Regional Environmental Monitoring and Assessment Program:

2009 Lower mid-Columbia River Ecological Assessment Final Report

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List of Abbreviations

Abbreviation	Definition
ATON	Aid to Navigation
<	Less Than
µg/L	Micrograms per Liter
C	Centigrade
CERC	USGS Columbia Environmental Research Center
C.I.	Confidence Interval
CDF	Cumulative Distribution Function
cm	Centimeter
CR	Columbia River
CRTRWG	Columbia River Toxics Reduction Working Group
DDD	Dichloro-diphenyl-dichloroethane
DDE	Dichloro-diphenyl-dichloroethylene
DDT	Dichloro-diphenyl-trichloroethane
DEQ	Oregon Department of Environmental Quality
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DS or D/S	Downstream
E. coli	Escherichia coli
EPA	United States Environmental Protection Agency
EST	Environmental Sampling Technologies, Inc.
g	Gram
g/day	Grams per Day
GIS	Geographic Information System
GPS	Global Positioning System
HRGC/HRMS	High Resolution Gas Chromatography / High Resolution Mass Spectrometry
K_{ow}	Octanol-water Coefficients
L or l	Liter
LASAR	Laboratory Analytical Storage and Retrieval database
LCREP	Lower Columbia River Estuary Partnership
LCS	Laboratory Control Standard
LCS	Laboratory Control Sample
LIMS	Laboratory Information Management System
LMC	Lower-Middle-Columbia River
LOD	Limit of Detection
LOQ	Limit of Quantitation
m	Meter
mg/Kg wet wt	Millograms per Kilogram Wet Weight
mg/l	Milligrams per liter
Mkr	Marker (aid to navigation)
ml	Milliliter
mm	Millimeter
MPN	Most Probable Number
MS	Matrix Spike
NA	Not Applicable
ng/Kg wet wt	Nanograms per Kilogram Wet Weight
ng/SPMD	Nanograms per Semipermeable Membrane Device
NGO	Non-governmental Organization
NH_3 –N	Ammonia reported as nitrogen
NO_2 +NO_3 –N	Nitrite plus Nitrate reported as nitrogen
NRSA	National Rivers and Streams Assessment
NTU	Nephelometric Turbidity Units

Abbreviation	Definition
OAR	Oregon Administrative Rules
ORP	Oxidation-Reduction Potential
P.I.	Principal Investigator
PAH	Polycyclic Aromatic Hydrocarbon
PBDE	Polybrominated diphenylether
PCB	Polychlorinated biphenyl
PGE	Portland General Electric
PO_4-P	Phosphate reported as phosphorus
PRC	Performance Reference Compound
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RARE	Regional Applied Research Effort
REMAP	Regional Environmental Monitoring and Assessment Program
RM	River Mile
RPD	Relative Percent Difference
SAP	Sampling and Analysis Plan
SOP	Standard Operating Procedure
SPMD	Semipermeable Membrane Device
SRM	Standard Reference Material
Std. Dev.	Standard Deviation
SV	Screening Value
TOC	Total Organic Carbon
TSS	Total Suspended Solids
UMC	Upper-Middle-Columbia River
US or U/S	Upstream
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WDOE	Washington Department of Ecology
YSI	Yellow Springs Instruments, Inc.

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Introduction

The Columbia River Basin has been a priority for States, Tribes, Federal Agencies, and others for several years. The Basin was identified by EPA as one of seven Great Water Bodies in EPA's 2006-2011 Strategic Plan (USEPA, 2006). The goal of EPA's Strategic Plan for the Columbia Basin is to prevent water pollution, and improve and protect water quality and ecosystems to reduce risks to human health and the environment. EPA studies and state monitoring programs have found significant levels of toxins in fish and the water of the Columbia River.

Accumulation of toxic contaminants in fish threatens the survival of fish species, and human consumption of these fish can lead to health problems. Many governments, communities, and citizens have rallied to launch long term and intensive recovery efforts to restore fish health and populations in the Columbia River. Contaminants, such as polychlorinated biphenyls (PCBs) and mercury, have been found in various fish species in rivers throughout the Columbia River Basin. To ensure the continued good health of the citizens of the Columbia River Basin, the states issue fish consumption advisories for specific fish species to protect the general public or sensitive populations such as women of childbearing age, nursing mothers, pregnant women, and children.

The mainstem Columbia River (Bonneville Dam to Grand Coulee) and its tributaries have several fish consumption advisories issued by Oregon and Washington. Oregon has a crayfish and clam advisory for the pool behind Bonneville Dam due to elevated PCB levels. Washington fish consumption advisories for Columbia tributaries include the Yakima River (DDT and DDE), the Walla Walla River (PCBs), and the Wenatchee River (PCBs and Hg). Water quality is also an important factor in the survival of other wildlife and plants in the Columbia River Basin. The Columbia River is water quality limited for DDT, DDE, PCBs, arsenic, and PAHs. The states, tribes, federal government, and non-governmental organizations (NGOs) are all engaged in efforts to restore and improve the water, land, and air quality of the Columbia River Basin and have committed to work together to restore critical ecosystems.

The opportunity to participate in a toxics study of the mid-Columbia River couldn't have come at a better time for Oregon. In 2007, the Oregon Department of Environmental Quality received funds from Oregon Legislature to establish a watershed-based toxics monitoring program for Oregon's waters. DEQ began implementing the program in early 2008 with an initial focus on the Willamette Basin. Since 2008, DEQ laboratory staff collected water samples in ten basins across the state. This sampling is continuing through 2012 and 2013 to complete the initial statewide effort. Information collected as part of the Columbia River project will help to identify issues on the Columbia River and provide insights in the major tributaries that feed the Columbia River in Oregon. This will help to shape the toxics monitoring program moving forward.

Background

The 2009, the EPA published the "Columbia River Basin: State of the River Report for toxics" which identified mercury, DDT and its breakdown products, polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs), flame retardants, as the most widespread contaminants in the Columbia River Basin. In addition, the report highlighted the general lack of toxics data along many reaches of the Columbia River. In particular, there is a general lack of knowledge regarding the extent of contamination in the mid-Columbia. Current monitoring efforts are targeted to specific sites, or are based on sampling designs that preclude making inferences outside of the set of sampled sites. A probability-based assessment of the lower Columbia River estuary was conducted in 2000 as part of the National Coastal Assessment (Hayslip, et al., 2007), but nothing similar has been attempted for the remainder of the river.

States often omit or inadequately address large or great rivers in their comprehensive water quality assessments, and Oregon is no exception. The DEQ monitors Oregon's major Columbia River tributaries as part of its ambient monitoring program for conventional pollutants, but has done little monitoring for toxic contaminants in water or fish tissue.

This project fills an important data gap by providing information on the spatial extent and major tributary concentrations on the following suite of chemical contaminants:

- DDT and breakdown products (fish tissue and Semi-permeable Membrane Devices)
- Chlorinated pesticides (fish tissue and SPMDs)
- PCB congeners (fish tissue and SPMDs)
- PBDE congeners (fish tissue and SPMDs)
- PAH (SPMDs)
- Arsenic, copper, lead, selenium (total recoverable in water)
- Mercury and methylmercury, total and dissolved (water)
- Total mercury (fish tissue)
- Conventional water quality parameters

The EPA Office of Water is implementing a series of National Aquatic Resource Surveys for various types of waterbodies. The National River and Stream Assessment (NRSA) is the component that is intended to assess the condition of all flowing waters (including large and great rivers). The feasibility of the proposed field methods for NRSA has not been robustly demonstrated for large rivers like the Columbia. Also, assessing contaminant conditions in synoptic resource surveys may require approaches that integrate conditions over time, as individual grab samples may not provide representative estimates of concentrations or exposure.

This study builds DEQ's capacity by testing a probability-based survey design and new methods for acquiring contaminant data for large river systems; and provides an initial assessment of contaminant conditions in the middle portion of the Columbia River. The mid-Columbia River is divided into an upper reach (UMC) that is entirely within the state of Washington (from Grand Coulee Dam to just upstream of McNary Dam), and a lower reach (LMC) that forms the border between the states of Washington and Oregon (from just upstream of McNary Dam to Bonneville dam, which includes approximately 150 river miles). This study is intended to address important research questions regarding assessing the ecological condition of large rivers, and to collect information from the LMC to support the goals of Oregon's Water Quality Toxics Monitoring Program to protect human health and other beneficial uses.

Outputs from this project contribute to several real environmental outcomes. It demonstrates the feasibility of large river survey designs, sampling methods and ecological indicators relevant to water and fish tissue contaminants, and provides the first statistically valid assessment on the condition of the LMC based on these indicators.

One of EPA's strategic targets for the Columbia River is making a ten percent reduction in the mean concentration of contaminants of concern found in water and fish tissue(USEPA, 2006). This project will improve DEQ's, EPA Region 10's, and Northwestern States and Tribes' ability to monitor large rivers, assess their condition relative to contaminants, and determine if strategic targets are being met.

This assessment identifies the extent of chemical contamination throughout the LMC mainstem, reports potential tributary sources, and provides the DEQ with an improved approach for tracking and reporting on the strategic target listed above. It's an important step towards DEQ's compliance with EPA guidance for improving state and tribal capacity to monitor and report on water quality, including the implementation of a comprehensive state monitoring strategy and collaboration on statistically-valid surveys of the Nation's waters.

The project's Access database contributes to addressing primary DEQ data needs in the mid-Columbia River Basin as identified by DEQ and the EPA Columbia River Toxics Reduction Working Group (CRTRWG; (http://yosemite.epa.gov/r10/ECOCOMM.NSF/Columbia/ Toxics+Reduction). The data also contribute to CRTRWG initiatives for implementing long-term monitoring and research programs, and to an ongoing ecological assessment of the entire Columbia River by EPA Region 10 (USEPA Region 10, 2009b). The data also provide States and Tribes within Region 10 with a base for tracking changes; and information for making management decisions, directing protection and restoration efforts, and estimating the extent of contamination in the Columbia River.

Primary Objectives

I. Evaluate the feasibility of implementing a probability-based sampling design to assess the ecological condition of the mid-Columbia River, and the potential for integration with designs being used for:

A. NRSA and the state water quality monitoring strategy for Oregon
B. Proposed multi-agency long-term monitoring and research programs advocated by the CRTRWG.

II. Assess ecological contaminant conditions in the water column and fish tissue for the LMC (based on summer sampling), to answer the following questions:

A. What percent of the LMC river length is characterized by poor physical habitat conditions?

B. What percent of the LMC river length has impaired water quality for conventional parameters? (e.g., E. coli, dissolved oxygen, pH, Secchi depth, turbidity, total PO_4-P, NO_2 +NO_3 –N, NH_3 –N, chlorophyll *a*, and total suspended solids)

C. What is the extent of mercury concentrations (total and methylmercury) and methylization cofactors (redox-potential, total organic carbon, dissolved organic carbon, sulfate, selenium, and water hardness) in the LMC?

D. What is the extent of priority contaminants in the water column and common food-fish fillets?

E. What percent of the river length is potentially at risk from contaminants (i.e., that exceed criteria for either human or wildlife consumption)?

III. Compare contaminant conditions in the mainstem LMC with those near the mouths of major tributaries.

IV. Evaluate stressor indicators and associated methods to assess ecological condition in the LMC, specifically conventional water pollutants, the use of semipermeable membrane devices (SPMDs) and contaminants in fish tissue.

Note: Objectives III and IV will be addressed concurrently with Objective II.

Secondary Objectives

Collaborate with EPA Region 10 on their Regional Applied Research Effort (RARE) study of the UMC. The REMAP and RARE studies share a common survey design, sampling period, and field collection methods.

Provide data on contaminants in the water column and fish tissue for potential use by DEQ and the CRTRWG to help address data gaps. These water quality, biological, and habitat data may provide additional information needed by EPA Region 10 and state and local decision makers to complete an ecological condition assessment, and a contaminant source assessment for the mid-Columbia Basin.

This project is not intended to test specific statistical hypotheses regarding contaminant extent or severity in the LMC. The primary use of the data is to produce an initial statistically-based assessment of contaminant conditions in the LMC and evaluate the feasibility of implementing such a program for future monitoring.

Statistical confidence in the assessment depends primarily on the study design and the number of randomly selected sampling locations in the LMC. Twenty-three random sampling points were selected, and 90% confidence intervals were calculated for most indicators. Each sampling location (site/station) represents a single random sample of the LMC. Two targeted locations were chosen on the mainstem LMC based on proximity to potential contaminant sources. Six major tributaries were sampled as indicators of potential watershed contaminant sources.

The primary data output from the survey design is an estimate of the cumulative proportion of the target population (expressed as a percentage of reach length) with a particular value for an ecological indicator, or the percentage of river length present in discrete "condition classes" based on specified criteria (e.g., greater than some concentration of concern). Data quality objectives related to "decision statements", "alternative actions", "action levels", and "decision rules" were not developed.

Different data users or decision makers will have their own “action levels” of interest for particular indicators. This project’s sponsors wish to compare fish fillet data for Hg, PCBs, DDT, and other pesticides to DEQ’s criteria. DEQ has no PBDE criteria for fish tissue or SPMDs to put the data in context. The Washington Department of Ecology (WDOE) and the Lower Columbia River Estuary Program (LCREP) published several reports, which may give context to the PBDE data. The purpose of these comparisons is to put the extent of LMC contamination in context. There is no intention of evaluating individual sampling locations for determining if fish consumption advisories are warranted.

Methods

Study Design

The project used a probabilistic sampling design developed by the EPA’s Western Ecology Division and the EPA Region 10 office in Seattle, WA. Twenty three random sites were selected along the centerline of the river channel. Each site was given an alpha numeric identification number, which DEQ reduced to simple consecutive numbers. Odd numbered sites were sampled along the Oregon shore, and even numbered sites along the Washington shore. Extra random sampling sites (oversample sites) were provided in case any of the original 23 locations could not be sampled for safety reasons, etc. (Detailed procedures for determining how to locate sites and when to reject sites are given in the project field guide.)

Eight targeted (hand-picked) sites were also selected. Six of these sites were located in the lower free-flowing reaches of major tributaries: the Hood, White Salmon, and Klickitat, John Day, Deschutes, and Umatilla rivers. Two sites were chosen on the mainstem Columbia in areas of concern to project sponsors: downstream of the PGE-Boardman coal-fired power plant (a potential Hg source), and downstream of The Dalles (a potential urban contaminant source).

Details on site locations and field procedures are given in referenced SOPs and the project field guide. An overview map is shown in Figure 1; matrices sampled, and probabilistic and targeted site lists in Table 1and Table 2.

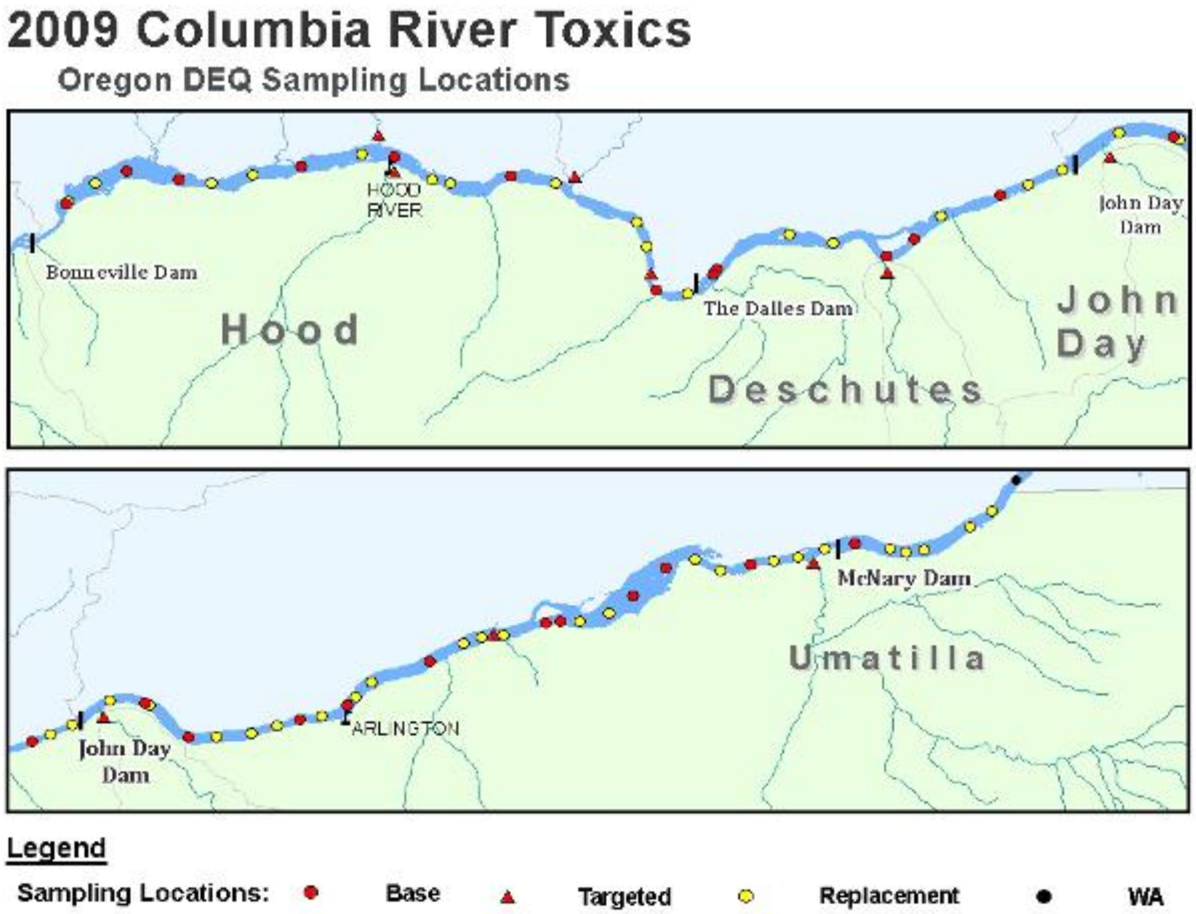


Figure 1. Probabilistic and targeted sampling locations from Bonneville Dam to Lake Wallula.

Table 1. Randomly selected stations and matrices sampled.

Table Item	Short ID	Latitude (DD.d)	Longitude (DD.d)	EPA ID	LASAR ID	Description	Matrices Sampled Fish	SPMD	Water	Habitat
1	01	45.675508	-121.8953988	CR206637-001	35317	CR at Cascade Locks 0.3 Mi US of Mkr 12	✓	✓	✓	✓
2	05	45.704130	-121.8232919	CR206637-005	35321	CR at Trotter Point	✓	✓	✓	✓
3	06	45.697336	-121.7610611	CR206637-006	35322	CR at Wind Mountain	✓	✓	✓	✓
4	02	45.709947	-121.6155034	CR206637-002	35318	CR US of Drano Lake at Channel Mkr 30	✓	✓	✓	✓
5	17	45.719026	-121.5028143	CR206637-017	35333	CR 0.3 Mi DS of Hood River Bridge	✓	✓	✓	✓
6	13	45.703909	-121.3631010	CR206637-013	35329	CR at Memaloose Channel Mkr 48	✓	✓	✓	✓
7	19	45.609188	-121.1882855	CR206637-019	35335	CR at The Dalles	✓	✓	✓	✓
8	23	45.622764	-121.1208145	CR206637-023	35340	CR US of the Dalles Locks Channel Mkr 1	✓	✓	✓	✓
9	09	45.626801	-121.1154536	CR206637-009	35325	CR at Lake Celilo Channel Marker 1	✓	✓	✓	✓
10	20	45.638964	-120.9134561	CR206637-020	35336	CR at Miller Is 0.2 Mi US Channel Mkr 4	✓	✓	✓	✓
11	10	45.653876	-120.8801182	CR206637-010	35326	CR at East end of Miller Is.	✓	✓	✓	✓
12	14	45.690345	-120.7774183	CR206637-014	35330	CR at Rufus 0.5 Mi US of Channel Mkr 41	✓	✓	✓	✓
13	07	45.739881	-120.5696933	CR206637-007	35323	CR at Lake Umatilla Channel Mkr 6	✓	✓	✓	✓
14	21	45.697051	-120.4911580	CR206637-021	35337	CR at Lake Umatilla 0.6 Mi US Chanel Mkr 10	✓	✓	✓	✓
15	03	45.719420	-120.2878769	CR206637-003	35319	CR Lake Umatilla at Channel Mkr 18	✓	✓	✓	✓
16	11	45.736789	-120.1993882	CR206637-011	35327	CR at Arlington Channel Marker 21	✓	✓	✓	✓
17	15	45.793259	-120.0491317	CR206637-015	35331	CR at Hepner Jct 1.25 Mi DS of Willow Cr.	✓	✓	✓	✓
18	04	45.841641	-119.8351293	CR206637-004	35320	CR at Crow Butte Power line	✓	✓	✓	✓
19	18	45.843338	-119.8101284	CR206637-018	35334	CR at Crow Butte Channel Mkr 35	✓	✓	✓	✓
20	22	45.874630	-119.6757040	CR206637-022	35338	CR at Lake Umatilla N Channel Blalock Islands	✓	✓	✓	✓
21	08	45.909436	-119.6152974	CR206637-008	35324	CR at Big Blalock Island	✓	✓	✓	✓
22	12	45.912465	-119.4594616	CR206637-012	35328	CR at Irrigon Channel Mkr 64	✓	✓	✓	✓
23	16	45.936969	-119.2682384	CR206637-016	35332	CR at McNary Dam 0.5 Mi US Channel Mkr 1	✓	✓	✓	✓

Table 2. Targeted stations and matrices sampled.

Table Item	Short ID	Latitude (DD.d)	Longitude (DD.d)	LASAR ID	Description	Matrices Sampled Fish	SPMD	Water	Habitat
1	Dal	45.623080	-121.1944600	35341	CR DS of The Dalles at RM 188.	✓	✓	✓	✓
2	Des	45.630200	-120.9102000	10411	Deschutes River at Deschutes River Park	✓	○[a]	✓	✓
3	Hoo	45.710700	-121.5067000	12012	Hood River at footbridge.	✓	✓	✓	✓
4	Joh	45.702900	-120.5998000	11826	John Day River at Philippi Park	✓	✓	✓	✓
5	Kli-A	45.700500	-121.2870900	36037	Klickitat R WA at RM 0.4 (Note: fish samples)	✓	○	○	✓
6	Kli-B	45.702570	-121.2818100	36038	Klickitat R WA RM 0.7 DS of Klickitat County Park.	○	✓	✓	○
7	PGE	45.826380	-119.9305400	35339	CR DS of PGE – Boardman	✓	✓	✓	✓
8	Uma-A	45.913460	-119.3465600	35539	Umatilla River 0.3 mile US of Hwy 730.	✓	○	○	✓
9	Uma-B	45.835690	-119.3319444	11489	Umatilla River at Westland Rd.	○	✓	✓	○
10	Whi-A	45.728300	-121.5218000	34193	White Salmon River WA at mouth.	✓	○	○	✓
11	Whi-B	45.739240	-121.5231900	36025	White Salmon R WA at RM 0.8	○	✓	✓	○

[a] The Deschutes River SPMD sample was lost at the lab.

The Klickitat, Umatilla, and White Salmon Rivers required two sampling locations. The White Salmon River's fish collection site was moved to the mouth (mainstem-influenced) due to the presence of adult salmonids at river mile 0.8. Fish sampling began in June when water levels in the mainstem and tributaries were relatively high. Later in the season river levels had dropped, and required selecting alternate sites for SPMD deployments and water sampling. The original sampling locations were either no longer accessible or had high vandalism risk.

Sampling

Field sampling was conducted during the period when water and weather conditions were conducive to safe and efficient fieldwork. The sampling index period was from June – September.

All samples were collected, preserved, transported, and analyzed following SOPs developed by DEQ (2010c), EPA, or the Washington Dept. of Ecology. Water grab samples were collected on the cross-channel transect (defined by the EMAP Great Rivers Protocol) near the SPMD mooring. If the SPMD mooring couldn't be placed on the cross-channel transect, water samples were collected near the SPMD.

Electrofishing followed the project field manual (also based on the EMAP Great Rivers Protocols) and SPMDs were moored following the Washington Department of Ecology protocol(Johnson A. , 2007). The samples adequately represented the river margin habitat in which they were collected, and did not account for cross-channel variability. Probabilistic sampling alternated from bank to bank in a longitudinal progression. Targeted tributary sites were located upstream of Columbia backwater whenever possible, to maximize watershed representativeness.

Water sampling followed the project field guide and standard DEQ protocols (DEQ, 2010c). Water sampling for trace metals followed EPA Method 1669(USEPA, 1996).

Specific Quality Assurance Objectives for this project were:

- Collect a sufficient number of samples, and field blanks to evaluate the sampling and measurement error.
- Analyze a sufficient number of QC Standards, blanks and duplicate samples in the Laboratory environment to effectively evaluate results against numerical QA goals established for precision and accuracy.
- Implement sampling techniques in such a manner that the analytical results are representative of the media and conditions being sampled.

Completeness

The completeness goal was 90%. All intended samples were collected, but the DEQ laboratory lost the SPMD extract from the Deschutes River. This loss did not compromise the study, but was disappointing because the Deschutes River fish fillet samples showed above average contaminant levels. The missing data could have been used to correlate the SPMD sampling method with fish tissue.

Some PCB congeners listed in the QAPP were not recovered (Table 3) as were others noted in the data tables. A possible explanation is that these comparatively low molecular weight congeners were either not successfully extracted from fish tissue or SPMDs, or were lost during one of the sample clean-up stages. The mass sum of PCB congeners (Total PCBs) is the primary measure for which toxicity screening values are available. Thus, the loss of some congeners did not compromise the dataset.

Table 3. QAPP-listed PCBs not recovered by the laboratory.

PCBs Listed in the QAPP --Not Recovered from Fish Fillets or SPMDs.				
PCB-1	PCB-4	PCB-7	PCB-10	PCB-13
PCB-2	PCB-5	PCB-8	PCB-11	PCB-14
PCB-3	PCB-6	PCB-9	PCB-12	PCB-15

Vandalism to SPMDs was anticipated, and projected at 10-15% of sites. However, the Washington DOE deployment method provided good concealment (surface floats were not attached to the moorings) and none were lost. By comparison, a DEQ pilot study on the Willamette River (with surface floats) lost about 50% of SPMDs to vandalism.

No samples were lost from the probability sites, but some Secchi measurements were inadvertently not taken. The missing Secchi data appeared to be a random error. Although some Secchi data was missing, the proportion of length estimates was assumed applicable to the entire target river length. The loss in Secchi sample size resulted in larger confidence intervals.

Physical Habitat Assessment

After navigating to the sample site, the crew leader evaluated whether the site was safe to sample under the existing conditions. The objective of the visual habitat assessment was to record field team observations of catchment and river characteristics for data validation, future data interpretation, ecological value assessment, development of associations, and verification of stressor data. Additional detail is provided in the project field guide(Caton, 2009). The assessment methods were based on the EMAP Great River Ecosystems Field Operations Manual, Section 7, Channel and General Assessment, and Riparian Classification and Human Influence (Angradi, 2006).

Invasive Species

An Aquatic Invasive Species Form was completed for each sampling site. The field objective was to record observations of invasive plant, invertebrate and fish species. The crew recorded observations within the sample reach either along the bank or in the water. The assessment methods were based on the EMAP Great River Ecosystems Field Operations Manual (Angradi, 2006).

Water Column Profile and Grab Samples

Instantaneous water column profile (DO, pH, redox-potential, conductivity, temperature, and turbidity) were collected with a datasonde. Secchi depth was measured with a standard black and white, eight-inch diameter disk.

Water quality grab samples were collected with a peristaltic pump – the trace metal sampling followed EPA Method 1669. Grab sample parameters included: chlorophyll *a*; nutrients and sulfate; hardness and alkalinity; total suspended solids; total recoverable arsenic, copper, lead, and selenium; total and dissolved organic carbon; total and dissolved mercury; total and dissolved methylmercury; and E. coli.

Dissolved samples were collected by attaching a capsule filter to the tubing outlet. The capsule filters used to collect dissolved constituents were certified as trace cleaned, and were purged for several minutes with site water prior to collecting samples. Crews collected the filtrate during purging to ensure an adequate water volume (minimum of 2 L, which is >20 capsule filter volumes) passed through the filter. The water samples were pumped directly into appropriate sample containers.

Figure 2. Water samples were collected using EPA Method 1669 for trace

Fish Sampling

Figure 3. U.S. EPA Region 10 assisted with fish collection by providing a boat and operator, Doc Thompson.

Boat electrofishing was the primary fish collection method. Hook and line or backpack electrofishers were used when electrofishing wasn't successful. The fish-sampling crew located a 500-m near-shore transect for sampling. The field objective was for sampling teams to obtain a representative composite sample of target species from each sample site. Each composite consisted of individuals that were all the same species with individual fish of similar size. The composite samples provided >200 g of skinless, belly-flap-free fillet at the majority of sites.

Crews began by electrofishing a 500 m reach downstream from the X-site along one bank. The right bank (facing downstream) was fished if the site number was even and the left bank was fished if the site number was odd. If adequate numbers and species of fish were not captured on one pass, the crew made a second pass starting at the top of the reach. When necessary, additional area along the bank or even the opposite bank was fished to obtain an adequate sample. No field duplicate fish samples were collected. The list of target fish species and associated length criteria are shown in **Table** 4.

Table 4. Targeted Fish Species

Priority Ranking	Family	Scientific Name	Common Name	Min. Length	Max. Length
1	Cyprinidae	*Ptychocheilus oregonensis*	northern pikeminnow	240 mm	500 mm
1	Percidae	*Stizostedion vitreum*	walleye	240 mm	500 mm
1	Centrarchidae	*Micropterus dolomieu*	smallmouth bass	240 mm	500 mm
1	Centrarchidae	*Micropterus salmoides*	largemouth bass	240 mm	500 mm
2	Percidae	*Perca flavescens*	yellow perch	240 mm	500 mm
2	Catostomidae	*Catostomus macrocheilus*	large-scale sucker	240 mm	500 mm

Figure 4. DEQ crew member Nick Haxton displays a bass about to be filleted.

Samples predominantly consisted of 5 individuals of the same species from each sample location. The highest priority species were retained when multiple species were captured. Smallmouth bass were retained at approximately 80% of sites; the remainder were large-scale suckers.

Fish were weighed and measured for total length prior to being filleted. Once filleted, the belly flap and skin were removed. Fillets from each site were wrapped in foil, double freezer bagged, packaged together with appropriate labels, and frozen on dry ice in the field.

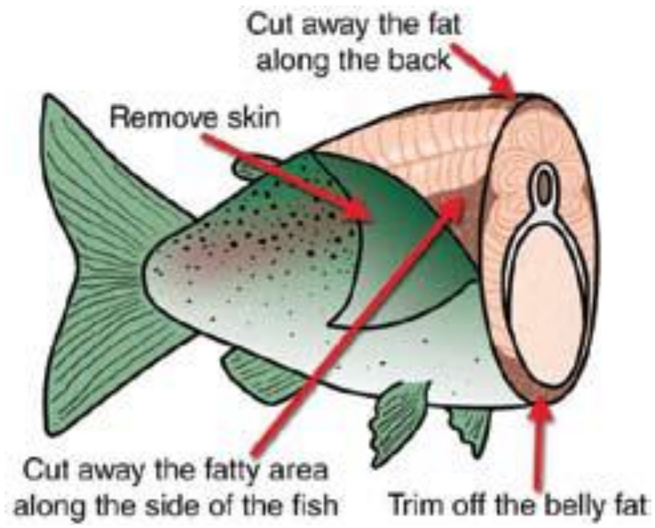
EPA's "Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories" (USEPA, 2000b) recommends scaling and filleting fish without removing the skin, but also notes:

> "If complete homogenization of skin-on fillets for a particular target species is a chronic problem or if local consumers are likely to prepare skinless

fillets of the species, the state should consider analyzing skinless fillet samples."

Other EMAP studies in which DEQ has participated, such as assessments of estuaries and coastal ocean waters also examined skinless fillets (USEPA, 2008a), so we continued the practice. Doing so also eliminated the homogenization problems frequently encountered with whole-body and skin-on fillets.

Furthermore, local consumers are known to prepare bass fillets with and without skin. A portion of our study area, upstream of Bonneville Dam to Ruckles Creek, is under a smallmouth bass fish consumption advisory due to PCB contamination. The public health consumption guidelines are published in the Oregon Department of Fish and Wildlife's angling regulations, and advise removing the skin, belly flap, and other fatty areas prior to cooking (Figure 5).



PCBs, DIOXINS & PESTICIDES
All persons should reduce or avoid eating fatty parts of fish. Exposure can be reduced by removing the skin and all fat, eggs, and internal organs.

Figure 5. Recommended smallmouth bass preparation procedures to reduce exposure to PCBs, pesticides, and dioxins. (ODFW, 2012)

Semi-permeable Membrane Devices (SPMD)

Standard SPMDs (91 x 2.5 cm membrane containing 1 ml triolein) and the stainless steel canisters (16.5 x 29 cm) and carriers that hold the membranes during deployment were obtained from Environmental Sampling Technologies(2009). The SPMD membranes were preloaded onto the carriers by EST in a clean-room and shipped in solvent-rinsed metal cans under argon gas. Five membranes were used in each canister, with one canister per sampling site. Duplicate samples (two canisters on the same mooring) were deployed at two sampling locations to provide estimates of the total variability in the data (field + laboratory). Deployment durations ranged from 28 to 30 days.
EST manufactured the SPMDs with internal performance reference compounds (PRCs) provided by DEQ. PRCs are analytically non-interfering compounds with moderate to relatively high fugacity (escape tendency). The PRCs are typically used as an *in situ* calibration mechanism. It has been shown that uptake rates of compounds with a wide range of octanol-water coefficients (K_{ow}) can be predicted by loss rates of PRCs with a much narrower Kow range (Huckins, et al., 2002). The loss rate of PRCs is proportional to the uptake of target compounds. PRC loss rates

Figure 6. An SPMD canister about to be retrieved. The lid has been removed underwater, revealing the first of five

during field exposure may be used to normalize sampling rates and estimate water column concentrations of target compounds.

The SPMDs were deployed out of strong currents, situated in such a way as to minimize the potential for vandalism, and placed deep enough to allow for any anticipated fluctuations in water level (typically mid-depth).
Prior to deployment, the SPMDs were kept frozen on ice. On arrival at the sampling site, the cans were pried open, carriers slid into the canisters, and the device anchored in the river as described in the Washington Department of Ecology's SOP (Johnson A. , 2007). Because SPMDs are potent air samplers, the deployment procedure was done as quickly as possible (typically within 1 minute or less). Field personnel wore nitrile gloves and did not touch the membranes unless they had come loose. Handling was only required at a few sites and was noted on the field forms. The SPMDs were deployed for 28 to 30 days, as recommended by USGS(McMarthy & Gale, 1999), (McCarthy, 2008) and EST.

The retrieval procedure was essentially the opposite of deployment. The cans holding the SPMDs were carefully sealed with a rubber mallet, and the SPMDs were maintained at or near freezing until they arrived at EST for extraction. The latitude and longitude of each sampling site was recorded by a global positioning receiver (GPS). The cans holding the SPMDs were labeled showing project name, sampling site, three-digit site number, DEQ's LASAR number, the number of cans per sample, and the deployment and retrieval dates. The SPMDs and a chain-of-custody record were shipped to EST by overnight Federal Express, in coolers with wet ice or a combination of about 80% wet ice and 20% dry ice.

As noted above, SPMDs absorb vapors while exposed to air. Three field blanks were used to document chemical accumulation during deployment, retrieval, and transport. Each field blank (five SPMD membranes in a can) was opened to the air for the same amount of time it took to open and place the SPMD canisters in the water. The blanks were then sealed and refrozen. During retrieval, the blanks were taken back into the field and opened and closed again to mimic the entire process. Blanks were processed and analyzed with the regular SPMD samples (Johnson & Norton, 2003).

Field blanks are typically used at sites judged to have the greatest potential for air-borne contamination, and sites judged to have a low contamination potential. It would be cost prohibitive to collect a blank at every location, or attempt to account for potential air contamination across the study area. Field crews exposed air blanks based on proximity to potential contamination sources. Studies conducted by EPA and Washington Department of Ecology (Johnson & Norton, 2003) chose high contamination risk sites near cities, and low contamination sites downwind of rural areas. On the Columbia, the greatest contamination risk was assigned to sites close to interstate 84 and The Dalles. The site above McNary Dam was considered a low contamination risk due to the general lack of development and distance from the freeway. However, the field crew noted a passing barge and freight train during retrieval.

SPMDs were shipped overnight from the field directly to EST in St. Joseph, MO. EST dialyzed all of the membranes in hexane and sealed the extracts in amber glass ampoules. No holding times have been established for SPMDs. EST's website (www.est-lab.com) states that ampoulated extracts may be stored for long periods in a freezer at -4.0 C or below. Terri Spencer (EST) acknowledged there is no recommended holding time between retrieval and dialysis --as long as the SPMDs remained frozen (-20 C) they are OK for long periods (months), and extracts ampoulated in hexane keep "indefinitely". "But there are no studies, to my knowledge, that would verify this, or the length of time an exposed SPMD can be kept when frozen." (Spencer, 2009). Therefore, the DEQ Lab used a functional 40-day holding time that began when the extract ampoules were opened.

Analytical Methods and Parameters by Matrix

All laboratories involved with this project were required to follow methods described in the Quality Assurance Project Plan (Caton, 2010) and make analytical SOPs available upon request. All methods were either EPA approved or from the current edition of Standard Methods for the Examination of Water and Wastewater (By E.W. Rice, 2012); exceptions were noted. Field analytical methods can be found in the project field manual (Caton, 2009), the Washington Department of Ecologies SPMD SOP (Johnson A. , 2007), and the Watershed Assessment Mode of Operations Manual (DEQ, 2010c).

Water

Water column field measurements were made with a Yellow Springs Instruments model 6920 data sonde with a YSI model DM-650 hand held display. The sonde was calibrated daily for all of the parameters listed in Table 5 (except Secchi). Normally at least three depths were sampled with the sonde (surface, middle, near bottom) starting at 0.2 m. There were some instances where the sonde's turbidity sensor malfunctioned. In such cases, the crews used portable turbidimeters, and obtained measurements from grab samples.

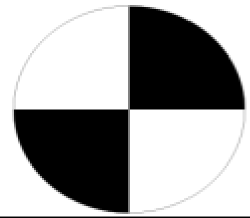


Figure 7. Secchi disk pattern. (Wikipedia,

The Secchi disc was a standard 8-inch diameter, with black and white quadrants (Figure 7). In areas where water current carried the disc downstream, lead weights were attached below the disc to return the tape to a vertical position.

Table 5. Water methods and field parameters.

Parameter	Units	Method
Dissolved Oxygen	mg/L	Optical Probe
Percent DO Saturation	%	Calculated
Sample Depth	m	Press. Sensor
Temperature	°C	EPA 170.1
Specific Conductivity (@ 25°C)	µmhos/cm	EPA 120.1
pH	S.U.	EPA 150.1
Redox	mV	Electrometric probe
Turbidity	NTU	SM 2130 B
Secchi Depth	m	Standard Disc

Table 6. Non-metal water methods and parameters.

Parameter	Units	Method
Alkalinity	mg/L	SM 2320 B
Hardness by ICP-AES	mg/L	SM 2340 B
Total Suspended Solids	mg/L	SM 2540 D
Ammonia	mg/L	EPA 350.1
Nitrate/Nitrite	mg/L	EPA 353.2
Orthophosphate	mg/L	EPA 365.1
Total Phosphorus	mg/L	EPA 365.1
Sulfate, Dissolved	mg/L	EPA 300.0
Dissolved Organic Carbon	mg/L	EPA 415.1
Total Organic Carbon	mg/L	EPA 415.1
Chlorophyll / Pheophytin	µg/L	EPA 445.0
Escherichia coli (E.coli)	MPN / 100 mL	SM 9223B

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Table 7. Metal and metalloid water methods and parameters.

Parameter	Units	Method
Arsenic	µg/L	EPA 6020[1]
Copper	µg/L	EPA 6020
Lead	µg /L	EPA 6020
Selenium[a]	µg /L	EPA 6020
Mercury, Total[b]	ng/L	EPA 1631E[2]
Mercury, Dissolved [b]	ng/L	EPA 1631E
Methylmercury, Total[c]	ng/L	EPA 1630[3]
Methylmercury, Dissolved[c]	ng/L	EPA 1630

1(USEPA, 2007e Revision 1.) 2(USEPA, 2002) 3(USEPA, 1998)

[a]Selenium is more commonly categorized as a non-metal, but is grouped here with the other method EPA-6020 analytes.

[b] Water column mercury was analyzed by the EPA Region 10 Manchester Environmental Laboratory in Port Orchard, WA.

[c] Water column methyl mercury was analyzed under state contract by Brooks Rand Labs, Seattle, WA.

Fish

Fillets were homogenized at the DEQ laboratory according to DEQ's fish homogenization SOP (DEQ, 2012a), which complies with EPA's National Fish Health Advisory Laboratory Procedures, Section 7 (USEPA, 2000a). Fillets were processed in a dedicated fish sample preparation lab. The work area was fitted with a glass bench liner, and glass or foil-covered cutting boards were used. Ceramic knives were used to cube partially frozen tissue prior to homogenization in a blender with ceramic blades. Individual fish homogenates were mixed, transferred to trace-cleaned muffled jars with Teflon-coated utensils, and frozen at -20 C.

Prior to freezing the individual homogenates, a monitoring site composite was prepared by combining an equal mass from each fish's homogenate. The composite was mixed and transferred to a container as described above, and at least 200 g was stored at -20 C prior to analysis. Up to 500 g of surplus composite was archived for back-up in case the primary container was lost or compromised. Table 8 and Table 9 show the EPA methods and DEQ standard operating procedures used to measure fish in the field, and analyze the percent solids and lipid content in the lab.

Fish and SPMD Analytical Methods and Parameters

The list of contaminants analyzed in fish fillets and SPMDs is the same, except that fish were not tested for PAHs.

Table 8. Fish methods and field parameters

Field Measurements	Units	Method[a]
Fish Total Length	mm	EPA /600/R-92/111
Fish Weight	g	EPA /600/R-92/111

[a](Klemm, Stober, & Lazorchak, 1993)

Table 9. Fish fillet methods and ancillary parameters.

Parameter	Units	Method
Fish Fillet Solids	%	DEQ97-LAB-0010-SOPa
Fish Fillet Fats and Lipids	%	DEQ98-LAB-0002-SOPb

a (DEQ, 2010a). **b**(DEQ, 2012c)

Table 10. Fish fillet and SPMDs – Dioxins / Furans by HRGC/HRMS EPA method 1613 (USEPA, 1994)

Dioxins and Furans	
Total 2,3,7,8 Substituted Dioxin-Furans	
Tetra-	
2,3,7,8-Tetrachlorodibenzodioxin	
2,3,7,8-Tetrachlorodibenzofuran	
Penta-	**Hepta-**
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	1,2,3,4,6,7,8- Heptachlorodibenzo-p-dioxin
1,2,3,7,8-Pentachlorodibenzofuran	1,2,3,4,6,7,8- Heptachlorodibenzofuran
2,3,4,7,8-Pentachlorodibenzofuran	1,2,3,4,7,8,9- Heptachlorodibenzofuran
Hexa-	**Octa-**
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	1,2,3,4,6,7,8,9- Octachlorodibenzo-p-dioxin
1,2,3,4,7,8-Hexachlorodibenzofuran	1,2,3,4,6,7,8,9- Octachlorodibenzofuran
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	
1,2,3,6,7,8-Hexachlorodibenzofuran	
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	
1,2,3,7,8,9-Hexachlorodibenzofuran	
2,3,4,6,7,8-Hexachlorodibenzofuran	

Table 11. Fish fillet and SPMD pesticides by HRGC/HRMS EPA method 1699 (USEPA, 2007c)

Chlorinated Pesticides		
Total DDTs	Aldrin	Endosulfan I
2,4`-DDD	alpha –BHC (IUPAC: *a*-1,2,3,4,5,6 hexachlorocyclohexane) aka: alpha-Lindane	Endosulfan II
2,4`-DDE	beta –BHC (isomer)	Endosulfan sulfate
2,4`-DDT	delta-BHC (isomer)	Endrin + cis-Nonachlor
4,4`-DDD	gamma -BHC (Lindane)	Endrin Aldehyde
4,4`-DDE	cis-Chlordane	Endrin Ketone
4,4`-DDT	(trans-Chlordane + trans-Nonachlor)	Heptachlor
	cis -Nonachlor	Heptachlor epoxide
	Oxychlordane	Hexachlorobenzene
	∑ Chlordane[a]	Methoxychlor
	Dieldrin	Mirex

[a]∑ Chlordane (total chlordane) is the sum of cis-Nonachlor, trans-Nonachlor, cis-Chlordane, trans-Chlordane, and Oxychlordane.

Table 12. Fish fillet and SPMD – PBDEs by HRGC/HRMS EPA method 1614 (USEPA, 2007a)

Flame Retardants				
BB 153	PBDE-47	PBDE-138	PBDE-191	PBDE-209
BTBPE	PBDE-49	PBDE-139	PBDE-196	
DBDPE	PBDE-66	PBDE-140	PBDE-197	
Hexabromo- benzene	PBDE-71	PBDE-153	PBDE-201	
PBDE-1	PBDE-77	PBDE-154	PBDE-203	
PBDE-2	PBDE-85	PBDE-156/169	PBDE-204	
PBDE-3	PBDE-99	PBDE-171	PBDE-205	
PBDE-7	PBDE-100	PBDE-180	PBDE-206	
PBDE-10	PBDE-119	PBDE-183	PBDE-207	
PBDE-15	PBDE-126	PBDE-184	PBDE-208	

Table 13. SPMD – PAHs by GC/MS SIM EPA method 8270 (USEPA, 2007d)

PAHs	
Anthracene	1-methylnaphthalene
Benz(a)anthracene	2-methylnaphthalene
Dibenz(a,h)anthracene	2,6-dimethylnaphthalene
Biphenyl	2,3,5-trimethylnaphthalene
Chrysene	Benzo(g,h,i)perylene
Fluoranthene	Phenanthrene
Benzo(b)fluoranthene	1-methylphenanthrene
Benzo(k)fluoranthene	Pyrene
Fluorene	Benzo(a)pyrene
Acenaphthene	Indeno(1,2,3-c,d)pyrene
Naphthalene	Dibenzothiophene
Acenaphthylene	Phenanthrene

Table 14. Fish fillet and SPMD – PCBs by HRGC/HRMS EPA method 1668 (USEPA, 2008b)

PCBs							
PCB-1	PCB-29	PCB-56	PCB-84	PCB-116	PCB-145	PCB-171	PCB-197
PCB-2	PCB-30	PCB-57	PCB-85	PCB-117/87	PCB-146	PCB-172	PCB-198
PCB-3	PCB-31	PCB-59	PCB-88/91	PCB-118	PCB-147	PCB-173	PCB-199
PCB-5	PCB-32	PCB-60	PCB-89	PCB-119/112	PCB-148	PCB-174	PCB-200
PCB-6	PCB-34	PCB-61	PCB-90	PCB-120	PCB-149	PCB-175	PCB-201
PCB-8	PCB-35	PCB-62	PCB-92	PCB-121	PCB-150	PCB-176	PCB-202
PCB-9/7	PCB-36	PCB-63	PCB-93	PCB-122	PCB-151	PCB-177	PCB-203
PCB-10/ 4	PCB-37	PCB-64	PCB-94	PCB-124	PCB-152	PCB-178	PCB-204
PCB-11	PCB-38	PCB-66	PCB-95	PCB-125/86	PCB-153	PCB-179	PCB-205
PCB-12	PCB-39	PCB-67/58	PCB-97	PCB-126	PCB-154	PCB-180/193	PCB-206
PCB-13	PCB-40	PCB-68	PCB-98	PCB-127	PCB-155	PCB-181	PCB-207
PCB-14	PCB-41/72	PCB-69	PCB-99	PCB-128/162	PCB-156	PCB-182	PCB-208
PCB-15	PCB-42	PCB-70	PCB-100	PCB-129	PCB-157	PCB-183	PCB-209
PCB-16	PCB-44	PCB-71	PCB-101/113	PCB-130	PCB-158	PCB-184	Total PCB
PCB-17	PCB-45	PCB-73	PCB-102	PCB-132	PCB-159	PCB-185	
PCB-18	PCB-46	PCB-74	PCB-103	PCB-133/ 131/142	PCB-160	PCB-186	
PCB-19	PCB-47	PCB-75/65	PCB-104	PCB-134	PCB-161	PCB-187	
PCB-20/21/33	PCB-48	PCB-76	PCB-105	PCB-135	PCB-163/138	PCB-188	
PCB-22	PCB-49	PCB-77	PCB-106	PCB-136	PCB-164	PCB-189	
PCB-23	PCB-50	PCB-78	PCB-107	PCB-137	PCB-165	PCB-190	
PCB-24	PCB-51	PCB-79	PCB-108	PCB-139	PCB-166	PCB-191	
PCB-25	PCB-52/43	PCB-80	PCB-109/123	PCB-140	PCB-167	PCB-192	
PCB-26	PCB-53	PCB-81	PCB-110	PCB-141	PCB-168	PCB-194	
PCB-27	PCB-54	PCB-82	PCB-114	PCB-143	PCB-169	PCB-195	
PCB-28	PCB-55	PCB-83	PCB-115/111	PCB-144	PCB-170	PCB-196	

Data Quality Assessment

Data Verification and Validation

The Principal Investigator reviewed all data and determined if the field and laboratory work met the QA Plan objectives. The decisions to accept, qualify or reject data was documented in DEQ's LASAR database (with DEQ's standard data qualifiers), and in the project's Access database with project specific qualifiers described in the QAPP.

The assessment verified sampling completeness, parameter and analyte reporting and the acceptability of reporting levels. Analytical and preparation batch data were examined to determine whether method blanks, calibration and control standards, matrix spikes, surrogates, standard reference materials, laboratory control standards, duplicates and replicates met quality control limits.

The data review process used by the lab's analytical sections was monitored through the Laboratory Information Management System. The analysts entered and reviewed analytical data, and flagged results not meeting QC criteria. A second qualified analyst reviewed the data in LIMS and advanced batches to the analytical section manager review level. Once data was reviewed and approved by the manager, QA officer, and PI, the data was released to the LASAR database.

Figure 8. Jim Coyle (left) and the P.I. preparing for trace metal sampling (EPA method 1669) during the EPA field audit.

Compliance with QA/QC protocols was also audited by EPA Region 10 both in the field (Figure 8) and at the DEQ lab.

Water Quality

All water quality grab samples and analytes were graded as "A", with the following exceptions:

- 40% of the *E. coli* data was estimated due to non-detects or holding time exceedances. The QAPP (Caton, 2010) allowed an operational 40-hour holding time, and noted that any samples held beyond the lab's routine 30-hour holding time would be estimated.
- 45% of the total methylmercury results, and 23% of the dissolved methylmercury results were estimated due to detections between the LOD and LOQ. However, Brooks Rand Labs achieved the QAPP's targeted minimum level and method detection limits for both analytes.
- A few DOC and TOC results were estimated due to holding time exceedance or inadequate acid preservation in the field.
- At least one chlorophyll and pheophytin sample was voided due to centrifuge tube breakage in the lab.

Fish Fillets and SPMDs

The fish fillet and SPMD organic analyte suites (pesticides, PCBs, PBDEs, Dioxins/Furans, and PAHs) produced most of the project's data. To facilitate data review and creation of the project's Access database, the lab modified the data approval process at the request of the P.I. Analytical results were downloaded from LIMS prior to final approval and paired with many QC elements that could not be tracked by the outdated LIMS software. For example, the data tables included raw instrument output from the HRGC/HRMS paired with the acceptable high and low recovery limits, a QC data reduction (e.g. Pass/Fail or High/Low recovery), standard data qualifiers, and analyst comments. Modifying the data approval process saved time and avoided data entry errors by allowing electronic data manipulation outside the LIMS, but did not circumvent any QA/QC procedures. Once the P.I. approved the data, and any necessary corrections were made in LIMS, the routine data flow resumed and the results were stored in DEQ's LASAR database.

Since many organic analytes are only present at trace levels in the environment, it's natural to expect much data reported as non-detects or as estimates. As requested, the chemists reported data between the detection limit and the reporting limit. This decreased the percentage of non-detect flags, but increased the number of estimated or otherwise qualified results. The same was true for reporting other trace-level project analytes such as mercury and methylmercury in water column samples (see water quality above).

Table 15 shows fish fillet parameter groups and six quality control measures (Method blank, Lab Control Standard, Standard Reference Material, isotope-labeled Surrogate, Matrix Spike, and field duplicate Relative Percent Difference), expressed as the overall percent of analyses that met the QAPP's control limits (Caton, 2010). Laboratory blank contamination increased the percentage of estimated results for pesticides and PBDEs. However, approximately 78% of the PBDE and pesticide analytical laboratory blank contamination was at levels below the reporting limits. The estimated results were deemed useful, and were included in statistical analyses. Results reported as "not detected" were assigned the value zero in statistical summaries and graphs.

Table 15. Fish fillet quality controls by parameter group: percent of analyses within control limits.

Parameter	Blank	LCS	SRM	Surrogate	MS	RPD	Acceptable Results	Estimated Results
Pesticides	71%	96%	100%	84%	80%	96%	54%	46%
PCBs	96%	98%	82%	96%	94%	100%	79%	21%
PBDEs	68%	90%	100%	98%	94%	93%	60%	40%
Dioxins	100%	100%	NA[a]	97%	86%	NA[b]	100%	0%
Furans	100%	100%	NA[a]	98%	81%	NA[b]	99%	1%
Mercury	100%	100%	100%	-	100%	100%	100%	0%

[a]Analyte not present in SRM. [b]Too few detections to calculate RPD.

In SPMDs, the brominated flame retardants had the highest percentage of estimated results. As noted in Table 16, laboratory blank contamination was below the LOQ and had little effect on data quality. The LCS recovery failures had a greater influence on data qualifiers, however 87% of the failed recoveries were above the control limits and were associated with low or ND sample results. As a whole, the analytical lab's quality control results were good.

Unfortunately, the SPMD results from laboratory stored blanks (which never left EST) and the field blanks show contamination for many analytes. The data suggest that the contamination originated at EST during either SPMD manufacture or extraction. The problem is notable for Total PCBs where additive contamination from many congeners produced blank values between 4,000 to 5,200 ng/SPMD. The dioxins, furans, and PAHs showed no contamination, which is somewhat ironic given that SPMDs are considered "potent" PAH air samplers. Generally, the DDT and organo-chlorine pesticide blanks were contaminated, and required arithmetic correction prior to data analyses. The contamination reduced the usefulness of the data.

Given the SPMD blank contamination and uncertain results from the Performance Reference Compounds (higher concentrations reported in samples than in lab blanks), DEQ elected not to back-calculate water column contaminant concentrations.

The PRCs were spiked in the triolein during SPMD manufacture, and were expected to diffuse into the water column at a rate proportional to the volume of water cleared by the SPMD. It is likely that the diffusion process proceeded as expected, but varying analyte recoveries obscured the concentration change. Recoveries typically vary from sample to sample due to losses during sample preparation and clean-up. Such losses occur even when analytical batch quality control parameters are within acceptable limits. For example, the project QAPP allowed variability in matrix spike and laboratory control samples of 50 – 120%, and ± 30%, respectively. These ranges are typical for the sample matrices and analytical methods employed, but were too variable to make predictions based on the PRCs. Therefore the P.I. elected to evaluate SPMD performance solely via comparison to fish contamination at the same location.

Table 16. SPMD quality controls by parameter group: percent of analyses within control limits.

Parameter	Blank	LCS	SRM	Surrogate	MS	RPD	Acceptable Results	Estimated Results
Pesticides	92%[a]	100%	NA	74%	NA	94%	87%	13%
PCBs	94% [a]	100%	NA	90%	NA	100%	89%	11%
PBDEs	58% [a]	67%	NA	97%	NA	97%	60%	40%
Dioxins	100%	100%	NA	100%	NA	NA[b]	100%	0%
Furans	100%	100%	NA	100%	NA	NA[b]	94%	6%

[a] DEQ laboratory blank contamination was below the LOQ. [b]Too few detections to calculate RPD.

Results and Discussion

Note: Throughout this section of the report, results are frequently described in terms of an estimated proportion or percent of the LMC, or as a percentage of sites. In probabilistic survey designs sampling locations are often stratified by assigning site weights. For example, this survey could have nested a sub-population of sites in marinas within the overall survey. The sub-population could then be evaluated separately, or included in the larger survey by applying probability weighting factors to account for the proportion of the sub-population within the overall LMC.

The LMC survey was not stratified, and all sites were sampled. All sites had the same survey inclusion probability, and describing results as a percentage of sites or percentage of the LMC is synonymous. The charts, cumulative distribution graphs, and statistical summary tables of probabilistic data were all based on equal site weights.

The LMC survey was designed as a sub-population of the entire middle Columbia River, and future reports could combine LMC results with EPA's RARE survey of the upper-middle Columbia.

Objective I --Feasibility of Implementing Probability-based Sampling

The field work portion of this study was nearly flawless and was completed on time and within budget. We encountered far fewer problems than expected in terms of probabilistic site potential hazards and our ability to collect samples. In fact, none of the probabilistic sites were rejected and none of the alternate locations were used. Prior probabilistic surveys conducted by DEQ on rivers, streams, lakes, wetlands, and estuaries invariably rejected some sampling locations because they were either non-target (not within the intended sampling frame); or on-target but not sampleable due to physical inaccessibility, safety concerns, or denied access.

The targeted sites on a few of the tributaries presented some problems, but didn't result in data loss. Site reconnaissance was done using mapping tools such as Google Earth (Google, Inc.). At some locations this didn't provide high enough resolution to determine if a site was sampleable. For example, the reach selected near a Klickitat River bridge turned out to be a treacherous gorge and had to be re-located. The field crew elected to move the site downstream a safe distance and accessed the river by boat. Also, on the Klickitat, White Salmon, and Umatilla Rivers it wasn't possible to collect the fish and water samples at the same locations. Fish samples were collected early in the season while water levels were comparatively high. When crews returned to deploy SPMDs and collect water samples on the Klickitat and Umatilla, the sites were no longer accessible by boat and/or would have put the SPMDs at high vandalism risk. The targeted site on the White Salmon was accessible for boat electrofishing, but was full of migrating salmonids and couldn't be fished under the conditions of our scientific take permits. In each scenario, we decided to divide the sampling locations to work around obstacles. Had these been probabilistic locations, the sites would have been rejected as target non-sampleable. With the flexibility to make adjustments, we collected fish, water, and SPMDs in these problematic areas. These modifications are reflected in Table 2, which shows three of the tributaries with "A" and "B" locations.

Objective II --Part A: Habitat Assessment

Field crews completed a series of rapid habitat visual assessment forms at each of the probabilistic sites. The results are summarized in the following charts.

Land Use Disturbance

Field crews categorized each sampling site into one of five dominant land uses (urban and sub-urban were combined for summary purposes). The idea was to get a broad sense of the "*waterbody character*". Crews assigned each site a disturbance score ranging from 1 to 5, with the least disturbed choice labeled "Pristine" and the most disturbed as "Highly Disturbed". Similar scores were assigned ranging from "Appealing" to "Unappealing" to capture aesthetic impressions. Crews were instructed to complete the assessment form "based on your general impression of the intensity of impact from human disturbance".

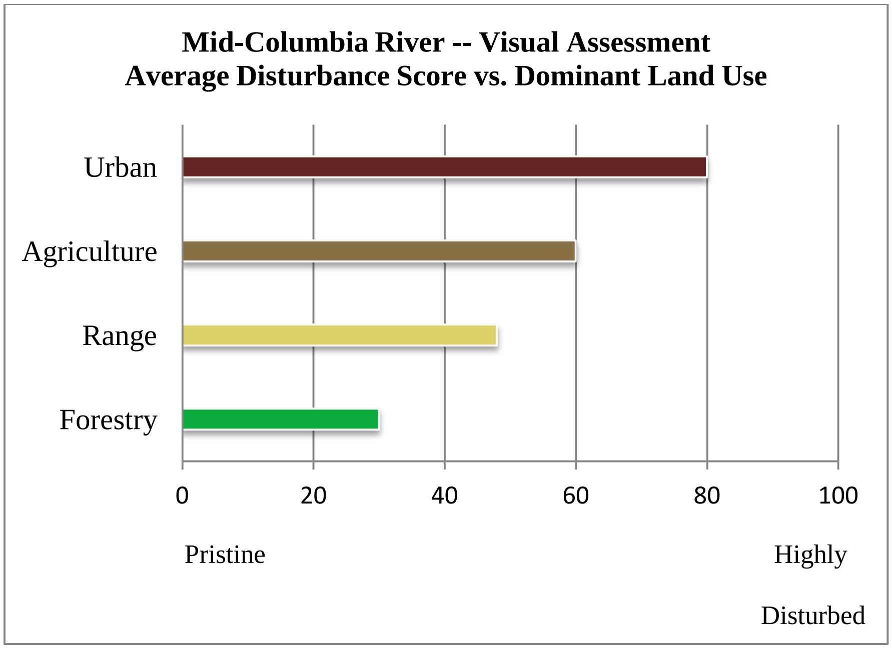

Figure 9. LMC land use versus disturbance scores based on probabilistic sampling.

The land use disturbance scores were averaged and normalized for the twenty three probabilistic sites (Figure 9). The scores clearly show increasing disturbance as the land use intensity progresses from forestry through range, agriculture, and urban. The rankings make sense in that disturbance increased with anthropogenic activity. It's not clear from the rankings whether the disturbance could be mitigated through changes in practices.

Reach Characteristics

This assessment gives a more detailed view of the extent of ten different landscape features observed at the probabilistic sites. This assessment differed from the Land Use Disturbance evaluation in that crews were instructed to focus on the sampling reach "*immediately adjacent to the river"* versus a broad sense of "waterbody character". This distinction is important; if ignored the data from the two assessments may seem contradictory.

The Reach Characteristics assessment focused on the near-field riparian zone. Some of the categories were broad land uses, while others evaluated vegetation type and density. Field crews were asked to visually quantify each of the characteristics as Rare (<5%), Sparse (5-25%). Moderate (25-75%), or Extensive (>75%). The results are shown in Figure 10 as a 100% stacked bar chart.

Urban/Residential, logging, grazing, row crops, wetlands, and forest were rare in roughly 75% of riparian areas. Shrubs, bare ground, and grass were more common. Shrub was the most extensive vegetation type in the riparian zone, with much bare ground because of rip rap, natural basalt, or low vegetation densities in arid areas. About 40% of sites had at least a quarter of the riparian area as bare ground, with some sites nearly barren. Macrophytes were typically sparse to rare, but were notable particularly in areas with slack water (typically in the form of submerged aquatic vegetation). This data could prove useful for ground-truthing GIS layers.

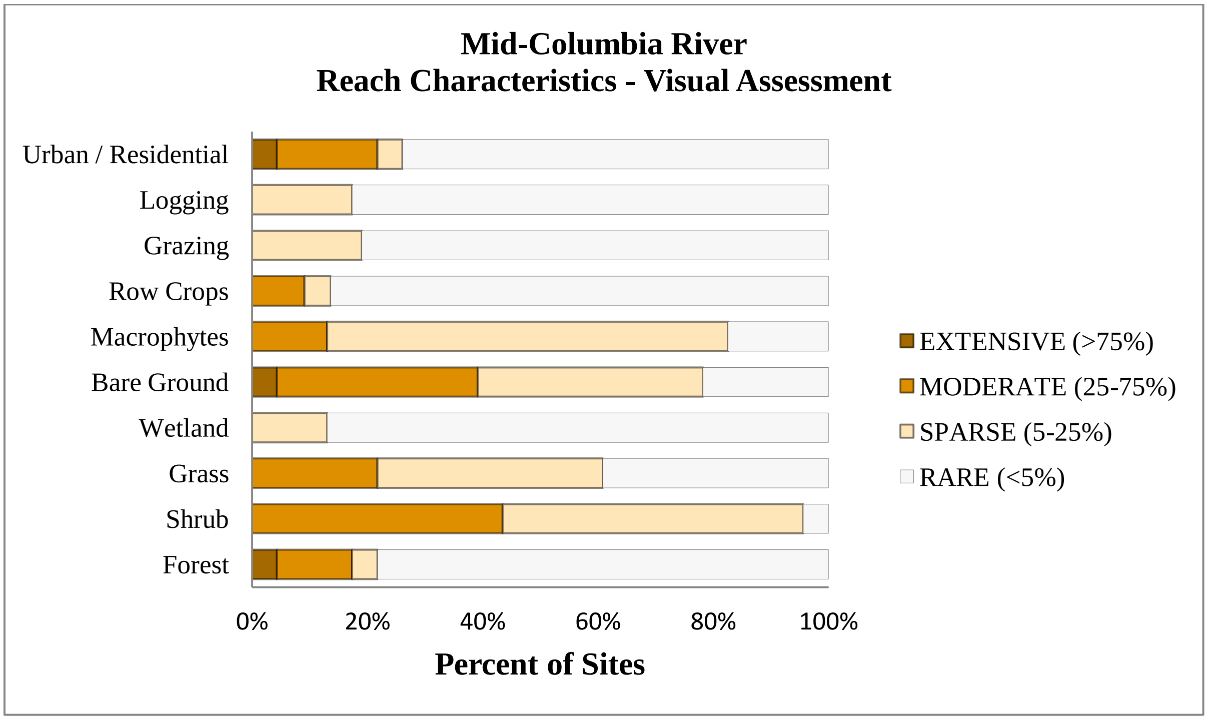

Figure 10. Extent of land use and vegetation characteristics of the LMC based on probabilistic sampling.

Fish Cover

The fish cover assessment examined the submerged area adjacent to the bank out to 10 m from shore. This is essentially the same zone that was electrofished. Eight types of cover were considered:

1. Filamentous algae
2. Aquatic macrophytes
3. Large woody debris (>0.3 m diameter)
4. Brush and small debris
5. Overhanging vegetation
6. Undercut banks
7. Boulders/rock ledges
8. Artificial structures (including intentionally placed structures and discarded materials)

Crews visually estimated the areal cover for each category, and assigned a code from 0-4. The codes were assigned as follows:

0. Absent, zero cover
1. Sparse, <10%
2. Moderate, 10-40%
3. Heavy, 40-75%
4. Very heavy, >75%

The fish cover results are shown as a stacked bar graph in Figure 11. Artificial structure was present at over half the sites, none of which was purposeful habitat restoration. Pilings, docks, wing dams, concrete, and remnants of human development dominated this category. Much of the pre-hydroelectric dam landscape had exposed basalt and rocks from ancient lava flows. Thus, boulders and rock ledge were common fish habitat . Undercut bank was quite rare, as one might expect given the extent of rip rap and natural basalt. Overhanging vegetation was mostly sparse, which makes sense given the modified and rocky shoreline conditions that dominated the LMC. There was comparatively little opportunity for woody vegetation to flourish, and thus most vegetation didn't achieve sufficient size to overhang the banks. (It would be interesting to compare these results to GIS vegetation mapping that may have been done by other researchers).

Given the rarity of large or small woody vegetation in the riparian zone, it makes sense that woody debris provided little submerged fish cover. Large wood was absent or sparse at 90% of sites, while submerged brush was mostly sparse or absent at 95% of sites. The combination of submerged macrophytes and filamentous algae rivaled boulder/ledge as the dominant fish habitat. Field observations show that the algae and macrophytes were much less dominant in areas with higher water velocities. By inference, the impoundments have produced conditions favorable to submerged aquatic vegetation.

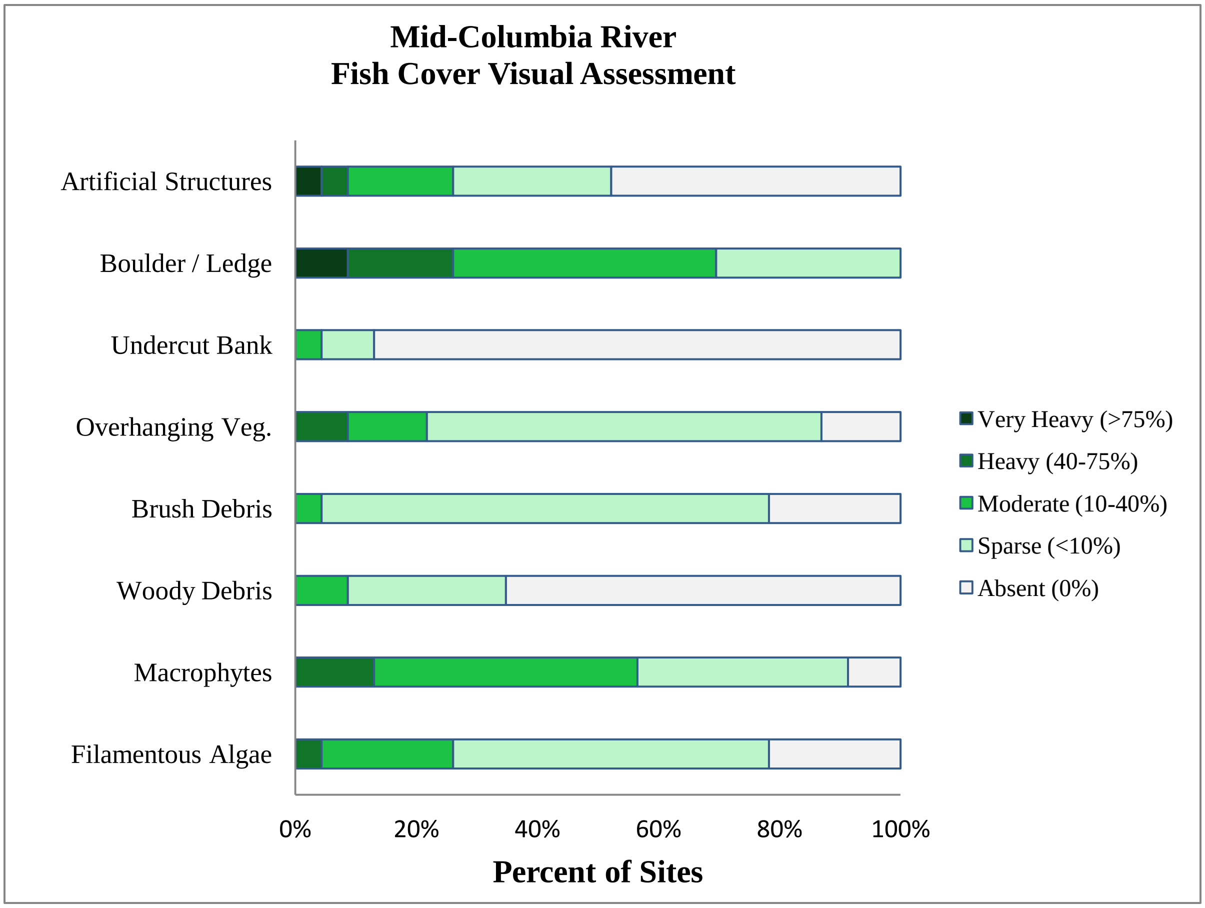

Figure 11. Fish cover assessment based on probabilistic survey.

Non-native Invasive Species

Field crews were asked to record observations of any invasive plant, fish, or invertebrate species listed in

Table 17 that were observed within the 500 m sample plot either along the bank or in the water. This list is a subset of the 100 Primary Aquatic Invasive Species of Concern recommended by Oregon State University Sea Grant Extension (Oregon Invasive Species Council, 2007).

Table 17. Primary aquatic invasive species of concern.

Fish	Invertebrates	Plants
Grass carp	Zebra mussels	Hydrilla
Bighead carp	Quagga mussel	Knotweed (giant/ Japan)
Silver carp	N.Z. mudsnail	Himalayan blackberry
Mosquito fish		English ivy
Amur goby		Yellow flag Iris

No invasive fish or invertebrates were observed, but two invasive plants were detected (Table 18). Himalayan Blackberry was found at four of the probabilistic survey sites (an estimated 17% of the LMC), and at the Umatilla and White Salmon Rivers. English Ivy was found at Trotter Point, representing an estimated 4% of the LMC. Trotter Point was the only location with two invasive plant species. .

Table 18. Invasive plants observed in the LMC and tributaries.

LASAR	Description	Himalayan Blackberry	English Ivy
35321	Columbia R. at Trotter Point	✓	✓
35330	Columbia R. at Rufus	✓	○
35340	Columbia R. upstream of The Dalles Locks	✓	○
35539	Umatilla River 0.3 mile upstream of Hwy 730	✓	○
36025	White Salmon R WA at RM 0.8	✓	○

General Habitat Condition

The general habitat assessment required crews to examine the entire reach sampled during fish collection. This assessment differed from those previously described in that it used four habitat *condition classes* in conjunction with scores.

Table 19. General habitat assessment condition classes.

Habitat Parameter	Poor	Fair	Good	Excellent
Mean Riparian Width (m)	<10	10-18	18-24	>24
	0 to 5	6 to 12	13 to 19	20 to 25
Large Woody Debris (pieces)	<10	10-25	25-75	>75
	0 to 5	6 to 10	11 to 15	16 to 20
Aquatic Vegetation	<5%	5-15%	15-25%	>25%
	0 to 5	6 to 10	11 to 15	16 to20
Bottom Deposition	>50%	25-50%	5-25%	0-5%
	0 to 2	3 to 5	6 to 8	9 to 10
Bank Stability	Poor stability. Slopes >60%. High erosion potential.	Moderate stability. Slopes < 40%. Slight erosion potential.		Stable. No bank failure. Slopes <30%. Low erosion potential
	0 to 5	6 to 8		9 to 10
Off-Channel Habitat (units)	<2	2-3	4-5	>5
	0	1 to2	3 to 4	5

Crews first determined the condition class for a habitat parameter (Excellent, Good, Fair, or Poor), then chose a score from the values available within each class. The results are summarized in Figure 12. In terms of method evaluation, the "condition class" method was preferred compared to the other visual habitat assessment strategies presented above. Pre-assigning condition classes immediately put the data in context without the need for additional processing. It also made habitat scoring within a category relevant to field crews; especially since visual estimates as opposed to direct measurements were the basis for observation.

The dominance of poor and fair condition across five out of six general habitat indicators in the LMC primarily reflects a degraded riparian zone. The only indicator with exclusively excellent and good conditions was bank stability. The stable banks resulted from a combination of rip rap and natural basalt, and to a lesser extent riparian vegetation. These findings were corroborated with a cursory look at the LMC with the map tool Google Earth (Google, Inc., 2012). The narrow riparian zone and extent of bank stabilization for roads and railroads was immediately obvious, and could be verified by GIS in the future. Riparian zone condition shows a strong visual relationship with the lack of woody debris (only 2% of the LMC had woody debris categorized at least "good").

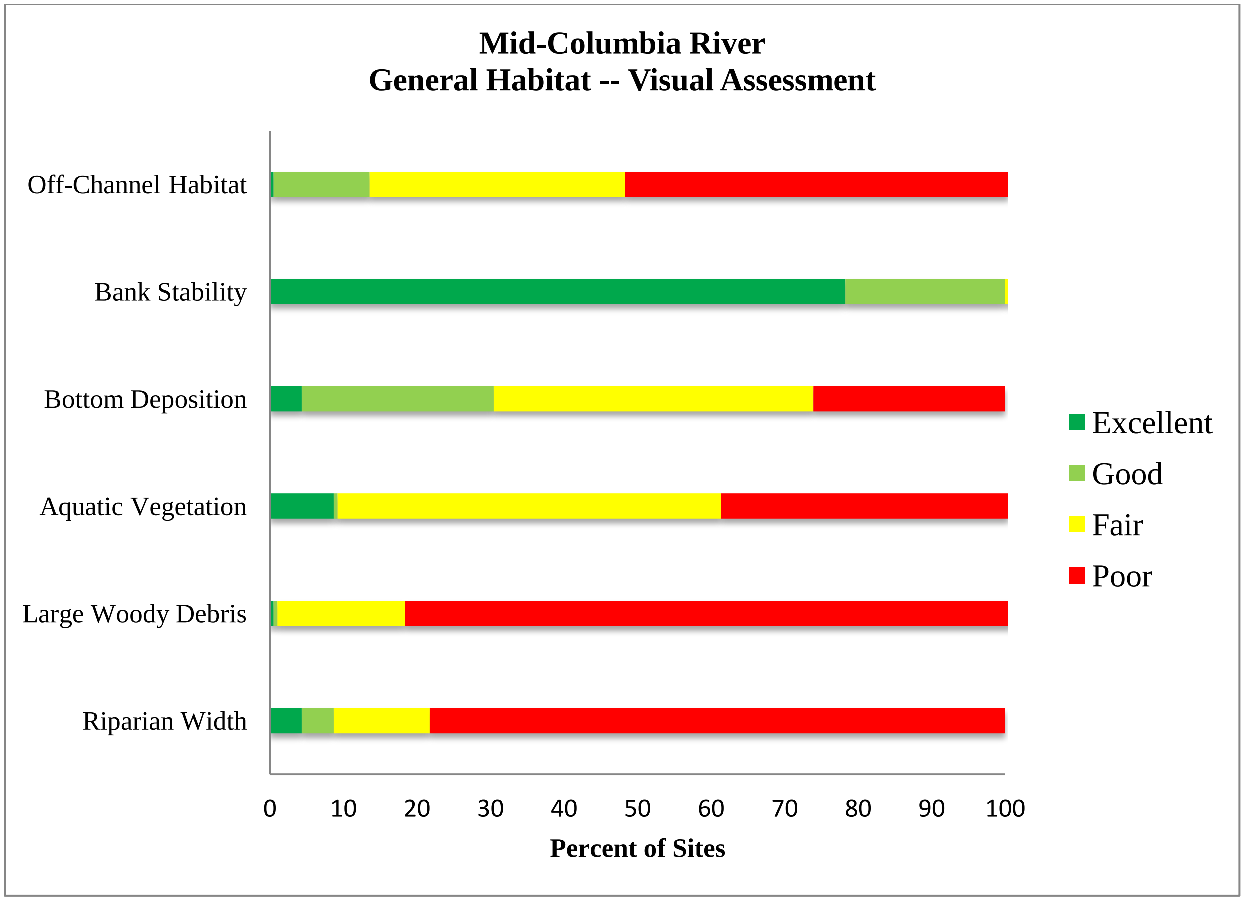

Figure 12. General habitat assessment condition classes.

The poor and fair off-channel habitat and aquatic vegetation conditions indicate a limited presence of salmonid rearing habitat; and may make juvenile fish more susceptible to predation while reducing the abundance of important forage insects. After removing a dike and restoring hydrologic connectivity between an estuary and marsh, the Oregon Plan for Salmon and Watersheds found juvenile salmon survival rates improved due to feeding upon energy rich flies, and the fish were more resilient to high water temperatures (State of Oregon, 2012). A similar relationship may exist with off-channel and aquatic vegetation habitats on the LMC. In an assessment of habitat restoration efforts in the lower Columbia River, the U.S. Army Corps of Engineers monitored juvenile Chinook salmon densities at Cottonwood Island (tidal fresh water near Longview, WA). Mean juvenile salmon densities were highest in off-channel habitat (~0.26 fish/m^2), followed by wetland channels (~0.18 fish/m^2), and the main channel (~0.07 fish/m^2) (Diefenderfer, et al., 2011).

Objective II --Part B: Water Quality Assessment

E. coli Bacteria

Fecal indicator bacteria concentrations are used to determine if recreational waters meet the Clean Water Act's "swimmable" goal. In Oregon the acceptable levels of *E. coli*. are 406/100 ml based on a single water sample, and 126/100 ml based on a geometric mean of five or more samples collected in a 30-day period. As shown in Figure 13, all of the probabilistic mainstem samples were orders of magnitude below water quality criteria. The same is true for the targeted mainstem sites and tributaries (Table 21). The Hood River had the highest E. coli concentration (35/100 ml) –a $\log_{10}$ below the single sample criterion, and nearly 3x lower than the geometric mean criterion. These findings corroborate the results of DEQ's ambient river monitoring in the lower reaches of major Columbia River tributaries.

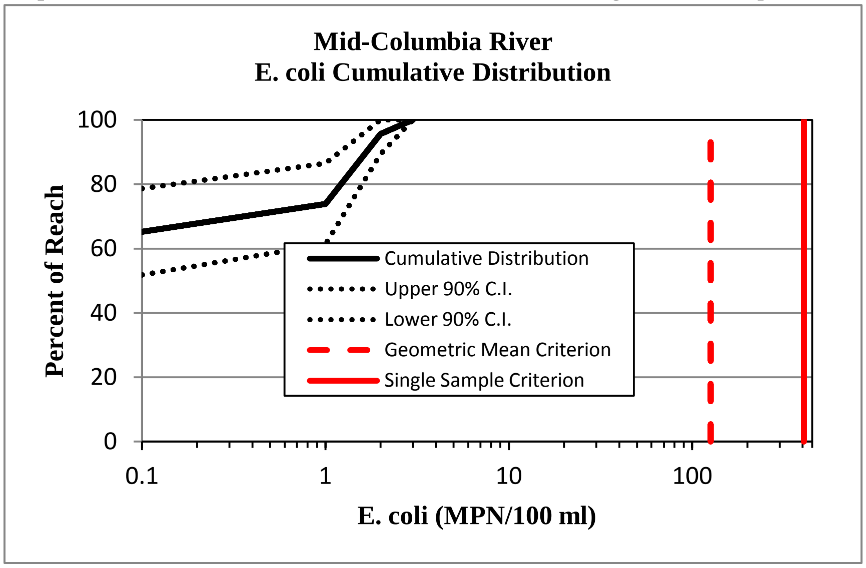

Figure 13. Distribution of E. coli from the probabilistic survey.

Total Suspended Solids, Turbidity and Secchi Depth

TSS is defined as the total amount of organic and inorganic particles suspended in water (measured in mg/l), whereas turbidity and Secchi depth measure water clarity. Turbidity meters report nephelometric turbidity units (NTU). The instrument passes a beam of light through the water, and the detects the proportion of light scattered by suspended particles. A Secchi measurement is made by lowering an 8-inch diameter black and white disk into the water to the depth where it is no longer visible. As show in Figure 16 , the probabilistic survey found ten percent of the LMC has impaired water clarity based on the sub-ecoregion reference criterion (USEPA, 2001).

Figure 14. Residual sediment on John Day River SPMD canister.

Oregon regulates TSS at point sources via permits with numeric criteria, but is among the majority of states with non-numeric *narrative* criteria for ambient waters(State of Oregon, OAR 340-041-0007 - 0046). Turbidity criteria are site-specific, and limit more than a 10% increase above background levels immediately upstream from a source. Secchi depth is not regulated.

In order to improve controls over nonpoint sources of pollution, Oregon rules encourage land management agencies to implement programs to regulate or control runoff, erosion, and turbidity on a basin-wide scale.

The narrative rules prohibit, "The formation of appreciable bottom or sludge deposits or the formation of any organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry…" (OAR 340-041-0007 (12)).

As a result of sediment related water quality impairment, TSS average monthly effluent discharges to streams in the Hood River Basin (excluding the mainstem Columbia) are limited to 10 mg/l during low flow conditions (approximately May 1 to October 31) (State of Oregon, 340-41-0165). Oregon's other Columbia River tributaries lack waterbody-specific TSS criteria.

Hawaii has the strictest numeric ambient TSS criteria, with a geometric mean of readings not to exceed 10 mg/L, less than 10% of readings to exceed 30 mg/L, and less than 2% of readings to exceed 55 mg/L. Utah, North Dakota, and South Dakota have similar criteria for their cold water streams; 35 mg/L, 30 mg/L, and 30 mg/L as a 30 day average or 58 mg/L daily maximum, respectively (USEPA, Consultation Science Advisory Board, 2003). Short-term pulses of suspended sediment with turbidities above 30 NTU have been shown to adversely affect juvenile Coho social behavior, gill-flaring, feeding behavior, and feeding success (Berg & Northcoat, 1985).

Figure 15. Google Earth Image of the Hood River delta showing a turbidity plume in the Columbia.

(Google, Inc., 2012).

A statistical summary of TSS results and related field measurements are presented in Table 20 and Table 21. The LMC probabilistic sites easily met the aforementioned criteria with a maximum TSS of 5 mg/l and a mean of 2 mg/l. The John Day River had the highest TSS concentration (26 mg/l) followed by the Deschutes River (13 mg/l) and the Hood River (10 mg/l). All other sampling locations were at or below 5 mg/l.

Oregon's 2010 Integrated Report Database (DEQ, 2010b) lists the lower John Day River as having insufficient data to apply the narrative sedimentation criteria noted above. Field crews measured a John Day River turbidity of 17 NTU, and a Secchi depth of 0.4 m which fails the EPA's recommended sub-ecoregion 2 m criterion for lakes and reservoirs (USEPA, 2001). Field crews also noted heavy siltation (sufficient to sink beyond ankle depth while wading), and observed that the moored SPMD canister was partially embedded during its 30-day deployment (FFigure 14).

The Deschutes River TSS was half that of the John Day River, with a turbidity of 4 NTU. The Secchi depth of 0.9 m also failed the EPA sub-ecoregion 2 m criterion (USEPA, 2001). The 2010 Integrated Report Database (DEQ, 2010b) lists the lower Deschutes River as having insufficient data to apply the narrative sedimentation criteria.

Field observations and anecdotal information from local anglers at the Deschutes Heritage Landing indicate that much of the suspended sediment is sand. This could explain why the Secchi depth fails criteria even though the turbidity is relatively low. On a mass basis, sand particles scatter less light than finer particles and cause less turbidity. The field crew observed much sand and shallow water at the Deschutes' delta, and was unable to retrieve the SPMD canister, which became deeply buried in sand. The rope attached to the canister disappeared into the nearly fluid sandy substrate and could not be excavated or pulled free. The SPMD was replaced and relocated upstream on a bedrock substrate.

The Hood River's TSS was comparable to the John Day's; as was the turbidity (Secchi was inadvertently not recorded). The Hood's turbidity is driven by glacial silt during low flow periods, and a large delta extends into the mainstem Columbia (Figure 15). On occasion, commercial barges run aground on the delta's extended arm. In summer, much of the delta is exposed and is heavily used as a bathing beach. The 2010 Integrated Report Database (DEQ, 2010b) lists the lower Hood River as having insufficient data to apply the narrative sedimentation criteria.

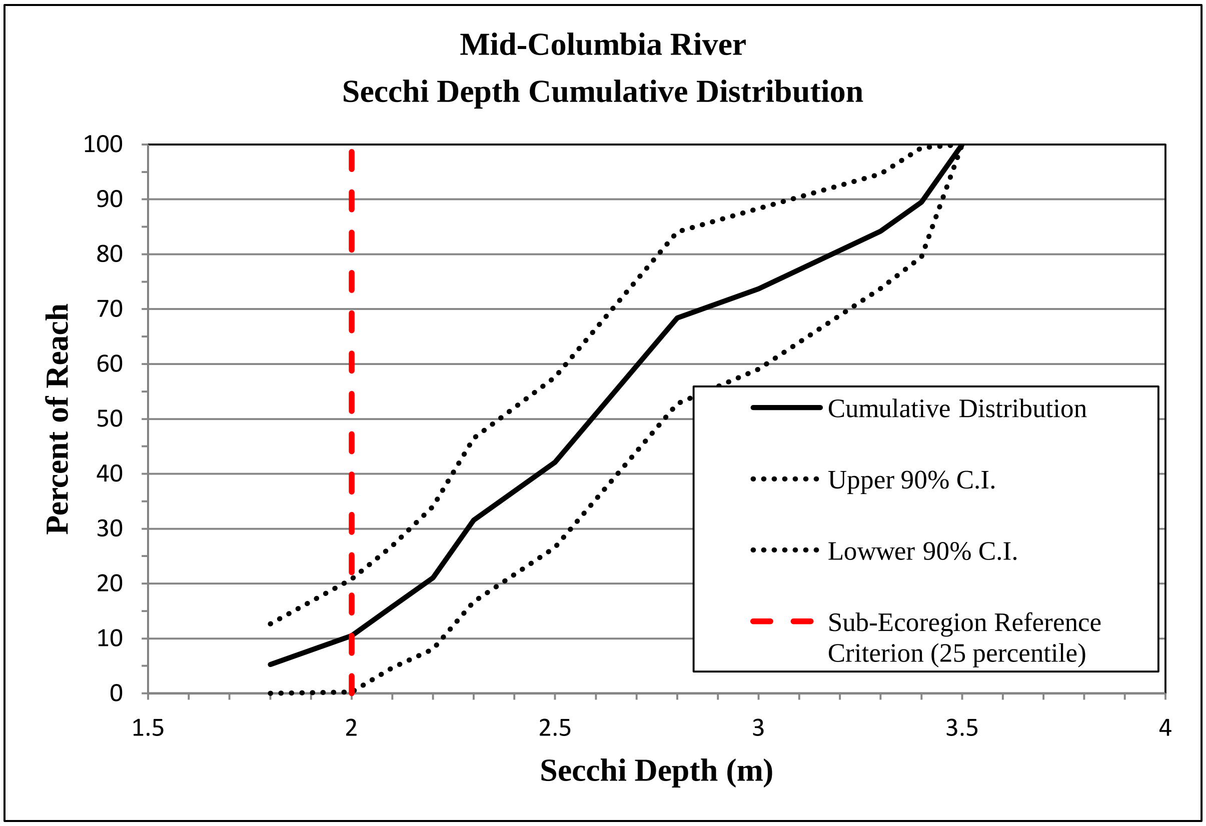

Figure 16. Distribution of Secchi depth (water clarity) from the probabilistic survey.

Chlorophyll a.

Chlorophyll *a* is the phytoplankton pigment primarily responsible for photosynthesis. By filtering water samples and measuring the amount of chlorophyll *a* retained on the filter, one can infer the degree of phytoplankton productivity. Excessive chlorophyll *a* concentrations indicate eutrophication. Oregon's ambient water quality chlorophyll *a* criterion for lakes and reservoirs is 15 µg/l. As depicted in Figure 17 , the probabilistic survey found the entire LMC was well below Oregon's chlorophyll *a* eutrophication criterion. However, only 65% of the reach attained EPA's sub-ecoregion reference criterion of 3.4 µg/l (USEPA, 2001). All targeted sites met the 3.4 µg/l criterion, with the exception of the Deschutes and John Day Rivers, and the mainstem site downstream of PGE –Boardman (Table 21). The John Day River concentration (41 µg/l) soundly failed DEQ's 15 µg/l criterion, which was remarkable given its poor light penetration (17 NTU, Secchi 0.4 m).

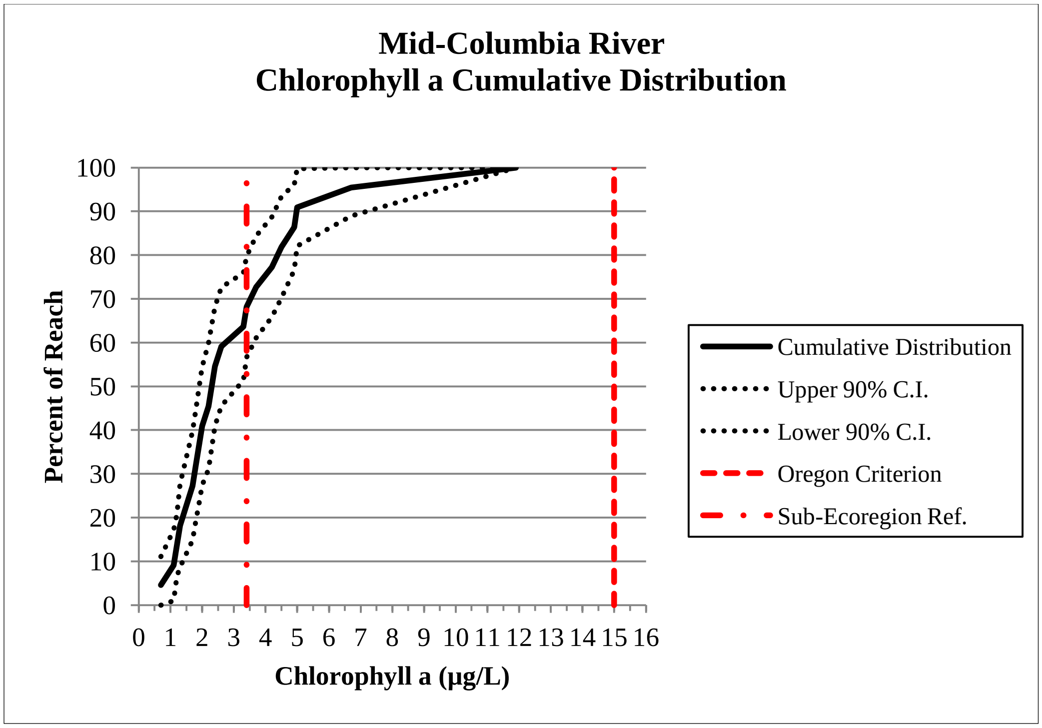

Figure 17. Chlorophyll *a* distribution from the probabilistic survey.

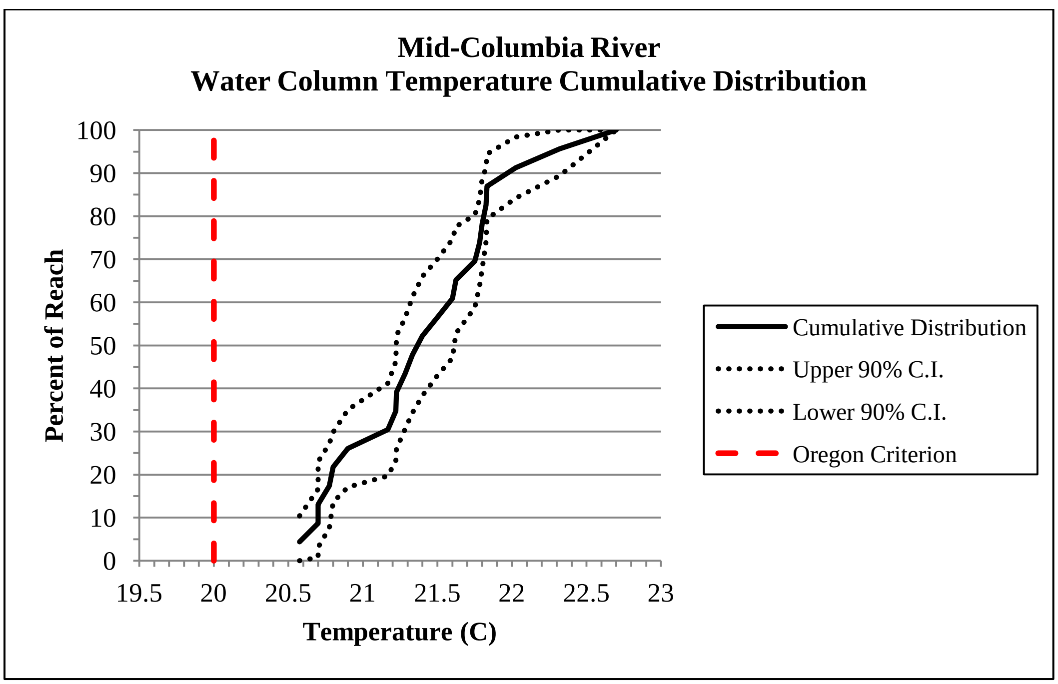

Figure 18. Water column temperature from probabilistic survey.

Temperature

All of the mainstem Columbia sites and the John Day and Umatilla Rivers exceeded Oregon's Columbia Basin 20 C temperature criterion intended to protect salmonids (State of Oregon, OAR 340-041-0101) (see Figure 18 and Table 20).

The White Salmon (9.8 C), Hood (15.6 C), Klickitat (15.6 C), and Deschutes (19.1 C) Rivers met the criterion and may provide thermal refugia to migrating salmonids. Anecdotal information from steelhead anglers frequenting the Deschutes suggests that some large steelhead bound for other rivers shelter in the lower Deschutes cooler waters.

> "What makes the lower river so unique is that it attracts many fish destined for other Columbia River tributaries. As the steelhead ascend the warm Columbia, the cooler Deschutes invites them in for a break from 70 degree water. Many of these "strays" will go 15 miles up the Deschutes." (Duddles, 2012)

Dissolved Oxygen

All of the probabilistic (Figure 19) and targeted mainstem sites(Table 20)failed the Oregon cold water dissolved oxygen concentration criterion (11 mg/L), but passed the 95% saturation rule. The same is true for the tributaries, with the exception of the White Salmon River, which only attained 93% saturation.

Mid-Columbia River

Water Column Dissolved Oxygen Cumulative Distribution

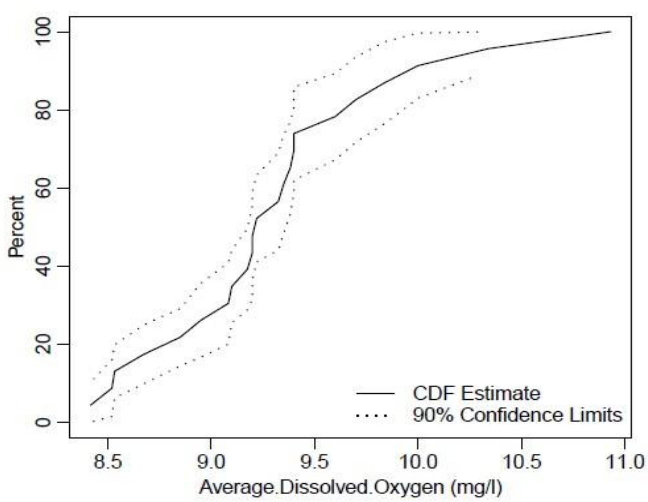

Figure 19. Dissolved oxygen distribution from probabilistic survey.

pH

As shown in Table 20 and Figure 20 the mean and median water column pH was 8.1 SU, well within the Oregon water quality criteria range. About ten percent of the LMC failed the criteria with an equal percentage above and below the acceptable range for the protection of aquatic life.

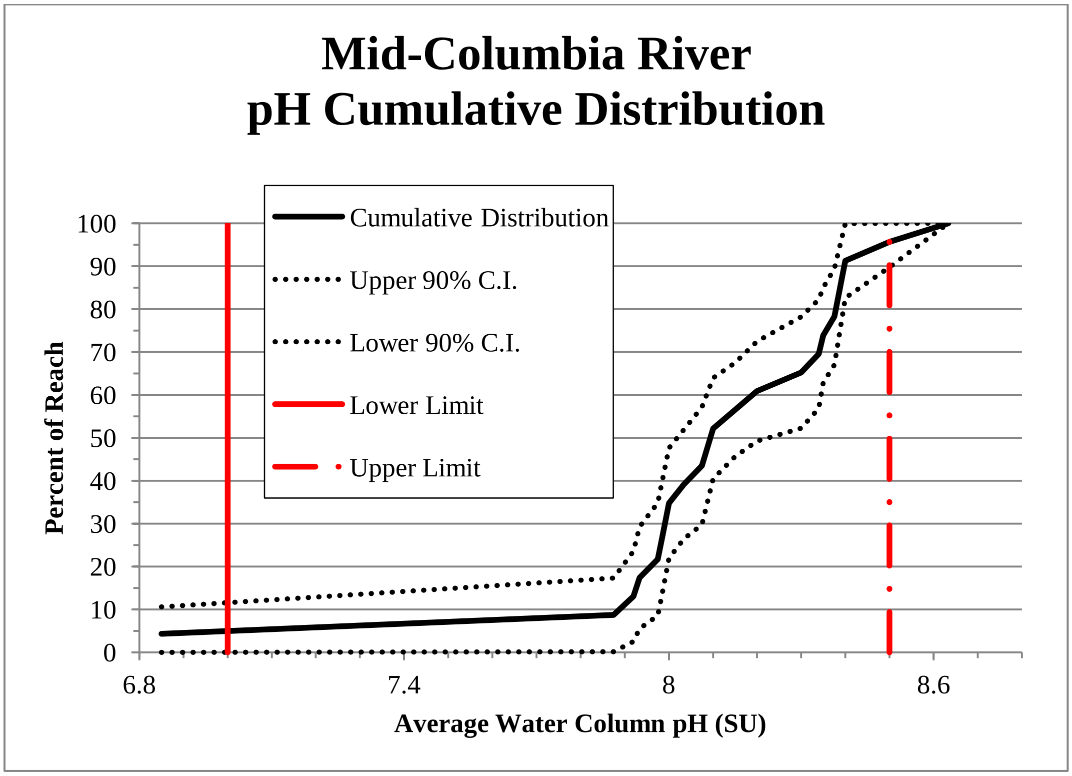

Figure 20. pH distribution from probabilistic survey.

Ammonia

Ammonia is an important plant nutrient that is readily taken up by phytoplankton and aquatic macrophytes. In aquatic systems, most ammonia is usually present as the ammonium ion, NH_4^+, which isn't toxic to aquatic life. However, the water temperature and pH affect the equilibrium between ionized (NH_4^+) and un-ionized (NH_3) ammonia. Increases in pH and temperature shift the equilibrium towards the toxic un-ionized form. EPA's recommended acute ammonia toxicity limit (with freshwater mussels present) is 0.833 mg/L NH_3-N, at the maximum Columbia River or tributary pH and temperature recorded (pH 8.6 and 22.7 C). The recommended chronic toxicity criteria under the same conditions is 0.103 mg/L NH3-N (USEPA, 2009a). All of the water samples from the Columbia River and tributaries had ammonia concentrations below the laboratory's reporting limit of <0.02 mg/L NH3-N. Therefore, none of the LMC or tributaries exceeded the acute or chronic toxicity criteria.

Nitrate + Nitrite

Nitrate and nitrite are important plant nutrients, commonly applied as fertilizers. These compounds are abundant in domestic sewage and animal waste, and are not completely removed by conventional wastewater treatment. Nitrate is typically the dominant form of nitrogen in oxygenated surface waters. Nitrite is readily oxidized to nitrate by naturally occurring nitrifying bacteria such as *Nitrobacter*. Nitrate and nitrite concentrations are often reported as a sum because the cadmium reduction analytical method converts the nitrate to nitrite and then measures the resulting total nitrite concentration(USEPA, 2012). With this method, the original ratio of nitrate to nitrite in the water sample is unknown.

In addition to being an important plant nutrient and potential cause of eutrophication, consumption of excessive nitrate in drinking water causes oxygen deprivation in the body's tissues. Infants are particularly susceptible to methaemoglobinaemia, and the condition is commonly refered to as "blue baby syndrome". Figure 21 shows the LMC's cummulative frequency distribution of NO_2 +NO_3-N in comparison to DEQ's drinking water (10 mg/L) and EPA's sub-ecoregion eutrophication criteria (0.12 mg/L) (USEPA, 2001). None of the LMC exceeded either criterion, but the White Salmon (0.12 mg/L), Hood (0.22 mg/L), and the Umatilla (3.4 mg/L) had NO_2 +NO_3-N concentrations at or above the eutrophication limit (Table 21). The Hood and Umatilla results from this survey were in the 60th and 80th percentiles, respectively, of over 120 samples DEQ collected at these sites in the last decade.

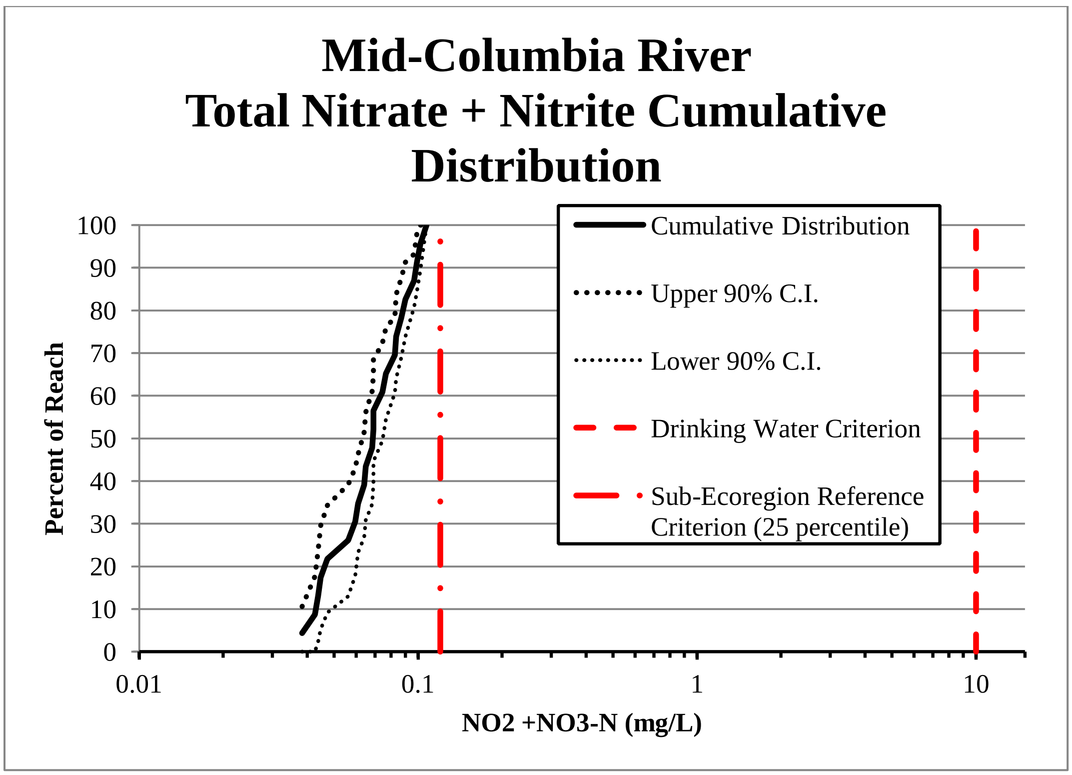

Figure 21. Cumulative Distribution of NO_2+NO_3 from the probabilistic survey.

Total Phosphorus

While nitrogen is an important in aquatic systems, phosphorus is usually the nutrient limiting excessive phytoplankton or weed growth. Total phosphorus measurements include dissolved forms as well as phosphorus not immediately available for plant uptake. The analytical procedure (USEPA, 2012) involves a digestion step which recovers dissolved inorganic orthophosphate, hydrolysable phosphorus (such as poly-phosphates), and organic phosphorus found in plant materials. Less than five percent of the LMC exceeded the EPA's recommended sub-ecoregion criterion of 0.035 mg/L, with a median value of 0.02 mg/L (Figure 22). The targeted LMC mainstem sites values were the same as the probabilistic survey'smedian. Most of the tributary rivers exceeded the 0.035 mg/L criterion; the John Day River claimed the highest value in the entire survey (0.12 mg/L), nearly 3.5x the criterion (Table 21). As noted above, the John Day River's chlorophyll *a* result also showed signs of enrichment.

While the sub-ecoregion phosphorus criterion gives the tributary data context relative to the mainstem LMC, the reference value is intended for use in lakes and reservoirs. In prior river and stream surveys, DEQ used an ecoregion reference site approach to set benchmarks for total phosphorus. Rivers in the East Cascades, Blue Mountains, and Columbia Plateau were classified as "Poor Condition" when total phosphorus concentrations exceeded 0.1, 0.065, and 0.069 mg/L respectively (Mulvey, Leferink, & Borisenko, 2009). In this context, only the John Day River exceeds the East Cascades 0.1 mg/L benchmark, and the Deschutes River marginally exceeds the Columbia Plateau benchmark. The remaining tributaries are at or below 0.06 mg/L.

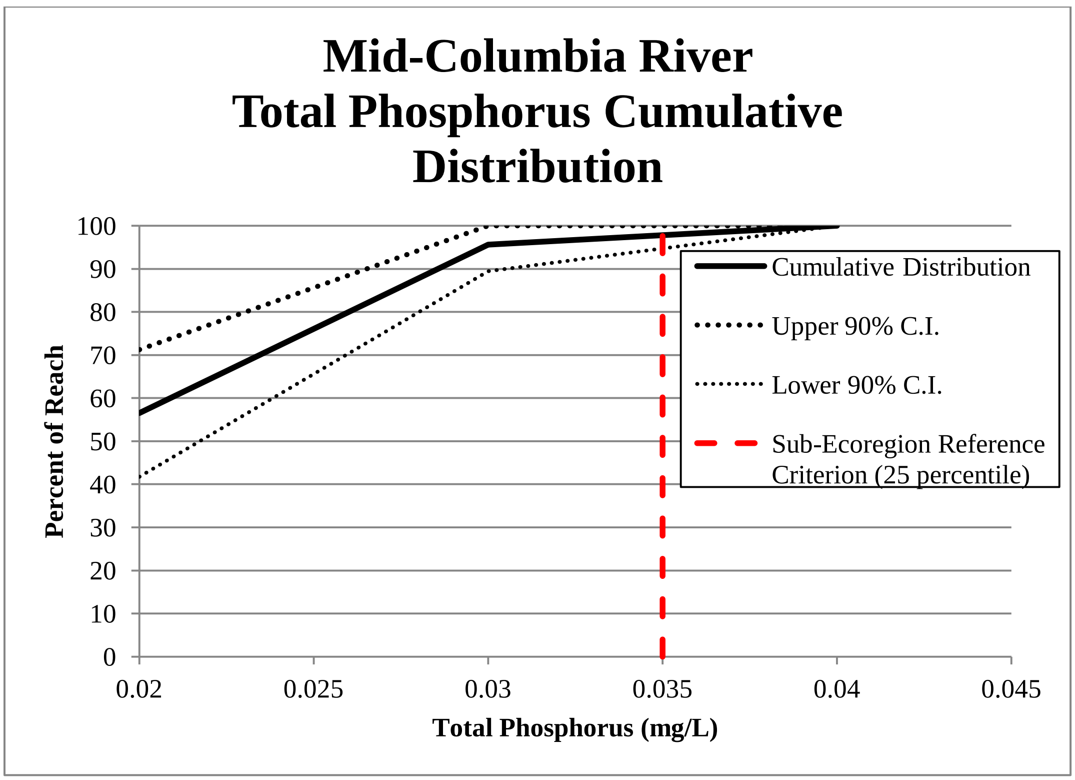

Figure 22. Total phosphorus cumulative frequency distribution from the probabilistic survey.

Table 20. Water quality field parameters statistical summary.

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	**Unit**	**Min**	**Max**	**Median**	**Mean**	**Std. Dev.**	**Percent Detects**	**White Salmon R.**	**Hood River**	**Klickitat River**	**Columbia R. d/s The Dalles**	**Deschutes River**	**John Day River**	**Columbia R. d/s PGE Boardman**	**Umatilla River**	**Screening Values**
Temperature	°C	**20.6**	**22.7**	**21.4**	**21.4**	0.5	100%	9.8	15.6	15.6	**21.4**	19.1	**21.8**	**22.0**	**22.5**	20.0[a]
Specific Conductance	μS/cm	147	154	151	151	2	100%	71	72	83	154	112	214	152	376	--
Dissolved Oxygen	mg/L	**8.4**	**10.9**	**9.2**	**9.3**	0.6	100%	**10.5**	**9.7**	**10.7**	**9.7**	**9.9**	**8.6**	**9.4**	**9.1**	11.0[b]
Oxygen Saturation	%	96	126	105	106	7	100%	93	96	106	108	108	102	109	106	95[b]
pH	SU	**6.9**	**8.6**	8.1	8.1	0.3	100%	7.9	8.1	8.0	8.1	**8.9**	7.6	8.4	8.2	7.0-8.5[a]
Turbidity	NTU	1	6	2	2	1	100%	3	20	6	4	4	17	2	0.5	--
ORP	mV	90	421	226	236	83	100%	250	259	143	281	157	178	227	78	--
Secchi Depth	m	**1.8**	3.5	2.8	2.7	0.52	83%[d]	1	Void	Void	2.5	**0.9**	**0.4**	**1.9**	>2	2[c]

[a] Columbia Basin water quality criteria(State of Oregon, OAR 340-041-0101).
[b] Statewide water quality criteria (State of Oregon, OAR 340-041-0007 - 0046)
[c] EPA Sub-ecoregion reference criterion. (USEPA, 2001).
[d] Field crews forgot to collect Secchi data at some locations.

Table 21. Water quality laboratory parameters statistical summary --non-metals.

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	**Unit**	**Min**	**Max**	**Median**	**Mean**	**Std. Dev.**	**Percent Detects**	**White Salmon R.**	**Hood River**	**Klickitat River**	**Columbia R. d/s The Dalles**	**Deschutes River**	**John Day River**	**Columbia R. d/s PGE Boardman**	**Umatilla River**	**Screening Values**
Alkalinity	mg/L $CaCO_3$	58	62	60	60	0.75	100%	31	31	40	60	54	98	60	141	--
Hardness as $CaCO_3$	mg/L	61.4	64.3	63.4	63.1	0.85	100%	26	27	32	63	37	81	63	145	--
Calcium	mg/L	16.7	17.7	17.4	17.3	0.30	100%	6	6	7	17	7	19	17	38	--
Magnesium	mg/L	4.69	4.94	4.85	4.84	0.07	100%	3	3	4	5	5	8	5	12	--
Sulfate	mg/L	9.5	11.1	10.8	10.7	0.38	100%	4	2	2	11	2	9	11	19	--
NH_3-N	mg/L	<0.02	<0.02	<0.02	<0.02	--	0%	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	--
NO_2+NO_3-N	mg/L	0.04	0.11	0.07	0.07	0.020	100%	**0.12**	**0.22**	<0.005	0.101	0.045	<0.005	0.020	**3.37**	10[a] 0.12[b]
ortho- PO_4-P	mg/L	<0.005	0.015	0.007	0.006	0.0052	65%	0.036	0.042	0.026	0.014	0.049	0.008	<0.005	0.043	--
Total P	mg/L	0.02	**0.04**	0.02	0.02	0.006	100%	**0.04**	**0.06**	0.03	0.02	**0.08**	**0.12**	0.02	**0.06**	0.035[b]
TSS	mg/L	<1	5	2	2	1.1	91%	<1	10	5	2	13	26	2	3	--
DOC	mg/L	2	3	2	2	0.2	100%	<1	<1	<1	2	<1	3	2	3	--
TOC	mg/L	2	2	2	2	--	100%	<1	<1	<1	2	1	6	2	4	--
E. coli	MPN/ 100 ml	<1	3	<1	<1	0.98	35%	26	35	6	5	2	<1	<1	24	406[c]
Chlorophyll a	µg/L	0.7	11.9	2.4	3.2	2.46	100%	0.6	0.6	0.4	1.7	5.1	40.8	5.6	2.7	15 3.4[b]
Pheophytin a	µg/L	0.6	2.6	1.1	1.2	0.50	100%	0.6	0.6	0.8	1.3	4.4	15.9	0.8	4.2	--

[a] Drinking water Maximum Contaminant Level, (Matzke, Sturdevant, & Wigal, 2011).
[b] EPA Sub-ecoregion reference criterion. (USEPA, 2001). [c](State of Oregon, OAR 340-041-0007 - 0046): Water Contact single sample maximum, OAR 340-041-0009.

Objective II --Part C: Water Mercury and Methylmercury Concentrations

Mercury

Oregon withdrew its water column mercury human health criteria, and adopted a methylmercury fish tissue criterion in its place. This action was consistent with EPA's National Toxics Rule; the rational for this decision is that most human mercury exposure in Oregon is via fish and shellfish consumption (Matzke, Sturdevant, & Wigal, 2011)

The DEQ retained mercury criteria for the protection of aquatic life; 2,400 ng/L acute exposure, and 12 ng/L for chronic exposure. As shown in Figure 23, the entire LMC passed the chronic criterion by a wide margin.

Most water column mercury was associated with particulate matter. The mean water total mercury concentration was 0.71 ng/L with a maximum of 1.9 ng/L, whereas the dissolved mercury fraction peaked at 0.64 ng/l with a mean of 0.03 ng/L (the total vs. dissolved maximum values differed by a factor of three). Also, total mercury was detected in 78% of the LMC, while dissolved mercury was only found in 4%.

The total mercury concentrations at the targeted mainstem sites were within 0.07 ng/L of the LMC mean, and the dissolved fractions were non-detects. Washington's White Salmon and Klickitat Rivers both exceeded the total mercury chronic toxicity criterion for the protection of aquatic life. The Klickitat had the highest recorded mercury values in the survey, with total water concentrations approximately 4x the Screening Value (Table 22).

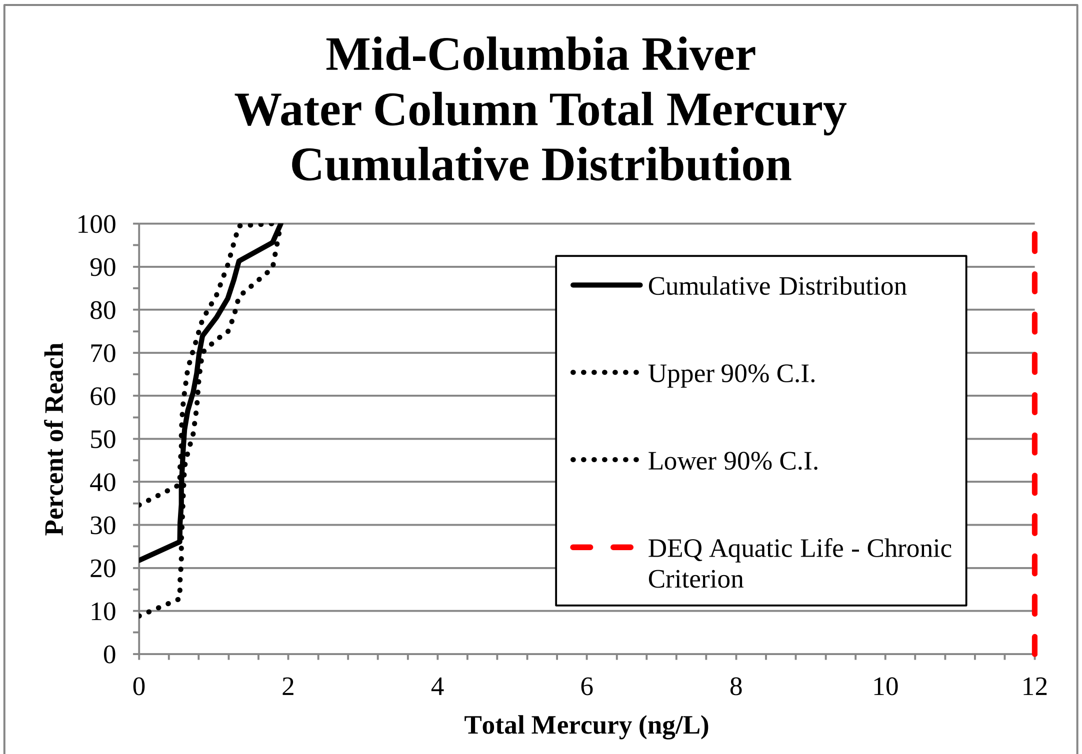

Figure 23. Water column total mercury from the probabilistic survey.

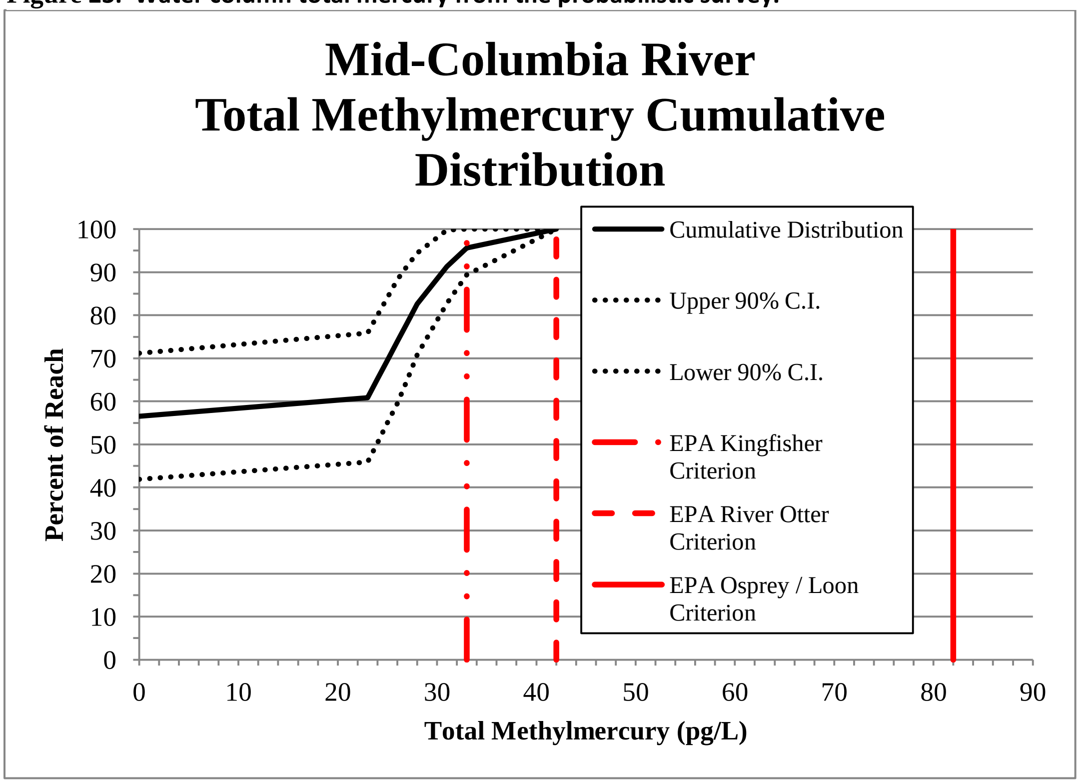

Figure 24. Water column total methylmercury from the probabilistic survey.

Methylmercury

Methylmercury is considerably more toxic than elemental mercury, and is infamous for human and wildlife morbidity and mortality at comparatively low concentrations. Figure 24 shows the cumulative frequency distribution of total methylmercury from the probabilistic survey, relative to several examples of wildlife protection criteria published by the USEPA in an extensive eight volume report to congress (USEPA, 1997). ***Note that the methylmercury concentration units in are picograms per liter in Figure 24 versus nanograms per liter for mercury in Figure 23*).** Interestingly, two tributaries with the highest total mercury concentrations, the Klickitat and White Salmon Rivers, had total to dissolved mercury ratios of 32:1 and 15:1 respectively, whereas the total to dissolved methylmercury concentrations were approximately 1.5:1 for both rivers. These tributaries' fish fillet mercury concentrations were the highest measured in the survey (seeTable 22).

The relative risk of methylmercury exposure is complex. The wildlife criteria vary considerably, in part due to varying toxicity among species (for example, mammals vs. birds), but also due to each species body weight and exposure routes. The calculations and assumptions used to derive the protective criteria are similar to the methods used to set human health benchmarks, and include factors such as trophic feeding levels.

Osprey feed heavily on largescale suckers, and bioaccumulate mercury. It's encouraging that the entire LMC's *water column* methylmercury estimate is well below the osprey criterion, but unfortunate that *fish tissue* levels exceed the human health screening value. The bald eagle methylmercury water criterion is 100 pg/L (USEPA, 1997). These raptor populations suffered serious declines due to DDT and other stressors, but osprey in particular have shown remarkable recovery along the Columbia River (USGS, 2005).

Belted Kingfishers feed on smaller fish, but are more sensitive to methylmercury toxicity. About 5% of the LMC exceeds their criterion (Figure 24) as do five of the six tributaries sampled (Table 22).

Methylation Cofactors

Mercury methylation in the aquatic environment is mediated by bacteria (Hamdy & Noyes, 1975) and related to oxidation reduction potential, and water concentrations of alkalinity, hardness, calcium, magnesium, selenium, sulfate, and organic carbon. The results for these parameters are reported in Table 20 and Table 21. This data was collected because it may prove useful to scientists interested in modeling mercury methylation in the LMC.

Table 22. Surface Water and Fish Fillet Mercury Statistical Summary (values in ng/L and mg/Kg wet weight, respectively).

Columbia Mainstem Probabilistic Sites							Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	Deschutes River	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Screening Values
Dissolved Mercury	<0.5	0.64	<0.5	0.03	0.133	4%	1.18	<0.5	1.54	<0.5	<0.5	<0.5	<0.5	0.54	12[a]
Total Mercury	<0.5	1.90	0.61	0.71	0.536	78%	**18.1**	3.3	**49.8**	0.77	0.55	1.3	0.64	0.69	12[a]
Dissolved Methyl mercury	<0.05	**0.04**	<0.05	0.01	0.011	22%	**0.04**	<0.05	0.10	<0.05	<0.05	<0.05	<0.05	0.03	0.033
Total Methyl mercury	<0.05	**0.04**	<0.05	0.01	0.015	43%	**0.06**	0.02	**0.14**	<0.05	**0.04**	**0.12**	0.02	**0.05**	0.033
Total Fillet Mercury (mg/Kg wet)	**0.11**	**0.5**	**0.19**	**0.22**	0.11	100%	**0.46**	**0.35**	**0.77**	**0.21**	**0.12**	**0.41**	**0.14**	**0.31**	0.04[c]

[a] Aquatic life chronic toxicity criterion. (Matzke, Sturdevant, & Wigal, 2011) (DEQ, 2011)

[b] Multiple SVs apply for the protection of wildlife (see Figure 24).

[c] DEQ's human health fish consumption criterion for total methylmercury(Matzke, Sturdevant, & Wigal, 2011), is presented here as a SV for total fillet mercury (i.e. assumes 100% of the fillet mercury is methylated).

Objective II --Part D: Priority Contaminants in Water and Food-fish Fillets

Metals

In addition to mercury and methylmercury, water column arsenic, copper, lead, and selenium were identified as data gaps/potential concerns based on DEQ's water quality assessment database (DEQ, 2010b). As shown in Table 23, none of these contaminants were detected in the LMC or tributary water samples with the exception of the John Day River, where copper and lead were detected below SVs.

The DEQ laboratory routinely analyzes water samples for suites of metals by EPA method 6020, and provided results for thirteen additional analytes at no additional cost. Antimony, barium, and uranium were detected at all of the probabilistic survey sites.

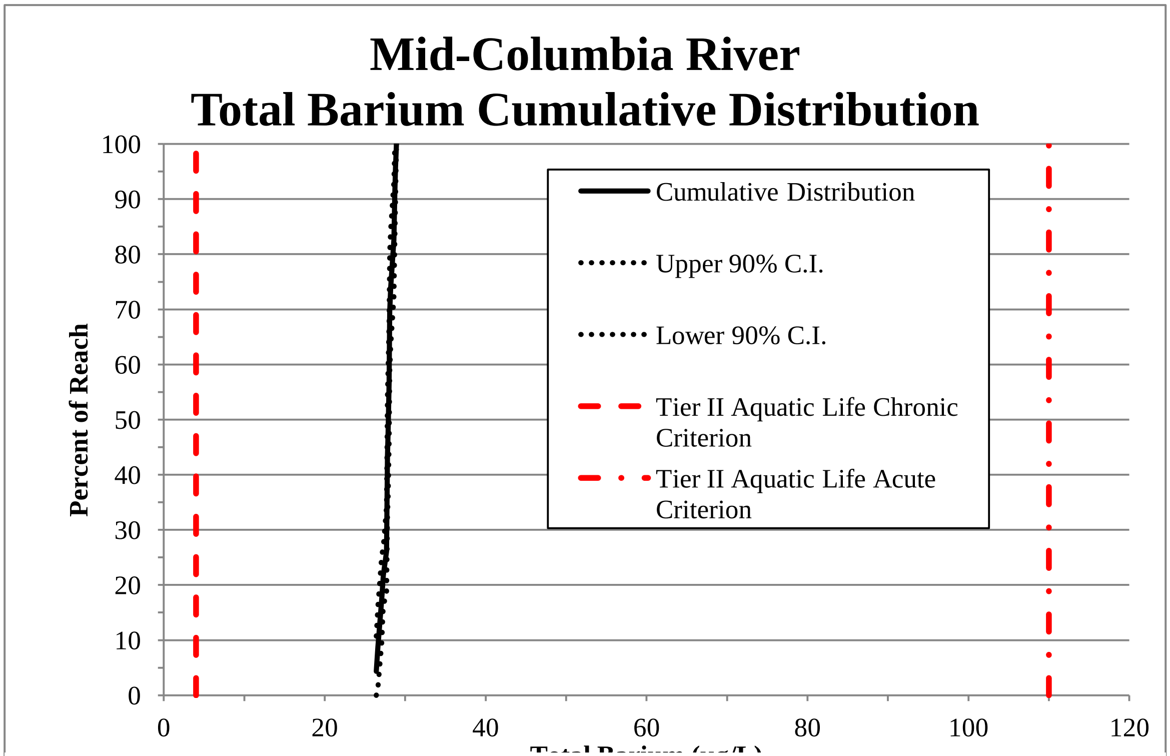

Figure 25. Water column total barium from the probabilistic survey.

The DEQ doesn't have aquatic life criteria for antimony, barium or uranium (DEQ, 2011). However, some benchmarks were available from the Oak Ridge National Laboratory (Suter II & Tsao, 1996) and Canada (CCME, 2011). The entire LMC was well below the barium acute criterion, but above the chronic level. Some tributaries also exceeded the chronic level. The Tier II criteria are based on a limited number of studies, and a more extensive literature review may be worthwhile. None of the LMC or tributaries exceeded the Canadian uranium chronic criterion Figure 26.

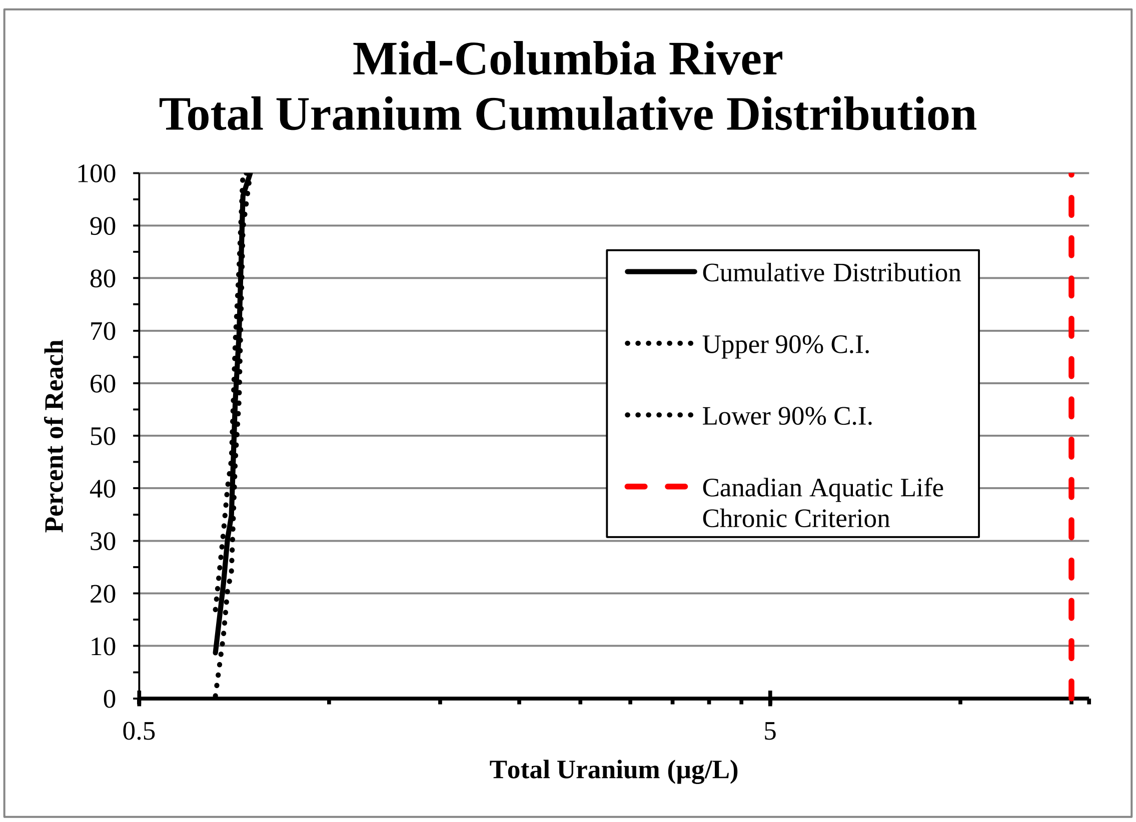

Figure 26. Water column total uranium from the probabilistic survey.

Table 23. Water quality laboratory parameters statistical summary -- total metals (values in µg/L).

Columbia Mainstem Probabilistic Sites							Tributaries and Targeted Sites								
Total Analyte	**Min**	**Max**	**Median**	**Mean**	**Std. Dev.**	**Percent Detects**	**White Salmon R.**	**Hood River**	**Klickitat River**	**Columbia R. d/s The Dalles**	**Deschutes River**	**John Day River**	**Columbia R. d/s PGE Boardman**	**Umatilla River**	**Screening Values**
Antimony	<2.0	<2.0	<2.0	<2.0	--	100%	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	--
Arsenic	<2.0	<2.0	<2.0	<2.0	--	0%	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.1[a]
Barium	**26**	**29**	**28**	**28**	0.67	100%	<2.0	**6**	3.4	**28**	**4.4**	**20**	**29**	**49**	4[b]
Beryllium	<0.3	<0.3	<0.3	<0.3	--	0%	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	--
Cadmium	<0.3	<0.3	<0.3	<0.3	--	0%	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	--
Chromium	<1.0	<1.0	<1.0	<1.0	--	0%	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	--
Cobalt	<0.2	<0.2	<0.2	<0.2	--	0%	<0.20	<0.20	<0.20	<0.20	<0.20	0.52	<0.20	<0.20	--
Copper	<1.5	<1.5	<1.5	<1.5	--	0%	<1.5	<1.5	<1.5	<1.5	<1.5	2.7	<1.5	<1.5	12[c]
Lead	<0.2	<0.2	<0.2	<0.2	--	0%	<0.20	<0.20	<0.20	<0.20	<0.20	0.21	<0.20	<0.20	3.2[c]
Molybdenum	<3.0	<3.0	<3.0	<3.0	--	0%	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--
Nickel	<1.0	<1.0	<1.0	<1.0	--	0%	<1.0	<1.0	<1.0	<1.0	<1.0	1.6	<1.0	<1.0	--
Selenium	<2.0	<2.0	<2.0	<2.0	--	0%	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	35[c]
Silver	<0.10	<0.10	<0.10	<0.10	--	0%	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	--
Thallium	<0.10	<0.10	<0.10	<0.10	--	0%	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	--
Uranium	0.66	0.75	0.71	0.71	0.02	100%	<0.10	<0.10	<0.10	0.72	0.16	0.57	0.75	1.89	15[d]
Vanadium	<4.0	<4.0	<4.0	<4.0	--	0%	4.4	<4.0	<4.0	<4.0	12.3	6.9	<4.0	11.8	--
Zinc	<3.0	<3.0	<3.0	<3.0	--	0%	<3.0	<3.0	<3.0	16.6	<3.0	<3.0	<3.0	<3.0	--

[a] Human health criterion for water & organism consumption (State of Oregon, OAR 340-41-0033 (7)).
[b] Tier II Chronic aquatic life(Suter II & Tsao, 1996).
[c](Matzke, Sturdevant, & Wigal, 2011).
[d] Chronic aquatic life criterion(CCME, 2011)

Fish Catch

The overall fish catch was 81% smallmouth bass (Micropterus dolomieu) and 19% largescale sucker (Catostomus macrocheilus). The species distribution was similar among the targeted and probabilistic sites, 75% bass/25% sucker, and 83% bass/17% sucker, respectively. Six of the fish composite samples fell short of the five fish target, but in most cases there was sufficient sample mass to complete all analyses. The number of fish per composite, the species, and the average length, mass, and fillet lipid content are shown inTable 24. The suckers were generally larger than the bass, and had slightly higher fillet lipid content.

Table 24. Fish composites, taxa, and physical measurements by station[a].

Site Description	Fish per Composite	%Fat	Average Fish Length (mm)	Average Fish Weight (g)	Taxa
Columbia R at Cascade Locks	4	<1	265	335	*Micropterus dolomieu*
Columbia R at Trotter Point	5	<1	373	772	*Micropterus dolomieu*
Columbia R at Wind Mountain	3	<1	373	793	*Micropterus dolomieu*
Columbia R US of Drano Lake	5	<1	315	466	*Micropterus dolomieu*
White Salmon River	3	<1	333	500	*Micropterus dolomieu*
Hood River	5	3.4	560	1,840	*Catostomus macrocheilus*
Columbia DS of Hood River Bridge	5	<1	409	992	*Micropterus dolomieu*
Columbia R at Memaloose	5	<1	524	1,586	*Catostomus macrocheilus*
Klickitat River	4	1.5	355	712	*Micropterus dolomieu*
Columbia River DS of The Dalles	5	<1	301	352	*Micropterus dolomieu*
Columbia R at The Dalles	5	<1	252	206	*Micropterus dolomieu*
Columbia R US of the Dalles Locks	5	3.3	484	1,370	*Catostomus macrocheilus*
Columbia R US The Dalles Dam	5	<1	302	364	*Micropterus dolomieu*
Deschutes River	5	2.4	438	868	*Catostomus macrocheilus*
Columbia R at Miller Is (S. Channel)	5	<1	262	254	*Micropterus dolomieu*
Columbia R at East end of Miller Is.	5	<1	277	274	*Micropterus dolomieu*
Columbia R at Rufus	5	<1	296	333	*Micropterus dolomieu*
John Day River	5	<1	366	564	*Micropterus dolomieu*
Columbia R at Lake Umatilla ATON 6	5	<1	258	218	*Micropterus dolomieu*
Columbia R at Lake Umatilla ATON 10	5	<1	230	276	*Micropterus dolomieu*
Columbia R Lake Umatilla at ATON 18	5	<1	302	316	*Micropterus dolomieu*
Columbia R at Arlington	3	<1	360	560	*Micropterus dolomieu*
Columbia R at Hepner Jct.	5	4.9	554	1,450	*Catostomus macrocheilus*
Columbia River DS of PGE Boardman	5	<1	271	246	*Micropterus dolomieu*
Columbia R at Crow Butte	5	<1	397	862	*Micropterus dolomieu*
Columbia R at Crow Butte East	5	<1	371	630	*Micropterus dolomieu*
Columbia R at Boardman	5	<1	402	850	*Micropterus dolomieu*
Columbia R at Big Blalock Island	4	<1	364	640	*Micropterus dolomieu*
Columbia R at Irrigon	5	<1	262	251	*Micropterus dolomieu*
Umatilla River	5	<1	326	455	*Micropterus dolomieu*
Columbia R at McNary Dam	5	2.7	547	1,640	*Catostomus macrocheilus*

[a]Stations arranged by increasing Columbia River mile.
Bold text indicates targeted sites.
Plain text indicates random sites.

Fish Fillet Contaminant Screening Values

With the exception of methylmercury, DEQ's fish consumption criteria for protecting human health are expressed as water concentrations. The concept is that the degree of contamination in the water is related to the amount of contaminants taken up by fish. By regulating water contamination, we hope to prevent unhealthy levels of contamination in fish and protect the health of people who eat fish.

The equation used to calculate water quality criteria takes into account an average person's weight, the amount of fish they eat, the toxicity or carcinogenicity of the pollutant, the tendency of the pollutant to accumulate in fish, and an acceptable level of risk a person is exposed to over a lifetime.

An average person is assumed to weigh 70 kilograms (154 lbs), the fish consumption rate is 0.175 kilograms per day (approximately one 6-ounce meal), and the acceptable risk of illness or cancer is set at 1 in a million. The values for a contaminant's toxicity or carcinogenicity, and the tendency to accumulate in fish (Bioconcentration Factor or BCF) come from tables published by EPA and adopted by Oregon. Additional information on calculating water quality criteria can be found in EPA guidelines (USEPA, 2000b).

The fish consumption Screening Values presented in this report were calculated from the same equation used to generate water column SVs:

$$Water\ Screening\ Value = \left(\frac{\boldsymbol{risk^{a}} \times \boldsymbol{body\ mass^{b}}}{\boldsymbol{toxicity\ or\ cancer\ potency\ factor^{c}} \times \boldsymbol{fish\ consumption\ rate^{d}} \times \boldsymbol{Bioaccumulation\ Factor^{e}}}\right)$$

[a]**Risk** = 1 in a million.
[b]**Body mass** = 70 Kg.
[c]**Cancer potency** (or reference dose for non-carcinogens) from EPA tables. If a contaminant is a carcinogen the cancer potency factor is used in the equation. For non-carcinogens the toxicity reference dose from bioassays is used in the equation.
[d]**Oregon fish consumption rate is 175 g/day**.
[e]**BAF taken from EPA tables.**

The following example illustrates the water SV calculation for 2,3,7,8-TCDD (Dioxin):

$$Water\ Screening\ Value\ for\ Dioxin = \left(\frac{\mathbf{1 \times 10^{-6}} \times \mathbf{70}\ \boldsymbol{Kg}}{\mathbf{1.56 \times 10^{5}} \times \mathbf{0.175\ Kg} \times \mathbf{5,000}\,\frac{\boldsymbol{L}}{\boldsymbol{Kg}}}\right) \times 1\,\frac{Kg}{L} = 5.13 \times 10^{-13}\ \frac{mg}{L}$$

$$Water\ Screening\ Value\ for\ Dioxin\ = 5.13 \times 10^{-10}\quad \mu g/L$$

In this study, fish fillet contaminant concentrations were measured directly. There was no need to apply a bioaccumulation factor because we knew the contaminant concentrations in the fish. ***Therefore, the bioaccumulation factor was removed from the SV equation:***

$$Fish\ Fillet\ Screening\ Value = \left(\frac{\boldsymbol{risk} \times \boldsymbol{body\ mass}}{\boldsymbol{toxicity\ or\ cancer\ potency\ factor} \times \boldsymbol{fish\ consumption\ rate}}\right)$$

The following example illustrates the fillet SV calculation for 2,3,7,8-TCDD (Dioxin):

$$Fish\ Fillet\ Screening\ Value\ for\ Dioxin = \left(\frac{\mathbf{1 \times 10^{-6}} \times \mathbf{70}\ \boldsymbol{Kg}}{\mathbf{1.56 \times 10^{5}} \times \mathbf{0.175}\ \boldsymbol{Kg}}\right) = 2.56 \times 10^{-9}\ \frac{mg}{Kg}$$

$$Fish\ Fillet\ Screening\ Value\ for\ Dioxin = \ 2.6 \times 10^{-3}\quad \text{ng/Kg}$$

Fish Fillet Dioxins and Furans

The fish filet analyses for dioxins and furans (Table 26) resulted in non-detects for nearly every compound. Among the probabilistic sites, only 2,3,7,8-Tetrachlorodibenzofuran was detected, but it was found across 22% of the LMC and every detection was above DEQ's human health SV for the 175g/day fish consumption rate. The high toxicity and carcinogenic effects of dioxins and furans results in an extremely low screening concentration – 2.6 parts per quadrillion of raw fillet.

The Hood and Deschutes Rivers also failed the screening criterion for 2,3,7,8-Tetrachlorodibenzofuran, while the John Day River exceeded the limit for 1,2,3,4,6,7,8-Heptachlorodibenzofuran. The highest tributary concentrations were obtained at sites where largescale suckers (*Catostomus macrocheilus*) were collected. The same was true for the probabilistic mainstem sites. The three highest LMC concentrations were observed in largescale suckers near The Dalles locks, Memaloose, and Hepner Junction.

Fish Fillet DDTs

Figure 27 shows the extent of fish fillet total DDTs relative to the Washington Department of Health's SV (at Oregon's 175g/day fish consumption rate)(McBride, 2012). Total DDT was detected above the fish fillet SV (1,200 ng/kg wet wt.) at every LMC site, and in samples from all of the tributaries. As with the dioxins and furans, the three highest DDT concentrations in the probabilistic survey came from largescale suckers (*Catostomus macrocheilus*) collected near The Dalles locks, Hepner Junction, and Memaloose.

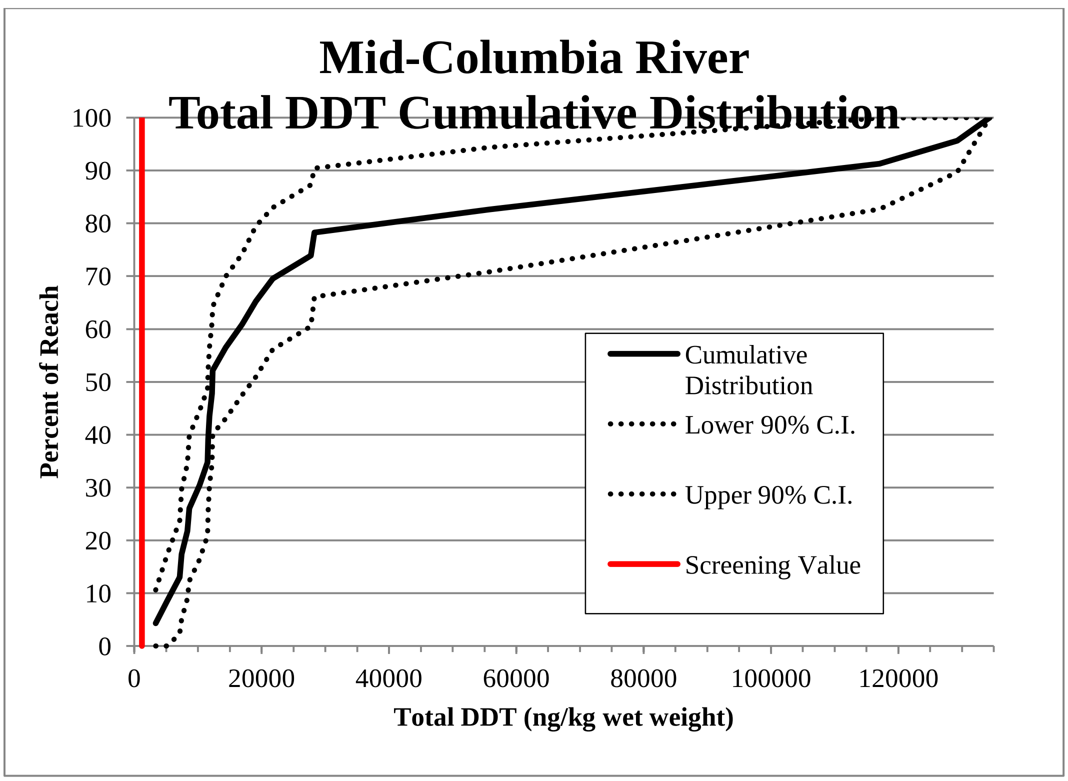

Figure 27. Fish fillet total DDTs from the probabilistic survey.

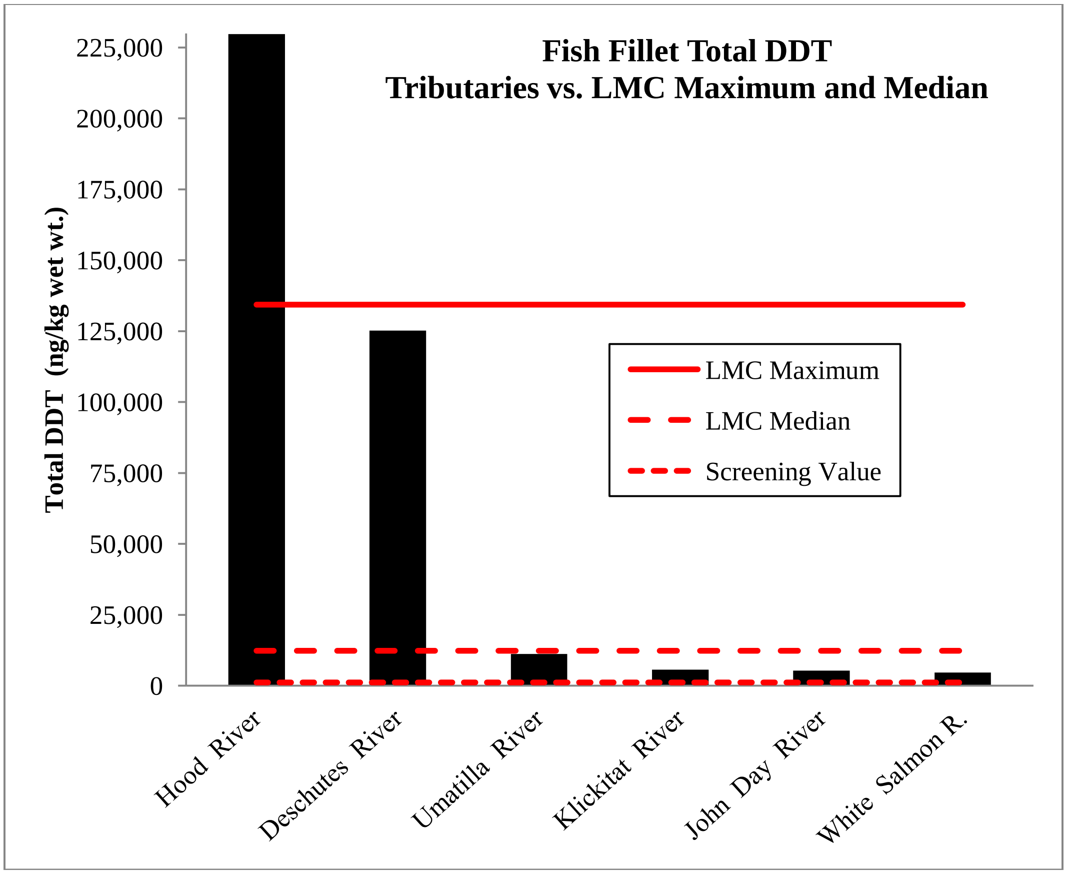

Figure 28. Tributary fillet Total DDT vs. the probabilistic survey's maximum and median, and DEQ's screening value.

The Hood and Deschutes River samples (also largescale suckers) had the project's two highest tributary DDT concentrations 230,000 and 125,000 ng/kg wet weight, respectively. These concentrations are 192x and 104x the SV. The other tributary's fillet samples were at or below the LMC's median DDT concentration, but the median was 10x the SV. The DDT break-down product, 4,4`-DDE was the dominant compound among the total DDTs and exceeded DEQ's SV in every fish sample. 4,4`-DDD, and 4,4`-DDT SVs were typically exceeded at sites with the most 4,4`-DDE (Table 27).

Fish Fillet Non-DDT Chlorinated Pesticides

Fish fillets were screened for a suite of chlorinated pesticides other than DDT (Table 28). Whereas half of the pesticides were detected at all of the LMC probabilistic sites, Aldrin, delta-BHC, and Endosulfan II were rarely detected (0-4% of sites). The lab could not recover endrin aldehyde or endrin ketone.

As noted above, total DDT was detected above the fish fillet SV at every LMC site, and in samples from all of the tributaries. Linear regressions showed that total DDT was a good predictor of total chlordane and Dieldrin in the LMC and tributaries (Figure 29 and Figure 30) .

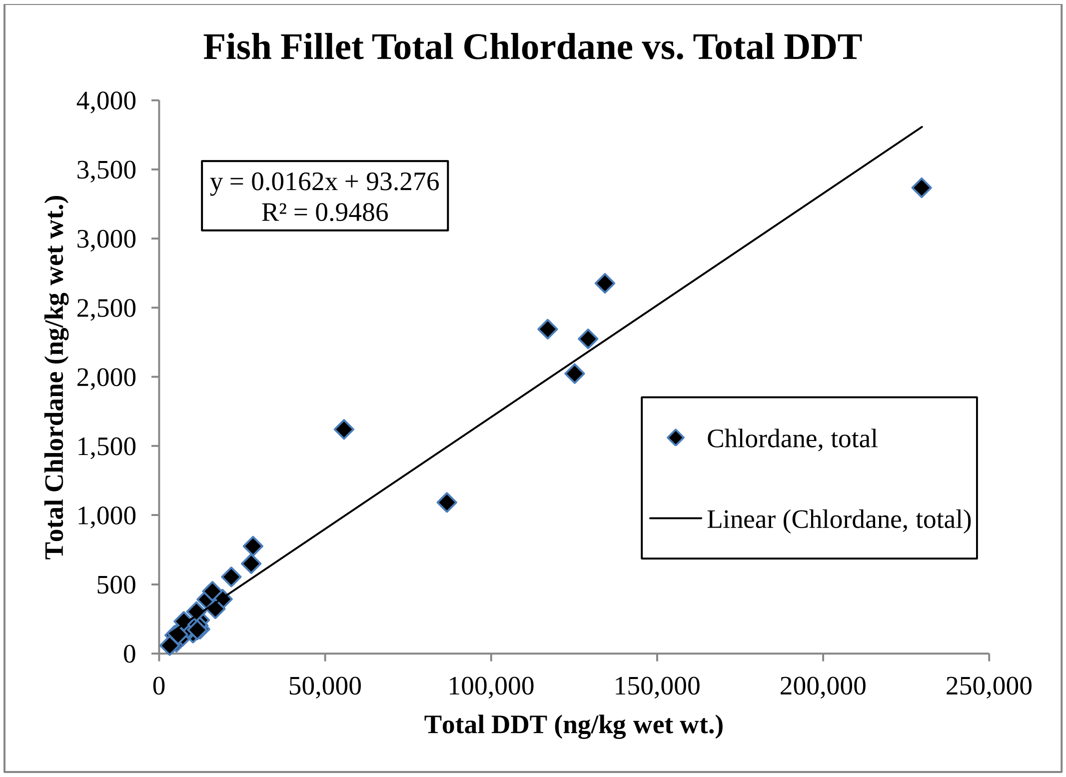

Figure 29. Linear regression of fish fillet total chlordane versus total DDT.

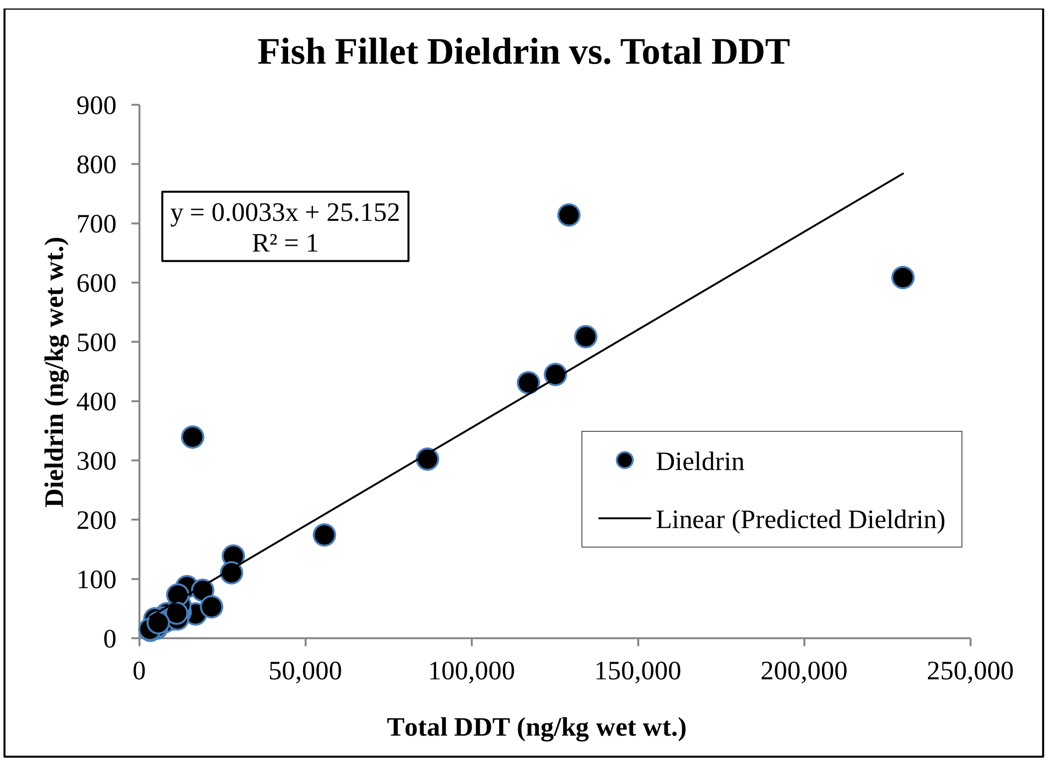

Figure 30. Linear regression of fish fillet Dieldrin vs. total DDT.

Apart from DDTs, the chlordanes, Dieldrin, and heptachlor epoxide were the only chlorinated pesticides exceeding human health SVs. Summed tributary concentrations of these pesticides are shown in Figure 31 relative to the probabilistic survey's maximum and median for the same combination. The tributary fish show the same pattern found with DDTs in Table 27 –the Hood River exceeds the LMC maximum, the Deschutes River approaches it, and the other tributaries fall near or below the median. As with the dioxins, furans, and DDTs, the three highest concentrations in the probabilistic survey came from largescale suckers (*Catostomus macrocheilus*) collected near The Dalles locks, Hepner Junction, and Memaloose.

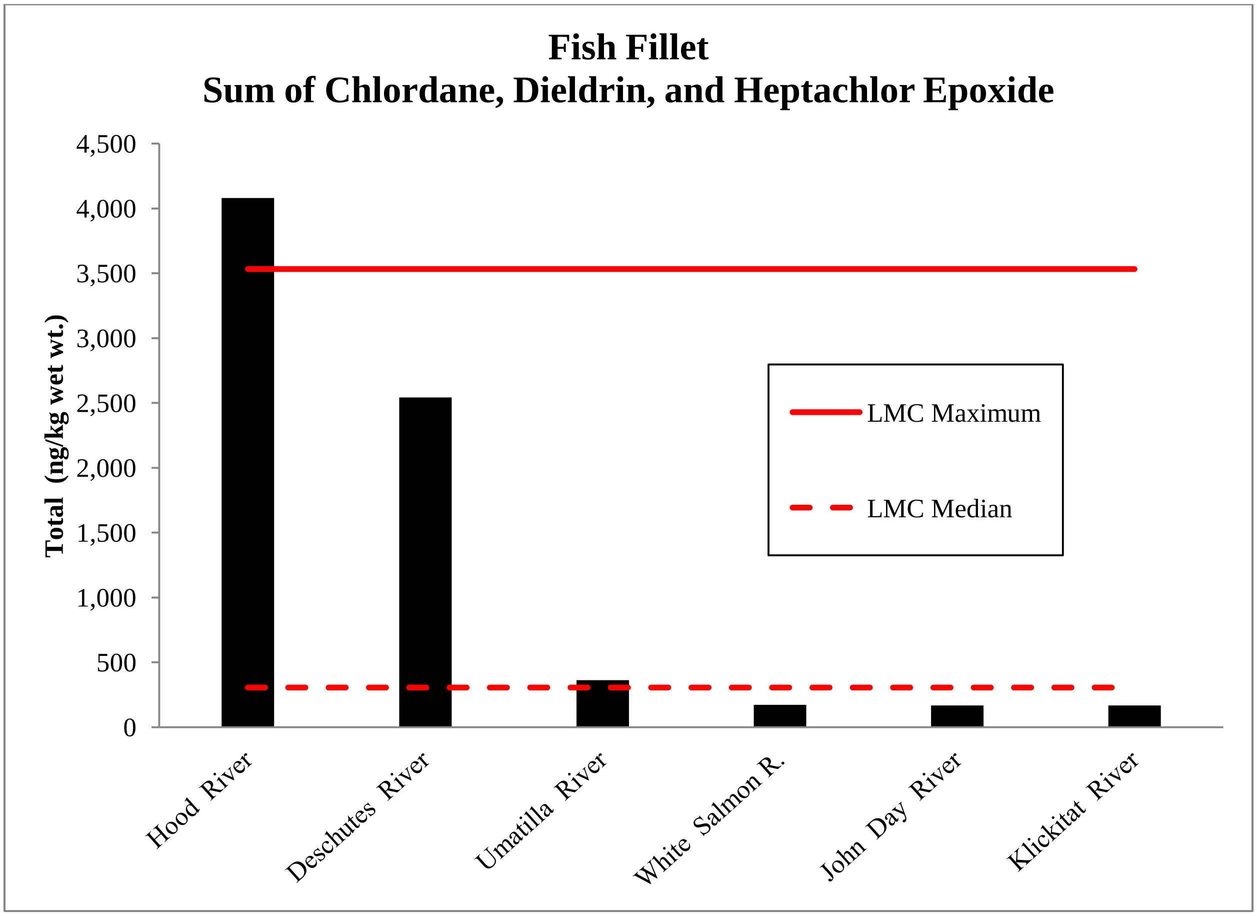

Figure 31. Tributary fillet concentrations of total chlordane, Dieldrin, and heptachlor epoxide vs. the probabilistic survey's maximum and median.

Fish Fillet PCBs

PCBs are endocrine disrupters and are toxic to many species. They cause a variety of maladies in animals, including wasting syndrome, dermal toxicity, hepatotoxicity, immunotoxicity, neurotoxicity; reproductive failure and developmental disorders; and gastrointestinal, respiratory, mutagenic, and carcinogenic effects (USEPA, 2000c). The toxicity of individual congeners relates to the number and position of chlorine substitutions on the biphenyl structure. "In general, higher chlorine content typically results in higher toxicity, and PCB congeners that are chlorinated in the ortho position are typically less toxic than congeners chlorinated in the meta and para positions." (USEPA, 2000c). Coplanar PCBs resembling the structure of 2,3,7,8-TCDD are generally more toxic than non-coplanar congeners.

No congeners with BZ numbers (Ballschmiter & Zell, 1980) below sixteen were recovered (Table 29), and another twenty-seven congeners were not detected in fish fillets (Table 30). However, fifty congeners individually exceeded DEQ's total PCB human health SV; and every probabilistic, mainstem targeted, and tributary site failed the total PCB screening value. The minimum probabilistic site total PCB concentration was 7x the SV, and the mean was 47x the SV. The Hood and Deschutes River largescale sucker fillets had the highest PCB concentrations, at 358x and 163x the SV, respectively (Table 31). As with some of the chlorinated pesticides, the Hood River's fillet concentrations exceed the LMC's maximum, the Deschutes River approaches the LMC's maximum, and the other tributaries fall near or below the median (Figure 32). The fillet concentrations of dioxin-like PCB congeners 105, 118, 156, and 167 exceeded the total PCB screening value in some LMC and tributary samples, particularly in the Hood and Deschutes Rivers (Table 31).

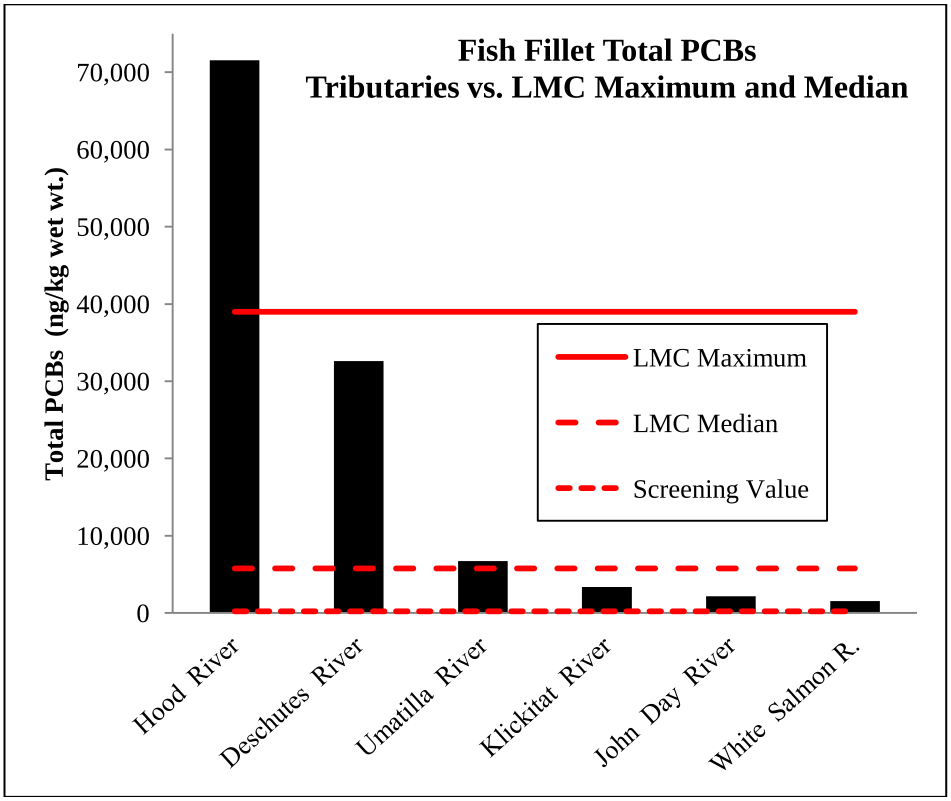

Figure 32. Tributary fillet total PCB concentrations vs. the probabilistic survey's maximum and median. All sites exceed DEQ's screening value.

Fish Fillet PBDEs

Polybrominated diphenyl ether flame retardants were produced in the 1970s, and have been used worldwide. They are added to many consumer products such as plastics, electronics, textiles, polyurethane foams, and construction materials.

Brominated flame retardants are persistent in the environment and bioaccumulate (Natural Resources Defense Council, 2012) (Wikipedia, 2012b). Their basic structure (two halogen substituted aromatic rings) is similar to dioxins and PCBs (Figure 33).

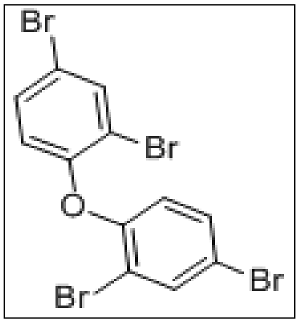

Figure 33. 2,2',4,4'-Tetrabromdiphenyl ether (Chemical Book, 2012)

Due to their toxicity, bioaccumulation, and persistence in the environment, some congeners have been banned or restricted since 2010 under the Stockholm Convention on Persistent Organic Pollutants (Table 25).

None of the fish fillet samples exceeded human health SVs[a], but about one third of the PBDE congeners detected were found in every sample (Table 33). Although ten of the PBDE congeners listed in the QAPP were not recovered by the lab (Table 25), PBDEs 17 and 28 were added to the original analytical suite and detected.

The total PBDE results mimic the pattern observed in every group of organic analytes –the highest concentrations were found in largescale suckers from the Hood and Deschutes Rivers and LMC sites near The Dalles locks, Memaloose, and Hepner Junction (Figure 34).

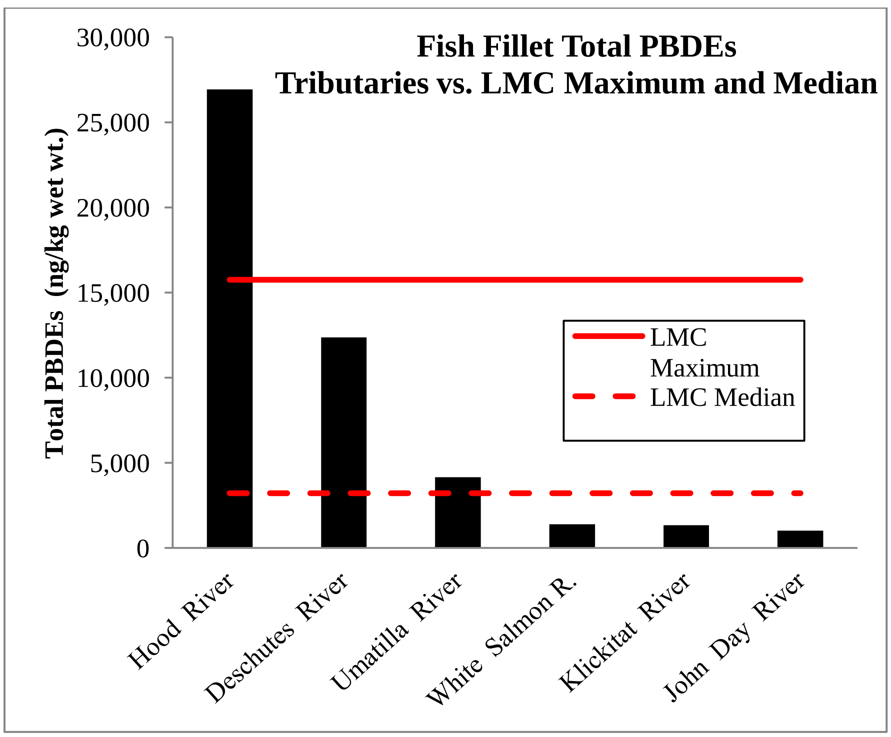

Figure 34. Tributary fillet total PBDE concentrations vs. the probabilistic survey's maximum and median.

[a] DEQ does not have PBDE criteria, so Washington's draft criteria were used.

Table 25. Banned and restricted brominated flame-retardants (Wikipedia, 2012a).

Name	Exemptions
Hexabromobiphenyl (PBB-153 and -155)	None
Hexabromodiphenyl ether (PBDE-153 and -154 and heptabromodiphenyl ether (PBDE-175 and -183)	**Production** none **Use** recycling and reuse of articles containing these compounds
Tetrabromodiphenyl ether (PBDE-47) and pentabromodiphenyl ether (PBDE-82 to -127)	**Production** none **Use** recycling and reuse of articles containing these compounds

Table 26. Fish fillet Dioxin-Furan statistical summary (values in ng/Kg wet wt). Screening values are based on a 175 g/day fish consumption rate.

	Columbia Mainstem Probabilistic Sites						Tributaries and Targeted Sites								
Analyte	Min	Max	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	Deschutes River	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Screening Values
Total 2,3,7,8 Substituted Dioxin-Furans	<LOD	**1.8**	**0.23**	0.50	22%	0.2 -- 0.7	<LOD	**1.7**	<LOD	<LOD	**1.5**	**0.14**[a]	<LOD	<LOD	0.0026[b]
2,3,7,8-Tetrachlorodibenzodioxin	<LOD	<LOD	<LOD	<LOD	0%	0.3 -- 0.6	<0.5	<0.5	<0.5	<0.3	<0.4	<0.2	<0.4	<0.3	--
2,3,7,8-Tetrachlorodibenzofuran	<LOD	**1.8**	**0.23**	0.5	22%	0.2 -- 0.7	<0.4	**1.7**	<0.4	<0.2	**1.5**	<0.2	<0.8	<0.3	0.0026 [b]
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	<LOD	<LOD	<LOD	<LOD	0%	0.2 -- 0.5	<0.4	<0.4	<0.3	<0.4	<0.6	<0.2	<0.3	<0.3	--
1,2,3,7,8-Pentachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	0.2-- 0.7	<0.5	<0.4	<0.4	<0.4	<0.5	<0.2	<0.3	<0.3	--
2,3,4,7,8-Pentachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	0.2 -- 0.7	<0.5	<0.4	<0.5	<0.4	<0.6	<0.2	<0.3	<0.3	--
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	<LOD	<LOD	<LOD	<LOD	0%	0.3 -- 0.6	<0.5	<0.5	<0.4	<0.5	<0.6	<0.2	<0.3	<0.3	--
1,2,3,4,7,8-Hexachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	0.1 -- 0.6	<0.3	<0.3	<0.3	<0.2	<0.4	<0.1	<0.2	<0.2	--
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	<LOD	<LOD	<LOD	<LOD	0%	0.3 -- 0.6	<0.5	<0.5	<0.4	<0.5	<0.6	<0.2	<0.3	<0.3	--
1,2,3,6,7,8-Hexachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	0.1 -- 0.7	<0.3	<0.3	<0.3	<0.2	<0.4	<0.1	<0.2	<0.2	--
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	<LOD	<LOD	<LOD	<LOD	0%	0.3 -- 0.7	<0.5	<0.6	<0.5	<0.5	<0.6	<0.2	<0.4	<0.3	--
1,2,3,7,8,9-Hexachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	0.2 -- 0.5	<0.4	<0.4	<0.4	<0.3	<0.5	<0.1	<0.3	<0.3	--
2,3,4,6,7,8-Hexachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	0.1 -- 0.5	<0.3	<0.3	<0.3	<0.2	<0.4	<0.1	<0.2	<0.2	--
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	<LOD	<LOD	<LOD	<LOD	0%	0.3 -- 0.8	<0.6	<0.5	<0.6	<0.4	<0.9	<0.3	<0.3	<0.4	--
1,2,3,4,6,7,8-Heptachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	0.2 -- 0.4	<0.3	<0.2	<0.3	<0.2	<0.4	**0.14**[a]	<0.2	<0.2	0.0026 [b]
1,2,3,4,7,8,9-Heptachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	0.2 -- 0.6	<0.5	<0.4	<0.4	<0.3	<0.6	<0.2	<0.3	<0.3	--
1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	<LOD	<LOD	<LOD	<LOD	0%	0.5 -- 1.0	<0.8	<0.8	<0.8	<0.8	<1.1	<0.5	<0.6	<0.5	--
1,2,3,4,6,7,8,9-Octachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	0.6 -- 1.4	<1.0	<0.8	<1.0	<0.8	<1	<0.6	<0.8	<0.7	--

[a] Analyte detected, but failed ion ratio criteria. The reported value is the estimated maximum possible concentration (EMPC). [b]DEQ human health screening value based on 175 g/day fish consumption rate. **Bold** values exceed the SV.

Table 27. Fish fillet DDT statistical summary (values in ng/Kg wet wt). Screening values are based on a 175 g/day fish consumption rate.

Columbia Mainstem Probabilistic Sites							Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	Deschutes River	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Screening Values
Total DDTs	**3,338**	**134,312**	**12,309**	**33,086**	41,501	100%	**4,706**	**229,720**	**5,712**	**16,062**	**125,193**	**5,323**	**3,201**	**11,244**	1,200 [a]
2,4`-DDD	37	3,008	138	534	854	100%	53	2,878	66	265	1,784	50	30	99	--
2,4`-DDE	21	800	73	170	212	100%	30	760	38	89	535	27	21	57	--
2,4`-DDT	15	564	33	115	166	100%	21	721	21	574	427	14	12	52	--
4,4`-DDD	281	**20,125**	971	**4,090**	6,468	100%	411	**22,475**	473	1,333	**13,570**	468	226	850	1,667 [b]
4,4`-DDE	**2,879**	**109,585**	**10,878**	**27,227**	32,676	100%	**4,039**	**195,483**	**4,978**	**10,975**	**105,490**	**4,657**	**2,831**	**9,732**	1,176 [b]
4,4`-DDT	103	**4,081**	279	950	1,327	100%	152	**7,403**	136	**2,825**	**3,386**	108	81	455	1,176 [b]

[a]Draft Washington Department of Health screening values based on the Oregon fish consumption rate. (D. McBride, 2012 personal communication)
[b] DEQ only has criteria for the 4,4’ isomers (Matzke, Sturdevant, & Wigal, 2011).
Bold values exceed the SV.

Table 28. Fish fillet non-DDT pesticides statistical summary (values in ng/Kg wet wt). Screening values are based on a 175 g/day fish consumption rate.

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	Deschutes River	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Screening Values
Aldrin	<LOD	1	<LOD	0	0.3	4%	0.4 – 1.6	<0.6	1.0	<0.5	<0.8	0.8[a]	<0.6	<0.4	<0.7	24
alpha –BHC [b]	6	20	7	9	4	100%	--	7	20	6	7	14	8	7	5[a]	63
beta -BHC	<LOD	4	3	2	2	65%	1.8 – 3.4	<2	5	3	3	4†	3[a]	2	2	222
delta-BHC	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2.7 – 15	<4	<2	<3	<4	<4	<16	<9	<2	--
gamma -BHC (Lindane)	<LOD	12	4	5	4	74%	3.4 – 5	4	10	4	5	7	<3	4	4	24,000
cis-Chlordane	6	583	19	101	181	100%	--	16	695	13	85	447	14	4[a]	24	1,143
(trans-Chlordane + trans-Nonachlor)	37	**1,409**	138	357	411	100%	--	72	**1,794**	77	261	1,096	77	33	184	1,143
cis -Nonachlor	14	559	51	143	167	100%	--	27	688	30	61	380	30	14	64	1,143
Oxychlordane	5	189	34	55	54	100%	--	17	191	17	43	101	20	6	31	1,143
∑ Chlordane[d]	62	**2,677**	242	655	794	100%	--	132	**3,367**	136	450	**2,024**	141	57	303	1,143
Dieldrin	13	**714**	**53**	**134**	**182**	100%	--	**33**	**609**	**26**	**339**	**445**	20	15	**42**	25
Endosulfan I	<LOD	2,546	<LOD	181	547	22%	13.4 -- 322	<1,380	1,981	<902	<47	261	<42	<203	<1,061	2,400,000
Endosulfan II	<LOD	62	<LOD	3	13	4%	17.7 -- 171	<55	171	<55	<115	<46	<92	<64	<45	2,400,000
Endosulfan sulfate	<LOD	149	<LOD	28	46	35%	14.9 – 39	<16	385	<13	36	161	<22	<18	<13	2,400,000
Endrin + cis-Nonachlor	28	895	96	229	256	100%	--	57	1,382	61	119	378	35	28	141	96,000
Endrin Aldehyde	Not Recovered			--	--	--	--	--	--	--	--	--	--	--	--	--
Endrin Ketone	Not Recovered			--	--	--	--	--	--	--	--	--	--	--	--	--
Heptachlor	<LOD	5	1	1	1.3	87%	0.8 – 1.1	2	5	1	1	3	1	<0.4	9	89
Heptachlor epoxide	3	**140**	10	27	38	100%	--	6	**104**	5	15	**72**	7	2	17	44
Hexachlorobenzene	103	842	150	242	214	100%	--	130	709	117	146	581	130	104	104	--
Methoxychlor	36	162	86	86	30	100%	--	124	70	98	108	61	82	25	99	--
Mirex	3	48	9	15	14	100%	--	6	104	8	8	49	8	2	9	80,000[c]

[a]Analyte detected, but failed ion ratio criteria. The reported value is the estimated maximum possible concentration (EMPC). [b]The result is less than 10 times the blank value and may be biased high.
[c]Draft Washington Department of Health SVs based on the Oregon fish consumption rate. (D. McBride, 2012 personal communication).
[d]∑ Chlordane (total chlordane) is the sum of cis-Nonachlor, trans-Nonachlor, cis-Chlordane, trans-Chlordane, and Oxychlordane. **Bold** values exceed the SV.

Table 29. PCBs listed in the QAPP --not recovered from fish fillets.

PCB-1	PCB-4	PCB-7	PCB-10	PCB-13
PCB-2	PCB-5	PCB-8	PCB-11	PCB-14
PCB-3	PCB-6	PCB-9	PCB-12	PCB-15

Table 30. PCBs not detected in fish fillets.

PCB-23	PCB-38	PCB-55[a]	PCB-73	PCB-88	PCB-98	PCB-109	PCB-143	PCB-192
PCB-24[a]	PCB-47	PCB-61	PCB-80	PCB-92	PCB-104	PCB-127	PCB-161	PCB-198
PCB-30	PCB-54	PCB-62	PCB-86	PCB-93	PCB-106	PCB-139	PCB-168	PCB-204

[a]Yellow shaded PCB congeners were not detected in fish fillets or SPMDs.

Table 31. Fish Fillet PCBs Statistical Summary (values in ng/Kg wet wt). Screening values are based on a 175 g/day fish consumption rate.

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	Deschutes River	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Screening Values
Total PCBs	**1,430**	**38,969**	**5,768**	**9,466**	10,531	100%	--	**1,562**	**71,561**	**3,380**	**3,485**	**32,599**	**2,175**	**866**	**6,716**	200[a]
PCB-16/32	<LOD	26	<LOD	4	7.4	39%	0.7 – 1	<1	28	<1	<1	15	<1	<1	<1	--
PCB-17	<LOD	29	<LOD	5	9	30%	0.7 -- 5	<2	54	<2	<2	20	1	<3	<3	--
PCB-18	<LOD	59	5	11	15	78%	2 -- 3	<2	88	4	4	32	2	<3	4	--
PCB-19	<LOD	4	<LOD	<LOD	1	13%	1 -- 6	<3	5	<3	<3	<3	<1	<4	<4	--
PCB-20/21/33	2	53	6	12	14	100%	--	3	86	5	5	32	2	<1	8	--
PCB-22	<LOD	49	5	10	14	91%	1 -- 2	2	93	4	4	34	2	<2	5	--
PCB-23	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.6 -- 3	<2	<2	<2	<2	<1	<1	<2	<3	--
PCB-24	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.5 -- 4	<2	<1	<2	<2	<1	<1	<2	<2	--
PCB-25	<LOD	8	<LOD	1	2.4	26%	0.6 -- 3	<2	11	<2	<2	5	<1	<2	<3	--
PCB-26	<LOD	19	3	4	5	70%	0.8 – 2	<2	23	<2	3	12	1	<2	<3	--
PCB-27	<LOD	6	<LOD	1	1.7	13%	0.5 -- 4	<2	11	<2	<2	3	<1	<2	<2	--
PCB-28	5	134	20	32	37	100%	--	9	160	12	16	87	5	3	19	--
PCB-29	<LOD	1	<LOD	<LOD	0.2	4%	0.6 -- 3	<2	<2	<2	<2	<1	<1	<2	<2	--
PCB-30	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.6 -- 4	<2	<2	<2	<2	<1	<1	<2	<2	--

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	Deschutes River	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Screening Values
PCB-31	4	97	13	22	26	100%	--	5	117	9	10	58	4	<2	14	--
PCB-34	<LOD	1	<LOD	<LOD	0.2	4%	0.6 -- 3	<2	<2	<2	<2	<1	<1	<2	<3	--
PCB-35	<LOD	4	<LOD	<LOD	1.1	13%	0.6 -- 3	<2	7	<2	<2	3	<1	<3	<3	--
PCB-36	<LOD	1	<LOD	<LOD	0.2	4%	0.5 – 3	<2	2	<2	<2	<1	<1	<2	<3	--
PCB-37	<LOD	24	2	5	8	61%	0.8 -- 3	<2	32	<3	4	21	1	0	4	--
PCB-38	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.6 -- 4	<2	<3	<2	<2	<1	<1	<3	<3	--
PCB-39	<LOD	5	<LOD	1	1.7	17%	0.5 -- 2	<2	10	<2	<2	4	<1	<2	<2	--
PCB-40	<LOD	22	2	4	6.6	57%	0.3 -- 3	<2	30	<2	2	13	1	<1	<2	--
PCB-41/72	<LOD	20	<LOD	4	6.6	43%	0.3 -- 2	<1	36	<1	2	13	<1	<1	<1	--
PCB-42	<LOD	94	6	19	30	78%	1 -- 3	<2	**224**	<2	5	82	2	<1	8	200 [a]
PCB-43/52	8	**400**	35	79	103	100%	--	10	**327**	18	44	**305**	17	5	29	200 [a]
PCB-44	8	**300**	24	61	89	100%	--	9	**678**	21	17	**245**	8	<1	25	200 [a]
PCB-45	<LOD	18	<LOD	3	5.1	30%	0.3 -- 3	<2	22	<2	<1	9	<1	<1	<2	--
PCB-46	<LOD	4	<LOD	1	1.4	13%	0.3 -- 2	<1	7	<2	<1	2	<1	<1	<2	--
PCB-47	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.2 -- 2	<1	<1	<1	<1	<1	<1	<1	<1	--
PCB-48	<LOD	48	3	9	15	70%	0.8 -- 2	<1	91	3	3	34	1	<1	4	--
PCB-49	5	**249**	24	59	75	100%	--	8	**418**	19	19	160	7	3	27	200 [a]
PCB-50	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.3 -- 2	<1	<1	<2	<1	<1	<1	<1	<2	--
PCB-51	<LOD	4	<LOD	1	1.4	17%	0.2 -- 2	<1	9	<1	<1	3	<1	<1	<1	--
PCB-53	<LOD	20	<LOD	3	6	35%	0.3 – 2	<1	39	<1	<1	13	<1	<1	<2	--
PCB-54	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.4 -- 3	<2	<1	<2	<1	<1	<1	<2	<2	--
PCB-55	<LOD	3	<LOD	<LOD	0.7	9%	0.3 – 7	<1	5	<2	<1	<1	<1	<1	<1	--
PCB-56	2	93	9	20	29	100%	--	3	180	6	7	66	3	2	6	--
PCB-57	<LOD	3	<LOD	<LOD	0.7	13%	0.2 -- 2	<1	6	<1	<1	2	<1	<1	<1	--
PCB-58/67	<LOD	11	<LOD	2	3.3	48%	0.1 -- 0.3	<1	20	<1	2	7	<1	<1	<1	--

Dioxin-like congeners are shaded in red.

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	Deschutes River	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Screening Values
PCB-59	<LOD	18	1	3	5.4	52%	0.2 -- 2	<1	36	<1	1	13	<1	<1	<1	--
PCB-60	5	134	15	34	40	100%	--	5	**255**	11	14	106	6	3	15	200 [a]
PCB-61	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.3 – 7	<1	<4	<2	<1	<1	<1	<1	<1	--
PCB-62	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.2 -- 2	<1	<1	<1	<1	<1	<1	<1	<1	--
PCB-63	<LOD	25	4	7	8	87%	1 -- 2	<1	55	<2	4	19	1	<1	4	--
PCB-64/68	5	152	15	37	47	100%	--	6	**252**	12	13	105	6	3	17	200 [a]
PCB-65/75	4	88	14	25	27	100%	--	6	141	10	11	68	9	<1	17	--
PCB-66	20	**574**	63	144	176	100%	--	21	**1,113**	44	65	**459**	23	11	62	200 [a]
PCB-69	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.2 – 2	<1	3	<1	<1	<1	<1	<1	<2	--
PCB-70	18	459	53	122	149	100%	--	18	**745**	35	45	310	18	8	50	200 [a]
PCB-71	<LOD	34	3	7	11	78%	0.6 -- 2	<1	68	3	3	23	1	<1	5	--
PCB-73	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.2 -- 2	<1	3	<1	<1	<1	<1	<1	<1	--
PCB-74/76	10	**285**	36	77	91	100%	--	11	**554**	23	35	**223**	13	6	36	200 [a]
PCB-77	2	44	6	10	12	100%	--	<1	70	4	6	34	2	1	4	--
PCB-78	<LOD	2	<LOD	<LOD	0.4	4%	0.4 -- 8	<2	<4	<2	<1	<1	<1	<1	<1	--
PCB-79	<LOD	3	<LOD	<LOD	0.6	4%	0.3 -- 7	<1	4	<2	<1	<1	<1	<1	<1	--
PCB-80	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.3 -- 6	<1	<3	<2	<1	<1	<1	<1	<1	--
PCB-81	<LOD	19	2	4	6	70%	1-- 3	<2	39	<2	2	13	<1	<1	<1	--
PCB-82	<LOD	78	10	20	25	83%	2 -- 5	<5	127	<5	7	45	3	<6	<6	--
PCB-83	<LOD	55	8	13	16	78%	2 -- 3	<4	100	<3	5	43	2	<4	8	--
PCB-84	<LOD	130	13	32	40	91%	4 -- 5	<5	**220**	10	9	77	3	<6	15	200 [a]
PCB-85	14	**363**	58	97	109	100%		15	**659**	31	30	**282**	14	<5	50	200 [a]
PCB-86	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.8 -- 13	<7	<5	<6	<3	<2	<1	<6	<6	--
PCB-87/111/ 116/117	<LOD	**414**	38	85	120	96%	2	12	**674**	31	36	**295**	19	7	39	200 [a]

Dioxin-like congeners are shaded in red.

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	Deschutes River	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Screening Values
PCB-88	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.8 -- 13	<5	<4	<5	<3	<2	<1	<6	<6	--
PCB-89	12	**317**	55	86	93	100%	--	15	**563**	29	27	**229**	13	<6	46	200 [a]
PCB-90	<LOD	56	<LOD	6	16	30%	0.6 -- 8	<4	<3	<3	6	53	5	<4	<4	--
PCB-91	<LOD	134	13	31	42	87%	3 -- 4	<4	271	10	9	101	4	<5	12	--
PCB-92	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 -- 13	<5	<4	<5	<3	<2	<1	<8	<8	--
PCB-93	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 -- 12	<5	<3	<4	<3	<2	<1	<6	<6	--
PCB-94	<LOD	10	<LOD	1	2.6	13%	0.5 -- 3	<2	16	<2	<2	8	<1	<2	<3	--
PCB-95/121	19	**597**	64	138	176	100%	--	19	**1,132**	46	40	**471**	17	10	53	200 [a]
PCB-96	<LOD	3	<LOD	<LOD	0.7	9%	0.5 -- 3	<2	5	<2	<2	<1	<1	<2	<2	--
PCB-97	18	**762**	63	147	**211**	100%	--	17	**1,655**	55	42	**687**	17	10	40	200 [a]
PCB-98	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.8 -- 11	<5	5	<4	<3	<1	<1	<	<5	--
PCB-99	35	**1,024**	163	**268**	301	100%	--	47	**2,019**	96	88	**829**	43	22	141	200 [a]
PCB-100	<LOD	3	<LOD	<LOD	0.9	13%	0.6 -- 3	<2	6	<2	<2	<1	<1	<2	<3	--
PCB-101/113	58	**1,788**	**256**	**443**	532	100%	--	62	**3,633**	149	123	**1,380**	60	35	185	200 [a]
PCB-102	<LOD	20	<LOD	3	6.7	17%	0.8 -- 9	<5	47	<4	<3	16	<1	<6	<6	--
PCB-103	<LOD	9	<LOD	1	2.8	13%	0.6 -- 3	<2	19	<	<2	6	<1	<2	<3	--
PCB-104	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.9 -- 5	<4	<2	<4	<3	<1	<1	<4	<4	--
PCB-105	42	**875**	155	**240**	253	100%	--	40	**1,553**	78	86	**689**	40	23	141	200 [a]
PCB-106	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.6 -- 9	<4	<3	<4	<2	<1	<1	<4	<4	--
PCB-107/123	<LOD	**253**	25	48	74	61%	2 -- 3	12	**447**	22	29	**212**	14	<3	<3	200 [a]
PCB-108	<LOD	153	<LOD	25	40	39%	0.4 -- 9	<4	<2	<3	<2	<1	<1	10	55	--
PCB-109	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.6 -- 15	<8	<6	<7	<2	<1	<1	<7	<7	--
PCB-110	51	**1,572**	188	**376**	472	100%	--	47	**2,936**	123	109	**1,172**	49	29	128	200 [a]
PCB-112/119	<LOD	47	7	12	15	74%	1.4 -- 4	<4	85	<4	5	34	2	<5	<5	--
PCB-114	<LOD	82	16	23	22	96%	2.8	<3	167	8	10	75	5	<	15	--

Dioxin-like congeners are shaded in red.

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	Deschutes River	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Screening Values
PCB-115	<LOD	48	6	12	16	70%	2.1 -- 4	<4	<3	<4	4	37	2	<4	<4	--
PCB-118	133	**3,036**	**453**	**766**	809	100%	--	141	**5,653**	**251**	**319**	**2,663**	149	79	**464**	200 [a]
PCB-120	<LOD	13	<LOD	1	3.3	17%	1.1 -- 9	<4	<3	<3	<2	9	<1	<4	<4	--
PCB-122	<LOD	36	<LOD	2	7.4	17%	0.7 -- 9	<3	<2	<3	<2	<1	<1	<4	<4	--
PCB-124	<LOD	71	10	17	20	91%	2.7 -- 3	<4	112	<3	7	53	3	<4	7	--
PCB-125	<LOD	3	<LOD	<LOD	0.6	4%	0.5 -- 10	<5	<4	<5	<2	2	<1	<8	<8	--
PCB-126	<LOD	7	<LOD	1	2.2	22%	1.2 -- 5	<2	15	<2	<3	6	<1	<3	<4	--
PCB-127	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 -- 7	<4	<6	<3	<3	<2	<1	<4	<5	--
PCB-128	23	**473**	86	133	137	100%	--	25	**791**	46	41	**356**	23	12	85	200 [a]
PCB-129	<LOD	46	7	10	13	70%	2 -- 20	<3	<18	<7	<6	30	3	<2	9	--
PCB-130	<LOD	**250**	32	50	67	87%	12 -- 285	9	**459**	20	19	**208**	11	6	28	200 [a]
PCB-131/133	<LOD	19	<LOD	2	5.0	22%	0.2 -- 2	<1	54	<1	2	12	<1	<1	<1	--
PCB-132/153	**231**	**6,260**	**907**	**1,472**	1,645	100%	--	**284**	**10,850**	**562**	**468**	**5,759**	**319**	148	**974**	200 [a]
PCB-134	3	97	11	21	26	100%	--	3	156	8	7	75	2	2	10	--
PCB-135	6	**254**	22	49	68	100%	--	7	**331**	17	14	186	6	4	18	200 [a]
PCB-136	<LOD	8	<LOD	1	2.3	13%	0.2 -- 2	<1	16	<1	<1	6	<1	<1	<1	--
PCB-137	<LOD	121	19	29	33	83%	10 -- 230	8	**203**	11	17	80	8	4	27	200 [a]
PCB-138/163	154	**3,929**	**605**	**979**	1062	100%	--	173	**7,407**	**362**	**328**	**3,287**	187	90	**607**	200 [a]
PCB-139	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.2 -- 2	<1	<1	<1	<1	<1	<1	<1	<1	--
PCB-140	<LOD	19	<LOD	3	5.4	48%	0.2 -- 2	<1	30	<1	2	16	1	<1	<1	--
PCB-141	<LOD	**208**	31	54	61	91%	14 -- 236	12	**412**	22	23	146	12	7	40	200 [a]
PCB-142	<LOD	93	12	21	25	91%	0.4	3	122	7	8	79	6	2	14	--
PCB-143	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.2 -- 2	<1	<1	<1	<1	<1	<1	<1	<1	--
PCB-144	<LOD	92	10	20	26	96%	1.8	<1	163	6	7	70	3	<1	8	--
PCB-145	<LOD	2	<LOD	<LOD	0.4	4%	0.1 -- 1	<1	3	<1	<1	<1	<1	<1	<1	--

Dioxin-like congeners are shaded in red.

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	Deschutes River	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Screening Values
PCB-146	34	**651**	121	184	184	100%	--	33	**1,330**	68	60	**552**	40	22	135	200 [a]
PCB-147	<LOD	71	9	15	17	96%	1.6	3	114	4	6	55	3	<1	12	--
PCB-148	<LOD	151	16	32	42	96%	1.3	4	192	10	9	112	3	<1	14	--
PCB-149	18	**2,188**	143	**311**	490	100%	--	<1	**2,964**	141	103	**1,754**	50	32	105	200 [a]
PCB-150	<LOD	6	<LOD	1	1.5	13%	0.1 -- 1	<1	8	<1	<1	3	<1	<1	<1	--
PCB-151	3	**579**	79	129	153	100%	--	19	**812**	45	40	**426**	21	2	70	200 [a]
PCB-152	<LOD	3	<LOD	<LOD	0.6	9%	0.2 -- 1	<1	4	<1	<1	1	<1	<1	<1	--
PCB-154	<LOD	52	7	12	14	96%	1.4	<1	82	5	3	42	2	<1	8	--
PCB-155	<LOD	5	<LOD	<LOD	1.3	13%	0.2 -- 2	<1	10	<1	<1	3	<1	<1	<1	--
PCB-156	4	291	56	91	86	100%	--	20	**578**	29	49	**251**	23	11	76	200 [a]
PCB-157	<LOD	67	13	19	21	83%	7 -- 16	5	126	<4	<4.	54	5	3	17	--
PCB-158/160	13	**316**	50	82	91	100%	--	14	**619**	30	25	**249**	14	7	50	200 [a]
PCB-159	<LOD	3	<LOD	<LOD	0.6	4%	0.3 -- 207	<2	<12	<5	<5	<2	<2	<1	<3	--
PCB-161	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.2 -- 1	<1	<1	<1	<1	<1	<1	<1	<1	--
PCB-162	<LOD	10	<LOD	1	2.2	13%	0.3 -- 171	<2	<9	<4	<4	10	<2	<1	<3	--
PCB-164	<LOD	134	18	26	34	87%	7 -- 176	5	**212**	11	11	104	5	3	17	200 [a]
PCB-165	<LOD	2	<LOD	<LOD	0.3	4%	0.2 -- 1	<1	<1	<1	<1	<1	<1	<1	<1	--
PCB-166	<LOD	28	5	7	8	74%	2 -- 14	<2	58	<4	<5	24	<2	<1	7	--
PCB-167	<LOD	**229**	28	44	54	91%	12 -- 188	10	**416**	18	24	**217**	12	7	34	200 [a]
PCB-168	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.1 -- 1	<1	<1	<1	<1	<1	<1	<1	<1	--
PCB-169	<LOD	8	<LOD	2	2.5	35%	0.4 -- 224	<2	<11	<5	<6	<2	<2	<1	<3	--
PCB-170	23	**373**	63	117	112	100%	--	23	**680**	39	57	**308**	49	16	111	200 [a]
PCB-171	9	**222**	29	53	59	100%	--	10	**394**	20	18	193	11	5	39	200 [a]
PCB-172	6	91	16	28	27	100%	--	7	177	11	13	69	10	4	26	--
PCB-173	<LOD	7	<LOD	1	2.1	22%	0.3 -- 3	<2	17	<2	<2	6	<1	<1	<2	--

Dioxin-like congeners are shaded in red.

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	Deschutes River	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Screening Values
PCB-174	9	**290**	31	62	81	100%	--	<1	**413**	24	24	**228**	13	8	29	200 [a]
PCB-175/182	<LOD	30	4	7	9	83%	0.9 -- 3	<2	66	3	<2	29	2	<1	6	--
PCB-176	<LOD	88	6	15	24	96%	2.5	2	149	6	4	74	2	1	4	--
PCB-177	<LOD	**637**	53	122	171	96%	0.6	18	**1,159**	48	42	**557**	25	11	57	200 [a]
PCB-178	2	**291**	32	51	65	100%	--	11	**507**	25	21	**258**	16	6	43	200 [a]
PCB-179	7	**345**	25	60	90	100%	--	2	**480**	22	16	**275**	8	4	23	200 [a]
PCB-180/193	99	**1,755**	**323**	**506**	472	100%	--	120	**4,057**	**218**	**212**	**1,243**	173	75	702	200 [a]
PCB-181	<LOD	31	<LOD	4	7.4	48%	0.2 – 3	<1	18	<1	<1	7	<1	<1	<2	--
PCB-183	18	**502**	65	120	132	100%	--	23	**956**	47	49	**470**	35	11	97	200 [a]
PCB-184	<LOD	5	1	1	1.4	78%	0.1 -- 0.5	<1	9	<1	<1	4	<1	<1	2	--
PCB-185	<LOD	66	7	14	18	96%	3.0	10	113	5	5	55	3	1	9	--
PCB-186	<LOD	2	<LOD	<LOD	0.4	4%	0.2 -- 2	<1	<2	<1	<1	<1	<1	<1	<1	--
PCB-187	54	**1,485**	**207**	**340**	373	100%	--	63	**2,745**	134	161	**1,274**	123	39	**331**	200 [a]
PCB-188	<LOD	6	1	1	1.5	65%	0.1 -- 0.6	1	10	<1	1	4	<1	<1	1	--
PCB-189	1	15	3	5	4.6	100%	--	<1	32	2	3	13	2	1	4	--
PCB-190	10	183	29	48	48	100%	--	10	**298**	16	20	164	20	6	47	200 [a]
PCB-191	<LOD	23	4	7	6.6	96%	2.8	<1	50	3	4	20	2	1	8	--
PCB-192	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.2 -- 3	<1	<3	<1	<1	<1	<1	<1	<2	--
PCB-194	2	182	28	50	52	100%	--	13	**312**	22	42	115	55	6	147	200 [a]
PCB-195	7	117	19	32	32	100%	--	7	**218**	13	18	102	21	4	51	200 [a]
PCB-196	8	103	16	29	27	100%	--	6	127	9	17	71	27	4	112	--
PCB-197	1	16	2	4	4.3	100%	--	1	30	<1	2	15	2	<1	6	--
PCB-198	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.3 -- 3	<2	<1	<1	<1	<1	<1	<1	<2	--
PCB-199	13	**250**	42	71	71	100%	--	17	**448**	29	51	170	74	10	**226**	200 [a]
PCB-200	1	26	2	6	8	100%	--	<1	40	2	3	18	2	<1	12	--

Dioxin-like congeners are shaded in red.

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	Deschutes River	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Screening Values
PCB-201	2	62	9	16	17	100%	--	3	118	7	8	57	9	2	42	--
PCB-202	4	151	16	32	40	100%	--	3	**281**	15	12	134	14	3	40	200 [a]
PCB-203	14	**286**	40	71	75	100%	--	16	**525**	29	40	**250**	61	8	197	200 [a]
PCB-204	<LOD	<LOD	<LOD	<LOD	<LOD	0%	0.2 -- 2	<1	<1	<1	<1	<1	<1	<1	<1	--
PCB-205	<LOD	16	3	4	4.4	87%	0.9 -- 1	<1	33	3	2	13	2	<1	7	--
PCB-206	5	83	15	26	26	100%	--	7	145	12	17	55	33	3	132	--
PCB-207	2	19	4	6	5.3	100%	--	2	31	2	5	12	7	1	25	--
PCB-208	2	37	6	10	10	100%	--	3	62	5	6	23	10	1	35	--
PCB-209	3	43	8	12	11	100%	--	4	59	7	7	22	8	3	12	--

[a] DEQ's total PCB water quality criterion for human health protection was converted to the equivalent tissue residue concentration by removing the bioaccumulation factor from the demoninator (see also,p. 51) :

$$Fish\ tissue\ criterion = \left(\frac{risk^{a} \times body\ mass^{\mathrm{b}}}{cancer\ potency\ factor^{c}\ \text{or toxicity factor} \times fish\ consumption\ rate^{\mathrm{d}}}\right)$$

[a]Risk = 1 in a million.
[b]Body mass = 70 Kg.
[c]Cancer potency (or reference dose for non-carcinogens) from EPA tables.
[d]Oregon fish consumption rate is 175 g/day.

The Total PCB criterion was also applied to individual congeners where congener specific criteria have not been adopted.

Dioxin-like congeners are shaded in red.

Table 32. Brominated flame retardants listed in the QAPP --not recovered from fish fillets.

PBDE-1	BB 153 [hexabrominated biphenyl]
PBDE-2	BTBPE [Bis(tribromo phenoxy) ethane]
PBDE-3	DBDPE[iii] [decabromodiphenyl ethane]
PBDE-7	HBB [Hexabromobenzene]
PBDE-10	

Table 33. Fish fillet PBDEs statistical summary (values in ng/Kg wet wt).

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	Deschutes River	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Screening Values
Total PBDEs	800	15,746	3,226	4,600	4,416	100%	--	1,406	26,936	1,347	1,511	12,363	1,014	884	4,167	--
PBDE-15	1	45	3	9	14	100%	--	2	48	2	2	28	1	1	3	--
PBDE-17	<LOD	97	6	21	31	96%	1.5	5	147	3	3	65	<2	1	12	--
PBDE-28	6	472	38	106	147	100%	--	20	1,120	19	19	471	13	6	51	--
PBDE-47	327	11,553	1,778	3,041	3,322	100%	--	689	18,300	671	935	8,250	430	273	2,620	40,000 [a]
PBDE-49	10	440	78	114	126	100%	--	29	674	29	33	345	23	15	67	--
PBDE-66	<LOD	68	14	19	14	96%	18	9	33	8	12	7	8	6	30	--

Columbia Mainstem Probabilistic Sites												Tributaries and Targeted Sites				
Analyte	**Min**	**Max**	**Median**	**Mean**	**Std. Dev.**	**Percent Detects**	**Non-Detect Range**	**White Salmon R.**	**Hood River**	**Klickitat River**	**Columbia R. d/s The Dalles**	**Deschutes River**	**John Day River**	**Columbia R. d/s PGE Boardman**	**Umatilla River**	**Screening Values**
PBDE-71	<LOD	0.9	<LOD	<LOD	0.2	4%	0.5 -- 27	<1	<3	<1	<2	<4	<1	<1	<1	--
PBDE-77	<LOD	1.1	<LOD	0.3	0.4	39%	0.1 -- 10	<1	1	<1	<1	<1	<1	<1	<1	--
PBDE-85	<LOD	14.4	1.9	2.4	2.9	78%	1 -- 2	4	<35	3	3	<2	<7	2	2	--
PBDE-99	35	863	230	277	225	100%	--	179	75	111	162	49	184	98	576	40,000 [a]
PBDE-100	76	2,616	360	607	713	100%	--	114	5,350	167	142	2,540	116	64	409	--
PBDE-119	<LOD	50	3	8	13	52%	0.7 -- 5	<1	<48	<1	<1	<2	<7	2	<1	--
PBDE-126	<LOD	4.7	<LOD	0.8	1.5	35%	0.2 -- 2	<1	<24	1	<1	6	<5	<1	<1	--
PBDE-138	<LOD	2.2	<LOD	0.5	0.8	30%	0.6 -- 3	1	4	2	<1	<1	<2	<1	1	--
PBDE-139	<LOD	1.3	<LOD	0.4	0.5	48%	0.4 -- 3	1	3	2	1	<1	<1	1	1	--
PBDE-140	<LOD	4.7	0.9	1.2	1.3	65%	0.5 -- 3	1	9	2	<1	3	<1	<1	2	--
PBDE-153	27	425	62	93	88	100%	--	32	187	32	42	97	43	15	124	--
PBDE-154	23	393	57	111	116	100%	--	26	671	39	33	390	39	14	99	--
PBDE-156	<LOD	2.3	<LOD	0.3	0.7	17%	0.5 -- 3	1	6	3	<1	<1	<1	<1	<1	--
PBDE-171	<LOD	3.3	<LOD	0.6	0.9	39%	0.4 -- 4	1	7	4	<1	<2	<2	<1	1	--
PBDE-180	<LOD	2.9	<LOD	0.5	0.8	39%	0.4 -- 4	1	7	3	<1	<2	<2	<1	<1	--
PBDE-183	<LOD	3.6	1.3	1.4	1.1	78%	1.2 -- 2	2	<1	3	1	<1	2	1	2	--
PBDE-184	<LOD	2.8	0.7	0.7	0.8	65%	0.7 -- 2	1	6	3	<1	<1	<1	<1	1	--
PBDE-191	<LOD	3.4	<LOD	0.6	0.9	39%	0.5 -- 4	1	6	4	<1	<2	<2	<1	1	--
PBDE-196	<LOD	4.5	0.7	1.1	1.4	52%	0.8 -- 3	2	8	4	<2	<2	<4	1	2	--
PBDE-197	<LOD	3.8	1.0	1.1	1.1	65%	0.7-- 2	2	7	4	<1	<1	<2	1	1	--
PBDE-201	<LOD	4.2	1.2	1.1	1.3	52%	1 -- 2	1	9	4	<1	<1	<3	<1	2	--
PBDE-203	<LOD	4.8	0.9	1.1	1.4	52%	0.8 -- 3	2	7	4	<1	<1	<4	1	1	--
PBDE-204	<LOD	2.9	<LOD	0.4	0.9	17%	0.7 -- 2	<1	6	3	<1	<1	<4	<1	<1	--
PBDE-205	<LOD	3.4	<LOD	0.1	0.7	4%	1 -- 5	<1	7	3	<3	<3	<6	<1	<1	--
PBDE-206	<LOD	67	8	9	14	61%	14 -- 26	14	29	16	<14	<11	<8	12	8	--

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	**Min**	**Max**	**Median**	**Mean**	**Std. Dev.**	**Percent Detects**	**Non-Detect Range**	**White Salmon R.**	**Hood River**	**Klickitat River**	**Columbia R. d/s The Dalles**	**Deschutes River**	**John Day River**	**Columbia R. d/s PGE Boardman**	**Umatilla River**	**Screening Values**
PBDE-207	<LOD	18	4	4	5	57%	4 -- 24	7	22	12	<13	<10	<8	6	5	--
PBDE-208	<LOD	13	<LOD	2	4	17%	3 -- 27	7	24	11	<14	<11	<9	<3	<4	--
PBDE-209	54	1,279	111	166	245	100%	--	251	150	176	124	114	155	362	144	571,400 [a]

[a] Draft Washington Department of Health SVs based on the Oregon fish consumption rate. (McBride, 2012)

Evaluation of SPMDs as Ecological Condition Indicators

SPMD Methods

The deployment and retrieval of the SPMDs was essentially flawless. WDOE's field method ((Johnson A. , 2007) uses a main mooring line with a submerged float to hold the SPMD at the chosen depth. A second buoyant, submerged line (snag line) was run from the main mooring to a smaller secondary mooring. No surface floats were used, and no SPMDs were lost to vandalism. To retrieve the SPMDs, the field crew navigated to the site using GPS. Often the submerged float, SPMD canister, and snag line were visible on the boat's sonar. A grappling hook was towed across the snag line, and the SPMD was brought alongside the vessel. Once the canister was secured just below the water surface, a crewmember could easily remove the end cap (Figure 35) and transfer the membranes to their original containers.

Figure 35. An SPMD canister held below water during retrieval. The end cap has been removed, and the first membrane visibly winds back and forth on the "spider" array. The yellow float held the snag line off the bottom during deployment to facilitate retrieval with a grapple.

Crews typically spent less than ten minutes locating and retrieving the SPMDs; at least twenty minutes less than anticipated. This was true even at sites with water depths of ten to thirteen meters. The SPMDs were also readily deployed at wadeable sites such as tributaries, where they were tethered or anchored and concealed by the natural habitat. Field crews timed the air exposure of membranes during deployment and retrieval. The total air exposure averaged about one minute, and the blanks showed no signs of *field* contamination. These findings convinced us that SPMDs are a viable sampling method using equipment on hand, under typical field conditions.

During deployment, the water velocity at each site was estimated with a flow meter. Measurements were typically made at approximately 1m depth, with the exception of the Umatilla River site where the measurement was made at mid-depth due to shallow water. The velocities at mainstem sites ranged from 0-1.1 ft/sec, with a mean of 0.51ft/sec and standard deviation of 0.29. Similarly, the tributary velocities ranged from 0.3 – 1.1 ft/sec, with a mean of 0.54 ft/sec and a standard deviation of 0.36.

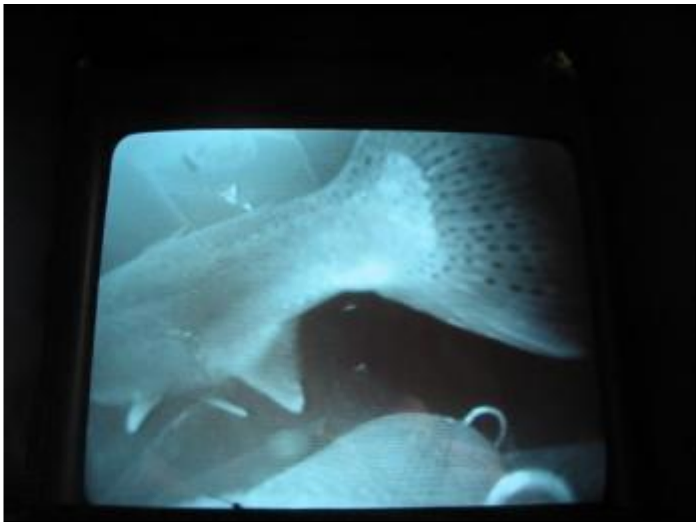

Figure 36. An underwater view of a migrating steelhead trout, hiding beneath a root wad on the White Salmon River. Our SPMD canister is visible in the foreground.

In addition to field blanks, EST prepared lab stored blanks (SPMDs held at EST, dialyzed with the sample batch, and shipped to the analytical lab). As described in the Data Quality Assessment (p. 26), both EST's laboratory stored blanks and the field blanks showed contamination for many analytes, but DEQ's analytical lab blanks were clean (Table 16). The data suggest that the contamination originated at EST during either SPMD manufacture or extraction.

Fish Tissue Samples vs. SPMDs

The DEQ traditionally collects and analyzes fish tissue to assess biological contamination. This project was DEQ's first full scale use of SPMDs. A primary research objective was gaining experience using SPMDs, and exploring their use as stressor indicators for assessing ecological conditions.

SPMDs were invented and patented by the USGS Columbia Environmental Research Center, and have been used by researchers and environmental regulatory agencies worldwide. As described by CERC, the SPMDs are biomimetic devices.

> "We at CERC have invented an artificial device called a ***semipermeable membrane device*** (SPMD) that is designed to mimic the parts of animals that cause bioconcentration. It is a long, flat, plastic tube containing oil. We call them 'fatbags.' The special plastic of the SPMD allows contaminants to pass through, like membranes of animal cells. The oil inside is similar to a highly purified fish fat. The contaminants dissolve in this oil just as they do in the fats of a fish." (Chapman, 2012).

However, the USGS researchers at CERC note that SPMDs do not mimic biomagnification of contaminants that occurs through dietary intake (i.e. through predation)(USGS, 2012). The bass collected in our survey are in trophic level four. Multiple bass specimens spontaneously regurgitated sculpins while held in the boat's livewell. In contrast, young largescale suckers are known to feed on plankton, insect larvae, and bottom ooze; while adults consume algae, diatoms, insects, amphipods, mollusks, and possibly salmonid eggs (Scott & Crossman, 1973)

A number of researchers have explored the mechanisms and capacity of SPMDs to collect a wide range of hydrophobic contaminants, and controlled experiments have compared SPMD uptake to mollusks and fish. A few examples are presented here to help put our data in context.

We considered lipid normalizing our fish fillet and SPMD data, however CERC does not recommend it:

> "…comparisons of whole-body and whole-SPMD concentrations and/or total mass of chemical accumulated per sample is more appropriate."(USGS, 2012). Lipid normalization assumes an organism's lipids have equilibrated with contaminants in the environment. SPMDs have a much higher capacity to sequester contaminants than fish due to their high lipid content (triolein) and the lipophilic nature of the membrane. Whereas the fish tissues may have reached equilibrium with the environment, the SPMD is most likely in the linear phase of chemical uptake (USGS, 2012).

Researchers monitoring organochlorine pesticides in the Holland Marsh (Canada) used SPMDs to track contaminants in places where conditions were too harsh to support fish(Lembcke, Ansell, McConnell, & Ginn, 2011). They estimated fish tissue contaminant concentrations by adjusting their initial results (analyte mass/SPMD) by accounting for the mass of triolein in the SPMD and the combined mass of the triolein + membrane. The adjusted results were then compared to fish tissue screening values. We used the same approach for comparing SPMD data to fish fillet results from the same locations. The results were first blank corrected by subtracting the larger of either the average lab-stored blank or the average field blank. Then the results were normalized as described by Lembcke (Lembcke, Ansell, McConnell, & Ginn, 2011):

$$Mass\ normalized\ concentration\ = \frac{A\ x\ 0.915}{5.6}$$

Where: A = contaminant concentration as mass per SPMD.

0.915 g = the mass of triolein per SPMD.

5.6 g = the total SPMD mass (including triolein).

Lu and Wang (2003) found that SPMD wet-weight uptake rates of PCBs and organochlorine pesticides were 1 to 2.5 times faster than in rainbow trout (trophic level 4). Thus, the Holland Marsh researchers divided their mass normalized SPMD results by 1 and 2.5 to obtain a conservative range of potential fish tissue concentrations. Similarly, the USGS Columbia Environmental Research Center (USGS, 2012) found SPMD PCB and PAH uptake rates were about 1/2 to 1 times faster than in bivalves, and 1 to 2 times faster than in fish. The USGS also found that SPMDs accumulated a broader range of chemicals.

Dioxins and Furans

A statistical summary of Columbia River and tributary SPMD dioxin-furan concentrations is shown in Table 35. These results have not been mass normalized or corrected for field or lab-stored blanks. Tetrachlorodibenzofuran (2,3,7,8-TCDF) was the only dioxin-furan compound detected in the mainstem LMC, but the results were less than twice the average lab-stored blank or average field blank. In contrast, 2,3,7,8-TCDF in fish fillets was above DEQ's human health screening values at five LMC sampling sites (22% of the reach). Fish collected in the Hood, Deschutes, and John Day Rivers exceeded SVs. These results contradict CERC's findings (USGS, 2012) showing more contaminants sequestered in SPMDs than fish.

The White Salmon River was the only tributary with SPMD dioxin-furan detections. The furan (1,2,3,4,6,7,8-Heptachlorodibenzofuran) was detected at more than twice the highest blank, and two dioxins (1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin, and 1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin) were present at levels greater than 5x the highest blank value. Yet no dioxin-furans were found in the White Salmon's smallmouth bass fillets.

A difference in sampling locations is a possible explanation for the anomalous results. The White Salmon River is true to its name. Throughout the summer, the White Salmon River was clear, cold (10^{o} C lower than every other sampling location), and occupied by migrating adult salmonids (Figure 36) .

Our fish collection permits prohibited electrofishing where salmonids were obviously present, and we were forced to move downstream and collect bass where the White Salmon mixes with the Columbia River. The fish weights and lengths were close to the survey's medians, but only three bass (vs. the intended five) were collected. The White Salmon's SPMD was deployed upstream at a more representative location. Thus, the SPMD results may better reflect the White Salmon's true environmental condition with respect to dioxins and furans.

Total DDTs

As shown in Table 36, DDTs were detected in every SPMD sample at more than twice the levels found in the lab-stored and field blanks, and only the White Salmon and Klickitat Rivers were less than 5x the blanks. Figure 37 shows a comparison of fish tissue and SPMD total DDT data. The paired results were sorted by increasing fish fillet concentration, after blank-correcting and mass-normalizing the SPMD data as described above (p. 74). The SPMD concentrations wander above and below the fish fillet screening value(Table 27), whereas the fish fillets consistently exceed the criterion. Also, the SPMD concentrations remain comparatively constant even when the total DDT fish fillet results increase by multiple orders of magnitude. The SPMD data approximates the lower smallmouth bass concentrations, but show limited response even when the bass and sucker fillets exceed the screening value by nearly five fold.

Non-DDT Chlorinated Pesticides

The detection frequency of non-DDT pesticides is shown in **Table** 34. Over half of the compounds showed good agreement, the rest were a "split decision" with no clear "winner". For example, fish outperformed SPMDs for beta-BHC and Mirex, but SPMDs captured more Aldrin and Endosulfan I.

Table 34. Detection frequencies in fish and SPMD.

Analyte	Percent Detects SPMD	Percent Detects Fish
Aldrin	70%	4%
alpha-BHC	100%	100%
beta-BHC	0%	65%
delta-BHC	0%	0%
gamma-BHC (Lindane)	91%	74%
cis-Chlordane	100%	100%
(trans-Chlordane + trans-Nonachlor)	100%	100%
cis-Nonachlor	83%	100%
Oxychlordane	74%	100%
∑ Chlordane	89%	100%

Analyte	Percent Detects SPMD	Percent Detects Fish
Dieldrin	100%	100%
Endosulfan I	100%	22%
Endosulfan II	17%	4%
Endosulfan sulfate	86%	35%
Endrin + cis-Nonachlor	87%	100%
Heptachlor	100%	87%
Heptachlor epoxide	100%	100%
Hexachlorobenzene	100%	100%
Methoxychlor	56%	100%
Mirex	0%	100%

Total PCBs

Whereas 39 PCB congeners were not detected in fish fillets, 76 congeners were not detected in the SPMDs. This result is contrary to the USGS finding that SPMDs accumulated a broader range of chemicals (USGS, 2012).

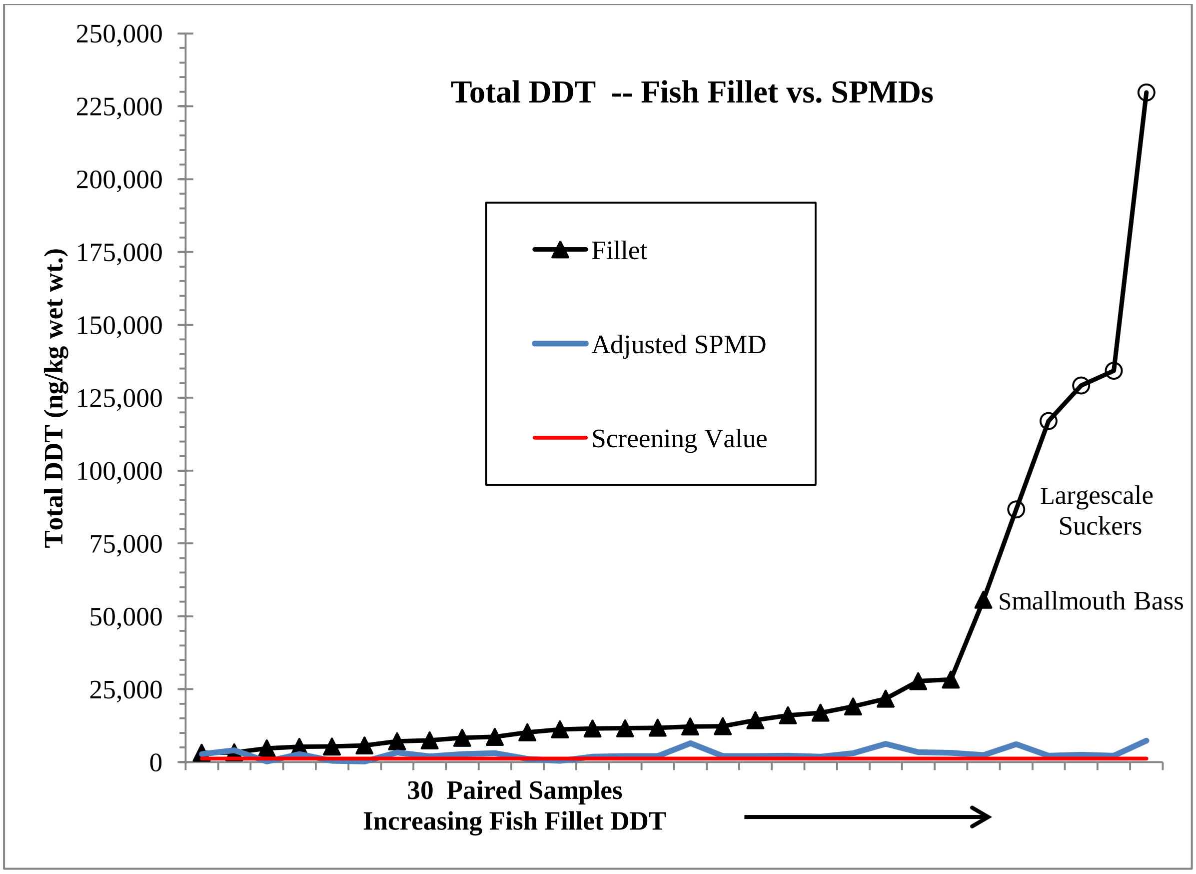

Figure 37. Fish fillet total DDTs vs. mass-normalized SPMD data from the same locations (results are arranged by increasing fish tissue concentrations).

PBDEs

A comparison of Table 33 (p.70) and Table 41 (p. 89) shows that PBDEs were detected at similar frequencies in both fish fillets and SPMDs.

PAHs

Fluoranthene and Phenanthrene were the only two PAH compounds detected in the survey, and at very low levels (Table 42). The Total PAH detection frequency was 22% of the probabilistic sites, and in the Hood River. These two compounds often occur as combustion byproducts.

Table 35. SPMD Dioxin-Furan Statistical Summary (values in ng/SPMD).

Columbia Mainstem Probabilistic Sites							Tributaries and Targeted Sites								
Analyte	Min	Max	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Avg. Lab-Stored Blank	Avg. Field Blank
Total 2,3,7,8 Substituted Dioxin-Furans	<LOD	3.0	0.22	0.75	9%	0.4 - 16	**75**[a]	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
2,3,7,8-Tetrachlorodibenzodioxin	<LOD	<LOD	<LOD	<LOD	0%	1 - 5	<5	<2	<2	<4	<1	<1	<1	<4	<2
2,3,7,8-Tetrachlorodibenzofuran	<LOD	3.0	0.22	0.75	9%	1 - 9	<5	<3	<3	<5	<2	<2	<2	<5	<3
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	<LOD	<LOD	<LOD	<LOD	0%	1 - 7	<5	<3	<3	<5	<1	<2	<1	<3	<2
1,2,3,7,8-Pentachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	1 - 6	<7	<3	<3	<5	<2	<2	<2	<3	<2
2,3,4,7,8-Pentachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	1 - 7	<7	<3	<3	<6	<2	<2	<2	<4	<2
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	<LOD	<LOD	<LOD	<LOD	0%	1 - 6	<5	<4	<3	<5	<2	<2	<2	<5	<2
1,2,3,4,7,8-Hexachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	0.5 - 3	<6	<2	<2	<3	<1	<1	<1	<3	<1
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	<LOD	<LOD	<LOD	<LOD	0%	1 - 6	<6	<4	<3	<5	<2	<2	<2	<5	<3
1,2,3,6,7,8-Hexachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	0.4 - 3	<6	<2	<2	<2	<1	<1	<1	<3	<1
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	<LOD	<LOD	<LOD	<LOD	0%	2 - 7	<6	<4	<3	<5	<2	<2	<2	<3	<3
1,2,3,7,8,9-Hexachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	1 - 6	<11	<3	<3	<4	<1	<1	<1	<3	<2
2,3,4,6,7,8-Hexachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	0.5 - 3	<6	<2	<2	<3	<1	<1	<1	<3	<1
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	<LOD	<LOD	<LOD	<LOD	0%	1 - 8	**22**[a]	<5	<5	<7	<2	<2	<2	<5	<3
1,2,3,4,6,7,8-Heptachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	0.6 - 4	7[a]	<2	<2	<2	<1	<1	<1	<2	<2
1,2,3,4,7,8,9-Heptachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	1 - 7	<11	<4	<4	<4	<1	<2	<2	<4	<2
1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	<LOD	<LOD	<LOD	<LOD	0%	2 - 12	**46**[a]	<6	<7	<12	<3	<4	<3	<7	<5
1,2,3,4,6,7,8,9-Octachlorodibenzofuran	<LOD	<LOD	<LOD	<LOD	0%	2 - 16	<14	<9	<8	<15	<3	<4	<3	<10	<6

[a] Analyte detected, but failed ion ratio criteria. The reported value is the estimated maximum possible concentration (EMPC).

Bold results are greater than 2x the highest blank value. **Bold** (highlighted) results are greater than 5x the highest blank value.

Table 36. SPMD DDT Statistical Summary (values in ng/SPMD).

Analyte	Columbia Mainstem Probabilistic Sites: Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	Tributaries and Targeted Sites: White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Avg. Lab-Stored Blank	Avg. Field Blank
Total DDTs	**7,159**	**39,923**	**15,769**	**18,713**	8,877	100%	--	**1,772**	**45,576**	**1,931**	**13,759**	**2,790**	**17,196**	**3,174**	348	407
2,4`-DDD	**1,087**	**4,062**	**1,593**	**1,693**	662	100%	--	**59**	**2,460**	**62**	**1,170**	**185**	**1,700**	**136**	<24	<16
2,4`-DDE	<LOD	**520**	**219**	**207**	103	91%	26 - 210	<40	**323**	<35	**170**	<32	**205**	<27	<54	<30
2,4`-DDT	<LOD	**385**	**205**	**185**	98	83%	123 - 630	163	**1,950**	**238**	**188**	114	**203**	**192**	70	85
4,4`-DDD	**2,984**	**11,689**	**4,816**	**5,124**	1,918	100%	--	**126**	**7,940**	**178**	**3,870**	**750**	**5,350**	**415**	<24	<16
4,4`-DDE	**870**	**22,103**	**8,599**	**9,402**	3,732	100%	--	**1,090**	**25,000**	**707**	**7,980**	**1,550**	**9,190**	**2,010**	178	185
4,4`-DDT	<LOD	**1,164**	**437**	**417**	283	78%	15 - 922	**331**	**7,890**	**746**	**369**	193	**542**	**417**	122	137

Bold results are greater than 2x the highest blank concentration. **Bold** results are greater than 5x the highest blank concentration. . Analytes with inexplicably high blank contamination are highlighted in grey.

Table 37. SPMD non-DDT Pesticide Statistical Summary (values in ng/SPMD).

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	**Min**	**Max**	**Median**	**Mean**	**Std. Dev.**	**Percent Detects**	**Non-Detect Range**	**White Salmon R.**	**Hood River**	**Klickitat River**	**Columbia R. d/s The Dalles**	**John Day River**	**Columbia R. d/s PGE Boardman**	**Umatilla River**	**Avg. Lab-Stored Blank**	**Avg. Field Blank**
Aldrin	<LOD	40	22	19	14	70%	15 - 26	22	42	<19	23	<15	22	**42**	<15	<12
alpha-BHC	65	**124**	**93**	**93**	12	100%	--	<38	**126**	**99**	81	**122**	86	<33	<46	<35
beta-BHC	<LOD	<LOD	<LOD	<LOD	--	0%	33 - 74	<42	47	<45	<40	<35	<34	<41	<56	<38
delta-BHC	<LOD	<LOD	<LOD	<LOD	--	0%	31 - 91	<39	<29	<42	<37	<38	<33	<42	<51	<37
gamma-BHC (Lindane)	<LOD	105	74	70	26	91%	37 - 53	94	97	74	73	75	72	84	70	<43
cis-Chlordane	356	**852**	**589**	**591**	111	100%	--	297	**582**	392	**549**	422	**542**	329	224	207
(trans-Chlordane + trans-Nonachlor)	684	**1,349**	**951**	**982**	153	100%	--	575	**1,010**	700	**901**	**923**	**960**	772	435	417
cis-Nonachlor	<LOD	**205**	**106**	**106**	60	83%	34 - 623	<34	**106**	50	**121**	<45	**103**	**90**	<33	<27
Oxychlordane	<LOD	**150**	75	69	47	74%	37 - 125	<50	75	<46	70	<37	88	48	<54	<42
∑ Chlordane	**1,040**	**2,556**	**1,721**	**1,748**	371	89%	--	872	**1,773**	**1,142**	**1,640**	**1,345**	**1,693**	**1,239**	186	173
Dieldrin	**1,408**	**2,440**	**1,960**	**1,961**	284	100%	--	137	**4,990**	**315**	**1,930**	**371**	**1,970**	**963**	57	55
Endosulfan I	361	**3,845**	**767**	**1,137**	946	100%	--	**674**	**6,820**	**2,020**	**609**	**230**	**1,380**	**449**	<74	<61
Endosulfan II	<LOD	**574**	<LOD	47	129	17%	95 – 1,275	171	**3,220**	208	114	<125	<95	<113	<118	<130
Endosulfan sulfate	<LOD	**1,538**	**1,102**	**1,042**	473	86%	475 - 968	148	**4,930**	**291**	**1,450**	**846**	**1,030**	**393**	<74	<70
Endrin + cis-Nonachlor	<LOD	**287**	**206**	**187**	**83**	87%	91 - 467	67	**304**	58	**216**	**83**	**211**	**80**	<36	<28
Endrin Aldehyde Endrin Ketone			Not Recovered								Not Recovered					
Heptachlor	40	116	73	75	20	100%	--	122	132	101	90	65	58	68	85	67
Heptachlor epoxide	**250**	**409**	**319**	**319**	42	100%	--	<36	**355**	70	**318**	**281**	**331**	**562**	<42	<32
Hexachlorobenzene	**1,447**	**4,841**	**2,182**	**2,394**	713	100%	--	**674**	**1,530**	**1,850**	**1,970**	**990**	**2,370**	**624**	164	97
Methoxychlor	<LOD	256	150	110	102	56%	46 – 3,468	341	353	185	151	<62	132	185	253	159
Mirex	<LOD	<LOD	<LOD	<LOD	--	0%	8 - 216	<8	<8	<10	<11	<12	<9	<10	<8	<10

Bold results are greater than 2x the highest blank concentration. **Bold** results are greater than 5x the highest blank concentration. Analytes with inexplicably high blank contamination are highlighted in grey.

Table 38. PCBs listed in the QAPP --Not recovered from SPMDs.

PCB-1	PCB-4	PCB-7	PCB-10	PCB-13
PCB-2	PCB-5	PCB-8	PCB-11	PCB-14
PCB-3	PCB-6	PCB-9	PCB-12	PCB-15

Table 39. PCBs not detected in SPMDs.

PCB-23	PCB-50	PCB-63	PCB-79	PCB-90	PCB-96	PCB-104	PCB-120	PCB-136	PCB-143	PCB-154	PCB-163	PCB-173	PCB-180	PCB-197	PCB-205
PCB-30	PCB-54	PCB-69	PCB-80	PCB-93	PCB-98	PCB-106	PCB-125	PCB-130	PCB-145	PCB-155	PCB-166	PCB-184	PCB-191	PCB-198	
PCB-38	PCB-57	PCB-73	PCB-86	PCB-92	PCB-100	PCB-108	PCB-127	PCB-140	PCB-150	PCB-159	PCB-168	PCB-186	PCB-193	PCB-200	
PCB-47	PCB-61	PCB-78	PCB-88	PCB-94	PCB-103	PCB-109	PCB-131/133	PCB-142	PCB-153	PCB-161	PCB-169	PCB-188	PCB-195	PCB-204	

[a]Yellow shaded PCB congeners were not detected in fish fillets or SPMDs.

Table 40. SPMD PCB Statistical Summary (values in ng/SPMD).

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Avg. Lab-Stored Blank	Avg. Field Blank
Total PCBs	5,465	**19,589**	8,620	9,762	3,467	100%	--	6,223	7,408	6,393	8,546	5,712	7,973	5,024	5,200	4,000
PCB-16/32	49	372	230	229	59	100%	--	250	271	240	234	233	238	208	256	173
PCB-17	86	260	158	163	34	100%	--	164	179	160	169	146	158	136	166	114
PCB-18	198	621	379	390	82	100%	--	378	416	374	400	349	384	321	392	268
PCB-19	0	56	39	38	11	96%	<14	39	44	36	43	35	37	31	42	30
PCB-20/21/33	168	518	332	332	65	100%	--	354	383	344	329	310	327	274	311	233
PCB-22	90	245	167	170	32	100%	--	153	173	155	160	145	169	129	135	103
PCB-23	<LOD	<LOD	<LOD	<LOD	<LOD	0%	3 - 10	<7	<6	<6	<6	<4	<5	<3	<6	<6
PCB-24	<3	8	5	3	3	52%	3 - 10	<6	7	6	6	5	<4	6	8	<5
PCB-25	22	68	44	45	8	100%	--	45	50	45	46	40	42	36	40	30
PCB-26	50	146	98	99	19	100%	--	94	106	96	98	87	97	77	87	63
PCB-27	16	42	27	28	5	100%	--	27	29	26	29	25	28	22	28	18
PCB-28	278	763	516	529	104	100%	--	455	509	459	510	418	524	390	406	307
PCB-29	<LOD	10	7	7	3	87%	7 - 10	9	10	8	8	8	7	5	10	6
PCB-30	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 - 11	<7	<5	<4	<5	<3	<4	<5	<5	<6
PCB-31	292	839	540	550	101	100%	--	510	578	530	542	487	520	413	460	344
PCB-34	<LOD	3.8	<LOD	0.2	1	4%	3 - 12	<8	<7	<7	<6	<5	<5	<3	<7	<7
PCB-35	14	29	20	21	4	100%	--	8	10	9	20	8	18	8	8	<7
PCB-36	<LOD	7	<LOD	3	3	43%	3 - 11	<7	<6	<6	<4	<4	6	<3	<7	<7
PCB-37	75	**205**	136	140	27	100%	--	111	126	112	129	109	137	98	86	82

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Avg. Lab-Stored Blank	Avg. Field Blank
PCB-38	<LOD	<LOD	<LOD	<LOD	<LOD	0%	4 - 13	<9	<8	<8	<7	9	<6	<4	<8	<8
PCB-39	<LOD	7	4	3	2	70%	2 - 10	<7	4	<6	5	<4	5	3	<5	<6
PCB-40	29	72	48	48	9	100%	--	45	49	40	44	41	44	33	30	29
PCB-41/72	22	52	35	36	7	100%	--	36	38	35	38	31	32	24	27	21
PCB-42	36	149	100	101	22	100%	--	84	96	87	97	85	92	69	63	56
PCB-43/52	364	**945**	**560**	**587**	139	100%	--	368	428	381	527	353	526	290	277	233
PCB-44	180	**462**	297	303	62	100%	--	220	266	239	283	218	288	185	160	146
PCB-45	36	95	64	65	12	100%	--	58	61	58	64	56	60	45	48	36
PCB-46	<LOD	34	23	22	6	96%	<6	22	25	19	22	21	23	16	17	15
PCB-47	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 - 4	<3	<2	<2	<2	<1	<1	<1	<3	<3
PCB-48	36	110	74	74	14	100%	--	57	67	68	68	61	74	54	49	44
PCB-49	161	**425**	269	282	59	100%	--	211	242	216	272	196	252	163	165	137
PCB-50	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 5	<3	<3	<3	<3	<2	<2	<1	<5	<4
PCB-51	<LOD	23	16	15	4	96%	<4	17	18	16	17	14	15	13	14	11
PCB-53	28	74	49	50	9	100%	--	41	48	43	50	40	45	35	37	28
PCB-54	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 7	<4	<3	<3	<4	<2	<2	<2	<5	<5
PCB-55	<LOD	5	<LOD	2	2	30%	2 – 7	<3	<4	4	<3	<2	<3	<2	4	<3
PCB-56	57	**130**	86	87	16	100%	--	66	75	67	77	64	80	58	43	41
PCB-57	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 - 4	<3	<2	<2	<3	<2	<1	<1	<3	<3
PCB-58/67	8	15	12	12	2	100%	--	12	10	11	12	8	10	7	10	7
PCB-59	16	41	27	28	5	100%	--	22	26	24	26	21	26	18	17	16
PCB-60	50	**109**	**63**	**66**	14	100%	--	41	52	47	56	41	**63**	37	30	29
PCB-61	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 7	<4	<4	<3	<3	<2	<3	<2	<3	<3

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Avg. Lab-Stored Blank	Avg. Field Blank
PCB-62	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 - 4	<3	<2	<2	<3	<1	<1	<1	<3	<3
PCB-63	<LOD	22	15	15	4	96%	<4	12	13	11	15	9	13	8	7	<6
PCB-64/68	113	**267**	173	177	35	100%	--	121	136	125	160	117	160	96	87	76
PCB-65/75	65	**154**	101	105	19	100%	--	81	86	81	97	75	103	61	59	53
PCB-66	178	**416**	**267**	**270**	53	100%	--	164	205	183	**231**	172	**246**	142	107	113
PCB-69	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 - 4	<3	<2	<2	<3	<2	<1	<1	<3	<3
PCB-70	212	**572**	**328**	**344**	79	100%	--	215	264	235	**288**	211	**319**	189	138	143
PCB-71	38	99	64	66	13	100%	--	62	73	62	62	61	61	49	45	42
PCB-73	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 - 4	<2	<2	<2	<2	<1	<1	<1	<2	<2
PCB-74/76	99	**249**	**156**	**160**	32	100%	--	106	124	111	**146**	98	**148**	86	70	72
PCB-77	14	38	19	20	5	100%	--	10	14	12	18	11	17	9	9	7
PCB-78	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 8	<4	<4	<3	<3	<2	<3	<2	<3	<2
PCB-79	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 7	<3	<4	<2	<3	<2	<3	<2	<4	3
PCB-80	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 6	<3	<4	<2	<3	<2	<2	<2	<3	3
PCB-81	<LOD	7	<LOD	2	2	26%	2 – 8	<3	<4	<2	<3	<2	<3	<2	4	3
PCB-82	<LOD	**54**	21	**23**	9	96%	<18	<12	<13	14	21	16	22	11	<10	11
PCB-83	<LOD	11	7	5	4	61%	3 – 14	<8	<9	<4	<5	<4	8	<2	<7	6
PCB-84	45	**132**	**66**	**68**	20	100%	--	29	**46**	35	**53**	**41**	**61**	28	19	16
PCB-85	**37**	**96**	**49**	**53**	14	100%	--	24	**33**	25	**48**	21	**42**	19	14	12
PCB-86	<LOD	<LOD	<LOD	<LOD	<LOD	0%	3 – 20	<12	<12	<6	<7	<6	<4	<3	<9	8
PCB-87/111/116/117	64	193	93	93	29	100%	--	42	65	47	81	40	79	35	36	26
PCB-88	<LOD	<LOD	<LOD	<LOD	<LOD	0%	4 – 22	<13	<13	<7	<8	<7	<5	<3	<10	9

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Avg. Lab-Stored Blank	Avg. Field Blank
PCB-89	53	137	68	73	21	100%	--	24	37	30	63	26	61	22	16	12
PCB-90	<LOD	<LOD	<LOD	<LOD	<LOD	0%	3 – 20	<12	<12	<6	<8	<5	<4	<3	<8	8
PCB-91	26	76	39	41	12	100%	--	20	25	21	35	20	34	17	12	10
PCB-92	<LOD	<LOD	<LOD	<LOD	<LOD	0%	4 - 21	<12	<12	<6	<7	<7	<4	<3	<10	9
PCB-93	<LOD	<LOD	<LOD	<LOD	<LOD	0%	4 – 19	<12	<13	<6	<8	<6	<4	<3	<9	9
PCB-94	<LOD	<LOD	<LOD	<LOD	<LOD	0%	3 – 11	<7	<5	<4	<4	<4	<3	<2	<5	6
PCB-95/ 121	169	457	227	249	72	100%	--	115	152	120	214	110	214	97	82	73
PCB-96	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 10	<7	<5	<4	<4	<4	<3	<2	<5	5
PCB-97	60	200	82	89	32	100%	--	43	54	39	70	36	74	37	29	22
PCB-98	<LOD	<LOD	<LOD	<LOD	<LOD	0%	4 - 20	<11	<12	<6	<7	<6	<4	<3	<9	<8
PCB-99	91	244	129	132	36	100%	--	52	69	52	115	47	107	43	34	29
PCB-100	<LOD	<LOD	<LOD	<LOD	<LOD	0%	3 – 13	<9	<6	<5	<5	<4	<4	<2	<6	<7
PCB-101/ 113	232	636	324	330	95	100%	--	138	196	147	279	136	285	117	103	87
PCB-102	<LOD	14	<LOD	1	4	13%	3 – 19	<12	<12	<6	<7	<6	<4	<3	<9	<8
PCB-103	<LOD	<LOD	<LOD	<LOD	<LOD	0%	3 – 12	<8	<6	<5	<5	<4	<4	<2	<6	<7
PCB-104	<LOD	<LOD	<LOD	<LOD	<LOD	0%	3 – 17	<11	<8	<7	<6	<5	<5	<3	<9	<9
PCB-105	58	206	87	92	32	100%	--	35	49	33	86	26	72	25	20	17
PCB-106	<LOD	<LOD	<LOD	<LOD	<LOD	0%	3 – 15	<9	<10	<5	<6	<5	<3	<2	<8	<7
PCB-107/ 123	15	54	23	25	9	100%	--	10	15	10	26	7	21	7	<10	<5
PCB-108	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 12	<7	<8	<4	<5	<4	<3	<2	<7	<6
PCB-109	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 12	<8	<9	<4	<5	<4	<3	<2	<6	<6
PCB-110	213	625	304	311	99	100%	--	103	166	116	257	106	258	91	59	58
PCB-112/ 119	<LOD	26	11	10	7	74%	8 – 14	<10	<10	<5	14	<5	11	4	<8	<7

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Avg. Lab-Stored Blank	Avg. Field Blank
PCB-114	<LOD	22	<LOD	4	6	35%	2 – 10	<8	<7	<4	<5	<5	8	<2	<6	<5
PCB-115	<LOD	12	4	4	4	49%	4 – 15	<10	<10	<5	7	<5	6	<2	<7	<7
PCB-118	155	462	220	232	72	100%	--	86	129	85	211	65	181	63	58	42
PCB-120	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 15	<9	<9	<5	<6	<4	<3	<2	<7	<6
PCB-122	<LOD	6	<LOD	0	1	4%	2 – 19	<10	<12	<6	<7	<4	<4	<3	<7	<7
PCB-124	<LOD	14	7	6	4	70%	6 – 15	<8	<9	<4	9	<4	<3	<2	<7	<6
PCB-125	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 14	<8	<8	<4	<5	<4	<3	<2	<7	<6
PCB-126	<LOD	6	<LOD	0	1	9%	3 – 13	<7	<6	<4	<4	<3	<3	<2	7	<6
PCB-127	<LOD	<LOD	<LOD	<LOD	<LOD	0%	3 – 20	<10	<6	<6	<6	<4	<5	<3	<8	<7
PCB-128	19	55	26	28	9	100%	--	11	19	12	26	8	21	8	11	6
PCB-129	<LOD	9	3	3	3	52%	4 – 17	4	<9	<5	<6	<3	8	<3	<8	<6
PCB-130	<LOD	22	13	12	6	87%	10 – 14	7	<8	7	14	5	10	4	<8	<6
PCB-131/ 133	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 7	<6	<3	<6	<5	<2	<2	<1	<2	<4
PCB-132/ 153	224	510	322	335	78	100%	--	183	232	177	368	134	243	<1	128	100
PCB-134	<LOD	**29**	**14**	**13**	6	91%	4 – 5	<7	**10**	<6	**15**	<3	<2	<1	<5	4
PCB-135	23	61	36	36	9	100%	--	20	25	20	36	18	29	<1	15	9
PCB-136	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 6	<6	<3	<5	<5	<2	<2	<1	<2	<3
PCB-137	<LOD	14	5	5	4	78%	3 – 12	5	<6	<4	7	<3	4	<3	<7	<5
PCB-138/ 163	**142**	**366**	**191**	**206**	57	100%	--	102	132	98	**211**	71	**165**	75	69	50
PCB-139	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 5	<5	<2	<4	<4	<2	<1	<1	<2	<3
PCB-140	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 5	<5	<2	<5	<4	<2	<1	<1	<4	<3
PCB-141	21	51	29	31	7	100%	--	22	28	24	30	15	28	18	15	14
PCB-142	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 7	<7	<3	<6	<5	<3	<2	<1	<3	<4

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Avg. Lab-Stored Blank	Avg. Field Blank
PCB-143	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 6	<6	<3	<5	<5	<2	<2	<1	<3	<3
PCB-144	<LOD	21	14	13	5	96%	<4	9	12	12	13	8	10	6	10	5
PCB-145	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 4	<4	<2	<3	<3	<2	<1	<1	<1	<2
PCB-146	24	52	37	38	8	100%	--	20	24	19	40	16	24	9	20	8
PCB-147	<LOD	5	<LOD	1	2	13%	1 – 5	<5	<2	<4	<4	<2	<1	<1	3	<3
PCB-148	28	64	39	41	9	100%	--	28	32	27	42	25	35	21	20	20
PCB-149	147	319	207	211	44	100%	--	106	144	115	209	103	164	88	82	72
PCB-150	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 4	<4	<2	<3	<3	<2	<1	<1	<1	<2
PCB-151	5	126	80	80	26	100%	--	53	65	55	88	47	68	38	39	24
PCB-152	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 5	<4	<2	<4	<4	<2	<1	<1	<2	<2
PCB-154	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 5	<4	<2	<4	<4	<2	<1	<1	<2	<3
PCB-155	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 6	<5	<2	<4	<4	<2	<2	<1	<2	<3
PCB-156	<LOD	26	13	13	6	91%	4 – 10	8	11	7	14	6	11	5	<6	<5
PCB-157	<LOD	9	<LOD	2	3	39%	2 – 11	3	<5	<4	4	<3	<2	<2	6	<4
PCB-158/160	<LOD	28	16	15	7	91%	4 – 9	10	12	11	18	7	9	7	7	<5
PCB-159	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 10	<2	<6	<3	<4	<2	<2	<2	<6	<4
PCB-161	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 6	<5	<2	<4	<4	<2	<2	<1	<2	<3
PCB-162	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 9	<2	<5	<2	<3	<2	<2	<2	<5	<4
PCB-164	<LOD	23	11	12	5	96%	<9	8	9	7	15	5	10	4	<6	<4
PCB-165	<LOD	24	<LOD	1	5	4%	1 – 5	<4	<2	<3	<3	<2	<1	<1	<3	<2
PCB-166	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 10	<2	<5	<3	<4	<2	<2	<2	<6	<4
PCB-167	<LOD	18	8	8	4	87%	6 – 9	8	<5	7	10	4	8	3	<7	4
PCB-168	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 4	<4	<2	<4	<3	<2	<1	<1	<1	<2
PCB-169	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 10	<2	<6	<3	<4	<2	<3	<2	<7	<4

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Avg. Lab-Stored Blank	Avg. Field Blank
PCB-170	11	28	16	16	4	100%	--	12	15	12	22	7	10	9	12	<7
PCB-171	<LOD	11	7	6	4	65%	2 – 12	6	7	6	10	<3	<2	<3	7	<6
PCB-172	<LOD	9	<LOD	1	3	22%	2 – 14	<4	<3	<2	<5	<3	<2	<3	7	<7
PCB-173	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 10	<3	<3	<2	<4	<3	<2	<3	<6	<7
PCB-174	<LOD	44	27	20	16	65%	2 – 9	22	27	22	35	16	<2	<2	15	12
PCB-175/ 182	<LOD	95	54	41	35	61%	2 – 9	43	52	43	75	32	<2	<3	<5	<20
PCB-176	<LOD	10	7	6	3	78%	4 – 10	8	8	8	10	<2	5	4	<6	5
PCB-177	<LOD	34	21	22	7	96%	<14	7	19	14	27	10	17	10	10	<8
PCB-178	<LOD	20	12	12	6	87%	5 – 14	9	12	9	14	<3	10	6	<6	<7
PCB-179	21	38	27	28	5	100%	--	19	25	23	31	18	24	15	17	14
PCB-180/ 193	32	77	47	50	11	100%	--	39	47	39	63	27	34	26	33	21
PCB-181	<LOD	23	<LOD	2	6	9%	1 – 11	<3	<3	<2	<4	<2	<2	<2	<5	<6
PCB-183	13	34	19	21	6	100%	--	17	20	19	27	11	15	11	14	12
PCB-184	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 5	<2	<2	<2	<2	<2	<1	<1	<2	<2
PCB-185	<LOD	42	5	12	13	70%	3 – 11	4	4	3	5	<3	25	17	<6	9
PCB-186	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 9	<2	<2	<2	<3	<2	<2	<2	<4	<5
PCB-187	<LOD	78	<LOD	22	29	39%	1 – 5	<3	<2	<2	<4	<2	41	29	27	<11
PCB-188	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 6	<2	<2	<2	<1	<2	<2	<1	<2	<2
PCB-189	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 7	<3	<3	<2	<3	<2	<2	<1	4	<3
PCB-190	<LOD	11	4	4	3	74%	4 – 12	5	5	4	7	<2	3	<2	7	<6
PCB-191	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 10	<3	<2	<2	<3	<2	<2	<2	<5	<5
PCB-192	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 9	<2	<2	<2	<3	<2	<2	<2	<4	<5
PCB-194	<LOD	9	<LOD	3	4	43%	2 – 8	8	9	5	9	<2	<3	<2	<7	<4
PCB-195	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 8	<5	<4	<3	<4	<2	<3	<2	7	<4

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	**Min**	**Max**	**Median**	**Mean**	**Std. Dev.**	**Percent Detects**	**Non-Detect Range**	**White Salmon R.**	**Hood River**	**Klickitat River**	**Columbia R. d/s The Dalles**	**John Day River**	**Columbia R. d/s PGE Boardman**	**Umatilla River**	**Avg. Lab-Stored Blank**	**Avg. Field Blank**
PCB-196	<LOD	10	<LOD	2	4	30%	2 – 10	<8	<4	6	8	<3	<4	<2	8	<6
PCB-197	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 6	<4	<2	<2	<3	<2	<2	<1	<4	<3
PCB-198	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 9	<7	<3	<3	<4	<4	<3	<2	<12	<5
PCB-199	<LOD	22	11	11	6	87%	4 – 9	15	18	12	21	6	<3	8	10	<5
PCB-200	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 7	<5	<2	<2	<3	<3	<2	<2	<5	<4
PCB-201	<LOD	3	<LOD	0	1	4%	1 – 6	<5	4	<2	<3	<3	<2	<1	6	<4
PCB-202	<LOD	10	<LOD	3	4	43%	1 – 5	6	6	6	9	<2	4	3	7	<3
PCB-203	<LOD	11	<LOD	4	4	48%	1 – 7	<5	9	5	11	<3	<2	<1	10	<4
PCB-204	<LOD	<LOD	<LOD	<LOD	<LOD	0%	1 – 7	<6	<3	<2	<3	<2	<2	<1	4	<5
PCB-205	<LOD	<LOD	<LOD	<LOD	<LOD	0%	2 – 7	<4	<3	<3	<4	<2	<2	<2	5	<6
PCB-206	<LOD	9	<LOD	1	3	17%	1 – 7	<4	10	4	9	<2	<3	<2	8	<7
PCB-207	<LOD	3	<LOD	0.1	0.6	4%	1 – 5	<3	<4	<2	<3	<2	<2	<1	6	<3
PCB-208	<LOD	6	<LOD	1	2	26%	1 – 5	4	<3	2	4	<1	<2	<1	6	<3
PCB-209	<LOD	5	<LOD	1	2	39%	1 - 5	4	5	3	4	<2	<2	<2	5	<3

Bold results are greater than 2x the highest blank concentration. **Bold** results are greater than 5x the highest blank concentration. Congeners with inexplicably high blank contamination are highlighted in grey.

Table 41. SPMD PBDE Statistical Summary (values in ng/SPMD).

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Avg. Lab-Stored Blank	Avg. Field Blank
Total PBDEs	**2,158**	**7,669**	**3,345**	**3,657**	**1,258**	100%	-	**2,614**	**3,700**	**3,152**	**3,363**	**2,268**	**3,097**	**5,628**	54	63
PBDE-15	43	102	68	71	14	100%	-	4	12	7	63	6	78	10	4	3
PBDE-17	29	273	60	77	52	100%	-	10	24	20	43	27	55	35	10	9
PBDE-28	51	130	75	76	18	100%	-	24	59	46	68	34	69	50	19	23
PBDE-47	1,057	2,213	1,467	1,494	276	100%	-	891	1,489	1,289	1,422	968	1,379	1,633	580	781
PBDE-49	63	184	93	100	30	100%	-	22	67	50	76	56	110	84	16	30
PBDE-66	20	45	30	30	6	100%	-	17	36	30	31	20	26	30	10	15
PBDE-71	<LOD	15	6	7	4	13%	5 - 6	2	5	5	6	<4	7	7	<2	3
PBDE-77	<LOD	2	<LOD	0.4	0.7	22%	1 - 4	<2	<1	<1	<1	<2	<1	1	<1	<1
PBDE-85	13	56	26	28	10	100%	-	25	34	28	25	21	24	29	14	24
PBDE-99	367	1,031	601	617	134	100%	-	604	880	697	651	534	583	697	375	533
PBDE-100	129	274	198	203	37	100%	-	139	221	187	209	120	183	209	81	110
PBDE-119	<LOD	5	<LOD	1	1	13%	2 - 30	<5	<6	<4	<4	<2	<2	<3	<5	<2
PBDE-126	<LOD	5	<LOD	1	2	22%	1 - 10	<4	<5	<2	<4	2	2	2	<3	<1
PBDE-138	<LOD	14	6	6	4	87%	6 - 12	<4	<4	<3	<5	6	7	7	5	6
PBDE-139	<LOD	13	6	6	3	91%	5 - 6	6	7	5	6	4	6	6	4	5
PBDE-140	<LOD	9	3	3	2	83%	3 - 6	<3	<3	<3	<3	3	4	4	<1	2
PBDE-153	25	95	46	47	13	100%	-	42	62	46	48	38	41	47	34	43
PBDE-154	28	81	43	47	12	100%	-	34	52	42	44	34	43	49	27	33
PBDE-156	<LOD	**15**	<LOD	1	3	22%	2 - 12	<4	<4	<3	<5	<3	<2	4	2	<1
PBDE-171	<LOD	**27**	<LOD	4	7	43%	3 - 13	<5	<4	<6	<8	<3	4	<3	5	<3
PBDE-180	<LOD	26	<LOD	3	6	43%	3 - 17	<6	<5	<6	<9	<3	4	5	4	6

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Avg. Lab-Stored Blank	Avg. Field Blank
PBDE-183	13	67	26	28	12	100%	-	29	22	25	25	23	25	24	15	33
PBDE-184	<LOD	**10**	3	2	2	56%	3 - 8	<3	<2	<3	<4	3	4	4	<1	2
PBDE-191	<LOD	17	<LOD	1	4	22%	3 - 19	<6	<5	<7	<10	<4	<3	<4	<3	<2
PBDE-196	<LOD	31	7	7	9	56%	5 - 21	<13	<14	<12	<16	7	8	9	10	16
PBDE-197	<LOD	33	11	12	7	87%	7 - 19	13	<8	9	<10	12	12	12	<10	15
PBDE-201	<LOD	20	<LOD	2	5	26%	5 - 32	<15	<14	<15	<17	5	<5	<7	<5	5
PBDE-203	<LOD	26	<LOD	6	6	61%	10 - 30	<14	<15	<13	<18	7	7	9	6	10
PBDE-204	<LOD	14	<LOD	1	3	4%	4 - 32	<16	<14	<15	<17	<4	<4	<6	<11	<4
PBDE-205	<LOD	21	<LOD	1	4	4%	7 - 51	<25	<25	<22	<30	<7	<7	<10	<9	<7
PBDE-206	<LOD	118	<LOD	20	34	35%	21 - 76	37	34	<28	49	<51	<46	78	40	25
PBDE-207	<LOD	76	<LOD	13	21	35%	25 - 66	29	30	29	36	<51	<46	<45	33	30
PBDE-208	<LOD	<LOD	<LOD	<LOD	<LOD	0%	24 - 91	<29	<38	<34	<38	<76	<69	<68	<29	<27
PBDE-209	207	679	451	457	134	100%	-	686	668	637	562	338	416	2,584	728	389

Bold results are greater than 2x the highest blank concentration. **Bold** results are greater than 5x the highest blank concentration. Congeners with inexplicably high blank contamination are highlighted in grey.

Table 42. SPMD, PAH statistical summary (values in µg/SPMD.

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Avg. Lab-Stored Blank	Avg. Field Blank
Total PAHs	<LOD	0.8	<LOD	0.1	0.2	22%	0.4 - 0.8	<LOD	1	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Acenaphthene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Acenaphthylene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Anthracene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Benzo[a] anthracene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Benzo[a] pyrene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Benzo[b] fluoranthene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Benzo[g,h,i] perylene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Benzo[k] fluoranthene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Biphenyl	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Chrysene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Dibenz[a,h] anthracene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.8	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.8	<0.8
Dibenzo thiophene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Fluoranthene	<LOD	0.5	<LOD	0.1	0.2	22%	<0.4	<LOD	0.5	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Fluorene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Indeno[1,2,3-cd] pyrene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.8	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.8	<0.8
Naphthalene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Perylene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
Phenanthrene	<LOD	0.4	<LOD	<0.1	0.1	4%	<0.4	<LOD	0.5	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4

Columbia Mainstem Probabilistic Sites								Tributaries and Targeted Sites								
Analyte	Min	Max	Median	Mean	Std. Dev.	Percent Detects	Non-Detect Range	White Salmon R.	Hood River	Klickitat River	Columbia R. d/s The Dalles	John Day River	Columbia R. d/s PGE Boardman	Umatilla River	Avg. Lab-Stored Blank	Avg. Field Blank
Pyrene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
1-Methyl naphthalene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
1-Methyl phenanthrene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
2,3,5-Trimethyl naphthalene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
2,6-Dimethyl naphthalene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4
2-Methyl naphthalene	<LOD	<LOD	<LOD	<LOD	<LOD	0%	<0.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<0.4	<0.4

Summary

This project met all of its primary and secondary objectives. We evaluated the feasibility of implementing a probability-based sampling design to assess the ecological condition of the mid-Columbia River, and found the study design, methods, and data useful. Future reports written in collaboration with EPA Region 10 will integrate this study with the RARE project results from the upper mid-Columbia. The probabilistic survey combined with targeted tributaries could serve as a multi-agency long-term monitoring program design, and could be incorporated into DEQ's toxics monitoring program for rivers and streams.

The visual habitat condition survey showed that the LMC is dominated by poor and fair condition across multiple indicators, and primarily reflects a degraded riparian zone. The only indicator with exclusively excellent and good condition was bank stability –primarily due to a combination of rip rap and natural basalt. Habitat disturbance grew worse with increasing land use intensity, declining from forestry through range, agriculture, and urban areas. Roughly 40% of the riparian area was characterized as having 25% or mores bare ground, with some sites nearly barren. Large and small woody debris was absent or sparse in 90% or more of the LMC. Invasive Himalayan Blackberry (17% of the LMC) and English Ivy (4% of the LMC) appeared to be held in check by rip rap and basalt. The limited extent and fair condition of off-channel habitat and aquatic vegetation reflect the loss of salmonid rearing habitat due to anthropogenic activities.

The LMC and tributaries generally showed good quality as indicated by conventional water quality parameters. All water samples met DEQ's recreational contact criteria for *E. coli*, and 90% met water clarity criteria. Unfortunately, the entire LMC exceeded DEQ's 20^{o} C temperature criterion for salmonid protection.

Ninety percent of the LMC had acceptable pH values, and the full extent had ammonia and nitrate+nitrite concentrations below toxicity and eutrophication criteria. Ninety-five percent of the mainstem also met the total phosphorus sub-ecoregion eutrophication reference criterion. Water clarity was good, with a maximum turbidity of 6 NTU, and the minimum Secchi measurement just 0.2 meters shy of the sub-ecoregion reference value. All chlorophyll *a* samples were well below DEQ's 15 ug/L criterion, though the mean and standard deviation (3.2 ug/L, std. dev. 2.46) show some samples exceed the sub-ecoregion reference of 3.4 ug/L.

Water column total mercury concentrations were well below criteria. Methylmercury levels were protective of osprey, loons, and river otter, but about 5% of the LMC had levels above guidelines for kingfishers. However, the water column concentrations of mercury and methylmercury do not directly reflect the excessive concentrations of mercury found in fish fillets. DEQ's 175g/day fish consumption rate is a ten-fold increase over the previous criterion. Therefore, the acceptable concentration of total mercury in fish fillets was reduced to 0.04 mg/kg wet weight. Every fish sample collected on the LMC and tributaries failed the criterion; some by ten to twenty fold. The difficulty and expense associated with collecting trace level water column mercury and methylmercury samples, combined with the regulatory change to a fish fillet criterion makes fish tissue analyses a more practical alternative. This survey collected data on multiple mercury methylization cofactors, which may support future development of methylization and fish uptake models.

All other water column metals met water quality criteria, with the exception of barium, which failed a Tier II aquatic life chronic exposure criterion. The barium criterion is based on limited data, and the LMC's concentrations are not a serious concern. The DEQ recently eliminated its barium criteria based on the National Toxics Rule.

Legacy chlorinated pesticides and PCBs are still present at measurable concentrations in fish tissue and SPMDs. The concentrations of DDTs and PCBs grossly exceed DEQ's human health criteria at the 175g daily consumption rate, both in smallmouth bass and largescale suckers. The sucker fillets had higher body fat than bass, and accumulated more lipophilic contaminants than bass even though the bass are at a higher trophic level. Differences in the fish niches (for example, suckers being bottom feeders) or differences in contaminant metabolism may also explain why contaminant concentrations were much higher in suckers. Largescale suckers were readily available at many sampling locations, and should be considered a target species in future surveys.

SPMDs tended to collect a narrower range of contaminants that what was observed in fish fillets. The equipment costs and restraints imposed by the patents detract from the reduction in field labor when compared to fish tissue collection. Contamination most likely originating from SPMD construction made the data much less useful. Also, the poor recovery of PRCs from the lab-stored and field blanks made comparisons among site specific sampling rates impossible. Until these problems can be resolved, the SPMDs are a secondary sampling choice compared to fish tissue. They could be useful at locations where fish cannot be collected, and where presence-absence contaminant data is desired.

Brominated flame retardants were not detected at levels above human health guidelines, but about one third of the congeners on the analyte list were found in every fish sample. The SPMDs showed a similar pattern of detections, and corroborated the ubiquitousness of these compounds. DEQ should continue monitoring for PBDEs, and include them in long term monitoring projects where possible.

The PAHs found in SPMDs were few, and at inconsequential concentrations. These results should be compared to other existing data.

This survey's dataset deserves additional analysis, which is beyond the scope of this report due to time constraints. Future reports done in collaboration with EPA Region 10 will incorporate data from the RARE project, such as whole-body contaminant levels found in prey fish. Comparisons to other studies conducted on the Columbia would also prove useful.

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