An Assessment of the PCB and Dioxin Background in Washington Freshwater Fish, with Recommendations for Prioritizing 303(d) Listings

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Contact Information

For more information contact:

Publications Coordinator
Environmental Assessment Program
P.O. Box 47600, Olympia, WA 98504-7600
Phone: (360) 407-6764

Washington State Department of Ecology - www.ecy.wa.gov/

- Headquarters, Olympia (360) 407-6000
- Northwest Regional Office, Bellevue (425) 649-7000
- Southwest Regional Office, Olympia (360) 407-6300
- Central Regional Office, Yakima (509) 575-2490
- Eastern Regional Office, Spokane (509) 329-3400

Cover photo: Lake Ozette (Casey Deligeannis, 10/31/08).

An Assessment of the PCB and Dioxin Background in Washington Freshwater Fish, with Recommendations for Prioritizing 303(d) Listings

by
Art Johnson, Keith Seiders, and Dale Norton

Toxics Studies Unit
Statewide Coordination Section
Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

Waterbody Numbers: See Appendix A

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Abstract

Section 303(d) of the federal Clean Water Act requires states to prepare a list every two years of waterbodies that do not meet water quality standards. A Total Maximum Daily Load (TMDL) must be developed for every waterbody and pollutant on the list. A TMDL includes a written, quantitative assessment of water quality problems and pollutant sources that cause the problems. The TMDL determines the amount of a pollutant that can be discharged to the waterbody and allocates that pollutant load among sources.

Washington State has approximately 90 waterbodies 303(d) listed for not meeting human health criteria for polychlorinated biphenyls (PCBs) and dioxin (2,3,7,8-TCDD) in edible fish tissue samples from rivers, lakes, and streams. In order to prioritize the state's TMDL resources to address human health concerns, the Washington State Department of Ecology (Ecology) determined that better information was needed on what constitutes background levels of PCBs and dioxin in local fish populations.

In response to this need, Ecology collected 52 fish fillet samples from 24 lakes, rivers, and streams across Washington considered representative of background conditions. The samples were analyzed for PCBs, polychlorinated dibenzodioxins, polychlorinated dibenzofurans, and percent lipids. The results are used to recommend approaches for prioritizing 303(d) listings for these chemicals, with the intent of accelerating cleanup actions across the state.

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Introduction

303(d) Listings for PCBs and Dioxin

Section 303(d) of the federal Clean Water Act requires states to prepare a list every two years of waterbodies that do not meet water quality standards. The Act requires that a Total Maximum Daily Load (TMDL) be developed for every waterbody and pollutant on the list. A TMDL includes a written, quantitative assessment of water quality problems and pollutant sources that cause the problems. The TMDL determines the amount of a pollutant that can be discharged to the waterbody and allocates that pollutant load among sources.

Washington's current (2008) 303(d) list has 113 Category 5 listings for PCBs and 48 Category 5 listings for dioxin (2,3,7,8-tetrachlorodibenzo-*p*-dioxin or TCDD) not meeting (exceeding) U.S. Environmental Protection Agency (EPA) human health criteria for fish consumption. The listings cover 59 waterbodies for PCBs and 32 waterbodies for dioxin (Figures 1 and 2, Appendix B and C). Approximately one-third of the listings are for waterbodies where there are no obvious local sources of these chemicals. A number of the listings are based on fish tissue concentrations that are not substantially above criteria.

There are an additional 47 Category 2 (Waters of Concern) listings (32 waterbodies) for dioxin toxicity equivalents (TCDD TEQs) exceeding human health criteria (Appendix D). TEQs are a measure of the combined toxicity of a mixture of polychlorinated dibenzodioxins (PCDDs) and related compounds called polychlorinated dibenzofurans (PCDFs), based on the toxicity of TCDD, the most toxic of these compounds. Here again, sources of contamination are not always readily apparent.

Category 5 listings require a TMDL. Category 2 listings are for waters where there is some evidence of a problem, but not enough data to qualify for Category 5 and require a TMDL.

Studies have shown there can be a significant underlying PCB, PCDD, and PCDF background in aquatic and terrestrial environments unrelated to local sources (e.g., Meijer et al., 2003; Wania and Mackay, 1993; Gillian and Wania, 2005). The question that arises in connection with 303(d) listings is what level of contamination indicates the presence of significant local sources which may be amenable to cleanup actions? Without better information on what constitutes background levels of these chemicals in local fish populations, it is difficult to prioritize the state's TMDL resources to address human health concerns.

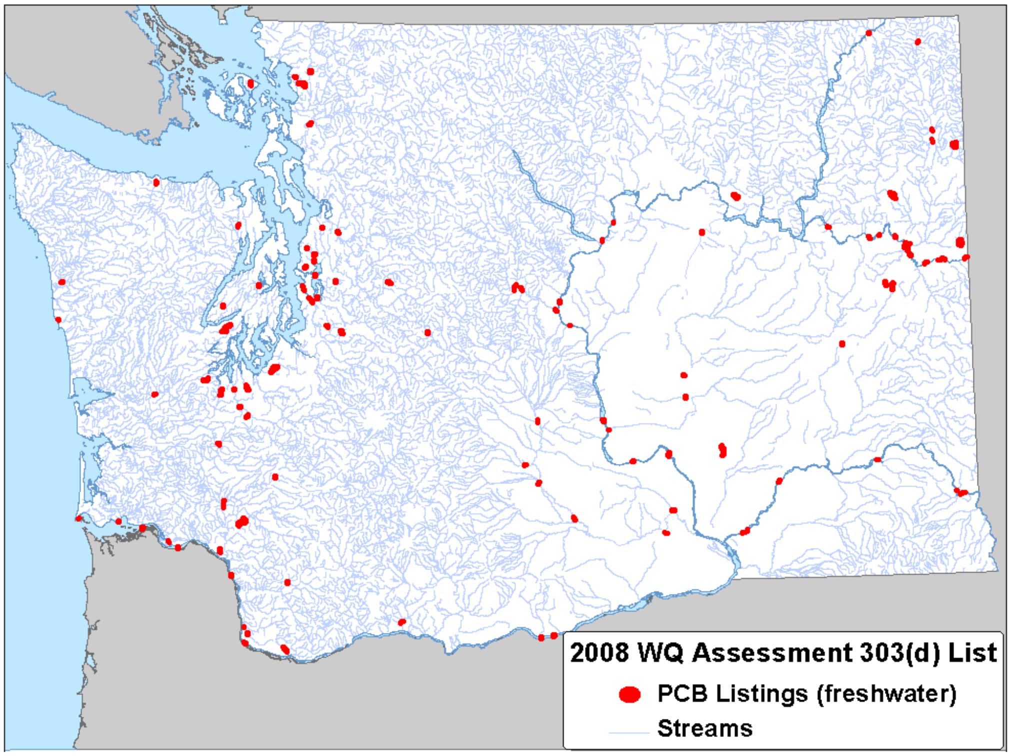


Figure 1. Locations of Waterbodies with Washington State Category 5 Listings for PCBs in Freshwater Fish.

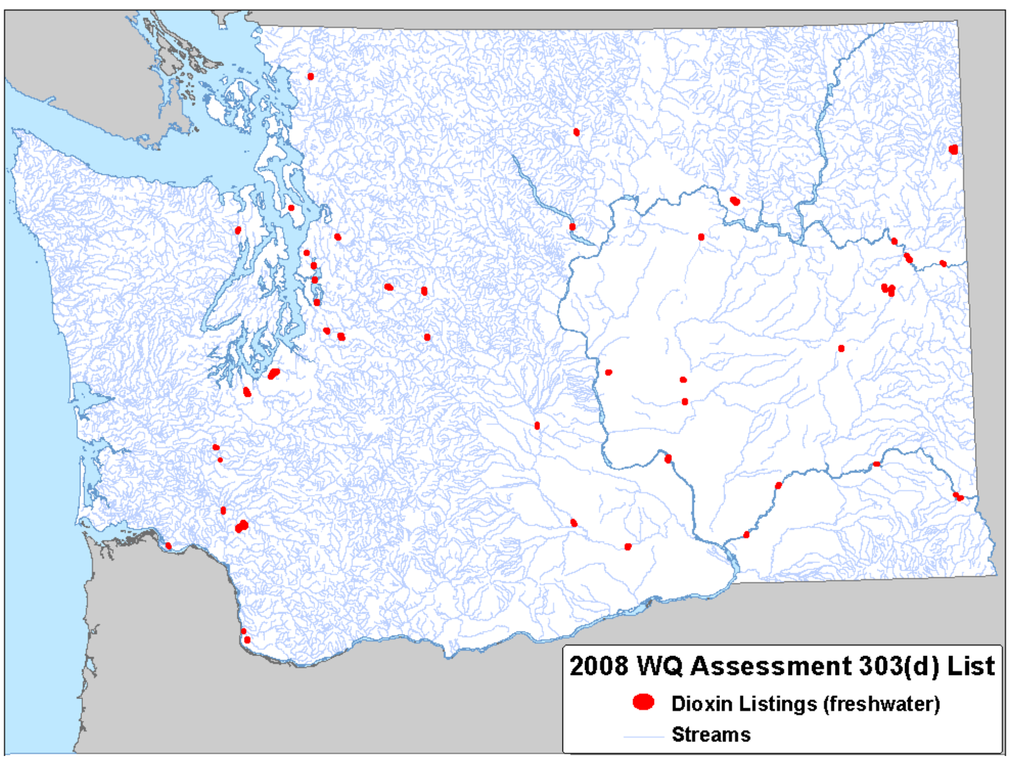


Figure 2. Locations of Waterbodies with Washington State Category 5 Listings for Dioxin (2,3,7,8-TCDD) in Freshwater Fish.

Study Objectives and Overview

The objective of this project is to characterize PCB, TCDD, and TCDD TEQ levels in edible fish tissue from background lakes, rivers, and streams in Washington. The results are used in conjunction with existing data and other information (e.g., human health-based water quality criteria and screening values) to recommend approaches for prioritizing 303(d) listings for these chemicals, with the intent of accelerating cleanup actions across the state.

The Background Study analyzed 52 fish tissue samples from 24 waterbodies in four regions of Washington: western Washington, West Slope of the Cascades, East Slope of the Cascades, and eastern Washington. From one to six species were analyzed from each waterbody, depending on availability. The fish were collected during the summer and fall of 2007 and 2008.

Composite fillets, typically from four to five individuals of each species, were analyzed for PCBs, PCDDs, PCDFs, and percent lipids. High resolution gas chromatography and mass spectrometry (HR-GC/MS) methods were used to achieve low detection limits. A subset of samples was analyzed for PCB Aroclor-equivalents by gas chromatography/electron capture detection (GC/ECD).

The Washington State Department of Ecology (Ecology) Environmental Assessment Program (EA Program) conducted the study, following a Quality Assurance Project Plan (Johnson, 2008).

PCBs, Dioxins, and Furans

PCBs, dioxins, and furans are classed as persistent, bioaccumulative, and toxic substances www.ecy.wa.gov/programs/swfa/pbt. Their chemical structure is shown in Figure 3.

PCBs are a class of 209 discrete chemical compounds containing from 1 to 10 chlorines. Commercial PCBs were manufactured as mixtures with varying chlorine content. In the United States, PCBs were primarily sold under the trade name Aroclors. PCBs were used in closed industrial systems such as electrical transformers and capacitors, plasticizers, lubricants, and hydraulic fluids, as well as in inks and sealers for gaskets and furnaces. Manufacture and use of PCBs was banned by EPA in the 1970s and 1980s due to ecological concerns.

Polychlorinated dioxins and furans are unintended byproducts found in association with certain industrial sites, waste incinerators, and combustion, especially of chlorinated material. Pulp and paper mills that used chlorine in their bleaching process were a major historical source of dioxins and furans in the Pacific Northwest. This practice was discontinued in the 1990s. Nationwide, reductions in dioxin and furan emissions have occurred from a combination of regulatory activities, improved emission controls, voluntary actions on the part of industry, and the closing of a number of facilities.

PCBs, dioxins, and furans enter waterbodies through direct discharge, runoff, and atmospheric deposition. Atmospheric deposition occurs because these compounds are sufficiently volatile to evaporate and then deposit in cooler regions.

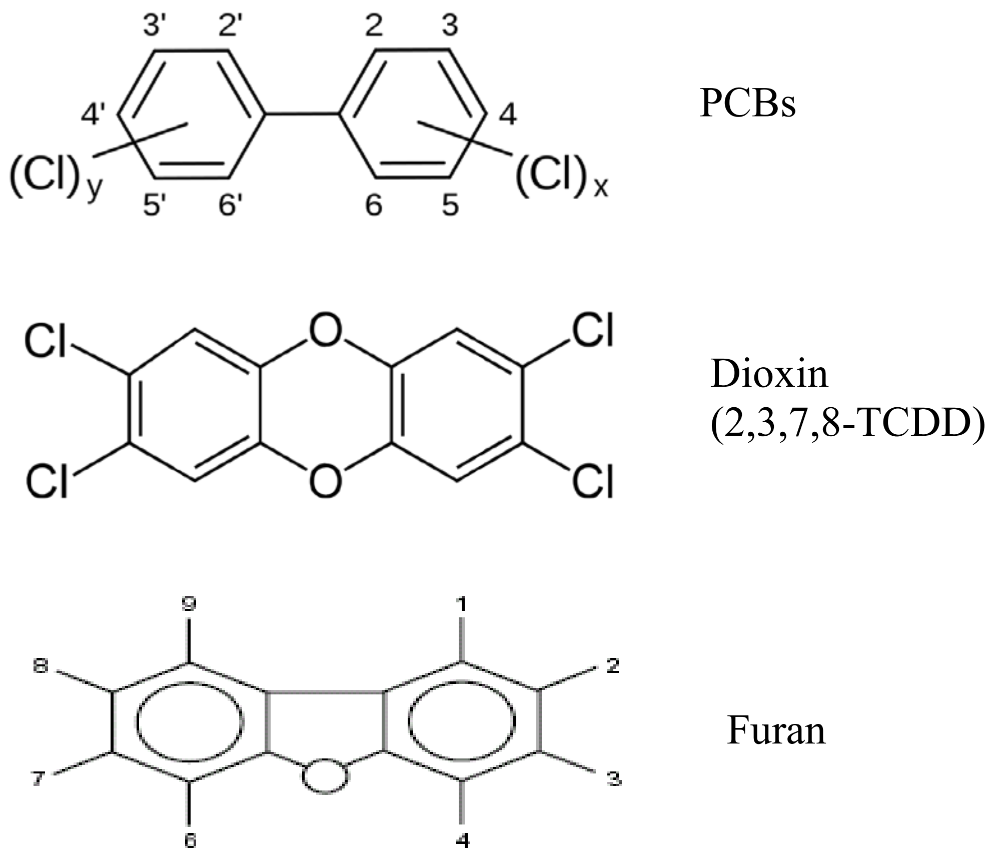


Figure 3. Chemical Structure of PCBs, Dioxin, and Furans.

PCB, dioxin, and furan levels can be elevated in the absence of local sources solely due to atmospheric deposition. Meijer et al. (2003), for example, showed that >80% of the soil burden of PCBs in the northern hemisphere was derived from atmospheric as opposed to local sources. Contamination of mountain lake and polar food webs with PCBs, dioxins, and other organochlorines has been attributed to atmospheric sources (Wania and Mackay, 1993; Blais et al., 1998; Gillian and Wania, 2005).

303(d) Human Health Criteria

Washington's human health criteria were issued to the state in 1992 in what is commonly called the EPA National Toxics Rule (NTR; 40 CFR Part 131; Federal Register Vol. 57, No. 246; Vol. 63, No. 63 – Revision of Polychlorinated Biphenyls (PCB) Criteria). Washington was one of 14 states issued criteria in the federal promulgation. The criteria apply to approximately 91 different chemicals.

EPA's human health criteria minimize or specify the potential risk of adverse human effects due to substances in ambient water. The criteria are generally assumed to be set at levels that will avert negative effects to the majority of the public, as well as special subpopulations that, because of high water or fish-intake rates or biological sensitivities, have an increased risk of receiving a dose that will elicit adverse effects. If the criteria are met, the concentrations of contaminants should remain below the levels that would generally raise public health concerns and result in fish advisories.

The criteria are based on a set of exposure assumptions as follows: a chemical-specific laboratory-derived bioconcentration factor, 6.5 g/day fish consumption, 2 L/day water consumption, 70 kg body weight, 70 year duration of exposure, and 70 year lifespan.

The toxicity values used to calculate the criteria for both non-carcinogens and carcinogens are from the EPA Integrated Risk Information System (IRIS) database. Criteria for carcinogens such as PCBs and dioxins are based on a one-in-one-million (10^{-6}) additional cancer risk from exposure to a specific contaminant in fish and shellfish. Criteria for non-carcinogens are calculated so that non-cancer effects should not occur (criteria are set so that toxicity thresholds are not exceeded)

Ecology's 303(d) listing criteria for PCBs and dioxin in edible fish tissue are shown in Table 1. The criteria are derived from EPA bioconcentration factors and human health water column criteria established for fish consumption under the NTR. In essence, the 303(d) fish tissue criteria are the human health water quality criteria expressed in tissue form.

Table 1. Human Health Criteria Used to 303(d) List Waterbodies for PCBs and Dioxin in Edible Fish Tissue* (wet weight).

Chemical	Water Quality Criteria	x	Bioconcentration Factor	x	Unit Conversion Factor	=	Fish Tissue Criteria
Total PCBs	0.17 ng/L†		31,200 L/Kg		0.001		5.3 ug/Kg**
Dioxin (2,3,7,8-TCDD)	0.013 pg/L††		5,000 L/Kg		0.001		0.07 ng/Kg†

*10^{-6} health risk @ 6.5 grams per day.
†parts per trillion.
**parts per billion.
††parts per quadrillion.

Ecology (2006) sets out the policies for assessing 303(d) listed waters (www.ecy.wa.gov/programs/wq/303d/wqp01-11-ch1Final2006.pdf). A waterbody segment is placed in Category 5 if either the mean of three single fish samples with the highest concentration or one composite sample made up of at least five fish exceeds the applicable criteria for total PCBs or dioxin. Only detected PCB congeners or detected Aroclor-equivalents are used in calculating total PCBs.

The water quality standards do not include criteria for dioxin TEQs. Applying dioxin TEQs to the dioxin criterion confers greater protection than provided by using the TCDD concentrations alone. Waterbodies that exceed the dioxin criterion based on TEQs are placed in Category 2 (Waters of Concern).

WDOH Screening Values

The Washington State Department of Health (WDOH), Office of Environmental Health, Safety, and Toxicology (OEHST), uses a different set of criteria called *screening values* to determine if chemical contaminants in edible fish tissue warrant further assessment, possibly leading to a fish consumption advisory. When screening values are exceeded, OEHST compares the concentrations with known background levels, concentrations in other foods, reductions from cleaning and cooking techniques, and known benefits from fish consumption. A range of fish consumption rates are considered, from recreational anglers to Native American subsistence consumers.

Because WDOH uses a non-cancer approach, the NTR target cancer risk is often exceeded without prompting an advisory. Another important consideration for WDOH is that advisories must be fashioned so that they can be communicated effectively to the public.

Table 2. WDOH Screening Values for PCBs and Dioxin in Edible Fish Tissue: Eight Meals per Month.* (wet weight)

Chemical	Fish Tissue Screening Values			
	Non-carcinogens	Carcinogens		
		(RL=10^{-4})	(RL=10^{-5})	(RL=10^{-6})
Total PCBs (ug/Kg)	23	59	6	0.6
TCDD TEQs (ng/Kg)	- -	0.75	0.075	0.008

*60 grams per day.
RL = risk level.

OEHST was contacted about using the WDOH screening values to help prioritize the 303(d) listings for PCBs and dioxin. For PCBs they recommended using the 23 ug/Kg screening value for non-cancer effects (Table 2). The Table 2 values are for a consumption rate of eight meals per month at 60 grams per day. The consumption rate behind Washington State's human health criteria is 6.5 grams per day.

Because PCBs often exceed 23 ug/Kg in both freshwater and marine fish species, OEHST typically views 100 ug/Kg total PCBs as a cutoff above which there is a strong possibility that a fish advisory will be needed. Again, the final decision on issuing an advisory depends on consumption rates and favored fish species of the population at risk, as well as mitigating factors described above.

WDOH uses TCDD TEQs in its screening values. The screening values for TCDD TEQs are extremely low (Table 2) and, thus, are exceeded almost anytime TCDD is detected. Unlike PCBs, WDOH has not yet established a level of concern below which TCDD is considered to represent an insignificant health risk. WDOH will re-evaluate both the dioxin screening level and level of concern once EPA completes their comprehensive reassessment of dioxin exposure and human health effects that is expected to come out sometime in 2010 (Dave McBride, personal communication). http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=55265&CFID=8435202&CFTOKEN=22303812&jsessionid=4a30f63c0215f4705a991c5180233233802e.

EPA Screening Values

EPA has also developed screening values for carcinogenic and non-carcinogenic substances to help prioritize areas that may present risks to humans from fish consumption (EPA, 2000). The EPA values are for guidance only and are not regulatory thresholds. The approach in their development was the same as for the NTR/303(d) criteria except (1) a cancer risk level of 10^{-5} was used rather than 10^{-6} and (2) consumption rates were set at 17.5 grams/day for recreational fishers and 142 grams/day for subsistence fishers. Table 3 shows the EPA screening values for PCBs and dioxins.

Table 3. EPA Screening Values for PCBs and Dioxins in Edible Fish Tissue.* (wet weight)

Chemical	Recreational Fishers†		Subsistence Fishers**	
	Non-carcinogens	Carcinogens	Non-carcinogens	Carcinogens
Total PCBs (ug/Kg)	80	20	9.83	2.5
TCDD TEQs (ng/Kg)	- -	0.26	- -	0.032

*10^{-5} health risk.
†17.5 grams per day.
**142 grams per day.

The 303(d) criteria are compared to WDOH and EPA screening values in Table 4.

Table 4. Comparison of Human Health Edible Fish Tissue Criteria and Screening Values.

Type	Risk Level	Consumption Rate (gms/day)	Criteria/ Screening Value	
			PCBs	TCDD/TCDD TEQs
			(ug/Kg)	(ng/Kg)
Carcinogens				
303(d) Listing Criteria*	10^{-6}	6.5	5.3	0.07
WDOH Screening Values†	10^{-6}	60	0.6	0.008
	10^{-5}	60	6.0	0.075
EPA Screening Values**	10^{-5}	17.5	20	0.26
	10^{-5}	142	2.5	0.032
Non-carcinogens				
WDOH Screening Values†	10^{-5}	60	23	- -
EPA Screening Values**	10^{-5}	17.5	80	- -
	10^{-5}	142	9.8	- -

*EPA National Toxics Rule.
†8 meals/month.
**EPA (2000).

Study Design

Selection of Background Waterbodies

For purposes of this study, the term "background" denotes a waterbody where the only known or likely PCB or dioxin source of significance is the atmosphere. These are lakes, rivers, and streams where no reason was found to suspect significant past use or sources of PCBs, dioxins, or furans in the watershed.

Background sites were selected by examining Washington State maps and GIS coverages showing population density, agricultural land use, public lands, annual precipitation, and wind direction. This exercise identified areas that have a low probability of local sources of contamination.

Fisheries biologists and resource managers for the Washington Department of Fish and Wildlife (WDFW), National Park Service, U.S. Forest Service, and Ecology were asked to identify potential background lakes and rivers within these areas, using the following criteria:

- Elevation under approximately 3,000 ft.
- Watershed relatively undisturbed or logging only.
- At least two nonplanted fish species of catchable size.
- Good accessibility.

Based on the mapping exercise and waterbody recommendations, four lakes and two rivers were selected for sampling in each of four regions: Western Washington, West Slope of the Cascades, East Slope of the Cascades, and eastern Washington. The location of these regions relative to the Pacific Ocean air mass and atmospheric sources in urban Puget Sound, and the barrier to these influences caused by the Cascade Mountains were viewed as having the potential to result in substantially different rates of chemical deposition. There are large differences in precipitation across the study area.

An effort was made to distribute the sampling effort along a north-south gradient within each of the four regions. The waterbodies selected included a mix of impoundments and natural waterbodies of various sizes, as is the case with the 303(d) list. The sampling effort was weighted toward lakes because of (1) the low diversity of fish species in most rivers that might qualify as background and (2) the greater ability of fish to move into and out of rivers as opposed to lakes. Lakes and impoundments also dominate the 303(d) list. It was not possible to locate good background sites within the major Eastern Washington agricultural basins of the Yakima, Columbia, Palouse, and Walla Walla Rivers.

The appropriateness of the waterbodies selected as background sites was checked against Ecology's Facility Site Identification System (http://ecyapps3/facilitysite/). Facility Site identifies sites known to Ecology as having an active or potential impact on the environment. Table 5 lists the 24 waterbodies where fish samples were ultimately collected for the study; their locations are shown in Figure 4.

Table 5. Waterbodies Where Fish Samples Were Collected.

Region and Waterbody Name	Location	Lake Elevation (ft)	Lake Area (acres)	River Drainage Area (mi^2)
Western Washington				
Mountain Lake	Moran State Park, Orcas Island	914	198	- -
Ozette Lake	Olympic NP	29	7,787	- -
Quinault River	Quinault Reservation/Olympic NP	- -	- -	264
Cushman Lake	Olympic NF	731	4,003	- -
North River	Chehalis River drainage	- -	- -	219
Loomis Lake	Loomis Lake State Park, Long Beach	25	200	- -
West Slope of the Cascades				
Baker Lake	N. Cascade NP/Baker-Snoqualmie NF	724	3,616	- -
Sauk River	Baker-Snoqualmie NF	- -	- -	714
Spada Lake	Baker-Snoqualmie NF	1,435	1,870	- -
Chester Morse Lake	Baker-Snoqualmie NF	1,555	1,682	- -
Panamaker Creek	Gifford Pinchot NF	- -	- -	~10
Merrill Lake	Gifford Pinchot NF	1,541	344	- -
East Slope of the Cascades				
Patterson Lake	Okanogan NF	2,740	18	- -
Entiat River	Wenatchee NF	- -	- -	419
Fish Lake	Wenatchee NF	2,257	513	- -
Cle Elum Lake	Wenatchee NF	2,224	4,810	- -
Bumping Lake	Wenatchee NF	3,426	1,310	- -
Klickitat River	Klickitat County	- -	- -	1,297
Eastern Washington				
Kettle River	Colville NF	- -	- -	4,070
Sullivan Lake	Colville NF	2,546	1,290	- -
South Twin Lake	Colville Indian Reservation	2,572	977	- -
Omak Lake	Colville Indian Reservation	954	3,244	- -
Badger Lake	South of Turnbull NWR	2,178	244	- -
Pataha Creek	Umatilla NF	- -	- -	200

NP – National Park.
NF – National Forest.
NWR – National Wildlife Reserve.

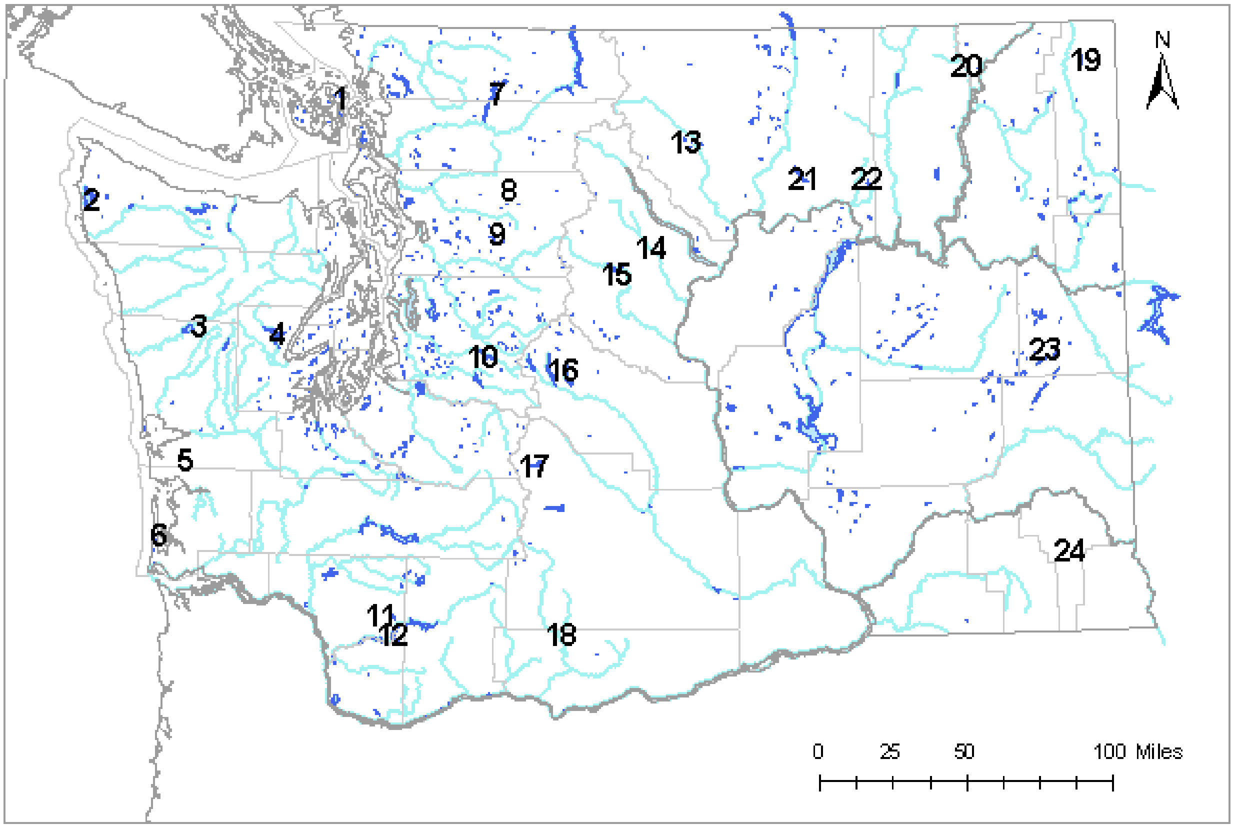


Figure 4. Location of Background Lakes, Rivers, and Streams Selected for Sampling.

Western Washington	West Slope Cascades	East Slope Cascades	Eastern Washington
1 = Mountain Lake	7 = Baker Lake	13 = Patterson Lake	19 = Sullivan Lake
2 = Ozette Lake	8 = Sauk River	14 = Entiat River	20 = Kettle River
3 = Quinault River	9 = Spada Lake	15 = Fish Lake	21 = Omak Lake
4 = Cushman Lake	10 = Chester Morse Lake	16 = Cle Elum Lake	22 = South Twin Lake
5 = North River	11 = Merrill Lake	17 = Bumping Lake	23 = Badger Lake
6 = Loomis Lake	12 = Panamaker Creek	18 = Klickitat River	24 = Pataha Creek

While pristine, high mountain lakes obviously qualify as background, they were not included in this study because of enhanced atmospheric deposition due to colder temperatures and greater amounts of precipitation (Blais et al., 1998; Gillian and Wania, 2005). High lakes have the additional drawbacks of difficult access and low fish diversity.

The U.S. Geological Survey (USGS) has analyzed PCBs in fish from 14 Washington mountain lakes over 3,000 ft. in elevation (Moran et al., 2007). Of the 19 samples in the study, 78% were nondetect for PCBs because a relatively insensitive GC/ECD method was used (50 ug/Kg reporting limit). However, USGS estimated concentrations of 17 – 20 ug/Kg total PCBs in approximately 20% of the samples, higher levels than a number of the waterbodies on the 303(d) list. This finding supports the approach of using lower elevation sites as a background reference for 303(d) listed waters.

Some historical data were available on PCBs and dioxin in fish from several of the lakes and rivers selected for the 2007-08 Background Study. The results confirmed low concentrations in Mountain, Ozette, Chester Morse, and Patterson Lakes, and the Entiat River (0.9 to <10 ug/Kg total PCBs, <0.1 ng/Kg TCDD; Seiders et al., 2007, EPA, 2005).

Fish Samples

The Background Study focused on the larger fish species more likely to be consumed and on which most of the contaminant data and 303(d) listings for Washington exist. The species of primary interest were rainbow trout (*Oncorhynchus mykiss*), cutthroat trout (*Oncorhynchus clarki*), brook trout (*Salvelinus fontinalis*), kokanee (*Oncorhynchus nerka*), mountain whitefish (*Prosopium williamsoni*), brown trout (*Salmo trutta*), yellow perch (*Perca flavescens*), and largemouth bass (*Micropterus salmoides*). A few samples were also obtained of largescale suckers (*Catostomus macrocheilus*), pike minnow (*Ptychocheilus oregonensis*), and peamouth (*Mylocheilus caurinus*).

Based on past experience, it was anticipated that from one to three species could be collected from each waterbody. An effort was made to collect at least one predator and one bottom feeder from each site, as recommended by EPA (2000). Planted fish were avoided to the extent possible, unless planted as fry.

Fish were collected in 2007 and 2008, primarily during the late summer and fall. The majority of the 303(d) listings are based on studies conducted around this time of year. Lipid content of most fish species is highest at this time, and PCBs and dioxins are primarily associated with lipids.

Fillets were analyzed for all fish samples. Each sample consisted of a composite of pooled tissues, typically from four to five individual fish. Composite samples provide a more cost efficient estimate of mean contaminant concentrations than single fish. At least one composite sample was analyzed from each waterbody. To provide an indication of the potential effect fish size might have on the results, two size classes were analyzed for several waterbodies. Length, weight, age, and sex were determined for each fish used in the composites.

Chemical Analysis

All samples were analyzed for PCBs (209 compounds), PCDDs/PCDFs (17 compounds), and percent lipids. HR-GC/MS methods were used to give detection limits down to 0.04 ug/Kg for PCB congeners and down to 0.01 ng/Kg for PCDDs/PCDFs. Lipids were analyzed for potential use in normalizing concentrations between samples. PCB Aroclor-equivalents were analyzed in a subset of samples for comparison with the congener data.

Sampling Procedures

Fish Collection

Fish sampling followed the EA Program SOP (Sandvik, 2006a). Fish were collected by electroshocking, beach seines, gill net, or hook and line. Only legal size fish were taken. For species with no size limits, only those large enough to reasonably be retained for consumption were taken.

Fish selected for analysis were killed by a blow to the head. Each fish was given a unique identifying number and its length and weight recorded. The fish were individually wrapped in aluminum foil, put in plastic bags, and placed on ice for transport to Ecology headquarters, where the samples were frozen pending preparation of the tissue samples.

Tissue Preparation

Tissue samples were prepared follow the EA Program SOP (Sandvik, 2006b). Techniques to minimize potential for contamination were used. People preparing the samples wore non-talc nitrile gloves and worked on heavy duty aluminum foil or a polyethylene cutting board. The gloves and foil were changed between samples, and the cutting board was cleaned between samples as described below.

The fish were thawed to remove the foil wrapper and rinsed with tap water, then deionized water, to remove any adhering debris. The entire fillet from one or both sides of each fish was removed with stainless steel knives and homogenized in a Kitchen-Aid blender. The fillets were scaled and analyzed skin-on. The sex of each fish was recorded, and hard structures were saved for age determination (scales, otoliths, opercles, dorsal, and/or pectoral spines as appropriate for each species). Age was determined by WDFW or a private laboratory.

Two to seven individual fish (19 small fish in one case) were used for each composite sample. To the extent possible, the length of the smallest fish in a composite was no less than 75% of the length of the largest fish. The composites were prepared using equal weights from each fish. The pooled tissues were homogenized to uniform color and consistency, using three passes through the blender. The homogenates were placed in glass jars with Teflon lid liners, cleaned to EPA (1990) QA/QC specifications.

Cleaning of resecting instruments, cutting boards, and blender parts was done by washing in tap water with Liquinox detergent, followed by sequential rinses with tap water, de-ionized water, and pesticide-grade acetone. The items were then air dried on aluminum foil in a fume hood before use.

The fish tissue samples were refrozen for shipment with chain-of-custody records to the Ecology Manchester Laboratory. The samples were stored frozen at Manchester until shipped to the contract laboratory. Excess tissue was retained for all samples and stored frozen at Ecology Headquarters. The holding time for frozen tissue samples being analyzed for PCBs and PCDDs/PCDFs is up to one year (Methods 1668A and 1613B).

Laboratory Methods

Table 6 shows the laboratory methods used in the study. PCB and PCDD/PCDF congeners were analyzed by accredited laboratories, Pace Analytical Services of Minneapolis, MN, and Pacific Rim Laboratories Inc. of Surrey, BC, through a contract with Manchester Laboratory. Manchester analyzed PCB Aroclor-equivalents and percent lipids. Manchester reviewed and verified all contract laboratory results.

At Ecology's request, the PCDD/PCDF results were reported down to the limit of detection, with values qualified as estimates if they were between the detection limit and quantitation limit. Because the lipid data from contract labs have been highly variable in the past, all samples were analyzed for percent lipids by Manchester to provide a more consistent data set.

Table 6. Laboratory Procedures.

Analysis	Method	Reporting Limit* (wet weight)	Laboratory	
			2007	2008
PCB congeners	High Resolution. GC/MS EPA 1668A	0.04 - 1.2 ug/Kg	Pace	Pacific Rim
PCB Aroclor-equivalents	GC/ECD EPA 8082	0.98 - 2.2 ug/Kg	Manchester	Manchester
PCDDs/PCDFs	High Resolution GC/MS EPA 1613B	0.01 - 1.0 ng/Kg	Pace	Pacific Rim
Percent lipids	Gravimetric MEL SOP 700009	0.1%	Manchester	Manchester

*Varies with congener.

MEL – Manchester Environmental Laboratory.

Data Quality

Data Review and Verification

Manchester Laboratory reviewed the chemical data for this project. For results generated by Manchester, final review was performed by the unit supervisor or an analyst experienced with the method. Chemists on the Manchester staff performed the review for analytical work sub-contracted to commercial laboratories. Quality assurance and quality control at Manchester are described in their Laboratory Users Manual.

Manchester prepared written case narratives assessing the quality of all data collected. These reviews include a description of analytical methods and an assessment of holding times, initial and continuing calibration and degradation checks, method blanks, surrogate and labeled compound recoveries, matrix spike recoveries, laboratory control samples, and laboratory duplicates. The reviews and the complete Manchester data reports are available from the author on request.

A Quality Assurance Project Plan (Johnson, 2008) established measurement quality objectives (MQOs) for accuracy, bias, and reporting limits. To determine if MQOs were met, the project lead compared results on field and laboratory quality control samples to the MQOs. To evaluate whether the reporting limit targets were met, the results were examined for non-detects and to determine if any values exceeded the lowest concentration of interest. Based on these assessments and a review of the laboratory data packages and Manchester's data verification reports, the data were either accepted, accepted with appropriate qualifications, or rejected and re-analysis or re-sampling considered.

The data contained in this report are useable as qualified. Qualified data are flagged as follows:

- U = The analyte was not detected at or above the reported sample quantitation limit.
- UJ = The analyte was not detected at or above the reported sample quantitation limit (PCB congeners) or detection limit (PCDDs/PCDFs). However, the reported quantitation and detection limits are approximate and may or may not represent the actual limits necessary to accurately measure the analyte in the sample.
- J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
- N = The analysis indicates the presence of an analyte for which there is presumptive evidence to make a tentative identification.
- NJ = The analysis indicates the presence of an analyte that has been tentatively identified, and the associated numerical value represents its approximate concentration.

Precision

The field variability inherent in the chemical residues accumulated by fish was minimized by using composite samples. Estimates of analytical precision were obtained by analyzing laboratory duplicates (splits). The results are summarized in terms of relative percent difference (RPD) in Appendix F. RPD is the difference between duplicates as a percent of the mean value.

RPDs for PCB congeners were 26% or better, except 66% for a single low-level sample. The duplicates analyzed for Aroclor-equivalents agreed within 13% or better. TCDD was unambiguously detected in one sample only, with an RPD of 24%. RPDs for TCDD TEQs ranged from 6-73%; the higher RPDs were again associated with the lower level samples. The lipid duplicates were in good agreement, 0-16% RPD.

Results[1] and Discussion

Samples and Species Analyzed

A total of 52 fish fillet samples were analyzed for the 2007-08 PCB and Dioxin Background Study (Table 7). These samples were obtained from 24 waterbodies, six in each of four regions of the state (see Figure 4). Similar numbers of samples were collected from each region (13-16). Two species were analyzed per waterbody, on average. Each sample typically consisted of composite muscle tissue from four or five individual fish.

Table 7. Number of Samples, Waterbodies, and Species Analyzed.

Samples Analyzed	52
Waterbodies Sampled	24
Waterbodies per Region	6
Samples per Region	13-16
Fish Species Sampled	11
Fish Species per Waterbody	1-6
Average Fish Species per Waterbody	2

Salmonids were encountered more frequently than spiny rayed fishes (35 versus 19 samples; Table 8). Of the 11 species collected for the study, cutthroat, rainbow trout, mountain whitefish, and largescale suckers were most common at 11-17% of samples. Brook trout, largemouth bass, kokanee, and northern pike minnow constituted 6-9% of samples. One brown trout and one peamouth were also analyzed. Cutthroat, mountain whitefish, and largescale suckers were collected from all four regions.

Table 8. Fish Species Analyzed.

Species	Number of Samples	Percent of Samples
Cutthroat Trout	9	17%
Rainbow Trout	9	17%
Mountain Whitefish	7	13%
Largescale Sucker	6	11%
Brook Trout	5	9%
Largemouth Bass	5	9%
Yellow Perch	4	8%
Kokanee	3	6%
Northern Pike Minnow	3	6%
Brown Trout	1	2%
Peamouth	1	2%

[1] See Appendix G for the complete data.

PCB Concentrations

Congeners

Results from the PCB congener analysis of the fish fillet samples are summarized as total PCBs in Table 9. Total PCBs are the sum of all detected congeners, including estimated values (J qualified) and tentative identifications (N and NJ qualified). Table 10 has a statistical summary of the data. Units of ug/Kg are equivalent to parts per billion. All data in this report are on a wet weight basis.

Table 9. Total PCB Concentrations in Fish Fillets from 24 Background Waterbodies Across Washington State (ug/Kg, wet weight, congener data).

Waterbody	Species	Total PCBs	
Western Washington			
Mountain Lake	Kokanee	11	
Ozette Lake	Largemouth Bass	0.26	J
	Northern Pike Minnow (large)	1.4	J
	Northern Pike Minnow (small)	1.3	J
	Yellow Perch	0.25	J
Quinault River	Cutthroat Trout	0.45	
Cushman Lake	Kokanee	1.1	J
	Largescale Sucker	0.60	J
	Mountain Whitefish	1.3	J
North River	Cutthroat Trout	1.0	
Loomis Lake	Largemouth Bass	0.35	
	Yellow Perch (large)	0.04	NJ
	Yellow Perch (small)	0.04	NJ
West Slope Cascades			
Baker Lake	Cutthroat Trout	1.2	J
	Largescale Sucker	0.51	J
	Rainbow Trout	0.91	J
Sauk River	Mountain Whitefish	2.0	J
Spada Lake	Cutthroat Trout (large)	2.4	J
	Cutthroat Trout (small)	1.2	J
	Rainbow Trout	1.7	J
Chester Morse Lake	Rainbow Trout	1.4	J
Merrill Lake	Cutthroat Trout	4.4	
Panamaker Creek	Kokanee	3.0	
East Slope Cascades			
Patterson Lake	Rainbow Trout	3.4	
	Yellow Perch	0.23	

Waterbody	Species	Total PCBs	
Entiat River	Brook Trout	0.29	
	Rainbow Trout	0.53	
Fish Lake	Brown Trout	88	
	Largemouth Bass	25	
	Largescale Sucker (large)	3.5	
	Largescale Sucker (small)	2.4	
	Northern Pike Minnow	38	
	Rainbow Trout	5.4	
Cle Elum Lake	Largescale Sucker	6.6	
	Mountain Whitefish (large)	5.1	
	Mountain Whitefish (small)	1.7	
Bumping Lake	Brook Trout	7.3	
	Cutthroat Trout	2.6	
Klickitat River	Mountain Whitefish	6.0	
Eastern Washington			
Sullivan Lake	Cutthroat Trout	3.5	J
	Mountain Whitefish (large)	3.4	J
	Mountain Whitefish (small)	2.0	J
Kettle River	Largescale Sucker	0.24	UJ
	Rainbow Trout	0.31	J
Omak Lake	Cutthroat Trout	3.8	
	Peamouth	3.0	
South Twin Lake	Brook Trout (large)	1.2	
	Brook Trout (small)	0.83	
	Largemouth Bass	0.25	NJ
Badger Lake	Largemouth Bass	1.4	
	Rainbow Trout	1.0	
Pataha Creek	Brook Trout	0.71	

U = Not detected at or above reported result.
J = Result is an estimated value.
NJ = There is evidence the analyte is present. The associated numerical result is an estimate.

Table 10. Summary of Results for Total PCB Congeners (ug/Kg, wet weight).

Number of Samples	52
Detection Frequency	98%
Minimum	0.04
Maximum	88
Mean	4.9
Median	1.4
90th Percentile	6.5

PCBs were detected in all but one fish tissue sample. Approximately 130 individual congeners were reported overall, with about 60 of these detected in at least half the samples. Congeners found in more the 90% of the samples included: PCB-52/69, -70, -74, -85, -86/97/117, -87/115, -93/95/98/102, -101, -105, -128, -138, -146, -153, -163/164, -180, and -182/187. [2]

Total PCB concentrations ranged from 0.04 to 88 ug/Kg, wet weight. The mean and median were 4.9 and 1.4 ug/Kg, respectively. The 90^{th} percentile value was 6.5 ug/Kg. The 90^{th} percentile is the value exceeded by only 10% of the samples.

Figure 5 shows the PCB data plotted on a regional basis. The highest total PCB concentrations were observed in waterbodies on the east slope of the Cascades. Regional differences were statistically significant for PCBs (Kruskal-Wallis test, $p < 0.05$). The gradual increase in PCB levels from Western Washington to the East Slope Cascades may reflect an elevation effect, previously discussed (see Study Design).

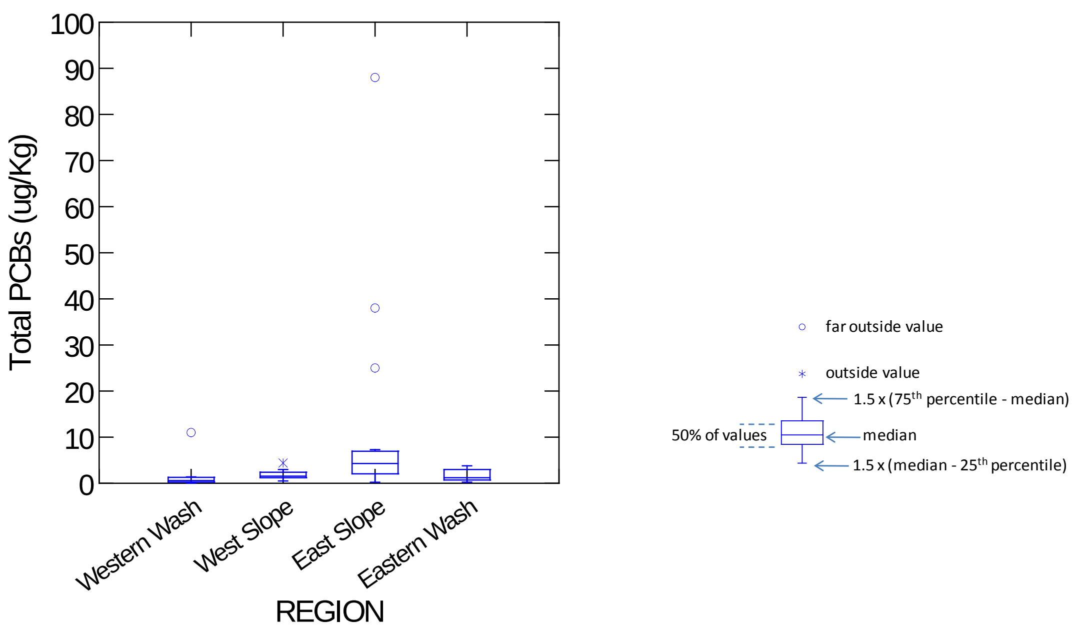


Figure 5. Box-and-Whisker Plot of the PCB Congener Data by Region.

[2] Some compounds could not be distinguished due to coelution.

Aroclor-Equivalents

The 303(d) fish tissue listings for PCBs are either based on an analysis of individual congeners or Aroclor-equivalents. Congeners are usually analyzed by high-resolution GC/MS methods that are more costly, but more sensitive and thus give lower detection limits than the GC/ECD method typically employed for Aroclor mixtures. Most of the historical fish tissue data for Washington State are from an Aroclor analysis.

Fish tissues from the Background Study were analyzed in conjunction with other Ecology fish samples from the Washington State Toxics Monitoring Program (WSTMP), discussed later in this report. Forty samples from the Background Study and the WSTMP were analyzed for PCBs by both high resolution GC/MS and GC/ECD methods. The results are compared in Figure 6.

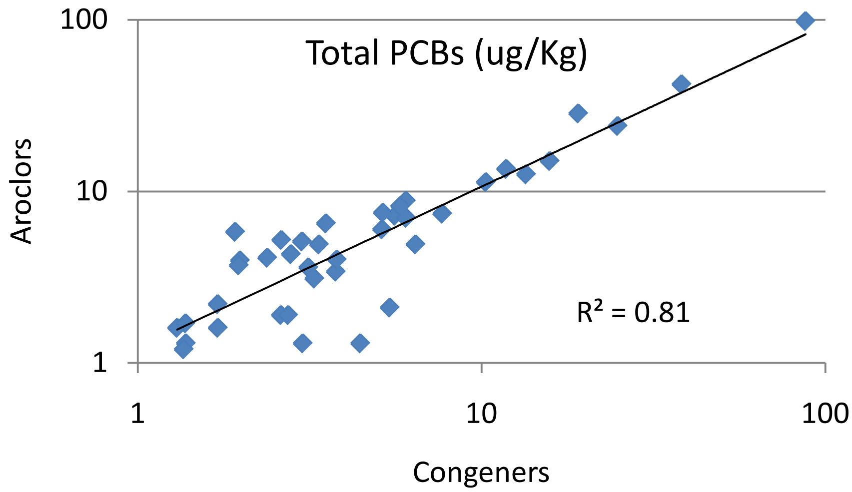


Figure 6. Results of Split Fish Fillet Samples Analyzed for PCB Congeners and Aroclor-Equivalents.

There was a good correlation between congeners and Aroclor-equivalents ($R^2 = 0.81$)[3]. Samples having approximately 10 ug/Kg or greater total PCBs showed better agreement that samples with lower concentrations approaching the 1 – 2 ug/Kg reporting limit for Aroclors. Overall, 60% of the Aroclor results had the higher total PCB concentration. In four instances, the Aroclor result qualified for a 303(d) listing, while the congener result did not (Appendix G).

Weathering of PCBs in environmental samples, mixing of different Aroclors, and bioaccumulation complicate quantitation by the Aroclor method. In addition, the Aroclor method does not allow for recovery correction as the congener method does. These factors can lead to errors in assessing the total PCB concentration. Most studies point to a congener analysis

[3] R^2, the coefficient of determination, represents the proportion of common variation in two variables, i.e., the strength or magnitude of the relationship. A value of 1.0 represents a perfect positive correlation.

as being more accurate (e.g., Conner et al., 2005; Sather et al., 2001; Bernhard and Petron, 2001; Schwartz and Stalling 1987).

PCB Toxicity Equivalents (TEQs)

PCB compounds with chlorine atoms located at the ends of the molecule (3/3' to 5/5' in Figure 3) are structurally similar to TCDD and are more toxic than PCBs with chlorines at the inner positions (2/2' and 6/6'). Human and mammalian Toxicity Equivalency Factors (TEFs) have been established for 12 of these compounds, based on their toxicity relative to TCDD (Van den Berg et al., 2006; Appendix H). The TEFs can be used to calculate the TCDD TEQ of a PCB mixture in fish tissue or other types of environmental samples. Ecology does not use PCB TEQs for 303(d) listing purposes (Connor et al., 2005). PCB TEQs can, however, be used to refine the toxicity estimate. This is a potentially useful means of ranking 303(d) listed waterbodies for TMDLs.

An example of how waterbody ranking can differ when done according to total PCB congeners and PCB TEQs is shown in Table 11 for the background lakes and rivers sampled in the Puget Sound basin for the present study. The waterbodies in question move up or down in rank order by up to three places when prioritized by TEQs.

Table 11. Puget Sound Background Waterbodies Ranked by Total PCBs versus PCB TEQs (ug/Kg, wet weight).

Ranked by Total PCBs			Ranked by PCB TEQs			Change in Rank
Waterbody	Species	Total PCBs	Waterbody	Species	PCB TEQ	
Mountain Lake	Kokanee	11	Mountain Lake	Kokanee	0.00034	none
Spada Lake	Cutthroat – large	2.4	Sauk River	Mountain whitefish	0.0000040	3rd to 2nd
Sauk River	Mountain whitefish	2.0	Chester Morse Lake	Rainbow trout	0.0000030	5th to 3rd
Spada Lake	Rainbow trout	1.7	Spada Lake	Cutthroat – large	0.0000025	2nd to 4th
Chester Morse Lake	Rainbow trout	1.4	Spada Lake	Rainbow trout	0.0000022	4th to 5th
Cushman Lake	Mountain whitefish	1.3	Spada Lake	Cutthroat – small	0.0000020	7th to 6th
Spada Lake	Cutthroat – small	1.2	Cushman Lake	Mountain whitefish	0.0000019	5th to 7th
Cushman Lake	Kokanee	1.1	Cushman Lake	Kokanee	0.0000019	none
Baker Lake	Rainbow trout	0.91	Baker Lake	Rainbow trout	0.0000016	none
Cushman Lake	Sucker	0.60	Baker Lake	Sucker	0	none
Baker Lake	Sucker	0.51	Cushman Lake	Sucker	0	tie for 10th

Statewide, the congeners contributing the most to the PCB TEQ in the background samples were PCB-118, -105, and -126 (Figure 7). These compounds were detected in 79%, 62%, and 8% of the samples, respectively.

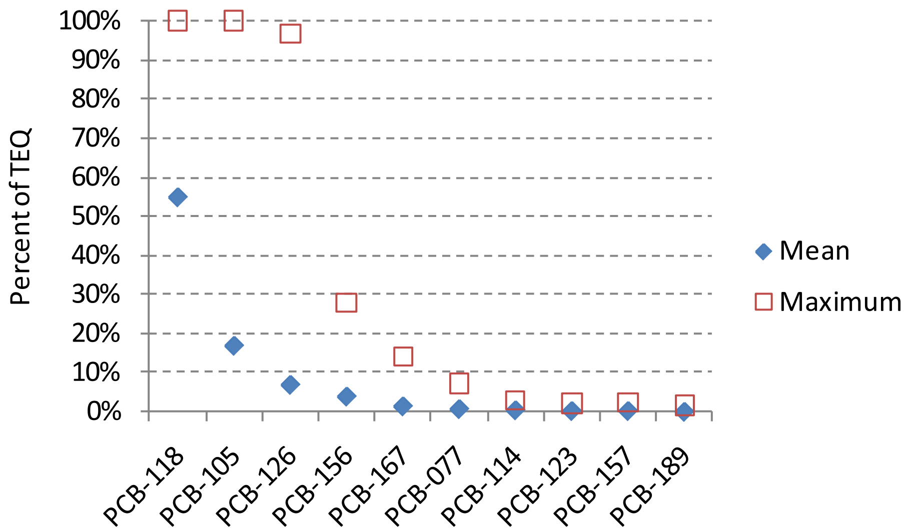


Figure 7. Percent Contribution of Dioxin-Like PCBs to TEQ in Background Fish Fillet Samples.

In the remainder of this report, the term *total PCBs* refers to the sum of individual PCB congeners and not total PCB TEQs, unless stated otherwise.

Dioxin and Furan Concentrations

Table 12 has the results for TCDD (dioxin) and TCDD TEQs in the background fish samples. In this table, detections are highlighted in bold to better identify where these compounds were detected. A statistical summary follows in Table 13. Units of ng/Kg are equivalent to parts per trillion.

TCDD was detected in only 27% of the fish tissue samples. Most of the detections (10 out of 14) were in western Washington. Overall, concentrations ranged from less than 0.008 to 0.12 ng/Kg. The mean and median were non-detect at 0.03 ng/Kg, and the 90^{th} percentile was 0.041 ng/Kg.

Most waterbodies had one or more PCDDs/PCDFs detected (Figure 8). Thus, the detection frequency for TCDD TEQs was high (94%). TEQ concentrations ranged from 0.007 to 0.65 ng/Kg, with a mean of 0.091 ng/Kg, a median of 0.051 ng/Kg, and a 90^{th} percentile of 0.18 ng/Kg. 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDF, 2,3,7,8-TCDD, and 2,3,7,8-TCDF were the primary contributors to the TEQ (Figure 9).

Table 12. TCDD and TCDD TEQ Concentrations in Fish Fillets from 24 Background Waterbodies Across Washington State (ng/Kg, wet weight).

Waterbody	Species	TCDD		TCDD TEQ	
Western Washington					
Mountain Lake	Kokanee	**0.12**		**0.65**	
Ozette Lake	Largemouth Bass	0.019	UJ	**0.028**	J
	Northern Pike Minnow (large)	0.033	UJ	**0.010**	J
	Northern Pike Minnow (small)	0.026	UJ	**0.012**	J
	Yellow Perch	0.014	UJ	**0.016**	J
Quinault River	Cutthroat Trout	0.03	U	**0.071**	J
Cushman Lake	Kokanee	**0.016**	NJ	**0.14**	J
	Largescale Sucker	0.008	UJ	**0.051**	J
	Mountain Whitefish	**0.014**	NJ	**0.056**	J
North River	Cutthroat Trout	**0.032**	NJ	**0.032**	J
Loomis Lake	Largemouth Bass	0.03	U	**0.042**	
	Yellow Perch (large)	0.03	U	**0.033**	
	Yellow Perch (small)	**0.031**	NJ	**0.091**	J
West Slope of the Cascades					
Baker Lake	Cutthroat Trout	0.031	UJ	**0.092**	J
	Largescale Sucker	**0.011**	NJ	**0.035**	J
	Rainbow Trout	**0.063**	NJ	**0.35**	J
Sauk River	Mountain Whitefish	**0.060**	NJ	**0.18**	J
Spada Lake	Cutthroat Trout (large)	0.045	UJ	**0.15**	J
	Cutthroat Trout (small)	**0.027**	NJ	**0.12**	J
	Rainbow Trout	0.039	UJ	**0.017**	J
Chester Morse Lake	Rainbow Trout	0.024	UJ	**0.070**	J
Merrill Lake	Cutthroat Trout	0.03	U	0.050	U
Panamaker Creek	Kokanee	**0.03**	NJ	**0.45**	J
East Slope of the Cascades					
Patterson Lake	Rainbow Trout	0.03	U	**0.031**	
	Yellow Perch	0.03	U	**0.10**	J
Entiat River	Brook Trout	0.03	U	**0.049**	J
	Rainbow Trout	**0.059**	NJ	**0.090**	J
Fish Lake	Brown Trout	0.03	U	**0.062**	J
	Largemouth Bass	0.03	U	**0.048**	
	Largescale Sucker (large)	0.03	U	**0.13**	J
	Largescale Sucker (small)	0.03	U	**0.050**	
	Northern Pike Minnow	0.03	U	**0.025**	J
	Rainbow Trout	0.03	U	**0.026**	

Waterbody	Species	TCDD		TCDD TEQ	
Cle Elum Lake	Largescale Sucker	0.03	U	**0.15**	J
	Mountain Whitefish (large)	0.03	U	**0.021**	J
	Mountain Whitefish (small)	0.03	U	**0.095**	J
Bumping Lake	Brook Trout	0.03	U	**0.025**	J
	Cutthroat Trout	0.03	U	**0.014**	
Klickitat River	Mountain Whitefish	**0.041**		**0.19**	
Eastern Washington					
Sullivan Lake	Cutthroat Trout	**0.017**	NJ	**0.12**	J
	Mountain Whitefish (large)	**0.041**	NJ	**0.19**	J
	Mountain Whitefish (small)	0.039	UJ	**0.011**	J
Kettle River	Largescale Sucker	0.04	UJ	**0.008**	J
	Rainbow Trout	0.03	UJ	**0.16**	J
Omak Lake	Cutthroat Trout	0.03	U	**0.013**	J
	Peamouth	0.03	U	**0.077**	J
South Twin Lake	Brook Trout (large)	0.03	U	**0.075**	
	Brook Trout (small)	0.03	U	**0.035**	J
	Largemouth Bass	0.03	U	**0.007**	
Badger Lake	Largemouth Bass	0.03	U	0.050	U
	Rainbow Trout	0.03	U	0.050	U
Pataha Creek	Brook Trout	0.03	U	**0.056**	J

Detections are highlighted in **bold.**
U = Not detected at or above reported result.
J = Result is an estimated value.
NJ = There is evidence the analyte is present. The associated numerical result is an estimate.

Table 13. Summary of Results for TCDD and TCDD TEQs (ng/Kg, wet weight).

	TCDD		TCDD TEQ
Number of Samples	52		52
Detection Frequency	27%		94%
Minimum	0.008	UJ	0.007
Maximum	0.12		0.65
Mean	0.03	U	0.091
Median	0.03	U	0.051
90th Percentile	0.041		0.18

U = Not detected at or above reported result.
J = Result is an estimated value.

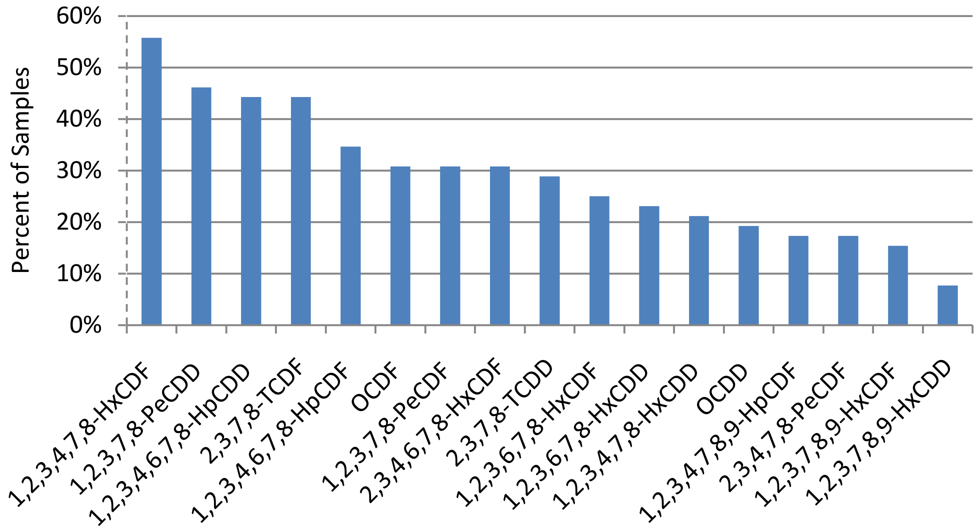


Figure 8. Detection Frequency of PCDDs and PCDFs in Background Fish Fillet Samples.

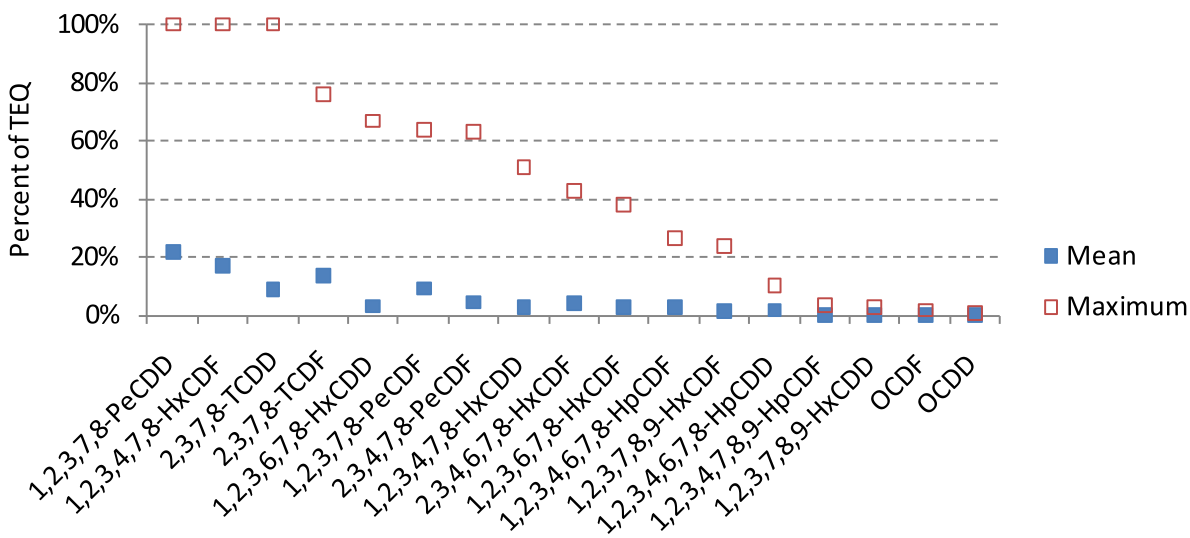


Figure 9. Percent Contribution of PCDD/PCDF Congeners to the TCDD TEQ in Background Fish Fillet Samples.

There were no significant regional differences in either TCDD or TCDD TEQ concentrations (Figure 10).

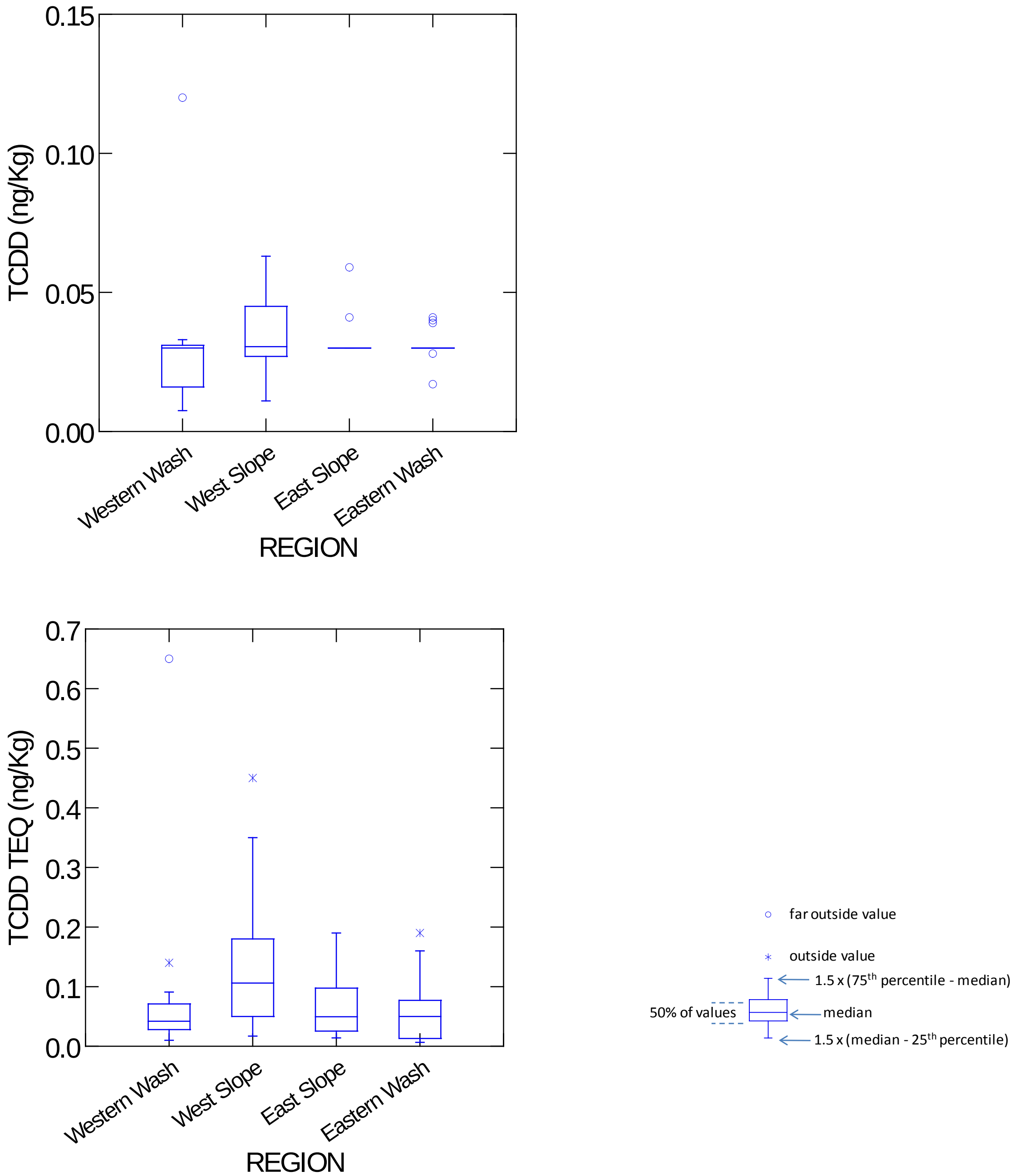


Figure 10. Box-and-Whisker Plots of the TCDD and TCDD TEQ Data by Region (non-detects plotted at the detection limit).

Background versus Non-background

The 303(d) list is not representative of PCB or dioxin levels in Washington State because the list is biased toward contaminated sites and includes some older studies. A more recent and balanced assessment is provided by Ecology's WSTMP (Seiders and Deligeannis, 2009). WSTMP is a screening-level effort which targets waterbodies across Washington. Results are used primarily to identify areas of concern for follow-up actions. The bulk of the newer fish tissue listings comes from this program.

Results from the Background Study were compared to statewide results from the WSTMP to assess the extent to which the sites selected as background were in fact "cleaner" than those having potential for contamination. Fifty-seven of the waterbodies analyzed for PCB congeners or PCDDs/PCDFs in fish fillets by WSTMP between 2001 and 2008 were identified as non-background, using the same approach as in the present 2007-08 study.

The background and non-background total PCB congener data are compared in Figure 11. Table 14 summarizes the two data sets.

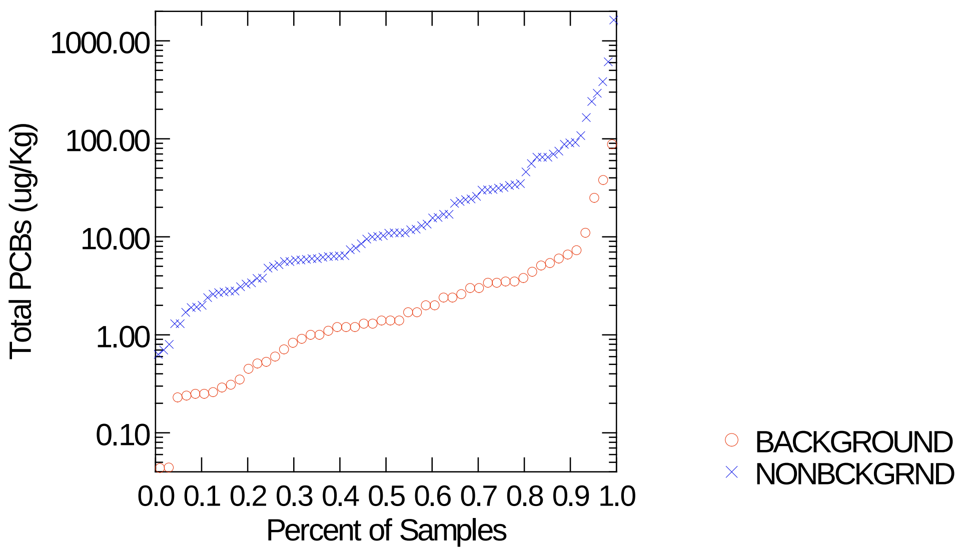


Figure 11. Total PCBs in Fish Fillets from Background (present study) and Non-Background (selected WSTMP sites) Waterbodies Across Washington State.

Table 14. Summary of Total PCB Data on Fish Fillets from Background and Non-Background Waterbodies Across Washington State (ug/Kg, wet weight; congener analysis).

	Background Sites 2007-08	Non-Background Sites 2001-08
Number of Samples	52	84
Detection Frequency	98%	74%
Minimum	0.044	0.63
Maximum	88	1632
Mean	4.9	58
Median	1.4	10
90th Percentile	6.5	90

Waterbodies sampled in the Background Study clearly have much lower PCB concentrations than non-background waterbodies surveyed through the WSTMP. The background mean, median, and 90^{th} percentile total PCB values are an order of magnitude below non-background. Detection frequency is somewhat lower for non-background due to differences in reporting limits.

The TCDD and TCDD TEQ data are similarly compared in Figure 12 and Table 15.

Roughly a third of the non-background samples had low to non-detectable TCDD concentrations similar to background. TCDD concentrations in the remaining samples were elevated over background to a greater extent that was evident for PCBs. The distribution of the two data sets suggests that significant TCDD sources are less widespread in Washington than PCB sources.

TCDD TEQs in background and non-background waterbodies differ to a much lesser extent than either PCBs or TCDD. Mean and median TCDD TEQs for background and non-background are within a factor of 2 or less. This relatively modest elevation in non-background waterbodies suggests there is a significant background contribution to the TCDD TEQ at many locations in Washington.

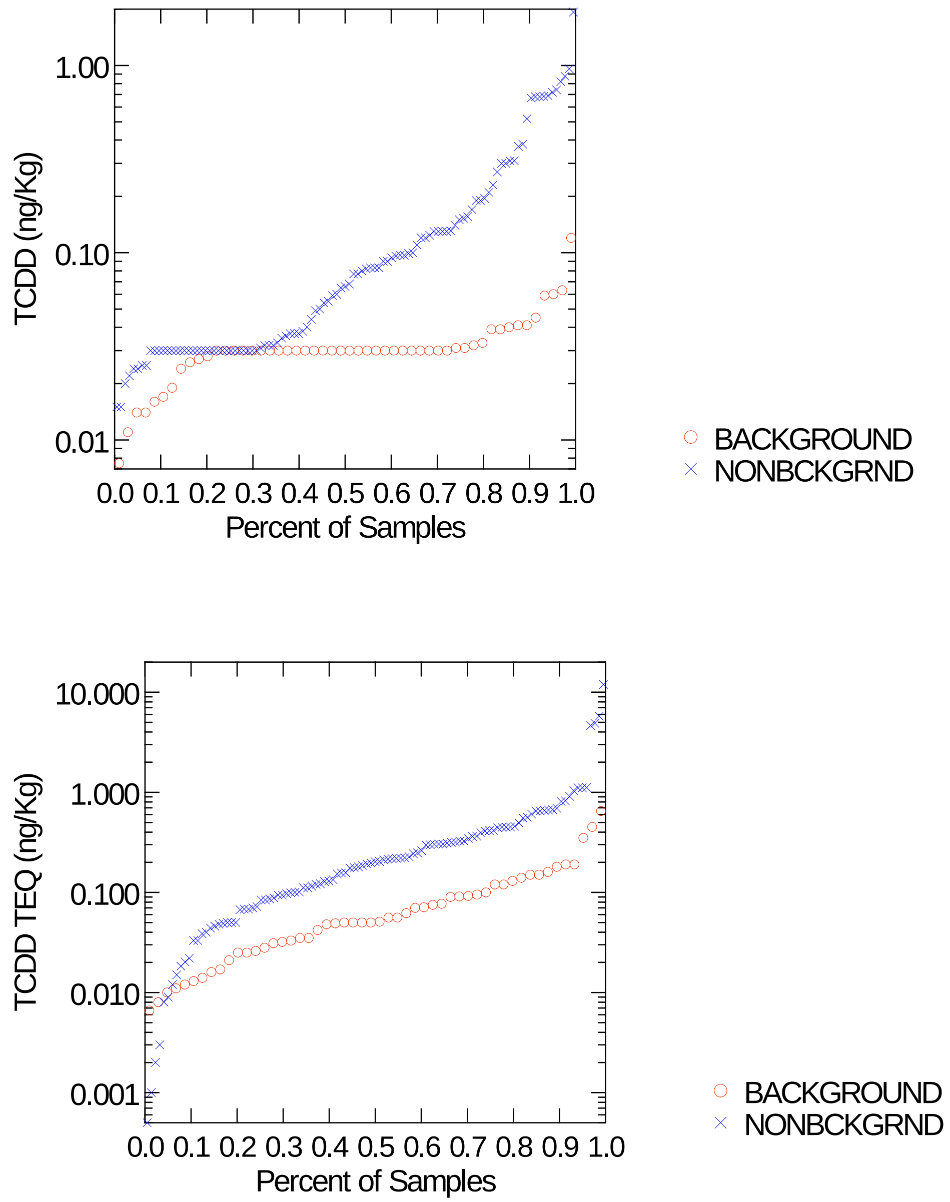


Figure 12. TCDD and TCDD TEQs in Fish Fillets from Background and Non-Background Waterbodies Across Washington State.

Table 15. Summary of TCDD and TCDD TEQ Data on Fish Fillets from Background and Non-Background Waterbodies Across Washington State (ng/Kg, wet weight).

	TCDD			TCDD TEQ	
	Background Sites		Non-Background Sites	Background Sites	Non-Background Sites
Number of Samples	52		109	52	109
Detection Frequency	27%		96%	94%	96%
Minimum	0.0075	UJ	0.0005	0.0066	0.015
Maximum	0.12		12	0.65	1.9
Mean	0.033	U	0.51	0.091	0.17
Median	0.03	U	0.20	0.051	0.066
90th Percentile	0.041		0.71	0.18	0.55

U = Not detected at or above reported result.
J = Result is an estimated value.

Biological Parameters

Lipid Content

Concentrations of lipophilic contaminants such as PCBs and dioxins are frequently corrected for variation in lipid content of the tissues analyzed. The lipid normalized data may reveal patterns not apparent on a wet weight basis. Lipid normalizing, however, is only appropriate when the chemical concentrations are directly proportional to lipids.

The total PCB congeners and TCDD TEQ data from the Background Study are plotted against percent lipids in Figures 13 and 14. The correlation between PCBs and percent lipids was poor (R^2 = 0.26). There was no apparent correlation between TCDD TEQs and lipids (R^2 = 0.03). TCDD was not detected frequently enough to assess the correlation.

Lipid content, therefore, was not a major factor influencing either total PCB congeners or TCDD TEQ levels in the background data set overall. Herbert and Keenleyside (1995), Stow et al. (1997), Exponent (2003), and others have concluded that lipid normalization may be justified when bioconcentration (uptake from water) is the primary mechanism of accumulation, but is not warranted under many situations for biomagnifying chemicals such as PCBs or dioxins. PCB and dioxin concentrations increase with trophic level due to uptake from food and long retention time in tissue.

Lipid content is probably related to site-specific factors including but not limited to temperature, trophic status, and food availability. Much better correlations were evident for individual lakes. For example, R^2 values for total PCBs versus percent lipids were 0.76 - 0.77 in Fish Lake and Ozette Lake, where the largest variety of species were collected for the background study.

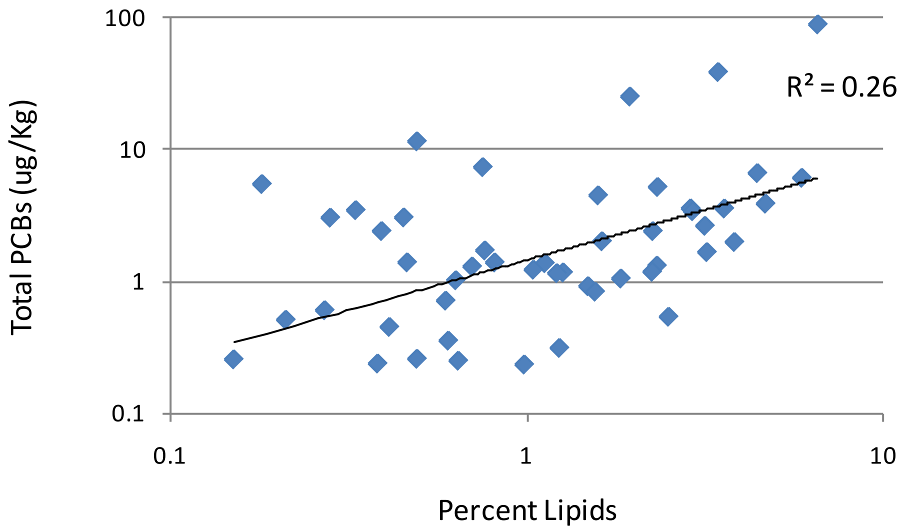


Figure 13. Total PCBs versus Lipid Content in Fish Fillets from Background Waterbodies.

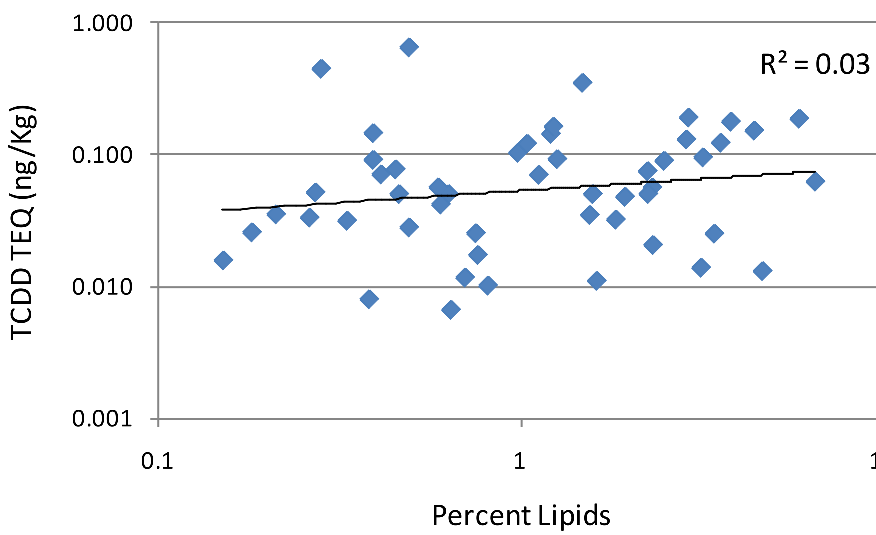


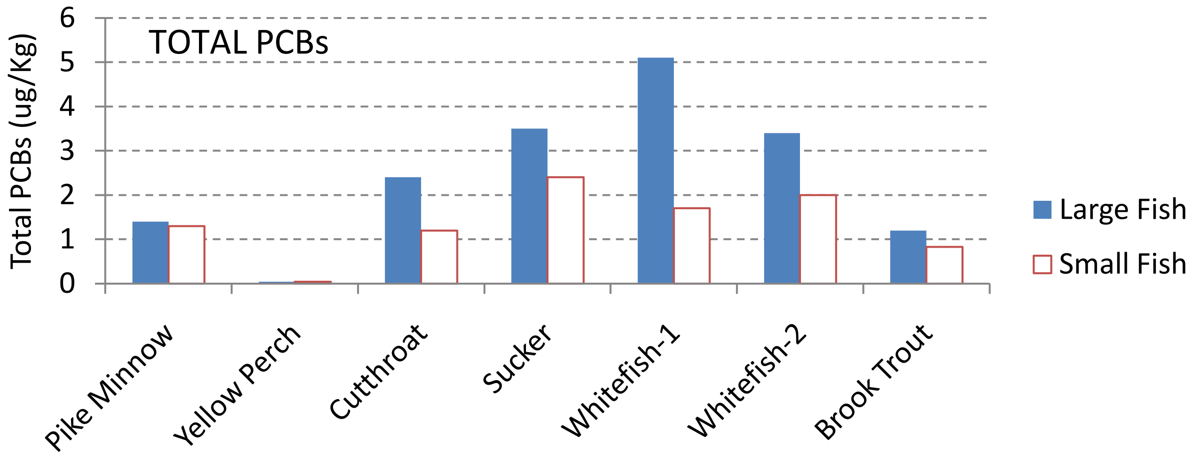
Figure 14. TCDD TEQs versus Lipid Content in Fish Fillets from Background Waterbodies.

Fish Size

Larger, older fish at the tops of food chains tend to have higher concentrations of bioaccumulative chemicals (e.g., DeVault et al., 1989).

As part of this study, two size classes of fish were analyzed for six species to provide estimates of the influence of fish size on PCB and dioxin concentrations. The samples came from seven waterbodies (see Tables 9 and 12).

Figure 15 shows how total PCB and TCDD TEQ concentrations varied by fish length. Size effects could not be assessed for TCDD because concentrations were at or below detection limits in these samples.



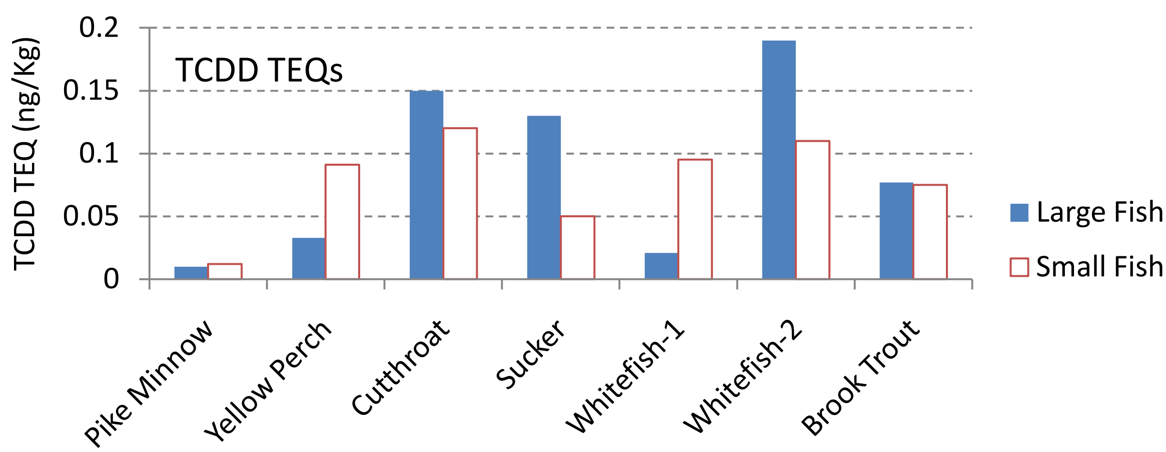


Figure 15. Total PCB congeners and TCDD TEQs in Large versus Small Fish of Six Species. (*Individual sample results from Tables 9 and 12*)

Total PCBs were clearly affected by fish size. PCB levels were substantially higher (by factors of 1.5 to 3) in five of the large fish samples out of the seven sample pairs analyzed and marginally higher in one additional pair of samples. One low-level sample had similar PCB concentrations in both large and small fish. A consistent size affect was not readily apparent for TCDD TEQs.

The Background Study focused on the larger fish more likely to be retained and eaten by anglers. The same is true of most efforts that have resulted in 303(d) listings. If there is a size bias in the background data, would tend to favor higher concentrations.

Species Differences

Contaminant residues in fish vary from species to species due to the many factors that affect bioaccumulation. This study was not designed to evaluate species differences in PCB or dioxin levels. Species were generally analyzed in accordance with their abundance and ease of collection.

Salmonids were encountered more frequently than spiny rayed fishes – 35 versus 19 samples – and thus dominate the sample set. Out of the 10 samples with the highest total PCB concentrations, seven were salmonids. Spiny rays had eight out of the 10 lowest total PCB concentrations. Of the 13 samples where TCDD was detected, 11 were salmonids. Similarly, salmonids tended to dominate TCDD TEQs, with eight out of the 10 highest concentrations.

Chemical Patterns

The PCB and PCDD/PCDF background data were examined for spatial patterns that might indicate local versus regional sources.

Penta-, hexa-, and hepta-chlorobiphenyls were the dominant PCB homologues in the background fish tissue samples. Trichlorobiphenyls were substantially more abundant in several northwest Washington waterbodies (Ozette, Baker, Sauk, and Cushman) and in one northeastern Washington lake (Sullivan) (Figure 16). Other than the suggestion of a clustering in northwest Washington, it is unclear what these locations might have in common that would cause this result. Detection limit differences between 2007 and 2008, coupled with a number of coeluting congeners in the 2007 data, obscured spatial patterns that might have existed among specific PCB congeners.

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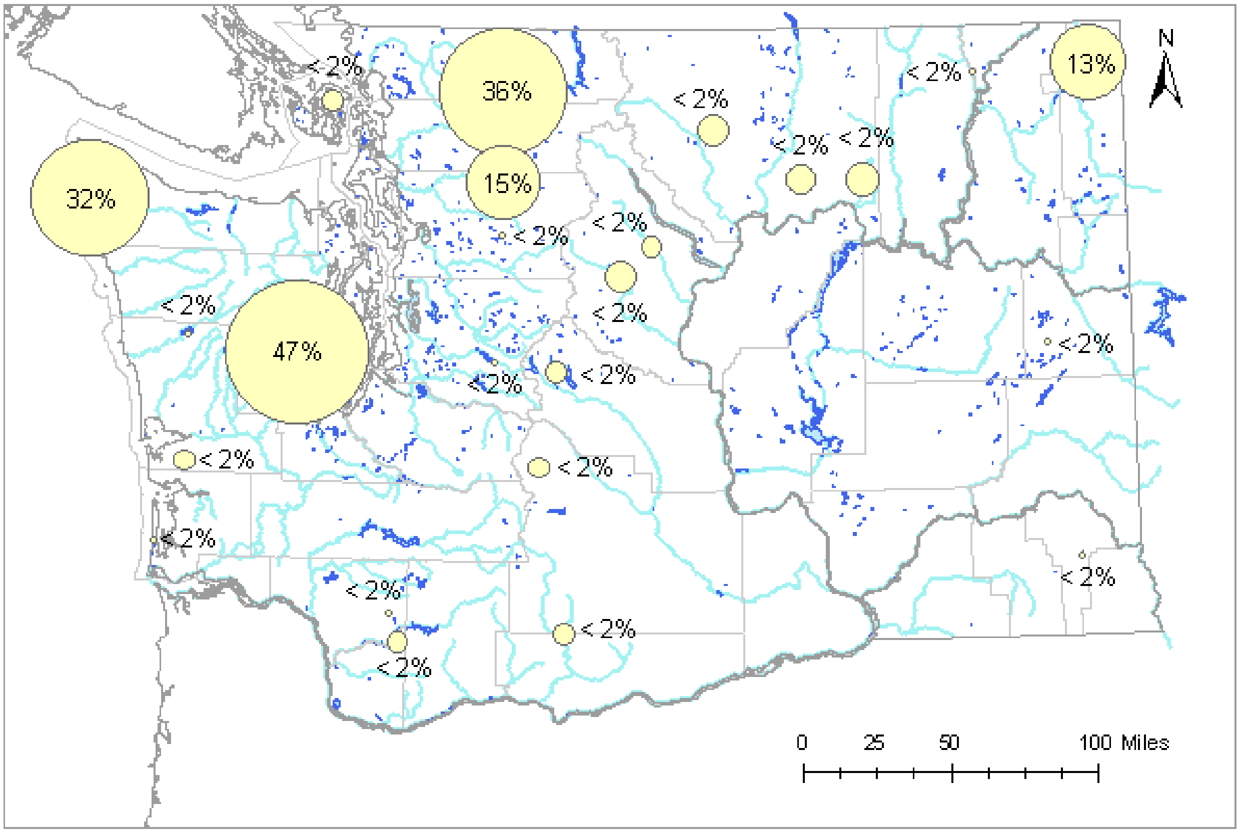


Figure 16. Relative Abundance of Trichlorobiphenyls in Fish Tissue Samples from Background Waterbodies (mean TriCB concentration as percent of total PCBs).

None of the PCDD or PCDF congeners were detected consistently enough statewide to analyze spatial patterns in the data. 1,2,3,4,7,8-HxCDF, 1,2,3,7,8-PeCDD, 1,2,3,4,6,7,8-HpCDD, and 2,3,7,8-TCDF were most frequently found, but were only reported in about half (44-56%) of the samples. TCDD was detected in about one-third (29%) of the samples (see Figure 8). On the basis of detection frequency alone, Western Washington and the West Slope of the Cascades, with eight out of the 10 samples detected, appeared to be more impacted by TCDD sources than Eastern Washington. Unlike PCB congeners, detection limits for PCDDs/PCDFs were comparable between sampling years

Comparison with Human Health Criteria

The total PCB concentrations measured in the Background Study are compared to the human health criterion used for 303(d) listing in Figure 17.

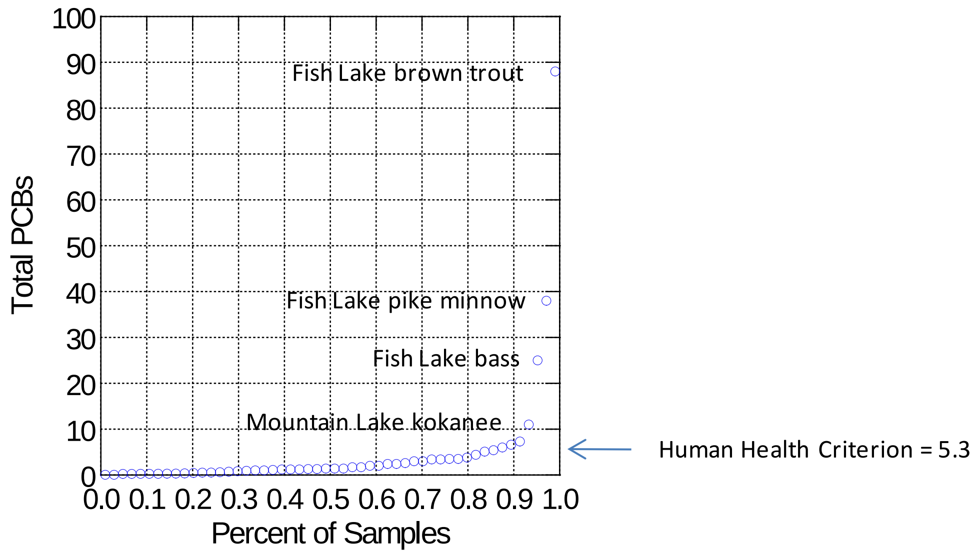
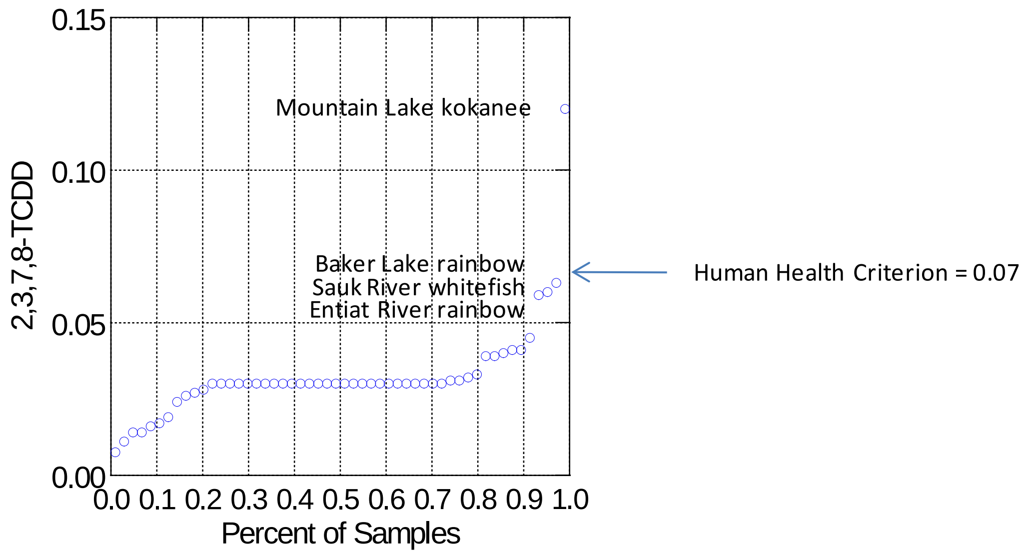


Figure 17. Total PCBs in Background Fish Fillet Samples Compared to 303(d) Listing Criterion (ug/Kg, wet weight; congener analysis).

Most samples (85%) met the 5.3 ug/Kg criterion for total PCBs. Criteria exceedances were observed for PCBs in several waterbodies on the East Slope of the Cascades. These included Fish Lake (25-88 ug/Kg), Bumping Lake (7.3 ug/Kg), Cle Elum Lake (6.6 ug/Kg), and the Klickitat River (6.0 ug/Kg). Mountain Lake on Orcas Island in the San Juans also exceeded the criterion at 11 ug/Kg. Mountain Lake is currently 303(d) listed based on a total PCB concentration of 10 ug/Kg measured in a sample of kokanee fillets collected in 2004 (Seiders et al., 2007).

Plots of the TCDD and TCDD TEQ data are in Figure 18. Only Mountain Lake (0.12 ng/Kg) exceeded (did not meet) the 0.07 ng/Kg human health criterion for TCDD. One sample each from Baker Lake, Sauk River, and the Entiat River approached this criterion, 0.059 – 0.063 ng/Kg.

Forty percent of the samples exceeded human health criteria when viewed in terms of TCDD TEQs. Mountain Lake (0.65 ng/Kg), Panamaker Creek (0.45 ng/Kg), and Baker Lake (0.35 ng/Kg) had substantially higher concentrations than other waterbodies. Mountain Lake, Ozette Lake, and the Quinault River are currently in Category 2 for TCDD TEQs exceeding the TCDD human health criterion.



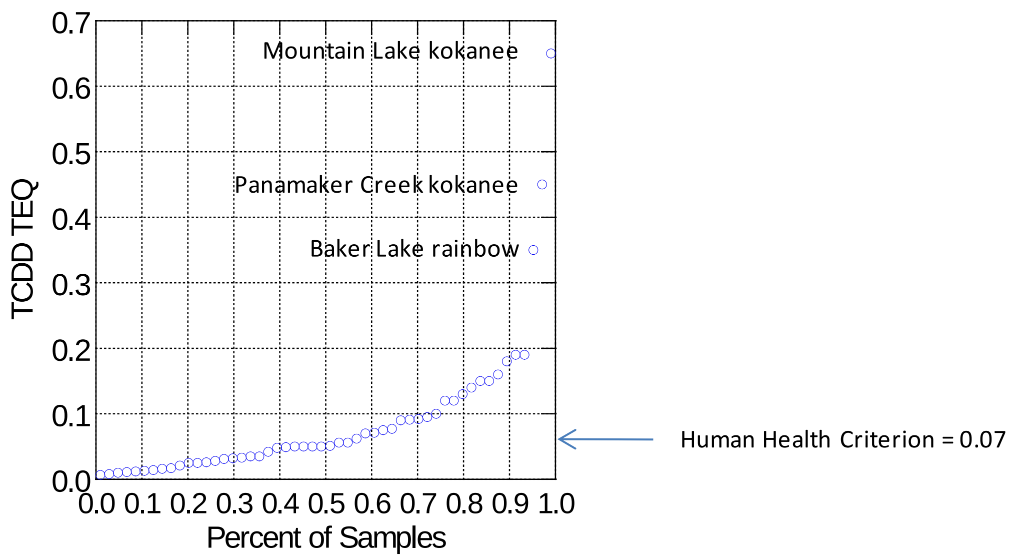


Figure 18. TCDD and TCDD TEQs in Background Fish Fillet Samples Compared to 303(d) Listing Criteria (ng/Kg, wet weight).

Table 16 summarizes the criteria exceedances observed, showing the number of waterbodies exceeding in each of the four areas where background samples were collected.

Table 16. Summary of Human Health Criteria Exceedances Observed in Fish Fillets from Background Waterbodies.

Chemical	Human Health Criterion	Percent of Samples Exceeding Criterion (n=52)	Range of Concentrations Exceeding Criterion	Region and Number of Waterbodies Where Exceedances Occurred (out of 6 each)			
				Western Washington	West Slope	East Slope	Eastern Washington
Total PCBs	5.3 ug/Kg	15%	5.4 - 88	1*		4	
TCDD	0.07 ng/Kg	2%	0.12	1*			
TCDD TEQ	0.07 ng/Kg	40%	0.071-0.65	4	5	5	4

*Mountain Lake, Orcas Island.

Four of the five exceedances for total PCBs were in lakes or rivers on the East Slope of the Cascades. The only western Washington waterbody exceeding the PCB criterion was Mountain Lake, as noted previously.

Other high elevation waterbodies on the east slope of the Cascades have also exceeded the PCB criterion in recent fish tissue studies. Total PCB levels in Keechelus Lake and Kachess Lake, the two large Yakima River reservoirs adjacent to the Cle Elum Lake reservoir, exceeded the criterion in 16 out of 19 fillet samples analyzed in 2006, with concentrations reaching 17 ug/Kg (Johnson et al., 2009 draft).

A sample of kokanee fillets analyzed in 2004 from Cascade Lake, west of Mountain Lake on Orcas Island, had a low concentration of total PCBs, 1.1 ug/Kg (Seiders et al., 2007). Cascade Lake is at a lower elevation than Mountain Lake (346 ft. versus 914 ft.). The difference in PCB concentrations could be partly due to an elevation effect.

Mountain Lake was also the only waterbody in the Background Study that exceeded the TCDD criterion. The Cascade Lake kokanee sample was not analyzed for PCDDs/PCDFs.

Criteria exceedances were common and more equitably distributed statewide for TCDD TEQs. Four to five waterbodies exceeded the criteria in each of the four regions.

The human health exceedances in background versus non-background waterbodies from the WSTMP are compared in Table 17.

Table 17. Comparison of Human Health Criteria Exceedances Observed in Background and Non-Background Waterbodies.

Chemical	Human Health Criterion	Percent of Samples Exceeding Criterion		Percent of Waterbodies Exceeding Criterion	
		Background Sites	Non-Background Sites*	Background Sites	Non-Background Sites*
		(n = 52)	(n =84 - 109)	(n=24)	(N = 46 - 57)
Total PCBs	5.3 ug/Kg	15%	73%	21%	81%
TCDD	0.07 ng/Kg	2%	30%	4%	38%
TCDD TEQ	0.07 ng/Kg	40%	73%	75%	77%

*Data from the Washington State Toxics Monitoring Program (see text).

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Conclusions

The fish tissue data generated through the 2007-08 PCB and Dioxin Background Study are summarized in Table 18.

Table 18. Summary Statistics on Background Concentrations of PCBs, TCDD, and TCDD TEQs Measured in Fish Fillets from 24 Washington Lakes, Rivers, and Streams During 2007-08 (N=52, wet weight).

Chemical	Detection Frequency	Minimum	Maximum	Mean	Median	90th Percentile
Total PCBs (ug/Kg)	98%	0.04	88	4.9	1.4	6.5
TCDD (ng/Kg)	27%	0.008 UJ	0.12	0.03 U	0.03 U	0.041
TCDD TEQ (ng/Kg)	94%	0.007	0.65	0.091	0.051	0.18

U = Not detected at or above reported result.
J = Result is an estimated value.

The following overall conclusions are indicated for PCBs and dioxins in Washington State freshwater fish:

- In non-background waterbodies, it is common for PCBs and TCDD to be higher than (exceed) Washington State human health criteria for edible fish tissue. Exceedances of the TCDD criteria are also common when viewed in terms of TCDD TEQs.

- Marginal to occasionally substantial (factor of 2 or more) exceedances of the human health criterion can be expected for PCBs in fish from background waterbodies. In the present study, the highest concentrations were encountered in waterbodies on the east slope of the Cascades, possibly due to an elevation effect.

- The TCDD human health criterion is approached but infrequently exceeded in fish from background waterbodies. TCDD sources to Washington waterbodies appear to be less widespread than PCB sources.

- Exceedances of the TCDD human health criterion when calculated using TCDD TEQs are common in background waterbodies. There appears to be a significant background contribution to the TCDD TEQ in Washington freshwater fish.

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Recommendations

1. Recommendations for prioritizing Washington State's 303(d) listings for PCBs and dioxins in edible freshwater fish tissue are provided in Table 19. Decision points in the prioritization scheme are based on: (1) fish tissue concentrations measured in the 2007-08 Background Study; (2) Washington State human health criteria; and (3) WDOH and EPA screening values. Situations where subsistence or other fishers are consuming certain fish species at especially high rates may justify allocating TMDL resources to waterbodies with lower levels of contamination.

2. Caution should be used in applying the results of this work outside the confines of 303(d). The use of statewide values may inappropriately bias outcomes, for example in MTCA actions. In view of regional variability, case-by-case decision making based on additional data gathering may be appropriate.

3. Other recommendations that follow from the Background Study include:

   - All Category 5 (the 303(d) List) and Category 2 (Waters of Concern) listings for TCDD, dioxin, and TCDD TEQs should be reviewed and a consistent rule applied for Category 5 and 2 before prioritizing sites for further action.
   - In evaluating the 303(d) listings, be cognizant of the effect that waterbody elevation, fish size, and fish species can have on the chemical residues in fish.
   - Consider using PCB TEQs to help prioritize 303(d) PCB listings for TMDLs or other follow-up work.
   - Where practical, include a high resolution GC/MS analysis for PCB congeners in fish tissue studies when the data will be used for 303(d) listing. This is especially important when marginal exceedances of criteria are anticipated.
   - Conduct verification sampling before taking action on listings for PCBs, TCDD/dioxin, or TCDD TEQs unless based on a large sample size. A range of size classes and fish species should be analyzed.

4. The Background Study identified several waterbodies that qualify for Category 5 or Category 2 listing:

   - Fish Lake, Bumping Lake, Cle Elum Lake, and the Klickitat River should be placed in Category 5 of the 303(d) list for not meeting (exceeding) the PCB human health criterion in edible fish tissue. (Mountain Lake is currently listed, see Appendix B.)
   - Mountain Lake should be placed in Category 5 of the 303(d) list for exceeding the TCDD human health criterion in edible fish tissue.
   - Cushman Lake, Loomis Lake, Baker Lake, Sauk River, Spada Lake, Patterson Lake, Entiat River, Fish Lake, Cle Elum Lake, Klickitat River, Sullivan Lake, Kettle River, Omak Lake, and South Twin Lake qualify for Category 2 listing due to the TCDD TEQ exceeding the TCDD human health criterion in edible fish tissue.

Table 19. Recommendations for Prioritizing 303(d) *Freshwater* Fish Tissue Listings for PCBs and Dioxins.

Chemical/ Concentration	Recommendation	Rationale
Total PCBs (ug/Kg) [303(d) listing criterion is 5.3 ug/Kg for Category 5: TMDL required]		
< 10	No further action	• Fish from most background waterbodies have less than 10 ug/Kg. • EPA screening level for non-carcinogenic effects for subsistence fishers is 9.8 ug/Kg.
10 - 20	Low priority for TMDL	• Concentrations sometimes encountered in background waterbodies. • EPA screening level for recreational fishers for carcinogenic effects is 20 ug/Kg.
20 - 100	Medium priority for TMDL	• Concentrations sometimes encountered in background waterbodies. • WDOH non-carcinogen screening level is 23 ug/Kg. • Concentrations above 53 ug/Kg exceed Washington human health criteria by a factor of 10 (10^{-5} risk level). • EPA screening level for recreational fishers for non-carcinogenic effects is 80 ug/Kg.
>100	High priority for TMDL	• Exceeds maximum concentration encountered in background waterbodies. • WDOH considers >100 ug/Kg as indicating strong possibility of need for fish consumption advisory.
TCDD (ng/Kg) [303(d) listing criterion is 0.07 ng/Kg for Category 5: TMDL required]		
>0.07 - 0.30	Low priority for TMDL	• Concentrations exceeding 0.07 ng/Kg potentially encountered in background waterbodies. • EPA screening level for recreational fishers for carcinogenic effects is 0.26 ng/Kg.
0.30 - 0.70	Medium priority for TMDL	• Exceeds EPA screening level for recreational fishers for carcinogenic effects.
>0.70	High priority for TMDL	• Concentrations above 0.70 ng/Kg exceed Washington human health criteria by a factor of 10 (10^{-5} risk level).
TCDD TEQs (ng/Kg) [Waters of Concern, listing criterion is 0.07 ng/Kg for Category 2: TMDL not required]		
<0.20*	No further action	• Background waterbodies often approach 0.20 ng/Kg.
0.20 - 0.70*	Low priority for follow-up action	• Within range of concentrations encountered in background waterbodies.
>0.70*	Take follow-up actions (e.g., verification sampling, source identification)	• Exceeds maximum concentration encountered in background waterbodies. • Concentrations above 0.70 ng/Kg exceed Washington human health TCDD criteria by a factor of 10 (10^{-5} risk level).

* Assumes TCDD contribution is <0.07 ng/Kg; if not, then qualifies for Category 5.

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Appendices

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Appendix A. Waterbody Numbers for 2007-08 Background Study of Lakes, Rivers, and Streams.

Table A-1. Waterbody Numbers for the PCB and Dioxin Background Study.

Region and Waterbody Name	Waterbody Number
Western Washington	
Mountain Lake	WA-02-9060
Ozette Lake	WA-20-9040
Quinault River	WA-21-2020
Cushman Lake	WA-16-9010
North River	WA-24-1010
Loomis Lake	WA-24-9040
West Slope of the Cascades	
Baker Lake	WA-04-9010
Sauk River	WA-04-1080
Spada Lake	WA-07-9710
Chester Morse Lake	WA-08-9060
Panamaker Creek	- -
Merrill Lake	WA-27-9020
East Slope of the Cascades	
Patterson Lake	WA-13-9120
Entiat River	WA-46-1020
Fish Lake	WA-56-9020
Cle Elum Lake	WA-39-9010
Bumping Lake	WA-38-9010
Klickitat River	WA-30-1010
Eastern Washington	
Kettle River	WA-60-1010
Sullivan Lake	WA-62-9190
South Twin Lake	WA-58-9040
Omak Lake	WA-49-9250
Badger Lake	WA-34-9060
Pataha Creek	WA-35-2013

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Appendix B. 2008 303(d) Category 5 Listings for PCBs in Freshwater Edible Fish Tissue.

Table B-1. Category 5 303(d) Listings for Total PCBs in Edible Fish Tissue.

Listing Detail	WRIA	Waterbody Name	Map Link
7022	13	Ward Lake	7022
7023	18	Elwha River	7023
7350	37	Yakima River	7350
8201	57	Spokane River	8201
8202	57	Spokane River	8202
8207	57	Spokane River	8207
8741	23	Chehalis River	8741
8746	24	Columbia River	8746
8755	33	Snake River	8755
8765	25	Columbia River	8765
8772	25	Columbia River	8772
8773	25	Columbia River	8773
8783	27	Columbia River	8783
8863	37	Yakima River	8863
8864	37	Yakima River	8864
8953	41	Lower Crab Creek	8953
9015	54	Spokane Lake	9015
9021	54	Spokane Lake	9021
9027	54	Spokane River	9027
9033	54	Spokane River	9033
9051	55	Little Spokane River	9051
14025	1	Whatcom Lake	14025
14036	3	Skagit River	14036
14090	9	Duwamish River	14090
14261	37	Yakima River	14261
14299	45	Wenatchee River	14299
14385	54	Spokane River	14385
14397	57	Spokane River	14397
14398	57	Spokane River	14398
14400	54	Spokane River	14400
14402	57	Spokane River	14402
14407	61	Columbia River (Franklin D. Roosevelt Lake)	14407
17164	26	Cowlitz River	17164
17299	1	Padden Lake	17299

Listing Detail	WRIA	Waterbody Name	Map Link
17366	3	Samish (West Arm) Lake	17366
17383	8	Green Lake	17383
17431	13	McIntosh Lake	17431
17484	57	Liberty Lake	17484
18801	31	Columbia River (Lake Umatilla)	18801
18802	31	Columbia River (Lake Umatilla)	18802
19120	35	Snake River	19120
19121	35	Snake River	19121
19390	36	Columbia River	19390
19391	36	Columbia River	19391
19393	36	Columbia River	19393
20045	37	Yakima River	20045
20047	37	Yakima River	20047
20219	39	Yakima River	20219
20306	45	Icicle Creek	20306
36440	54	Spokane Lake	36440
36441	54	Spokane Lake	36441
42169	12	American Lake	42169
42170	15	Kitsap Lake	42170
42171	41	Moses Lake	42171
42172	28	Vancouver Lake	42172
42173	43	Medical Lake, West	42173
42269	42	Banks Lake	42269
42386	34	Sprague Lake	42386
42412	34	Silver Lake	42412
43146	39	Keechelus Lake	43146
43215	53	Buffalo Lake	43215
43251	7	Calligan Lake	43251
43383	62	Pend Oreille River	43383
43385	36	Scooteney Reservoir	43385
43465	28	Lacamas Lake	43465
43482	8	Washington Lake	43482
52646	8	Ballinger Lake	52646
52647	62	Bead Lake	52647
52648	23	Black Lake	52648
52651	22	Chehalis River	52651
52653	25	Columbia River	52653
52654	44	Columbia River	52654
52655	45	Columbia River	52655

Listing Detail	WRIA	Waterbody Name	Map Link
52656	47	Columbia River (Lake Entiat)	52656
52657	47	Columbia River (Lake Entiat)	52657
52658	41	Columbia River (Priest Rapids Lake)	52658
52659	26	Cowlitz River	52659
52662	15	Haven Lake	52662
52663	17	Leland Lake	52663
52666	13	Long Lake	52666
52667	59	Loon Lake	52667
52668	14	Mason Lake	52668
52669	26	Mayfield Lake	52669
52670	9	Meridian Lake	52670
52671	27	Merwin Lake	52671
52673	2	Mountain Lake	52673
52674	57	Newman Lake	52674
52675	29	Northwestern Lake	52675
52676	13	Offutt Lake	52676
52683	62	Pend Oreille River	52683
52684	41	Potholes Reservoir	52684
52685	21	Queets River	52685
52686	21	Quinault River	52686
52689	25	Sacajawea Lake	52689
52690	8	Sammamish Lake	52690
52691	9	Sawyer Lake	52691
52692	26	Silver Lake	52692
52693	8	Silver Lake	52693
52695	33	Snake River	52695
52696	35	Snake River	52696
52697	35	Snake River	52697
52698	33	Snake River (Sacajawea Lake)	52698
52699	7	Snohomish River	52699
52701	14	Summit Lake	52701
52703	8	Washington Lake	52703
52704	8	Washington Lake	52704
52705	8	Washington Lake	52705
52707	45	Wenatchee River	52707
52708	1	Whatcom Lake	52708
52833	38	Cowiche Creek	52833
52935	62	Pend Oreille River	52935
52947	45	Wenatchee River	52947
53209	28	Lake River	53209

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Appendix C. 2008 303(d) Category 5 Listings for Dioxin (2,3,7,8-TCDD) in Freshwater Edible Fish Tissue.

Table C-1. Category 5 303(d) Listings for 2,3,7,8-TCDD in Edible Fish Tissue.

Listing Detail	WRIA	Waterbody Name	Map Link
42381	43	Medical Lake, West	42381
42405	34	Sprague Lake	42405
42410	54	Spokane Lake	42410
42411	54	Spokane River	42411
42431	34	Silver Lake	42431
42434	41	Moses Lake	42434
42440	42	Banks Lake	42440
42443	12	American Lake	42443
51543	8	Ballinger Lake	51543
51544	62	Bead Lake	51544
51549	25	Columbia River	51549
51552	26	Cowlitz River	51552
51554	17	Leland Lake	51554
51556	13	Long Lake	51556
51560	9	Meridian Lake	51560
51562	48	Methow River	51562
51572	41	Potholes Reservoir	51572
51577	9	Sawyer Lake	51577
51578	26	Silver Lake	51578
51581	33	Snake River	51581
51582	35	Snake River	51582
51583	33	Snake River (Sacajawea Lake)	51583
51584	7	Snohomish River	51584
51586	54	Spokane River	51586
51587	57	Spokane River	51587
51588	41	Stan Coffin Lake	51588
51591	8	Washington Lake	51591
51592	8	Washington Lake	51592
51593	8	Washington Lake	51593
51595	1	Whatcom Lake	51595
53204	28	Vancouver Lake	53204
53206	28	Lake River	53206
34887	37	Yakima River	34887
34889	39	Yakima River	34889
34904	36	Columbia River	34904

Listing Detail	WRIA	Waterbody Name	Map Link
34905 34913	37 37	Yakima River Yakima River	34905 34913
34926	36	Columbia River	34926
34927 34942	35 35	Snake River Snake River	34927 34942
36354	23	Chehalis River	36354
36355	23	Dillenbaugh Creek	36355
43061	47	Chelan Lake	43061
43094	7	Dorothy Lake	43094
43128	39	Keechelus Lake	43128
43162	6	Lone Lake	43162
43197	53	Buffalo Lake	43197
43233	7	Calligan Lake	43233

Appendix D. 2008 Category 2 Listings for TCDD TEQs in Freshwater Edible Fish Tissue.

Table D-1. Category 2 Listings for TCDD TEQs in Edible Fish Tissue.

Listing Detail	WRIA	Waterbody Name	Map Link
42437	15	Kitsap Lake	42437
51596	8	Ballinger Lake	51596
51597	62	Bead Lake	51597
51598	22	Chehalis River	51598
51599	22	Chehalis River	51599
51600	25	Columbia River	51600
51601	44	Columbia River	51601
51602	45	Columbia River	51602
51603	47	Columbia River (Lake Entiat)	51603
51604	41	Columbia River (Priest Rapids Lake)	51604
51605	26	Cowlitz River	51605
51606	15	Haven Lake	51606
51607	17	Leland Lake	51607
51609	13	Long Lake	51609
51610	59	Loon Lake	51610
51613	9	Meridian Lake	51613
51614	27	Merwin Lake	51614
51615	48	Methow River	51615
51616	2	Mountain Lake	51616
51618	29	Northwestern Lake	51618
51620	20	Ozette Lake	51620
51622	34	Palouse River	51622
51623	34	Palouse River	51623
51624	34	Palouse River, S.F.	51624
51625	41	Potholes Reservoir	51625
51626	21	Queets River	51626
51627	21	Quinault River	51627
51629	8	Sammamish Lake	51629
51630	9	Sawyer Lake	51630
51631	26	Silver Lake	51631
51632	3	Skagit River	51632
51633	33	Snake River	51633
51634	35	Snake River	51634
51635	35	Snake River	51635
51636	33	Snake River (Sacajawea Lake)	51636

Listing Detail	WRIA	Waterbody Name	Map Link
51637	7	Snohomish River	51637
51638	54	Spokane River	51638
51639	57	Spokane River	51639
51640	57	Spokane River	51640
51641	41	Stan Coffin Lake	51641
51642	14	Summit Lake	51642
51643	13	Ward Lake	51643
51644	8	Washington Lake	51644
51645	8	Washington Lake	51645
51646	8	Washington Lake	51646
51647	45	Wenatchee River	51647
51648	1	Whatcom Lake	51648

Appendix E. Latitude and Longitude of Waterbodies Sampled for the 2007-08 PCB and Dioxin Background Study.

Table E-1. Latitude and Longitude of Waterbodies Sampled for the 2007-08 PCB and Dioxin Background Study.

Region and Waterbody Name	Location	Latitude	Longitude
Western Washington			
Mountain Lake	Moran State Park, Orcas Island	48.66	122.82
Ozette Lake	Olympic NP	48.10	124.64
Quinault River	Quinault Reservation/Olympic NP	47.54	123.74
Cushman Lake	Olympic NF	47.47	123.25
North River	Chehalis River drainage	46.83	123.59
Loomis Lake	Loomis Lake SP, Long Beach	46.44	124.04
West Slope of the Cascades			
Baker Lake	N. Cascade NP/Baker-Snoqualmie NF	48.72	121.66
Sauk River	Baker-Snoqualmie NF	48.10	121.39
Spada Lake	Baker-Snoqualmie NF	47.97	121.65
Chester Morse Lake	Baker-Snoqualmie NF	47.39	121.70
Panamaker Creek	Gifford Pinchot NF	46.06	122.29
Merrill Lake	Gifford Pinchot NF	46.09	122.33
East Slope of the Cascades			
Patterson Lake	Okanogan NF	48.46	120.24
Entiat River	Wenatchee NF	48.00	120.61
Fish Lake	Wenatchee NF	47.83	120.70
Cle Elum Lake	Wenatchee NF	47.29	121.11
Bumping Lake	Wenatchee NF	46.85	121.32
Klickitat River	Klickitat County	45.71	121.26
Eastern Washington			
Kettle River	Colville NF	48.89	118.60
Sullivan Lake	Colville NF	48.80	117.29
South Twin Lake	Colville Indian Reservation	48.27	118.39
Omak Lake	Colville Indian Reservation	48.28	119.40
Badger Lake	South of Turnbull NWR	47.35	117.63
Pataha Creek	Umatilla NF	46.26	117.53

NAD 83.
NP – National Park; NF – National Forest; NWR – National Wildlife Refuge.

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Appendix F. Results of Duplicate Samples

Table F-1. Results of Duplicate (Split) Sample Analyses.

Chemical/ Sample No.	Field ID	Subsample #1	Subsample #2	RPD
Total PCBs: Congeners (ug/Kg)				
081201107	FISHNPM	38.2	38.5	1%
081201118	OMAKCTT	3.84	3.86	1%
081201121	KLICKMWF	6.03	5.06	17%
081201262	PANAMKOK	3.01	3.17	5%
07494503	OZETTNPM	1.38	1.79	26%
07494537	SPADACTT	2.38	1.20	66%
Total PCBs: Aroclor-equivalents (ug/Kg)				
0812011-13	SNOQMWF*	14.4 J	14.2 J	1%
0812011-27	STEVEKOK*	9.8 J	9.6 J	2%
07494508	SAMLNPM*	13.8 J	15.3 J	10%
07494519	SULBNT*	28.4 J	32.2 J	13%
TCDD (ng/Kg)				
081201107	FISHNPM	0.03 U	0.03 U	- -
081201118	OMAKCTT	0.03 U	0.03 U	- -
081201121	KLICKMWF	0.041	0.052	24%
081201262	PANAMKOK	0.03 NJ	0.03 UJ	- -
07494503	OZETNPML	.033 UJ	0.039 UJ	- -
07494537	SPADCTTL	0.045 UJ	0.024 UJ	- -
TCDD TEQs (ng/Kg)				
081201107	FISHNPM	0.0250 J	0.50 U	- -
081201118	OMAKCTT	0.0130 J	0.0167 J	25%
081201121	KLICKMWF	0.187	0.156	18%
081201262	PANAMKOK	0.448 J	0.422	6%
07494503	OZETNPML	0.010 J	0.018 J	58%
07494537	SPADCTTL	0.145 J	0.067 J	73%
Percent Lipids				
081201107	FISHNPM	3.43	2.91	16%
081201118	OMAKCTT	4.66	4.58	2%
081201262	PANAMKOK	0.28	0.28	0%

U = Not detected at or above reported result.
J = Result is an estimated value.
NJ = There is evidence the analyte is present. The associated numerical result is an estimate.
*WSTMP samples analyzed in conjunction with samples from present 2007-08 study.

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Appendix G. Chemical and Biological Data for the 2007-08 PCB and Dioxin Background Study.

Table G-1. Chemical Data for the PCB and Dioxin Background Study.

(See Ecology's Environmental Information Management system for individual congener data, www.ecy.wa.gov/eim/.)

Site	Species Code	Sample Number	Date Collected	Total PCB Congeners (ug/Kg)		Total PCB Aroclors (ug/Kg)		2378 TCDD (ng/Kg)		2378 TCDD TEQ (ng/Kg)		Lipids (%)
Badger Lake	LMB	081201123	11/18/08	1.38		1.3		0.03	U	0.050	U	0.46
Badger Lake	RBT	081201122	11/18/08	1.01		1.9	U	0.03	U	0.050	U	0.63
Baker Lake	CTT	07494512	10/9/07	1.16	J	0.98	U	0.031	UJ	0.092	J	1.26
Baker Lake	LSS	07494513	10/9/07	0.51	J	na		0.011	NJ	0.035	J	0.21
Baker Lake	RBT	07494511	10/9/07	0.91	J	0.98	U	0.063	NJ	0.35	J	1.48
Bumping Lake	BKT	081201117	10/16/08	7.27		na		0.03	U	0.025	J	0.75
Bumping Lake	CTT	081201115	10/16/08	2.61		1.9	J	0.03	U	0.014		3.15
Chester Morse Lake	RBT	07494545	11/5/07	1.36	J	1.2	J	0.024	UJ	0.070	J	1.12
Cle Elum Lake	LSS	081201260	7/17/08	6.55		na		0.03	U	0.15	J	4.42
Cle Elum Lake	MWF	081201102	10/30/08	5.14		6.0	J	0.03	U	0.021	J	2.32
Cle Elum Lake	MWF	081201250	10/30/08	1.65		na		0.03	U	0.095	J	3.19
Panamaker Cr.	KOK	081201262	11/24/08	3.01		na		0.03	NJ	0.45	J	0.28
Cushman Lake	KOK	07494515	10/4/07	1.14	J	2.0	U	0.016	NJ	0.14	J	1.21
Cushman Lake	LSS	07494520	9/27/07	0.60	J	na		0.0075	UJ	0.051	J	0.27
Cushman Lake	MWF	07494516	9/27/07	1.30	J	1.6	J	0.014	NJ	0.056	J	2.31
Entiat River	BKT	081201259	7/28/08	0.29		na		0.03	U	0.049	J	na
Entiat River	RBT	081201255	7/28/08	0.53		na		0.059	NJ	0.090	J	2.49
Fish Lake	BNT	081201109	7/16/08	87.7		98	J	0.03	U	0.062	J	6.53
Fish Lake	LMB	081201106	7/16/08	24.9		24	J	0.03	U	0.048		1.94
Fish Lake	LSS	081201258	7/16/08	3.54		na		0.03	U	0.13	J	2.87
Fish Lake	LSS	081201257	7/16/08	2.38		na		0.03	U	0.050		2.25
Fish Lake	NPM	081201107	7/16/08	38.2		42	J	0.03	U	0.025	J	3.43
Fish Lake	RBT	081201108	7/16/08	5.41		2.1	J	0.03	U	0.026		0.18
Kettle River	LSS	07494525	10/10/07	0.24	UJ	na		0.04	UJ	0.008	J	0.38
Kettle River	RBT	07494526	10/10/07	0.31	J	0.99	U	0.028	UJ	0.16	J	1.23
Klickitat River	MWF	081201121	12/8/08	6.03		8.8	J	0.041		0.19		5.89

Site	Species Code	Sample Number	Date Collected	Total PCB Congeners (ug/Kg)		Total PCB Aroclors (ug/Kg)		2378 TCDD (ng/Kg)		2378 TCDD TEQ (ng/Kg)		Lipids (%)
Loomis Lake	LMB	081201254	11/5/08	0.35		na		0.03	U	0.042		0.6
Loomis Lake	YP	081201252	11/5/08	0.044	N	na		0.03	U	0.033		0.26
Loomis Lake	YP	081201253	11/5/08	0.044	NJ	na		0.031	NJ	0.091	J	0.39
Merrill Lake	CTT	081201133	6/24/08	4.44		1.3	J	0.03	U	0.050	U	1.58
Mountain Lake	KOK	081201261	11/12/08	11.4		na		0.12		0.65		0.49
North River	CTT	081201132	8/29/08	1.04		2.2	UJ	0.032	NJ	0.032	J	1.83
Omak Lake	CTT	081201118	7/1/08	3.84		2.2	UJ	0.03	U	0.013	J	4.66
Omak Lake	PEA	081201120	7/1/08	3.02		1.3	J	0.03	U	0.077	J	0.45
Ozette Lake	LMB	07494506	9/12/07	0.26	J	na		0.019	UJ	0.028	J	0.49
Ozette Lake	NPM	07494503	9/12/07	1.38	J	1.7	J	0.033	UJ	0.010	J	0.81
Ozette Lake	NPM	07494504	9/12/07	1.28	J	na		0.026	UJ	0.012	J	0.7
Ozette Lake	YP	07494505	9/12/07	0.25	J	na		0.014	UJ	0.016	J	0.15
Pataha Creek	BKT	081201114	10/15/08	0.71		2.2	UJ	0.03	U	0.056	J	0.59
Patterson Lake	RBT	081201263	12/23/08	3.43		na		0.03	U	0.031		0.33
Patterson Lake	YP	081201251	12/23/08	0.23		na		0.03	U	0.103	J	0.98
Quinault River	CTT	081201101	8/28/08	0.45		1.1	U	0.03	U	0.071	J	0.41
Sauk River	MWF	07494514	10/4/07	1.97	J	3.7	J	0.06	NJ	0.18	J	3.81
South Twin L.	BKT	081201103	6/25/08	1.17		1.1	U	0.03	U	0.075		2.24
South Twin L.	BKT	081201256	6/25/08	0.83		na		0.03	U	0.035	J	1.55
South Twin L.	LMB	081201104	6/25/08	0.25	NJ	1.7	UJ	0.03	U	0.007		0.64
South Twin L.	RBT	081201105	6/25/08	na		1.1	U	na		na		1.25
Spada Lake	CTT	07494537	10/17/07	2.38	J	4.1	J	0.045	UJ	0.15	J	0.39
Spada Lake	CTT	07494538	10/17/07	1.21	J	na		0.027	NJ	0.12	J	1.04
Spada Lake	RBT	07494539	10/17/07	1.70	J	na		0.039	UJ	0.017	J	0.76
Sullivan Lake	CTT	07494521	9/17/07	3.53	J	6.5	J	0.017	NJ	0.12	J	3.57
Sullivan Lake	MWF	07494522	9/17/07	3.37	J	4.9	J	0.041	NJ	0.19	J	2.91
Sullivan Lake	MWF	07494523	9/17/07	1.99	J	na		0.039	UJ	0.011	J	1.62

Table G-2. Biological Data on Fish Samples Collected for the 2007-08 PCB and Dioxin Background Study.

Site	Species Code	Mean Total Length (mm)	Mean Weight (g)	Mean Age (years)	# Fish in Composite
Badger Lake	LMB	244	189	3.0	5
Badger Lake	RBT	300	279	1.0	5
Baker Lake	CTT	235	121	2.2	5
Baker Lake	LSS	366	411	na	5
Baker Lake	RBT	215	103	1.0	5
Bumping Lake	BKT	237	110	2.7	3
Bumping Lake	CTT	256	151	1.0	5
Chester Morse Lake	RBT	412	603	3.6	5
Cle Elum Lake	LSS	495	1355	15.2	5
Cle Elum Lake	MWF	353	428	5.4	5
Cle Elum Lake	MWF	258	149	2.0	5
Panamaker Creek	KOK	352	353	2.0	4
Cushman Lake	KOK	254	146	3.0	5
Cushman Lake	LSS	295	262	na	5
Cushman Lake	MWF	276	181	6.0	5
Entiat River	BKT	143	75	3.5	2
Entiat River	RBT	200	85	4.0	5
Fish Lake	BNT	487	1430	4.4	5
Fish Lake	LMB	425	1371	7.4	5
Fish Lake	LSS	409	804	7.8	5
Fish Lake	LSS	370	571	5.8	5
Fish Lake	NPM	404	620	6.8	5
Fish Lake	RBT	313	241	1.0	5
Kettle River	LSS	262	165	na	5
Kettle River	RBT	283	193	2.0	5
Klickitat River	MWF	413	724	5.0	5
Loomis Lake	LMB	198	110	1.0	4
Loomis Lake	YP	221	155	1.8	4
Loomis Lake	YP	170	68	1.0	4
Merrill Lake	CTT	307	274	3.0	5
Mountain Lake	KOK	270	160	2.6	5
North River	CTT	219	102	2.0	5
Omak Lake	CTT	385	516	2.2	5
Omak Lake	PEA	233	116	9.0	7

Site	Species Code	Mean Total Length (mm)	Mean Weight (g)	Mean Age (years)	# Fish in Composite
Ozette Lake	LMB	377	768	3.8	5
Ozette Lake	NPM	377	433	9.0	5
Ozette Lake	NPM	318	267	6.8	5
Ozette Lake	YP	251	199	4.0	5
Pataha Creek	BKT	174	51	3.6	19
Patterson Lake	RBT	263	185	1.0	5
Patterson Lake	YP	174	72	2.0	5
Quinault River	CTT	276	175	3.3	4
Sauk River	MWF	255	173	2.5	4
South Twin Lake	BKT	297	308	1.2	5
South Twin Lake	BKT	243	156	1.0	3
South Twin Lake	LMB	230	193	4.0	5
South Twin Lake	RBT	302	321	1.0	5
Spada Lake	CTT	291	173	3.4	5
Spada Lake	CTT	229	102	2.4	5
Spada Lake	RBT	241	113	2.0	4
Sullivan Lake	CTT	300	267	2.4	5
Sullivan Lake	MWF	265	164	2.6	5
Sullivan Lake	MWF	247	125	2.2	5

Species Codes: BKT = Brook trout, BNT = Brown trout, CTT = Cutthroat trout, KOK = Kokanee salmon, LMB = Largemouth bass, LSS = Largescale sucker, MWF = Mountain whitefish, NPM = Northern pikeminnow, PEA = Peamouth, RBT = Rainbow trout, YP = Yellow Perch

Appendix H. Toxicity Equivalency Factors for PCBs, Dioxins, and Furans.

Table H-1. Human and Mammalian Toxic Equivalency Factors (TEFs) for PCBs, Dioxins, and Furans.

Compound	WHO (2005) TEF*
Non-ortho substituted PCBs	
PCB-77	0.0001
PCB-81	0.0003
PCB-126	0.1
PCB-169	0.03
Mono-ortho substituted PCBs	
PCB-105	0.00003
PCB-114	0.00003
PCB-118	0.00003
PCB-123	0.00003
PCB-156	0.00003
PCB-157	0.00003
PCB-167	0.00003
PCB-189	0.00003
Chlorinated Dibenzo-p-dioxins	
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
OCDD	0.0003
Chlorinated Dibenzofurans	
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.03
2,3,4,7,8-PeCDF	0.3
1,2,3,4,6,7,8-HpCDF	0.1
1,2,3,4,7,8,9-HpCDF	0.1
1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.01
2,3,4,6,7,8-HxCDF	0.01
OCDF	0.0003

Van den Berg et al., 2006.

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Appendix I. Glossary, Acronyms, and Abbreviations

Glossary

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards, and are not expected to improve within the next two years.

90th percentile: A statistical number obtained from a distribution of a data set, above which 10% of the data exists and below which 90% of the data exists.

Background: For this study, denotes a waterbody where the only known or likely PCB or dioxin source of significance is the atmosphere.

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Dioxin: Polychlorinated dibenzo-p-dioxins.

Furan: Polychlorinated dibenzofuran.

Exceeded Criteria: Did not meet criteria.

Salmonid: Any fish that belong to the family *Salmonidae*. Basically, any species of salmon, trout, or char. www.fws.gov/le/ImpExp/FactSheetSalmonids.htm.

Spiny Rayed Fish: Fish with fins supported by both spines and soft rays, such as bass and yellow perch, as opposed to salmonids and other soft rayed fish.

Total Maximum Daily Load (TMDL): A distribution of a substance in a waterbody designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

BC	British Columbia, Canada
Ecology	Washington State Department of Ecology
EA	Environmental Assessment
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System
Manchester	Ecology Manchester Environmental Laboratory
MTCA	Model Toxics Control Act
NTR	National Toxics Rule
PBT	persistent, bioaccumulative, and toxic substance
PCB	polychlorinated biphenyls
PCDD/Fs	polychlorinated dibenzo-p-dioxins and –furans
QA/QC	Quality Assurance/Quality Control
RPD	Relative percent difference
SOP	Standard operating procedures
TCDD	tetrachlorodibenzo-p-dioxin
TEF	Toxicity Equivalent Factor
TEQ	Toxic Equivalent
TMDL	Total Maximum Daily Load (water cleanup plan)
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDOH	Washington Department of Health
WRIA	Water Resources Inventory Area
WSTMP	Washington State Toxics Monitoring Program

Units of Measurement

g	a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams.
mm	millimeter, one thousandth of a meter
ng/Kg	nanograms per kilogram (parts per trillion)
ng/L	nanograms per liter (parts per trillion)
pg/L	picograms per liter (parts per quadrillion)
ug/Kg	micrograms per kilogram (parts per billion)