKW appear to assimilate 4-6.6 times as much ΣPCB as the northern resident populations, partly because of higher PCB concentrations in prey and partly because SRKW prey have lower lipid content, requiring more prey consumption (Cullon et al. 2009). SRKW consume fish, with Chinook salmon as a major part of their diet; in turn, adult Chinook consume herring, which feed on zooplankton and smaller pelagic fish. Steller sea lions and seals consume pelagic and demersal fish and shellfish. Numerous studies (e.g., Ylitalo et al. 2005, West et al. 2011) have confirmed the presence of relatively high levels of ΣPCB in herring, hake, and Chinook salmon, and noted the relationship to SRKW. ΣPCB levels in Puget Sound biota are higher than in San Francisco Bay, despite comparably high levels of sediment ΣPCB. Puget Sound is a partially "closed" system for sediment, due to 2 sills near the outlet into the Strait of Juan de Fuca; San Francisco Bay is an open system, which loses sediment to offshore currents.

Quantitative food-web models for predicting transfer of ΣPCB from sediment to biota and subsequently through the food-web to higher consumers have been developed for the Great Lakes, San Francisco Bay (Gobas et al. 2010), and for the Lower Duwamish Waterway Superfund Site (LDWG 2010). For Puget Sound and adjacent Canadian waters, monitoring and modeling efforts by Shaw et al. (2005), West et al. (2008, 2011), Arnot and Gobas (2004), Condon et al.(2005), and Álava et al.(2012) have undertaken to understand effects of ΣPCB (and reported ΣPBDE levels) in Chinook and other species representing diet of SRKW. The West et al. (2011) study confirmed that, for pelagic fish (including hake, which are trophically similar to Chinook salmon) within Puget Sound, the more developed basins are correlated with higher concentrations of PBTs than less developed or reference basins.

Álava et al. (2012) presents an ecosystem level, steady-state ΣPCB food-web bioaccumulation model subdivided by resident killer whale CH areas including Puget Sound. This model relates ΣPCB content in sediment, surface water, and prey tissue residues to the resident killer whales of British Columbia and Puget Sound. It estimates killer whale uptake based upon equilibrium partitioning calculations from one

[1] The Σ symbol is used to indicate total as it relates to a sum of PCB or PBDE congeners.

environmental compartment to another, for example, ΣPCB migration from sediment into surface water, benthos, plankton, benthic fish, pelagic fish, and into killer whales. "Backward" calculations are used to develop a sediment value protective of SRKW by estimating concentrations in Chinook that are associated with critical mammalian toxicological benchmarks. The report states that geometric mean sediment ΣPCB concentrations of 0.058-0.0044 µg/kg dw at 1.9% OC (average organic carbon content for Puget Sound) are "target concentrations that would, once attained, presumably protect (southern) resident killer whales from PCB-related adverse health effects. This critical concentration may be a useful tool to identify whether areas are at all suitable for disposal of PCB contaminated sediments."

In 2010, following the last PBE for this program, based on the soon-to-be-published Álava et al. model, Canada's Department of Fisheries and Oceans (2010) provided an "advice" paper under Canada's Species at Risk Act (analogous to the ESA) to Environment Canada in order to inform decisions under its Disposal at Sea program. The advice (slightly reworded) follows.

a) Recommends that disposing of dredged material into CH containing ΣPCBs at concentrations higher than ambient PCB concentrations could increase the dietary availability of ΣPCBs to killer whales.
b) Recommends disposal of greater-than-ambient PCB levels into nondispersive (i.e., net depositional) sites as opposed to dispersive sites, in order to bury ΣPCBs, and reduce overall habitat exposure for killer whales.
c) Recommends use of congener-specific (high resolution) methods to characterize ΣPCBs and ΣPBDEs.
d) Notes that, while modeling predicts sediment levels from 0.012 to 0.2 µg/kg dw would protect killer whales, it is acknowledged that many areas are greater than this (both in coastal BC and in adjacent US waters). [2]
e) Recommends additional understanding of ΣPCB pathways in coastal waters, emphasizing sources, sinks, sedimentation rates, and substrate types in dredged and disposal sites to inform future risk-based decisions regarding fate and consequences of disposal activities in killer whale CH.

The DMMP was aware of both the "advice" paper and the unpublished model at the time of the 2010 PBE, and participated in a meeting regarding the development of the papers. At the time of the last PBE, it was not possible to cite the papers, because they were then confidential Canadian documents subject to internal review. The DMMP PBE did consider the essential information. See Section 6 for this consideration.

This Appendix merges information from the 2010 PBE with updates from the monitoring program over the intervening 5 years as well as recent dredged material characterizations. It concludes that the programmatic actions of transport, placement, and disposal of dredged materials with biomagnifying substances are unlikely to increase the existing levels of contamination to the food web. Therefore, continued disposal of approved sediments at the DMMP open-water disposal sites in Puget Sound will have discountable effects on ESA-listed species, including SRKW. Continued disposal will also have discountable effects on harbor seals, Steller sea lions and other mammals protected under the Marine Mammal Protection Act.

[2] We note that the sediment numbers mentioned here are 3-4 times higher than those in the later, peer-reviewed Alava et al. (2012) paper. However, as discussed below, both the citations state values that are well below natural background values for Puget Sound in general.

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1. Objectives

This document first appeared as an appendix to the Biological Evaluation for Fiscal *Year 2014 through 2039 Maintenance Dredging Program for Authorized Navigation Channels, and Disposal of Dredged Material from Federal and Non-Federal Dredging at Authorized Disposal Sites in the Seattle District, U.S. Army Corps of Engineers*, pursuant to Sections 7(a)(2) and 7(c) of the Endangered Species Act (ESA) of 1973, as amended. It addresses some requirements under the ESA, and discusses biomagnifying compound suites present in dredged material in Puget Sound as they relate to the programmatic actions of determination of suitability of dredged materials for disposal at unconfined, open water disposal sites, and the physical transport and disposal of dredged materials at unconfined, open-water sites in Puget Sound.

As context to this appendix, several lines of evidence suggest that persistent, bioaccumulating toxicants (PBTs) such as polychlorinated biphenyls (ΣPCBs), polychlorinated dioxins/furans (ΣPCDD/F), and polybrominated diphenyl ethers (ΣPBDEs) are entering the food web in Puget Sound at concentrations that may have toxic effects on organisms protected under the ESA or the Marine Mammal Protection Act (MMPA).

This document describes a) the evidence for endangerment and food-web relationships from sediment to Southern Resident killer whale (SRKW, *Orcinus orca*), the Steller sea lion (*Eumetopias jubatus*), and the Harbor seal (*Phoca vitulina*); and b) how the Dredged Material Management Program (DMMP) evaluates its programmatic actions in terms of impacts to mammalian species protected under the ESA and/or MMPA in Puget Sound.

The DMMP is the joint responsibility of the US Army Corps of Engineers (Seattle District USACE), US EPA Region 10, and the State of Washington Departments of Ecology and Natural Resources. Activities addressed under this program include dredged material placement at approved disposal sites, and nondispersive disposal site management. Sediment dredging occurs under individual or nationwide permits granted by USACE, and are scrutinized in Biological Evaluations/Assessments and consultations as needed; the consultation associated with permitting is not addressed in this document.

The endangered population discussed in this paper is the SRKW. The SRKW, as well as the Steller sea lion and the harbor seal are protected under the MMPA.

2. Issue Formulation - Evidence of Effects on Marine Mammals

SRKW are a top predator with both migrant and resident populations in Puget Sound (Calambokidis et al. 1984, Ross et al. 2000). SRKW have Critical Habitat designated in Washington waters (Figure 1). For the location of DMMP disposal sites, compare Figures 1 and 15; all but the Port Townsend site in northern Puget Sound are in SRKW Critical Habitat.

SRKWs have demonstrated significant decreases in population in the last 30 years, likely associated with pollution. Ross et al. (2005) stated the following:

> "Marine mammals are often exposed to high concentrations of persistent organic pollutants as a result of their long lives, relative inability to breakdown such contaminants, and their high position in marine food chains. We previously demonstrated that southern resident killer whales are heavily contaminated with polychlorinated biphenyls (PCBs). Our harbour seal monitoring work has supported evidence that Puget Sound is a regional PCB hotspot. In a further attempt to characterize local killer whale habitat quality, we measured new generation flame retardants,

polybrominated diphenyl ethers (PBDEs), in non-migrating harbour seals from four sites in Washington State and British Columbia. Our results suggest that the largely unregulated PBDEs represent a significant and emerging concern at the top of the coastal food chain. In a study of harbour seal "food baskets", PCBs and DDT represented the major contaminant classes in the diet of Strait of Georgia seals, but PBDEs have taken second place in the diet of Puget Sound seals. Increasing concentrations over time, and higher concentrations in Puget Sound seals and their prey, highlight the emergence of this new concern in this transboundary region. This information should be relevant to Conservation Planning for the southern resident killer whale community."

The recovery plan for SRKW (NMFS 2008), says the following with respect to environmental contaminants:

> "Ross et al. (2000a) described the organochlorine loads of killer whale populations occurring in British Columbia and Washington. Male transient killer whales were found to contain significantly higher levels of total PCBs (ΣPCBs hereafter) than Southern Resident males, whereas females from the two communities carried similar amounts. Both populations had much higher ΣPCB concentrations than Northern Resident whales. A similar pattern exists in Alaska, where transients from the Gulf of Alaska and AT1 communities contained ΣPCB levels more than 15 times higher than residents from the sympatric Prince William Sound pods of the southern Alaska community (Ylitalo et al. 2001). Profiles of specific PCB congeners were similar among the three killer whale communities from British Columbia and Washington, with congeners 153, 138, 52, 101, 118, and 180 accounting for nearly 50 percent of ΣPCB load (Ross et al. 2000a). Recent results from a much broader sample of killer whale communities from the North Pacific suggest that all transient populations and the Southern Residents possess high ΣPCB levels, whereas other resident populations and offshore whales have lower levels (G. M. Ylitalo et al., unpubl. data)."

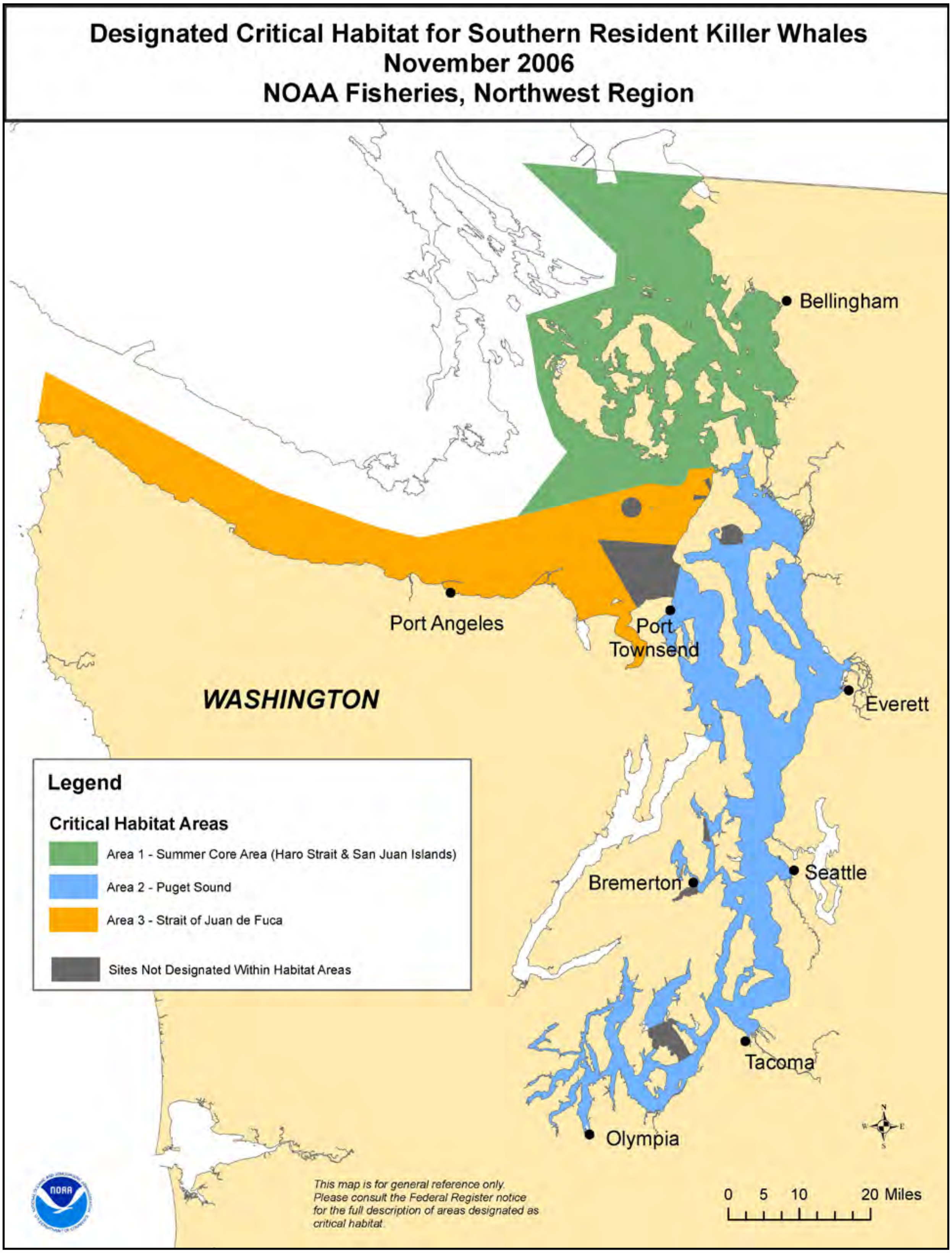

Figure 1. Designated SRKW Critical Habitat in Washington [http://www.fakr.noaa.gov/protectedresources/whales/killerwhales/attachmentb.pdf

Tissue Levels of PCB in Marine Mammals

Ross et al. (2000) stated, "Southern Resident and transient killer whales of British Columbia can now be considered among the most contaminated cetaceans in the world." As of spring 2014, the SRKW population totals 80 individuals (J Pod has 25, K Pod, 19, and L Pod, 36).

http://www.whaleresearch.com/#!orca-population/cto2

Biomagnification of PCBs into transient killer whale populations is significantly higher than in SRKW or northern resident killer whales, probably related to transient's preferred diet of marine mammals (Hayteas and Duffield 2000, and Ross et al. 2000). Migrant pods may be exposed to more contaminated prey items during migration than resident populations (Hayteas and Duffield 2000).

Regarding harbor seals, Puget Sound populations are more contaminated than the more northerly populations (Figure 2).

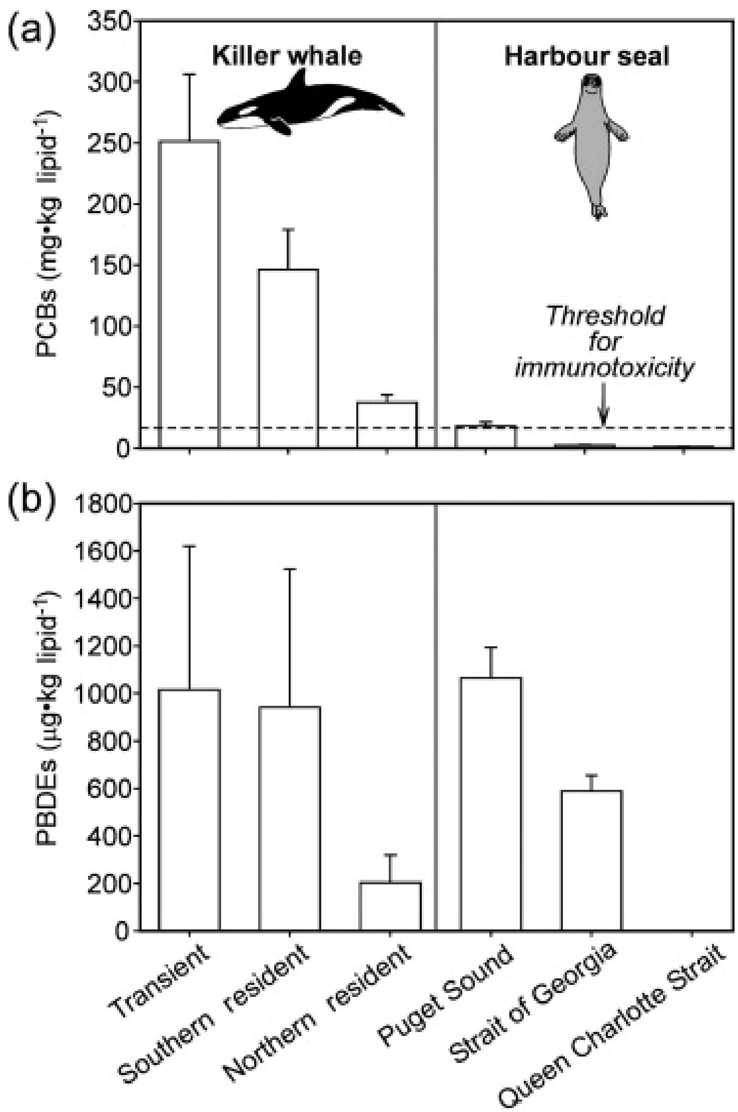

Figure 2. Comparison of Killer Whale and Harbor Seal Body Burdens of ΣPCB and ΣPBDE in US and Canada, from Ross et al. (2000).

Ross et al. (2000) and Krahn et al. (2007) reported SRKW ΣPCB concentrations for the periods 1993-6 and 2004-6, respectively (Figure 3). There is a suggestion of reduction in ΣPCB in male SRKW.

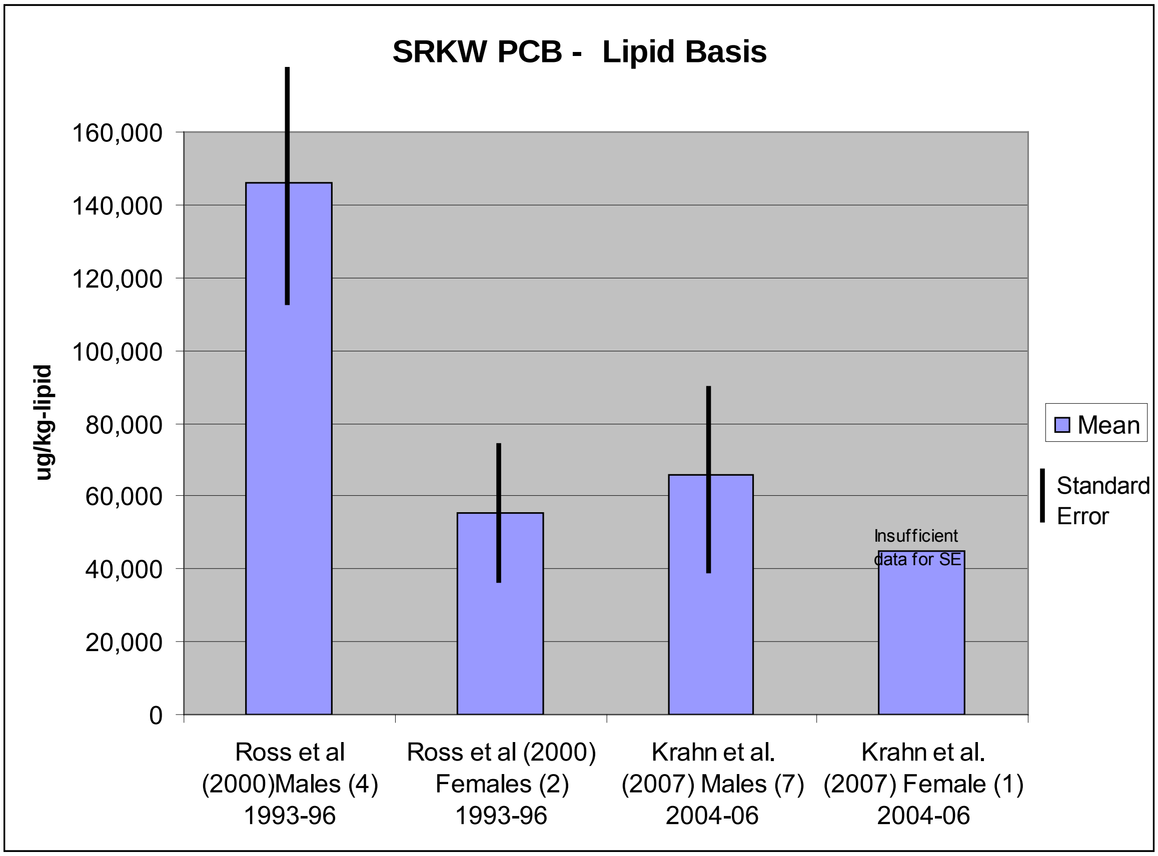

Figure 3. Southern Resident Killer Whale Blubber ΣPCB (regraphed from cited sources)

Resident killer whale populations preferentially feed on Chinook, which comprise about 96% of their total diet (Ross et al. 2000, Hayteas and Duffield 2000, and Jarman et al. 1996). Hanson et al. (2010) estimate from fecal analysis that 80-90% of the Chinook consumed by SRKW originate from the Fraser River (including the South Thompson River), and only 6 to 14% originate from natal streams in the Puget Sound region. However, these latter Chinook have fed in relatively PCB-rich Puget Sound. So, despite a much larger range than Puget Sound and the Straits of Juan de Fuca, a significant portion of the PCB burden in SRKW is believed to come from Puget Sound.

Prey fish concentrations of ΣPCBs from the Puget Sound Ambient Monitoring Program (PSAMP) were summarized in Washington Department of Health (2006). For English sole, all of Puget Sound had a range of 2-462 µg/kg-wet, and a mean of 38.6 µg/kg-wet. In the same units, the following are area-wise means: urban (73.6), near-urban (17.2), and non-urban (9.3). English sole are demersal; therefore, their body burdens are correlated better with their location.

O'Neill et al. (2006) noted that Chinook salmon from Puget Sound are approximately three times more contaminated with PCBs than other northeastern Pacific Chinook populations because of the increased residence time of some stocks or individuals in Puget Sound. Wild coho salmon from Puget Sound also have higher PCB levels than coho from the southern Georgia Basin, likely associated with their longer residence in Puget Sound. The Puget Sound Chinook-muscle-ΣPCB range was 11-223 µg/kg-wet, with a mean of 73.2 µg/kg-wet for fish caught in saltwater. The means for saltwater Chinook in central and south Puget Sound were very similar (70.6 and 75.6 µg/kg-wet, respectively).

Correlation of concentration with location was much less notable with these pelagic fish. DOH (2006) noted that PSAMP data indicated higher PCB concentrations are found in resident Chinook salmon (blackmouth) caught in winter in south Puget Sound than non-resident fish captured in Puget Sound during the spring or fall fishery. The authors used a Washington Department of Fisheries regression model of PCB to body length to estimate PCB concentration in blackmouth muscle tissue could range from 65 µg/kg -wet at the minimum legal length to a large fish with 100 µg/kg-wet.

Herring is a food source for many animals that are higher in the food web. Juvenile and adult herring inhabit the water column and are eaten by seals, diving birds, and many marine fish species including Chinook and coho salmon which are both prey eaten by SRKW. Between 1999 and 2003, PSAMP results from 1,055 three-year old male herring in 6 of 14 major Puget Sound and Georgia Basin stocks were reported by O'Neill et al. (2006). Results are shown in Figure 4 below. ΣPCB in whole bodies of herring from Port Orchard and Squaxin (central and southern Puget Sound, respectively) were four to nine times higher than those from the Georgia Basin. Levels of ΣPCB in Puget Sound herring are similar to levels measured in herring from the Baltic Sea in Northern Europe, one of the most highly contaminated marine ecosystems in the world (O'Neill et al. 2006)

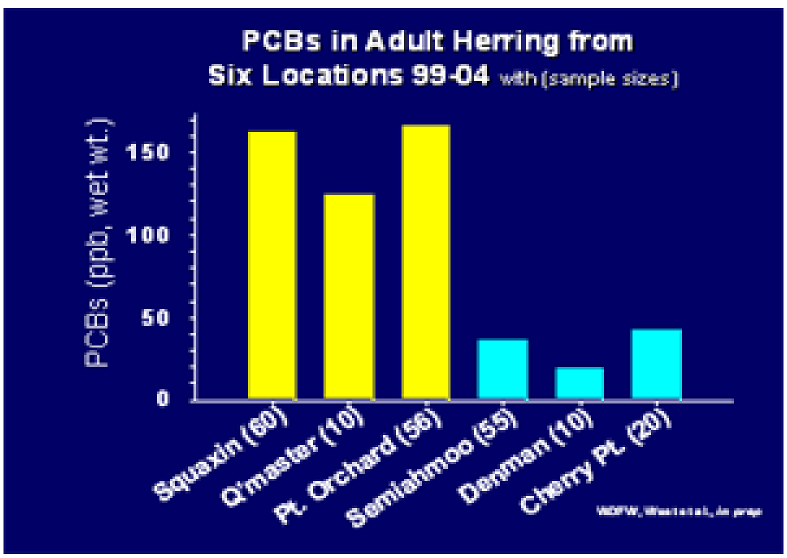

Figure 4. ΣPCB in Adult Herring from Six Puget Sound Locations, 1999-2004.

West et al. (2011) report that for Pacific hake (*Merluccius productus*) and walleye pollock (*Theragra chalcogramma*) tissue PBT data are consistent with other pelagic species such as Pacific herring and Pacific salmon species evaluated previously. Hake are similar in feeding behavior to resident Chinook, and lipid-normalized PCB congener patterns in hake were comparable to those found in Chinook. ΣPCB, PBDE, and organochlorine pesticides occurred in a clear gradient of concentrations, from high in Puget Sound basins that have experienced extensive development, to low in basins where watersheds have been less developed. For ΣPCBs, the data suggest focused, point sources of ΣPCBs that have migrated throughout the ecosystem from urbanized areas over a long period. For ΣPBDE, patterns suggested ubiquitous, terrestrial sources; congener and ΣPBDE patterns were similar across regions, but total concentrations were greater in developed portions of Puget Sound.

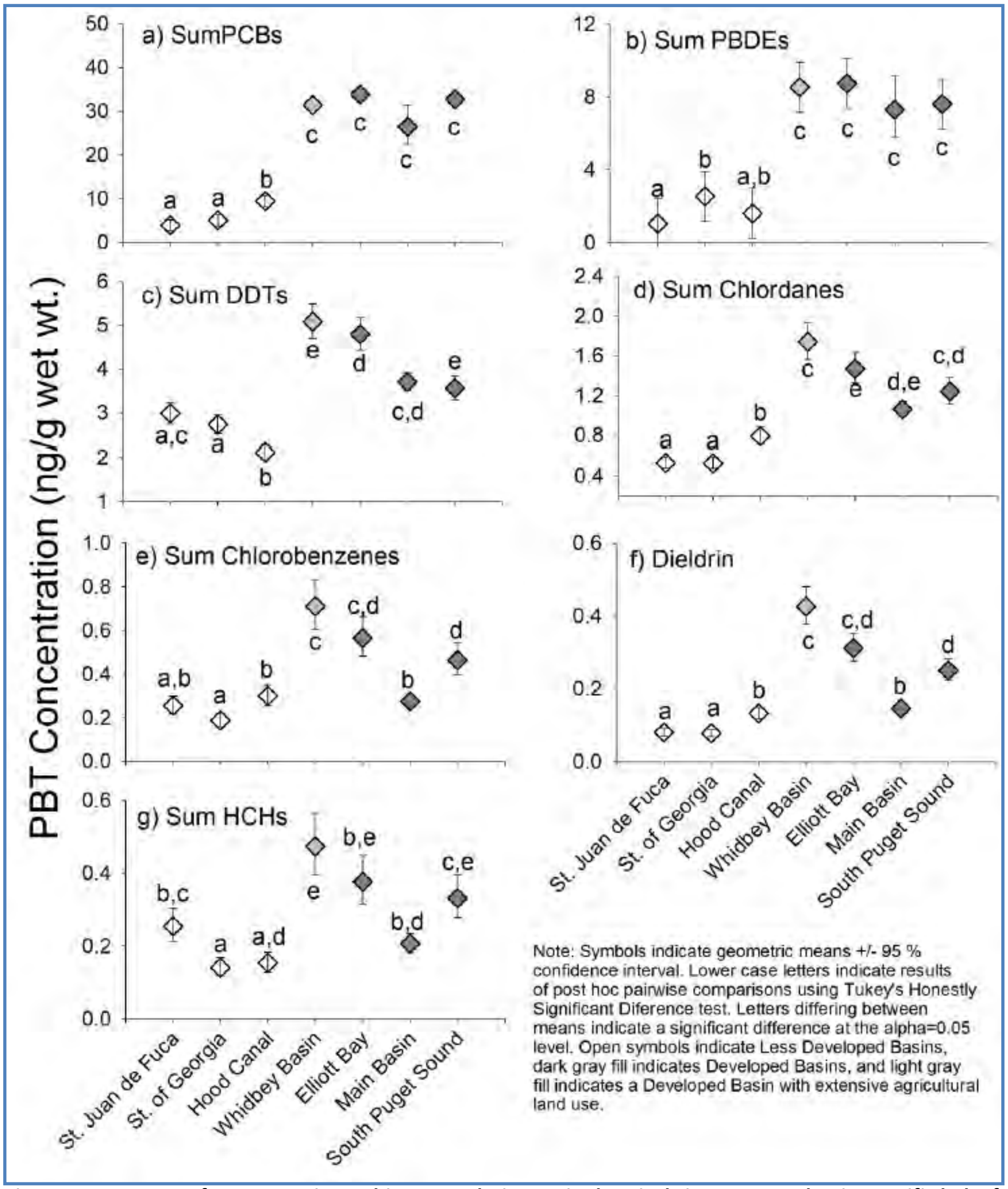

Figure 5. Summary of seven persistent bioaccumulative toxic chemicals in pre-reproductive Pacific hake from seven sampling Basins in Puget Sound. (West et al. 2011)

Steller sea lions declined precipitously in the 1970s to 1990s, and the western distinct population segment (DPS) is listed as endangered. However, the eastern DPS, which includes all Steller sea lions in Washington State, has since recovered and was de-listed in December 2013 (NMFS 2013). Steller sea lion numbers vary seasonally in Washington with haulout sites primarily along the outer coast from the Columbia River to Cape Flattery, as well as along the Vancouver Island side of the Strait of Juan de Fuca. This species may be found occasionally on navigation buoys in Puget Sound. Although breeding rookeries are located along the Oregon and British Columbia coasts, no breeding rookeries occur in Washington (WDFW 2000). Their prey species consist of fish, bivalves, cephalopods and gastropods, including herring, capelin, sand lance, pollock, mackerel, rockfish, cod, salmon, and squid (NMFS 2014).

Concentrations of ΣPCB in some Steller sea lions from Alaska approach or exceed levels that cause physiological problems in other marine mammals. Myers and Atkinson (2005) measured 239 Steller sea lions from the Gulf of Alaska, pups from southwest Alaska, and three captive animals. Myers and Shannon (2005, 2006) noted the following in conference proceedings (slightly rearranged here):

> “Kannan et al. (2000) recommended a PCB threshold concentration of 11,000 ng/g lipid weight for marine mammal blood.
>
> - Western Alaskan sea lion pups’ mean ΣPCBs was 5,155 ± 610 µg/kg - lipid weight (below threshold levels). However, 9 out of 76 pups (or 12%) exceeded the threshold concentration.
> - [PCB related] TEQs measured in the blood of immune-compromised harbor seals (DeSwart et al. 1994, 1996; Ross et al., 1995) was 72 pg/g (ng/kg) lipid. Western Alaskan pups’ TEQ averaged 71 pg/g (ng/kg) lipid.”

Toxic Effects of PCB and PCDD/F on Marine Mammals

These two compound suites’ toxicity are treated together, as they are believed to be related. In the petition to list SRKW (CBD 2001), the following statements appear:

> “On the basis of studies in other mammals, additional adverse health effects of DDT and metabolites, PCBs, dioxins, and furans are possible in killer whales, and even likely in individuals with high exposure. Exposure to mono-*ortho* and di-*ortho* PCB (non dioxin-like) congeners and metabolites may result in effects not mediated by the same biochemical pathways as 2,3,7,8-TCDD, and therefore not predicted by TEQs. Such effects include neurobehavioral, neurochemical, carcinogenic, and endocrinological changes (Ahlborg et al., 1992). Because these types of effects are difficult to observe in wild populations, there is no way to account for such effects in Southern Resident killer whales with available information.
>
> Direct assessments of DDT, PCB, dioxin, and furan effects in many species of mammals (as well as fish and birds) have proven these organochlorines to be potent agents of numerous adverse health effects (Eisler and Belisle 1996; Eisler 1986; Smith 1991). For example, Beland et al. (1993) and DeGuise et al. (1995) documented high incidences of tumors, including malignant neoplasms, in St. Lawrence beluga whales contaminated with PCBs (8.3 – 412 mg/kg lipid weight in blubber) and lower levels of dioxins and furans (Muir et al. 1996). From an Atlantic beluga whale population estimated at 500 animals, 18 collected post-mortem had tumors, a rate of 3.6 percent. The possibility that such effects occur in Southern Resident killer whales is relevant to its risk of extinction: an animal fighting an infection or the development of a tumor, one that has neurobehavioral abnormalities, liver disease or an altered endocrine system, or some combination of these effects, will be less fit for survival in the wild.”

Ross et al. (2000) states the following:

> “…low to moderate concentrations of both the `dioxin-like' and the non-`dioxin-like' PCBs, PCDDs and PCDFs are known to cause immunotoxicity, neurotoxicity, reproductive impairment and endocrine disruption in laboratory animals (Brouwer et al., 1998; Vos and Luster, 1989) and wildlife species (Colborn et al., 1993; Fry, 1995; Guillette et al., 1995; Luebke et al., 1997).

Additionally, PCBs have been linked to cancer in both humans (Bertazzi et al. 2001) and California sea lions (Ylitalo et al. 2005), and are listed as probable human carcinogens by the US EPA and International Agency for Research on Cancer (ATSDR 2000).”

Vitamin A is important in many mammalian developmental, reproductive, and immunological processes. Mos et al. (2007) noted that vitamin A physiology is under strict physiological regulation in all mammals. PCBs and structurally related compounds including PCDD/F can interfere with vitamin A transport, storage, and metabolism thereby promoting more rapid excretion. Observed vitamin A disruption in harbor seals suggests that PCBs are adversely affecting free-ranging marine mammals. Vitamin A may represent a sensitive biomarker in toxicological studies of marine mammals.

Adverse tissue-residue effects concentrations for these compounds for marine mammals are summarized in Table 1. The affected organism is listed in the left column; the basis column shows the tissue residue source. For instance, the first row indicates that mammals may be adversely affected when their tissue residue exceeds the value shown in the third column. The fourth row discloses data based upon observed effects to dolphin as they apply to SRKW tissue residue. Note that all SRKW measured by Ross (2000) and Krahn et al. (2007) (Figure 3) exceeded all of these lipid-based whale-tissue toxicity thresholds. In addition, the entire range of the Puget Sound Chinook PCB values cited in DOH (2006) are above the Chinook-based dietary threshold, and the mean is nearly an order of magnitude higher than that threshold.

Table 1. Residue-based PCB and PCDD/F TEQ Toxicity Values for Marine Mammals.

Compound: Organism (study)	Basis	Residue Effects Concentration
ΣPCB: Toxicity to Fish-eating Wildlife (Hickie et al. 2007)	Marine Mammal Tissue	50,000 µg/kg -wet
ΣPCB: Harbor Seal (Ross et al. 1996)	SRKW Tissue	17,000 µg/kg-lipid
ΣPCB: Revised Harbor Seal (Mos et al. 2010)	SRKW Tissue	1,300 µg/kg-lipid
ΣPCB: Bottlenose dolphin (Hall et al. 2007)	SRKW Tissue	10,000 µg/kg-lipid
ΣPCB: Chinook (Hickie et al. 2007) to protect 95% of SRKW below the toxicity threshold at the top of the table	Chinook Tissue in SRKW Diet	8 µg/kg -wet
ΣPCB: Harbor seal pups (Johnson et al. 2007) [A]	Fish Tissue in Seal Diet	0.8 µg/kg-wet
ΣPCDD/F TEQ (includes ΣPCB): toxicity to Harbor seals (Ross et al. 2005)	Marine Mammal Tissue	255 ng TEQ/kg (lipid)
ΣPCDD/F TEQ: Harbor seals exhibiting immune suppression (DeSwart et al. 1994, 1996; Ross et al. 1995)	Marine Mammal Tissue	72 ng TEQ/kg (lipid)

[A] Johnson et al. (2007) state, "The No Adverse Effects Level (NOAEL) for mink (*Mustela vison* - $NOAEL_{mink}$) was converted to effects levels for harbor seal pups ($NOAEL_{SealPup}$) by scaling the dose to the ratio of mink body weight to body weight (bw) of harbor seal pups: $NOAEL_{SealPup} = NOAEL_{Mink}(bw_{Mink}/bw_{SealPup})^{1/4}$ according to the method of Sample et al. (1996)."

Tissue Levels of PCDD/F

Ross (2000) measured ΣPCDD/F dioxin-like Toxicity Equivalents (TEQ) from SRKW Northern Resident, and Transient populations. Unlike ΣPCB, there were no significant differences amongst these populations. Figure 6 illustrates the results, using 1998 Toxicity Equivalence Factors.[3] The authors concluded that although ΣPCDD/F TEQ is less than PCB dioxin-like congeners, it still exceeds body burdens that are known to represent harm to harbor seals based upon mammalian toxicity equivalence factors. Ross et al. (2004) conclude that it appears that ΣPCB contamination in Puget Sound indicates localized sources, but that ΣPCDD/F are much more widespread (possibly suggesting atmospheric deposition), although there are some source-related signals for PCDD/F for the Strait of Georgia.

[3] These have changed since (WHO 2005), but the changes were not likely to substantially modify these results.

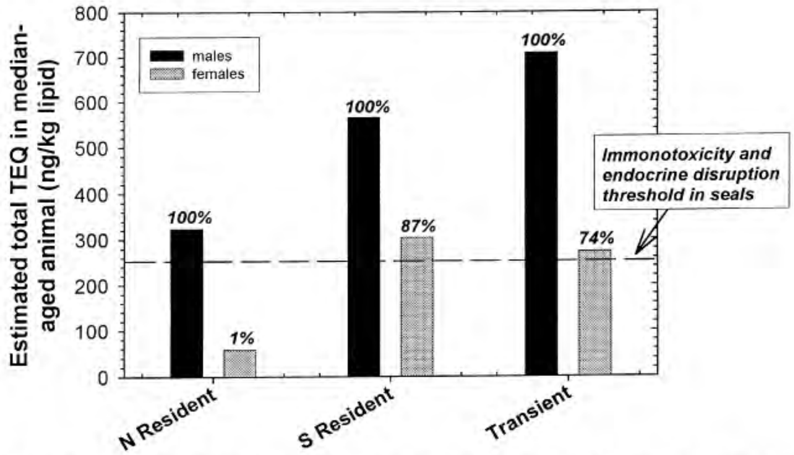

Fig. 5 Estimated total dioxin Toxic Equivalents (TEQ_{98}; ng kg^{-1} lw) in 12-year-old male and 25-year-old female killer whales from each of the three communities studied. These represent the median ages for the southern resident community, with the age-adjusted estimates allowing for a more direct comparative evaluation of risk among the three communities. Numbers above each bar represent the estimated percentage of males and females from the three free-ranging killer whale communities ($N = 212$, 89 and at least 219 individuals, respectively) in British Columbia that exceed the toxicity threshold established previously for harbour seals (De Swart et al., 1995; Ross et al., 1995).

Figure 6. PCDD/F TEQ from Ross (2000)

Tissue Levels of PBDE

Harbor seals provide a picture of tissue ΣPBDE that is also relevant for SRKW. Ross et al. (2005) compared PBDE concentrations from harbor seals in British Columbia and Washington (Figure 2). It is clear that harbor seals are significantly more contaminated in Puget Sound. The pattern holds for herring as well (Figure 7), which are a food source for seals.

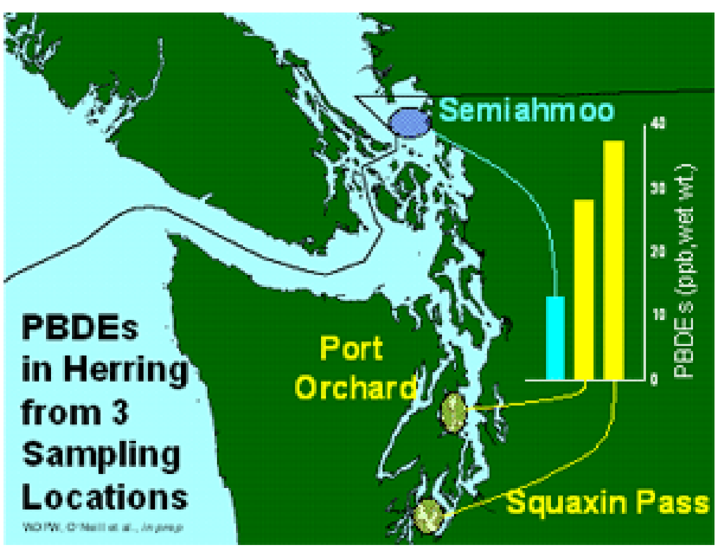

Figure 7. PBDEs in Herring from Puget Sound and Strait of Georgia (Dutch and Aasen 2007).

Ross et al. (2005) state: "An analysis of harbor seal samples collected between 1984 and 2003 revealed that PBDE concentrations in harbor seals from Gertrude Island, South Puget Sound, increased from 15 to 1,064 micrograms of pollutant per kilogram of fat – a meteoric increase of 1500 percent." (Figure 8).

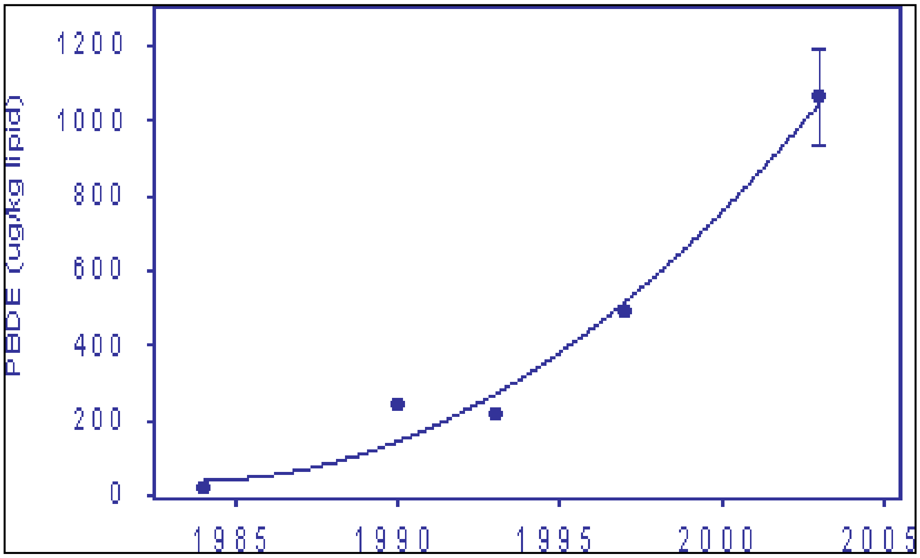

Figure 8. Increase in PBDE in Harbor Seal Fat, South Puget Sound, 1984-2003.

Lebeuf et al. (2004) indicated a ΣPBDE doubling time of 2.2-3 years in beluga whales in the St. Lawrence estuary, and Mongillo (2009) cites research indicating J pod individuals, which frequent Puget Sound, have higher ΣPCB concentrations than the more northerly ranging K or L pods, and the predicted blubber ΣPBDE doubling time for all three pods ranges from 3 to 4 years.

Regarding PBDE in prey fish, Puget Sound Resident salmon sampled in 2003 and 2004 had PBDE at 40 µg/g, about 28 times higher than those levels reported for Chinook salmon returning to northern British Columbia (O'Neill et al. 2006).

Dutch and Aasen (2007) report the following:

> "Eleven of the 12 congeners measured in the sediments were also measured in tissue from 5 species of fish collected from Puget Sound by O'Neill and West, Washington Department of Fish and Wildlife. Of these, seven were detected in the fish tissue, while four (BDE-71, -138/166, -183, and -209) were usually below method detection limits. … All species accumulated BDE-47 in the highest concentrations, while BDE-49 was relatively high in the herring and Chinook samples. Congeners BDE-99 and -100 were relatively high in all species except the Quillback Rockfish. Congeners BDE-66, -153, and - 154 were present, but relatively low in all five species. Levels of PBDEs in English Sole muscle tissue were highest in and near urban/industrial bays and decreased in more rural areas. Levels of PBDEs in herring tissue were highest in southern [Puget Sound] stocks and lowest in the most northern stocks. Whether high or low, proportions of the various BDE congeners appeared to remain consistent within species between locations."

Toxic Effects of PBDE

PBDEs are a class of endocrine disrupting compounds that have been found to affect neurological development, thyroid hormone levels, and immune function in animals (Rayne et al. 2004). Studies in laboratory animals link PBDEs with effects on hormone (thyroid) function, which are critical to normal brain function. PBDEs are very similar in structure to PCBs, are extremely persistent, and bind to sediments and fat. US EPA (2008) issued an Oral Reference Dose for deca-BDE (BDE-209) of 7 µg/kg body weight per day based on rat studies, with an Uncertainty Factor of 300. Deca-BDE is also a *possible human carcinogen* according to the citation. The Oral Reference Dose is not lipid-normalized; the range of average US male and female 30-50 year old body fat is 13-25%, so the lipid-normalized value would be 6.75-54 µg/kg body weight per day [lipid].

Summary of Hazards

There is sufficient information on biomagnification and toxic effects of PCB, PCDD/F, and PBDEs to SRKW, Steller sea lions, and harbor seals in Puget Sound.

3. PCBs, PCDD/Fs and PBDEs in Puget Sound Sediments

This section is intended to provide context for later discussion of the relationship between DMMP actions and the subject species.

a) PCB

Estimates of ΣPCB by mass in sediments. Data sets are difficult to compare, and it is difficult to confidently calculate a central tendency measure for Puget Sound. This is because of variable PCB analytical methodologies used in Puget Sound (measuring all 209 congeners, or a subset of 19 congeners multiplied by 2 to equal the 209 [a.k.a the NOAA method], sum of homologues, or Aroclor mixtures), the associated wide range of analytical sensitivities, as well as variable of methods to express results from datasets with a large number of nondetects. From a brief survey of analytical information in 2010, it is apparent that the Puget Sound sediment distribution of ΣPCB is skewed, with extreme values in the Lower Duwamish Waterway, and Elliott Bay, and in Everett Harbor. Based on the following paragraphs, the mean or median ΣPCB concentration in Puget Sound surface (0-10 cm) sediments likely falls between about 3 µg/kg (for nonurban areas) to approximately 54 µg/kg (for a representative mixture of urban and nonurban locations), and into the hundreds of µg/kg in urban Elliott Bay. Thus, estimates of central tendency of ΣPCB from Puget Sound are highly variable, as are the underlying data. It matters greatly whether (and how) urban sites are included in the evaluation.

A query on Washington State's Environmental Information Management (EIM) System conducted for the 2010 Appendix B to the 2010 PBE selected ΣPCB results from the 0-10 cm depth for the years 1998-2009. There were 513 marine subtidal and intertidal samples selected, and the EIM query did not exclude information on clean-up sites, and was not balanced with regard to urban versus nonurban area sampled; both of these facts likely bias the results, and the query is shown only to demonstrate all of the available data from the period. Slightly more than 90% of these data were detected values. The dataset did not conform to any parametric distribution, and a nonparametric (Kaplan-Meier) statistical analysis was conducted using EPA's software, ProUCL version 4.00.04 (most recent version 5.0 – EPA (2013)). The range of minimum to maximum concentrations was 5 orders of magnitude.

Table 2. EIM Query and Dutch et al. (2003) Estimates of Puget Sound ΣPCB by Mass.

Compound(Measure)	n	Minimum	Mean	Maximum
EIM: ΣPCB (µg/kg , congener+Aroclor)	513	0.105	261.2 ± 43.4 (by KM ± Standard Error)	11,000
Dutch et al. (2003) (µg/kg , 19 congeners x 2)	300	8.37	80.23	4,892
Dutch et al. (2003) (µg/kg , detected congeners only)	300	ND	50.11	4,658

The Dutch et al. paper includes information from Long et al. (2003), which evaluated 300 Puget Sound Ambient Monitoring Program (PSAMP) sediment sampling results for ΣPCBs taken from 1997 to 1999. This report appears to be more balanced than the EIM query shown, but does include urban bays. Regional means varied significantly (detected congeners only, in µg/kg): Strait of Georgia (0.1), Whidbey Basin (131.16), Admiralty Inlet (2.42), Central Puget Sound (76.06), and South Puget Sound (3.34).

PCB congener 153 was generally the highest concentration, followed by concentrations of congeners 101, 118, 138. The range of ΣPCBs was 2 orders of magnitude. The distribution of ΣPCB results was highly skewed towards the lower concentrations or non-detected values. Dutch et al. (2003) stated that 21 of the 300 samples exceeded the State of Washington PCB Sediment Quality Standard of 12 mg/kg organic-carbon normalized for ΣPCBs; and that these represented an area of only about 7.2 km^2, or about 0.3%, of the surveyed area of 2,363 km^2.

DMMP (2009) conducted a survey using the US EPA vessel OSV Bold, which showed considerably lower values, as it targeted only nonurban areas of Puget Sound and sought to exclude locations near outfalls or known cleanup sites. Seventy samples were taken. Only Aroclor 1268 was detected, and that only in 9% of samples, from Carr Inlet, Holmes Harbor, and South Sound. Detected ΣPCBs (Aroclors) ranged from 2.1 µg/kg to 31 µg/kg. A total of 166 PCB individual and co-eluting congeners (shown in brackets) were reported. The pentachlorobiphenyls [90+101+113], [110+115], 118, and the hexachlorobiphenyls [153+168] were detected in 94% of samples. The hexachlorobiphenyls [129+138+163] were detected in 96% of samples. Summarized congener-based sediments in this nonurban study are shown in Table 3.

Table 3. OSV Bold (DMMP 2009) Statistical Summary of Puget Sound Non-Urban Sedimentary ΣPCB and ΣPCDD/F by Mass.

Compound(Measure)	Minimum	50^{th} Percentile	90^{th} Percentile	Maximum
ΣPCB (µg/kg , all congeners; KMSum[A])	0.0385	0.765	2.79	10.6
ΣPCDD/F (µg/kg , all congeners; KM Sum)	0.00582	0.112	0.282	0.485

[A] Kaplan-Meier Summation is a nonparametric technique for summation without using surrogate values for nondetected congeners

The State of Washington Department of Ecology's (2013) Draft Sediment Cleanup Manual II (SCUM-II) used the concept of "natural background" to set final cleanup criteria for PBTs (and other contaminants) unless risk-based values are higher.

> *"Natural background means the concentration of a hazardous substance consistently present in the environment that has not been influenced by localized human activities. For example, several metals and radionuclides naturally occur in the bedrock, sediment, and soil of Washington state due solely to the geologic processes that formed these materials and the concentration of these hazardous substances would be considered natural background. Also, low concentrations of some particularly persistent organic compounds such as polychlorinated biphenyls (PCBs) can be found in surficial soils and sediment throughout much of the state due to global distribution of these hazardous substances. These low concentrations would be considered natural background."* Washington Administrative Code (WAC) 173-204-505(11).

The draft SCUM-II states the means of determining natural background is an expanded OSV Bold dataset, defined by the 90^{th} percent upper tolerance limit on 90^{th} percentile coverage. No data are included in the manual for ΣPBDEs.

Table 4. Puget Sound Natural Background (Ecology 2013).

PBT	Puget Sound Natural Background
ΣPCB (congeners)	3.5 µg/kg dw
ΣPCB (2,3,7,8-TCDD Toxicity Equivalents)	0.2 ng TEQ/kg dw
ΣPCDD/F	4 ng TEQ/kg dw

Ecology has also developed the concept of "regional background" intended to include concentrations of chemicals that are primarily from diffuse sources such as storm water and atmospheric deposition, but can also include chemical concentrations from "globally" distributed sources. Regional background requires determinations by Ecology and for most sites is not currently available.

Information compiled for the Lower Duwamish Waterway Superfund Site Feasibility Study (LDWG 2012) includes PCB data from Washington Department of Ecology and King County in the Green River above the Lower Duwamish Superfund Site. Scientists are using these data to ascertain inputs to that urbanized water- and air-shed to support the ongoing bed-load estimates Feasibility Study. The data include sediments and suspended solids quantified by the congener method for PCBs. These data suggest a baseline input to the river and Sound from the Seattle area near the high end of the mean values for the foreseeable future. The data in Table 5 are King County 2004-2007 data.

Table 5. Statistical Summary of ΣPCB by Mass in Urbanized Freshwater Bodies Draining into Puget Sound.

Compound(Measure)	n	Minimum Detected	Median	Mean	Maximum
Sediment in Green River; ΣPCB (µg/kg congener; 0.5*DL method)	73	0.3	10	17	140
Suspended Solids in Green River; ΣPCB (µg/kg congener; 0.5*DL method)	29	1	11	42	367
0-2 cm in Lake Washington; ΣPCB (µg/kg congener; 1*DL method; recalculated from gamma distribution)	52	1.8	11	14.3	57

Also in Table 5, Era-Miller (2010) surveyed the top 2 cm of sediments in Lake Washington for ΣPCBs by the congener method. The study included modeling of biomagnification into northern pikeminnow. The model was determined to be sensitive to freely dissolved water concentrations (which, however, were not measured in the study).

Figure 9 displays the marine ΣPCB data and suggests a plausible range for average Puget Sound ΣPCBs (µg/kg) for datasets that include some urban samples; it also includes Ecology's natural background for comparison.

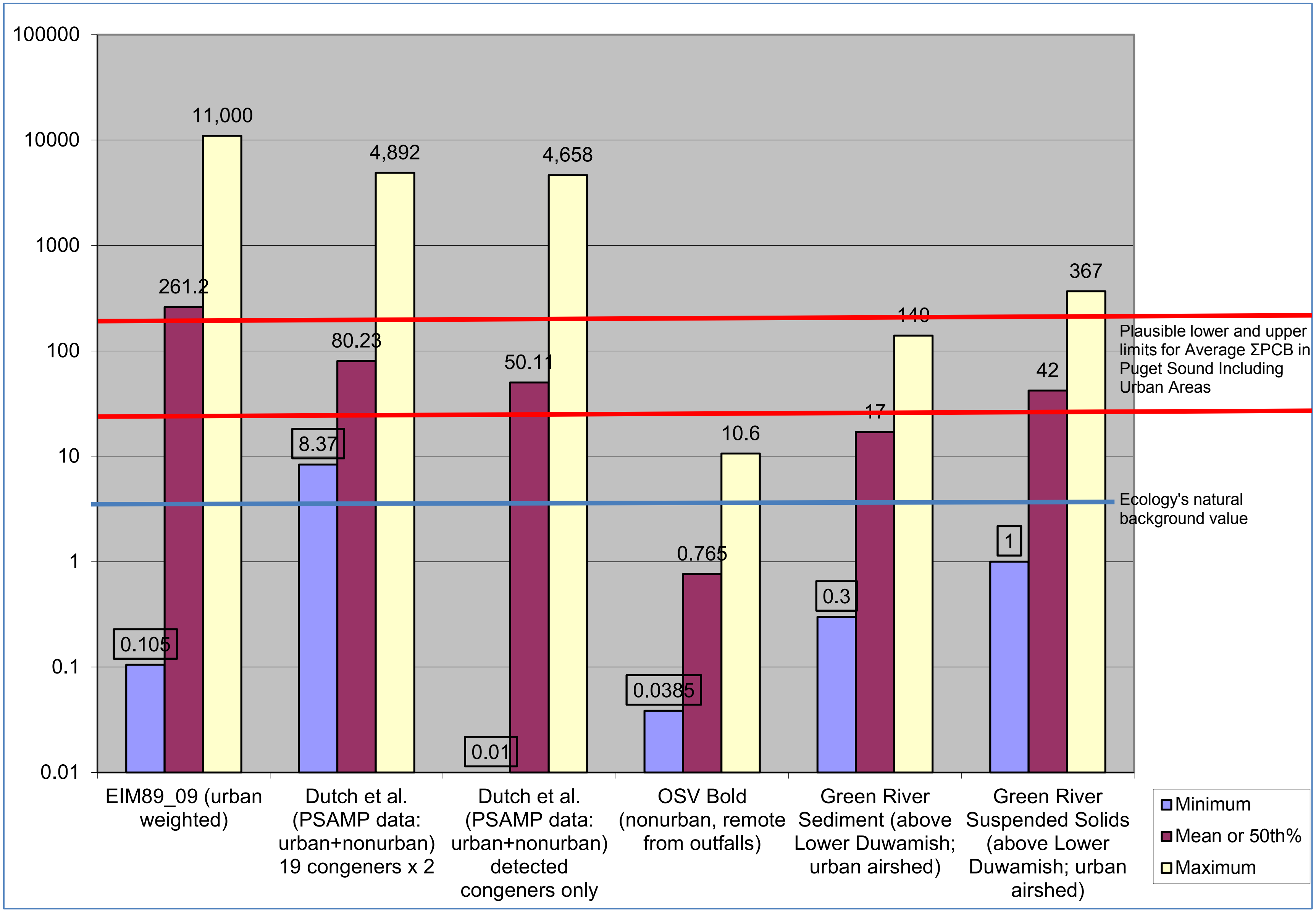

Figure 9. Synopsis of Puget Sound sediment ΣPCB (µg/kg dw) from several surveys and comparison to Ecology's natural background (blue line)

Estimates of PCB by sediment toxicity equivalents (TEQ) to 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD).

Inouye (2009) presented a paper at a June, 2009 DMMP Dioxin Workshop which described a query on the EIM database for Puget Sound marine sediment ΣPCB, and estimation of PCB TEQs from congeners.

Table 6. PCB TEQ from Washington Department of Ecology EIM Database With and Without Cleanup Sites.

Summation Method	n	Minimum, ng/kg	50th Percentile ng/kg	90th Percentile, ng/kg	Maximum, ng/kg
All EIM Stations					
SUM TEQ (ND=0)	1,649	0	0.06	0.06	1,359
SUM TEQ (ND=0.5*DL)		6E-05	0.18	0.36	1,384
EIM Minus Cleanup Sites					
SUM TEQ (ND=0)	803	0	0	0.18	140
SUM TEQ (ND=0.5*DL)		6E-05	0.05	0.25	140

In the DMMP (2009) Bold study, PCB congener TEQs were calculated using the World Health Organization (2005) toxic equivalency factors for mammals, and the Kaplan-Meier nonparametric method for summation of non-detected values. The non-urban sites in this study (Table 7) were significantly lower than those reported by Inouye (2009), which included urban areas (Table 5). Figure 9 compares the values from EIM and Bold. Figure 10 shows a map of the Bold TEQ results.

Table 7. OSV Bold (DMMP 2009) Statistical Summary of Puget Sound Non-Urban Sedimentary PCB and PCDD/F by Toxicity Equivalents.

Compound(Measure)	Minimum	50th Percentile	90th Percentile	Maximum
Bold PCB TEQ (ng/kg, dioxin-like congeners, KMSum)	0	0.0035	0.0071	0.168
PCDD/F TEQ (ng/kg, 2,3,7,8-chlorine-substituted congeners, KMSum)	0.047	0.774	2.69	11.6

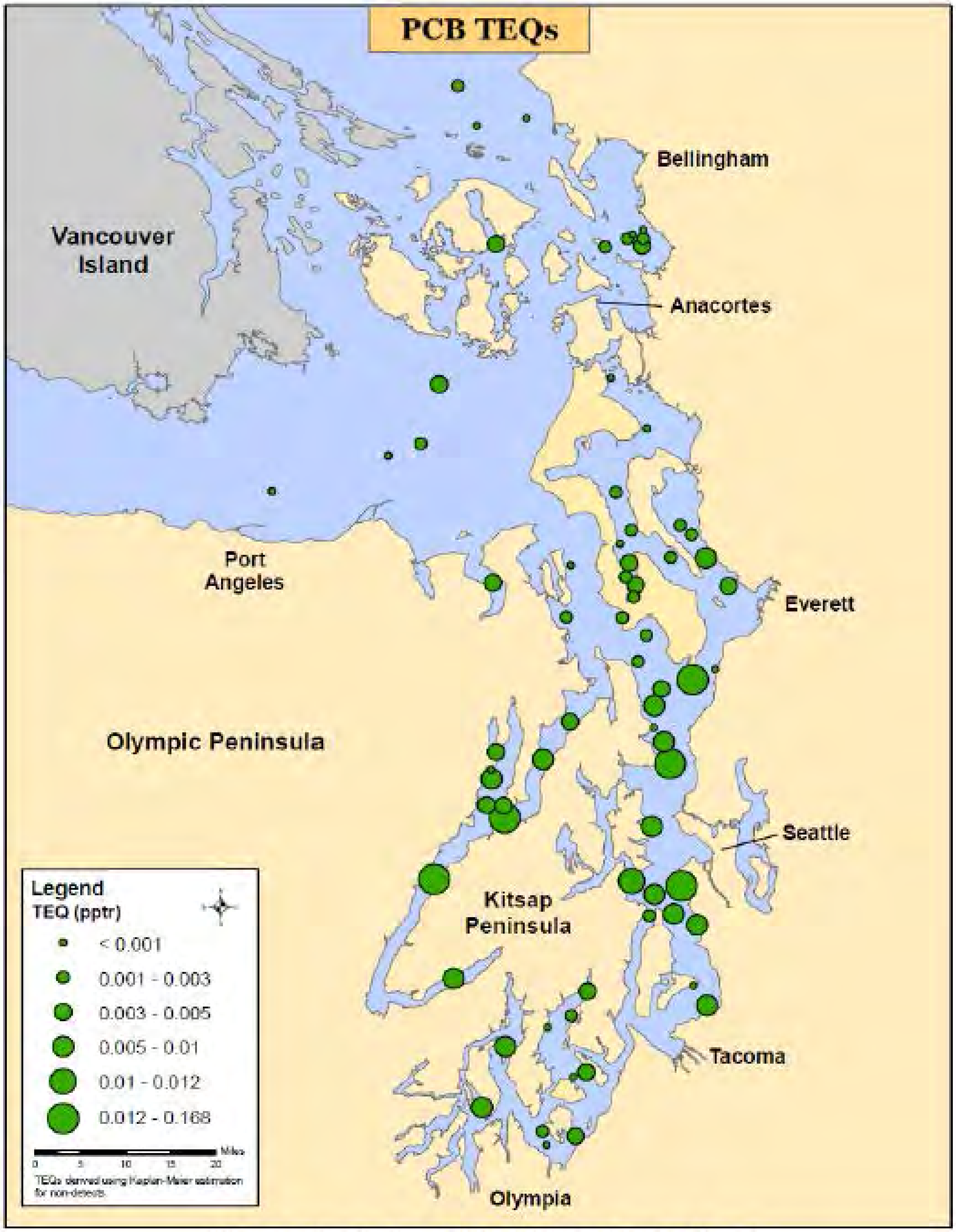

Figure 8. Distribution of PCB TEQs (weighted KM sum)

Figure 10. PCB TEQs taken from DMMP (2009).

Figure 10 shows the distribution of PCB TEQ in the OSV Bold survey. As noted in Table 4, Ecology selected a natural background for PCB TEQ of 0.2 ng TEQ/kg dw and PCDD/F 4 ng TEQ/kg, based upon an expanded ("Bold Plus") dataset.

Ecology (2011, shown in Figure 11 below) estimated annual atmospheric and runoff loadings of ΣPCBs to the surface of the Puget Sound, using three scenarios: scenario 1 - no seasonal or spatial differentiation, scenario 2 - spatial differentiation of sub-basins, and scenario 3 - spatio-temporal differentiation of fluxes in sub-basins. The atmospheric loading estimates are shown in a dot and whisker plot with the dot representing the 50th and the whiskers the 25th and 75th probability of exceedance for atmospheric deposition (ATMDEP) and surface runoff (RUNOFF) loading of ΣPCB.

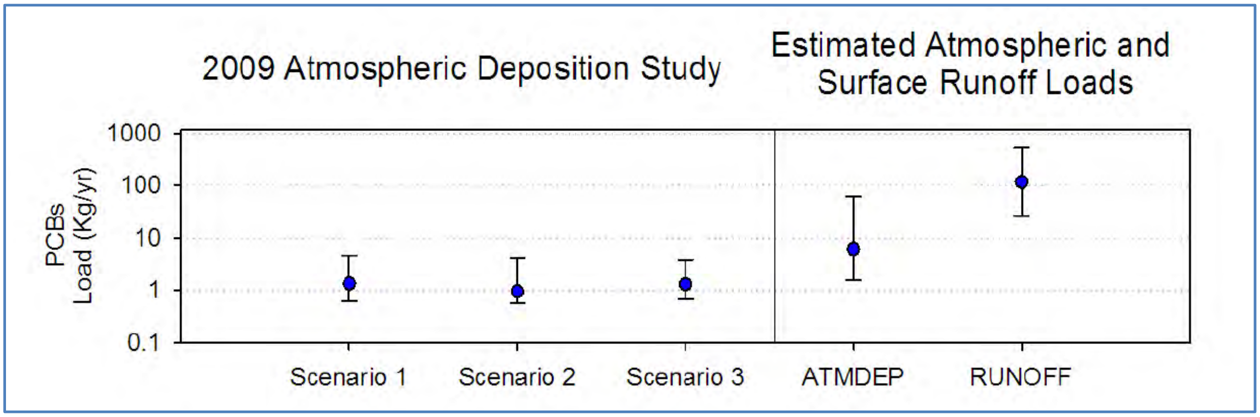

Figure 11. Ecology Loading Calculations for ΣPCB in Puget Sound (total area).

b) PCDD/F

The page at this URL (http://www.nws.usace.army.mil/Missions/CivilWorks/Dredging/Dioxin.aspx) summarizes ΣPCDD/F TEQs for Puget Sound, Grays Harbor, and adjacent freshwater bodies. Puget Sound appears in Figure 12. As noted above, Ecology (2013) has recommended additional reference sediment samples (the "Bold Plus" dataset) available in an appendix to the citation.

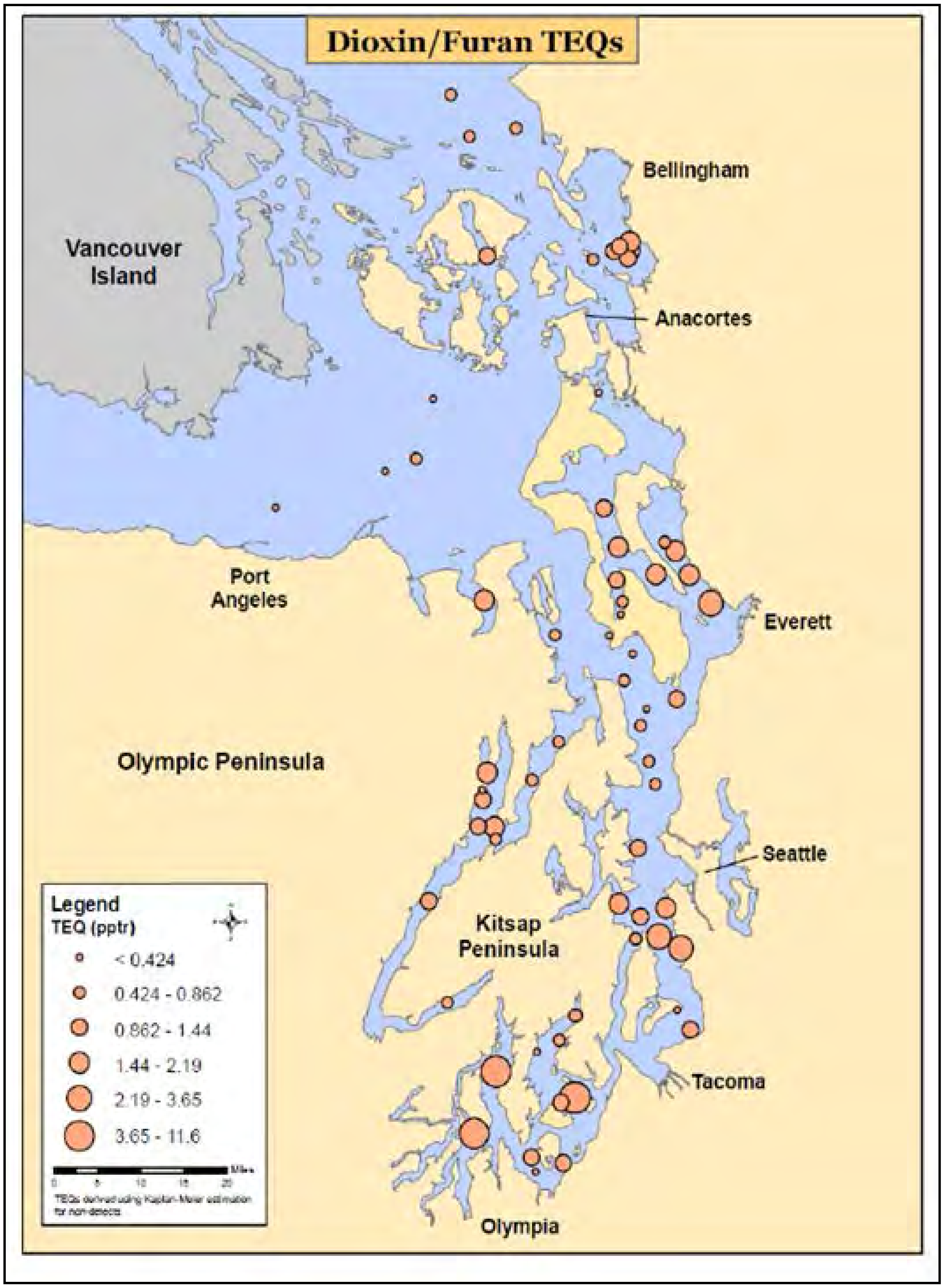

Figure 12. Distribution of PCDD/F in Puget Sound.

c) PBDE

Ross et al. (2009) state the following:

> "…the single congener BDE-209, the main ingredient in the Deca-BDE formulation, has surpassed the legacy PCBs and DDT as the top contaminant by concentration. Limited biomagnification of BDE-209 in aquatic food webs reflects its high log K_{ow} and preferential

partitioning into the particle phase. As a result, large environmental reservoirs of BDE-209 are being created in sediments, and these may present a long-term threat to biota: BDE-209 breaks down into more persistent, more bioaccumulative, more toxic, and more mobile PBDE congeners in the environment."

Information in Figures 13 and 6 is excerpted from a poster by Dutch and Aasen (2007). They indicate that, in terms of PBDE tissue concentration, and a predominance of higher molecular weight congeners, Central Sound is more highly contaminated than North Sound, which is more contaminated than South Sound.

"In April 2005, the 5 penta-BDE congeners measured in 2004 … BDE-209, the primary congener in commercial deca-BDE mixtures; and BDE-49, -66, -71, -138, -183, and -184, were measured at ten PSAMP temporal stations located throughout Puget Sound. Of 422 measured values, 16% were detected, while 83% were undetected. As in Hood Canal, BDE-47 and -99 were detected most frequently. Congener BDE-47 was detected at all 10 stations; while BDE-99 was detected at 5 stations, including the deep, depositional Shilshole Bay (sta. 29) and Point Pully (sta. 38) stations, and the stations near urban/industrial areas including Port Gardner (sta. 21), Sinclair Inlet (sta. 34), and the Thea Foss Waterway (sta. 40). Congener BDE-209 was also detected at these 5 stations, and at the station in Budd Inlet (sta. 44). Congeners BDE-49, -66, -71, and -100, were detected at 3, 1, 2, and 1 station(s), respectively."

In 2010, USACE performed an EIM query for marine sediments in Puget Sound. Sample-wise ND=0 and Kaplan-Meier statistics were used due to inconsistent reporting (many samples only list a subset of congeners without showing associated detection limits for the non-reported ones), and variable detection limits.

Table 8. Statistical Summary of PBDEs from 2010 EIM Query for Puget Sound Sediments (dry weight).

Data Set	n	Percent Detect	Minimum Detect µg/kg	Maximum Nondetect µg/kg	50^{th} Percentile µg/kg	90th Percentile µg/kg	Maximum µg/kg
ΣPBDE	201	91.54	0.069	5.5	3.7 ±0.496	12.69	42.67

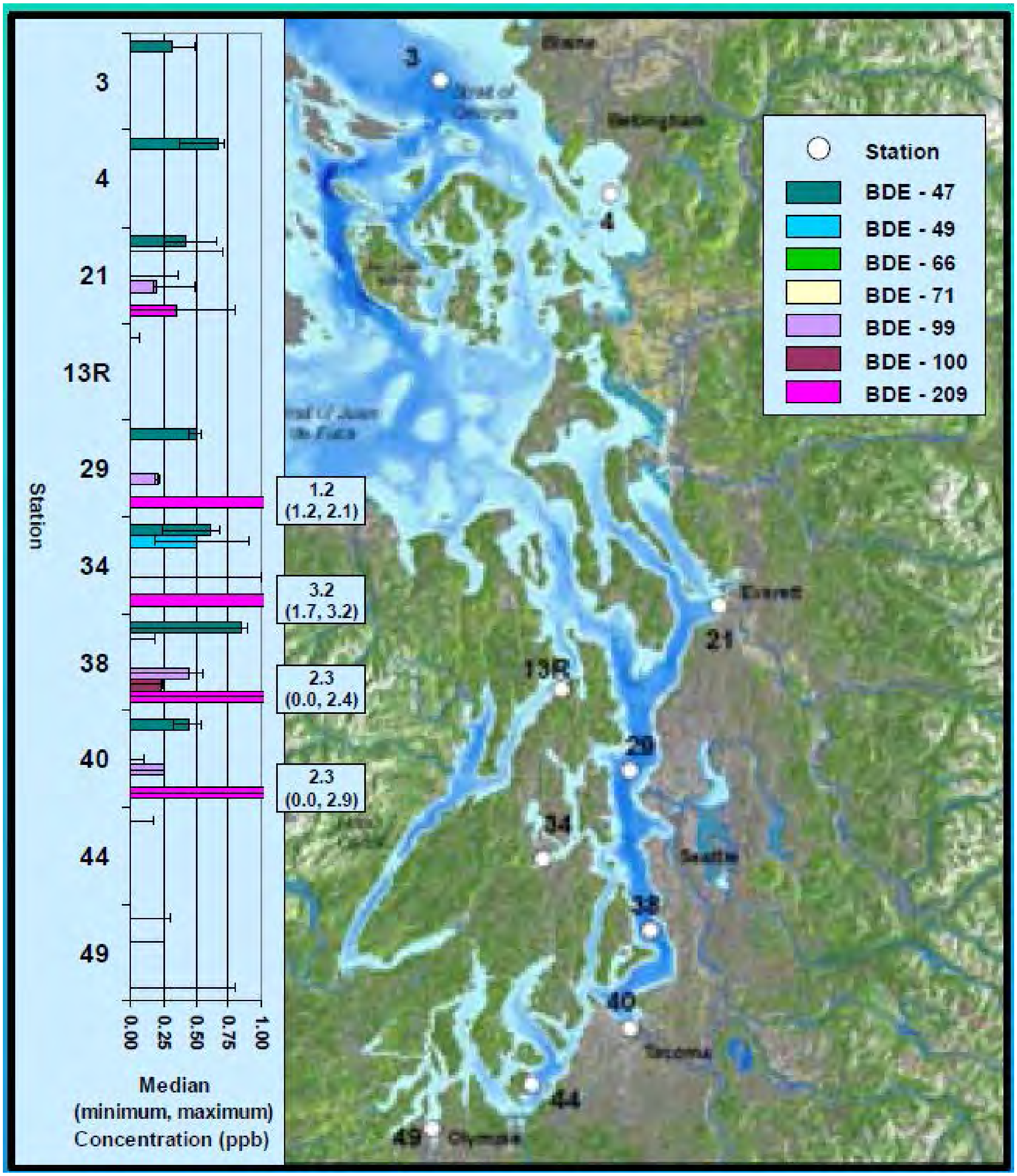

Figure 13. Distribution of PBDE congeners in Puget Sound Sediments (from Dutch and Aasen 2007).

Ecology (2011) has estimated atmospheric flux of PBDE to the surface of Puget Sound. The median atmospheric deposition flux of total PBDE was 7.0 ng/m2/d. The urban/industrial sites of Tacoma have significantly higher total PBDE fluxes than all other study stations, which were statistically similar; see Figure 13. The dry season has higher fluxes than the wet season for PBDE. Among all target PBDEs measured, BDEs-47, 99, and 209 are the major congeners in the samples and BDE-209 is the most abundant congener. The proportional contribution of these three congeners is similar across sampling stations in Puget Sound, suggesting there is a regional consistency in the sources. Ecology’s estimated median mass loading of total PBDE in Puget Sound ranges from 15.6-20.3 Kg/yr, using three estimation scenarios (described above for ΣPCB loading). The report notes that a similar magnitude of median PBDE mass loading (17.1±6.5 Kg/yr) was reported for the Strait of Georgia, which has a similar surface area to Puget Sound.

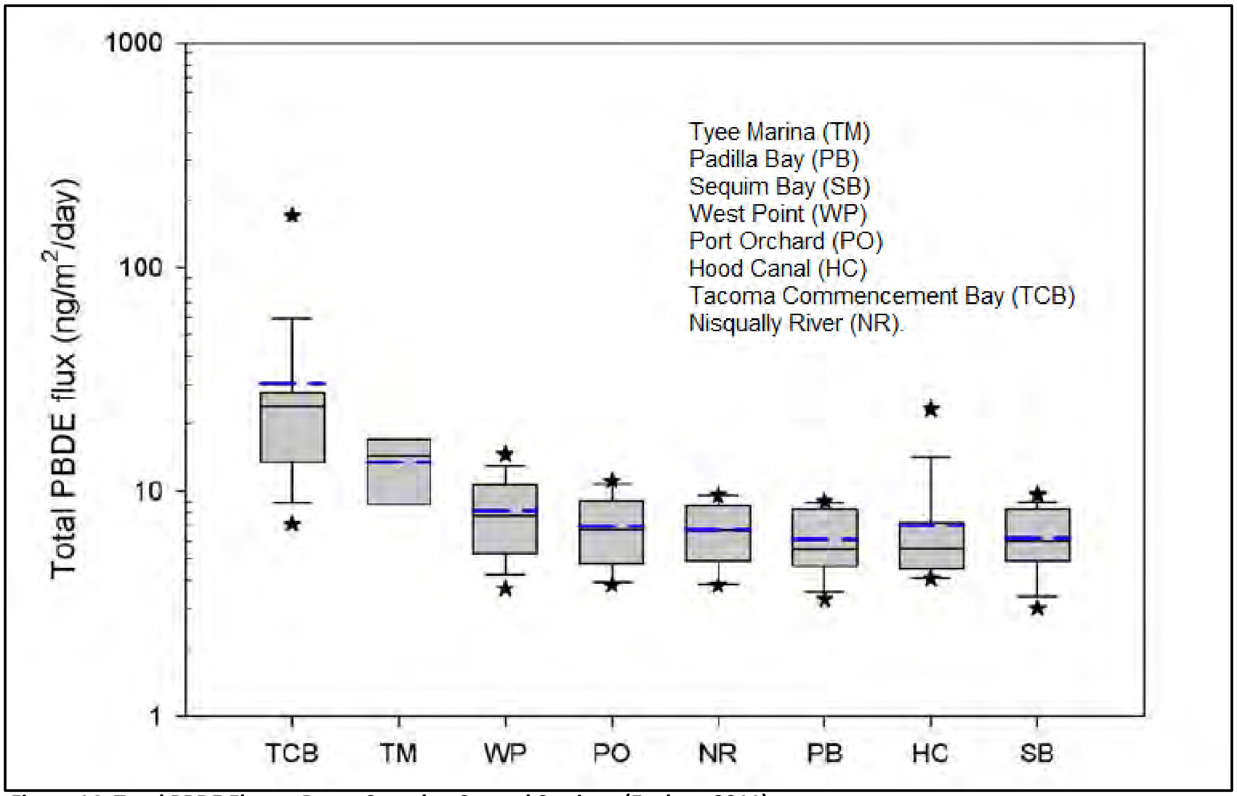

Figure 14. Total PBDE Flux to Puget Sound at Several Stations (Ecology 2011).

4. Current Programmatic DMMP Considerations of ΣPCB, ΣΣPCDD/F, and ΣPBDE

Under the DMMP, disposal-site-related effects including toxicity and bioaccumulation are limited to "minor adverse" effects to benthic organisms, as determined through testing for chemistry, toxicity, and (for persistent bioaccumulative toxicants) bedded bioaccumulation tests. At times, site specific evaluations including risk assessment and trophic modeling are used as tools for making this determination. The *Users' Manual* (DMMP 2013) describes dredged material testing procedures. Sediments proposed for disposal associated with an unacceptable level of adverse effect must be disposed of at an approved upland confined disposal site, or in an approved confined aquatic site. For PCBs, testing for benthic toxicity is required above the screening level; and testing for bioaccumulation potential above a bioaccumulation threshold. For ΣPCB, these consist of a benthic toxicity triggered by 130 µg/kg-dry, and human health effects triggered by the bioaccumulation trigger of 38 mg/kg (organic carbon normalized) which, if exceeded in dredged materials proposed for unconfined, open-water disposal leads to bioaccumulation testing using benthic test species listed in Section 10.2 of the cited manual. For the Elliott Bay site (only), a benthic target tissue level of 0.6 mg/kg ww was established for protection of human health (Section 10.4 of the manual). Significance of bioaccumulation is presently determined by comparison to a tissue-based toxicity threshold, based upon subsistence fishers' consumption of seafood.

The DMMP list of Bioaccumulative chemicals of concern includes ΣPCB and ΣPCDD/F. ΣPCDD/F are chemicals of concern for limited areas in the DMMP, and have become routine for all projects in DMMP within reason-to-believe areas since 2007. Because safe sediment values that relate to human health for seafood consumption appear to be below background values, the DMMP has proposed a "background-based" sediment management goal for nondispersive and dispersive sites. The DMMP agencies (DMMP, 2010) proposed an interim Puget Sound non-urban-background-based criterion for the placement of sediments at dispersive sites, and for non-dispersive sites a background-based goal that would be adaptively managed. This is 4 ng TEQ/kg, which approximates the 90th percentile of nonurban sites. [4]

The DMMP actively seeks to review the list of PBTs that are chemicals of concern, based on emergent information regarding bioaccumulation, biomagnification and toxicity. A list of "candidate" chemicals of concern currently (DMMP 2003) includes ΣPBDE; but this compound suite has not yet been determined necessary to test in all dredged material to date. However, Federal projects are tested as funds are available, and nondispersive site monitoring includes PBDE.

Materials proposed for placement at Puget Sound open-water sites are tested to assure that they do not exceed contaminant thresholds. Striplin et al. (1991) showed that non-dispersive site concentrations predicted based on volume-weighted averages from characterization were similar to actual monitoring data from these sites. The DMMP has committed to adaptively managing the non-dispersive sites for ΣPCDD/F, and is considering additional revisions to address ΣPCB.

The DMMP is committed to updating its programmatic guidelines with the most relevant scientific information related to the consequences of its activities. Scientific literature has increasingly indicated that members of top marine mammal species are adversely affected by persistent and toxic organic compounds that biomagnify (i.e., increase in concentration in tissue towards higher trophic levels). The compound suites discussed in this paper – ΣPCB, ΣPCDD/F, and ΣPBDE – are believed to be the chief biomagnifying compounds affecting marine mammals in Puget Sound. Biomagnification to upper trophic levels may occur at hundreds or thousands of times greater than environmental concentrations. Section 2b below describes the rationale for concern for biomagnification of these compounds, which may occur at low levels in dredged materials handled in the program.

The following paragraphs summarize programmatic considerations. To date, the DMMP has generally only evaluated ecological effects to lower trophic levels, including site benthos and bottom-foraging fish, and also prospective effects to human health. This is because the quantitative linkage between open-water dredged material disposal and prey species for marine mammals is highly uncertain. Open water dredged material disposal sites are generally in deep Puget Sound waters (Rosario Straits and Bellingham Bay sites are exceptions). All dredged material unconfined, open-water sites were selected for low quantities of benthic organisms relative to their surroundings, and represent areas of low resource density compared to most of Puget Sound. Thus, site management has focused on effects arising from anticipated close contact of sediment and site biota.

Chinook salmon are a pelagic species that constitute about 96 % of the food source for SRKW (Ross et al. 2000). Programmatic evaluations of potential effects due to dredged material placement on Chinook have cited the low likelihood of exposure to site chemicals. To illustrate, the following text is abridged from the PBE, which has citations to support the statements.

[4] The DMMP agencies added several existing reference studies to the OSV Bold data set in making this determination. This explains slight variance with Table 6.
http://www.nws.usace.army.mil/PublicMenu/documents/DMMO/DMMP_Proposed_Changes_to_Interim_Guidelines_for_Dioxins_4-19-2010.pdf

- Although adult and subadult Chinook salmon may coincidentally occur near areas of disposal activities, there are no site features that would encourage Chinook salmon to congregate.
- During disposal, Chinooks' exposure to dredged material related substances would be very short-term, a matter of minutes to an hour.
- The potential for toxic effects of contaminants released from discharged sediments is minimal, since sediments have been subjected to a series of physical, chemical, and biological testing procedures and thorough review by the regulating agencies and the public.
- Other than minor transitory effects during disposal activities, foraging habitat for Chinook would not be adversely affected by transport, placement, and management of the sites, as adult and sub-adult Chinook primarily feed on pelagic organisms that do not typically feed at depths of dredged material disposal sites.
- Disposal activities would not significantly affect Chinook forage base. Herring and sand lance spawn in intertidal and shallow subtidal areas. Although sand lance can sometimes rest on the bottom, this typically occurs in less than 100 meters of water, shallower than most DMMP sites.
- Dredging activities and associated disposal activities are regulated to avoid juvenile Chinook as they migrate from rivers to the Sound in the spring. During the early phases of estuarine/Puget Sound residence, juveniles reside in near-shore waters (typically no deeper than 30 to 70 meters) feeding on epibenthic and pelagic organisms, which would be unaffected by disposal activities. Most juveniles continue to occupy the nearshore environment during their migration to the Pacific Ocean, although they could coincidentally occur in surface waters near dredged disposal areas. Effects of elevated water column suspended sediments would be short and localized (as noted above), and are not expected to adversely affect migrating juvenile salmon.

Accurate prediction of effects from disposal events and sites to reflect trophic links to pelagic organisms such as Chinook is difficult. Benthic fish, such as halibut, English sole, and sablefish are eaten by SRKW (although at a low percentage of the diet), and by Steller sea lions and harbor seals; these fish may forage at both nondispersive and dispersive dredged material sites. The DMMP monitoring program periodically checks benthos near the nondispersive sites for elevations in tissue chemistry of ΣPCB. In some instances, fish trawls have been made as well. However, the program has not used a mechanistic multi-level trophic model to marine mammals because there are many uncertainties, and confirming links to pelagic food webs is a difficult undertaking. These include the following:

- Trophic relationships/pathways are documented in the literature, but fish behavior, including feeding ranges and the time a forage fish could potentially be exposed to site related chemicals are not sufficiently known at this time.
- DMMP requires characterization of dredged material by the less sensitive Aroclor method, but is considering, as presented at the 2014 Sediment Management Annual Review Meeting, more precise methods including the lower resolution GC/MS homologue method and the high-resolution GC/MS congener methods.[5] The high-resolution congener method has been used in nondispersive site monitoring since 2010, and in selected Federal navigation dredging programs; it is not required for all projects.
- ΣPBDEs have been added to the DMMP's list of potentially bioaccumulative substances for nondispersive site monitoring. Recent data are summarized for Port Gardner and Elliott Bay nondispersive sites, using a more sensitive method.
- ΣPCDD/F have been used since before the 2010 PBE for nondispersive sites.

[5] The most recent presentation is paper 10: Results of PCB Homologue Studies http://www.nws.usace.army.mil/Portals/27/docs/civilworks/dredging/SMARM%20minutes/SMARM-2014-Minutes-Final%20.pdf

- No existing trophic model is at a suitable scale nor calibrated to estimate trophic effects arising from dredged material management sites and activities.

The DMMP addressed bioaccumulation and biomagnification for PCDD/F in fish and crabs for the first time in 2006-7, and used both a trophic model (Gobas, 1993) and subsequent monitoring for the non-dispersive South Sound Anderson-Ketron site; model predictions were within 200% of the findings, although the model tended to predict high. The only analyte suite considered was PCDD/F, due to low concern for PCBs at this site. Crab were evaluated using published biota-sediment accumulation factors, but not modeled. Higher trophic modeling (for instance, from benthos to plankton to pelagic predators) was not believed warranted. Biomagnification for herring and Chinook were not evaluated, as water depths were greater than adult Chinook frequent while feeding, and due to the scarcity of benthic fauna at the site, the water depth, and the low solubility of PCDD/F (as determined from the literature).

For SRKW, a small proportion (<4%) of benthic prey species such as halibut, haddock, and sablefish are present in the diet. For Steller sea lions and seals, the proportion of bottom fish and other benthic species is higher. However, it is unlikely that either Steller sea lions or seals would spend time foraging at the depths of the sites. The pathway to their food would likely include migrating fauna; such migration patterns confound and attenuate the influence of each site on higher predators. Additionally, Steller sea lions are only present in Puget Sound for a short portion of their annual cycle. Contribution of the dredged material placed at open-water sites to exposure by these animals is indirectly and indefinitely linked to their consumption by marine mammals, and where it occurs, should be considered in the context of the Puget Sound background levels for ΣPCB, ΣPCDD/F and PBDE.

5. Site Chemical Inventories for PCB, PCDD/F and PBDE

The purpose of this section is to update the quantities of dredged material placed at DMMP disposal sites in Puget Sound, and the inventory of PCB, PCDD/F, and PBDE in context of vicinity and background ranges of the chemicals. Cumulative site use statistics for volume of materials placed from program inception to date are shown in Figure 15.

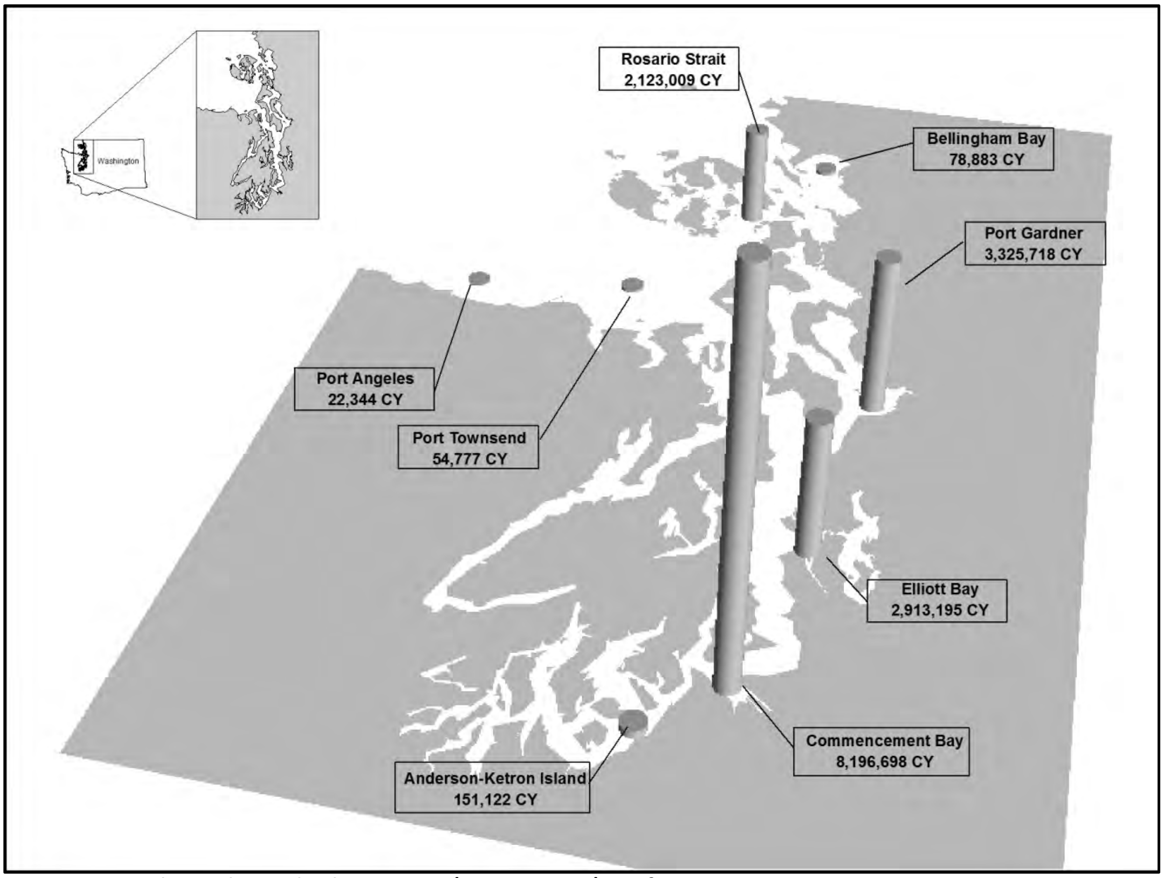

Figure 15. Cumulative disposal volumes in CY (over 25 years) as of May 2014.

a) Non-dispersive Sites

The monitoring program for these sites is activated by a disposal volume trigger according to the Management Plan for each site, or accumulation of 3 cm of sediment at the perimeter line[6], or by special considerations including concern for site conditions. In what follows, unaffected perimeter and "benchmark" stations are considered offsite stations; Z stations collected within the site perimeter are designated onsite. Programmatically, these stations are used to detect changes of the site that potentially affect site surroundings. The following text comparison is also made to the range of means and 50th percentiles from the general Puget Sound data sets described above.

1) ΣPCB

Table 11 displays the results of site monitoring from 1990-2010 for four of the five nondispersive sites. Despite a range of Reporting Limits (RLs) for PCBs by the Aroclor method, there is no systematic difference between the onsite and offsite stations. Note that the programmatic use of RLs for characterizing nondetected values results in "less than" values that are typically 3 or more times above detection limits; and thus the sensitivity of the analyses is greater than shown. For example, estimated (J-qualified) values never appear in these data sets at values below the RL. Through 2010, in every case but Elliott Bay (shown in later paragraphs), the values shown are below the maximum reporting limits, and the site conditions are within the plausible range of Puget Sound average concentrations discussed above. For the 2010-2014 period, higher resolution methods were employed for monitoring at two nondispersive sites, Port Gardner

[6] The perimeter line boundary extends 1/8 nautical mile outside the disposal site boundary.

near Everett and Elliott Bay near Seattle. These are summarized in graphics following the 2010 tables below.

For each site, EPA's (2013) statistical program ProUCL version 5 was used to generate box and whisker plots and conduct 2-sample hypothesis testing. The boxes represent the 25th and 75th percentiles of the data distribution; the 50th percentile is shown by a horizontal line; and the arithmetic mean is displayed as a number within the box. The nonparametric Wilcoxon-Mann-Whitney (WMW) and Quantile (Q) tests were used to compare "Z" and "S" stations (representing centroid of the disposal zone and radii within the site) against "P" (perimeter or offsite stations, offset at 1/3 nautical mile from disposal zone) stations. These test a null hypothesis that the onsite data are higher than the perimeter data. The graphics also show "B" or benchmark stations – these are located in the direction of suspected bay-specific sources, and used to determine whether these are contributing as well. (Benchmark stations were considered qualitatively in what follows). The method for estimating sums varies according to the form in which the data were available. DMMP (2010) for the Port Gardner site showed the 2,3,7,8-tetrachloro-dibenzo-p-dioxin toxicity equivalents by the half-quantitation limit method, but did not summarize the total PCB by congeners; this was done for this report, and the Kaplan-Meier method used, per programmatic guidance (ProUCL was used to calculate this with Efron's correction).

Port Gardner

Figure 16 shows Port Gardner's 2010 ΣPCB data. The onsite mean and range appear to be above the offsite stations (onsite mean of 6.9 µg/kg dw compared to offsite mean of 4.66 µg/kg dw); the WMW test confirms that it is statistically significantly higher at $p \leq 0.05$; however, the Q test does not confirm that it is elevated. Port Gardner is a central Puget Sound area that is within the plausible range of ΣPCB described in Figure 19. All means shown in this figure exceed the PCB natural background of 3.5 µg/kg dw.

As shown in Figure 17, onsite Port Gardner TEQs (mean 0.06 ng TEQ/kg dw) are lower than perimeter stations (mean 0.1 ng TEQ/kg dw), and both WMW and Q tests confirm that they are not higher. By inspection, the benchmark station appears to suggest an unrelated source. Note that none of the means or ranges shown in this figure exceed the PCB TEQ natural background of 0.2 ng TEQ/kg dw.

In summary, ΣPCBs onsite at Port Gardner are close to natural background, although one of two statistical tests suggested they are slightly elevated, while onsite PCB TEQs are lower than offsite. Port Gardner is located in central Puget Sound, where PCBs tend to be higher than in other basins.

Table 9. PCB Statistics (Aroclor Method) from Monitoring at Nondispersive Sites Except Elliott Bay through 2010.

	Anderson-Ketron		Bellingham Bay		Commencement Bay		Port Gardner[a]		Units
	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	
Number of Observations	4	20	1	6	16	135	11	32	Count
Proportion of Detections	0	0	0	0	0	0	0	0	%
Minimum Non-detected	<3	<3	<20	<20	<2	<7	<6	<6	µg/kg
Maximum Non-detected	<3	<3	<20	<20	<51	<86	<49	<67	µg/kg

[a] – The detection limits for 2010 monitoring at this site were 19 and 20 µg/kg dw.

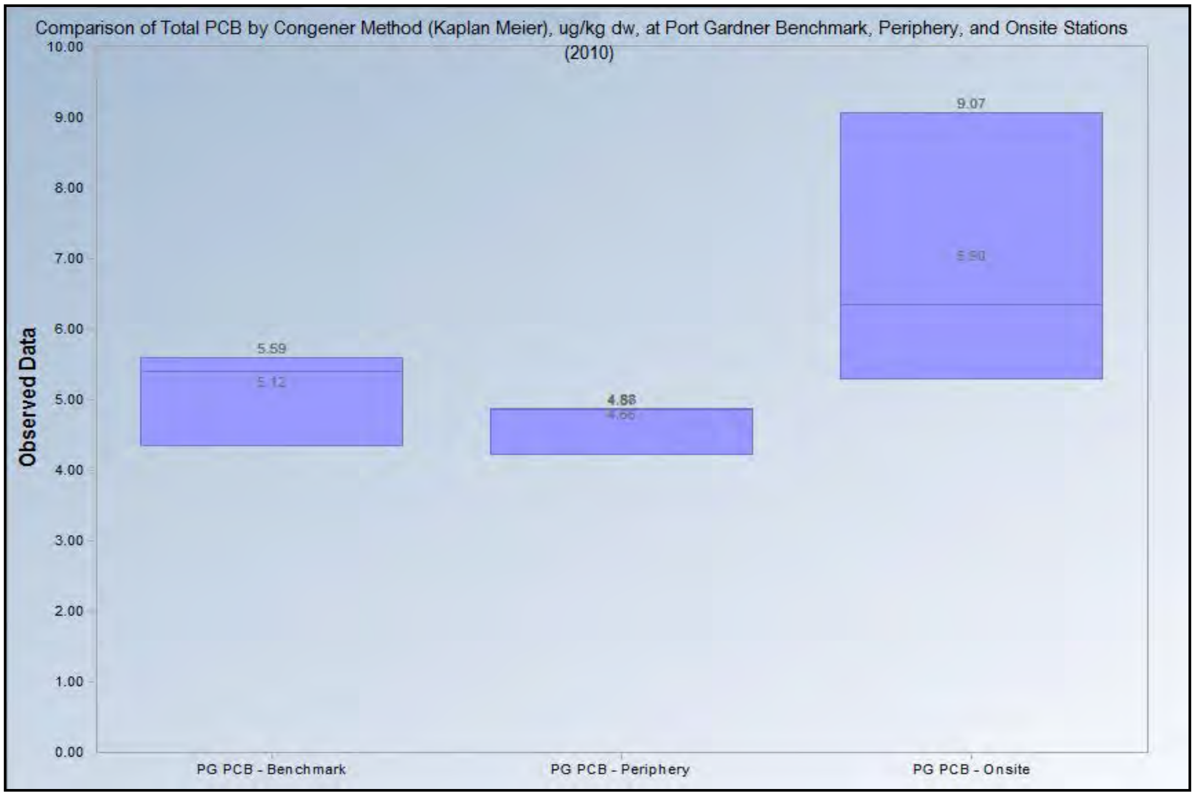

Figure 16. Port Gardner 2010 ΣPCB, Kaplan-Meier Sum µg/kg dw.

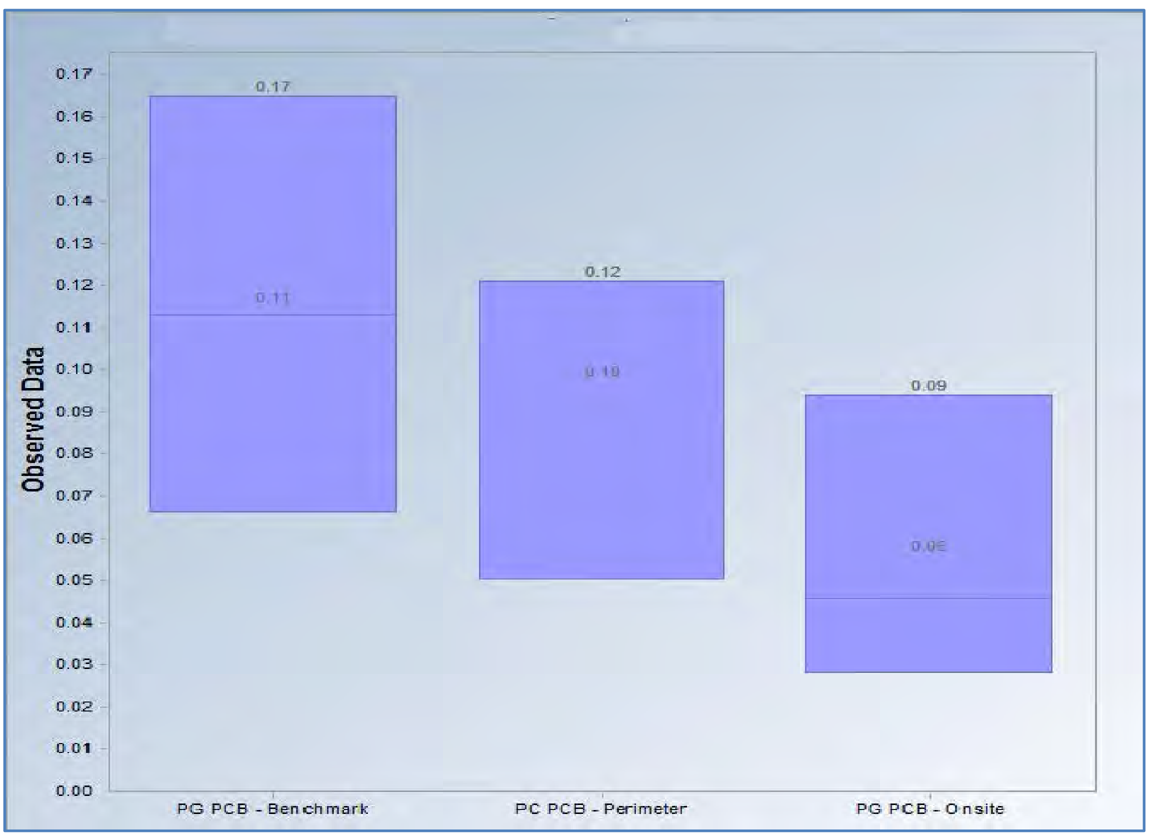

Figure 17. Port Gardner PCB, ng TEQ/kg dw.

Elliott Bay

The prior PBE stated that Elliott Bay site surroundings, as represented by the offsite perimeter stations, have always been higher than or comparable to onsite stations since the disposal sites began use in 1990 (Figure 18). This is confirmed by data shown after that figure. ΣPCB Aroclors (Figure 19), ΣPCB (Figure 20), and PCB and PCDD/F toxicity equivalents (Figure 21) show similar patterns.

- For Aroclors, the onsite concentration ΣPCB is less than offsite stations (Figure 18). The Lower Duwamish Waterway Work Group's (LDWG 2010) Phase 2 Remedial Investigation estimated a generalized Elliott Bay PCB mean background to be 135 µg/kg dw. This is essentially identical to the offsite stations (Figure 18).
- For ΣPCB by the Kaplan-Meier summation method (Figure 19), peripheral (i.e., offsite) stations are higher than the onsite station as confirmed by the WMW and Q tests at $p<0.05$. The same is true for ΣPCDD/F TEQ. The PCB congener method shows considerably more variability than the Aroclor method for benchmark and (especially) peripheral stations, with the peripheral mean about 5 times the Arocolor based mean.
- Onsite TEQs for ΣPCB and ΣPCDD/F are above Ecology's natural background of 0.2 and 4 ng TEQ/kg, respectively. This is consistent with high ambient values in Elliott Bay. Conclusions regarding benchmark stations' contribution to the site are mixed – ΣPCB suggests that peripheral values are greater than benchmark, but both PCB and PCDD/F TEQs suggest benchmark stations are higher, and may contribute to the site.
- The TEQs from PCDD/F are substantially higher than TEQs from PCB. Onsite values are about 1:6 (PCB to PCDD/F).
- All measured Elliott Bay values (onsite, peripheral, and benchmark) are above Ecology's PCB ΣTEQ natural background of 0.2 ng TEQ/kg dw.

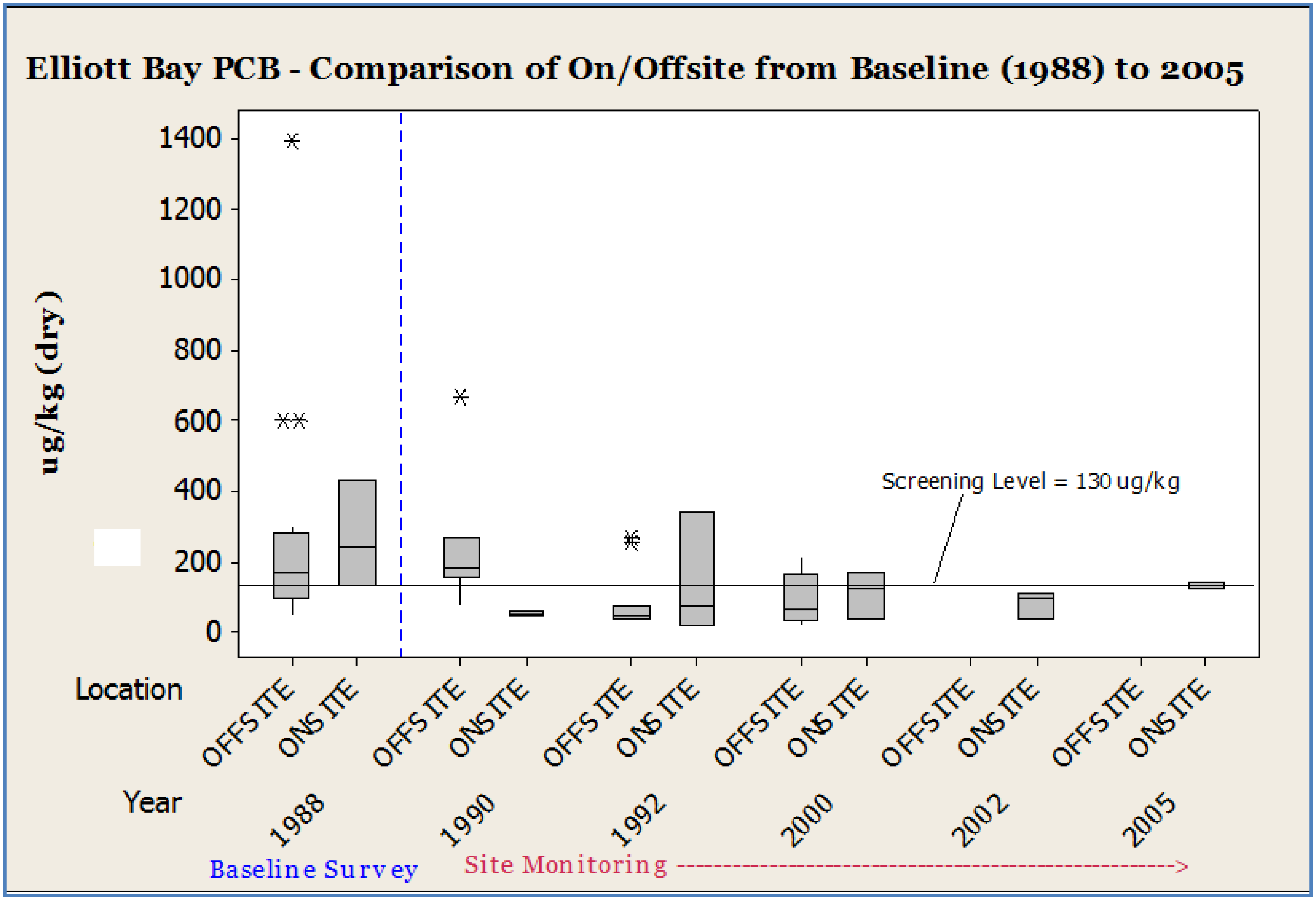

Figure 18. Comparison of On/Offsite Elliott Bay PCB from Baseline (1988) to 2005.

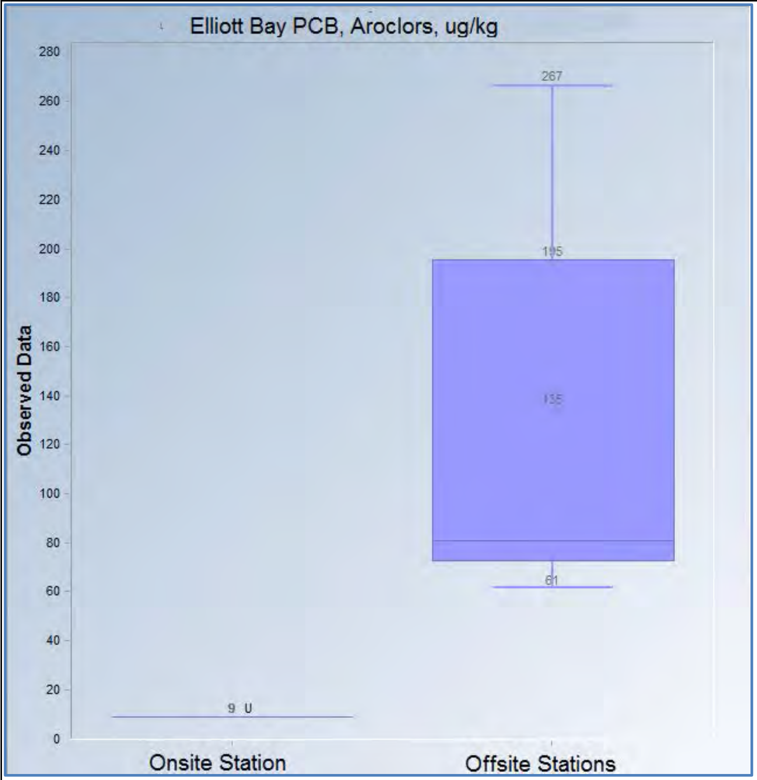

Figure 19. PCB Aroclors µg/kg dw from 2013 Partial Monitoring Event. U indicates that the onsite value was not detected with a quantitation limit of 9 µg/kg dw.

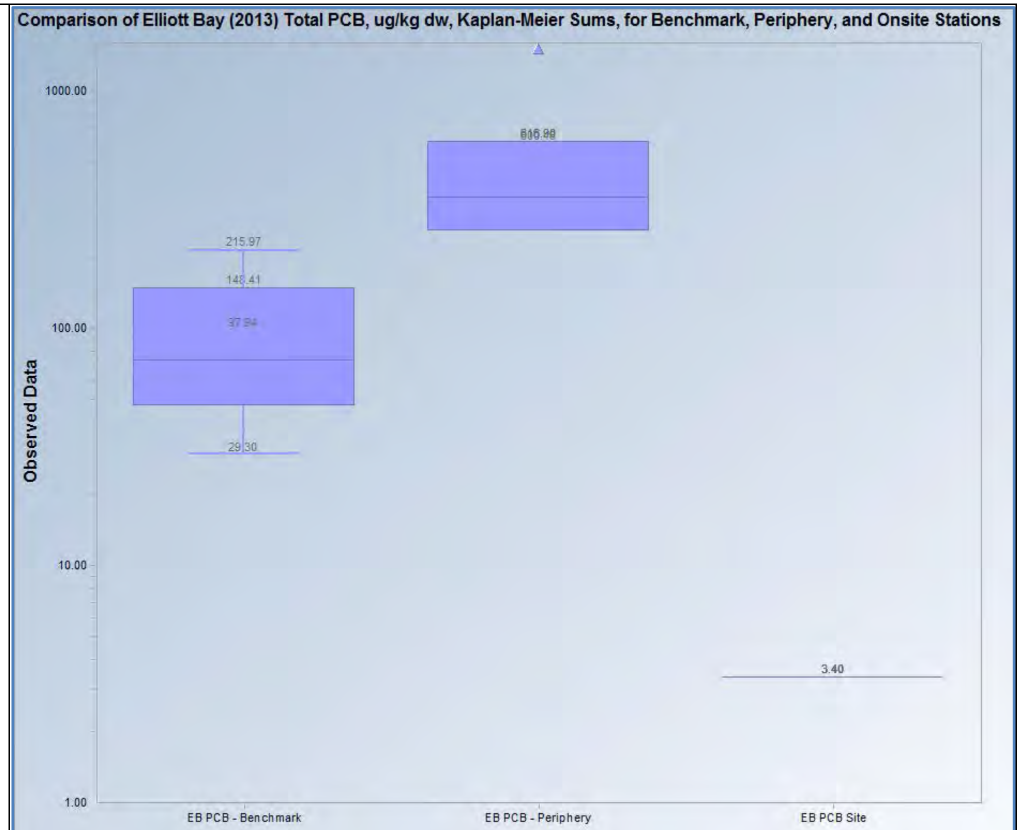

Figure 20. Comparison of Elliott Bay (Partial Monitoring Event, 2013) Total PCBs as Sum of Homologues, µg/kg dw, at Benchmark, Perimeter, and Onsite Stations. Note logarithmic scale.

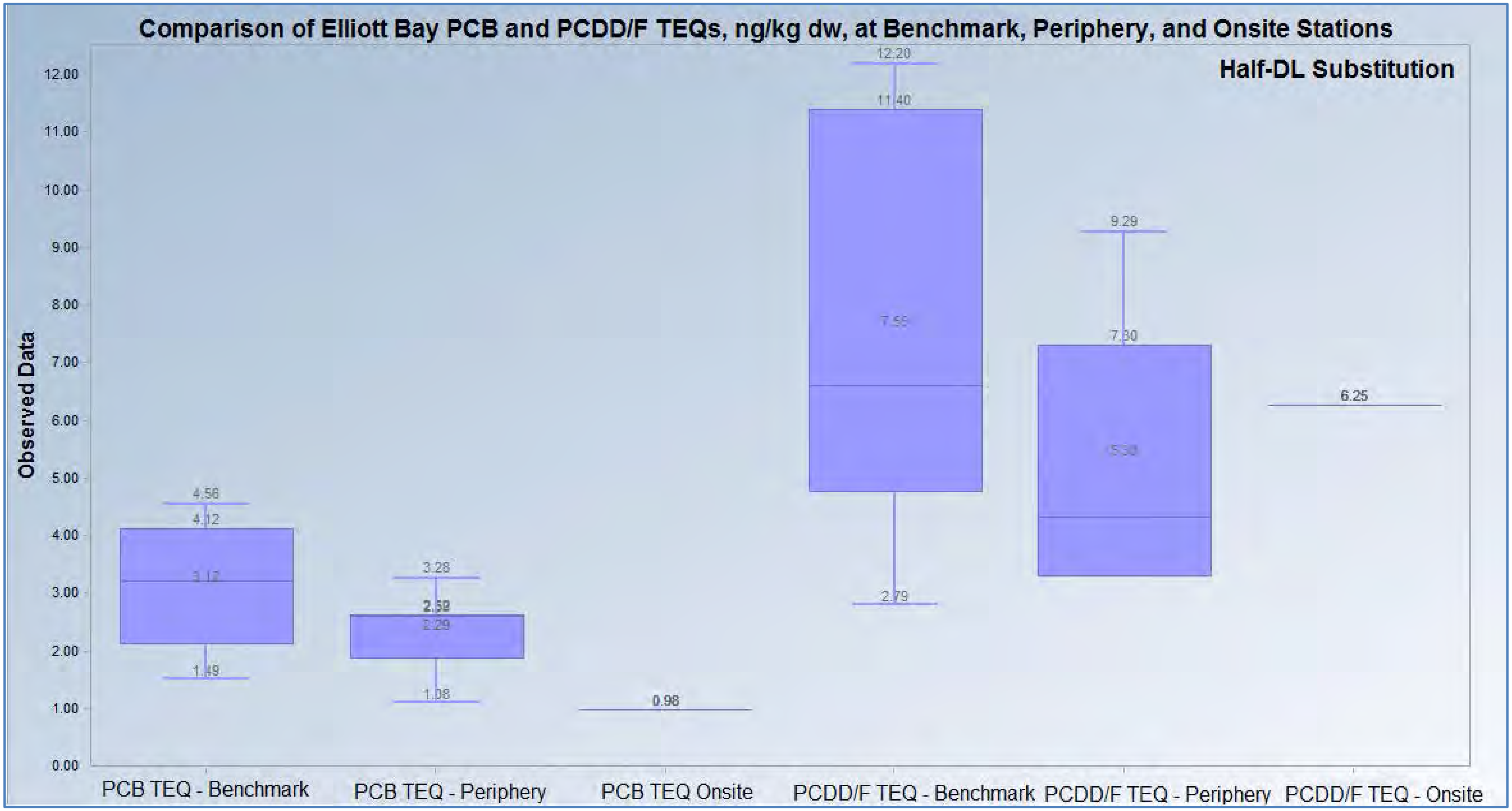

Figure 21. Comparison of Elliott Bay (Partial Monitoring Event, 2013) PCB and PCDD/F TEQ a, ng TEQ/kg dw half-detection limit substitution.

PCB Loading Comparison for Elliott Bay. The following compares the USACE maintenance dredging program for the Lower Duwamish Waterway (LDW) to the PCB annual export to downstream water bodies. LDWG (2012) prepared a recent FS (in particular, see Appendix M, Part 2) which calculated sediment transport through the LDW. This will be used as a point for comparison to the annual navigation dredging program activities and to the Ecology estimate of atmospheric and runoff loading.

Using most recent (and typical) 2011-2012 biennial dredging data, USACE dredged 47,200, cubic meters per year, which at 61% solids content amounts to 40,300 metric tons (MT) per year.[7] In the most recent characterization (which used the Aroclor method), 5 of 16 dredged materials management units (DMMU) had undetected PCBs at Detection Limits ranging from 19 to 93 µg/kg dw; from this, we used ProUCL version 5.0 to calculate a mean overall concentration of 39 µg/kg dw. Three below-detection-limit estimation methods (results of which are shown in Figure 22) were used to depict for the PCB budget as regards the dredging program:

- Low end estimate: substitution of 5 µg/kg dw for nondetected DMMUs; this represents the mean of Ecology's (2008) Green/Duwamish River surface sediment samples which contained fines >30%; this was also used as a low-end estimator by LDWG (2012).
- Midrange (most likely) estimate: the normal Regression-on-Order Statistic (ROS) used to replace nondetected values, in accordance with recommendation in ProUCL version 5.0.
- High range estimate: substitution of the 19 µg/kg dw value (that is, the detection limit of 4 of the 5 nondetected values) for all nondetected DMMUs.

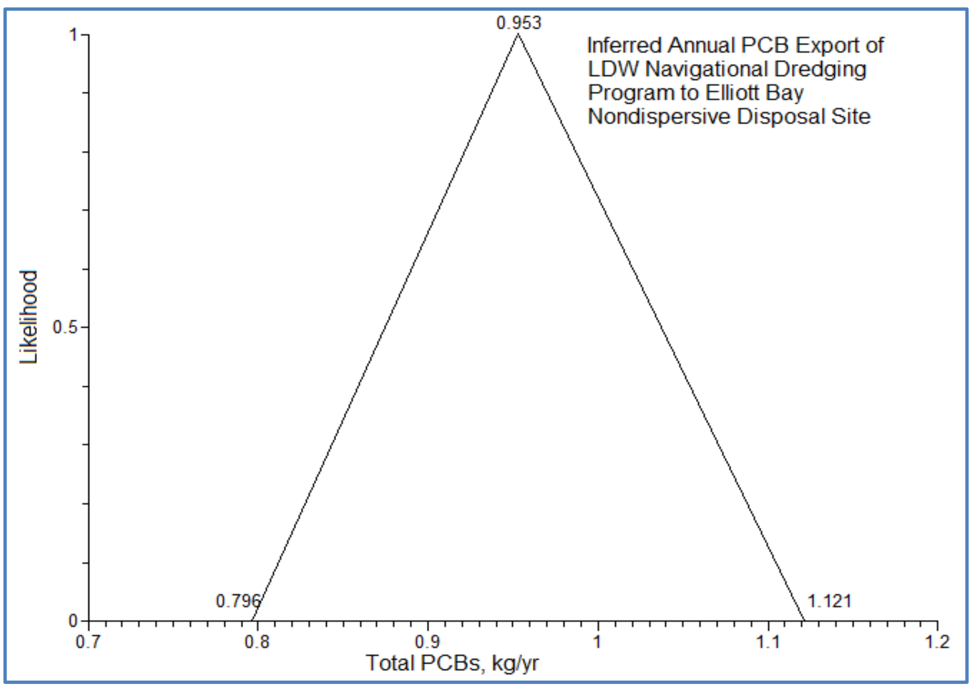

Figure 22. Inferred Annual PCB Export, kg/yr, of LDW Navigation Dredging Program to Elliott Bay Nondispersive Disposal Site.

The Lower Duwamish Work Group (LDWG 2012) estimated that, in addition to the navigation program, 584 MT (or a little more than 1% of the total navigation dredging) of sediment per year) are transported via erosion and lateral sources from the waterway to downstream areas (East and West Waterways and

[7] This does not include the contribution from other, non-Federal projects, which is small in comparison.

Elliott Bay at large). LDWG (2012) estimated that the spatially-weighted average PCB concentration in LDW is 380 µg/kg dw, or about 10 times the concentration in the Turning Basin and adjacent reaches that are regularly dredged to maintain the Federal channel. Apart from the dredging program, the ΣPCB exports attributable to erosion of sediments LDW were 3.7 kg/yr ΣPCB by bed sediment erosion and 0.2 kg/yr PCB from lateral sources, for a total of 3.9 kg/yr. Adding this to the navigation program, the total annual ΣPCB export is 4.7-5.0 kg PCB/yr.

Thus, the Federal program transports from 16% to 24% of the PCBs from the LDW, as high volume, low-concentration PCB dredged sediments. With the program, these materials are placed into a managed nondispersive disposal site and data presented above suggests that the values onsite are lower than ambient (or, in the case of both total PCBs by homologue sums and TEQ, below Ecology's natural background) concentrations. Without dredging in the turning basin, sediments would accumulate and, upon mixing with the existing contaminated sediments, necessitate more frequent dredging of more highly PCB-contaminated materials. EPA has directed ongoing "Early Actions" at some of the most PCB-contaminated areas on the LDW, and has published a Proposed Plan for environmental dredging of the highly PCB-contaminated sediments in the LDW, which will likely begin within the next 10 years. Thus, the Federal navigation dredging program is actively transporting and managing the bulk of the sediment in the LDW, diverting sediment from shoals in the waterway, facilitating future cleanup of this contaminated area, while maintaining dredged sediment disposal site ΣPCBs at comparable or lower concentrations as the Elliott Bay surroundings. For Puget Sound context, as noted in Figure 12 (and cited in Ecology 2013), the estimated export of sediments from the LDW (navigation and erosion and lateral loads) is about 5% of the incoming runoff related input.

2) ΣPCDD/F

The ND=0.5*DL and ND=0 methods were used to compare on- and offsite ΣPCDD/F TEQs, and to the 4 ng TEQ/kg background value in the Revised Interim Dioxin Guidelines (which is Ecology's natural background value). Figures 21a through 21e show these comparisons. The key to the illustrations follows:

- Site codes: *AK* = Anderson-Ketron. *BB* = Bellingham Bay, *CB* = Commencement Bay, *EB* = Elliott Bay, and *PG* = Port Gardner.
- Location designations: *ONS* = onsite, *OFS* = offsite.
- The methods for summation of toxicity equivalents are *Half* = one-half of DL substituted for non-detected values, and *Zero* = zero substituted for non-detected values.

In the box-plots, the line in the box represents medians, and means are shown by ⨁ or (in updated blue figures 20 and 22e), the mean is a number in the box.

For Port Gardner and Anderson-Ketron Island sites, the onsite mean values are less than the offsite values and less than the 4 ng TEQ/kg dw site management goal and Ecology's natural background value. For Bellingham Bay, the onsite mean is close to the offsite value. For Elliott Bay, onsite is statistically indistinguishable from offsite by the WMW and Q tests, as noted above under PCB TEQ. Onsite and offsite for Bellingham and Elliott Bay disposal sites are greater than the management goal of 4 ng TEQ/kg dw. For Commencement Bay, the onsite and offsite means, which are very similar, exceed the goal. Management of these sites should bring onsite values near or below the background-based goal.

The onsite and offsite sediment data below from 1995-2009 indicate that disposal of dredged material does not appear to have increased the contaminant inventory at any of the nondispersive sites. Figure 23 has several parts that compare between onsite (ONS) and offsite (OFS) Stations at 5 nondispersive open-water dredged disposal sites.

Figure 23. Onsite vs Offsite Views of Nondispersive Disposal Sites in the following figures:

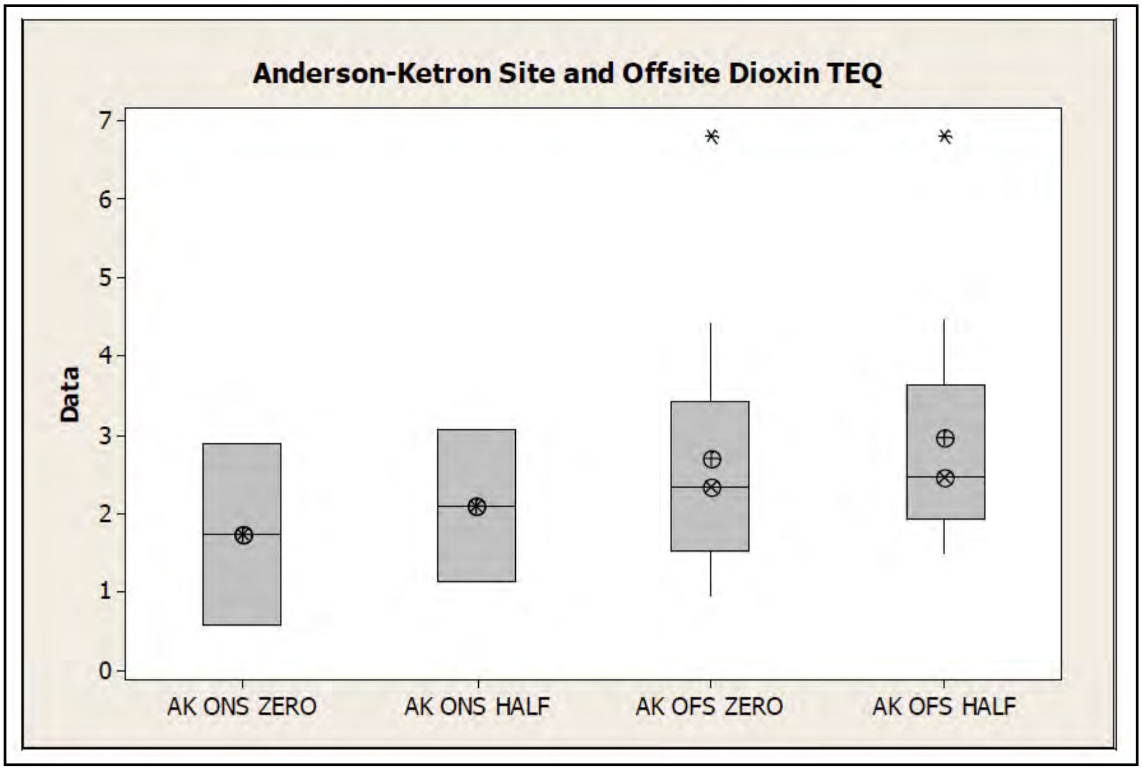

Figure 23a. Anderson-Ketron

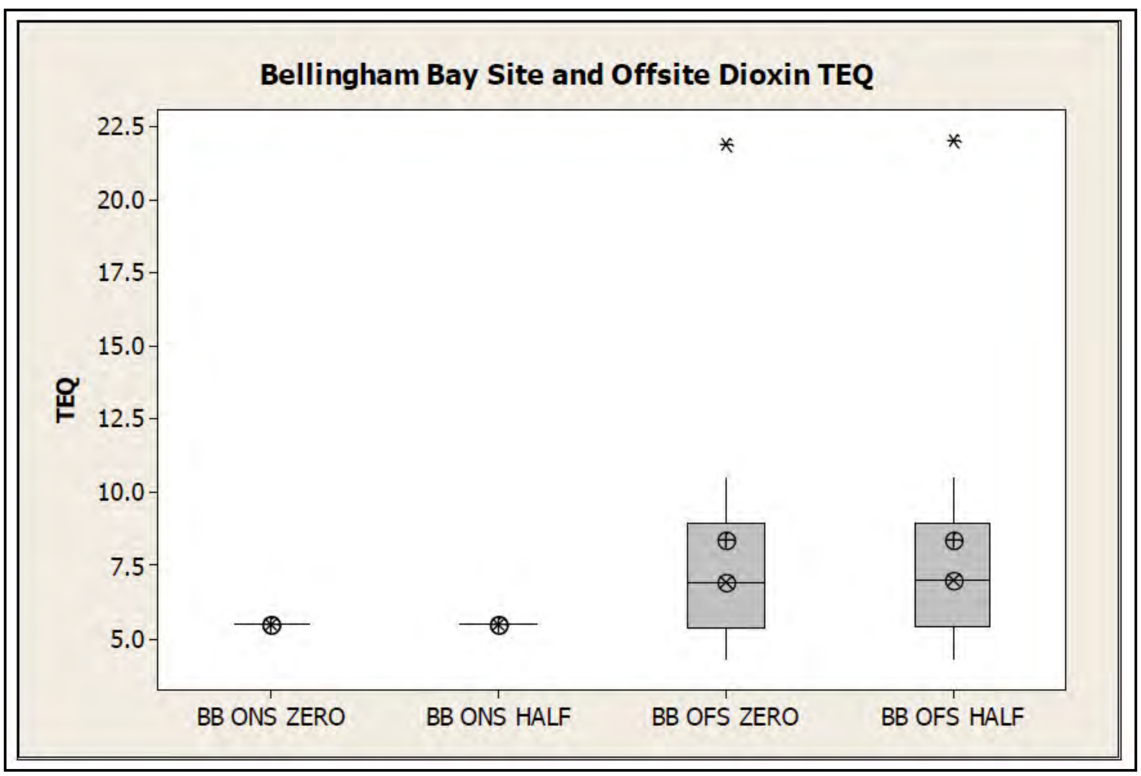

Figure 23b. Bellingham Bay to 2010

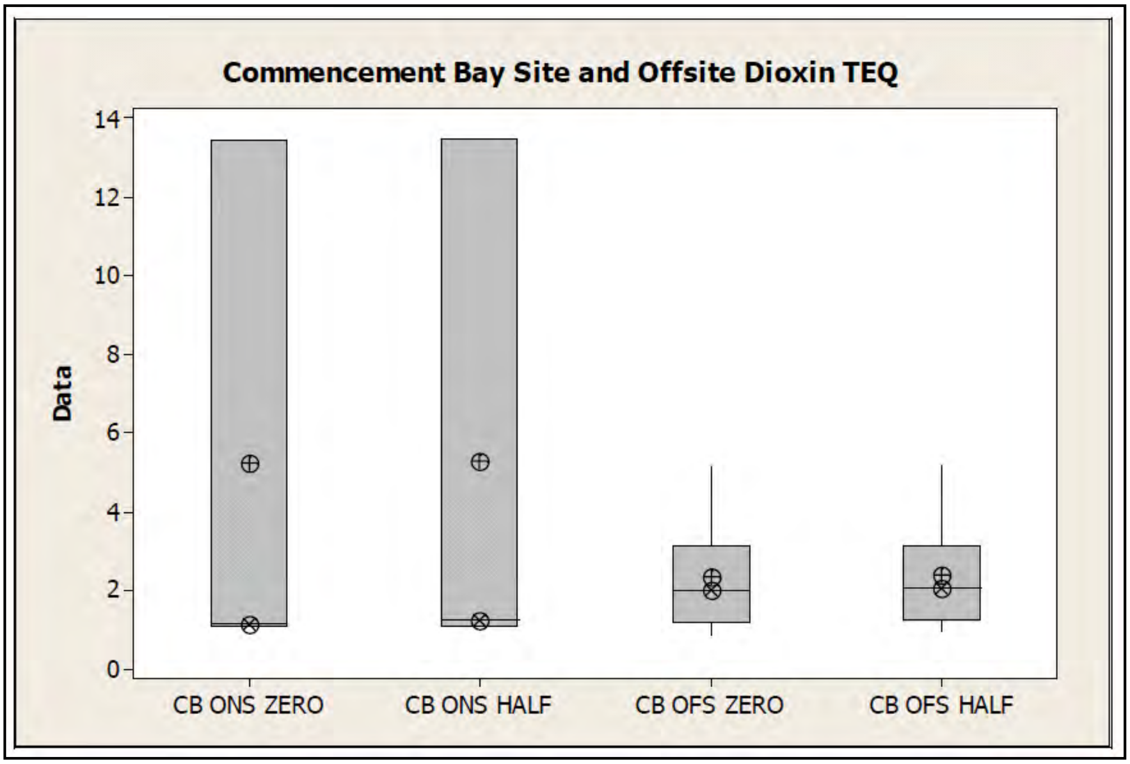

Figure 23c. Commencement Bay to 2010

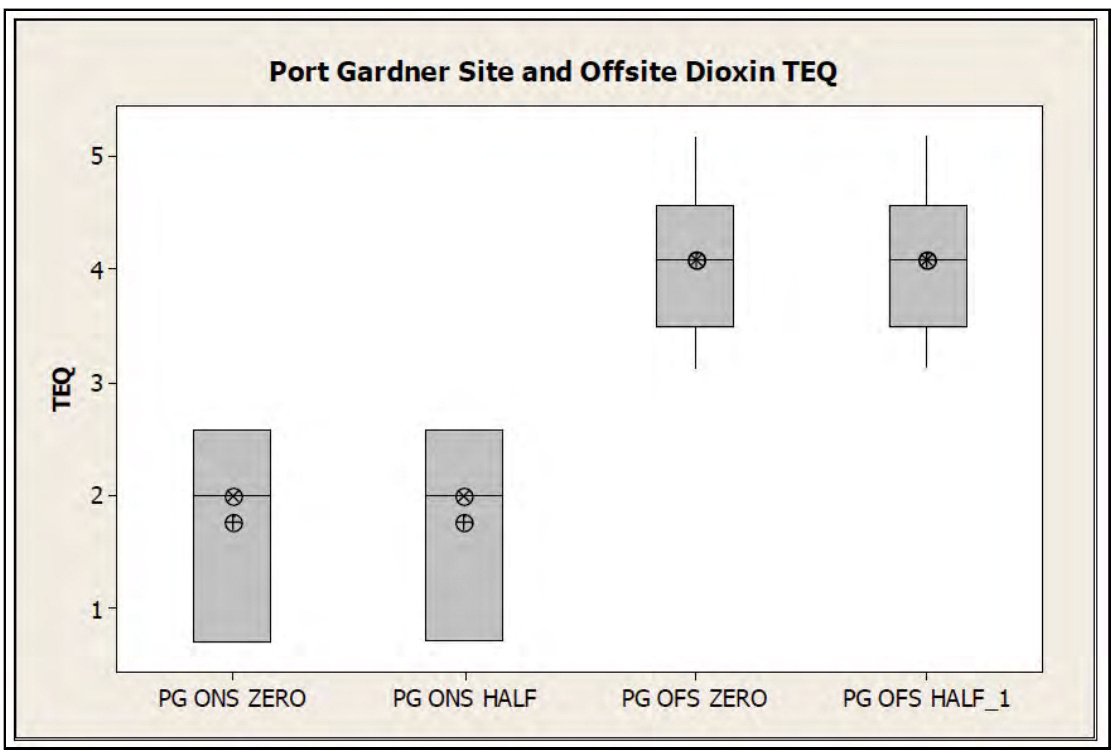

Figure 23d. Port Gardner Through 2009

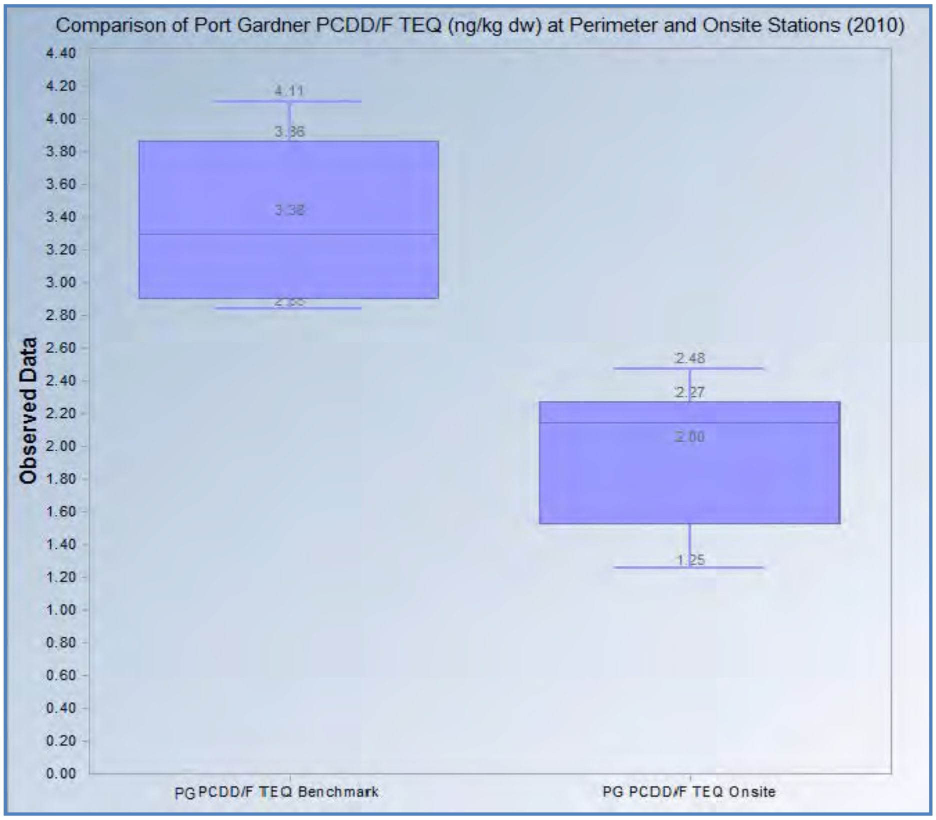

Figure 23e. Port Gardner in 2010 Characterization (Half DL Method)

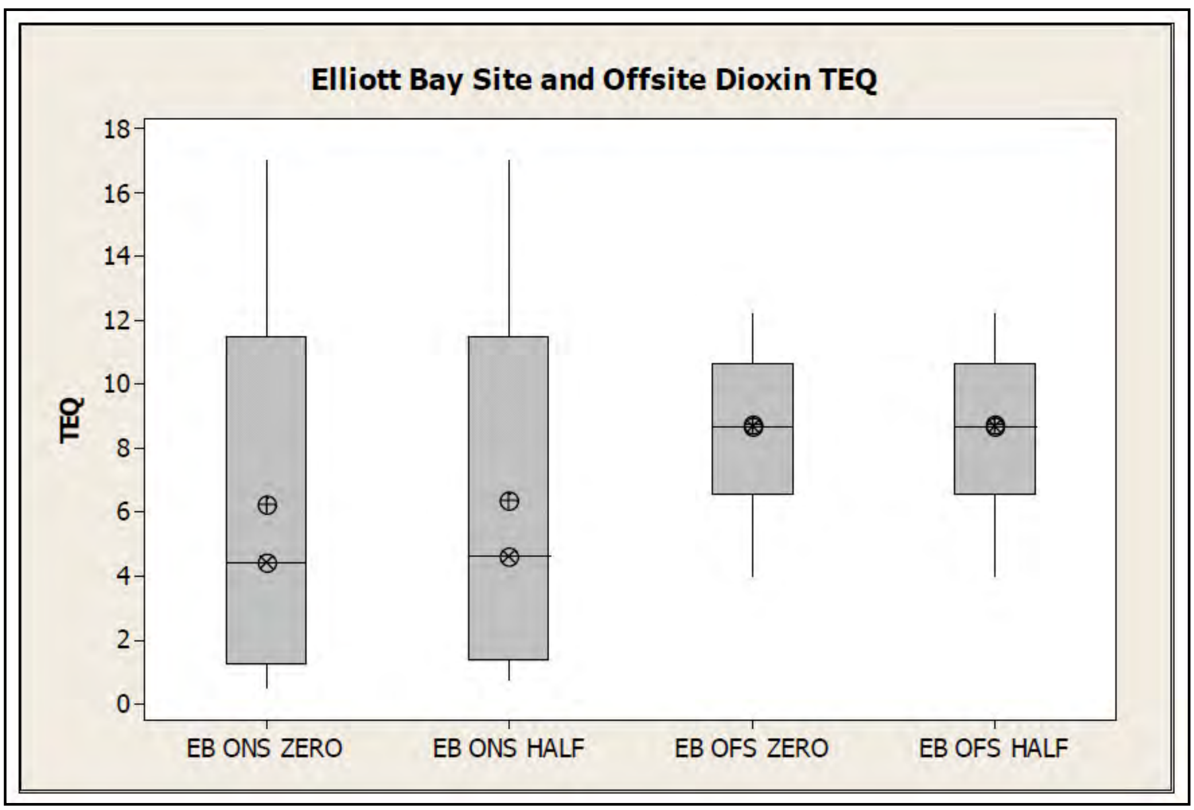

Figure 23f. Elliott Bay through 2009. For 2013 Elliott Bay Characterization, see Figure 20, right half of graphic.

3) ΣPBDE

Although dredged material is not routinely tested for ΣPBDE except in certain Federal navigation projects, site monitoring data for sediment and benthic tissue are available for nondispersive sites, and are shown through 2009 in Table 10 on the following page. All sediment values were non-detected, with the RLs displayed. Accordingly, higher-resolution analytical methodologies have since been used in the site-monitoring program; new site tissue data have yet to be collected. Since 2009, Port Gardner and Elliott Bay sediments have been characterized (Figures 23-25).

- For both Port Gardner and Elliott Bay sites, ΣPBDE onsite values no greater than offsite (WMW and Q tests), and appear to be lower. Elliott Bay (Figure 25) typifies the predominance of congener 209, as noted by researchers cited above.
- For both sites, the offsite mean and median values are compared to those of Dutch and Aasen (2007 – see Figure 14). In recent DMMP monitoring, BDE 209 was 1.14 µg/kg dw at Port Gardner, and 1.81 µg/kg dw at Elliott Bay; this is similar to or a bit higher than Dutch and Aasen's station 21 (0.3 µg/kg dw) and station 29 (1.2 µg/kg dw), as shown in Figure 14. Onsite values were substantially lower than the Dutch and Aasen ranges. This suggests that disposal site use is not worsening the near-field conditions, although the ambient conditions may be increasing for ΣPBDE (as noted by several researchers).

Table 10. ΣPBDE Statistics from Monitoring at Nondispersive Sites Through 2009

	Anderson-Ketron		Commencement Bay		Port Gardner		Elliott Bay		Units
	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	
Sediment									
Number of Observations	3	21	3	12	3	12	3	4	Count
Proportion of Detections	0	0	0	0	0	0	0	0	%
Minimum Non-detected	<19	<19	<20	<20	<19	<19	<99	<55	µg/kg (dry)
Maximum Non-detected	<20	<20	<20	<20	<20	<20	<140	<130	µg/kg (dry)
Tissue									
Number of Observations	--	6	--	14	--	5		3	Count
Proportion of Detections	--	0	--	0	--	0		0	%
Minimum Non-detected	--	<3	--	<26	--	<33		<73	µg/kg (wet)
Maximum Non-detected	--	<3	--	<33	--	<33		<76	µg/kg (wet)

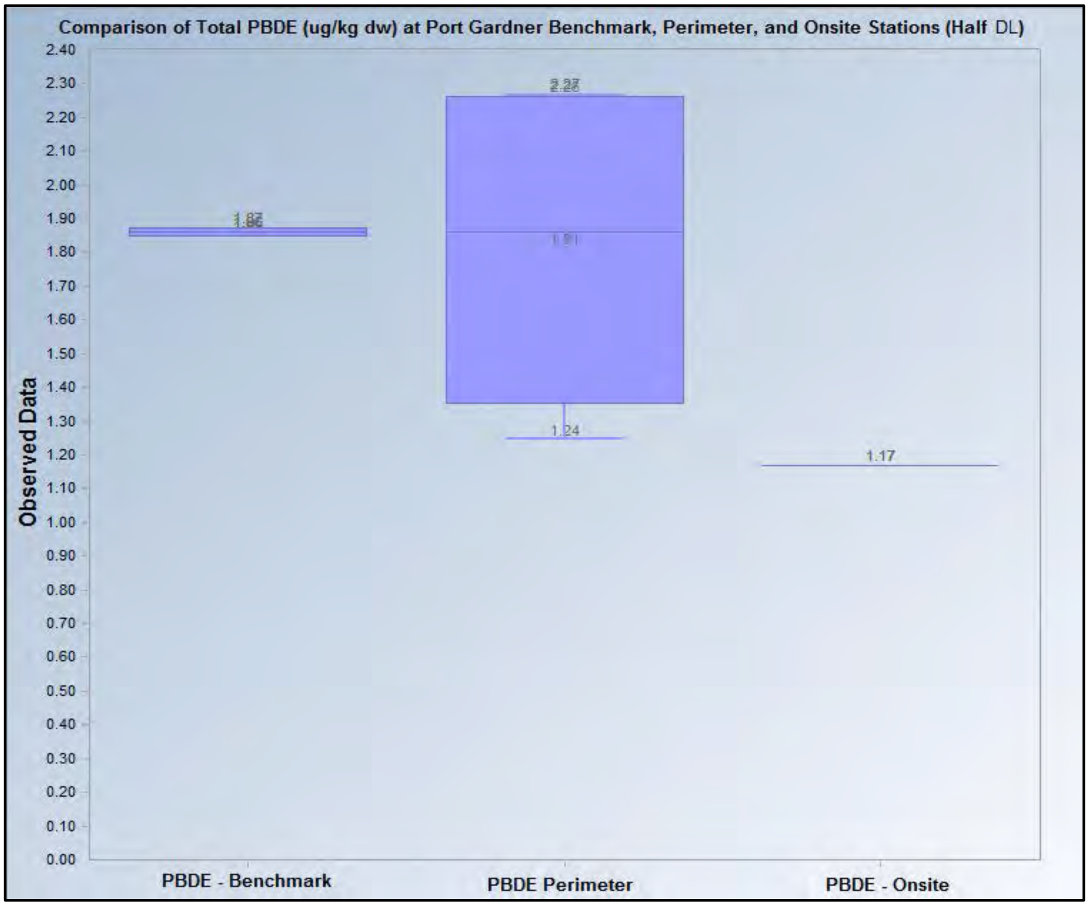

Figure 24. Comparison of ΣPBDE (µg/kg dw) at Elliott Bay Disposal Site Benchmark, Perimeter, and Onsite Stations (2010). Sum of detected PBDE congeners by half-DL substitution.

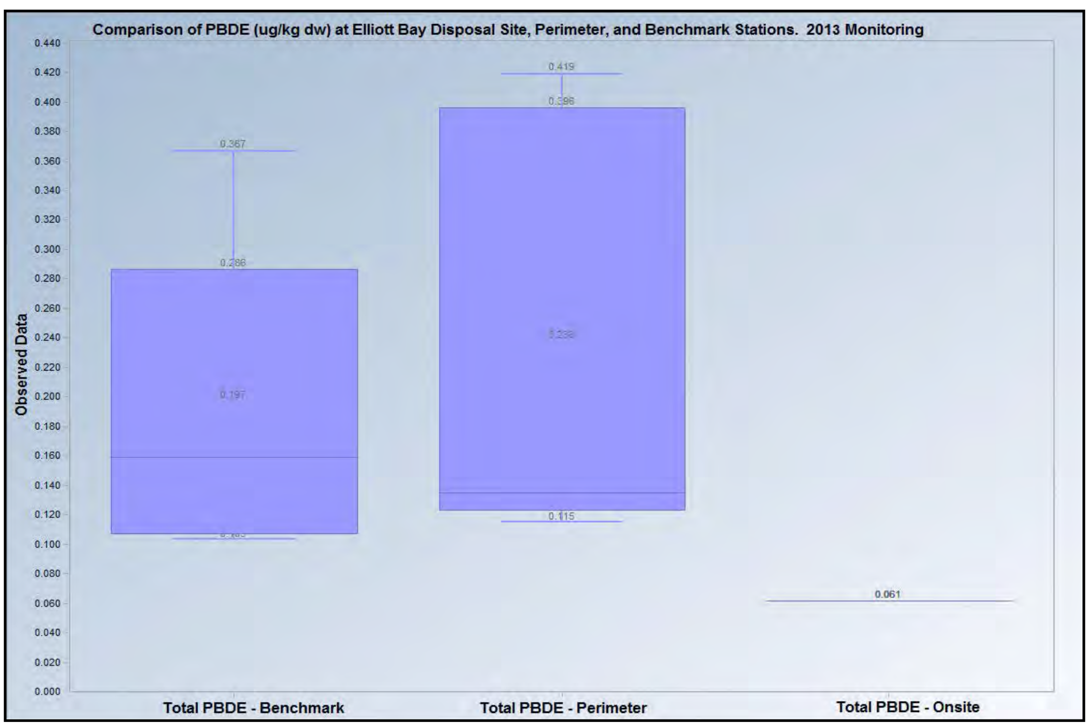

Figure 25. Comparison of ΣPBDE (µg/kg dw), 2013 Elliott Bay Site Benchmark, Perimeter, and Onsite Stations.

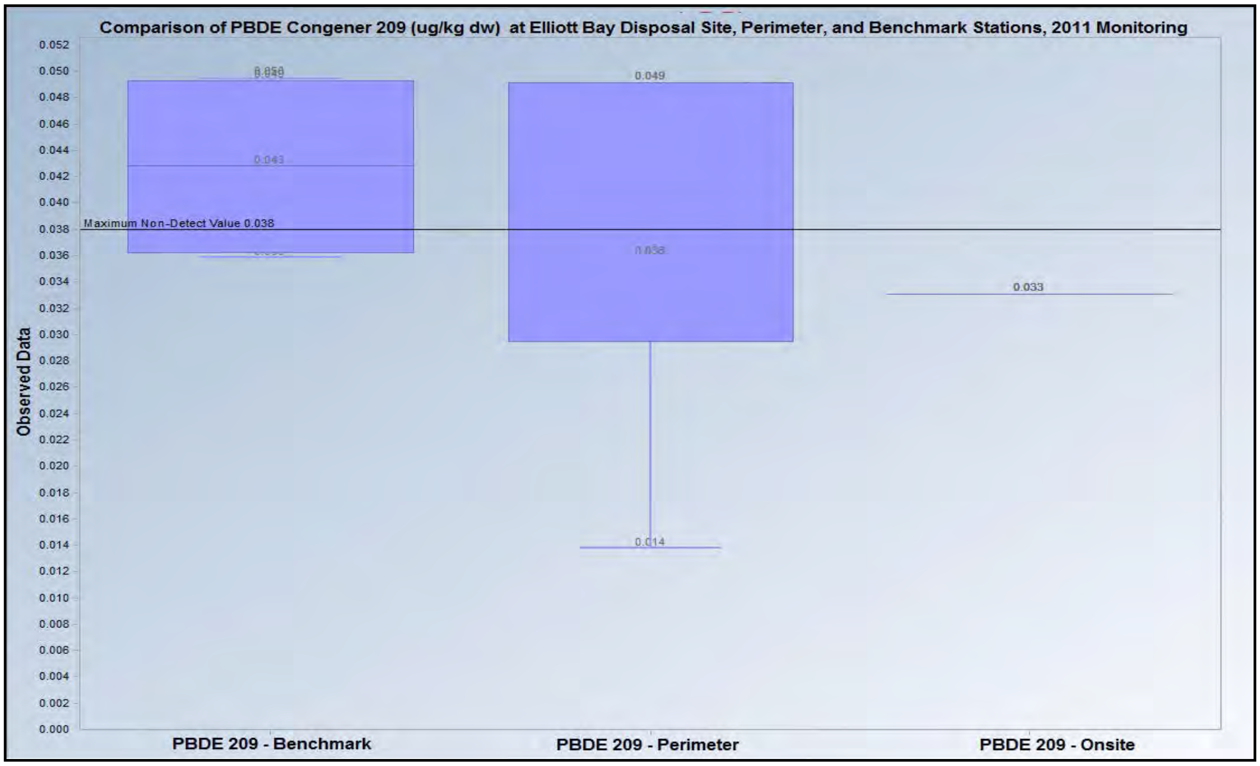

Figure 26. Comparison of PBDE Congener 209 (µg/kg dw), 2013 Elliott Bay Site Benchmark, Perimeter, and Onsite Stations.

4) Summary for Nondispersive Sites

Non-dispersive dredged material disposal site monitoring is ongoing to determine whether there is a significant increase of PBTs or an exceedance of the background-based site management goal for PCDD/F TEQ. Site monitoring has demonstrated that the dredged material evaluation procedures are keeping onsite sediment concentrations of ΣPCB, ΣPCDD/F and ΣPCDE below offsite concentrations, with one exception. At Port Gardner, one measure of ΣPCB (total homologues) suggests onsite is greater than offsite, but one of two statistical tests disagrees, and another measure, PCB TEQ, indicates that onsite is not significantly greater than offsite. In Elliott Bay, where the urban surroundings are significantly elevated relative to the rest of Puget Sound, there is evidence that on-site ΣPCB is lower (cleaner) than offsite ΣPCB. In addition, a case was made for how the dredging program facilitates another regional cleanup program by bypassing sediment from accumulating in the highly polluted LDW.

b) Dispersive Sites

Under the program, no site monitoring occurs for DMMP dispersive sites, so the contaminant inventory relies upon the chemistry of the materials characterized for the Suitability Determinations. The disposed materials rapidly migrate offsite due to strong currents. There are two sites in SRKW Critical Habitat: Port Angeles and Rosario Strait. Port Angeles has been used only once, in 1996. Rosario is summarized below. PCB Aroclor data only are available from Rosario Strait.

1) ΣPCB

Only the Aroclor method has been used to characterize dredged material deemed suitable for these sites. Note the low frequency of detected PCB in these samples in Table 11, which represents the 2008-2012 period. Many of the larger-volume Dredged Material Management Units (DMMUs) were nondetected at

Figure 26. Comparison of PBDE Congener 209 (µg/kg dw), 2013 Elliott Bay Site Benchmark, Perimeter, and Onsite Stations

the stated detection limits, and one-third were from Swinomish Channel maintenance, which has historically had clean sands and has been used for beneficial purposes including capping in Elliott Bay.

Table 11. Rosario Strait PCB Site Statistics, 2008-2012.

Parameter	Value	Units/Type
Amount of Dredged Material Disposed	234,625	CY in 4 years
Mass of Solids Disposed (60% Solids by Weight)	179,384	Metric Tons dw
Range of Detection Limits	19-39 (mean 20)	µg/kg dw
Frequency of Detection	10%	
Maximum Detected	24	µg/kg dw
Mean Concentration (0 DL Detection Method - 1/2 DL Method)	6.3 - 15	µg/kg dw
Estimated Annual ΣPCB Loading Associated with Above 2 Mean Concentrations	0.24 -0.57	kg PCB dw /year

DMMP (2012) reviewed sediment transport at Rosario; it is a single layered system with a net southerly direction, with a mean current speed of 50 cm/s and a 99th percentile speed of 134.7 cm/sec. The material that has been disposed at the Rosario site is predominantly sand (92%) and gravel (~8%); one small project in 1992 had higher fines, but low mass. A Particle Tracking Model for a predominantly sand disposal appears in Figure 26 over a 72-hour period. It is apparent that material rapidly moves offsite.

Note that the range for annual loading shown in Table 16 is a probable high-biased estimate, and it does not reflect “new” PCBs, but instead PCBs that are moved about in the aquatic environment. Ecology’s (2011 – see Figure 12) estimated mass loading of total ΣPCB in Puget Sound ranges from ~100 kg/yr from runoff and ~8 kg/yr from atmospheric deposition. Given the Rosario Strait site dynamics, which quickly moves the dredged material off-site, we do not believe it would be possible to measure the low ΣPCB input against the backdrop of Puget Sound.

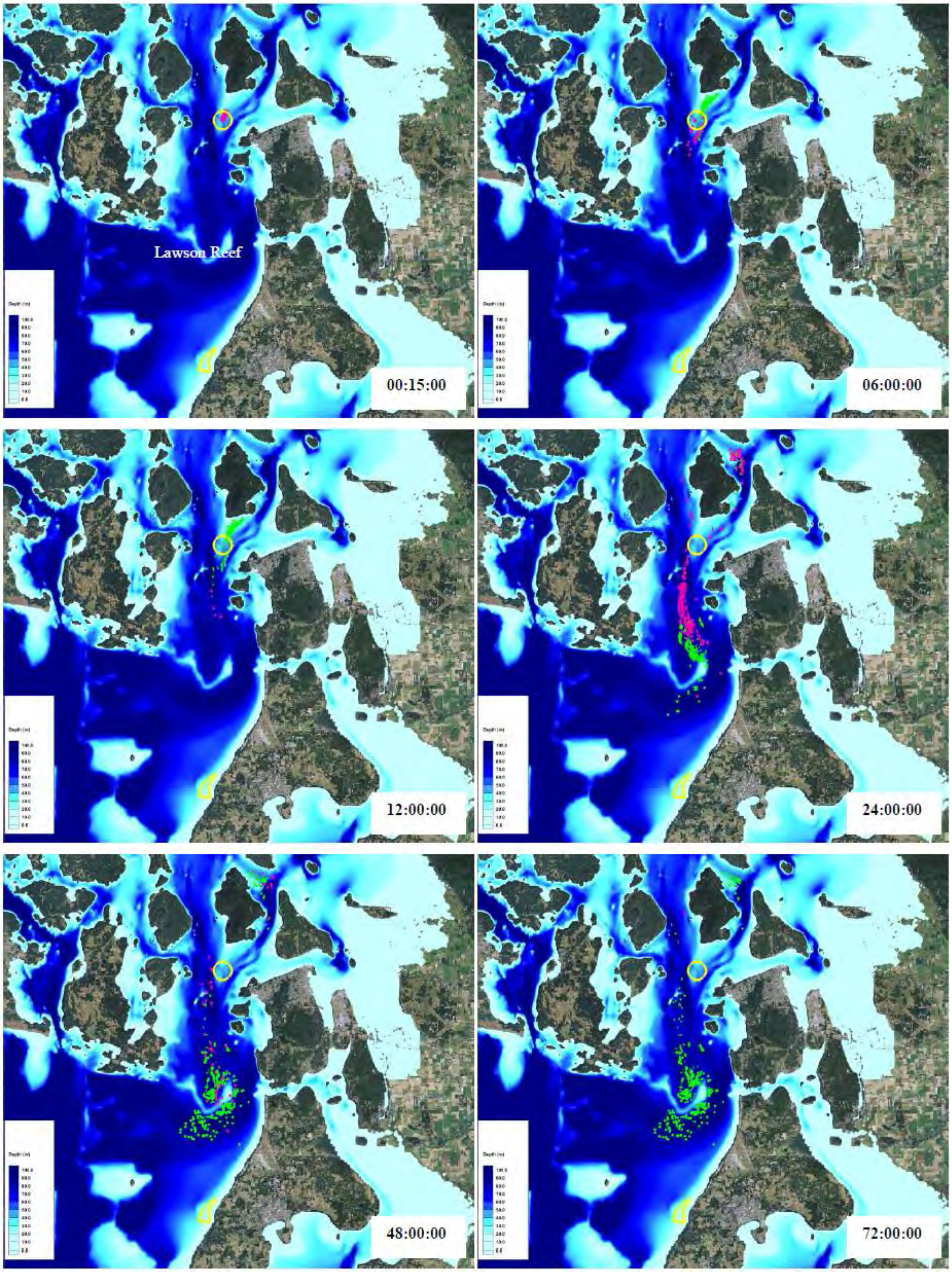

Figure 27. Rosario Straits Sands Results Based upon Disposal on August 12, 2011. Yellow circle is the site boundary, magenta areas are active parcels of the model, and green are inactive parcels.

2) ΣPCDD/F

As can be seen in Table 12, the Rosario Strait dispersive site have only received low or undetected levels of PCDD/F, and the average and range appears to be well below Ecology's natural background value of 4 ng TEQ/kg dw.

Table 12. Rosario Straits PCDD/F Statistics by Dredged Material Management Unit (DMMU) Permitted for Placement (ND=0.5*DL method), to 2009. (No more recent testing has occurred.)

Parameter	Value	Units/Type
Number of Observations	9	Count
Proportion of Detections	100	%
Minimum	0.16	ng TEQ/kg
Maximum	1.8	ng TEQ/kg
Mean ± Standard Error	0.69 ± 0.19	ng TEQ/kg

3) ΣPBDE

No data are available for this compound suite for any dispersive site.

6. Consideration of Canada Department of Fisheries and Oceans Advice for Dredged Material Management

While the DMMP acknowledges that there is evidence suggesting that the existing range of Puget Sound sediments likely affects health of SRKW, Steller sea lions, and harbor seals, the above review of PBTs onsite and offsite at nondispersive sites concentrations, and an inventory of these compounds for the dispersive sites indicates that the dredged materials placed do not result in an elevation relative to their surroundings. These surrounding bodies of water may be locally elevated (central Puget Sound and Commencement Bay in particular); and all of Puget Sound appears to be higher than values suggested by Álava et al. (2012) and Canada Department of Fisheries and Oceans (2010) to be protective of SRKW. Here is how the DMMP addressed the specific recommendations of the advice paper.

a) Disposing of dredged material into Critical Habitat (higher than ambient ΣPCB concentrations are predicted to increase the delivery of PCBs to killer whales.

The DMMP agrees that there is a demonstrated relationship with sediment and water concentrations, pelagic food-web concentrations and assimilation of ΣPCB into SRKW; however, the large scale of the model and the conflation of sediment and water concentrations (our program only manages sediment) limits ability to use the model for directed management decisions. This appendix describes how management policies generally converge with the recommendations, however. The number of inputs to Puget Sound and the Straits of Juan de Fuca are large. It is important to understand that the DMMP does not accept upland materials for in-water disposal, and does not "create" sediments containing PBTs, but "manages" them in a well-defined, science-based program that is annually updated as new information arises. It is difficult to distinguish how or if the program results in increases in sediment loads on the scale in this model. If these sediments they were not dredged and placed in unconfined, open-water sites, ΣPCBs and ΣPBDE would remain in the aquatic environment, e.g., in a riverbed or river delta and continue to contribute PBTs to the food web. For reasons presented in this appendix, careful review of prospective project contributions and management and monitoring of nondispersive sites suggests that the program's contribution of PCBs are less than or comparable to ambient levels within sub-regions (e.g., Elliott Bay) or within Puget-Sound ranges or natural background so far as this is understood.

b) *Dispose greater-than-ambient PCB levels into nondispersive (i.e., net depositional) sites as opposed to dispersive sites, in order to bury PCBs, and reduce overall habitat exposure for killer whales.*

The DMMP has 5 nondispersive sites and 3 dispersive sites (for which, sediments do not remain onsite and are rapidly dispersed). One dispersive site, Port Townsend, is not in SRKW Critical Habitat; the dispersive Port Angeles site seldom has been used; and only the Rosario Strait site receives significant volumes of dredged materials. Disposed dredged materials have had low PCB concentrations at the Rosario site, as explained in the text.

c) *Use congener-specific (high resolution) methods to characterize PCBs and PBDEs.*

The DMMP has adopted monitoring using high-resolution GC/MS methods to monitor ΣPCB, ΣPCDD/F, and ΣPBDEs at nondispersive sites. The program also uses these methods in Federal projects (although, because these are expensive, they are not always required for non-federal projects).

d) *While modeling predicts sediment levels from 0.012 to 0.2 µg/kg dw would protect killer whales, it is acknowledged that many areas are greater than this (both in coastal BC and in adjacent US waters).*

Both these values and those in Álava et al. (2012) -- 0.058-0.0044 µg/kg dw at 1.9% OC – are considerably below ambient values in Puget Sound. The State of Washington Department of Ecology's (2013) Sediment Cleanup Manual II (SCUM-II) uses "natural background" to set final cleanup criteria unless risk-based values are higher. As noted above, the natural background (90% coverage with 90% upper tolerance limit of the "OSV Bold Plus" dataset[8]) were shown in Table 4 above.

For ΣPBDE no natural background value has yet been set by Ecology, as this was not an analyte suite in the Bold and other studies. Historic and recent DMMP disposal site monitoring data have been compared above to these values as well as to the ambient conditions surrounding the sites. In several instances described above in regards to nondispersive site monitoring and management, the onsite concentrations are similar to or below these natural background values. In others, they are higher, but not statistically elevated above the surrounding perimeter stations.

e) *Additional understanding of PCB pathways in coastal waters, emphasizing sources, sinks, sedimentation rates, and substrate types in dredged and disposal sites to inform future risk-based decisions regarding fate and consequences of disposal activities in killer whale Critical Habitat.*

The flux of ΣPCB and ΣPBDE in dissolved and particulate form in the open waters of Puget Sound and the Strait of Georgia and their bioavailability are currently being evaluated by the State of Washington Departments of Fisheries and Wildlife (WDFW) and Ecology, and researchers in Canada. (These are briefly described in the text above, but it is difficult to use the Puget Sound PBT budgets to do more than contextualize the low contribution of the DMMP activities.)

In the Sediment Management Annual Review Meetings (SMARM), the best available science is considered and will continue to be considered in programmatic terms. The Álava et al (2012) model used to calculate safe ΣPCB levels for SRKW tends to conflate sediment and surface water as a source for bioavailable PCBs, and does not distinguish whether sediments are shallow or deep. Most dredged disposal sites are in

[8] The OSV Bold dataset consists of 70 samples taken on a stratified random grid with adjustments so that nearby industries or cleanup areas were avoided. The "plus" information consists of additional Puget Sound reference area data accepted by the Department of Ecology as suitable for inclusion. The entire dataset is in Appendix L of the citation.

relatively deep water, and while there are feasible linkages to a much shallower pelagic species (such as Chinook), these linkages are not well understood. It is difficult to evaluate, in terms of disposal site management, how sediment levels of PBTs affect overlying water and the pelagic food web. Few regional studies have collected data in such a manner that a linkage from sediment to plankton and to the pelagic food web may be quantified. An example is a recent paper by Desforges et al. (2014), which showed ΣPBDE relationships in plankton and other pelagic species along a transect from a strong sediment source in relatively shallow water, but generalizing this to Puget Sound disposal sites is difficult.

Per Table 1 of the 2014 PBE, most sites are at 91-171 m below mean lower low water (MLLW). The two exceptions are the nondispersive Bellingham Bay site and the dispersive Rosario site; these are 29-43 m below MLLW. Additionally, surface water discharge of PBTs is not well understood In Puget Sound, for which there are a number of industrial-and/or urban-affected rivers. In the text, we have summarized recent Ecology papers on atmospheric and runoff into Puget Sound, and looked in particular at the export model for sediment ΣPCB in Lower Duwamish Waterway. These values were used to contextualize the movement of PBTs in the program, although (as stated), the PBTs in sediments managed here are already in the aquatic environment, and it is not the mass, but the pathways from the disposal sites that matter most.

The DMMP related placement of PBTs is close to ambient levels or (in the case of the highly urbanized Elliott Bay site) appears to be cleaner than the ambient sediments. As models are refined and validated, the DMMP will follow progress and consider program implications.

7. Conclusion

The programmatic actions of transport, placement, and disposal of dredged materials with biomagnifying substances are unlikely to increase the existing levels of contamination to the food web. We are aware of no other related Federal decisions that would cause cumulative damages in conjunction with the DMMP activities.

Therefore, continued disposal of approved sediments at the DMMP open-water disposal sites in Puget Sound will have discountable effects on ESA-listed species, including SRKW and Steller sea lions. Continued disposal will also have discountable effects on harbor seals regulated under the MMPA.

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