Concentrations of 303(d) Listed Pesticides, PCBs, and PAHs Measured with Passive Samplers Deployed in the Lower Columbia River

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WASHINGTON STATE DEPARTMENT OF ECOLOGY

Concentrations of 303(d) Listed Pesticides, PCBs, and PAHs Measured with Passive Samplers Deployed in the Lower Columbia River

by
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March 2005

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List of Acronyms and Abbreviations

ACOE	U.S. Army Corps of Engineers
BAF	bioaccumulation factor
BCF	bioconcentration factor
BHC	benzene hexachloride
CFS	cubic feet per second
CRTG	Columbia River Toxics Group
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DOC	dissolved organic carbon
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
EST	Environmental Sampling Technologies
GC-ECD	gas chromatography – electron capture detection
GC-MS	gas chromatography – mass spectrometry
GPC	gel permeation chromatography
GPS	global positioning system
HMW	high-molecular weight
LMW	low-molecular weight
NTR	National Toxics Rule
ODEQ	Oregon Department of Environmental Quality
OHD	Oregon Health Department
PAH	polyaromatic hydrocarbons
PCB	polychlorinated biphenyl
PRC	performance reference compound
QA/QC	quality assurance/quality control
RPD	relative percent difference
SPMD	semipermeable membrane device
T-DDT	total DDT (sum of DDT+DDE+DDD)
T-PAHs	total PAHs
T-PCBs	total PCBs (sum of Aroclors, homologs, or congeners)
TMDL	total maximum daily load
TOC	total organic carbon
TSS	total suspended solids
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WSDH	Washington State Department of Health
mg/L	milligrams per liter (parts per million)
ng/L	nanograms per liter (parts per trillion)
pg/L	picograms per liter (parts per quadrillion)
ug/Kg	micrograms per kilogram (pars per billion)
ug/L	micrograms per liter (parts per billion)

Abstract

Semipermeable membrane devices were used to monitor chlorinated pesticides, polychlorinated biphenyls (PCBs), and polynuclear aromatic hydrocarbons (PAHs) in the Lower Columbia River below Bonneville Dam during 2003-2004. Washington and Oregon have placed the river on the federal Clean Water Act Section 303(d) list because fish and/or water samples have exceeded human health criteria for some of these compounds. Five mainstem sites and eight tributaries were monitored between Bonneville Dam and the Columbia River mouth to evaluate seasonal differences in contaminant levels and to identify and rank sources of contamination to the river.

Results showed that human health criteria were commonly exceeded for dieldrin and PCBs, less frequently exceeded for DDT compounds, and not exceeded for PAHs. The highest pesticide and PCB concentrations were generally found in the winter and spring, while PAHs were highest in the fall.

The major sources of DDT compounds and dieldrin were above Bonneville Dam. PCBs exceeded human health criteria at Bonneville Dam due to upstream sources, but there were additional important sources of PCBs below the dam. While PAHs did not exceed criteria, concentrations increased below Bonneville due to local sources. The Willamette River and Multnomah Channel were significant sources for all of these compounds. A screening-level loading assessment suggested there are other important PCB and PAH sources to the lower river that were not monitored in the study. Recommendations are made for follow-up studies and other actions.

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Introduction

Washington and Oregon currently have federal Clean Water Act Section 303(d) listings for the Lower Columbia River below Bonneville Dam for several chlorinated compounds that exceed human health criteria in fish tissue. The contaminants of concern are the DDT breakdown product DDE, dieldrin, and polychlorinated biphenyls (PCBs). Oregon also has segments listed for PCBs and polynuclear aromatic hydrocarbons (PAHs), based on water column exceedances of the human health criteria. Washington has an additional listing for inorganic arsenic in fish tissue, which is beyond the scope of the present study. Tables 1 and 2 have more information on the listings.

DDT, dieldrin, and PCBs are no longer used in the United States, having been banned in the 1970s and 1980s for ecological and human health concerns. They, along with the listed PAH compounds, are classed by EPA as known or probable human carcinogens and can have other adverse health effects. Detailed profiles including use, regulations, environmental occurrence, and health effects have been prepared by the Agency for Toxic Substances and Disease Registry and are available at http://www.atsdr.cdc.gov/toxpro2.html.

EPA requires the states to set priorities for cleaning up 303(d) listed waters and to establish a Total Maximum Daily Load (TMDL) for each. A TMDL entails an analysis of how much pollutant loading a waterbody can assimilate without violating water quality standards. The interagency Columbia River Toxics Group (CRTG) reviewed the available water quality data and concluded that little was known about the current levels or inputs of these chemicals to the Lower Columbia River. This information is needed to help EPA, Washington, and Oregon develop a TMDL strategy to address the toxics listings in the Lower Columbia.

Through the efforts of CRTG, EPA and the Washington State Department of Ecology (Ecology) entered into an agreement to conduct a one-year monitoring program for chlorinated pesticides, PCBs, and PAHs in the Lower Columbia River and selected tributaries. Because water column concentrations were expected to be low, a passive sampling technique employing a semipermeable membrane device (SPMD) was used to concentrate and quantify the chemicals of interest. The study was conducted by the Ecology Environmental Assessment Program during August 2003 – June 2004.

The objectives of this Lower Columbia SPMD study were to:

1. Measure ambient concentrations of 303(d) listed organic compounds at five mainstem sites and eight tributaries in the Lower Columbia River between Bonneville Dam and the Columbia River mouth.

2. Evaluate seasonal differences in contaminant levels by sampling in fall, winter, and spring.

3. Identify and rank sources of contamination to the river.

Table 1. Washington 303(d) Toxics Listings for the Lower Columbia River (1998 list and proposed 2002/2004 list)

WRIA*	Media	Parameter	Lat.	Long.	Basis for Listing†
25	Fish tissue	4,4'- DDE	46.275	123.745	LaFlamme and Gilroy (1996): excursions beyond the National Toxics Rule criterion in white sturgeon fillets in 1994 and 1995.
25	Fish tissue	Dieldrin	46.145	123.275	Tetra Tech (1993): three excursions beyond the National Toxics Rule criterion in white sturgeon fillets at RM 49.
25	Fish tissue	Total PCBs	46.245	123.555	LaFlamme and Gilroy (1996): excursions beyond the National Toxics Rule criterion in sturgeon, sucker, and carp fillets in 1994 and 1995.
25	Fish tissue	Total PCBs	46.145	123.275	Tetra Tech (1993): three excursions beyond the National Toxics Rule criterion in white sturgeon fillets at RM 49.
25	Fish tissue	Total PCBs	46.275	123.745	LaFlamme and Gilroy (1996): excursions beyond the National Toxics Rule criterion in carp, sturgeon, sucker, chinook, coho, and steelhead fillets in 1994 and 1995.
25	Fish tissue	Arsenic	46.145	123.275	Tetra Tech (1993): two excursions beyond the National Toxics Rule criterion in white sturgeon fillets at RM 49 and 67.
27	Fish tissue	Dieldrin	46.005	122.855	Tetra Tech (1993): three excursions beyond the National Toxics Rule criterion in white sturgeon fillets at RM 75.
27	Fish tissue	Total PCBs	46.005	122.855	Tetra Tech (1993): three excursions beyond the National Toxics Rule criterion in white sturgeon fillets at RM 75.

*Water Resource Inventory Area: WRIA 25 extends approximately from Astoria to the Cowlitz River; WRIA 27 extends approximately from the Kalama River to the Lewis River.

†Listings based on individual sturgeon and composite samples for other species.

Table 2. Oregon 303(d) Toxics Listings for the Lower Columbia River

Name	Parameter	Criteria Text	Season	Supporting Data or Information	List Date
Columbia River 0 to 35.2	DDT Metabolite (DDE)	Public health advisories…	Year-round	Levels of DDE/DDT found in some fish (carp, peamouth, sucker) exceed health criteria. OR/WA Health Depts. have issued recommendations regarding fish consumption for particular groups (WSDH/OHD, 96); reduced bald eagle reproduction in Lower Columbia River noted (USFWS, 96).	1998
Columbia River 0 to 35.2	PCB	Public health advisories…	Year-round	Levels of PCBs found in some fish (carp, peamouth, sucker) exceed health criteria. OR/WA Health Depts. have issued recommendations regarding fish consumption for particular groups (WSDH/OHD, 96); reduced bald eagle reproduction in Lower Columbia River noted (USFWS, 96).	1998
Columbia River 142 to 188.6	PCB	Table 20	Year-round	USGS data collected at RM 141. 35-day average concentration of 1004 pg/L. Criterion = 79 pg/L. Dissolved concentration estimated from semipermeable-membrane device data. (USGS Report 99-4051). Oregon Health Division crayfish advisory at Bonneville Dam, issued March 1, 2002.	2002
Columbia River 35.2 to 98	DDT Metabolite (DDE)	Public health advisories…	Year-round	Levels of DDE/DDT found in some fish (carp, peamouth, sucker) exceed health criteria. OR/WA Health Depts. have issued recommendations regarding fish consumption for particular groups (WSDH/OHD, 96); reduced bald eagle reproduction in Lower Columbia River noted (USFWS, 96).	1998
Columbia River 35.2 to 98	PCB	Public health advisories…	Year-round	Levels of PCBs found in some fish (carp, peamouth, sucker) exceed health criteria. OR/WA Health Depts. have issued recommendations regarding fish consumption for particular groups (WSDH/OHD, 96); reduced bald eagle reproduction in Lower Columbia River noted (USFWS, 96).	1998
Columbia River 98 to 142	DDT Metabolite (DDE)	Public health advisories…	Year-round	Levels of DDE/DDT found in some fish (carp, peamouth, sucker) exceed health criteria, OR/WA Health Depts. have issued recommendations regarding fish consumption for particular groups (WSDH/OHD, 96); reduced bald eagle reproduction in Lower Columbia River noted (USFWS, 96).	1998
Columbia River 98 to 142	PCB	Public health advisories…	Year-round	Levels of PCBs found in some fish (carp, peamouth, sucker) exceed health criteria. OR/WA Health Depts. have issued recommendations regarding fish consumption for particular groups (WSDH/OHD, 96); reduced bald eagle reproduction in Lower Columbia River noted (USFWS, 96).	1998
Columbia River 98 to 142	Polynuclear Aromatic Hydrocarbons	Table 20	Year-round	USGS site at RM 141. 35-day average sample = 33500 pg/L. Criterion = 2800 pg/L. Dissolved concentration estimated from semipermeable-membrane device data. (USGS Report 99-4051).	2002

Study Design

Ecology, the Oregon Department of Environmental Quality (ODEQ), and EPA selected 13 sites for monitoring (Figure 1, Table 3).

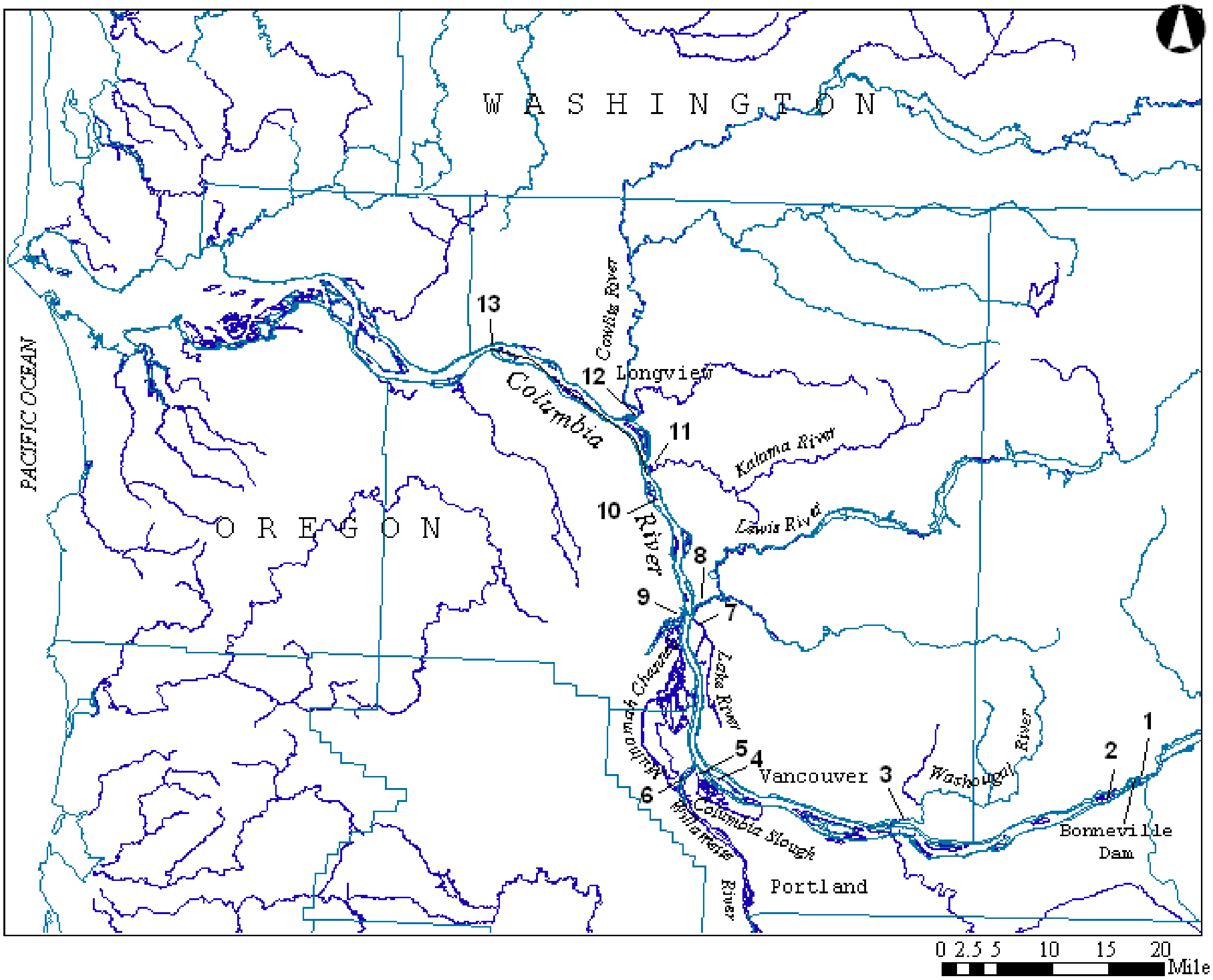

Figure 1. SPMD Deployment Sites.

The Washougal, Willamette, Lewis, Kalama, and Cowlitz rivers were selected for monitoring because they drain the largest and most developed watersheds in the region. Columbia Slough, Lake River, and Multnomah Channel were included in recognition of known or suspected contamination with target compounds (McCarthy and Gale, 1999; Gene Foster and Bruce Sutherland, ODEQ, personal communication). Mainstem sites were located above and below Bonneville Dam, above the Willamette River, above Kalama, and below Longview. A detailed description of each sampling site can be found in Appendix A.

Table 3. SPMD Deployment Sites in the Lower Columbia River

Site No.	River Mile (approx.)	Location
1	147	Mainstem above Bonneville Dam
2	142	Mainstem below Bonneville Dam
3	121	Mouth of Washougal River
4	103	Mainstem above Willamette River
5	102	Mouth of Columbia Slough
6	102	Mouth of Willamette River
7	88	Mouth of Lake River
8	87	Mouth of Lewis River
9	86	Mouth of Multnomah Channel
10	75	Mainstem above Kalama River
11	73	Mouth of Kalama River
12	68	Mouth of Cowlitz River
13	54	Mainstem below Longview

SPMDs were deployed at each site for approximately 30 days during the fall, winter, and spring of 2003-2004, as indicated in Figure 2. The deployments were timed to provide representative data over the range of flow conditions that normally occur in the drainage. August-September is the low-flow period. The Willamette River and other tributaries have their highest flows in the winter due to rain, while the highest flows in the Columbia River result primarily from snow-melt in the spring. Deployment dates were therefore approximately as follows:
August 27 - September 25, December 15 - January 13, and May 24 - June 23.

The SPMDs were placed in well-mixed locations, removed from any known sources of the chemicals of interest. For deep water deployments, the samplers were situated in the lower third of the water column. For shallow water, the samplers were approximately one foot off the bottom.

The SPMDs were extracted and analyzed for 22 chlorinated pesticides or breakdown products, 9 PCB Aroclor mixtures, and 22 PAH compounds. In an effort to improve detection limits for PCBs, the spring 2004 samples were analyzed for individual PCB congeners rather than Aroclors[1]. The complete list of target chemicals is in Appendix B.

Temperature was monitored continuously during deployment. At the beginning, middle, and end of each deployment period, ancillary data were obtained on conductivity, total suspended solids (TSS), total organic carbon (TOC), and dissolved organic carbon (DOC).

[1] PCBs can be analyzed as equivalent concentrations of the commercial mixtures (Aroclors in the U.S., e.g., Aroclor-1260) or through a more sensitive and expensive method for individual compounds, referred to as congeners, of which there are 209 possible.

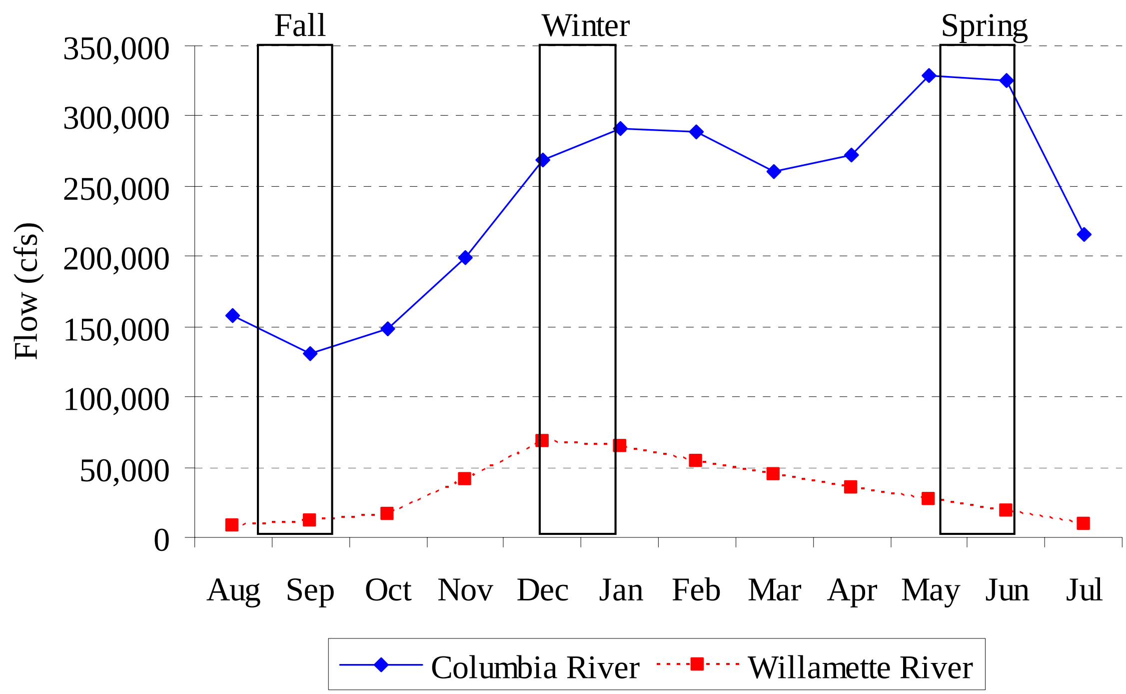

Figure 2. Historical Monthly Average Flow in the Columbia and Willamette Rivers, Showing Periods When SPMDs were Deployed in 2003-2004.

[USGS data for Columbia River @ Beaver Army Terminal, 1968-2003 (#14246900) and Willamette River @ Portland, 1972-2003 (#14211720)]

Background on SPMDs

SPMDs are passive samplers that mimic the biological uptake of organic compounds. The device used in the present study was developed by the U.S. Geological Survey (USGS) and is now of standardized design, patented, and commercially available through Environmental Sampling Technologies (EST), St. Joseph, MO (http://www.est-lab.com). Details of SPMD theory, construction, and application can be found at http://wwwaux.cerc.cr.usgs.gov/spmd/spmd_overview.htm.

Each SPMD is composed of a thin-walled, layflat polyethylene tube (91 x 2.5 cm) filled with triolein, the major neutral lipid in fish (Figure 3). When placed in water, dissolved lipophilic organic compounds diffuse through the membrane and are concentrated over time. A SPMD will effectively sample up to 10 liters of water per day, depending on the compound in question. The typical deployment period is 20 – 30 days. The SPMDs are then extracted and analyzed for the chemicals of interest.

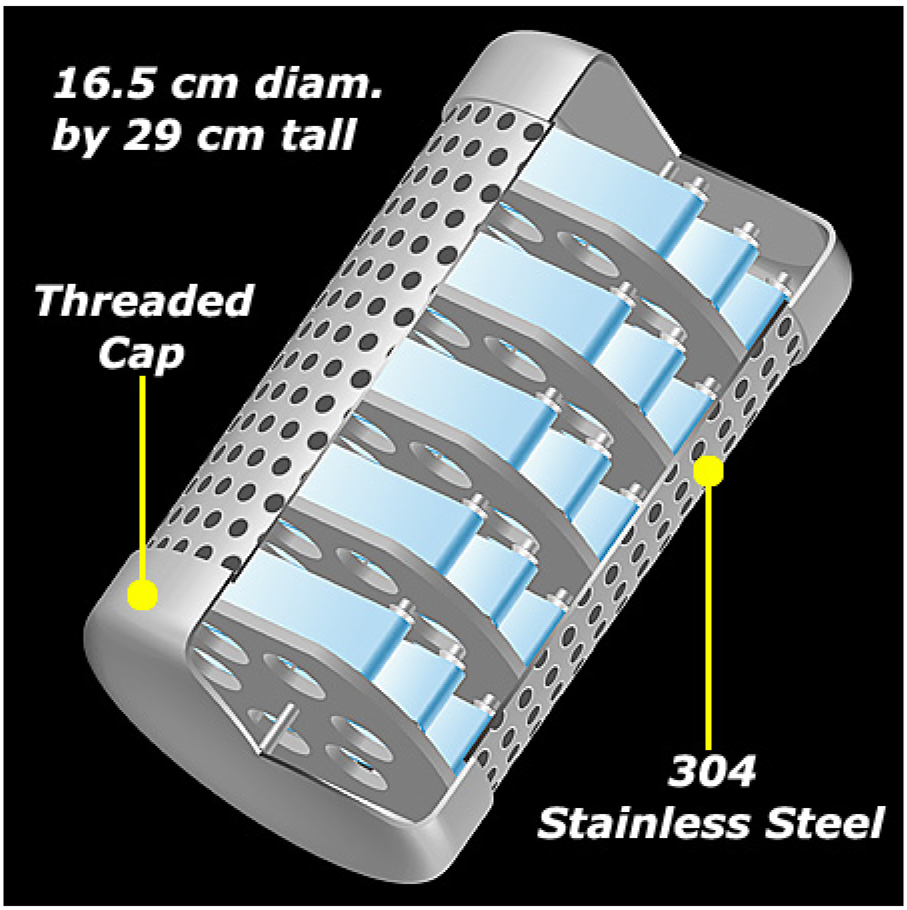

Figure 3. SPMD Membranes in Deployment Canister.
(http://wwwaux.cerc.cr.usgs.gov/spmd/spmd_overview.htm)

A combination of laboratory calibration data and Permeability/Performance Reference Compounds (PRCs) spiked into deployed SPMDs is used in conjunction with field temperature to obtain an estimate of average dissolved water column concentrations. PRCs are analytically non-interfering compounds with moderate to relatively high fugacity (escape tendency). The loss rate of PRCs is proportional to the uptake of target compounds. PRC loss rates in the field are used to derive an exposure adjustment factor (EAF) to recalibrate for the effects of temperature, water velocity, and biofouling on SPMD sampling rates that have been determined in the laboratory. A high rate of PRC loss translates into a lower calculated water column concentration for target compounds because the chemical residues in the SPMD represent a larger volume of water, and vice versa.

SPMDs provide a time-weighted average concentration for the chemicals of interest and only measure the dissolved and, therefore, readily bioavailable fraction. Studies have shown the results are comparable to other low-level sampling methods such as solid-phase and liquid-liquid extraction (Ellis et al., 1995; Rantalainen et al., 1998; Hyne et al., 2004).

A fundamental assumption of the PRC approach is that PRCs can be used to predict EAFs for chemicals over a wide range of octanol-water partition coefficients (K_{ow}[2]). Based on studies by Huckins et al. (2002), this assumption appears valid, and the difference between measured concentrations of an analyte and the PRC-derived estimates should be within a factor of 2.

[2] Octanol-water partition coefficient, a measure of a chemical's tendency to associate with the organic fraction in water.

Methods

Field Procedures

Deployment and retrieval procedures for SPMDs followed the guidance in Huckins et al. (2000). Standard SPMDs (91 x 2.5 cm membrane containing 1 mL triolein) and the stainless steel canisters (16.5 x 29 cm) and spindles that hold the membranes during deployment were obtained from EST. The SPMDs were preloaded onto the spindles by EST in a clean-room and shipped in solvent-rinsed metal cans under argon atmosphere. Five SPMDs were used in each canister, with one canister per sampling site. The SPMDs were kept frozen until deployed.

On arrival at the sampling site, the cans were pried open, spindles slid into the canisters, and the device anchored and tethered in the stream. Field personnel wore nitrile gloves and did not touch the membranes. The SPMDs were located out of strong currents, situated in such a way as to minimize the potential for vandalism, and placed deep enough to allow for anticipated fluctuations in water level.

The SPMDs were deployed for 27 - 30 days, as recommended by USGS and EST. The retrieval procedure was essentially the opposite of deployment. The SPMDs were put back in metal cans, the lids carefully sealed, and the SPMDs maintained at or near freezing until they arrived at EST for extraction, one to two days after being retrieved from the water.

Temperature data are required to determine dissolved chemical concentrations from SPMDs, and TOC data are needed to estimate total concentrations. An Onset StowAway Tidbit was attached to each canister to monitor temperature. At the beginning, middle, and end of each deployment period, TOC, DOC, and TSS samples were collected at each SPMD site. Conductivity was recorded with a meter. The water samples were collected in appropriate containers (Table 4) and returned to Ecology Headquarters where they were held in a secure cooler for later transport with chain-of-custody record to the Ecology Manchester Environmental Laboratory.

Table 4. Field Procedures for Ancillary Water Quality Parameters

Parameter	Minimum Sample Size	Container	Preservation	Holding Time
TSS	1000 mL	1 L poly bottle	Cool to $4^{o}C$	7 days
TOC	50 mL	125 mL poly bottle	HCl to pH<2, $4^{o}C$	28 days
DOC	50 mL	125 mL poly bottle	Filter, HCl to pH<2, $4^{o}C$	28 days

Laboratory Procedures

Permeability/Performance Reference Compounds

PCB congeners and PAH compounds were used as PRCs for the present study. EST spiked each SPMD membrane with 0.2 ng each of PCB-4 and PCB-29. These congeners are not found in significant amounts in commercial PCB mixtures or environmental samples. Each membrane was also spiked with radio-labeled PAHs. Deuterated PAH were used for the first deployment and carbon-13 labeled PAHs were used for the second and third deployments. The spiking level was 0.2 µg for each PAH. The spiking solutions were provided by Manchester Laboratory.

Extraction and Cleanup

On receipt of the SPMDs, EST spiked the membranes with pesticide, PCB, and PAH surrogate compounds specified in the analytical methods. The membranes were then extracted (referred to as dialysis), and cleaned up by gel permeation chromatography (GPC) at EST. EST's dialysis and GPC methods are documented in standard operating procedures (SOPs) on file at Ecology Headquarters. EST ampouled the extracts and shipped them to Manchester Laboratory.

Analysis

The cleaned-up extracts were analyzed by Manchester, except for PCB congeners which were analyzed by STL Sacramento, a contract laboratory. All the conventional water quality samples were analyzed by Manchester. The methods are shown in Table 5.

Table 5. Laboratory Procedures

Analysis	Sample Matrix	Sample Prep Method	Analytical Method
Chlorinated pesticides	SPMD extract	dialysis/GPC*	EPA 3620, 3665, 8081
PCB Aroclors	SPMD extract	dialysis/GPC*	EPA 3620, 3665, 8082
PCB congeners	SPMD extract	dialysis/GPC*	EPA 1668A
PAHs	SPMD extract	dialysis/GPC*	EPA 3630B / 8270
TSS	whole water	N/A	EPA 160.2
TOC	whole water	N/A	EPA 415.1
DOC	whole water	N/A	EPA 415.1

*EST SOPs E14, E15, E19, E21, E33, E44, E48

Analytical procedures for the SPMD extracts varied slightly between the three sample sets, but were generally as follows: The samples arrived at Manchester as hexane extracts of 4-5 mL volume in heat-sealed ampoules. The extracts were quantitatively transferred into centrifuge tubes and the volume adjusted to 10 mL with hexane. The extracts were then split, with 5 mL reserved for PAH analysis and 5 mL concentrated under a nitrogen gas stream to approximately 1 mL for the pesticide/PCB analysis.

Each pesticide/PCB extract was eluted through a micro Florisil® column: first with 100% hexane which was collected as the 0% Florisil® fraction, followed by a 50% hexane/preserved diethyl ether solution which was collected as the 50% Florisil® fraction. The extracts were then solvent exchanged into iso-octane and concentrated to approximately 1 mL. The 50% fraction was split into two portions. One portion of the 50% fraction and the 0% fraction were treated with concentrated sulfuric acid to remove interferences prior to analysis by dual column GC-ECD. The untreated portion of the 50% fraction was analyzed without further treatment. PAH extracts were cleaned up using silica gel. The cleaned-up extract was then analyzed by capillary GC/MS SIM isotopic dilution. Excess extract was stored at 0^{o}C.

For the spring 2004 samples, EST split the extracts in half, with half going to Manchester for pesticides and PAHs, and half going to STL Sacramento for PCB congeners. PCB congeners were analyzed by high resolution GC/MS.

Calculation Procedures for SPMDs

The data collected on exposure time, temperature, initial and final PRC concentration, and chemical residues in the SPMDs were entered into an Excel spreadsheet calculator developed by Dr. David Alvarez, USGS Columbia Environmental Research Center. These data are in Appendices C, D, and E. An example of the spreadsheet is shown in Appendix F. The equations behind the spreadsheet can be found at
http://wwwaux.cerc.cr.usgs.gov/spmd/SPMD-Tech_Tutorial.htm

PCB-29 was used as the PRC for pesticides and PCBs since its K_{ow} is closer to those of the target compounds than PCB-4. Anthracene (D10 or C13) was used as the PRC for PAHs, as recommended by Huckins et al. (2000).

No laboratory calibration data were available for some of the pesticides detected in this study. Therefore only the residue values (ng/SPMD) are reported.

Data Quality

Laboratory Case Narrative Summary

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

Data quality issues pertinent to the organics analyses are summarized below. No significant problems were encountered in the conventional water quality analyses.

Pesticides

Pesticide peaks in the SPMD extracts were generally large and easily distinguishable, and the data required little qualification.

Analyte response indicated a high bias for 4,4'-DDD and methoxychlor in the fall 2003 samples.

Recoveries of pesticide surrogates spiked into the winter 2003-04 sample from the Columbia River above Willamette River were much lower than other samples, indicating the results for target compounds were biased low. The pesticide data for this sample were multiplied by a factor of 1.5 to bring them into line with surrogate recoveries in comparable samples from the mainstem.

Lindane consistently had higher recoveries than other analytes and appeared to be an artifact introduced during sample processing at EST.

Percent recoveries of alpha- and delta-BHC were low in laboratory control samples for the fall sample set. Recoveries of delta-BHC, endrin aldehyde, aldrin, and endosulfan sulfate in matrix spikes and laboratory control samples were also low for the winter 2003-04 samples.

PCBs

There were low levels of Aroclor contamination in the EST blanks for the fall and winter SPMD samples, resulting in elevated reporting limits for PCBs. The PCB mixtures in the field samples most closely resembled Aroclor-1248 and -1254, but pattern recognition was difficult due to background contamination, co-eluting interfering peaks, and weathering. Due to the uncertain identification, all positive results for Aroclor-1248 were qualified as tentatively identified at an estimated concentration, and Aroclor-1254 results were qualified as estimates.

PAHs

Benzo(b)fluoranthene and benzo(k)fluoranthene experienced chromatographic problems and their peaks could not be resolved. Half the peak was assigned to each compound, based on the chromatography, and the results were qualified as estimates.

Field Quality Control Samples

Replicate Samples

Replicate SPMDs were deployed to provide estimates of the total variability (field + laboratory) associated with the water column data for this project. Five pairs of SPMDs were deployed side-by-side: one each for the Columbia River above Bonneville, Columbia River below Bonneville, Willamette River, Multnomah Channel, and Columbia River below Longview. Appendix G has the results. Replicates were not analyzed for PCB congeners.

In terms of residues per SPMD, the pesticide, PCB, and PAH results agreed closely. In most cases (90%), the relative percent difference (RPD) between replicates was 20% or better.

Differences in PRC recoveries between replicate SPMDs introduced additional variability in the calculated water column concentrations, more so for pesticides and PCBs than PAHs. For three of the five replicates, RPDs for the calculated pesticide and PCB concentrations remained generally within 20% or better. For the other two replicates, however, there was greater disparity in PRC recovery, resulting in RPDs of approximately 100 – 175%.

Recovery of the PRC was more consistent in the PAH analyses. Replicate agreement for the water column concentrations calculated for PAHs was better than 50% in most cases (90%).

The average of the replicate results is used in the remainder of this report.

Field Blanks

Because SPMDs sample vapors while being exposed to air, field blanks were used to assess chemical accumulation during deployment and retrieval. The field blank consisted of five membranes in an argon-filled stainless steel can. It was opened to the air for the average amount of time it took to open and place the SPMDs in the water. The blank was then resealed and refrozen. It was taken back into the field and opened and closed again to mimic the retrieval process. The blank was prepared, processed, and analyzed the same as deployed SPMDs.

There was one field blank for each sampling period. The total time each blank was exposed to the air ranged from three to seven minutes. The sampling site where the field blank was exposed was the Columbia River below Longview.

The results from analyzing pesticides and PCBs in the field blanks are in Appendix G. Gamma-BHC (lindane), 4,4'-DDE, 4,4'-DDT, trans-chlordane, cis-chlordane, and certain PCB congeners were detected in one or more blanks. Because the lindane concentrations were high relative to field samples, these data were rejected. Concentrations of the other pesticides and PCB congeners detected in the blanks were subtracted from those measured in deployed SPMDs before calculating water column concentrations.

Appendix G also has the field blank results for selected PAH compounds analyzed in this project. Low-molecular weight (LMW) PAH (2 – 3 ring compounds) were detected in the field blanks for all three deployments. The same compounds were detected in laboratory blanks provided by EST, although sometimes at lower concentrations, suggesting a combination of laboratory and field sources. Manchester's method blanks for PAHs showed no significant contamination.

Because the levels of LMW PAH in the blanks were significant compared to the field samples, only data for high-molecular weight (HMW) PAH (4 – 6 ring compounds) are reported here. This is not a significant shortcoming in that the 303(d) listings in the study area are for HMW PAH only. Although fluoranthene and pyrene were reliably detected and are 4-ring PAH, the data are not included in this report because human health criteria for these compounds are orders of magnitude higher (i.e., less restrictive) than the other HMW PAH at issue in the present study.

Data Qualifiers, Missing Data, and Use of Non-Detects

Manchester Laboratory assigned data qualifiers to certain results due to analytes being detected in blanks, spike recoveries outside quality control (QC) limits, interferences, or for other reasons. In most instances the qualifier was that the result was an estimated value. For the tables and figures in the remainder of this report, the qualifiers have been omitted for sake of clarity, but are retained in the data appendices.

A total of 39 SPMD deployments were made for this project, with 37 (95%) being successfully recovered. No data are available for the following three samples: The SPMDs deployed in the Columbia River above Kalama for fall 2003 and below Longview for winter 2003-04 could not be relocated and were presumed lost. The pesticide extract for the Columbia River above Kalama for spring 2004 was lost in a laboratory accident.

In this report, the detection limit is used to calculate a less-than value for water column concentrations where a compound was not detected. Where compounds are summed to give total DDT, total PCBs, or total PAHs, non-detects were treated as zero.

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Results[3] and Discussion

Runoff Conditions

Monthly average flows for the Columbia and Willamette rivers during the 2003-2004 Lower Columbia River SPMD study are compared to historical averages in Figure 4.

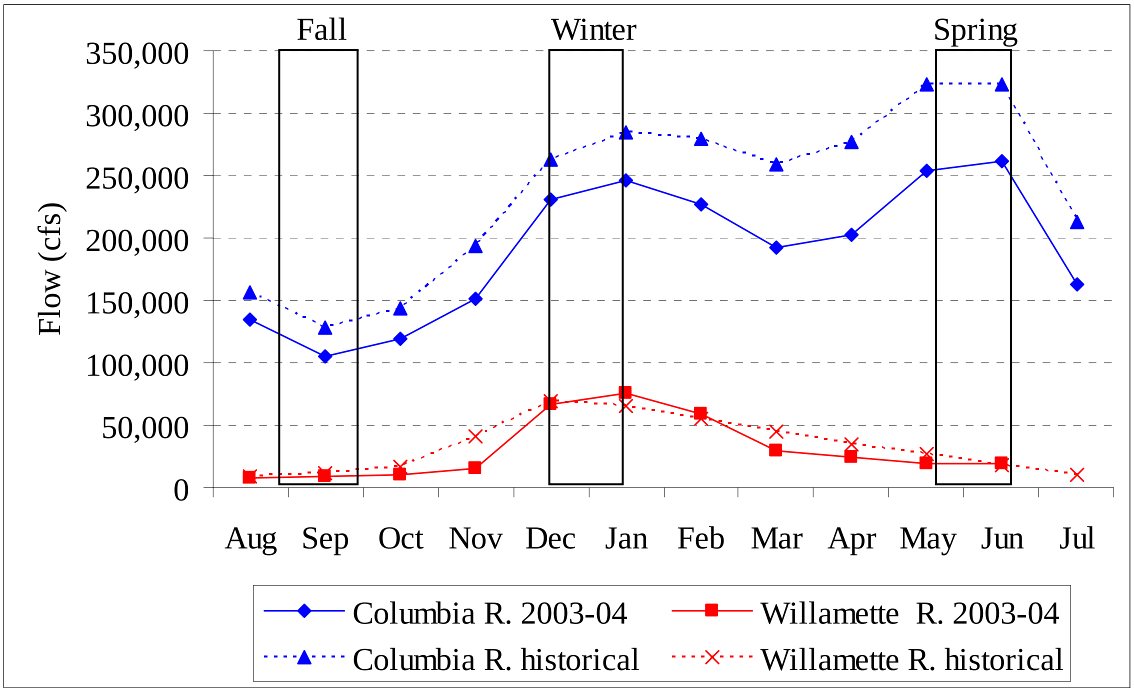


Figure 4. Monthly Average Flow in the Columbia and Willamette Rivers During the 2003-2004 Study Period Compared to Historical Monthly Averages, Showing Periods When SPMDs were Deployed. [USGS data for Columbia River @ Beaver Army Terminal (#14246900) and Willamette River @ Portland (#14211720)]

Lack of precipitation and above-average temperatures reduced streamflows in the Pacific Northwest in the late summer and fall of 2003. Above-normal precipitation occurred in October and November. By late December/early January most rivers were approaching or near their long-term mean flow levels. Eastern Washington rivers, however, remained generally low compared to the long-term mean.

From the end of January through April, flow levels were within expected historical ranges statewide. While most stations experienced normal flows during May, some eastern Washington rivers – Methow, Entiat, Wenatchee, Yakima – were below their historical 20th percentiles due to

[3] Ecology's Environmental Information Management (EIM) system http://www.ecy.wa.gov/eim/index.htm has the complete data from this project (AJOH0041).

reduced snow pack. Below normal precipitation for the month of June pushed most streams toward the lower end of their normal range. (Dzinbal, 2003, 2004).

Pesticides and PCBs

Dissolved Concentrations

Table 6 shows the water column concentrations of DDT compounds, dieldrin, and PCBs estimated from SPMDs deployed in the Lower Columbia River during the fall, winter, and spring of 2003-2004. These data are for the dissolved form of the chemical, reported in parts per quadrillion.

DDT, DDE, DDD, and dieldrin were detected at almost all sampling sites. Concentrations generally decreased following the order DDD > DDE > dieldrin > DDT. Because of elevated reporting limits in the Aroclor analysis, the detection of PCBs in the fall and winter samples was limited to the Willamette River, Columbia Slough, Multnomah Channel, and Columbia River below Longview (detected in the fall only). PCBs were detected at all sites in the spring, using the more sensitive congener analysis.

Concentration ranges in the mainstem Columbia River were 360 – 8,000 pg/L for T-DDT (total DDT, i.e., DDT+DDE+DDD) and 14 – 570 pg/L for dieldrin. Based on detected values, T-PCB concentrations (sum of Aroclors or congeners) ranged from 250 – 600 pg/L in the mainstem.

The highest concentrations of DDT compounds, dieldrin, and PCBs were found in the Willamette River drainage (Willamette River, Columbia Slough, and Multnomah Channel). Concentrations in the Willamette River reached 3,700 pg/L for T-DDT, 2,500 pg/L for dieldrin, and 1,600 pg/L for T-PCBs. Maximum dieldrin and T-PCB concentrations, 5,400 and 21,000 pg/L, respectively, were recorded in Columbia Slough, a system of interconnecting wetlands, channels, and lakes that receives stormwater runoff from an industrialized area of Portland. The lowest levels of pesticides and PCBs were in the Kalama and Cowlitz rivers.

Temporal and Spatial Patterns

The pesticide and PCB data for the mainstem Lower Columbia River are plotted in Figure 5. Concentrations of DDT compounds and dieldrin were highest in the winter and spring, and lowest in the fall. Because of elevated reporting limits, PCB concentrations could not be quantified for the winter period, but did appear to be higher in the spring than fall.

During each of the three deployment periods, T-DDT concentrations decreased going downstream from Bonneville Dam to below Longview. Mainstem concentrations of T-DDT below Longview were 40 – 70% lower than those above and immediately below Bonneville. Dieldrin concentrations appeared to either decrease or remain essentially unchanged. These findings suggest that the most important DDT and dieldrin sources are upstream of Bonneville Dam. A winter/spring peak for these compounds is consistent with runoff from agricultural lands in Eastern Washington.

Table 6. Concentrations of 303(d) Pesticides and PCBs Detected in Lower Columbia River SPMDs Deployed in 2003 - 2004 (pg/L, dissolved)

Site River Mile	Columbia Above Bonneville Dam 147	Columbia Below Bonneville Dam 142	Washougal River 121	Columbia Above Willamette River 103	Columbia Slough 102	Willamette River 102	Lake River 88	Lewis River 87	Multnomah Channel 86	Columbia Above Kalama 75	Kalama River 73	Cowlitz River 68	Columbia Below Longview 54
August - September 2003													
4,4'-DDT	**24**	**40**	<80	**19**	**31**	**64**	<34	**92**	**98**	no data	<280	<220	**24**
4,4'-DDE	**270**	**260**	**70**	**170**	**270**	**390**	**140**	**200**	**360**	"	**360**	**270**	**130**
4,4'-DDD	**390**	**390**	<120	**280**	**460**	**690**	**240**	**190**	**940**	"	<410	<320	**210**
T-DDT	**680**	**690**	**70**	**470**	**760**	**1,100**	**380**	**480**	**1,400**	"	**360**	**270**	**360**
Dieldrin	**46**	**64**	<110	**57**	**140**	**150**	**56**	<110	**240**	"	<390	<310	**14**
T-PCBs	<480	<620	<1,900	<450	**1,800**	**1,600**	**470**	<1,800	**2,600**	"	<6,500	<5,100	**250**
December 2003 - January 2004													
4,4'-DDT	**120**	**270**	**73**	**68**	**1,500**	**1,500**	**29**	**96**	**270**	**320**	<290	**13**	no data
4,4'-DDE	**1,000**	**2,100**	<250	**330**	**1,600**	**1,400**	**270**	<140	**310**	**520**	<170	**52**	"
4,4'-DDD	**2,900**	**5,600**	<440	**750**	**2,000**	**760**	**660**	<240	**260**	**670**	<300	<200	"
T-DDT	**4,000**	**8,000**	**73**	**1,100**	**5,100**	**3,700**	**960**	**96**	**840**	**1,500**	ND	**65**	"
Dieldrin	**490**	**570**	**250**	**86**	**5,400**	**2,500**	**450**	**170**	**720**	**500**	**130**	<340	"
T-PCBs	<1,700	<2,900	<2,900	<410	**21,000**	<2,900	<1,300	<1,600	<1,000	<860	<1,900	<1,300	"
May - June 2004													
4,4'-DDT	**72**	**64**	**120**	**91**	**36**	**25**	**59**	**78**	**120**	no data	<300	**31**	**58**
4,4'-DDE	**600**	**600**	**100**	**640**	**300**	**110**	**350**	**47**	**340**	"	**31**	**15**	**370**
4,4'-DDD	**980**	**880**	<380	**940**	**470**	**190**	**620**	<260	**590**	"	<310	<230	**620**
T-DDT	**1,700**	**1,500**	**220**	**1,700**	**810**	**330**	**1,000**	**130**	**1,100**	"	**31**	**46**	**1,000**
Dieldrin	**130**	**100**	**180**	**130**	**120**	**67**	**220**	**110**	**360**	"	<530	**47**	**130**
T-PCBs	**370**	**330**	**440**	**360**	**13,000**	**290**	**1,300**	**330**	**1,700**	**590**	**320**	**320**	**600**

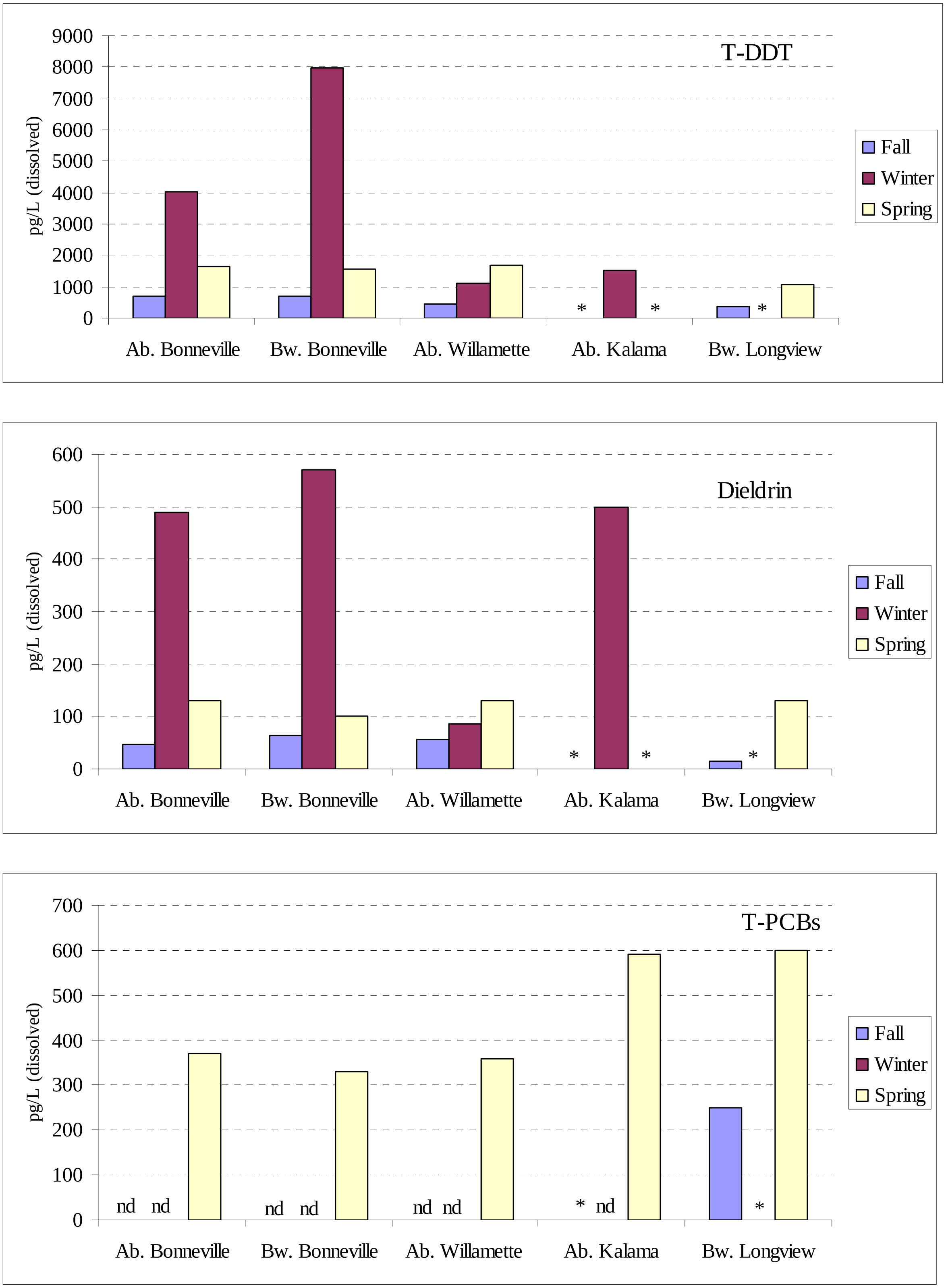


Figure 5. Estimated Concentrations of Dissolved T-DDT, Dieldrin, and T-PCBs in the Columbia River Mainstem (nd = not detected, * = no data)

The apparent instance of a winter increase in T-DDT and dieldrin downstream of Bonneville Dam is at least partly attributable to inconsistent PRC recoveries in the samples above the dam (see Data Quality). There are no known or potential DDT or dieldrin sources in the intervening five miles between these two sites, and there was no evidence of an increase immediately below the dam either in the fall or spring.

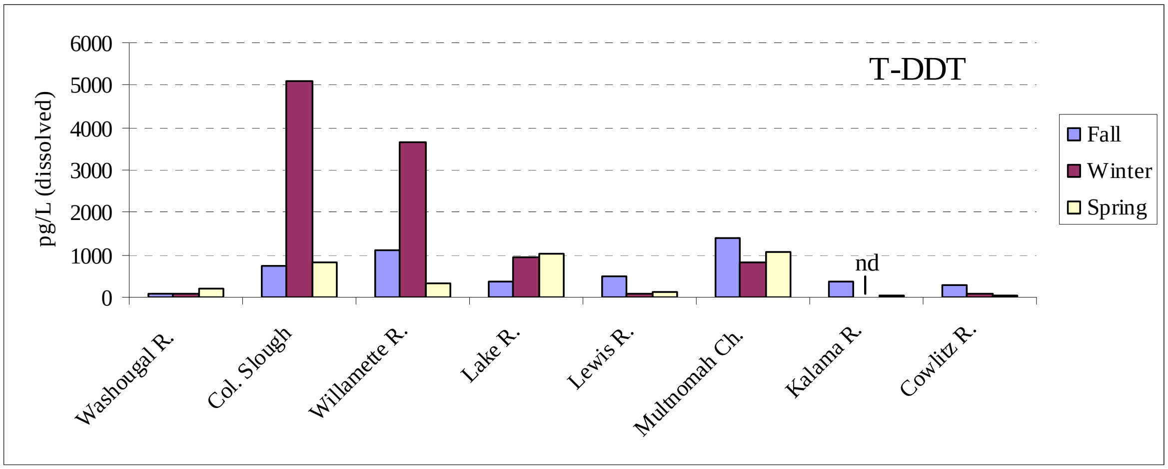
In the spring, mainstem PCB concentrations increased by almost a factor of 2 going downstream from Bonneville Dam to below Longview. In the fall, PCBs were only detectable below Longview, also suggesting a trend toward increasing concentrations in the lower vs. upper river. These results point to local rather than upstream sources being relatively more important for PCBs, than for T-DDT and dieldrin. Historically, spills involving PCBs have occurred at Bonneville, and sediments and debris piles in the vicinity of the dam have elevated concentrations of PCBs (URS, 2004). However, there was no evidence of an increase in water column PCB concentrations below the dam in the present study.

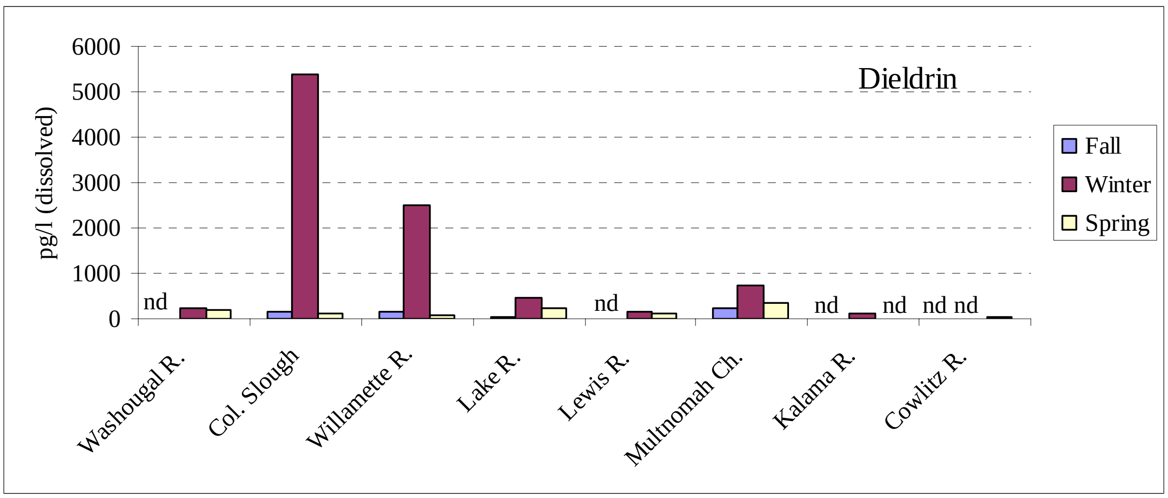
The pesticide and PCB data for the eight Lower Columbia tributaries monitored are plotted in Figure 6. There was no consistent seasonal pattern for T-DDT among the tributaries. Dieldrin, on the other hand, was consistently highest in the winter. PCBs were not detected frequently enough to make inferences about seasonal changes in most of the tributaries. In Columbia Slough, concentrations decreased from winter to spring to fall, similar to the mainstem.

The tributaries are ranked according to chemical concentrations in Table 7. Ranking was done by sorting the tributaries for each sampling period according to chemical concentration and then assigning a number from 1 to 8 from the highest to lowest concentration. Ties and non-detects were given the same number. The average for the three sampling periods was used for the final ranking.

Table 7. Tributaries Ranked According to Dissolved Pesticide and PCB Concentrations
(1 indicates most contaminated)

Rank	T-DDT	Dieldrin	T-PCBs
1	Multnomah Channel	Multnomah Channel	Columbia Slough
2	Columbia Slough	Columbia Slough	Multnomah Channel
3	Willamette River	Willamette River	Lake River
4	Lake River	Lake River	Willamette River
5	Lewis River	Washougal River	Washougal River
6	Cowlitz River	Lewis River	Lewis River
7	Kalama River	Kalama River	Kalama River
8	Washougal River	Cowlitz River	Cowlitz River





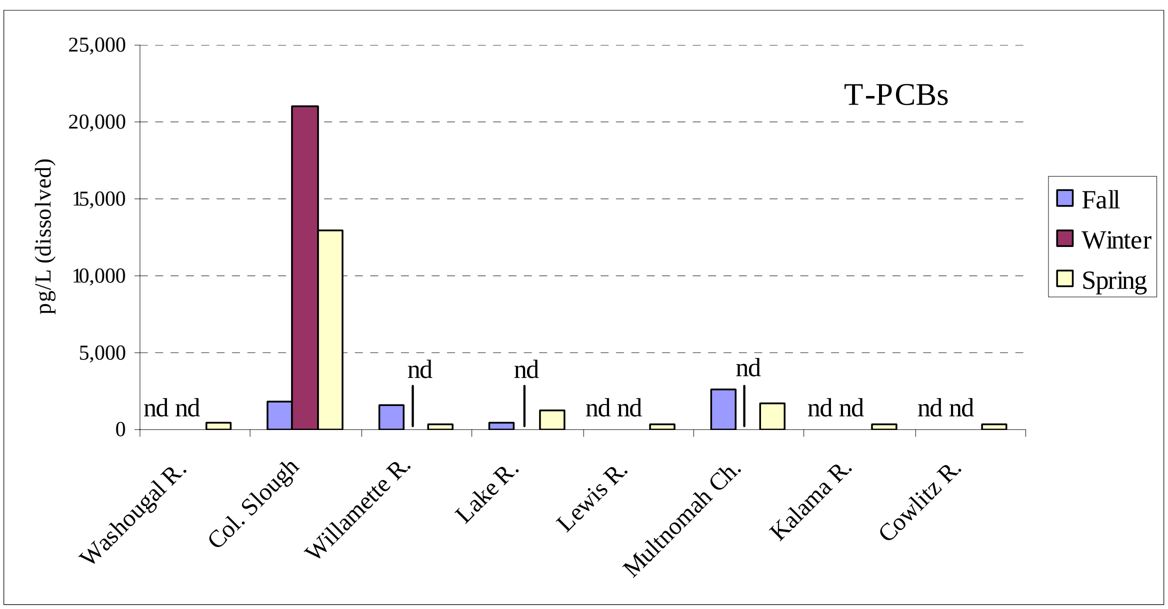


Figure 6. Estimated Concentrations of Dissolved T-DDT, Dieldrin, and T-PCBs in Columbia River Tributaries (nd = not detected)

The Willamette River, Multnomah Channel, Columbia Slough, and Lake River were the four most contaminated tributaries with respect to pesticide and PCB levels. Lake River ranked behind the three Willamette drainage sites except for PCBs. The Lewis, Washougal, Kalama, and Cowlitz rivers were the least contaminated. The Kalama and Cowlitz rivers ranked lowest in contamination in most cases.

Total Concentrations

Data on total pesticide and PCB concentrations are needed to assess contaminant loading in the Lower Columbia River, discussed later in this report. The relative amounts of the dissolved and total fractions may also have implications for source control efforts. Therefore, total pesticide and PCB concentrations (dissolved + particulate) were estimated from the dissolved data using the equation $C_{w\text{-}tot} = C_w (1 + TOC (K_{oc}/M_w))$ where C_w is the dissolved concentration, K_{oc} is the organic carbon-water equilibrium partition coefficient, and M_w is the mass of water (Meadows et al., 1998). The TOC data are in Appendix H. K_{oc} was calculated from the K_{ow} values used to determine the dissolved concentrations (Appendix F) and Karickhoff's (1981) approximation $K_{oc} = 0.411K_{ow}$. Results of these calculations are shown in Table 8.

Table 9 summarizes the dissolved percentages estimated for the mainstem. The relative amount of dissolved chemical was consistent from the upper to lower river. Calculations indicate that almost all of the dieldrin and approximately 70 – 80% of the DDD and DDT would be expected to be in dissolved form. DDE split about equally between dissolved and particulate fractions. Most of the PCBs are associated with particulates.

Table 8. Estimated Total Concentrations of 303(d) Pesticides and PCBs Detected in Lower Columbia River SPMDs Deployed in 2003 - 2004 (pg/L)

Site River Mile	Columbia Above Bonneville Dam 147	Columbia Below Bonneville Dam 142	Washougal River 121	Columbia Above Willamette River 103	Columbia Slough 102	Willamette River 102	Lake River 88	Lewis River 87	Multnomah Channel 86	Columbia Above Kalama River 75	Kalama River 73	Cowlitz River 68	Columbia Below Longview 54
August - September 2003													
4,4'-DDT	**29**	**48**	<93	**22**	**37**	**76**	<43	**110**	**120**	no data	<310	<250	**29**
4,4'-DDE	**510**	**490**	**120**	**310**	**520**	**740**	**300**	**340**	**660**	"	**560**	**450**	**250**
4,4'-DDD	**530**	**530**	<160	**380**	**630**	**950**	**350**	**250**	**1,300**	"	<500	<410	**290**
T-DDT	**1,100**	**1,100**	**120**	**710**	**1,200**	**1,800**	**650**	**700**	**2,100**	"	**560**	**450**	**570**
Dieldrin	**47**	**66**	<110	**58**	**140**	**150**	**58**	<110	**250**	"	<400	<320	**14**
T-PCBs	<1,300	<1,600	<4,400	<1,100	**4,800**	**4,200**	**1,500**	<4,200	**6,500**	"	<13,000	<11,000	**650**
December 2003 - January 2004													
4,4'-DDT	**140**	**310**	**82**	**77**	**1,800**	**2,000**	**36**	**110**	**350**	**390**	<330	**15**	no data
4,4'-DDE	**1,600**	**3,400**	<390	**540**	**3,200**	**3,600**	**560**	<220	**730**	**1,100**	<270	**91**	"
4,4'-DDD	**3,600**	**7,000**	<540	**940**	**2,800**	**1,200**	**950**	<300	<400	**950**	<370	<260	"
T-DDT	**5,300**	**11,000**	**82**	**1,600**	**7,800**	**6,800**	**1,500**	**110**	**1,100**	**2,400**	ND	**110**	"
Dieldrin	**500**	**580**	**250**	**88**	**5,600**	**2,600**	**460**	**170**	**750**	**510**	**130**	<350	"
T-PCBs	<3,600	<6,200	<5,900	<880	**60,000**	<11,000	<3,800	<3,300	<3,400	<2,500	<3,900	<3,100	"
May - June 2004													
4,4'-DDT	**89**	**79**	**140**	**110**	**49**	**31**	**77**	**87**	**140**	no data	<340	**36**	**71**
4,4'-DDE	**1,200**	**1,300**	**160**	**1,400**	**810**	**230**	**860**	**74**	**630**	"	**50**	**26**	**770**
4,4'-DDD	**1,400**	**1,300**	<470	**1,400**	**800**	**270**	**990**	<320	**790**	"	<390	<300	<890
T-DDT	**2,700**	**2,700**	**300**	**2,900**	**1,700**	**530**	**1,900**	**160**	**1,600**	"	**50**	**62**	**840**
Dieldrin	**130**	**100**	**180**	**130**	**130**	**69**	**230**	**110**	**370**	"	<540	**48**	**130**
T-PCBs	**1,100**	**1,000**	**920**	**1,200**	**53,000**	**850**	**4,700**	**670**	**4,300**	**1,900**	**670**	**760**	**1,800**

Table 9. Estimates of the Dissolved Fraction of Pesticides and PCBs in the Columbia River Mainstem (% dissolved)

	Mean	Minimum	Maximum
DDT	83	81	87
DDE	52	46	63
DDD	73	67	81
Dieldrin	99	97	100
T-PCBs	35	30	39

The high dissolved fraction estimated for dieldrin was unexpected, but is consistent, at least in relative terms, with its greater solubility compared to the other compounds. Published water solubilities are in the range of 0.1 – 0.25 mg/L for dieldrin compared to 0.01 – 0.06 mg/L for 4,4'-DDE and 0.001 – 0.07 mg/L for PCBs (Mackay et al., 1997).

As discussed later in this report, USGS conducted an SPMD study on the Columbia River during 1997 – 98 (McCarthy and Gale, 1999). They estimated a larger fraction of the pesticides and PCBs as being sorbed. The following average values were reported for the mainstem in the spring: dieldrin – 82% dissolved, DDD – 52% dissolved, and DDE – 26% dissolved. DDT was not detected in the USGS study. USGS did not provide an estimate for the dissolved fraction of T-PCBs, but the dominant PCB congeners occurred primarily in particulate form.

The discrepancy between Ecology and USGS estimates of the dissolved vs. particulate fractions is partly attributable to differences in the TOC concentrations during the two studies. Ecology measured an average mainstem TOC of 1.7 mg/L compared to 2.2 mg/L for USGS. TOC concentrations changed relatively little over the course of either study.

Other Pesticides Detected

An additional 11 pesticides or breakdown products were detected in Ecology's SPMD samples. The data required for determining dissolved water column concentrations were available for eight of them (Table 10).

Hexachlorobenzene was detected in all samples. Dissolved concentrations ranged from 57 – 800 pg/L in the mainstem and up to 2,300 pg/L in the Willamette River. The highest concentrations were in the winter, during which time concentrations appeared to increase downstream of Portland/Vancouver. Mainstem concentrations of hexachlorobenzene did not change appreciably during the fall or spring.

Chlordane (cis and trans isomers) was detected in most samples, but blank contamination may have contributed to these concentrations, as previously described. Some sites had detectable amounts of endosulfan, methoxychlor, heptachlor epoxide, and endrin. These detections were primarily in the tributaries rather than mainstem, and most occurred during the spring.

Table 10. Concentrations of Other Pesticides Detected or Analyzed in Lower Columbia River SPMDs Deployed in 2003 - 2004 (pg/L, dissolved)

Site	Columbia Above Bonneville Dam	Columbia Below Bonneville Dam	Washougal River	Columbia Above Willamette River	Columbia Slough	Willamette River	Lake River	Lewis River	Multnomah Channel	Columbia Above Kalama	Kalama River	Cowlitz River	Columbia Below Longview
River Mile	147	142	121	103	102	102	88	87	86	75	73	68	54
August - September 2003													
Hexachlorobenzene	**89**	**100**	**160**	**60**	**85**	**180**	**68**	**140**	**270**	no data	**690**	**340**	**57**
trans-Chlordane	**26**	**100**	**88**	**17**	**150**	**130**	**30**	**190**	**320**	"	**550**	**600**	**39**
cis-Chlordane	**24**	**91**	**81**	**15**	**170**	**142**	**27**	**180**	**350**	"	**390**	**530**	**40**
a-BHC	<54	<46	<320	<56	<53	<130	<130	<310	<230	"	<1,100	<880	<56
Heptachlor Epoxide	<32	<42	<130	<11	<33	<52	<52	<120	<90	"	<430	<340	<11
Methoxychlor	<11	<9	<73	<11	<11	<30	<30	<70	<52	"	<250	<200	<11
Endosulfan*	- -	- -	- -	- -	- -	- -	- -	- -	- -	"	- -	- -	- -
Endrin	<9	<31	<92	<9	<9	<38	<38	<88	<66	"	<320	<250	<9
December 2003 - January 2004													
Hexachlorobenzene	**350**	**800**	**370**	**150**	**1,100**	**2,300**	**210**	**200**	**480**	**590**	**360**	**400**	no data
trans-Chlordane	<230	<390	**16**	**85**	**810**	**300**	<180	<210	<140	<120	<270	<180	"
cis-Chlordane	<210	**200**	**25**	**78**	**720**	**320**	ND	ND	**64**	**42**	<250	ND	"
a-BHC	<880	<1,500	<1,800	<220	<2,100	<3,700	<690	<1,100	<990	<600	<1,000	<1,100	"
Heptachlor Epoxide	<270	<480	<480	<69	<480	<480	<210	<260	<170	<140	<320	<210	"
Methoxychlor	<530	<920	<920	<130	<920	<920	<410	<500	<330	<280	<620	<410	"
Endosulfan	<720	<1300	<1300	<180	**1,900**	<1,300	<560	**270**	<450	<380	<850	<560	"
Endrin	<260	<440	<440	<64	<440	<440	<200	<240	<160	<130	<300	<200	"
May - June 2004													
Hexachlorobenzene	**220**	**190**	**210**	**210**	**120**	**79**	**190**	**150**	**410**	no data	**180**	**230**	**190**
trans-Chlordane	**94**	<150	**170**	**76**	**150**	**37**	**100**	**77**	**290**	"	<270	**110**	**91**
cis-Chlordane	**120**	**82**	**140**	**130**	**200**	**60**	**150**	**69**	**360**	"	**65**	**120**	**110**
a-BHC	<480	<340	<1,300	<360	<120	<85	<620	<880	<650	"	<1,100	<620	<480
Heptachlor Epoxide	**65**	**34**	<400	**45**	**25**	<93	**67**	<270	<250	"	<330	<240	<190
Methoxychlor	54	**58**	<780	<82	<23	**27**	**77**	**170**	<150	"	**320**	**110**	**60**
Endosulfan*	- -	- -	- -	- -	- -	- -	- -	- -	- -	"	- -	- -	- -
Endrin	<140	<97	<380	<100	<19	<68	<180	<260	<180	"	<310	**140**	<140

*sampling rate not available for corresponding temperature

ND = Less than field blank

Beta-BHC, delta-BHC, and endosulfan sulfate were detected in a few samples (Appendix E), but the data required to estimate water column concentrations were not available. Manchester Laboratory also saw evidence of several non-target compounds in the pesticide analyses. These included the DDT metabolite DDMU, the organophosphorus insecticide chlorpyrifos, the herbicide dacthal, and PBDE-47, a polybrominated diphenylether flame retardant (Myrna Mandjikov, personal communication).

PAHs

Dissolved Concentrations

The concentrations of high-molecular weight (HMW) PAH measured in the Lower Columbia River drainage during 2003-2004 are shown in Table 11. As previously noted, blank contamination precluded reported results for low-molecular weight PAH (e.g., naphthalene, phenanthrene).

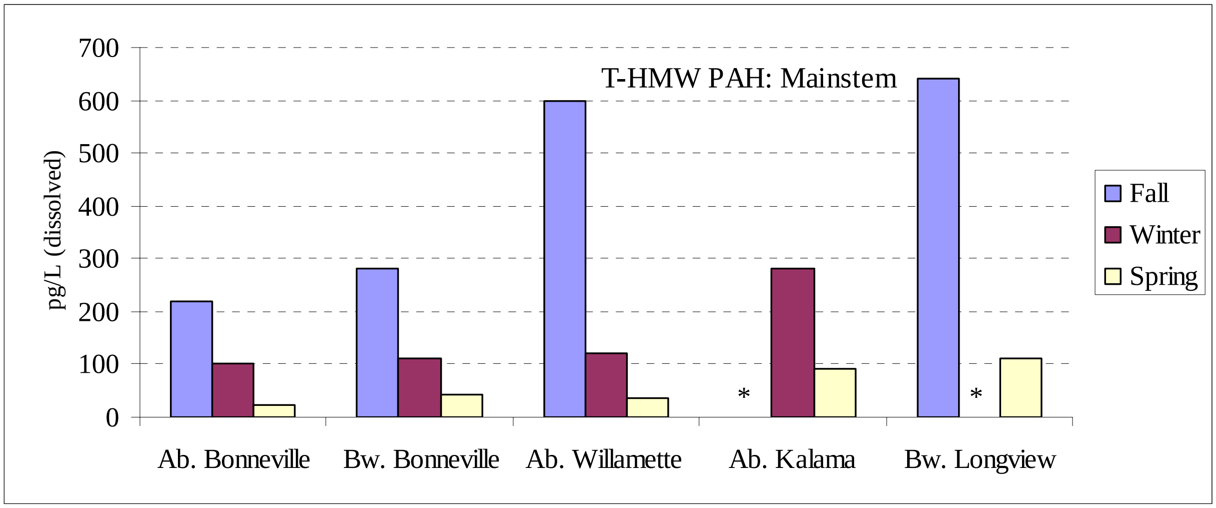
HMW PAHs were detected at all sampling sites. Mainstem concentrations of dissolved T-HMW PAH ranged from 23 to 640 pg/L. Chrysene and benzo(a)anthracene were consistently found at the highest concentrations. As with PCBs, sites in the Willamette River drainage were the most contaminated, with T-HMW PAH reaching 2,100 pg/L in Multnomah Channel and 8,300 pg/L in Columbia Slough. The lowest mainstem concentrations were above Bonneville Dam. Although the dam is a potential PAH source, there was not a substantial increase in PAHs below the dam at any time during the study period.

Temporal and Spatial Patterns

Figure 7 plots the T-HMW PAH data for the mainstem and tributaries. In the mainstem, HMW PAH progressively increased going downstream from Bonneville Dam to below Longview. This pattern was consistently observed during the fall, winter, and spring. Concentrations in the lower river were 3 – 5 times higher than above Bonneville Dam. These results clearly point to local sources being important contributors to PAH levels in the Lower Columbia River. The mainstem and tributary data concur in showing that the highest PAH concentrations occur in the fall, with progressively lower concentrations in winter and spring, possibly reflecting the greater amount of water available for dilution.

Table 11. Concentrations of 303(d) PAHs Detected in Lower Columbia River SPMDs Deployed in 2003 - 2004 (pg/L, dissolved)

Site	Columbia Above Bonneville Dam	Columbia Below Bonneville Dam	Washougal River	Columbia Above Willamette River	Columbia Slough	Willamette River	Lake River	Lewis River	Multnomah Channel	Columbia Above Kalama River	Kalama River	Cowlitz River	Columbia Below Longview
River Mile	147	142	121	103	102	102	88	87	86	75	73	68	54
August - September 2003													
Benzo(a)anthracene	**35**	**77**	**49**	**180**	**2,500**	**410**	**290**	**120**	**630**	no data	**180**	**120**	**190**
Chrysene	**78**	**72**	**140**	**180**	**2,500**	**370**	**190**	**82**	**670**	"	**94**	**92**	**200**
Benzo(b)fluoranthene	**32**	**36**	**96**	**74**	**1,200**	**150**	**120**	**59**	**220**	"	**89**	**80**	**93**
Benzo(k)fluoranthene	**32**	**37**	**69**	**73**	**1,100**	**130**	**100**	**63**	**300**	"	**66**	**100**	**83**
Benzo(a)pyrene	**10**	**15**	**17**	**52**	**520**	**32**	**23**	**17**	**110**	"	**21**	**13**	**26**
Indeno(1,2,3-cd)pyrene	**11**	**14**	**29**	**19**	**200**	**23**	**14**	**17**	**46**	"	**16**	**30**	**15**
Dibenzo(a,h)anthracene	**7**	**9**	<150	**13**	**83**	**12**	<30	**11**	**22**	"	<57	<110	**8**
Benzo(g,h,i)perylene	**12**	**21**	**38**	**14**	**280**	**39**	**25**	**29**	**83**	"	**28**	**54**	**28**
T-HMW PAH	**220**	**280**	**438**	**600**	**8,300**	**1,200**	**760**	**400**	**2,100**	"	**490**	**490**	**640**
December 2003 - January 2004													
Benzo(a)anthracene	**13**	**15**	**31**	**25**	**310**	**78**	**25**	**54**	**48**	**65**	**29**	**51**	no data
Chrysene	**43**	**48**	**63**	**57**	**760**	**130**	**54**	**130**	**82**	**140**	**52**	**98**	"
Benzo(b)fluoranthene	**12**	**14**	**45**	**11**	**130**	**21**	**14**	**61**	**15**	**15**	**20**	**26**	"
Benzo(k)fluoranthene	**14**	**14**	**34**	**10**	**170**	**25**	**15**	**49**	**16**	**23**	**27**	**32**	"
Benzo(a)pyrene	**4**	**5**	**16**	**4**	**84**	**16**	<26	**16**	**9**	**12**	**9**	**15**	"
Indeno(1,2,3-cd)pyrene	**5**	**4**	**13**	**3**	**22**	**6**	**3**	**12**	**4**	**6**	**6**	**7**	"
Dibenzo(a,h)anthracene	**5**	**4**	**12**	**3**	**18**	**6**	**3**	**7**	**5**	**6**	**6**	**6**	"
Benzo(g,h,i)perylene	**8**	**8**	**23**	**6**	**60**	**16**	**8**	**21**	**11**	**13**	**12**	**14**	"
T-HMW PAH	**100**	**110**	**240**	**120**	**1,500**	**300**	**120**	**350**	**190**	**280**	**160**	**250**	"
May - June 2004													
Benzo(a)anthracene	<35	**13**	<100	**11**	**98**	**15**	**22**	<34	**39**	**27**	<73	**22**	**41**
Chrysene	**23**	**31**	**46**	**25**	**220**	**27**	**38**	**29**	**59**	**47**	**50**	**31**	**73**
Benzo(b)fluoranthene	<37	<26	<120	<21	**66**	<16	<25	<38	**9**	**10**	<83	<38	<58
Benzo(k)fluoranthene	<31	<22	<110	<18	**53**	<14	<21	<36	**15**	**8**	<78	<33	<49
Benzo(a)pyrene	<29	<20	<110	<17	**27**	<13	<20	<35	<20	<13	<76	<30	<46
Indeno(1,2,3-cd)pyrene	<30	<21	<110	<17	**12**	<13	<20	<37	<20	<13	<80	<31	<47
Dibenzo(a,h)anthracene	<38	<26	<160	<22	<17	<17	<25	<53	<26	<17	<120	<40	<60
Benzo(g,h,i)perylene	<52	<36	<200	<30	**31**	<23	<35	<64	<35	<23	<140	<55	<82
T-HMW PAH	**23**	**44**	**46**	**36**	**510**	**42**	**60**	**29**	**120**	**91**	**50**	**53**	**110**



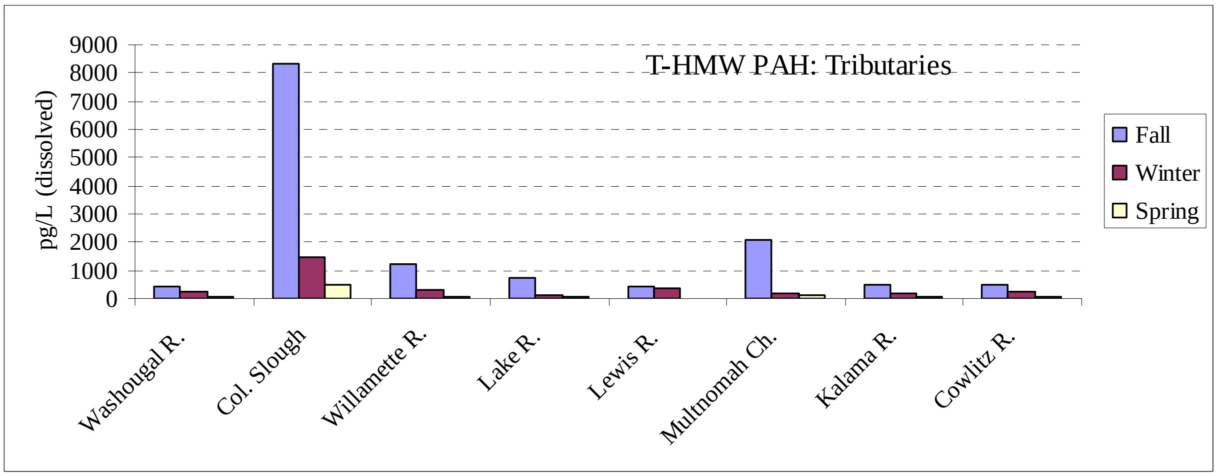


Figure 7. Estimated Concentrations of Dissolved High-Molecular Weight PAH in the Columbia River Mainstem and Tributaries (* = no data)

The tributaries are ranked according to PAH concentrations in Table 12. As with pesticides and PCBs, Willamette River sites had the highest levels of PAH contamination. The Lewis and Washougal rivers were the least contaminated with respect to PAH.

Table 12. Tributaries Ranked According to Dissolved PAH Concentrations
(1 indicates most contaminated)

Rank	T-HMW PAH
1	Columbia Slough
2	Multnomah Channel
3	Willamette River
4	Cowlitz River
5	Lake River
6	Kalama River
7	Lewis River
8	Washougal River

Total Concentrations

Total HMW PAH concentrations were estimated from the dissolved data using the same procedure described for pesticides and PCBs. The results are in Table 13. Table 14 shows how much of each PAH compound would be expected to be in dissolved form in the mainstem.

Table 13. Estimated Total Concentrations of 303(d) PAHs Detected in Lower Columbia River SPMDs Deployed in 2003 - 2004 (pg/L)

Site	Columbia Above Bonneville Dam	Columbia Below Bonneville Dam	Washougal River	Columbia Above Willamette River	Columbia Slough	Willamette River	Lake River	Lewis River	Multnomah Channel	Columbia Above Kalama River	Kalama River	Cowlitz River	Columbia Below Longview
River Mile	147	142	121	103	102	102	88	87	86	75	73	68	54
August - September 2003													
Benzo(a)anthracene	**53**	**120**	**70**	**270**	**3,800**	**630**	**490**	**170**	**940**	no data	**240**	**170**	**290**
Chrysene	**98**	**91**	**170**	**230**	**3,200**	**470**	**260**	**99**	**830**	"	**110**	**110**	**250**
Benzo(b)fluoranthene	**44**	**50**	**130**	**100**	**1,700**	**210**	**180**	**78**	**300**	"	**110**	**100**	**130**
Benzo(k)fluoranthene	**65**	**75**	**130**	**140**	**2,200**	**270**	**230**	**110**	**590**	"	**110**	**180**	**170**
Benzo(a)pyrene	**24**	**37**	**37**	**120**	**1,300**	**79**	**67**	**37**	**260**	"	**40**	**27**	**63**
Indeno(1,2,3-cd)pyrene	**51**	**65**	**120**	**85**	**940**	**110**	**81**	**67**	**200**	"	**53**	**110**	**69**
Dibenzo(a,h)anthracene	**23**	**28**	<410	**39**	**260**	**38**	<110	**30**	**65**	"	<130	<280	**25**
Benzo(g,h,i)perylene	**73**	**130**	**200**	**83**	**1,700**	**240**	**190**	**150**	**480**	"	**120**	**260**	**170**
T-HMW PAH	**430**	**600**	**860**	**1,100**	**15,000**	**2,000**	**1,500**	**740**	**3,700**	"	**780**	**960**	**1,200**
December 2003 - January 2004													
Benzo(a)anthracene	**18**	**21**	**41**	**34**	**500**	**150**	**41**	**72**	**86**	**100**	**39**	**74**	no data
Chrysene	**50**	**57**	**74**	**67**	**990**	**190**	**71**	**150**	**110**	**180**	**61**	**120**	"
Benzo(b)fluoranthene	**15**	**17**	**56**	**14**	**190**	**35**	**21**	**76**	**24**	**22**	**25**	**35**	"
Benzo(k)fluoranthene	**23**	**24**	**56**	**17**	**370**	**70**	**34**	**81**	**41**	**50**	**45**	**60**	"
Benzo(a)pyrene	**8**	**9**	**31**	**9**	**220**	**56**	<71	**31**	**30**	**32**	**17**	**33**	"
Indeno(1,2,3-cd)pyrene	**17**	**15**	**43**	**9**	**110**	**43**	**18**	**40**	**28**	**29**	**22**	**29**	"
Dibenzo(a,h)anthracene	**12**	**10**	**28**	**6**	**61**	**27**	**12**	**17**	**21**	**20**	**14**	**16**	"
Benzo(g,h,i)perylene	**36**	**36**	**98**	**26**	**410**	**160**	**58**	**90**	**96**	**91**	**52**	**75**	"
T-HMW PAH	**180**	**190**	**430**	**180**	**2,900**	**730**	**260**	**560**	**440**	**520**	**280**	**440**	"
May - June 2004													
Benzo(a)anthracene	<57	**22**	<140	**19**	**200**	**24**	**41**	<45	**59**	**46**	<99	**32**	**67**
Chrysene	**30**	**41**	**54**	**34**	**330**	**35**	**54**	**34**	**74**	**64**	**59**	**38**	**96**
Benzo(b)fluoranthene	<54	<39	<150	<32	**120**	<23	<41	<47	**12**	**15**	<100	<51	<85
Benzo(k)fluoranthene	<69	<50	<190	<43	**160**	<31	<56	<59	**30**	**18**	<130	<62	<110
Benzo(a)pyrene	<80	<56	<220	<50	**100**	<35	<67	<67	<48	<39	<150	<67	<130
Indeno(1,2,3-cd)pyrene	<160	<120	<380	<100	**95**	<69	<140	<120	<89	<77	<280	<130	<250
Dibenzo(a,h)anthracene	<130	<94	<390	<84	<85	<59	<110	<120	<78	<65	<290	<110	<210
Benzo(g,h,i)perylene	<370	<270	<900	<240	330	<160	<330	<270	<210	<180	<630	<290	<590
T-HMW PAH	**30**	**63**	**54**	**53**	**1,300**	**59**	**95**	**34**	**180**	**140**	**59**	**70**	**160**

Table 14. Estimates of the Dissolved Fraction of HMW PAH in the Columbia River Mainstem (% dissolved)

	Mean	Minimum	Maximum
Benzo(a)anthracene	65	58	74
Chrysene	79	73	85
Benzo(b)fluoranthene	73	64	79
Benzo(k)fluoranthene	51	42	59
Benzo(a)pyrene	44	38	50
Indeno(1,2,3-cd)pyrene	24	19	29
Dibenzo(a,h)anthracene	35	29	42
Benzo(g,h,i)perylene	18	14	22

The fraction of dissolved PAH decreased with increasing molecular size, going from 65% for benzo[a]anthracene (4-rings) to 18% for benzo[g,h,i]perylene (6-rings), on average. USGS reported similar percentages for their SPMD samples in the mainstem during the spring: 71% dissolved for benzo[a]anthracene and chrysene, 39% for benzo[b]fluoranthene, 49% for benzo[a]pyrene, and 15% for benzo[g,h,i]perylene (McCarthy and Gale, 1999).

Comparison with Human Health Criteria

The Washington and Oregon human health water quality criteria that apply to 303(d) listed pesticides, PCBs, and PAHs in the Lower Columbia River are shown in Table 15. These criteria are for a 1-in-1 million (10^{-6}) increased lifetime cancer risk from consumption of water and fish or fish only. The source of the Washington criteria is the EPA 1992 National Toxics Rule (40 CFR 131.36). The Oregon criteria come from the EPA (1986) Gold Book. The Oregon criteria are lower for the chlorinated compounds, but both states have the same criteria for PAH.

Table 15. Human Health Water Quality Criteria for 303(d) Compounds (pg/L)

	Washington*		Oregon†		EPA (2002)	
Chemical	Water + Fish Consumption	Fish Consumption	Water + Fish Consumption	Fish Consumption	Water + Fish Consumption	Fish Consumption
4,4'-DDT	590	590	24	24	220	220
4,4'-DDE	590	590	- -	- -	220	220
4,4'-DDD	830	840	- -	- -	310	310
Dieldrin	140	140	71	76	52	54
PCBs	170	170	79	79	64	64
HMW PAHs	2,800	31,100	2,800	31,100	3,800	18,000

*EPA 1992 National Toxics Rule
†EPA 1986 Gold Book

Oregon plans to revise their human health criteria (Martin Fitzpatrick, ODEQ, personal communication). When the new criteria go into effect, they will be based on the EPA (2002) National Recommended Water Quality Criteria. The EPA criteria are included in Table 15.

Figure 8 compares the DDT, DDE, DDD, dieldrin, PCB, and PAH concentrations measured in the Lower Columbia River drainage with the Washington state human health criteria. The figure shows the ratio of the dissolved water column concentration divided by the criterion for water and fish consumption. A value greater than 1.0 exceeds the state standard. For non-detected pesticides the less-than values were used to calculate the ratio. Because of variable and sometimes high reporting limits for PCBs, non-detects were not plotted.

The dissolved data (Table 6) were used in this comparison rather than total concentrations because it more accurately reflects the chemical fraction available for uptake by fish (EPA, 2000) and fish consumption is the primary concern behind most of the 303(d) listings. There is also greater uncertainty about the accuracy of the total concentrations, since they are estimates based on partitioning theory.

In the mainstem, exceedances of Washington's criteria for DDT compounds (590 and 830 pg/L) were limited to DDE and DDD, and substantial exceedances were only observed above and immediately below Bonneville Dam. Exceedances of criteria for DDT compounds in the tributaries were confined to the Willamette drainage.

More numerous exceedances were seen for the dieldrin criterion (140 pg/L). Although dieldrin concentrations in the Willamette drainage exceeded to the greatest extent, all tributaries had at least one exceedance for dieldrin. For the mainstem, one exceedance each of the dieldrin criterion was observed above Bonneville Dam, below Bonneville Dam, and above Kalama.

Detection limits for many of the spring and winter samples were not low enough to determine compliance with Washington's human health criterion for PCBs (170 pg/L). Where PCBs were detectable during these periods – Willamette River drainage sites, the Columbia River below Longview in the fall, and Columbia Slough in the winter – the criterion was exceeded. The concentration of dissolved T-PCBs measured in the Columbia River below Longview in the winter exceeded the criterion by approximately a factor of 2. Columbia Slough exceeded the criterion by 2 orders of magnitude in the winter.

All mainstem and tributary sites, including the site above Bonneville Dam, exceeded the PCB human health criterion in the spring. Dissolved T-PCB concentrations in the mainstem were approximately 2 – 4 times above the criterion. PCB concentrations in Columbia Slough, Multnomah Channel, and the Willamette River exceeded the criterion by an order of magnitude both in the spring and in the fall.

The human health criterion for HMW PAH is 2,800 pg/L for consumption of water and fish. Except for one instance in Columbia Slough, none of the samples collected for the present study exceeded this criterion, either as individual compounds or as summed PAH. The same general

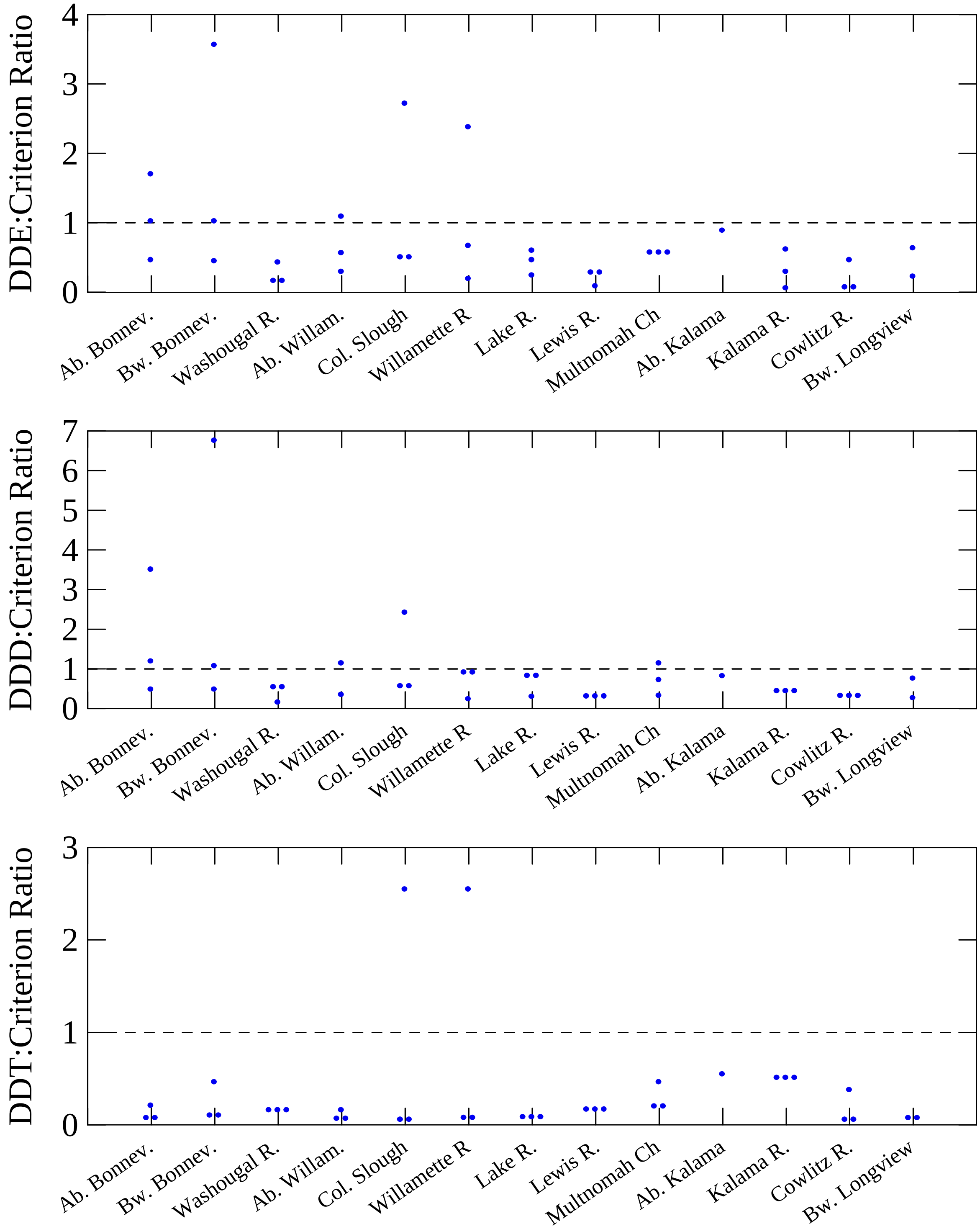


Figure 8. Dissolved Concentrations Compared to Washington State Human Health Criteria. (Values >1 exceed criterion)

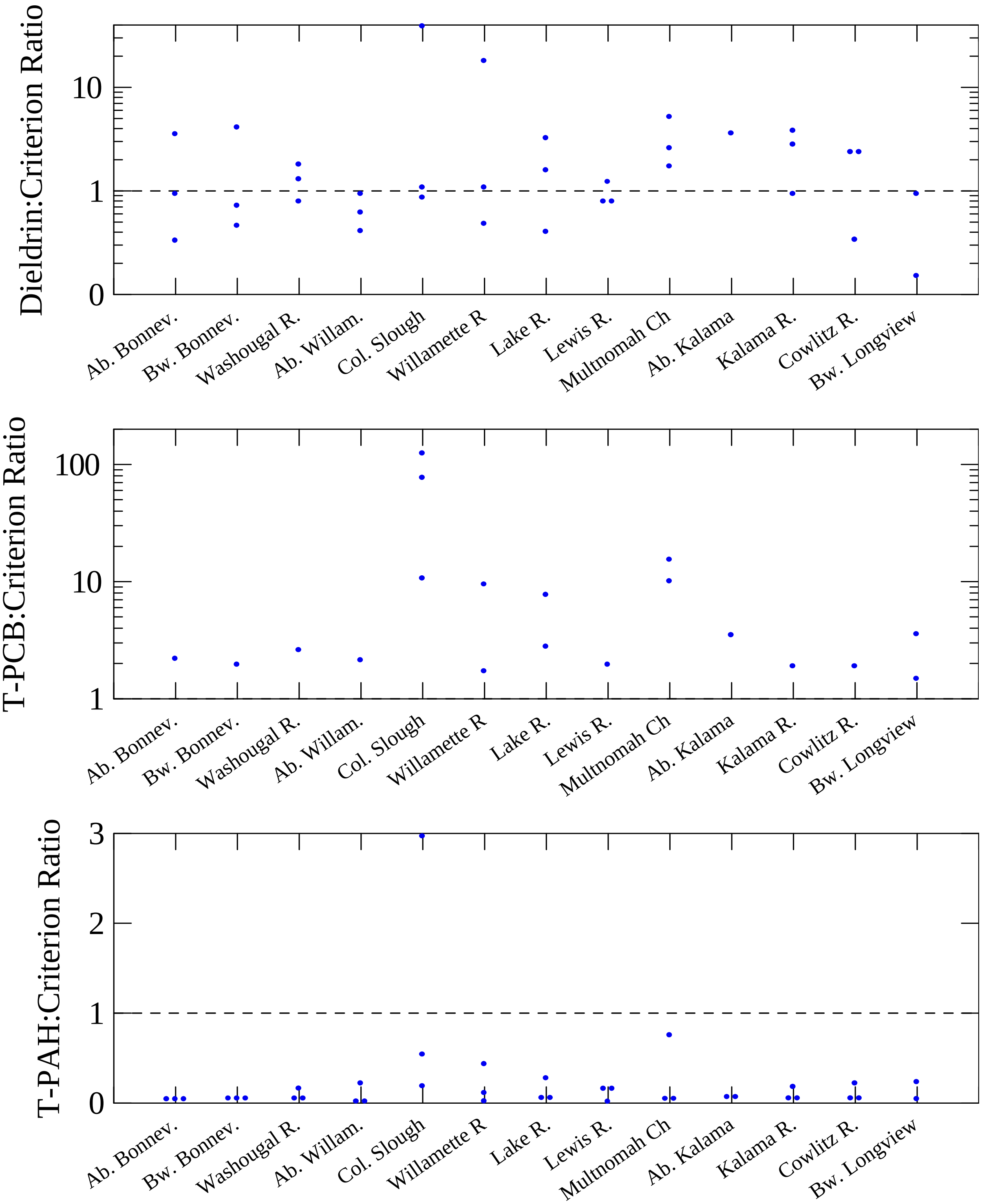


Figure 8. (continued)

conclusion holds true if the criterion is compared to the estimated total concentrations (Table 13), which is the more appropriate comparison for drinking water concerns. Multnomah Channel slightly exceeded the PAH criterion in the fall, based on an estimated total concentration of 3,700 pg/L.

Figure 9 has a similar set of graphs comparing the dissolved concentrations to the EPA (2002) human health criteria that Oregon plans to adopt. Table 16 summarizes the exceedance frequencies for the Washington and EPA (2002) criteria.

Table 16. Exceedance Frequencies of Washington State and EPA (2002) Human Health Criteria in the Lower Columbia River Drainage, 2003-2004 [based on dissolved concentrations]

Chemical	Washington State Criteria		EPA (2002) Criteria	
	Samples	Percent	Samples	Percent
DDE	5/36	14%	23/36	64%
DDD	7/36	19%	24/36	67%
DDT	2/36	6%	8/36	22%
Dieldrin	19/36	53%	33/36	92%
T-PCBs*	19/19	100%	19/19	100%
T-HMW PAH	1/37	3%	1/37	3%

*Spring 2004 data only.

Human health criteria for the other pesticides for which water column concentrations were determined are in Table 17. There were only a few exceedances of currently applicable criteria. Hexachlorobenzene marginally exceeded Washington and Oregon criteria in the Columbia River below Bonneville, but not in the sample collected immediately above the dam. There were sporadic exceedances of the chlordane criteria that included the Willamette drainage and the Kalama and Cowlitz rivers. Heptachlor epoxide exceeded criteria in several of the samples collected in the spring. In all cases, concentrations exceeded criteria by less than a factor of 2.

Table 17. Human Health Water Quality Criteria for Other Pesticides (pg/L)

Chemical	Washington*		EPA (2002)		Oregon†	
	Water + Fish Consumption	Fish Consumption	Water + Fish Consumption	Fish Consumption	Water + Fish Consumption	Fish Consumption
Hexachlorobenzene	750	770	720	740	280	290
Chlordane	570	590	460	480	800	810
a-BHC	3,900	13,000	9,200,000	31,000,000	2,600	4,900
Heptachlor epoxide	100	110	- -	- -	39	39
Methoxychlor	- -	- -	100,000,000	- -	- -	- -
Endosulfan	930,000	2,000,000	74,000,000	159,000,000	62,000,000	89,000,000
Endrin	760,000	810,000	1,000	- -	760,000	810,000

*EPA 1992 National Toxics Rule
†EPA 1986 Gold Book

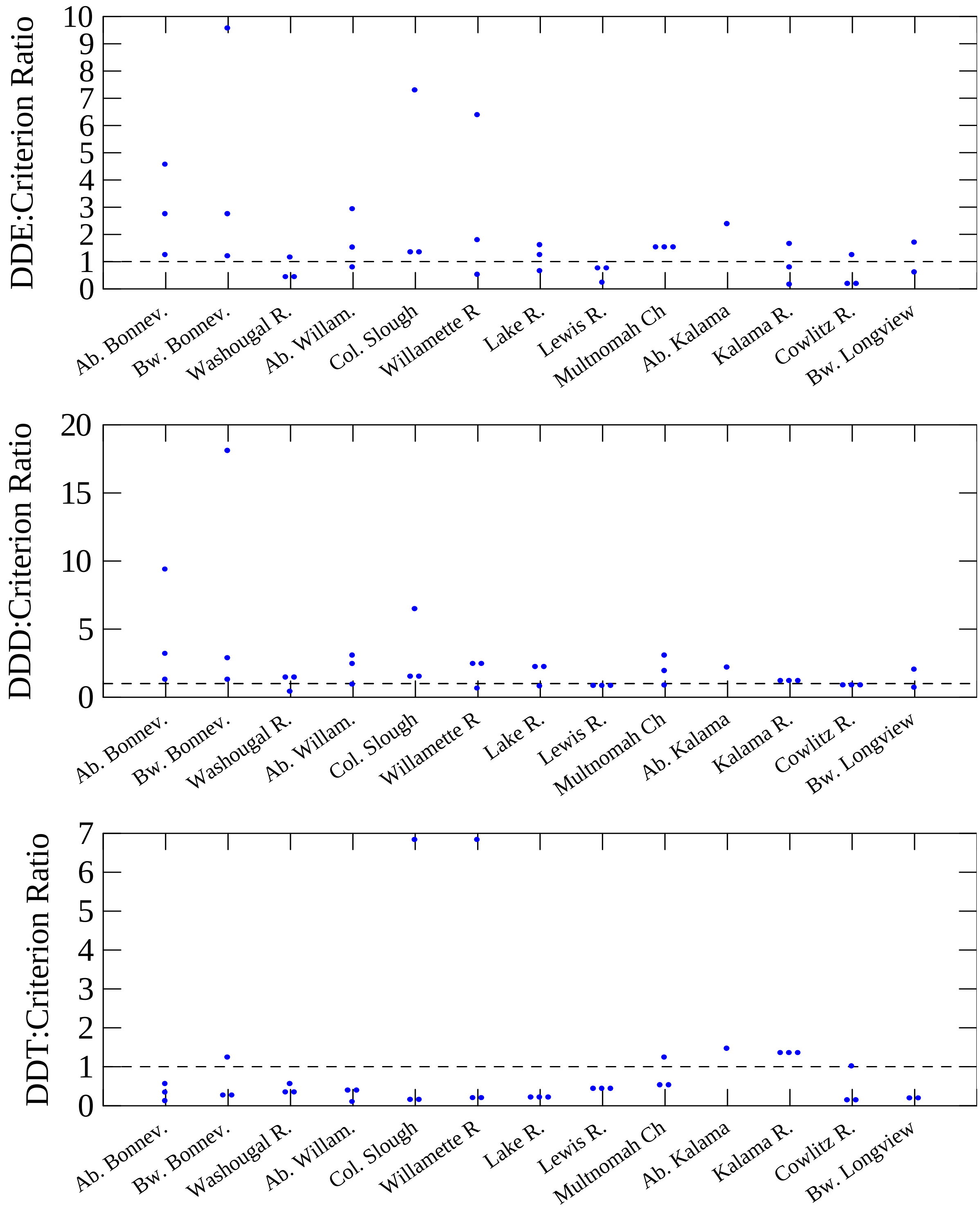


Figure 9. Dissolved Concentrations Compared to EPA (2002) Human Health Criteria.
(Values >1 exceed criterion)

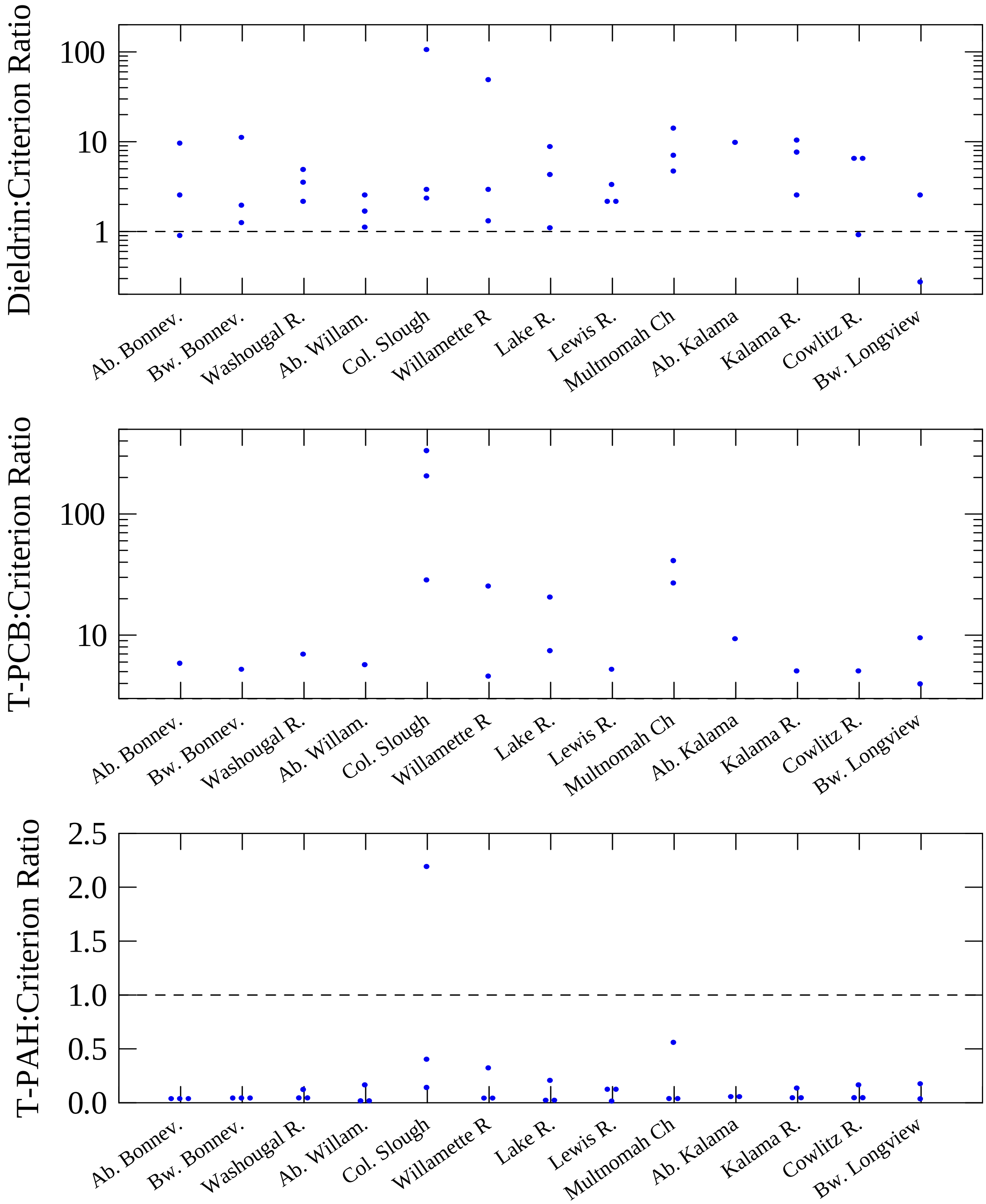


Figure 9. (continued)

Predicted vs. Measured Fish Tissue Concentrations

The EPA bioconcentration factors (BCFs[4]) used in establishing the human health water quality criteria were applied to the dissolved data to determine how well SPMDs predict fish tissue concentrations in the Columbia River and, in turn, the appropriateness of comparing this type of data to the criteria. The most recent data on edible tissues from mainstem, resident fish species are for samples collected in 1994-95 as part of the Lower Columbia River Bi-State Program (Appendix B-10 in Tetra Tech, 1996).

Results of the BCF calculation are in Table 18. Predicted and measured fish tissue concentrations agree well for DDT compounds, dieldrin, and PAH. The predicted T-DDT concentration of 100 ug/Kg (parts per billion) is bracketed by the range of mean concentrations found in carp, suckers, and sturgeon, 34 – 137 ug/Kg. Low dieldrin and T-HMW PAH concentrations of 0.9 and 0.01 ug/Kg, respectively, would be predicted from the SPMDs; these compounds were not detected in the 1994-95 fish samples. PAHs are metabolized by fish and so do not accumulate in their tissues.

Table 18. Fish Tissue Concentrations Predicted from Ecology SPMD Data and EPA Bioconcentration Factors, Compared to Most Recent Data for Resident Species in the Lower Columbia River

	Mean Water Column Concentration*			Predicted Fish Tissue	Mean Concentration in Fillets† (ug/Kg, wet)			
Chemical	(pg/L)	(ug/L)	EPA BCF	Concentration (ug/Kg, wet)	Common Carp[1]	Largescale Sucker[2]	White Sturgeon[3]	3 Species Mean
T-DDT	1,900	0.0019	53,600	100	137	34	49	73
Dieldrin	190	0.00019	4,670	0.9	<0.02	<0.02	<0.01	<0.02
T-PCBs	470	0.00047	31,200	15	188	40	58	95
T-HMW PAH	250	0.00025	30	0.01	<5	<5	<5	<5

*Dissolved data from present study; PCB mean for spring 2004 only.
†Tetra Tech (1996)
[1]One composite of seven individual fish
[2]Nine composites of eight individual fish
[3]Twelve individual fish

The Columbia River 303(d) listings for dieldrin are for white sturgeon collected in 1991 as part of an earlier study (Tetra Tech (1993); see Table 1). Dieldrin was detected in fillets from 5 out of 18 individual sturgeon. Detected concentrations ranged from 3 to 12 ug/Kg; the reporting limit was 3 ug/Kg. These results are inconsistent with those reported for 1994-95 when all samples were <0.02 ug/Kg.

Predicted T-PCB concentrations are an order of magnitude lower than measured concentrations. For superlipophilic chemicals like PCBs, uptake through food is a more important pathway than

[4] BCF= C_t/C_w, where C_t is the contaminant concentration in tissue (wet weight) and C_w is the concentration in water.

uptake from water alone (Mackay and Fraser, 2000). As a result, BCFs typically underestimate PCB bioaccumulation (EPA, 2000). The current human health water quality criteria for PCBs may not be low enough to protect consumers of Columbia River fish.

Comparison with USGS Data

USGS used SPMDs to monitor chlorinated pesticides, PCBs, PAHs, and dioxins in the Columbia River between Northport (r.m. 735) and Bradwood (r.m. 39) during 1997 – 1998 (McCarthy and Gale, 1999). The study included eight sites below Bonneville Dam, six on the mainstem, and one each in the Willamette River and Lake River. SPMDs were deployed during fall 1997 and spring 1998. Tables 19 and 20 show the dissolved data that correspond to the analyses conducted for Ecology's 2003-2004 study.

USGS adopted the conservative approach of not adjusting their results to account for site-specific differences in temperature, water velocity, or membrane fouling, all of which affect chemical uptake. The technique of using PRCs to more accurately estimate SPMD sampling rates had not been developed at that time. USGS therefore cautioned that their data were "only approximations of the exposure-period average dissolved concentrations of OC and PAH compounds." In assessing their accuracy, USGS estimated the error "to be less than an order of magnitude." (McCarthy and Gale, 1999)

Table 19. USGS Data on Dissolved Pesticide, PCB, and PAH Concentrations in the Lower Columbia River: Fall 1997* (pg/L)

Site	Warrendale	Hayden Island	Willamette River	Lake River	Columbia City	Longview	Beaver Army Terminal	Bradwood
River Mile	141	102	101	87	82	69	54	39
4,4'-DDE	700	90	200	200	300	400	200	100
4,4'-DDD	1,000	200	400	200	300	200	200	100
4,4'-DDT	- -	- -	- -	- -	- -	- -	- -	- -
T-DDT	1,700	290	600	400	600	600	400	200
Dieldrin	100	50	100	100	70	40	40	40
T-PCBs	600	80	2,000	900	1,000	700	500	300
Benzo(a)anthracene	600	100	2,000	300	1,000	800	1,000	- -
Chrysene	2,000	400	3,000	700	2,000	1,000	2,000	1,000
Benzo(b)fluoranthene	600	- -	2,000	400	2,000	800	1,000	- -
Benzo(k)fluoranthene	- -	- -	900	- -	- -	400	600	200
Benzo(a)pyrene	- -	- -	600	- -	500	- -	300	- -
Indeno(1,2,3-cd)pyrene	- -	- -	- -	- -	- -	- -	- -	- -
Dibenzo(a,h)anthracene	- -	- -	- -	- -	- -	- -	- -	- -
Benzo(g,h,i)perylene	- -	- -	600	- -	300	- -	- -	- -
T-HMW PAH	3,200	500	9,100	1,400	5,800	3,000	4,900	1,200

Source: McCarthy and Gale (1999)
*SPMDs deployed Aug. 4 - 6, retrieved Sept. 8 - 10, except Hayden Island, Lake River, and Warrendale deployed Oct. 15 and retrieved Nov. 20
- - = all information required for calculations not available.

Table 20. USGS Data on Dissolved Pesticide, PCB, and PAH Concentrations in the Lower Columbia River: Spring* 1998 (pg/L)

Site	Warrendale	Hayden Island	Willamette River	Lake River	Columbia City	Longview	Beaver Army Terminal	Bradwood
River Mile	141	102	101	87	82	69	54	39
4,4'-DDE	400	200	60	no	200	200	300	200
4,4'-DDD	300	200	40	sample	200	- -	300	200
4,4'-DDT	- -	- -	- -		- -	- -	- -	- -
T-DDT	700	400	100	"	400	200	600	400
Dieldrin	40	40	90	"	60	40	30	40
T-PCBs	100	100	70	"	300	100	300	200
Benzo(a)anthracene	- -	- -	300	- -	300	- -	800	- -
Chrysene	600	300	600	400	800	400	2,000	600
Benzo(b)fluoranthene	- -	- -	- -	- -	- -	- -	500	- -
Benzo(k)fluoranthene	- -	- -	- -	- -	- -	- -	300	- -
Benzo(a)pyrene	- -	- -	- -	- -	- -	- -	- -	- -
Indeno(1,2,3-cd)pyrene	- -	- -	- -	- -	- -	- -	- -	- -
Dibenzo(a,h)anthracene	- -	- -	- -	- -	- -	- -	- -	- -
Benzo(g,h,i)perylene	- -	- -	- -	- -	- -	- -	- -	- -
T-HMW PAH	600	300	900	400	1,100	400	3,600	600

Source: McCarthy and Gale (1999)
*SPMDs deployed May 19-22, retrieved June 22-24, except Willamette R. deployed Jan. 15 and retrieved Feb. 18
- - = all information required for calculations not available.

For the mainstem, the USGS study showed that PAH occurred in the highest concentrations of 300 – 5,800 pg/L T-HMW PAH, followed by T-DDT compounds at 200 – 1,700 pg/L, and T-PCBs[5] at 80 – 1,000 pg/L. Dieldrin concentrations were at or below 100 pg/L. The Willamette River again showed significant PCB and PAH contamination.

The USGS data for the Lower Columbia mainstem are plotted in Figure 10. These results show elevated PCB and PAH concentrations downstream of the Portland-Vancouver area (Columbia City site), while DDT compounds and dieldrin are highest at the upstream site in Warrendale, approximately six miles below Bonneville Dam. DDT compounds and dieldrin tended to decrease moving downstream from Warrendale, while PCBs and PAHs tended to increase. These findings are consistent with results of the present study.

USGS concluded that PCB and PAH concentrations in the Portland-Vancouver area were primarily from local rather than upstream sources (McCarthy and Gale, 1999). They saw a reduction in mainstem concentrations further downstream during the spring, which was attributed to dilution, volatilization, and settling of particulate matter. This is less apparent in the spring when the Beaver Army Terminal site showed similar or higher concentrations than Columbia City.

[5] Ortho-substituted PCBs; concentrations of non-ortho PCBs were insignificant.

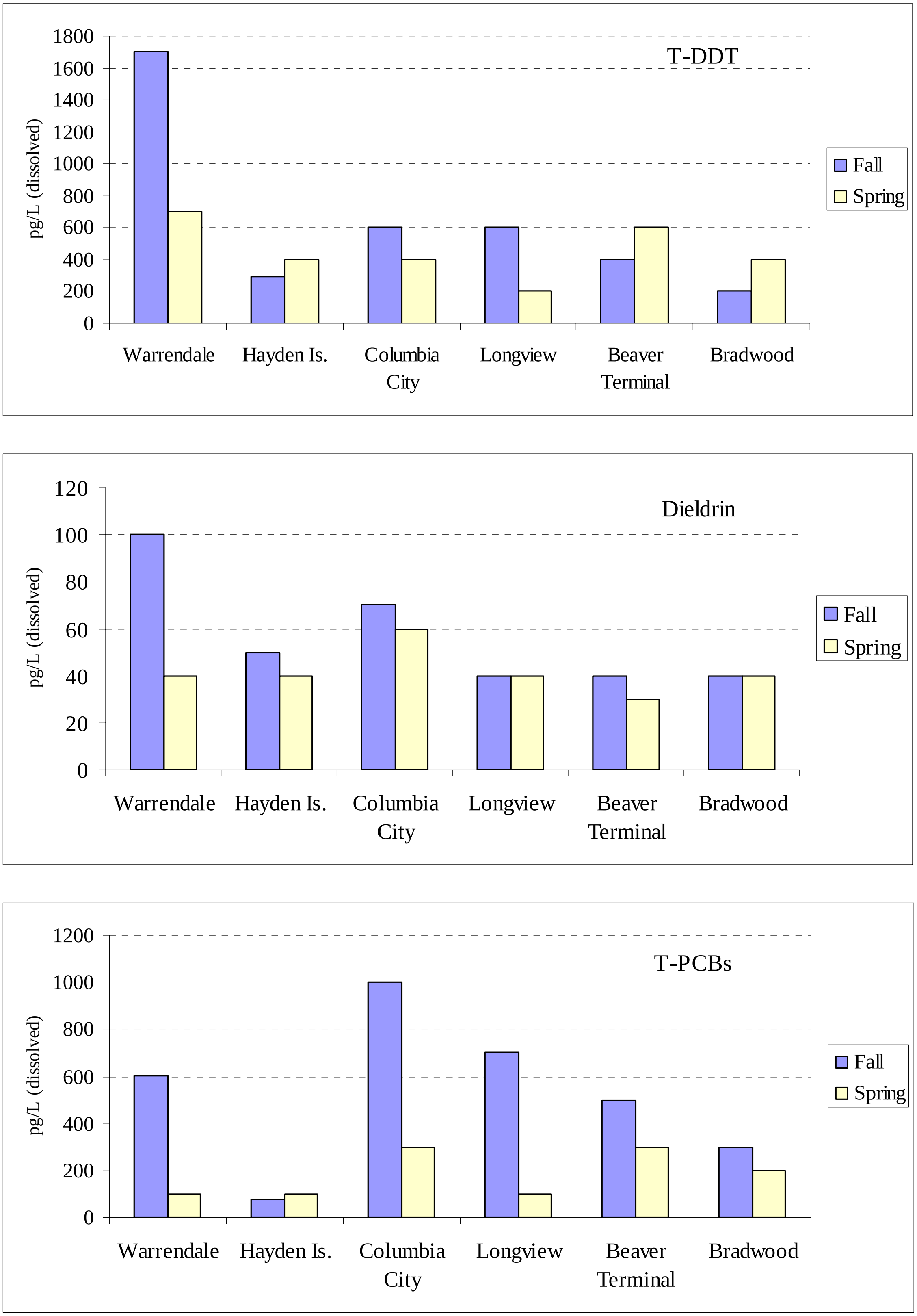


Figure 10. USGS SPMD Data for the Columbia River Mainstem (McCarthy and Gale, 1999)

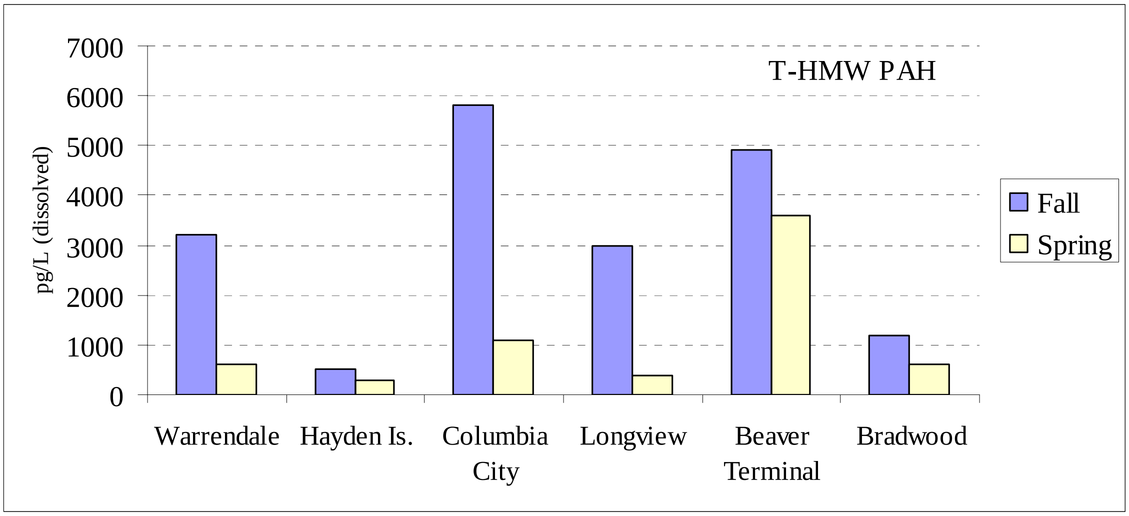


Figure 10. (continued)

USGS generally observed higher concentrations of PCBs and PAHs during low-flow conditions; for PAH, at least, this is inconsistent with findings from Ecology's survey. A consistent seasonal pattern was not apparent in the USGS data for DDT compounds or for dieldrin.

Ecology and USGS had four sampling sites that were close to one another and sampled at approximately the same time of year; Tables 21 and 22 compare the data. Given the many variables that could potentially affect results from these two studies, there is good agreement on T-DDT, dieldrin, and T-PCB concentrations in the mainstem, Willamette River (low flow only) and Lake River. Concentrations at these sites agree within a factor of 2.

Ecology found much higher pesticide and PCB concentrations in the Willamette River during high flow. This may be due to differences in sampling locations. The USGS SPMDs were deployed approximately 12 miles upstream of Ecology's SPMDs. The Portland Harbor Superfund site (r.m. 3.5 – 9) is located between these two sites and is a source of chlorinated pesticides and PCBs (http://www.deq.state.or.us/nwr/PortlandHarbor/ph.htm).

USGS has the better data set for PCBs during low flow where there are gaps in Ecology's data. Taken together, these results indicate the Lower Columbia River exceeds human health criteria for PCBs from Bonneville to below Longview during both low flow and high flow.

The USGS data are the basis for Oregon's 303(d) listings for PAH in the Columbia River. With the exception of their Hayden Island site, USGS reported T-HMW PAH concentrations that are 2 – 11 times higher than those measured by Ecology.

Table 21. Comparison of USGS and Ecology SPMD Data for Low-Flow Conditions in the Lower Columbia River (pg/L, dissolved)

USGS Site Name	Warrendale	Hayden Is.	Willamette R.	Lake River	Columbia City	Beaver Terminal
USGS River Mile	141	102	101	87	82	54
Ecology Site Name	Bw. Bonneville	Ab. Willamette R.	Willamette R.	Lake River	Ab. Kalama	Bw. Longview
Ecology River Mile	142	103	101	87	75	54
T-DDT: USGS	1,700	290	600	400	600	400
T-DDT: Ecology	690	470	1,100	380	- -	360
Dieldrin: USGS	100	50	100	100	70	40
Dieldrin: Ecology	64	57	150	56	- -	14
T-PCBs: USGS*	600	80	2,000	900	1,000	500
T-PCBs: Ecology	<620	<450	1,600	470	- -	250
T-HMW PAH: USGS	3,200	500	9,100	1,400	5,800	4,900
T-HMW PAH: Ecology	280	600	1,200	760	- -	640

*These USGS data are for ortho-substituted PCBs

Table 22. Comparison of USGS and Ecology SPMD Data for High-Flow Conditions in the Lower Columbia River (pg/L, dissolved)

USGS Site Name	Warrendale	Hayden Is.	Willamette R.	Lake River	Columbia City	Beaver Terminal
USGS River Mile	141	102	101	87	82	54
Ecology Site Name	Bw. Bonneville	Ab. Willamette R.	Willamette R.	Lake River	Ab. Kalama	Bw. Longview
Ecology River Mile	142	103	101	87	75	54
T-DDT: USGS	700	400	100	- -	400	600
T-DDT: Ecology	1,500	1,700	3,700	1,000	- -	1,000
Dieldrin: USGS	40	40	90	- -	60	30
Dieldrin: Ecology	100	130	2,500	220	- -	130
T-PCBs: USGS*	100	100	70	- -	300	300
T-PCBs: Ecology	330	360	290†	1,300	590	600
T-HMW PAH: USGS	600	300	900	400	1,100	3,600
T-HMW PAH: Ecology	44	35	360	60	91	110

*These USGS data are for ortho-substituted PCBs
†May-June data, since PCBs were not detected in December-January

The discrepancy in the PAH concentrations found in these two studies may be partly due to USGS not adjusting SPMD sampling rates for field conditions. It is also possible that the differences represent a real reduction in PAH levels in the river.

Related Activities

Monitoring activities and cleanup actions in the Lower Columbia River could provide data to complement the present study and help resolve the status of 303(d) listed chemicals. USGS, under contract from the Lower Columbia River Estuary Program, began water quality monitoring for a range of conventional and toxics parameters in May 2004. Toxics monitoring using SPMDs at up to six sites – some of which are the same locations sampled in the present study – is planned as part of this project (Jason Karnezis, USGS, personal communication).

In 1998, EPA approved a TMDL for Columbia Slough which included DDE, DDT, dieldrin, and PCBs. In addition, ongoing Superfund investigations and cleanup activities for Portland Harbor have been underway for several years. More information about the latter two efforts can be obtained at the ODEQ website http://www.deq.state.or.us and the EPA Superfund website http://www.epa.gov/superfund/sites/npl/or.html.

Contaminant Loading

Estimates of the total chemical concentrations (Tables 8 and 13) were used along with the available flow data (Appendix I) to do a screening-level assessment of loading of 303(d) compounds in the Lower Columbia River during 2003-2004. The mean flow for each deployment period was used.

Only historical flow data were available for the Washougal River and no published flow records data were available for the samples collected at the Columbia River above Willamette, Lake River, or Columbia River above Kalama. It was assumed that 2/3 of the Willamette's flow goes down Multnomah Channel, based on modeling done by Dr. Scott Wells at Portland State University (http://www.cee.pdx.edu/w2/). Because tidal fluctuation causes flow reversal in Columbia Slough, the recorded outflows were divided by 2 to provide a rough estimate of loading to the river. The estimated loads are shown in Table 23.

To put these loads in perspective, Table 24 shows the potential each tributary has to change contaminant concentrations in the mainstem. In order to compare the tributaries on an even basis, the Columbia River above Bonneville was used as the upstream condition in each case. This has the effect of slightly overstating the potential impact of the Lewis, Kalama, and Cowlitz rivers, especially in the winter, since the increased flow from the Willamette River drainage is not taken into account. The detection limit was used as a worst-case baseline for PCBs.

Table 23. Loading Estimates (grams/day; total chemical)

Site River Mile	Columbia Above Bonneville Dam 147	Columbia Below Bonneville Dam 142	Washougal River 121	Columbia Above Willamette River 103	Columbia Slough 102	Willamette River 102	Lake River 88	Lewis River 87	Multnomah Channel 86	Columbia Above Kalama 75	Kalama River 73	Cowlitz River 68	Columbia Below Longview 54
August - September 2003													
Mean Flow (cfs)	102,700	102,700	50	- -	19	2,467	- -	1,519	4,884	- -	160	3,196	106,045
T-DDT	280	280	0.01	- -	0.1	11	- -	3	25	- -	0.2	4	150
Dieldrin	12	17	ND	- -	0.01	1	- -	ND	3	- -	ND	ND	4
T-PCBs	ND	ND	ND	- -	0.2	25	- -	ND	78	- -	ND	ND	170
T-HMW PAH	110	150	0.1	- -	1	12	- -	3	44	- -	0.3	8	310
December 2003 - January 2004													
Mean Flow (cfs)	143,500	143,500	3,245	- -	70	24,049	- -	5,775	47,616	- -	1,509	10,704	232,214
T-DDT	1,900	3,900	0.7	- -	1	400	- -	2	130	- -	ND	3	no data
Dieldrin	180	200	2	- -	1	150	- -	2	87	- -	0.5	ND	"
T-PCBs	ND	ND	ND	- -	10	ND	- -	ND	ND	- -	ND	ND	"
T-HMW PAH	63	67	3	- -	0.5	43	- -	8	51	- -	1	12	"
May - June 2004													
Mean Flow (cfs)	267,200	267,200	449	- -	31	6,734	- -	4,447	13,334	- -	310	6,306	285,333
T-DDT	1,800	1,800	0.3	- -	0.1	9	- -	2	52	- -	0.04	1	590
Dieldrin	46	65	0.2	- -	0.01	1	- -	1	12	- -	ND	0.7	91
T-PCBs	390	650	1	- -	4	14	- -	7	140	- -	0.5	12	1,300
T-HMW PAH	11	41	0.1	- -	0.1	1	- -	0.4	6	- -	0.04	1	110

- - = flow data not available
ND = not detected

Table 24. Potential Changes in Mainstem Concentrations of 303(d) Compounds due to Tributary Loadings (% increase or decrease in total concentrations, based on Columbia River above Bonneville Dam)

	Washougal River	Columbia Slough	Willamette River	Lake River	Lewis River	Multnomah Channel	Kalama River	Cowlitz River
August - September 2003								
T-DDT	0	0	**+2**	- -	0	**+4**	0	-2
Dieldrin	ND	0	**+5**	- -	ND	**+19**	ND	ND
T-PCBs	ND	0	**>5**	- -	ND	**>18**	ND	ND
T-HMW PAH	0	**+1**	**+9**	- -	0	**+35**	0	**+5**
December 2003 - January 2004								
T-DDT	-2	0	**+4**	- -	-4	-20	ND	-7
Dieldrin	-1	0	**+60**	- -	-3	**+12**	-1	ND
T-PCBs	ND	**+1**	ND	- -	ND	ND	ND	ND
T-HMW PAH	**+3**	**+1**	**+44**	- -	**+8**	**+36**	**+1**	**+9**
May - June 2004								
T-DDT	0	0	-2	- -	-2	-2	0	-2
Dieldrin	0	0	-1	- -	0	**+9**	ND	-1
T-PCBs	0	**+1**	-1	- -	-1	**+14**	0	-1
T-HMW PAH	0	**+1**	**+2**	- -	0	**+24**	0	**+3**

Note: Positive values (increased concentration) in bold font
- - = flow data not available
ND = not detected

The following tributaries have the potential to increase total concentrations of 303(d) compounds in the Columbia River mainstem by 10% or more during the study period, relative to the Columbia River above Bonneville:

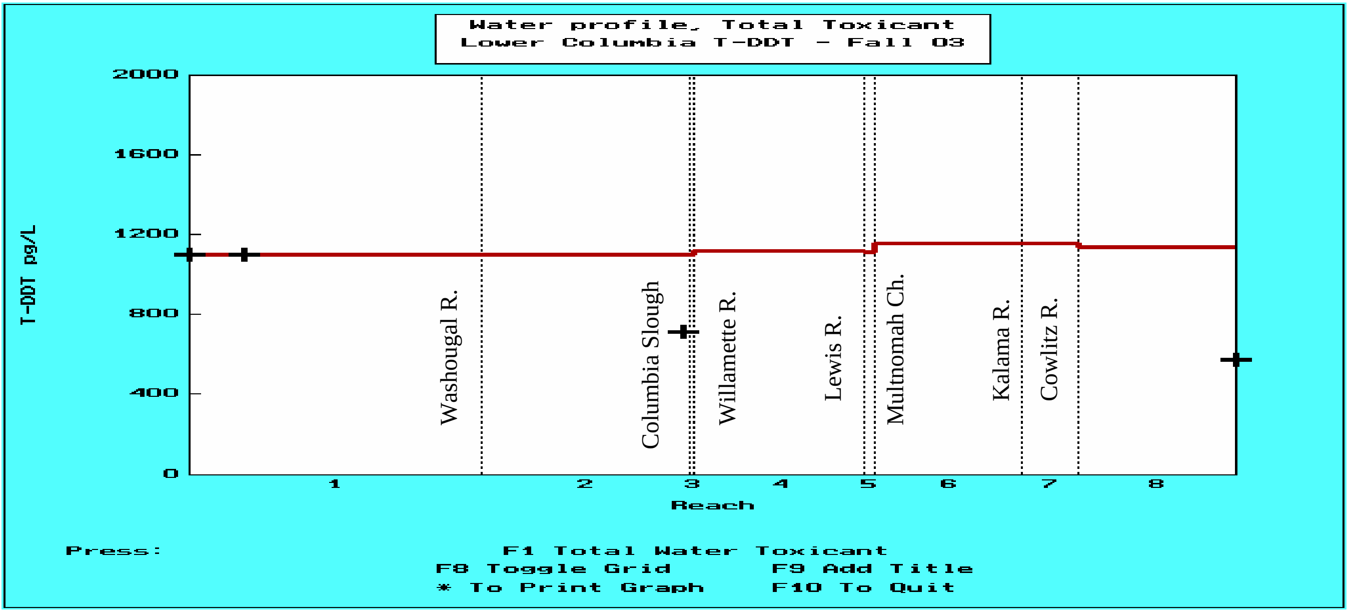
- Willamette River/Multnomah Channel: 5 – 60% increase in dieldrin during the fall, winter, and spring.
- Willamette River/Multnomah Channel: >5 – >18% increase in T-PCBs in the fall and spring.
- Willamette River/Multnomah Channel: 2 – 44% increase in T-HMW PAH during the fall, winter, and spring.

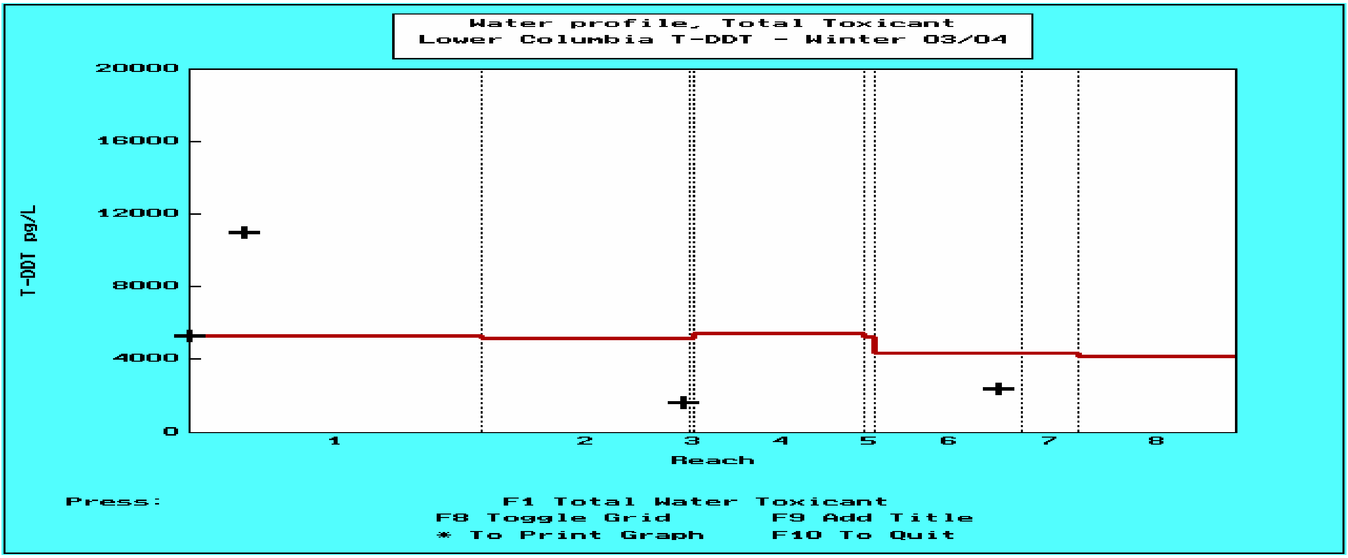
The Washougal River, Columbia Slough, Lewis River, Kalama River, and Cowlitz River appeared to have little or no potential to influence contaminant levels in the Columbia River. Lake River is a sluggish stream connecting Lake Vancouver with the Columbia. Although no flow data were available, it would require an unrealistically high flow for Lake River to affect the Columbia.

The potential effects of these tributaries on the Lower Columbia mainstem were simulated using EPA's SMPTOX program (http://epa.gov/ceampubl/swater/smptox3/index.htm) and compared to the concentrations measured in the river. For this application, the program was set to calculate water column concentrations through simple dilution, and the chemicals were assumed to act conservatively. The same flow and concentration data were used as above. The simulation differs in that it includes the progressive effect each tributary would have as it mixes with the mainstem. No simulation was done for dieldrin in the fall or PCBs in the fall or winter, because of numerous non-detects. The detection limit was used for the few non-detects in other cases. The results are shown in Figures 11 – 13.

Many factors could be responsible for the differences seen between predicted and observed concentrations of these contaminants in the Columbia River mainstem. The following observations seem warranted in the context of the present study:

- Predicted concentrations of T-DDT and dieldrin in the mainstem were higher than or similar to observed concentrations. This suggests there are no additional important sources of DDT compounds or dieldrin to the Lower Columbia River, beyond those monitored in the present study.
- There appears to be a net loss of DDT compounds from the water column between Bonneville Dam and Longview. A similar pattern was observed for dieldrin in the winter, but not in the spring.
- Observed concentrations of T-PCBs and T-HMW PAHs in the mainstem were higher than predicted. This suggests there are other important sources of PCBs and PAHs to the Lower Columbia River in addition to those identified in the present study.
- The discrepancy between observed and predicted concentrations of PCBs and PAHs is greatest downstream of Vancouver. The largest of the unidentified PCB and PAH sources therefore appear to be located between Vancouver and Longview.





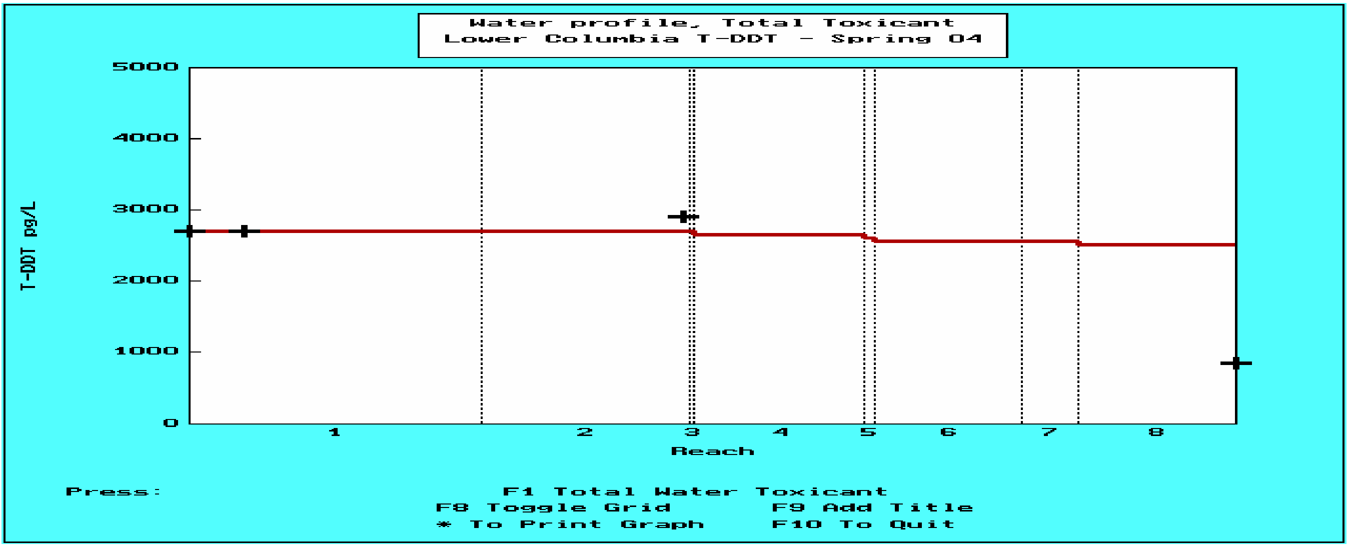
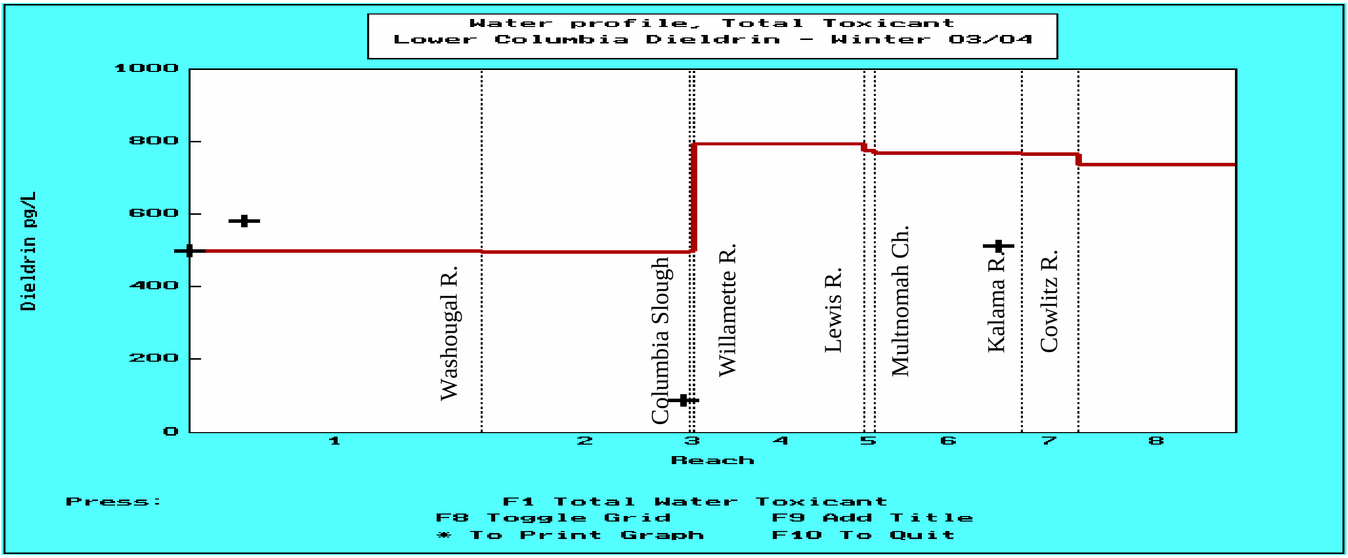
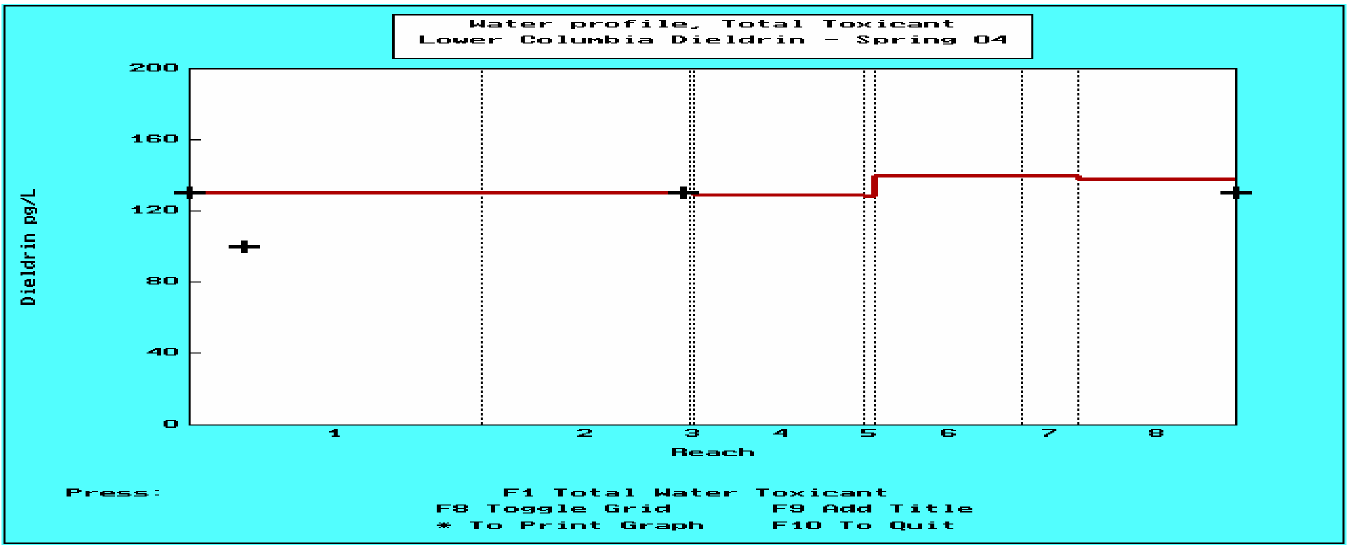


Figure 11. Simulated vs. Observed T-DDT Concentrations in the Columbia River Mainstem





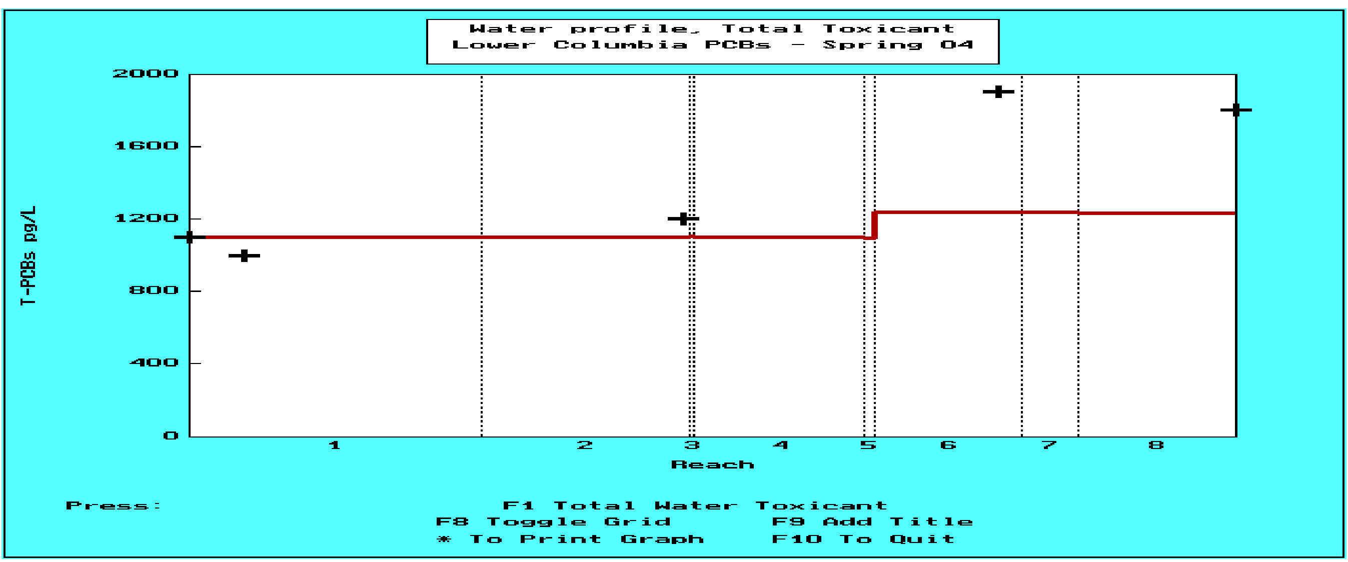
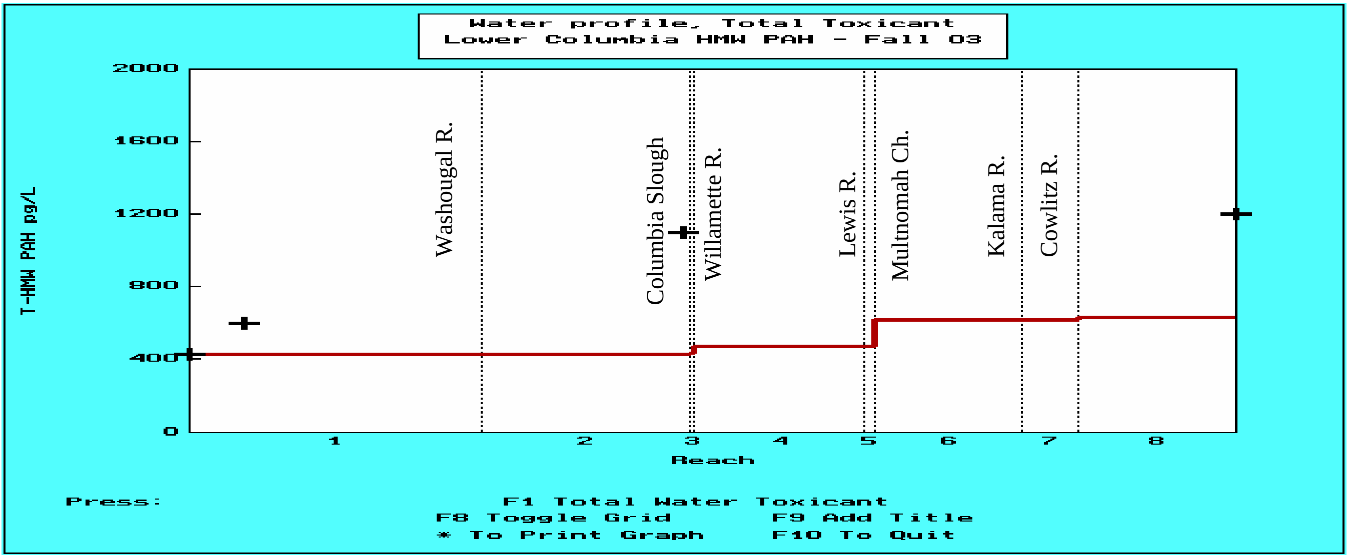
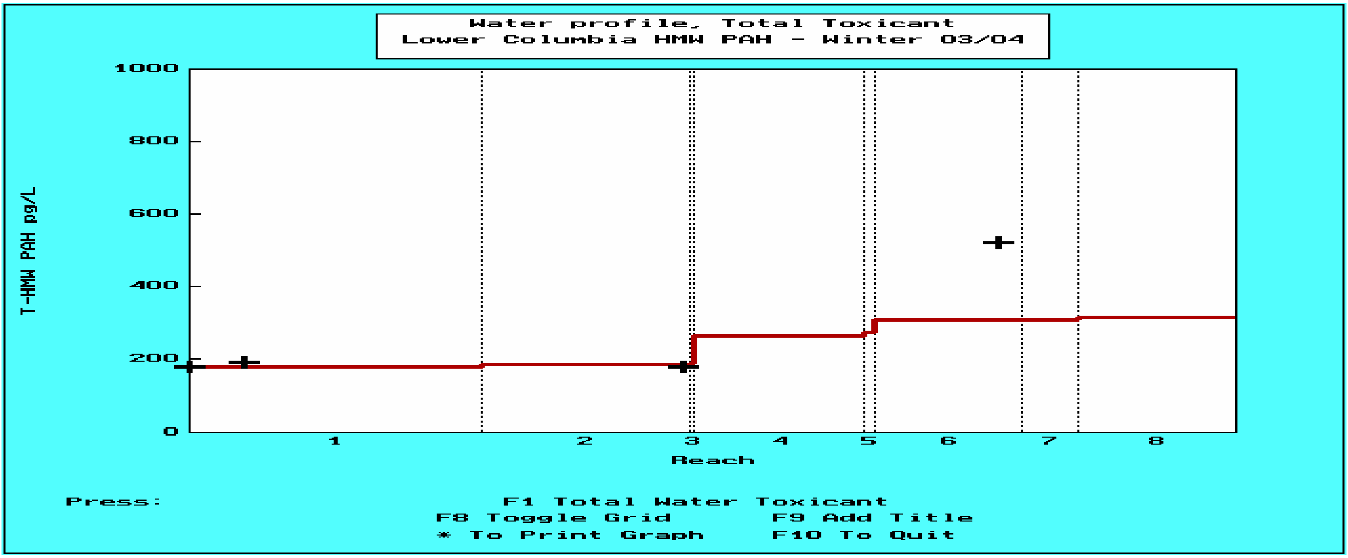


Figure 12. Simulated vs. Observed Dieldrin and T-PCB Concentrations in the Columbia River Mainstem





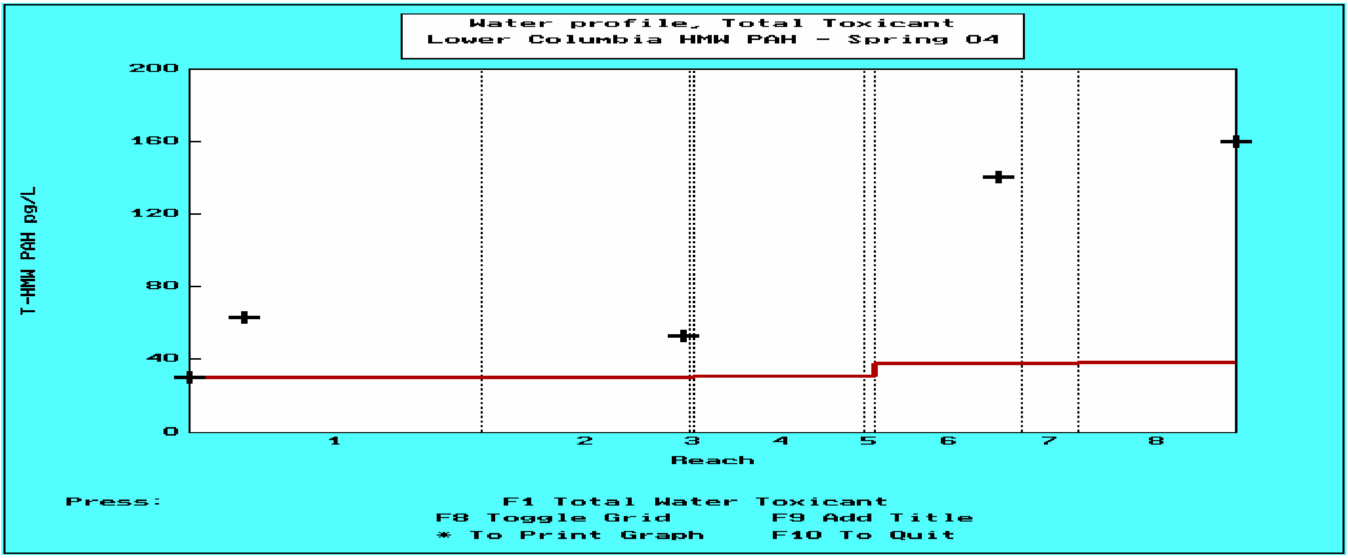


Figure 13. Simulated vs. Observed T-HMW PAH Concentrations in the Columbia River Mainstem

Conclusions

Within the area of the Lower Columbia River drainage monitored in the present study, human health criteria are commonly exceeded for dieldrin and PCBs, less frequently exceeded for DDT compounds, and, except for Columbia Slough, not exceeded for PAHs. The highest concentrations are generally found in the winter and spring for pesticides and PCBs, and in the fall for PAHs.

The major sources of DDT compounds and dieldrin are above Bonneville Dam. PCBs exceed human health criteria at Bonneville Dam due to upstream sources, but there are additional important sources of PCBs below the dam. While PAHs do not exceed criteria, concentrations are increased below Bonneville due to local sources. The Willamette River and Multnomah Channel are significant sources for all these compounds. The Washougal River, Columbia Slough, Lake River, Lewis River, Kalama River, and Cowlitz River have a low potential to influence levels of these chemicals in the Columbia River.

A screening-level loading assessment suggests there are other important PCB and PAH sources to the lower river that were not monitored in this study. These sources appear to be located primarily between Vancouver and Longview.

Recommendations

1. Efforts to reduce levels of DDT compounds and dieldrin in the Lower Columbia River should be directed at areas above Bonneville Dam and in the Willamette River drainage.

2. Efforts to reduce PCB concentrations in the Lower Columbia should include controls on upstream sources, in addition to the Willamette River drainage and other lower river sources.

3. Investigate sources of PCBs and PAHs between Vancouver and Longview that were not monitored during the present study.

4. If results of other ongoing or planned studies confirm that PAHs do not exceed human health criteria in the Lower Columbia, then the river should be de-listed for these compounds.

5. Do additional sampling to fill data gaps on PCB levels in the Columbia River mainstem.

6. Since the most recent data are 10 years old, resident Lower Columbia River fish should be re-analyzed to determine current levels of the 303(d) chemicals of concern in edible tissue.

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Appendices

A. Description of Sites Where SPMDs were Deployed in the Lower Columbia River During 2003-2004.

B. Chemicals Analyzed in the 2003-2004 Lower Columbia River SPMD Study.

C. Mean Temperatures and Exposure Times for the 2003-2004 Lower Columbia River SPMD Study.

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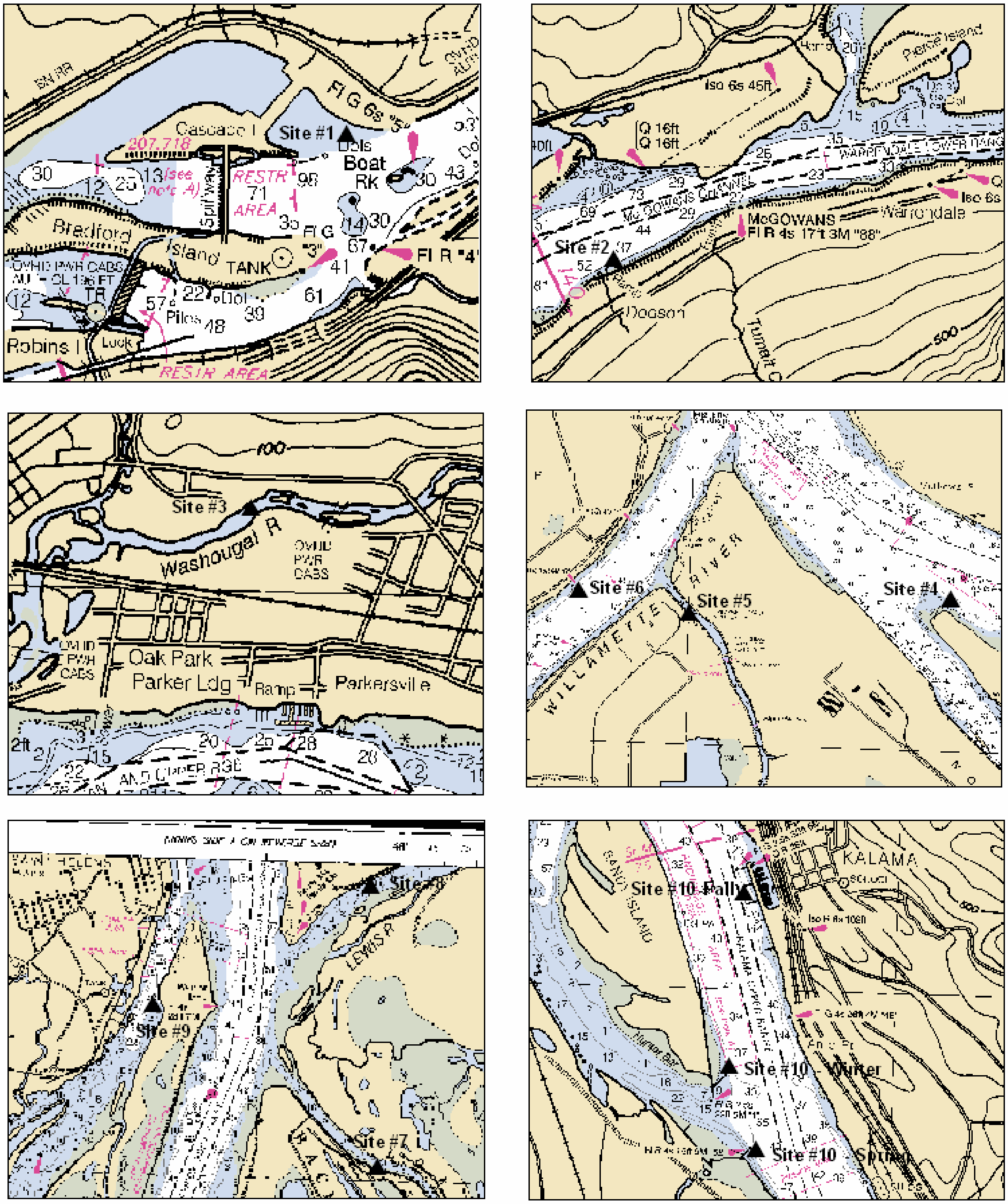
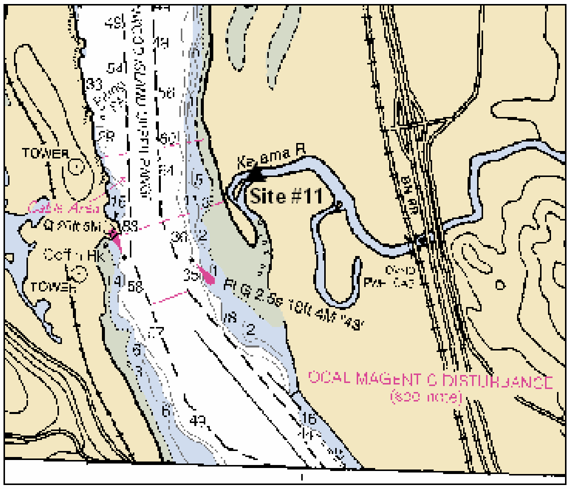
Appendix A. Description of Sites Where SPMDs Were Deployed in the Lower Columbia River During 2003-2004.

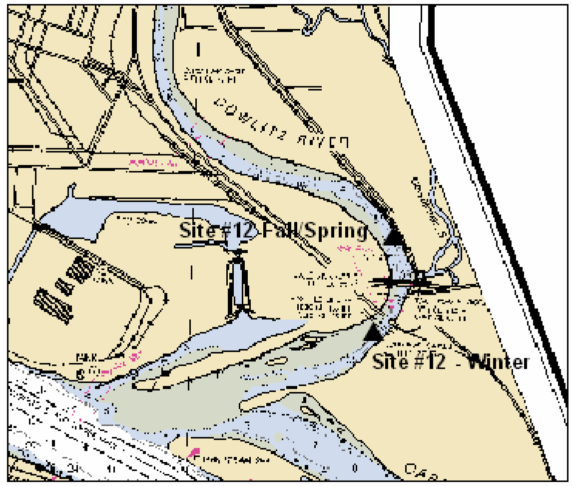
Site No.	Site Name	Description	Water Depth (ft.)	Latitude (NAD27)	Longitude (NAD27)
1	Columbia River above Bonneville Dam	Off right bank*, outside upstream end of Bonneville fish ladder	4-7	45^o 38' 52"	121^o 55' 59"
2	Columbia River below Bonneville Dam	Off left bank, under upstream end of dock at The Fishery boat launch	7-10	45^o 36' 31"	122^o 2' 14"
3	Washougal River	Off right bank, hung from massive rock at 2428 NE 3rd Loop, 1.3† miles above mouth	7-20	45^o 35' 16"	122^o 22' 48"
4	Columbia River above Willamette River	Just upstream from last line of pilings running out from downstream end of Hayden Island	25-27	45^o 38' 35"	122^o 44' 27"
5	Columbia Slough	At concrete bridge 0.2 mile above mouth	10-12	45^o 38' 21"	122^o 45' 44"
6	Willamette River	Off daymark "6"	30-35	45^o 38' 34"	122^o 46' 33"
7	Lake River	0.7 mile above mouth.	20-26	45^o 50' 05"	122^o 45' 59"
8	Lewis River	0.6 mile above mouth	4-13	45^o 51' 27"	122^o 46' 14"
9	Multnomah Channel	At metal tripod piling off right bank, 0.5 mile above mouth	32-41	45^o 50' 57"	122^o 47' 45"
10	Columbia River above Kalama	Off upstream end of Sandy Island (winter site);	40	45^o 59' 40"	122^o 50' 59"
		near daymark "52" (spring site)	35	45^o 59' 18"	122^o 50' 55"
11	Kalama River	Under dock at Clossom residence, Kalama Sportsmen's Club	8	46^o 02' 17"	122^o 52' 18"
12	Cowlitz River	Off left bank opposite boat ramp 1.2 miles above mouth (fall and spring site);	3-10	46^o 06' 39"	122^o 53' 32"
		near RR bridge 1.0 mile above mouth (winter site)	13	46^o 06' 10"	122^o 53' 38"
13	Columbia River below Longview	Off metal tripod piling at downstream end of Gull Island (fall and winter site);	20-22	46^o 11' 10"	123^o 09' 42"
		near right bank pilings across from Gull Island (spring site)	25	46^o 11' 33"	123^o 09' 31"

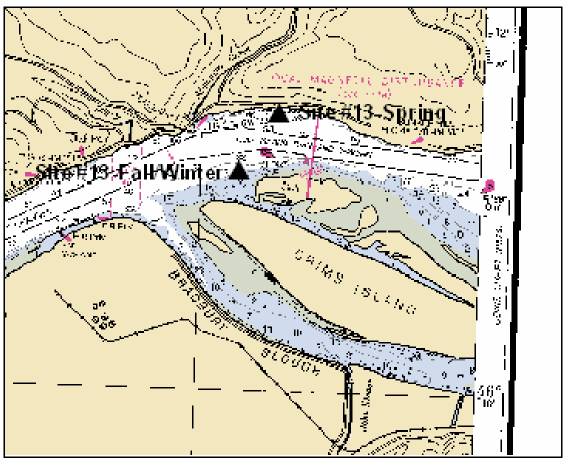
*facing downstream
†nautical miles
Note: The SPMDs were deployed in the lower 1/3 of the water column, except for sites 1, 5, 8, and 12 where the SPMDs were approximately 1 foot off the bottom.



Appendix A. Ecology SPMD Sites in the Lower Columbia River during 2003-2004.







Appendix A. (continued)

Appendix B. Chemicals Analyzed in the 2003-2004 Lower Columbia River SPMD Study.

Chlorinated Pesticides
4,4'-DDT
4,4'-DDE
4,4'-DDD
Dieldrin
a-BHC
b-BHC
gamma-BHC (Lindane)
d-BHC
Heptachlor
Aldrin
Heptachlor epoxide
Endosulfan I
Endrin
Endosulfan II
Endrin aldehyde
Endosulfan sulfate
Endrin ketone
Methoxychlor
Hexachlorobenzene
Toxaphene
trans-Chlordane
cis-Chlordane

PCB Aroclors
PCB-1016
PCB-1221
PCB-1232
PCB-1242
PCB-1254
PCB-1260

PCB Congeners (analyzed in spring 2004 samples only)

PAHs
Naphthalene
2-Methylnaphthalene
1-Methylnaphthalene
1,1'-Biphenyl
2-Chloronaphthalene
2,6-Dimethylnaphthalene
Acenaphthylene
Acenaphthene
Dibenzofuran
1,6,7-Trimethylnaphthalene

Appendix B (cont.)

PAHs (cont.)
Fluorene
9H-Fluorene, 1-methyl-
Dibenzothiophene
Phenanthrene
Anthracene
Carbazole
2-Methylphenanthrene
1-Methylphenanthrene
4,6-Dimethyldibenzothiophene
Phenanthrene, 3,6-dimethyl-
Fluoranthene
Pyrene
2-Methylfluoranthene
Retene
Benzo(a)anthracene
Chrysene
Chrysene, 5-methyl-
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(e)pyrene
Benzo(a)pyrene
Perylene
Indeno(1,2,3-cd)pyrene
Dibenzo(a,h)anthracene
Benzo(g,h,i)perylene

Appendix C. Mean Temperatures and Exposure Times for the 2003-2004 Lower Columbia SPMD Study.

Site	Aug.-Sept. 2003		Dec.-Jan. 2003/04		May-June 2004	
	Temp (^{o}C)	Time (days)	Temp (^{o}C)	Time (days)	Temp (^{o}C)	Time (days)
Above Bonneville Dam	20.6	29.1	5.2	29.0	15.3	29.0
Below Bonneville Dam	20.5	29.1	5.2	29.0	15.3	29.0
Washougal River	17.9	28.9	4.5	29.0	12.5	29.0
Above Willamette River	20.5	29.8	4.8	28.0	15.6	29.0
Willamette River	20.6	29.7	5.9	28.0	17.0	29.0
Columbia Slough	20.5	29.6	5.1	28.0	17.9	29.0
Lake River	20.2	29.2	4.5	28.0	16.8	29.0
Lewis River	16.3	27.8	6.7	28.0	11.8	29.0
Multnomah Channel	21.0	29.2	5.7	27.9	16.2	29.0
Above Kalama River	*	*	5.4	28.0	15.9	29.0
Kalama River	15.3	27.0	5.0	30.1	12.4	29.0
Cowlitz River	14.5	26.9	5.8	27.9	14.0	27.8
Below Longview	20.4	29.2	*	*	15.7	29.0

*SPMD lost

Appendix D. Percent Recovery of PRCs for the 2003-2004 Lower Columbia River SPMD Study.

Site	PCB-29 Aug.-Sept. 2003	PCB-29 Dec.- Jan. 2003-04	PCB-29 May-June 2004
Columbia ab. Bonneville	32	89 / 76*	68
Columbia bw. Bonneville	42	91 / 91*	58
Washougal River	75	100	80
Columbia ab. Willamette	30	52	60
Columbia Slough	33	100	28
Willamette River	50 / 75*	91	46
Lake River	50	81	74
Lewis River	74	84	72
Multnomah Channel	67	77	74 / 76*
Columbia ab. Kalama	**	73	54
Kalama River	92	87	76
Cowlitz River	90	81	74
Columbia bw. Longview	30 / 26*	**	68

Site	D10/D13-Anthracene Aug.-Sept. 2003	D10/D13-Anthracene Dec.- Jan. 2003-04	D10/D13-Anthracene May-June 2004
Columbia ab. Bonneville	12	41 / 34*	11
Columbia bw. Bonneville	16	41 / 32*	4
Washougal River	57	70	47
Columbia ab. Willamette	15	15	2
Columbia Slough	27	41	0
Willamette River	15 / 15*	45	1
Lake River	6	30	4
Lewis River	20	45	10
Multnomah Channel	20	32	1 / 7*
Columbia ab. Kalama	**	34	0
Kalama River	23	43	35
Cowlitz River	46	41	12
Columbia bw. Longview	14 / 13*	**	24

*replicate samples
**SPMD lost

Appendix E1. Pesticide and PCB Residues Measured in SPMD Extracts for the 2003-2004 Lower Columbia River SPMD Study: August - September 2003 Deployment (ng/SPMD)

	Field Blank 454427	Columbia River Above Bonneville Dam 454413	Columbia River Below Bonneville Dam 454414	Washougal River 454415	Columbia River Above Willamette River 454416	Columbia Slough 454417	Willamette River 454418	Willamette River (replicate) 454419
a-BHC	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
b-BHC	10 U	10 U	10 U	10 UJ	32	12 UJ	10 U	12 UJ
gamma-BHC	15	12	17	10 U	13	12	10 U	14
d-BHC	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ
Heptachlor	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Aldrin	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Heptachlor epoxide	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Endosulfan I	11 UJ	10 U	10 U	10 U	18 UJ	20 UJ	10 U	17 UJ
4,4'-DDE	10 U	160	120	11	110	160	77	86
Dieldrin	10 U	16	17	10 U	21	49	16	20
Endrin	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Endosulfan-II	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4,4'-DDD	10 U	130	100	10 U	98	150	79	84
Endrin aldehyde	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4,4'-DDT	10 U	12	15	10 U	10 U	15 NJ	12 NJ	11 NJ
Endosulfan sulfate	10 U	10 U	11 U	10 U	10 U	18	10	10 U
Endrin ketone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methoxychlor	10 U	10 U	10 U	10 U	10 U	10 U	10 U	12 UJ
HCB	10 U	28	24	13	20	26	12	24
Toxaphene	400 U	400 U	400 U	400 U	400 U	400 U	400 U	400 U
trans-Chlordane	11	18	32	17	16	51	19	26
cis-Chlordane	12	18	29	17	16	53	23	25
PCB-1016	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U
PCB-1221	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U
PCB-1232	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U
PCB-1242	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U
PCB-1248	200 U	200 U	200 U	200 U	200 U	350 NJ	100 NJ	120 NJ
PCB-1254	200 U	200 U	200 U	200 U	200 U	370 J	110 J	130 J
PCB-1260	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U
PCB-1262	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U
PCB-1268	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U

U = Not detected at or above the reported result.
UJ = Not detected at or above the reported estimated result.
J = The analyte was positively identified. The associated numerical results is an estimate.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate.

Appendix E1. (continued)

	Lake River 454420	Lewis River 454421	Multnomah Channel 454422	Columbia River Above Kalama River 454423	Kalama River 454424	Cowlitz River 454425	Columbia River Below Longview 454426	Columbia River Below Longview (replicate) 454428
a-BHC	10 U	10 U	10 U	sampler	10 U	10 U	10 U	10 U
b-BHC	18	11	46	lost in	31	18	10 U	10 U
gamma-BHC	11	10	11	field	11	12	10	10
d-BHC	10 UJ	10 UJ	10 UJ	"	10 UJ	10 UJ	10 UJ	10 UJ
Heptachlor	10 U	10 U	10 U	"	10 U	10 U	10 U	10 U
Aldrin	10 U	10 U	10 U	"	10 U	10 U	10 U	10 U
Heptachlor epoxide	10 U	10 U	10 U	"	10 U	10 U	10 U	10 U
Endosulfan I	10 U	10 U	13 UJ	"	10 U	10 U	12 UJ	10 UJ
4,4'-DDE	53	32	76	"	16	15	88	80
Dieldrin	12	10 U	29	"	10 U	10 U	18 U	15
Endrin	10 U	10 U	10 U	"	10 U	10 U	10 U	10 U
Endosulfan II	10 U	10 U	10 U	"	10 U	10 U	10 U	10 U
4,4'-DDD	49	17	110	"	10 U	10 U	79	78
Endrin aldehyde	10 U	10 U	10 U	"	10 U	10 U	10 U	10 U
4,4'-DDT	10 U	12	17 NJ	"	10 U	10 U	15	11
Endosulfan sulfate	10 U	10 U	10 U	"	10 U	10 U	10 U	10 U
Endrin ketone	10 U	10 U	10 U	"	10 U	10 U	10 U	10 U
Methoxychlor	10 U	10 U	10 U	"	10 U	10 U	10 U	10 U
HCB	13	12	30	"	16	10	20	20
Toxaphene	400 U	400 U	620 UJ	"	400 U	400 U	400 U	400 U
trans-Chlordane	16	25	42	"	22	26	28	17
cis-Chlordane	16	24	42	"	19	24	31	19
PCB-1016	200 U	200 U	200 U	"	200 U	200 U	200 U	200 U
PCB-1221	200 U	200 U	200 U	"	200 U	200 U	200 U	200 U
PCB-1232	200 U	200 U	200 U	"	200 U	200 U	200 U	200 U
PCB-1242	200 U	200 U	200 U	"	200 U	200 U	200 U	200 U
PCB-1248	120 NJ	200 U	190 NJ	"	200 U	200 U	200 U	200 U
PCB-1254	200 U	200 U	190 J	"	200 U	200 U	110 U	200 U
PCB-1260	200 U	200 U	200 U	"	200 U	200 U	200 U	200 U
PCB-1262	200 U	200 U	200 U	"	200 U	200 U	200 U	200 U
PCB-1268	200 U	200 U	200 U	"	200 U	200 U	200 U	200 U

U = Not detected at or above the reported result.
UJ = Not detected at or above the reported estimated result.
J = The analyte was positively identified. The associated numerical results is an estimate.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate.

Appendix E2. Pesticide and PCB Residues Measured in SPMD Extracts for the 2003-2004 Lower Columbia River SPMD Study: December 2003 - January 2004 Deployment (ng/SPMD)

	Field Blank 154245	Columbia River Above Bonneville Dam 154230	Columbia River Above Bonneville Dam - Rep 154231	Columbia River Below Bonneville Dam 154232	Columbia River Below Bonneville Dam - Rep 154233	Washougal River 154234	Columbia River Above Willamette River 154235	Columbia Slough 154236
a-BHC	10 UJ	10 U	10 U	10 U	10 U	12 UJ	10 U	14 UJ
b-BHC	10 UJ	10 U	10 U	10 U	10 U	10 U	10 U	10 U
gamma-BHC	13 J	13 J	13 J	13 J	14 J	12 J	8.7 J	14 NJ
d-BHC	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	18 UJ
Heptachlor	10 UJ	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Aldrin	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ
Heptachlor epoxide	10 UJ	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Endosulfan I	10 UJ	10 U	10 U	10 U	10 U	10 U	10 U	15 NJ
4,4'-DDE	2.2 J	76	60	83	89	10 U	94	65
Dieldrin	10 UJ	12	9.0 J	7.0 J	7.8 J	3.2 J	7.8 J	70
Endrin	10 UJ	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Endosulfan II	10 UJ	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4,4'-DDD	10 UJ	120	100	120	130	10 U	117 J	44 J
Endrin aldehyde	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ
4,4'-DDT	2.5 J	7.8 J	5.6 J	9.2 J	8.2 J	4.2 J	15 J	38 J
Endosulfan sulfate	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	16 J
Endrin ketone	10 UJ	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methoxychlor	10 UJ	10 U	10 U	10 U	10 U	10 U	10 U	10 U
HCB	10 UJ	12 J	10 J	15 J	15 J	7 J	20 J	20 J
Toxaphene	NA	NA	NA	NA	NA	NA	NA	NA
trans-Chlordane	5.4 J	10 U	10 U	10 U	10 U	5.8 J	15 J	26 J
cis-Chlordane	6.1 J	10 U	10 U	10 U	7.2 J	6.8 J	15 J	26 J
PCB-1016	50 U	100 U	100 U	100 U	100 U	100 U	100 U	260 UJ
PCB-1221	50 U	100 U	100 U	100 U	100 U	100 U	100 U	200 UJ
PCB-1232	50 U	100 U	100 U	200 U	100 U	100 U	100 U	400 UJ
PCB-1242	50 U	100 U	100 U	100 U	100 U	100 U	100 U	410 NJ
PCB-1248	50 U	100 U	100 U	100 U	100 U	100 U	100 U	330 NJ
PCB-1254	50 U	100 U	100 U	100 U	100 U	100 U	100 U	200 U
PCB-1260	50 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U
PCB-1262	50 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U
PCB-1268	50 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U

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Appendix E2. (continued)

	Willamette River 154237	Lake River 154238	Lewis River 154239	Multnomah Channel 154240	Columbia River Above Kalama River 154241	Kalama River 154242	Cowlitz River 154243	Columbia River Below Longview 154244
a-BHC	24 UJ	10 U	13 UJ	18 UJ	13 UJ	10 U	16 UJ	sampler
b-BHC	15 NJ	10 U	11 NJ	10 U	10 U	10 U	10 U	lost in
gamma-BHC	11 J	11 J	12 J	11 J	10 J	14 J	11 J	field
d-BHC	6.8 J	10 UJ	7.0 J	4.8 J	10 UJ	10 UJ	10 UJ	"
Heptachlor	10 U	10 U	10 U	10 U	10 U	10 U	10 U	"
Aldrin	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	"
Heptachlor epoxide	10 U	10 U	10 U	10 U	10 U	10 U	10 U	"
Endosulfan I	10 U	10 U	4.0 J	10 U	10 U	10 U	10 U	"
4,4'-DDE	57	26	10 U	37	72	10 U	6.8 J	"
Dieldrin	33	13 J	4.0 J	26	22	2.6 J	10 U	"
Endrin	10 U	10 U	10 U	10 U	10 U	10 U	10 U	"
Endosulfan II	10 U	10 U	10 U	10 U	10 U	10 U	10 U	"
4,4'-DDD	17 J	33 NJ	10 U	16 NJ	50 J	10 U	10 U	"
Endrin aldehyde	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	"
4,4'-DDT	37	4.0 J	6.6 J	20 J	27	10 U	3.2 J	"
Endosulfan sulfate	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	"
Endrin ketone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	"
Methoxychlor	10 U	10 U	10 U	10 U	10 U	10 U	10 U	"
HCB	44 J	8.9 J	7.1 J	25 J	37 J	10 J	17 J	"
Toxaphene	NA	NA	NA	NA	NA	NA	NA	
trans-Chlordane	13 NJ	10 U	10 U	10 U	10 U	10 U	10 U	"
cis-Chlordane	15 J	5 J	3.0 J	11 J	10 J	10 U	5.2 J	"
PCB-1016	100 U	100 U	100 U	100 U	100 U	100 U	100 U	"
PCB-1221	100 U	100 U	100 U	100 U	100 U	100 U	100 U	"
PCB-1232	200 U	100 U	100 U	200 U	200 U	200 U	200 U	"
PCB-1242	130 UJ	100 U	100 UJ	100 U	100 U	100 U	100 U	"
PCB-1248	100 U	100 U	100 U	100 U	100 U	100 U	100 U	"
PCB-1254	100 U	100 U	100 U	100 U	100 U	100 U	100 U	"
PCB-1260	100 U	100 U	100 U	100 U	100 U	100 U	100 U	"
PCB-1262	100 U	100 U	100 U	100 U	100 U	100 U	100 U	"
PCB-1268	100 U	100 U	100 U	100 U	100 U	100 U	100 U	"

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UJ = Not detected at or above the reported estimated result.
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NJ = There is evidence that the analyte is present. The associated numerical result is an estimate.

Appendix E3. Pesticide and PCB Residues Measured in SPMD Extracts for the 2003-2004 Lower Columbia River SPMD Study: May - June 2004 Deployment (ng/SPMD)

	Field Blank 314244	Columbia River Above Bonneville Dam 314230	Columbia River Below Bonneville Dam 314231	Washougal River 314232	Columbia River Above Willamette River 314233	Columbia Slough 314234	Willamette River 314235	Lake River 314236
a-BHC	20 U	20 U	20 U	20 U	20 U	20 UJ	20 UJ	20 U
b-BHC	20 U	20 U	20 U	20 U	20 U	20 UJ	20 UJ	20 U
gamma-BHC	67 J	56 J	34 J	40 J	42 J	63 J	31 J	34 J
d-BHC	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ
Heptachlor	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ
Aldrin	20 U	20 U	20 U	20 U	20 U	20 UJ	20 UJ	20 U
Heptachlor epoxide	20 U	6.9 J	5.2 J	20 U	6.4 J	22 J	20 UJ	5.6 J
Endosulfan I	20 U	36 J	41	11 J	41	72 J	28 J	28 J
4,4'-DDE	6.4 J	130	180	16 J	180	210 J	51 J	62
Dieldrin	20 U	15 J	17 J	5.6 J	20 J	135 J	16 J	20 J
Endrin	20 U	20 U	20 U	20 U	20 U	20 UJ	20 UJ	20 U
Endosulfan II	20 U	20 U	20 U	6.0 J	20 U	12 J	20 UJ	20 U
4,4'-DDD	20 U	110	140	20 U	140	174 J	43 J	55 J
Endrin aldehyde	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ
4,4'-DDT	20 U	12 J	15 J	6.8 J	20 J	20 UJ	8.4 J	7.6 J
Endosulfan sulfate	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ
Endrin ketone	20 U	20 U	20 U	20 U	20 U	20 UJ	20 UJ	20 U
Methoxychlor	20 U	10 J	15 J	20 U	20 U	20 UJ	10 J	11 NJ
HCB	20 U	23 J	28 J	9.2 J	30 J	42 J	17 J	16 J
Toxaphene	400 U	400 U	400 U	400 U	400 U	400 UJ	400 UJ	400 U
trans-Chlordane	20 U	8.6 NJ	20 U	10 J	9.2 J	45 NJ	6.8 J	7.4 J
cis-Chlordane	20 U	9.6 J	9.6 J	9.2 J	14 J	54 J	10 J	9.6 J
Dichlorobiphenyls	130	70	62	70	86	26	32	72
Heptachlorobiphenyls	0.10 U	1.6	2	0.88	2.2	7.8	2.6	2.4
Hexachlorobiphenyls	1.46	8.8	12.8	5	11.6	38	13	12
Monochlorobiphenyls	0.10 U	0.10 U	0.10 U	0.10 U	0.10	0.10 U	0.10 U	0.10 U
Nonachlorobiphenyls	0.10 U	0.10 U	0.10 U	0.10 U	0.10	0.10 U	0.10 U	0.10 U
Octachlorobiphenyls	0.10 U	0.10 U	0.10 U	0.10 U	0.10	0.74	0.10 U	0.10 U
Pentachlorobiphenyls	1.5	13	19	6.2	18	60	19	26
Tetrachlorobiphenyls	6	20	24	15	24	106	44	88
Trichlorobiphenyls	1.6	13	12	11	15	70	26	42

U = Not detected at or above the reported result.
UJ = Not detected at or above the reported estimated result.
J = The analyte was positively identified. The associated numerical results is an estimate.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate.

Appendix E3. (continued)

	Lewis River 314237	Multnomah Channel 314238	Multnomah Channel (replicate) 314239	Columbia River Above Kalama River 314240	Kalama River 314241	Cowlitz River 314242	Columbia River Below Longview 314243
a-BHC	20 U	20 U	20 U	extract	20 U	20 U	20 U
b-BHC	20 U	20 U	20 U	lost in	20 U	20 U	20 U
gamma-BHC	39 J	50 J	26 J	lab	29 J	26 J	25 J
d-BHC	20 UJ	20 UJ	20 UJ	accident	20 UJ	20 UJ	20 UJ
Heptachlor	20 UJ	20 UJ	20 UJ	"	20 UJ	20 UJ	20 UJ
Aldrin	20 U	20 U	20 U	"	20 U	20 U	20 U
Heptachlor epoxide	20 U	20 U	20 U	"	20 U	20 U	20 U
Endosulfan I	21 J	62	50	"	6.4 J	21 J	276 J
4,4'-DDE	13 J	61	55	"	10 J	8.8 J	82
Dieldrin	5.2 J	34	29 J	"	20 U	4.4 J	16 J
Endrin	20 U	20 U	20 U	"	20 U	16 NJ	20 U
Endosulfan II	4.8 J	20 U	10 J	"	20 U	4.0 J	20 U
4,4'-DDD	20 U	52 J	47 J	"	20 U	20 U	70 NJ
Endrin aldehyde	20 UJ	20 UJ	20 UJ	"	20 UJ	20 UJ	20 UJ
4,4'-DDT	6.3 J	17 J	14 J	"	20 U	4.0 J	9.6 J
Endosulfan sulfate	20 UJ	20 UJ	20 UJ	"	20 UJ	20 UJ	20 UJ
Endrin ketone	20 U	20 U	20 U	"	20 U	20 U	20 U
Methoxychlor	6.4 NJ	20 U	20 U	"	10 J	16 J	11 J
HCB	10 J	35 U	31 J	"	10 J	19 J	20 J
Toxaphene	400 U	400 J	400 U	"	400 U	400 U	400 U
trans-Chlordane	6.8 J	19 U	20 J	"	20 U	7.6 J	8.4 NJ
cis-Chlordane	6.6 J	23 J	22 J	"	5 J	7.6 J	8.8 J
Dichlorobiphenyls	74	146	70	54	72	82	96
Heptachlorobiphenyls	0.76	6.4	6.6	4.6	0.24	1.1	1.5
Hexachlorobiphenyls	4.6	26	26	20	4	7.2	8.8
Monochlorobiphenyls	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
Nonachlorobiphenyls	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
Octachlorobiphenyls	0.10 U	0.54	0.56	0.48 U	0.10 U	0.10 U	0.10 U
Pentachlorobiphenyls	5.4	30	32	36	7.6	11	20
Tetrachlorobiphenyls	20	68	82	50	15	14	42
Trichlorobiphenyls	16	40	46	26	7.8	6	16

U = Not detected at or above the reported result.
UJ = Not detected at or above the reported estimated result.
J = The analyte was positively identified. The associated numerical results is an estimate.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate.

Appendix E4. PAH Residues Measured in SPMD Extracts for the 2003-2004 Lower Columbia River SPMD Study: August - September 2003 Deployment (ng/SPMD)

	Field Blank 454427	Columbia River Above Bonneville Dam 454413	Columbia River Below Bonneville Dam 454414	Washougal River 454415	Columbia River Above Willamette River 454416	Columbia Slough 454417	Willamette River 454418	Willamette River (replicate) 454419
Benzo(a)anthracene	20 U	19 J	36	7 J	87	850	220	180
Chrysene	20 U	59	48	28	120	1200	270	230
Benzo(b)fluoranthene	20 U	16 J	16 J	13 J	34 J	370 J	70 J	66 J
Benzo(k)fluoranthene	20 U	19 J	19 J	11 J	39 J	400 J	66 J	73 J
Benzo(a)pyrene	20 U	6.5 J	8.2 J	3 J	30	210	26	11 J
Indeno(1,2,3-cd)pyrene	20 U	6.6 J	7.7 J	4.8 J	11 J	80	13 J	13 J
Dibenzo(a,h)anthracene	20 U	3.6 J	3.9 J	20 U	5.6 J	26	5.5 J	20 U
Benzo(g,h,i)perylene	20 U	4.4 J	6.6 J	3.6 J	4.6 J	63	13 J	12 J

	Lake River 454420	Lewis River 454421	Multnomah Channel 454422	Columbia River Above Kalama River 454423	Kalama River 454424	Cowlitz River 454425	Columbia River Below Longview 454426	Columbia River Below Longview (replicate) 454428
Benzo(a)anthracene	210	51	260	sampler	68	23	100	120
Chrysene	190	48	390	lost in	51	26	160	170
Benzo(b)fluoranthene	78 J	23 J	87 J	field	32 J	15 J	45 J	56 J
Benzo(k)fluoranthene	82 J	29 J	140 J	"	28 J	22 J	52 J	52 J
Benzo(a)pyrene	20	8.3 J	55	"	9.6 J	3.2 J	17 J	19 J
Indeno(1,2,3-cd)pyrene	12 J	8 J	22	"	7.1 J	6.9 J	10 J	9.7 J
Dibenzo(a,h)anthracene	20 U	4 J	8.5 J	"	0 U	20 U	20 U	5 J
Benzo(g,h,i)perylene	12 J	8 J	23	"	7.2 J	7.1 J	9.9 J	11 J

U = Not detected at or above the reported result.
UJ = Not detected at or above the reported estimated result.
J = The analyte was positively identified. The associated numerical results is an estimate.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate,

Appendix E5. PAH Residues Measured in SPMD Extracts for the 2003-2004 Lower Columbia River SPMD Study: December 2003 - January 2004 Deployment (ng/SPMD)

	Field Blank 154245	Columbia River Above Bonneville Dam 154230	Columbia River Above Bonneville Dam - Rep 154231	Columbia River Below Bonneville Dam 154232	Columbia River Below Bonneville Dam - Rep 154233	Washougal River 154234	Columbia River Above Willamette River 154235	Columbia Slough 154236
Benzo(a)anthracene	10 U	4.4 J	3.7 J	4.7 J	5.4 J	3.5 J	15	90
Chrysene	2.2	18	16	20	19	10	40	250
Benzo(b)fluoranthene	10 U	3.5 J	3.2 J	3.3 J	4.6 J	4.6 J	6 J	33 J
Benzo(k)fluoranthene	10 U	4.4 J	3.8 J	4.8 J	4 J	3.7 J	5.8 J	46 J
Benzo(a)pyrene	10 U	1.4 J	1 J	1.6 J	1.3 J	1.8 J	2.5 J	24 J
Indeno(1,2,3-cd)pyrene	10 U	1.4 J	1.5 J	1.3 J	1.3 J	1.4 J	1.4 J	5.8 J
Dibenzo(a,h)anthracene	10 U	1 J	0.97 J	0.92 J	0.82 J	0.87 J	0.95 J	3.3 J
Benzo(g,h,i)perylene	10 U	1.3 J	1.4 J	1.4 J	1.3 J	1.4 J	1.8 J	9.2 J

	Willamette River 154237	Lake River 154238	Lewis River 154239	Multnomah Channel 154240	Columbia River Above Kalama River 154241	Kalama River 154242	Cowlitz River 154243	Columbia River Below Longview 154244
Benzo(a)anthracene	20	10	14	18	23	8.1 J	15	sampler
Chrysene	40	26	39	36	56	18	34	lost in
Benzo(b)fluoranthene	4.8 J	5 J	14 J	5.1 J	4.8 J	5 J	6.8 J	field
Benzo(k)fluoranthene	6.1 J	5.6 J	12 J	5.6 J	7.8 J	7 J	8.9 J	"
Benzo(a)pyrene	3.9 J	10 U	4.1 J	3.4 J	4.1 J	2.3 J	4.4 J	"
Indeno(1,2,3-cd)pyrene	1.4 J	1.2 J	2.8 J	1.5 J	1.8 J	1.6 J	1.9 J	"
Dibenzo(a,h)anthracene	0.95 J	0.84 J	1.2 J	1.2 J	1.3 J	1 J	1.1 J	"
Benzo(g,h,i)perylene	2.2 J	1.7 J	2.8 J	2.2 J	2.4 J	1.7 J	2.1 J	"

U = Not detected at or above the reported result.
UJ = Not detected at or above the reported estimated result.
J = The analyte was positively identified. The associated numerical results is an estimate.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate,

Appendix E6. PAH Residues Measured in SPMD Extracts for the 2003-2004 Lower Columbia River SPMD Study: May - June 2004 Deployment (ng/SPMD)

	Field Blank 314244	Columbia River Above Bonneville Dam 314230	Columbia River Below Bonneville Dam 314231	Washougal River 314232	Columbia River Above Willamette River 314233	Columbia Slough 314234	Willamette River 314235	Lake River 314236
Benzo(a)anthracene	20 U	20 U	11 J	20 U	11 J	130	20	19 J
Chrysene	20 U	19 J	36 J	10 J	35 J	420 J	50 J	46 J
Benzo(b)fluoranthene	20 U	20 U	20 U	20 U	20 U	82 J	20 U	20 U
Benzo(k)fluoranthene	20 U	20 U	20 U	20 U	20 U	78 J	20 U	20 U
Benzo(a)pyrene	20 U	20 U	20 U	20 U	20 U	42	20 U	20 U
Indeno(1,2,3-cd)pyrene	20 U	20 U	20 U	20 U	20 U	18 J	20 U	20 U
Dibenzo(a,h)anthracene	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
Benzo(g,h,i)perylene	20 U	20 U	20 U	20 U	20 U	27 J	20 U	20 U

	Lewis River 314237	Multnomah Channel 314238	Multnomah Channel (replicate) 314239	Columbia River Above Kalama River 314240	Kalama River 314241	Cowlitz River 314242	Columbia River Below Longview 314243
Benzo(a)anthracene	20 U	33	34	36 J	20 U	12	15 J
Chrysene	19 J	69 J	72 J	87 J	15 J	24 J	38 J
Benzo(b)fluoranthene	20 U	10 J	20 U	12 J	20 U	20 U	20 U
Benzo(k)fluoranthene	20 U	12 J	16 J	11 J	20 U	20 U	20 U
Benzo(a)pyrene	20 U	20 U	20 U	20 UJ	20 U	20 U	20 U
Indeno(1,2,3-cd)pyrene	20 U	20 U	20 U	20 UJ	20 U	20 U	20 U
Dibenzo(a,h)anthracene	20 U	20 U	20 U	20 UJ	20 U	20 U	20 U
Benzo(g,h,i)perylene	20 U	20 U	20 U	20 UJ	20 U	20 U	20 U

U = Not detected at or above the reported result.
UJ = Not detected at or above the reported estimated result.
J = The analyte was positively identified. The associated numerical results is an estimate.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate,

Appendix F. Estimated Water Concentration Calculator From SPMD Data (D. Alvarez, USGS, 8/29/2002)

To calculate the estimated water concentrations (C_W) from SPMD data, enter the appropriate information into the highlighted yellow cells.

Enter a temperature value (10, 18, or 26) in °C which most closely approximates the actual exposure water temperature.

Temperature (°C) = 18 **Exposure Time (d) =** 21
mass of SPMD (g) = 4.5 (NOTE: a standard 81 cm SPMD has a mass of 4.5 g)
Volume of Lipid (L) = 0.001 **Volume of Membrane (L) =** 0.0037 **Volume of SPMD (L) =** 0.0047

(NOTE: a standard 81 cm SPMD has lipid volume of 0.001L, membrane volume of 0.0037L, and a total volume of 0.0047L.)

If a PRC was used, the $k_{e\text{-}PRC}$ can be calculated by $k_{e\text{-}PRC} = [\ln(C_{SPMDo}/C_{SPMD})]/t$. If a PRC was not used, enter the same number for the $k_{e\text{-}PRC}$ as for the $k_{e\text{-}cal}$.

$k_{e\text{-}PRC}$ (d^{-1})= 0.021

The $k_{e\text{-}cal}$ value is the laboratory calibration value for the native PRC analog.

$k_{e\text{-}cal}$ (d^{-1})= 0.021 (NOTE: the $k_{e\text{-}cal}$ for D_{10}-Phenanthrene is 0.021 d^{-1})

Estimated water concentrations can not be calculated for all compounds.
For compounds in which laboratory R_s values do not exist, the term N/A will appear in place of a numerical value, indicating the inability to estimate the water concentration.
The final Estimated Water Concentration values appear in the light blue highlighted cells.

Project Name: **Water Sampling Project No. 1**

Compound	Log K_{ow}	K_{SPMD}	Laboratory R_s (L/d)	PRC corrected R_s (L/d)	Theoretical $t_{1/2}$	Total Analyte (ng/SPMD)	Water Conc. (pg/L)	Model Used
p,p'-DDE	6.14 [a]	2.50E+05	6.9	6.9	118.1	10.0	69.0	linear
Dieldrin	4.60 [a]	2.38E+04	4.0	4.0	19.4	10.0	47.2	curvilinear
p,p'-DDD	5.75 [a]	1.54E+05	3.8	3.8	131.6	10.0	125.3	linear
p,p'-DDT	5.47 [a]	1.04E+05	5.6	5.6	60.2	10.0	85.0	linear
Total PCB [g, h]	6.40 [g, h]	3.33E+05	4.8	4.8	226.2	10.0	99.2	linear
Naphthalene	3.45 [f]	1.90E+03	0.9	0.9	6.9	10.0	988.7	curvilinear
Acenaphthylene	4.08 [f]	8.26E+03	1.4	1.4	19.2	10.0	137.1	curvilinear
Acenaphthene	4.22 [f]	1.11E+04	2.3	2.3	15.8	10.0	115.4	curvilinear
Fluorene	4.38 [f]	1.55E+04	1.7	1.7	29.7	10.0	280.1	linear
Phenanthrene	4.46 [f]	1.82E+04	3.4	3.4	17.4	10.0	66.5	curvilinear
Anthracene	4.54 [f]	2.12E+04	3.6	3.6	19.2	10.0	53.3	curvilinear
Fluoranthene	5.20 [f]	6.83E+04	4.6	4.6	48.4	10.0	103.5	linear
Pyrene	5.30 [f]	8.00E+04	5.2	5.2	50.1	10.0	91.6	linear
Benz[a]anthracene	5.91 [f]	1.89E+05	3.6	3.6	171.2	10.0	132.3	linear
Chrysene	5.61 [f]	1.27E+05	5.1	5.1	80.9	10.0	93.4	linear
Benzo[b]fluoranthene	5.78 [f]	1.60E+05	3.4	3.4	153.1	10.0	140.1	linear
Benzo[k]fluoranthene	6.20 [f]	2.68E+05	4.0	4.0	218.3	10.0	119.0	linear
Benzo[a]pyrene	6.35 [f]	3.16E+05	4.3	4.3	239.5	10.0	110.7	linear
Indeno[1,2,3-cd]pyrene	6.75 [f]	4.68E+05	4.2	4.2	363.1	10.0	113.4	linear
Dibenzo[a,h]anthracene	6.51 [f]	3.73E+05	3.3	3.3	368.2	10.0	144.3	linear
Benzo[g,h,I]perylene	6.90 [f]	5.33E+05	2.4	2.4	723.1	10.0	198.4	linear

The linear model of estimation was used in cases where a compound's log K_{ow}>6.
This calculator applies only to SPMDs which conform to the surface area-to-volume ratio of a standard SPMD.
If multiple log K_{ow} values were found in the literature, a mean value was selected using the t test at 95% Confidence for rejection of outliers.

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Appendix G1. Results on Field Replicates: Pesticides and PCBs

	Willamette River Aug-Sept 2003			Columbia R. bw Longview Aug-Sept 2003			Columbia R. ab Bonneville Dec-Jan 2003-04			Columbia R. bw Bonneville Dec-Jan 2003-04			Multnomah Channel May-June 2004		
	Rep. 1	Rep. 2	RPD	Rep. 1	Rep. 2	RPD	Rep. 1	Rep. 2	RPD	Rep. 1	Rep. 2	RPD	Rep. 1	Rep. 2	RPD
1. Residue Accumulated in SPMD (ng/SPMD)															
4,4'-DDE	77	86	**11**	88	80	**10**	76	60	**24**	83	89	**7**	61	55	**10**
Dieldrin	16	20	**22**	18 U	15	- -	12	9.0 J	**29**	7.0 J	7.8 J	**11**	34	29 J	**16**
4,4'-DDD	79	84	**6**	79	78	**1**	120	100	**18**	120	130	**8**	52 J	47 J	**10**
4,4'-DDT	12 NJ	11 NJ	**9**	15	11	**31**	7.8 J	5.6 J	**33**	9.2 J	8.2 J	**11**	17 J	14 J	**19**
HCB	12	24	**67**	20	20	**0**	12 J	10 J	**18**	15 J	15 J	**0**	35 U	31 J	- -
Total PCBs	210 J	250 J	**17**	110 J	200 U	- -	100 U	100 U	- -	100 U	100 U	- -	168	190	**12**
PCB-29*	50	75	**40**	30	26	**14**	89	76	**16**	91	91	**0**	74	76	**3**
2. Calculated Water Column Concentration (pg/L)															
4,4'-DDE	210	560	**91**	140	110	**24**	1,500	500	**100**	2,000	2,200	**10**	340	330	**3**
Dieldrin	75	230	**102**	<49	14	**- -**	740	240	**102**	540	600	**11**	370	340	**8**
4,4'-DDD	390	1,000	**88**	220	200	**10**	4,300	1,500	**97**	5,300	5,800	**9**	590	590	**0**
4,4'-DDT	40	89	**76**	29	19	**42**	180	46	**119**	290	250	**15**	130	120	**8**
HCB	63	300	**131**	60	54	**11**	510	180	**96**	800	800	**0**	420	410	**2**
Total PCBs	820	2,400	**98**	250	<400	**- -**	<2,300	<990	- -	<2,900	<2,900	- -	1,500	1,900	**24**

RPD = Relative Percent Difference (range as percent of mean)
U = Not detected at or above the reported result.
J = The analyte was positively identified. The associated numerical result is an estimate.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate,
*Performance Reference Compound (percent recovery)

Appendix G2. Results on Field Replicates: PAHs

	Willamette River Aug-Sept 2003			Columbia R. bw Longview Aug-Sept 2003			Columbia R. ab Bonneville Dec-Jan 2003-04			Columbia R. bw Bonneville Dec-Jan 2003-04			Multnomah Channel May-June 2004		
	Rep. 1	Rep. 2	RPD	Rep. 1	Rep. 2	RPD	Rep. 1	Rep. 2	RPD	Rep. 1	Rep. 2	RPD	Rep. 1	Rep. 2	RPD
1. Residue Accumulated in SPMD (ng/SPMD)															
Benzo(a)anthracene	220	180	**20**	100	120	**18**	4.4	3.7	**17**	4.7	5.4	**14**	33	34	**3**
Chrysene	270	230	**16**	160	170	**6**	18	16	**12**	20	19	**5**	69 J	72 J	**4**
Benzo(b)fluoranthene	70	66	**6**	45	56	**22**	3.5	3.2	**9**	3.3	4.6	**33**	10 J	20 U	- -
Benzo(k)fluoranthene	66	73	**10**	52	52	**0**	4.4	3.8	**15**	4.8	4	**18**	12 J	16 J	**29**
Benzo(a)pyrene	26	11	**81**	17	19	**11**	1.4	1	**33**	1.6	1.3	**21**	20 U	20 U	- -
Indeno(1,2,3-cd)pyrene	13	13	**0**	10	9.7	**3**	1.4	1.5	**7**	1.3	1.3	**0**	20 U	20 U	- -
Dibenzo(a,h)anthracene	5.5	20 U	- -	20 U	5	- -	1	1.0	**3**	0.9	0.8	**11**	20 U	20 U	- -
Benzo(g,h,i)perylene	13	12	**8**	9.9	11	**11**	1.3	1.4	**7**	1.4	1.3	**7**	20 U	20 U	- -
Total HMW PAH	684	585	**16**	414	443	**7**	35	32	**11**	38	38	**1**	124	122	**2**
D10/C13 Anthracene*	15	15	**0**	14	13	**7**	41	43	**5**	41	32	**25**	1	7	**150**
2. Calculated Water Column Concentration (pg/L)															
Benzo(a)anthracene	450	370	**20**	200	180	**11**	15	11	**31**	16	14	**13**	29	50	**53**
Chrysene	390	340	**14**	230	180	**24**	49	36	**31**	55	41	**29**	43	75	**54**
Benzo(b)fluoranthene	150	140	**7**	95	90	**5**	13	10	**26**	13	14	**7**	9	<31	- -
Benzo(k)fluoranthene	120	140	**15**	94	71	**28**	16	11	**37**	17	11	**43**	10	21	**75**
Benzo(a)pyrene	44	19	**79**	28	24	**15**	5	3	**51**	6	4	**43**	<15	<25	- -
Indeno(1,2,3-cd)pyrene	23	23	**0**	17	13	**27**	5	5	**12**	5	4	**23**	<15	<25	- -
Dibenzo(a,h)anthracene	12	<45	**- -**	<44	8	--	5	4	**23**	5	3	**36**	<19	<32	- -
Benzo(g,h,i)perylene	40	37	**8**	30	25	**18**	8	8	**11**	9	7	**32**	<26	<44	- -
Total HMW PAH	40	37	**8**	690	590	**16**	120	87	**32**	130	98	**28**	90	150	**50**

RPD = relative percent difference (range as percent of mean)
U = Not detected at or above the reported result.
J = The analyte was positively identified. The associated numerical result is an estimate.
*Performance Reference Compound (percent recovery)

Appendix G3. Results on Field Blanks: Pesticides and PCBs (ng/SPMD).

	Aug-Sept 2003		Dec-Jan 2003-04		May-June 2004	
a-BHC	10	U	10	UJ	20	U
b-BHC	10	U	10	UJ	20	U
gamma-BHC (Lindane)	**15**		**13**	J	**67**	J
d-BHC	10	UJ	10	UJ	20	UJ
Heptachlor	10	U	10	UJ	20	UJ
Aldrin	10	U	10	UJ	20	U
Heptachlor epoxide	10	U	10	UJ	20	U
Endosulfan I	11	UJ	10	UJ	20	U
4,4'-DDE	10	U	**2.2**	J	**6.4**	J
Dieldrin	10	U	10	UJ	20	U
Endrin	10	U	10	UJ	20	U
Endosulfan II	10	U	10	UJ	20	U
4,4'-DDD	10	U	10	UJ	20	U
Endrin aldehyde	10	U	10	UJ	20	UJ
4,4'-DDT	10	U	**2.5**	J	20	U
Endosulfan sulfate	10	U	10	UJ	20	UJ
Endrin ketone	10	U	10	UJ	20	U
Methoxychlor	10	U	10	UJ	20	U
Hexachlorobenzene (HCB)	10	U	10	UJ	20	U
Toxaphene	400	U	NA		400	U
trans-Chlordane	**11**		**5.4**	J	20	U
cis-Chlordane	**12**		**6.1**	J	20	U
PCBs (Aroclor equivalents)	200	U	50	U	NA	
Monochlorobiphenyls	NA		NA		0.10	U
Dichlorobiphenyls	NA		NA		**65**	
Tetrachlorobiphenyls	NA		NA		**3.0**	
Trichlorobiphenyls	NA		NA		**0.81**	
Pentachlorobiphenyls	NA		NA		**0.76**	
Hexachlorobiphenyls	NA		NA		**0.73**	
Heptachlorobiphenyls	NA		NA		0.10	U
Octachlorobiphenyls	NA		NA		0.10	U
Nonachlorobiphenyls	NA		NA		0.10	U

U = Not detected at or above the reported result.
UJ = Not detected at or above the reported estimated result.
J = The analyte was positively identified. The associated numerical result is an estimate.
NA = not analyzed

Appendix G4. Results on Field Blanks: PAH (ng/SPMD).

	Aug-Sept 2003		Dec-Jan 2003-04		May-June 2004	
Naphthalene	**330**		**660**		**160**	
Acenaphthylene	10	U	3	J	20	U
Acenaphthene	**4.2**		**9.8**	J	20	U
Fluorene	10	U	**12**	J	20	U
Phenanthrene	**24**		**74**		23	UJ
Anthracene	10	U	20	U	20	U
Fluoranthene	**9.4**	J	**27**		20	U
Pyrene	**9.1**	J	**20**		20	U
Benzo(a)Anthracene	10	U	20	U	20	U
Chrysene	**2.2**		20	U	20	U
Benzo(b)fluoranthene	10	U	20	U	20	U
Benzo(k)fluoranthene	10	U	20	U	20	U
Benzo(a)pyrene	10	U	20	U	20	U
Indeno(1,2,3-cd)pyrene	10	U	20	U	20	U
Dibenzo(a,h)anthracene	10	U	20	U	20	U
Benzo(g,h,i)perylene	10	U	20	U	20	U

U = Not detected at or above the reported result.
UJ = Not detected at or above the reported estimated result.
J = The analyte was positively identified. The associated numerical result is an estimate.

Appendix H. Ancillary Water Quality Data.

Site	Sample Number	Date	Conduct. umhos/cm)	TSS (mg/L)	TOC (mg/L)	DOC (mg/L)
Columbia River Ab. Bonneville Dam	354155	8/27/2003	140	8	1.9	1.7
Columbia River Bw. Bonneville Dam	354156	8/27/2003	121	sample lost	2.1	1.6
Washougal River	354157	8/27/2003	N/A	<1	1.4	1.3
Columbia River Ab. Willamette River	354158	8/27/2003	130	6	1.9	1.9
Columbia Slough	354159	8/27/2003	165	10	1.9	1.9
Willamette River	354160	8/27/2003	140	10	1.8	1.9
Lake River	354161	8/28/2003	130	15	1.9	1.9
Lewis River	354162	8/28/2003	43	4	1.2	1.2
Multnomah Channel	354163	8/28/2003	120	16	1.7	1.9
Columbia River Ab. Kalama River	354164	8/28/2003	108	6	2	2.1
Kalama River	354165	8/29/2003	43	2	<1.0	1
Cowlitz River	354166	8/29/2003	102	9	1.4	1.3
Columbia River Bw. Longview	354167	8/28/2003	130	13	1.8	1.9
Columbia River Ab. Bonneville Dam	384080	9/15/2003	133	3	1.7	1.3
Columbia River Bw. Bonneville Dam	384081	9/15/2003	135	3	1.6	1.4
Washougal River	384082	9/15/2003	46	1	1.5	1.4
Columbia River Ab. Willamette River	384083	9/15/2003	140	3	1.6	1.4
Columbia Slough	384084	9/15/2003	127	15	1.8	1.4
Willamette River	384085	9/15/2003	120	9	1.8	1.6
Lake River	384086	9/16/2003	156	41	3.1	2.7
Lewis River	384087	9/16/2003	105	3	1.6	1.4
Multnomah Channel	384088	9/16/2003	140	9	1.6	1.7
Columbia River Ab. Kalama River	384089	9/16/2003	136	3	1.6	1.3
Kalama River	384090	9/16/2003	70	2	<1.0	1.3
Cowlitz River	384091	9/16/2003	105	5	1.1	1
Columbia River Bw. Longview	384092	9/16/2003	140	7	1.6	1.6
Columbia River Ab. Bonneville Dam	394400	9/24/2003	127	4	1.1	1
Columbia River Bw. Bonneville Dam	394401	9/24/2003	138	3	1	1
Washougal River	394402	9/24/2003	46	2	<1.0	<1.0
Columbia River Ab. Willamette River	394403	9/25/2003	122	5	1	1.1
Columbia Slough	394404	9/25/2003	108	8	1.1	1.1
Willamette River	394405	9/25/2003	130	7	1.2	1
Lake River	394406	9/25/2003	129	14	1.2	1.2
Lewis River	394407	9/24/2003	42	5	<1.0	<1.0
Multnomah Channel	394408	9/25/2003	118	8	1.1	1.1
Columbia River Ab. Kalama River	394409	9/25/2003	129	4	1.2	1
Kalama River	394410	9/24/2003	66	1	<1.0	<1.0

Appendix H. (continued)

Site	Sample Number	Date	Conduct. umhos/cm)	TSS (mg/L)	TOC (mg/L)	DOC (mg/L)
Cowlitz River	394411	9/24/2003	101	6	<1.0	<1.0
Columbia River Bw. Longview	394412	9/25/2003	139	6	1.3	1.2
Columbia River Ab. Bonneville Dam	514105	12/15/2003	160	3	1.1	1.1
Columbia River Bw. Bonneville Dam	514106	12/15/2003	152	4	1.2	1.2
Washougal River	514107	12/15/2003	25	3	<1.0	<1.0
Columbia River Ab. Willamette River	514108	12/16/2003	155	6	1.1	1.3
Columbia Slough	514109	12/16/2003	75	26	2.3	2.5
Willamette River	514110	12/16/2003	73	40	2.7	2.9
Lake River	514111	12/17/2003	170	11	1.4	1.5
Lewis River	514112	12/17/2003	45	3	<1.0	<1.0
Multnomah Channel	514113	12/17/2003	65	31	2.7	2.7
Columbia River Ab. Kalama River	514114	12/17/2003	105	33	2.3	2.2
Kalama River	514115	12/15/2003	47	8	1.1	<1.0
Cowlitz River	514116	12/17/2003	76	121	1.5	1.4
Columbia River Bw. Longview	514117	12/17/2003	106	35	1.9	2
Columbia River Ab. Bonneville Dam	24105	1/5/2004	160	11	1.1	1.1
Columbia River Bw. Bonneville Dam	24106	1/5/2004	170	7	1.1	1
Washougal River	no samples due to ice and snow					
Columbia River Ab. Willamette River	24108	1/5/2004	170	19	1.1	1.1
Columbia Slough	no samples due to ice and snow					
Willamette River	24110	1/5/2004	86	35	3.1	2.1
Lake River	no samples due to ice and snow					
Lewis River	24112	1/5/2004	47	1	<1.0	<1.0
Multnomah Channel	24113	1/5/2004	70	7	2	1.8
Columbia River Ab. Kalama River	24114	1/5/2004	146	5	1.5	1.2
Kalama River	24115	1/5/2004	46	1	<1.0	<1.0
Cowlitz River	24116	1/5/2004	68	39	1.1	1.1
Columbia River Bw. Longview	no samples due to ice and snow					
Columbia River Ab. Bonneville Dam	34250	1/12/2004	150	2	1.1	1
Columbia River Bw. Bonneville Dam	34251	1/12/2004	150	4	1	1
Washougal River	34252	1/12/2004	34	2	<1.0	<1.0
Columbia River Ab. Willamette River	34253	1/12/2004	148	4	1.1	1.1
Columbia Slough	34254	1/12/2004	225	10	1.3	2.7
Willamette River	34255	1/12/2004	73	35	2.4	1.6
Lake River	34256	1/13/2004	119	8	2.4	1.9
Lewis River	34257	1/13/2004	41	2	<1.0	<1.0
Multnomah Channel	34258	1/13/2004	118	9	2.4	1.6

Appendix H. (continued)

Site	Sample Number	Date	Conduct. umhos/cm)	TSS (mg/L)	TOC (mg/L)	DOC (mg/L)
Columbia River Ab. Kalama River	34259	1/13/2004	112	11	1.7	1.4
Kalama River	34260	1/13/2004	52	18	<1.0	<1.0
Cowlitz River	34261	1/13/2004	83	40	1.4	1.3
Columbia River Bw. Longview	34262	1/13/2004	91	9	1.7	1.5
Columbia River Ab. Bonneville Dam	224105	5/24/2004	120	14	1.7	1.6
Columbia River Bw. Bonneville Dam	224106	5/24/2004	130	9	1.8	1.6
Washougal River	224107	5/24/2004	31	3	1.1	1.1
Columbia River Ab. Willamette River	224108	5/24/2004	125	10	2.1	1.6
Columbia Slough	224109	5/24/2004	210	22	3.4	1.8
Willamette River	224110	5/24/2004	110	12	2	1.5
Lake River	224111	5/25/2004	140	17	2.6	1.9
Lewis River	224112	5/25/2004	43	2	<1.0	1.1
Multnomah Channel	224113	5/25/2004	89	8	1.6	1.2
Columbia River Ab. Kalama River	224114	5/25/2004	110	12	2.1	1.5
Kalama River	224115	5/24/2004	46	2	1.2	<1.0
Cowlitz River	224116	5/25/2004	N/A	23	1.7	1
Columbia River Bw. Longview	224117	5/25/2004	122	11	1.9	2
Columbia River Ab. Bonneville Dam	244130	6/9/2004	98	8	2.2	2.1
Columbia River Bw. Bonneville Dam	244131	6/9/2004	102	8	2.2	2.3
Washougal River	244132	6/9/2004	28	4	1.1	<1.0
Columbia River Ab. Willamette River	244133	6/9/2004	99	11	2.4	2
Columbia Slough	244134	6/9/2004	91	11	1.8	1.6
Willamette River	244135	6/9/2004	78	9	1.7	1.5
Lake River	244136	6/9/2004	102	22	2.7	2.6
Lewis River	244137	6/9/2004	42	2	<1.0	<1.0
Multnomah Channel	244138	6/9/2004	64	15	1.5	1.4
Columbia River Ab. Kalama River	244139	6/9/2004	100	7	2.3	1.9
Kalama River	244140	6/9/2004	45	5	<1.0	<1.0
Cowlitz River	244141	6/9/2004	43	21	1.3	1.4
Columbia River Bw. Longview	244142	6/9/2004	84	13	2.2	2
Columbia River Ab. Bonneville Dam	264250	6/22/2004	118	9	1.8	1.9
Columbia River Bw. Bonneville Dam	264251	6/22/2004	120	5	1.9	1.8
Washougal River	264252	6/22/2004	35	2	<1.0	<1.0
Columbia River Ab. Willamette River	264253	6/22/2004	118	8	1.9	1.8
Columbia Slough	264254	6/22/2004	175	38	3.8	3.3
Willamette River	264255	6/22/2004	119	6	1.9	1.8
Lake River	264256	6/22/2004	138	17	2.4	2

Appendix H. (continued)

Site	Sample Number	Date	Conduct. umhos/cm)	TSS (mg/L)	TOC (mg/L)	DOC (mg/L)
Lewis River	264257	6/23/2004	48	2	<1.0	<1.0
Multnomah Channel	264258	6/23/2004	83	12	1.4	1.5
Columbia River Ab. Kalama River	264259	6/23/2004	104	13	2	1.8
Kalama River	264260	6/22/2004	53	2	<1.0	<1.0
Cowlitz River	264261	6/22/2004	66	12	<1.0	1
Columbia River Bw. Longview	264262	6/23/2004	149	9	1.6	1.9

Appendix I. Flow Data for Lower Columbia River SPMD Deployment Periods, 2003-2004.

Agency	Site No.	Site Name	Flow Data (cfs)					
Ecology	**1**	Mainstem Above Bonneville Dam	(No data available for time periods sampled)					
Ecology	**2**	Mainstem Below Bonneville Dam	8/27/03 - 9/24/03		12/15/03 - 1/12/04		5/24/04 - 6/22/04	
USACE/ USGS	***14128870***	*Columbia R. Below Bonneville Dam*	Range	80,700 - 192,700	Range	112,500 - 182,600	Range	222,200 - 311,700
			Mean	102,700	Mean	143,500	Mean	267,200
			Geometric Mean	100,000	Geometric Mean	142,200	Geometric Mean	266,200
			Median	101300	Median	144,600	Median	270,300
Ecology	**3**	Mouth of Washougal River	8/30/2000	53	12/15/1999	9300 est.	5/24/2000	415
Ecology	***28B110***	*Washougal River Below Canyon Ck*	9/27/2000	55	1/26/2000	760	6/28/2000	180
			9/28/2000	50.4	12/29/1997	1350	5/27/1998	666
			8/26/1998	43	1/7/1998	3182	5/27/1998	658.70
			9/30/1998	51	1/28/1998	1634	6/30/1998	324
					1/28/1998	1328		
Ecology	**4**	Mainstem Above Willamette River	8/20/2003	129,300				
USGS	***14144700***	*Columbia River at Vancouver, WA*	9/24/2003	105,300				
Ecology	**5**	Mouth of Columbia Slough	8/27/03 - 9/25/03		12/16/03 - 1/12/04		5/24/04 - 6/22/04	
USGS	***14211820***	*Columbia Slough at Portland, OR*	Range	0 - 88	Range	0 - 276	Range	0 - 136
			Mean	37.4	Mean	140.2	Mean	61.2
			Geometric Mean	22.0	Geometric Mean	93.6	Geometric Mean	51.3
			Median	29.0	Median	137.0	Median	49.0
Ecology	**6**	Mouth of Willamette River	8/27/03 - 9/25/03		12/16/03 - 1/12/04		5/24/04 - 6/22/04	
USGS	***14211720***	*Willamette River at Portland, OR*	Range	7,200 - 10,000	Range	47,100 - 116,000	Range	8,680 - 31,600
			Mean	7,400.0	Mean	72,146.3	Mean	20,202.9
			Geometric Mean	8,736.1	Geometric Mean	70,158.9	Geometric Mean	19,576.0
			Median	9,450.0	Median	72,500.0	Median	19,100.0
Ecology	**7**	Mouth of Lake River	(No data available for time periods sampled)					
Ecology	**8**	Mouth of Lewis River	8/28/03 - 9/24/03		12/17/03-1/13/04		5/25/04 - 6/23/04	
USGS	***14221700***	*Lewis River at Woodland, WA*	Range	1,210 - 2,350	Range	3,030 - 10,600	Range	2,700 - 9,230
			Mean	1,519	Mean	5,775	Mean	4,447
			Geometric Mean	1,464	Geometric Mean	5,376	Geometric Mean	4,173
			Median	1,491	Median	5,270	Median	4,355

Appendix I. (continued)

Agency	Site No.	Site Name	Flow Data (cfs)					
Ecology	**9**	Mouth of Multnomah Channel	(No data available for time periods sampled)					
Ecology *USGS*	**10** ***14222910***	Mainstem Above Kalama River *Columbia River at Kalama, WA*	(No data available for time periods sampled)					
Ecology *USGS*	**11** ***27B070***	Mouth of Kalama River *Kalama River near Kalama*	8/28/2003 9/24/2003	155 166	12/17/2003 1/28/2004	1242 1776	5/19/2004 6/23/2004	295 325
Ecology *USGS*	**12** ***14243000***	Mouth of Cowlitz River *Cowlitz River at Castle Rock*	8/29/03 - 9/24/03 Range Mean Geometric Mean Median	 2,819 - 3,550 3,196 3,188 3,220	12/17/03-1/13/04 Range Mean Geometric Mean Median	 7,450 - 16,100 10,705 10,382 9,330	5/25/04 - 6/22/04 Range Mean Geometric Mean Median	 4,890 - 8,880 6,307 6,239 6,190
Ecology *USGS*	**13** ***14246900***	Mainstem Below Longview *Columbia River near Quincy, OR*	8/29/03 - 9/25/03 Range Mean Geometric Mean Median	 82,900 - 154,000 106,044.8 104,901.0 105,000.0	12/17/03-1/13/04 Range Mean Geometric Mean Median	 188,000 - 308,000 232,214.3 230,558.4 231,500.0	5/25/04 - 6/23/04 Range Mean Geometric Mean Median	 214,000 - 343,000 285,333.3 282,985.1 293,000.0